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1920-1973

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MIDDLE ORDOVICIAN CRINOIDS FROM SOUTHWESTERN VIRGINIA AND EASTERN TENNESSEE

By

JAMES C. BROWER
AND
JULIA VEINUS

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Paleontological Research Institution
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April 26, 1974

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MIDDLE ORDOVICIAN CRINOIDS FROM SOUTHWESTERN VIRGINIA AND EASTERN TENNESSEE

JAMES C. BROWER
and
JULIA VEINUS

ABSTRACT

This paper describes the crinoid fauna of the Benbolt and allied formations of eastern Tennessee and southwestern Virginia. One new genus and 14 new species are proposed. These are *Ectenocrinus punctatus*, n. sp., *Anulocrinus latus*, n. sp., *Ristnacrinus ? altobasalis*, n. sp., *Hybocrinus punctatocristatus*, n. sp., *H. perperamnominatus*, n. sp., *Palaeocrinus planobasalis*, n. sp., *P. avondalensis*, n. sp., *Carabocrinus stellifer*, n. sp., *C. micropunctatus*, n. sp., *Pararchaeocrinus convexus*, n. sp., *Paradiabolocrinus irregularis*, n. gen., n. sp., *P. sinuorugosus*, n. gen., n. sp., *Rhaphanocrinus simplex*, n. sp., and *Wilsonicrinus culmensinuosus*, n. sp.

Due to poorly preserved material, two new species are not formally described but are referred to *Isotomocrinus* and *Diabolocrinus*.

Two previously described species, *Archaeocrinus peculiaris* Miller and Gurley and *Geraocrinus sculptus* Ulrich, are treated here.

The crinoid proposed by Miller and Gurley as *Indianocrinus punctatus* is a broken hybocrinid with some plates missing; consequently, *Indianocrinus* is placed in synonymy with *Hybocrinus* and the species retained as *H. punctatus* (Miller and Gurley).

The pores of the Tennessee and Virginia palaeocrinids are shown to be respiratory; in addition, the ontogeny of the pores is discussed.

Diabolocrinus vesperalis (White) is considered a highly variable form which includes six previously erected "species".

As indicated in the above tabulation, the fauna is dominated by archaeocrinids, hybocrinids, and peculiar dicyclic cyathocrinid inadunates. The greatest faunal affinities are with the Chazyan crinoids of New York and adjacent areas and with the Black River Bromide of Oklahoma. The high percentage of peculiar and presumably specialized crinoids (*e.g., Ristnacrinus, Hybocrinus, Carabocrinus,* and *Palaeocrinus*) suggests that Late Chazyan and Black River time was an epoch of evolutionary experimentation for crinoids. Three of the peculiar genera survived the Black River, and persisted into the Trenton of North America, but they all became extinct prior to the Upper Ordovician. Most of the Benbolt and allied formation genera which failed to survive after the Black River epoch in North America are "normal" crinoids such as *Anulocrinus, Pararchaeocrinus, Paradiabolocrinus,* and *Diabolocrinus.*

Reconstruction of the environment of the crinoids suggests that they were rooted in a relatively soft substrate and lived in shallow water of normal marine salinity and high oxygen content which was alternatingly agitated and calm. Agitated conditions probably prevailed as most species show structures which are best interpreted as adaptations to rough water conditions. The only crinoids which do not exhibit such adaptations are *Geraocrinus sculptus* Ulrich, two *Palaeocrinus* species, and *Rhaphanocrinus simplex,* n. sp.

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We would like to thank William A. Oliver, Jr., (Paleontology and Stratigraphy Branch, United States Geological Survey), and Porter M. Kier (United States National Museum) for the loan of United States National Museum (USNM) and Springer Collection (S) material. Ronald L. Parsley (Tulane University) kindly donated several critical specimens which he collected in the summer of 1965 in connection with his study of the cystoids. Kenneth E. Caster of the University of Cincinnati, and Matthew Nitecki of the Field Museum of Natural History (UC) allowed the writers access to the collections of Miller, and Miller and Gurley. James Sprinkle (formerly of the Museum of Comparative Zoology, MCZ, now at University of Texas, Austin, Texas), made some specimens available for study which had been found by him and Christopher R. C. Paul. Robert V. Kesling of the Museum of Paleontology, University of Michigan (UMMP) kindly provided some photographs and loaned the writers several crinoids collected by C. R. C. Paul.

We thank James Sprinkle and Robert V. Kesling for their comments on an earlier draft of the manuscript.

The photographs were taken by James R. Wilson and the text-figures were drawn by John Fonda and Don S. Thompson, all of Syracuse University.

The cost of engraving the illustrations has been defrayed by the Syracuse University Research Institute.

PREVIOUS WORK

The crinoid fauna of the Middle Ordovician Benbolt and allied formations in Tennessee and Virginia has not been described completely before, although a number of workers discussed some crinoids. In 1849, Gerard Troost, then State Geologist of Tennessee, submitted a manuscript entitled *A Monograph on Crinoids Discovered in the State of Tennessee* to the Smithsonian Institution. This monograph described 108 Paleozoic species and included 243 figures. Most of these crinoids were found in central Tennessee, but a few Ordovician species range into the eastern Tennessee and southwestern Virginia area studied here. Since 1849, many of the forms first noted by Troost have been described in works by other writers. Unfortunately, due to the regrettable treatment of the Troost manuscript by Hall (see Wood, 1909), few of Troost's species names are valid. Of the Middle Ordovician crinoids in the Troost monograph, the name *Gilbertsocrinus americanus* (*nomen nudum* in Wood, 1909, p. 104) was given to the form later described by White as *Rhodocrinus vesperalis* (1880, p. 252, pl. 1, figs. 11, 12). This crinoid was assigned to *Diabolocrinus* by Wachsmuth and Springer (1897).

In 1894 and 1895, Miller and Gurley proposed several species from eastern Tennessee by names which have since been clarified by later workers. *Diabolocrinus asperatus* (1894, p. 19, pl. 2, figs. 7-9), *D. knoxensis* (1895a, p. 34, pl. 3, figs. 10-11), and *D. parvus* (1894, p. 21, pl. 2, figs. 26-28) were placed in *Archaeocrinus*. As shown later, these "species" and other previously described diabolocrinids are conspecific, and they belong to a single population. *Archaeocrinus peculiaris* (1894, p. 17, pl. 2, figs. 1-3) is still valid.

Miller and Gurley erected *Indianocrinus* based on a single specimen described as *I. punctatus* (1895b, p. 83, pl. 5, figs. 8-13). According to Miller and Gurley, the main generic characteristic was the presence of four RR. Later authors (*e.g.*, Bather, 1900, p. 145; Bassler and Moodey, 1943, p. 515) believed *Indianocrinus* to be a synonym of *Hybocrinus*. This view is accepted here, and the holotype of *I. punctatus* is judged to be a broken specimen with the anal X and the C ray R missing. Consequently, *Indianocrinus* is not a valid genus and the type species is assigned to *Hybocrinus*.

Wachsmuth and Springer described two *Diabolocrinus, D. perplexus* (1897, p. 250, pl. 11, figs. 1a, b, d) and *D. hieroglyphicus* (1897, p. 252, pl. 10, figs. 5a, b, c) from eastern Tennessee.

Geraocrinus sculptus was proposed by Ulrich in 1924 (p. 92, fig. 9).

In 1940 and 1941, Butts published a monograph on the geology of the Appalachian Valley in Virginia. In the section on fossils, several forms from the stratigraphic unit referred to by Butts as Ottosee were included. As explained below, these belong to the "Benbolt" fauna which is discussed here. These crinoids are: *Diabolocrinus perplexus* (1941, p. 91, pl. 89, figs. 1-3) = *D. vesperalis* of this report. *Diabolocrinus asperatus* ? (1941, p. 91, pl. 89, figs. 4-8) = *D. vesperalis* (in part, figs. 6-8) and *Paradiabolocrinus sinuo-*

rugosus, n. sp. (in part, figs. 4, 5) of this report. *Palaeocrinus* aff. *P. striatus* (1941, p. 91, pl. 89, figs. 9-11) = *P. planobasalis,* n. sp. of this report. *Echinosphaerites* sp. (1941, p. 91, pl. 89, fig. 12) = *Carabocrinus micropunctatus,* n. sp. of this report. *Holocystites* ? sp. (1941, p. 91, pl. 89, fig. 13) = *Hybocrinus punctatus* of this study.

Kesling and Paul treated the following Benbolt crinoids in two papers: *Triboloporus cryptoplicatus* (1968, p. 13, pl. 1, figs. 1-8, text-fig. 7), *Agostocrinus xenus* (1971, p. 222, pl. 1, pl. 2, figs. 1-7; pl. 3, fig. 9, text-figs. 1, 2) and *Acolocrinus hydraulicus* (1971, p. 231, pl. 2, figs. 8-11; pl. 3, figs. 1-8; pls. 4-7, text-figs. 3-5). These crinoids are well described and will not be discussed here.

E. O. Ulrich and G. A. Cooper made extensive collections of crinoids from the Benbolt and allied formations, Ottosee Formation, and Heiskell Shale of eastern Tennessee and southwestern Virginia, which were never completely described. This material has lain in the United States National Museum undescribed for a number of years and is the main subject of this study.

This report includes all known "Benbolt" crinoids except for *Cleiocrinus* and one unknown crinoid or crinoid-like echinoderm of uncertain affinities.

STRATIGRAPHY

The Middle Ordovician crinoids studied here were collected from exposures along the base of Clinch Mountain and adjacent areas. Unfortunately, the stratigraphic nomenclature and relationships of these rocks are highly complex and the present status of work is somewhat chaotic. Nevertheless, the following general statement, principally summarized from Cooper (1956, pp. 45-48), is presented to aid the reader in relating the various faunules and localities to one another.

Virtually all crinoids are known from the following horizons: 1. Benbolt Formation or equivalent horizons in the Dryden Formation. 2. The Ottosee or Sevier Shale of Tennessee where the crinoids are roughly equivalent to the Benbolt in age. Both the Sevier-Ottosee and the Benbolt units are of Black River age (Cooper, 1956, see correlation chart). 3. According to Cooper (1956, see localities listed under the individual species), many of the Tennessee specimens in the outcrop belt running from near Thorn Hill to Washburn were collected from the Hogskin Member of the Lincolnshire Formation. This unit is uppermost Chazyan in age and is thus distinctly older than the Benbolt and Sevier crinoids (Cooper, 1956, correlation chart). Many of the common crinoids, such as *Hybocrinus punctatus, Archaeocrinus peculiaris* and *Diabolocrinus vesperalis,* are common in both the Black River and Chazyan sediments. These species are highly variable and the Chazyan populations cannot be separated from the Black River ones. If Cooper's interpretation is correct, such forms are long ranging, slowly evolving types. Brower examined some of the Thorn Hill to Washburn localities and was unable to separate the Benbolt age rocks from the Hogskin Member. This suggests that Cooper's stratigraphic interpretation may be in error, and possibly the Hogskin crinoids are of Benbolt age. Study of Cooper's brachiopod faunal lists (1956, p. 47, Benbolt; p. 67, Hogskin) discloses many common genera but no common species.

Also, rare crinoids are available from the following horizons: 1. Pierce Shale of central Tennessee which is roughly Upper Benbolt in age, and 2. Wardell formation which overlies the Benbolt. Where these two units cannot be differentiated, they are grouped together and termed Dryden. 3. Several crinoids may occur in the Red Knobs Formation which is equivalent to the Benbolt.

The type section of the Benbolt Formation, near Benbolt in Tazewell County, Virginia, is composed of two limestone members. The lower one is the Shannondale Limestone, an argillaceous, dark gray, weathered, nodular rock, often with a dark, bluish gray, coarse grained limestone at the base. The upper member, the Burkes Garden, is an argillaceous, crinoidal and bryozoan bearing limestone. Further southwest, the two members cannot be separated. In northeastern Tazewell County, the Benbolt is overlain by the Gratton Limestone, a rock characterized by mudcracked zones and edgewise conglomerates. The Gratton is followed by the Wardell Limestone which is environmentally and lithologically similar to the Benbolt. Toward the southwest, the Gratton disappears and the Wardell rests directly on the Benbolt. Often the two formations cannot be separated by lithology and they are collectively designated Dryden Formation. Faunally, the Dryden can generally be split into "Benbolt" and "Wardell" horizons. The Benbolt-Wardell contains a distinctive fauna which may be recognized even when the formation lithology changes considerably. Towards the southwest, it grades into a soft shale or an argillaceous limestone with shaly cobbles. In the Knoxville and adjacent areas to the south, fossils of Benbolt age are found in the lower Ottosee. This latter unit is equivalent to the Sevier Shale which is thickly developed south of Knoxville. Near Friendsville, Tennessee, the Sevier brachiopod fauna suggests a Benbolt age. The Sevier appears to be a recurrent facies rather than a definite formation. The Ottosee Formation also appears to be a recurrent facies, which ranges in age from Lincolnshire through Wardell of southern Virginia. The type section of the Ottosee is near Knoxville, and part of the unit is probably equivalent to the Benbolt.

A number of the crinoids occur in the Heiskell Shale. This unit was proposed by Ulrich (1911, pl. 27), with a partly exposed sequence of fossiliferous shaly limestone at Heiskell, Tennessee, as the type locality. The name was never widely accepted because of the poor nature of the type locality. When proposing the unit, Ulrich showed it as being underlain by Holston and overlain by Lowville, although this cannot be ascertained by the type locality. If so, this would indicate the Heiskell to be roughly equivalent to the Benbolt. The fauna contained in the unit is of Benbolt age, and the "Heiskell" is doubtless the shaly facies of the Benbolt Formation. Cooper (1956, p. 66) suggests that the well-established and validly proposed name of Benbolt be retained for this formation.

The Chazyan Lincolnshire Formation is widespread in Virginia and Tennessee. Typical lithology comprises dark colored cherty limestone. To the south and west, the top of the unit grades into the Hogskin Member of the Lincolnshire. The Hogskin is characterized by cobbly, nodular limestones and shale which weathers yellow. The Hogskin is separated from the Benbolt by one or more stratigraphic units depending on locality.

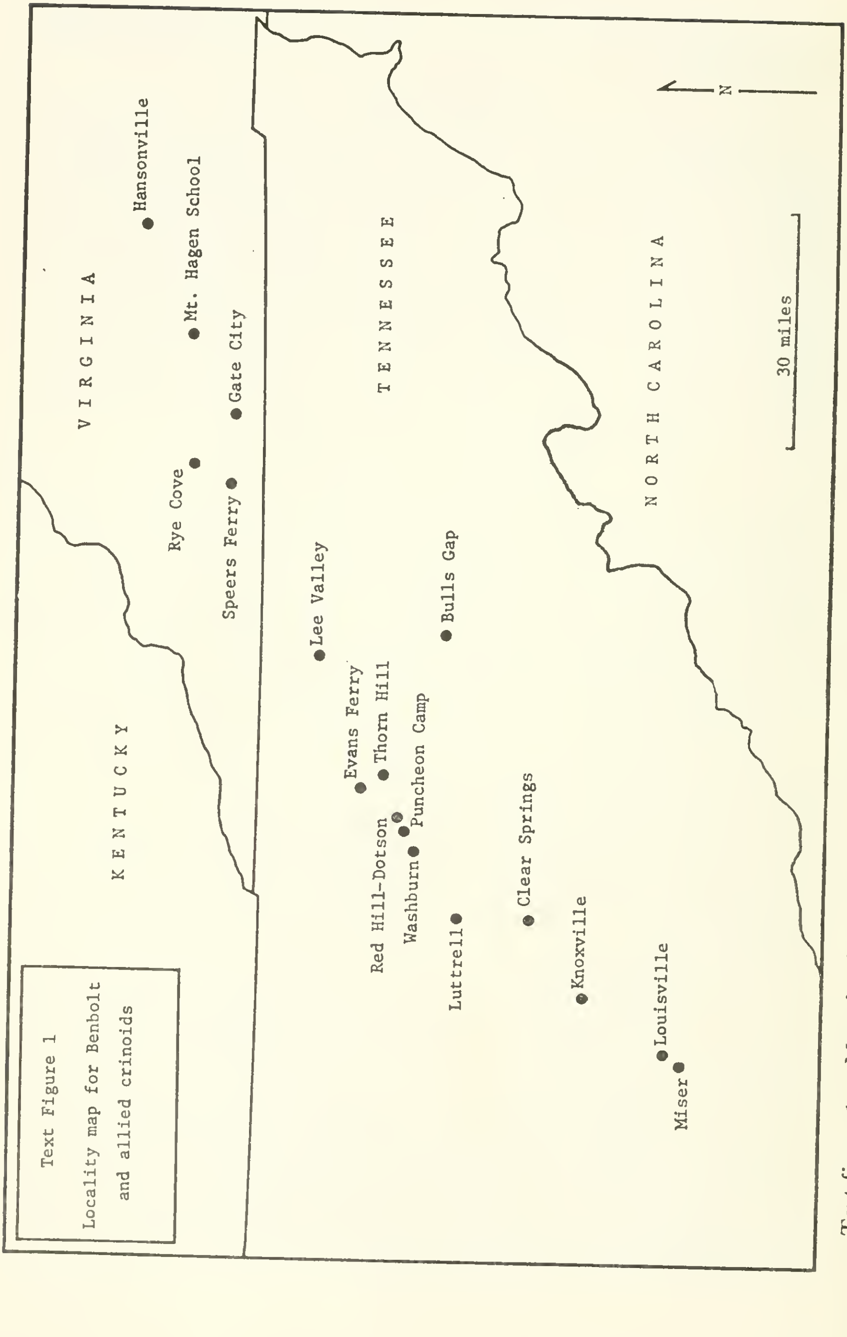
In later discussion, the entire crinoid fauna is referred to as the "Benbolt fauna" because most specimens are either from the Benbolt or its age equivalents. The term Benbolt, lacking parentheses, is used to denote crinoids from the Benbolt Formation or other units of roughly the same age. The purpose of this is not a formal stratigraphic nomenclature change; only a "short-hand" designation is intended to eliminate the necessity of using numerous local rock unit names.

LOCALITIES

Considerable difficulty was encountered in dealing with the crinoid occurrences for several reasons. Exact localities are not available for many crinoids. For example, many crinoids have locality labels that simply read "Knoxville". Possibly the specimens were obtained from several outcrops although only one Knoxville locality is definitely known to contain crinoids. In general, the Virginia localities are more precise than those in Tennessee. The stratigraphic position of various locales is questionable as previously mentioned. The following locality register is as complete and accurate as possible. Text-figure 1 presents a locality map.

LOCALITY REGISTER

1. Hansonville localities, Hansonville Quadrangle, Virginia, all Benbolt Formation.
    - 1a. South side, Moccasin Creek Middle Fork, 1.3 miles due south of Hansonville.
    - 1b. Shale bank on south side of dirt road along Moccasin Creek Middle Fork, about .35 mile southwest of intersection with U.S. Rte. 19, about 1.35 miles southeast of Hansonville.
    - 1c. Field exposure between Moccasin Creek Middle and South Forks and .25 mile south of County Rte. 676, 1.5 miles due south of Hansonville.
    - 1d. Weathered slope on southwest side of small knob about 1.5 miles due south of Hansonville.
    - 1e. In road cut along U.S. Rte. 19, immediately above yellow shale, about 1.25 miles eastsoutheast of Hansonville.
    - 1f. .5 mile south of Hansonville.
2. Mt. Hagen School localities, Virginia, all Benbolt Formation.
    - 2a. South side of Mt. Hagen School, Hilton Quadrangle.
    - 2b. Shale bank on north side of Virginia Rte. 613, about 1.1 miles east of Mt. Hagen School, Mendota Quadrangle.
3. Vicinity of Gate City, Virginia, Gate City Quadrangle, Virginia, all Benbolt Formation.
    - 3a. Roadcut along Gate City - Hansonville road, about 4.0 miles east-northeast of Gate City.
    - 3b. Flat vacant lot between houses on north side of Virginia Rte. 17, near Slabtown gas station, 2.25 miles northeast of Gate City.
4. In and near Rye Cove, Virginia, Clinchport Quadrangle, all Benbolt Formation or equivalent part of Dryden Limestone.
    - 4a. Roadcuts in Rye Cove.
    - 4b. About .25 mile north of Rye Cove Consolidated School, probably roadcut along State Rte. 649 or 652, possibly on small connecting road.
    - 4c. On hill, roughly .25 mile south of Carterstown Church.
    - 4d. Roadcut along Rye Cove-Brick Church road, first road cut west of L. McDavid house, about 1.0 mile west of Rye Cove.
    - 4e. On hill behind Brick Church, 1.5 miles west of Rye Cove.
    - 4f. Small roadside quarry on hill, located on Rye Cove-Brick Church road, roughly 1.5 miles west of Rye Cove.



Text-figure 1.—Map showing localities for "Benbolt" crinoids.

5. Railroad cuts .5 and 1.0 mile east of station at Speers Ferry, Virginia, Clinchport Quadrangle, Benbolt Formation.
6. Approximately .1 mile north of Lee Valley-Flat Gap road, 1.25 miles north of Lee Valley, Tennessee, boundary between Lee Valley Quadrangle and Pressmens Home Quadrangle, Benbolt Formation.
7. Roadcut along U.S. Rte. 25E, .5 mile north of Indian Creek, stratigraphic section near Evans Ferry, Tennessee, Howard Quarter Quadrangle, Benbolt and Wardell Formation or Wardell Formation.
8. Thorn Hill Localities, Avondale Quadrangle, Tennessee. These outcrops are typically poorly known with respect to exact geographic and stratigraphic placement. Most crinoids were collected from roadcuts, hillsides, and glades immediately adjacent to State Rte. 131. According to Cooper (1956, see localities listed under individual species), many of the occurrences lie in the Hogskin Member of the Lincolnshire Formation. Others are probably Benbolt or Wardell. Some localities were visited by Brower who was unable to separate the stratigraphic units.
    - 8a. Road cut on U.S. Rte. 25 (Dixie Highway) near Thorn Hill post office and general store. Probably Wardell Formation or Witten Formation.
    - 8b. One to 2.0 miles eastnortheast of Thorn Hill on State Rte. 131. Questionably Wardell Formation.
    - 8c. Three miles westsouthwest on Thorn Hill on State Rte. 131. Hogskin Member according to Cooper (1956).
    - 8d. About 4.5 miles westsouthwest of Thorn Hill on State Rte. 131. Hogskin Member according to Cooper (1956).
9. Red Hill-Dotson outcrops, Avondale Quadrangle, Tennessee. The general remarks for the Thorn Hill localities are also applicable here.
    - 9a. Roadcuts, hillsides and glades along Rte. 131 ranging from 1.0 to 1.5 miles east of Red Hill. Benbolt Formation or Hogskin Member.
    - 9b. About .38 miles eastnortheast of Red Hill along State Rte. 131. Hogskin Member according to Cooper (1956).
    - 9c. Roadcuts and associated slopes along side of Red Hill and the unnamed hill to the west, on State Rte. 131. Red Hill is not shown on most recent topographic maps, and it is located about .5 mile eastnortheast of the Dotson general store. Benbolt Formation or Hogskin Member.
10. Puncheon Camp localities, Tennessee, Dutch Valley Quadrangle. The remarks for the Thorn Hill occurrences also apply here; the crinoids are either from the Benbolt Formation or the Hogskin Member.
    - 10a. Field localities along State Rte. 131, between road and Dotson Creek, at and near Puncheon Gap, 2.6 miles eastnortheast of Puncheon Camp.
    - 10b. Along State Rte. 131 about .5 mile westsouthwest of Puncheon Gap and 1.0 mile westsouthwest of Red Hill.
    - 10c. Along State Rte. 131 approximately 1.0 mile westsouthwest of Puncheon Gap and 1.5 miles westsouthwest of Red Hill.
    - 10d. Along State Rte. 131 at or near Puncheon Camp.
11. Sally Cleveland farm, about 1.0 mile south of Washburn, Tennessee, Dutch Valley Quadrangle, Hogskin Member according to Cooper (1956).
12. Three miles south of Bulls Gap, Tennessee, Mohawk Quadrangle, horizon unknown.
13. Republic Marble Quarry, near Luttrell, Tennessee, Luttrell Quadrangle, probably Benbolt or Wardell.
14. Near Clear Springs, Tennessee, Mascot Quadrangle, horizon unknown.
15. Knoxville localities, Tennessee, Ottosee Shale or Sevier Shale.
    - 15a. The locality names associated with many crinoids merely read Knoxville. Possibly, the specimens came from various places within Knoxville. However, the only locality known to contain crinoids is the following: Roadcuts along Spruce Street between Glenwood and Woodbine Avenues, Knoxville Quadrangle.

15b. On side of Lake Ottosee, Knoxville Quadrangle.
15c. Two to 4.0 miles east of Knoxville, Knoxville Quadrangle or Shooks Gap Quadrangle.
15d. Outcrop near entrance to Chilhowee Park, roughly at junction of Knoxville Quadrangle and Shooks Gap Quadrangle.
15e. McNutts, 4.0 miles northeast of center of Knoxville, Shooks Gap Quadrangle.
16. Probably roadcut on Miser-Middle Settlement road, .25 mile northeast of Miser, Tennessee, Louisville Quadrangle, base of Sevier Shale.
17. About 1.25 miles south of Louisville, Tennessee, Louisville Quadrangle, Questionably Red Knobs Formation.
18. Quarry on west edge of Murfreesboro, Tennessee, Murfreesboro Quadrangle, top of Pierce Shale. The locality is in central Tennessee and is not shown on the map.

PALEOECOLOGY

The Benbolt and allied faunas are highly diversified. According to Butts (1940, p. 175), the Benbolt fauna consists of 66 species in which bryozoans and brachiopods predominate.

The assemblage is composed of epifaunal filter feeders except for the following: there are seven trilobite species which were probably detritus feeders, herbivores or micro-carnivores; two cephalopods which were swimming predators; and six gastropods whose feeding habits are unknown, except for *Cyclonema* sp. which lived on crinoid tegmens and ate crinoid fecal material.

The crinoids are usually found in association with cystoids, paracrinoids, parablastoids, bryozoans, and small brachiopods. These crinoids occur as isolated calyces and dorsal cups. Arms and long column segments, or long column segments are rarely observed attached to the calyces or dorsal cups. However, isolated stem fragments are common. Apparently after death, the crinoids fell to the sea floor where the soft tissues holding the arm and stem plates together decomposed, after which, wave or current action scattered the various plates over the sea floor. Arms are almost invariably represented by isolated Brr and pinnulars, and stems are known from individual columnals and short stem, or short stem fragments. This suggests that the arms decomposed most rapidly, then the stems, followed by the tegmen plates, and lastly the dorsal cup. The stems and perhaps the arms were probably partly broken up when the crinoids fell to the sea floor at death; such would have produced the rare arm and long stem segments. Burial seems to have taken place by normal sedimentation; there is no indication of mudflows.

Thin sections of the crinoid bearing shaly limestones show a grain fraction composed mostly of crinoid debris consisting of calyx plates, isolated Brr, with pinnulars in some cases, and columnals. Also observed are frequent twig-like bryozoans and rare massive ones. Brachiopods are generally rare, and only represented by a few fragments; in one thin section, numerous small brachiopods, both articulated and disarticulated, were seen. In addition, there are rock fragments composed of clay sized calcite and iron stained clay minerals. Part of the grain fraction (especially the rock fragments) may or may not be somewhat abraded. The matrix consists of a mixture of silt and clay sized calcite particles and iron-stained clays.

The environment in which the crinoids lived is reconstructed as follows. Normal marine salinity is denoted by the high faunal diversity, especially the diversified brachiopod fauna, and by the presence of numerous crinoids, of which all living and fossil species live only under conditions of normal marine salinity.

Shallow depth is denoted by the highly diversified filter feeding fauna, and the presence of agitated water. Agitation of the water is implied by the disarticulated nature of the crinoids and the brachiopod shells, by the abraded condition of many brachiopod shell fragments and by the presence of limestone fragments which are sometimes abraded. The water was intermittently quiet, allowing for the deposition of the fine-grained sediment forming the matrix. Agitated conditions probably prevailed as the structures of most crinoid species are most logically interpreted as adaptations to rough water conditions. These adaptations are:

1. Almost all crinoids are massive, robust and thick-plated relative to congeneric species. Most of these forms are: *Ectenocrinus punctatus*, n. sp., *Isotomocrinus*, n. sp., *Anulocrinus latus*, n. sp., *Ristnacrinus ? altobasalis*, n. sp., and the *Carabocrinus* species; other massive forms are annotated below. The only "Benbolt" taxa which do not fit the massive robust mold are: *Rhaphanocrinus simplex*, n. sp., *Geraocrinus sculptus* Ulrich, and the two *Palaeocrinus* species.

2. The hybocrinids possess a simple massive calyx which is composed of few plates. Although the arms are unknown, they are probably short, stumpy, unbranched, and made up of few Brr like those of other *Hybocrinus* species. The short arms and low food gathering capacity may have been augmented by the tegmen. The calyx is asymmetrical with the posterior side being higher than the

anterior one. Food grooves occur on the tegmen surface where they are covered by small moveable plates. If the crinoid was oriented with the anterior side facing up or down current, the food grooves on the tegmen surface would have aided the arms in food gathering. In defecation, fecal material would have tended to travel down-current and away from the crinoid, thus eliminating the sanitation problem. Several individuals of *H. punctatus* (Miller and Gurley) seem to have possessed stems which ran along the substrate like those of calcaeocrinids. This would have placed these animals below the level occupied by most other adult "Benbolt" crinoids. This "down to the mud" zone was, perhaps characterized by lower crinoid population density and lower agitation. Thus, the recumbent stem might have partly represented an attempt to avoid agitation.

3. *Diabolocrinus vesperalis* (White) is by far the most abundant camerate. These crinoids have low, massive flat calyces with lobate arm bases. Judging from isolated fragments, the arms were massive, biserial, and unbranched. A large column facet is located in a basal concavity. Most of the other camerates are constructed along the same lines, except that the arm bases are not strongly lobate, as in *Archaeocrinus peculiaris* Miller and Gurley, *Pararchaeocrinus convexus,* n. sp., and *Wilsonicrinus culmensinuosus,* n. sp.

High oxygen content of the water is denoted by the presence of crinoids which, judging by the ecology of living comatulids, required a high amount of dissolved oxygen, and by the presence of a diversified filter feeding fauna.

The most common rooting device found among the crinoids indicates a fairly soft substrate. A similar type of rooting device, formed of highly branched cirrus roots, is found in the living *Rhizocrinus* which is attached to a soft fine-grained mud substrate (Bather, 1900, p. 107). The relatively larger, heavier, and unbranched cirrus roots of the crinoids suggest that the "Benbolt" substrate was harder than the uncohesive mud on which *Rhizocrinus* lives. Examination of roots in matrix shows that the "Benbolt" crinoids were rooted in the sediment and not around rocks or other fragments.

TERMINOLOGY

Most terminology follows Moore (1952, text-fig. 18-2). The proximal plate of the CD interray is designated primanal following

Jaekel (1918, p. 28), and the brachials rigidly incorporated into the dorsal cup wall are termed fixed-brachials (FBr, pl. FBrr). These terms respectively replace the "tergal" and "cup-brachial" of Moore (1952).

Terminology for calceocrinids follows Moore (1962a). The anal plate designations of Philip (1965) are used for monocyclic inadunates, whereas Moore's (1962) system is adopted for dycyclic inadunates.

The ray designation used is that of Carpenter (1884, text-fig. 2).

The rays of most "Benbolt" camerates branch once and are divided into two half-rays. In some cases, the ray branches twice, and quarter rays are formed. The iBrr between the half-rays of the same ray are termed inter-half-ray iBrr; those between quarter-rays of the same half-ray comprise inter-quarter-ray iBrr. In some cases, not all interrays are differentiated. In these, lateral interrays include all but the posterior or CD interray.

Column terminology follows that of Moore, Jeffords, and Miller (1968, text-figs. 1-5).

SYSTEMATIC DESCRIPTIONS

Subclass INADUNATA Wachsmuth and Springer, 1885

Order DISPARIDA Moore and Laudon, 1943

Superfamily **HOMOCRINICAE** Ubaghs, 1953

Family **HOMOCRINIDAE** Kirk, 1914

Genus **ECTENOCRINUS** Miller, 1889 (p. 242)

Ectenocrinus punctatus, n. sp. Pl. 1, figs. 2-4; Pl. 2, figs. 1-6

Diagnosis of adult. — A species questionably referred to *Ectenocrinus,* characterized by barrel-shaped dorsal cup; round column composed of barrel-shaped nodals and internodals; all adult calyx plates with pitted surfaces, pits exhibit irregular polygonal outlines in plan view; nodals marked by longitudinal ridges parallel to long axis of stem; internodals weakly pitted.

Description of mature cup. — Dorsal cup barrel shaped; widest at RR level, narrows at BB circlet level and distal IBrr1 margins; cup base flat with deep concave stem facet; distal FBrr composed of IBrr1. Pitted surface of calyx plates apparent to naked eye; under magnification, fine polygonal ridges are present between adjacent pits; pits do not pierce plates. BB extremely short. The iRR of C, B, and E rays extremely short. The sRR of C, B, and E rays, and simple RR of A and D rays are largest plates in cup. IBrr1 less than half the height of the RR, with trapezoidal shape; IBr1 base forming wide articular surface with R; articular facet for IBr2 curved; IBr2 axillary. Elongated anal X rests in shallow notch on shoulders of C and D ray RR, and extends distally between C and D ray IBrr.

Column facet located in deep basal concavity; axial canal pentalobate with apices directed interradially. Proximal one or two columnals located in basal concavity; barrel-shaped in side view; slightly pentalobate in plan view; each proximal columnal divided into five pentameres with interradially oriented sutures which emerge between the lobes; axial canal pentalobate with apices located in interradial positions; articular surfaces like those of more distal columnals.

Distal columnals round in plan view; lacking pentameres; barrel shaped in side view. Column composed of alternating flattened barrel-shaped nodals and internodals; nodals approximately twice the height and twice the diameter of the internodals. Nodals ornamented with longitudinal ridges parallel to long axis of stem; internodals obscurely pitted. Wide crenellations mark sutures between nodals and internodals. Articular surfaces of columnals, both nodals and internodals, located in small concavities or collar-like projections. Articular surface consists of five elongate lobes arranged in petaloid pattern; petaloid areas with marginal crenularium composed of fine ridges (culmina); adjacent culmina separated by fine furrows (crenellae); long axes of crenellae and culmina perpendicular to edges of lobes. Centers of lobes depressed, presumably forming ligament pits. Adjacent columnals joined together by interlocking of crenellae and culmina, with concave ligament pits opposing each other; columnal suture type therefore relatively rigid (symplexy). Axial canal pentagonal, with apices of pentagon located in between petaloid lobes.

Remarks. — This species is based on six dorsal cups, two stem fragments and 18 isolated columnals. Four dorsal cups lack any traces of the column whereas two calyces have one or two proximal columnals located in the basal concavity. All of these columnals are divided into somewhat lobate pentameres. In addition, there are isolated columnals and stem segments; all of these stem plates lack pentameres and each columnal constitutes a single unit. The stem fragments and isolated columnals have not been seen attached to dorsal cups. The stem segments, isolated columnals and dorsal cups are clearly referable to the same crinoid for two reasons. All three occur together in the same bed at one locality (various Hansonville, Virginia localities). The isolated columnals and the plates within the stem fragments resemble the proximal columnals except that they are round in plan view and lack pentameres. Therefore, it is concluded that the loose columnals and stem segments represent the distal column of this species.

The generic assignment of this crinoid is somewhat questionable because of lack of arms. On the basis of its three compound RR and the alternating nodals and internodals of the column, this species might be referred to *Homocrinus*. However, the dorsal cup is almost identical in size and shape to that of an undescribed species of *Ectenocrinus* (USNM 164106) from the Bromide Limestone of Oklahoma. Only the surface ornamentation differs from that of the Oklahoma crinoid which is smooth, whereas the Virginia form has a distinctly pitted appearance. Unlike most species of *Ectenocrinus,* the "Benbolt" and Bromide forms show columns which are more narrow than the dorsal cup. The typical ectenocrinid stem width almost equals that of the calyx.

The column is represented by small segments composed of articulated nodals and internodals, by isolated columnals and by two dorsal cups with one or several columnals attached. In the stem fragments, a distinct crenellated suture can be detected between some of the columnals. This clearly is caused by interlocking of crenellae and culmina of opposing columnals. Consequently, an immovable suture was formed which resulted in a comparatively inflexible stem.

A five specimen growth sequence is available which consists of animals ranging from 2.5 to 6.3 mm in cup height (Pl. 1, figs. 2-4; Pl. 2, figs. 1, 2). All plates were fully in lateral contact with their neighbors throughout ontogeny. Consequently, the number of sides was stabilized for all plates. However, individual plate outlines were subject to change. For example, the proximal outlines of the immature RR and iRR were relatively angular but the angularity was flattened with progressive age. These changes dictated corresponding ones in the underlying BB where the angle between the distal BB margins expanded throughout ontogeny. The notch between the C and D ray RR for reception of anal X became smaller in older animals. The iRR of young specimens are high compared to width but these became relatively wider with progressive ontogeny. The orientation of the BB sides also varied with progressive ontogeny. These were comparatively erect in the youngest crinoid but became semihorizontal and subparallel to the cup base in larger animals.

Young cups have upward expanding sides, whereas adults exhibit nearly straight or barrel-shaped sides. This growth pattern was mainly dictated by the change in BB orientation and the growth rate differentials between the proximal and distal cup widths. The proximal cup width development vector ranged about 16% larger than the distal one.

The ectenocrinid ornamentation consists of a series of pits. Student's t tests show no significant change in number of pits during ontogeny and presumably the pit number was stabilized regardless of relative age. From nine to 12.5 pits may be counted across a R. Because of accretion to the underlying plates, the average pit diameter increased from about .13 mm in smaller crinoids to roughly .40 mm in the largest animal.

Specific name. — *Punctatus* in allusion to the pitted appearance of the plate surfaces.

Types. — Holotype, USNM 164097. Paratypes, USNM 164098 - 164105; UMMP 57521, 57522; MCZ 621.

Occurrence. — Benbolt Formation, localities 1a, 1c and 1d; Hogskin Member of Lincolnshire Formation or Benbolt Formation, locality 10a.

Superfamily **HETEROCRINICAE** Ubaghs, 1953

Family **HETEROCRINIDAE** Zittel, 1879

Genus **ISOTOMOCRINUS** Ulrich, 1924 (p. 86)

Isotomocrinus, n. sp.

Description. — Single small specimen consisting of dorsal cup only. C ray and E ray RR compound. RR facets wide, occupying total width of RR. Anal X between shoulder of D ray R and left side of C ray sR, anal X reaching base of latter. Stem facet round; axial canal pentalobate with lobes in interradial position.

Remarks. — This single specimen is tentatively placed in *Isotomocrinus*. The dorsal cup possesses three simple and two compound RR which denotes assignment to the Heterocrinidae. This crinoid also shows free IBrr1 (*i.e.*, not incorporated into the cup), an anal X which reaches deeply into the cup, down to the base of the C ray sR, and a round stem which is smaller in diameter than the cup. It is therefore clearly referable to *Isotomocrinus*. Ulrich (1924, p. 86, text-figs. 5a, b) described and figured *I. typus* and mentioned two undescribed isotomocrinid species. One, from the Black River Limestone of central Pennsylvania, has not been seen by the writers; the other, from the Upper Black River of the northern mid-continent area, exhibits smooth sutures like the type species *I. typus*. The Tennessee specimen has strongly depressed sutures. Although the Tennessee form probably represents a new species, it is not described here due to the lack of stem, arms and anal sac.

In the listing of species discussed by Ulrich (1924, p. 82), the type species of *Isotomocrinus* is cited as *typicaulus*. However, the form is referred to as *I. typus* in the text (p. 86) and in the figures (5A and B), leading one to believe that *typicaulus* is simply an error.

Mentioned specimen. — USNM 164107.

Occurrence. — Wardell Formation or Witten Formation, locality 8a.

Family **ANOMALOCRINIDAE** Wachsmuth and Springer, 1886

Genus **GERAOCRINUS** Ulrich, 1924 (p. 92)

Type species: By monotypy and original designation, *Geraocrinus sculptus* Ulrich, 1924, page 92, figure 9.

Diagnosis. — An anomalocrinid with widely conical cup and nodose dorsal cup plates. Arms branch isotomously on IBrr2; endotomous pinnulation. Columnals of different sizes.

Remarks. — *Geraocrinus* contains only one species which is based on a single specimen. It was placed doubtfully in the Anomalocrinidae by Ulrich. The genus resembles *Anomalocrinus* (Meek, 1873, p. 17, pl. 2, figs. 6a-f) in possessing uniserial arms which bear pinnules on only one side of each Br. The anomalocrinid dorsal cup plate formula is like that of the Heterocrinidae in having simple RR in the A, B, and D rays and compound RR in the C and E rays. However, pinnules are not found in the Heterocrinidae.

Geraocrinus differs from *Anomalocrinus* in the following characters. The cup of the former is widely conical while that of the latter is bowl-shaped with plates of irregular size and form. The geraocrinid arms branch once on the proximal IBr2 while those of anomalocrinids branch irregularly several times. In *Geraocrinus,* the pinnules on the two arms of a single ray face towards the ray axis whereas the anomalocrinid pinnulation alternates from one side of the arm to the other at each arm branching. The *Geraocrinus* stem consists of columnals of alternating sizes, but the anomalocrinid stem is composed of thin uniform columnals.

The Trenton crinoid *Glaucocrinus* Parks and Alcock (1912, p. 41) possesses a high globular cup with plates of irregular size and shape as in *Anomalocrinus.* The arms branch irregularly, but the pinnules are too poorly preserved for accurate observation. Springer, in unpublished notes, considered *Glaucocrinus* identical with *Anomalocrinus.* Apparently following Springer, Bassler (1915, p. 548) stated that this name is probably a synonym of *Anomalocrinus.*

Geraocrinus occurs in the lower part of the Middle Ordovician whereas *Anomalocrinus* is restricted to the Upper Ordovician. Based on stratigraphic position and by analogy with other monocyclic inadunate lineages, the geraocrinid conical cup shape and regular structure and the simple arm branching with its resultant pinnulation are deemed primitive features. These characters indicate that *Geraocrinus* was derived from heterocrinid ancestors as suggested by Moore and Laudon (1943, p. 31). The principal evolutionary trend was the development of endotomous pinnulation. *Anomalocrinus* was probably a direct descendent of *Geraocrinus.*

Occurrence. — Middle Ordovician, Ottossee Formation; Tennessee.

Geraocrinus sculptus Ulrich Text-fig. 2

1924. *Geraocrinus sculptus* Ulrich, *in* Foerste, Canada Geol. Sur., Mem. 138, p. 92, fig. 9.

1943. *Geraocrinus sculptus* Ulrich, Bassler and Moodey, Geol. Soc. America, Spec. Paper 45, p. 486.

Diagnosis. — One known species.

Description of holotype. — Cup widely conical, about 4.3 mm high, and 8.6 mm wide at distal edge. Plates nodose with deeply indented sutures. BB five, pentagonal, proximal edge truncated. RR simple in A, B and D rays, pentagonal, truncated distally. C and E ray RR compound; iRR similar in shape to the simple RR, but not as high; sRR irregularly quadrangular or hexagonal, almost twice as wide as high. C ray sR supports pentagonal X on small left shoulder above distal edge of cup. Wide facet for C ray arm on left shoulder.

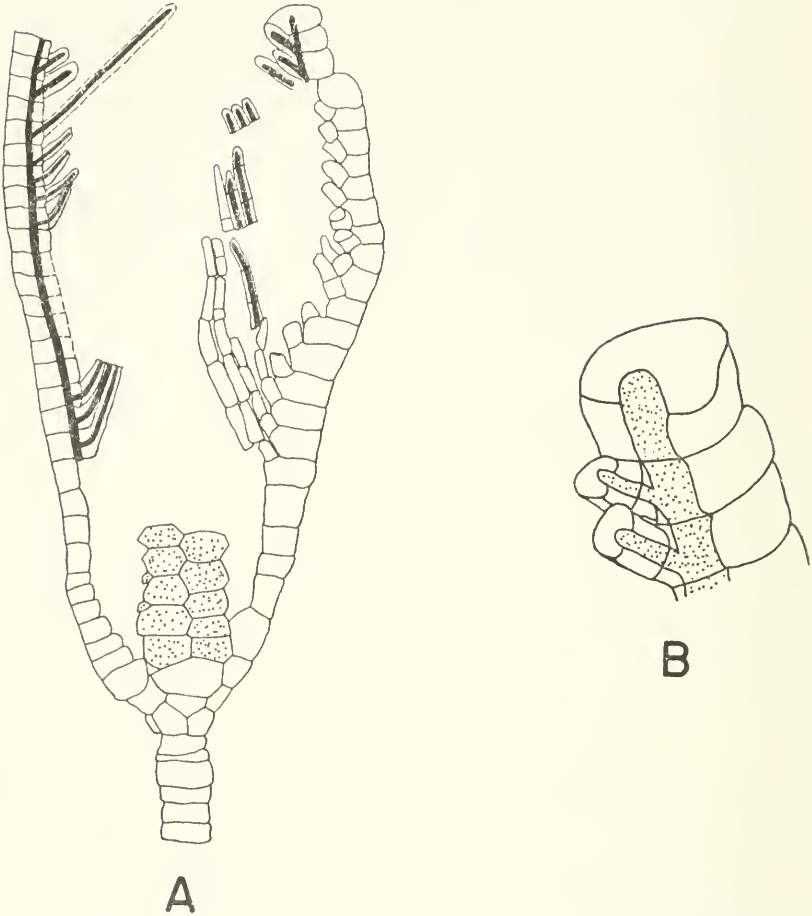
C ray arm missing. B ray arm bifurcates isotomously on IBr2; left branch not preserved. E ray arm partially preserved. Brr are uniserial, wider than high. Inner corner of each IIBr truncated for articulation with first pinnular.

Food grooves of Brr and pinnulars about same width, occupying approximately 25% of the width and 33% of the depth of the Brr, and 33% of the width and 50% of the depth of the pinnulars. Br food groove (*i.e.*, running from one Br to the next) straight, emerging in center of proximal and distal Br faces; axis of Br food groove at right angles to proximal and distal Br faces; four to six interlocking covering plates on food groove of each Br. Pinnule facet food groove runs from Br food groove to pinnule facet, straight, set at roughly a 40° angle to the Br food groove. Food grooves on pinnulars straight, with long axis parallel to the pinnular long axis; food grooves emerge at center of proximal and distal pinnular faces; about five sets of interlocking covering plates on food groove of each pinnular.

Pinnules directed upward, subparallel to arms, found only on inner side of each arm branch.

Anal tube incompletely known, composed of four rows of markedly convex, interlocking plates. Each row resembles a stack of pillows in front view. Articular surface between anal plates triangular.

Stem round, consisting of nodose columnals of alternating sizes.



Text-figure 2. — *Geraocrinus sculptus* Ulrich, holotype, USNM 89874, dorsal cup height 4.3 mm, locality 15d. A. CD interray view, × 2.4. Food grooves outlined in black. Anal tube plates stippled. B. Arm fragment, × 9. Food grooves stippled. Covering plates are poorly preserved and are omitted.

Remarks. — See genus.

Holotype. — USNM 89874.

Occurrence. — Ottosee Formation or Sevier Formation, locality 15d.

Family CALCEOCRINIDAE Meek and Worthen, 1869

Genus ANULOCRINUS Ramsbottom 1961 (p. 8)

Anulocrinus latus, n. sp. Pl. 3, fig. 1

Diagnosis. — A species of *Anulocrinus* with terminal main axil II in A ray, I in B ray. IBr1 and IIBr3 of E ray are axillary, with ray branching twice. Plates massive, wider than high; surface coarsely pitted.

Description. — Poorly preserved specimen consists of incomplete crown with robust arms; plates coarsely pitted; cup represented only by E ray iR and sR, A ray R, fragment of B ray sR, and BB circlet.

BB circlet composed of single large subtriangular plate presumably representing the original four (?) plates which are anchylosed.

E ray iR trapezoidal with proximal side wider than distal side; rather broad contact between iR and sR; sR square. Large A ray R higher than wide. Small fragment of B ray sR preserved.

E ray IBr1 axillary, followed by three IIBrr. IIBr1 square, IIBr2 wider than high, IIBr3 axillary. Six IIIBrr preserved on left side of E ray, all wider than high.

Primaxil arm of A ray consists of main axils I1 and I2 which are wider than high; seven alphabrachs, wider than high; higher alphabrachs not preserved. Secundaxil arm has main axils II1 through II5, wider than high; higher portions of arm represented by one poorly preserved alphabrach and one poorly preserved omegabrach.

B ray comprised of three main axils I, all wider than high, the third axillary; three alphabrachs, wider than high, third probably axillary; higher Brr consisting of one incomplete alphabrach and one incomplete betabrach. Omega-ramule represented by five poorly preserved Brr.

Remarks. — Although the holotype and only known specimen is incomplete, consisting only of part of the dorsal cup and the proximal parts of the A, B, and E rays, the generic assignment to *Anulocrinus* is considered definite. The dorsal cups of *Anulocrinus* and *Cremacrinus* (Moore, 1962a, p. 20) are identical, but these two genera differ in arm structure. The *Cremacrinus* axil arms branch heterotomously on every other Br whereas in *Anulocrinus,* two, three or four Brr separate each ramule. In view of the seven alphabrachs in the A ray of the primaxil arm, the Benbolt crinoid is placed in the latter genus.

The Benbolt species is larger than the other four anulocrinids both in overall size and in the size of the individual plates. *A. thraivensis* (type species, Ramsbottom, 1961, p. 8, pl. 2, figs. 1-8, text-fig. 7), *A.* n. sp. aff. *A. drummuckensis* (Brower, 1966, p. 619, pl. 75, figs. 10-12, text-figs. 1a-g), *A. drummuckensis* (Ramsbottom, 1961, p. 9, pl. 2, figs. 9 and 10), and *A. simplex* (Springer, 1926, p. 107, pl. 28, figs. 8, 8a) are progressively smaller. In *A. thraivensis, A.* n. sp. aff. *A. drummuckensis* and *A. drummuckensis,* the Brr shape varies from equidimensional to higher than wide in the more distal portions of the arms. All *A. simplex* Brr are higher than wide. The Brr of the Benbolt species are twice as wide as they are high, with few exceptions.

The pitting of the plates is coarser in the Benbolt species than in the other pitted anulocrinids. Only *A. simplex* has smooth plates.

The E ray of the Benbolt species is distinctive in branching twice and having an axillary IBr1 and at least six IIBrr. In *A. drummuckensis, A.* n. sp. aff. *A. drummuckensis* and in *A. simplex,* the E ray is unbranched. *A. thraivensis* possesses an E ray that branches with the formula, IAx=IBr7, IIAx=IIBr5.

The terminal axils of the A and B rays differ among the various anulocrinids. *A. thraivensis* is the most extensively branched, having the terminal main axil IV in the A ray and II in the B ray. In both *A. drummuckensis* and *A.* n. sp. aff. *A. drummuckensis,* the main axil II is terminal in the A and B rays. The A and B rays of *A. simplex* are both ended by main axil I. In the Benbolt species, the main axil II equals the highest one in the A ray and the main axil I in the B ray.

In addition, several calceocrinid BB circlets are available from various localities. Inasmuch as *Anulocrinus latus,* n. sp. is the only known calceocrinid in the "Benbolt" fauna, the BB probably belong to this form.

Specific name.—*Latus* referring to the greater relative width of the Brr in this species.

Holotype. — USNM 164108.

Occurrence. — Benbolt Formation, locality 1a, probably also localities 4d and 4f.

Family **EUSTENOCRINIDAE** Ulrich, 1924

Genus **RISTNACRINUS** Öpik, 1934 (p. 1)

Ristnacrinus ? altobasalis, n. sp. Pl. 3. fig. 5

Diagnosis. — A ristnacrinid with a conical cup; high BB; arms branching on IBr1, IIBr1, and on IIIBr2; stem obscurely pentagonal with pentagonal axial canal.

Description. — Conical cup; plates obscurely granular; sutures slightly beveled. Three BB evident, presumably five originally present, large, hexagonal, 3.7 mm high and 3.1 mm wide. Three compound RR evident. The iRR pentagonal, large, high, truncated distally, 3.7 mm high and 2.7 mm wide. The sRR wide, quadrangular, 1.9 mm high and 3.1 mm wide. RR facets occupy entire width of R; RR facet surfaces not seen. Articular surfaces between adjacent calyx plates smooth.

Proximal and youngest columnal composed of triangular pentameres which fit into proximal margins of BB like apparent IBB; (reasons for considering these plates as columnals are given under *Remarks*). Nodose stem weakly pentagonal with longitudinal pentameric divisions faintly apparent; pentameres can be traced throughout length of stem by small pores. About 21 mm of the stem is preserved. One complete noditaxis (nodal plus all internodals of contiguous internode) consists of (from distal end towards proximal) one nodal (N), one tertinternodal (3IN), one secundinternodal (2IN), one tertinternodal (3IN), one priminternodal (1IN), one tertinternodal (3IN), one secundinternodal (2IN), one tertinternodal (3IN). Most distal noditaxis incomplete with following formula: N, 2IN, 1IN, 3IN, 2IN, 3IN. Next noditaxis complete as in formula given above. Proximally, columnals smaller, and noditaxes not completely developed. Formula up to BB as follows: N, 3IN, 2IN, 3IN, 1IN, 2IN, 3IN, N, 2IN, 1IN, 2IN, N, 2IN, 1IN, 2IN, N; then several nodals with internodals in process of formation. Height of oldest and most distal nodals from 1.8 mm to 2 mm; of younger nodals from .9 mm to 1.2 mm; of youngest and most proximal nodals, with newly formed internodals apparent, .2 mm to .7 mm. Height of 1IN (largest order) from .4 mm to 1.5 mm. Height of 2IN from .3 mm to .8 mm. Height of 3IN from .1 mm to .2 mm. Collars or articulating rims on distal edge of most distal 1IN and on distal edge of second distal N from .1 mm to .2 mm in height.

Apparently, the proximal nodals formed first, with a 1IN then inserted between them. Two 2IN then formed on either side of the 1IN giving a total of three internodals. Then one 3IN was inserted between each columnal giving a total of seven internodals and one nodal with the formula for the complete noditaxis as stated above.

Stem heteromorphic (successive columnals differ from each other). Sutures between columnals symplectial with interlocking crenulae, *i.e.,* crenellae and culmina of adjacent columnals fit into each other.

Pentameres apparent at broken end of stem. Axial canal obscurely pentagonal with angles interradially disposed; axial canal angles originate at pentamere sutures.

Arms round, robust, branch isotomously on IBr1, and heterotomously on IIBr1 and again on IIIBr2. Brr massive, higher than wide; IBr1 5 mm high by 3.5 mm wide; IBr2 4.5 mm high by 3.2 mm wide. Brr possess shallow food grooves and separate round axial canals. Articular surfaces smooth.

Remarks. — This species is based on a single specimen which has the posterior side buried in matrix. The crinoid is somewhat crushed and the plates are slightly separated, so that the dorsal cup appears wider than when the animal was alive.

The proximal column is composed of pentameres, presumably five, of which two are visible. These plates are triangular or pentagonal with their proximal apices fitting into the angles formed by the hexagonal BB. At first glance, they appear to be IBB, but on closer inspection, these plates clearly represent the pentameres of the proximal column. One division seen between two of the pentameres is continuous and is denoted by a faint longitudinal line throughout the length of the stem. The line is easily traced by means of sutures between adjacent pentameres (proximal part of stem) or pores connected by a faint longitudinal line (distal portion). This pentameric division ends at one of the angles of the pentagonal axial canal as seen at the broken end of the column. Since this angle of the axial canal and the longitudinal pentameric division are interradial in position, this form is monocyclic. Therefore, the plates beneath the BB must be pentameric columnals and not low IBB.

Because there are three adjacent compound RR in evidence, this form can be neither a heterocrinid nor a homocrinid. By analogy with completely known monocyclic inadunates with compound RR, one may assume that this crinoid possesses five compound RR. The presence of a monocyclic cup and five compound RR places this form in the Eustenocrinidae. However, since the posterior side is unknown, it can be given only tentative generic assignment.

The Benbolt form is closest to *Ristnacrinus* in having a robust conical cup which expands slightly distally, in its high iRR, and in the branching of its arms. Although the arm structure in the new species is not identical to that of *R. marinus* Öpik (1934, p. 4, text-fig. 1, pl. 1, figs. 1-2), it is closer to it than to the other eustenocrinids. The arms of *R. marinus* branch on IBr1 or IBr2 while those of *R.* (?) *altobasalis*, n. sp. branch on IBr1 and IIBr1. In *Peniculocrinus* Moore (1962b, p. 33), the first arm bifurcation occurs on IBr6 or IBr7.

The new species resembles *Peniculocrinus* in its pentagonal column and pentagonal axial canal. But it resembles *Ristnacrinus marinus* in cup size and shape, in the branching of the arms and the height of the iRR. The Benbolt crinoid thus seems closer to *Ristnacrinus* than to *Peniculocrinus,* and until a specimen with a posterior side preserved is found, it may be considered a ristnacrinid.

The specific characteristics which differentiate the new species from *Ristnacrinus marinus* are the height of the BB and the arm branching formula. The BB in *R.* (?) *altobasalis,* n. sp. are as high as the iRR while in *R. marinus,* the BB are smaller and mostly hidden under the cup. The difference in arm branching is given above.

Specific name. — *Altobasalis* in reference to the marked height of the BB.

Holotype. — USNM 164109.

Occurrence. — Benbolt Formation, locality 6.

Order HYBOCRINIDA Jaekel, 1918

Family **HYBOCRINIDAE** Zittel, 1879

Genus **HYBOCRINUS** Billings, 1857 (p. 275)

Hybocrinus punctatus (Miller and Gurley) Pl. 4; Pl. 5, figs. 1-3

1895. *Indianocrinus punctatus* Miller and Gurley, Illinois State Mus. Nat. Hist., Bull. 7, p. 83, pl. 5, figs. 8-13.
1915. *Indianocrinus punctatus* Miller and Gurley, Bassler, U.S. Nat. Mus., Bull. 92, p. 665.
1941. *Holocystites* Butts, Virginia Geol. Sur., Bull. 52, Pt. 2, p. 91, pl. 89, fig. 13.
1943. *Hybocrinus punctatus* (Miller and Gurley), Bassler and Moodey, Geol. Soc. America, Spec. Paper 45, p. 515.

Diagnosis. — A species of *Hybocrinus* characterized by pitted plate surfaces; asymmetrical pear-shaped calyx; distal edge of anal X only slightly higher than edge of adjacent RR, without crenellations on border.

Description. — Calyx pear-shaped, markedly asymmetrical, posterior edge rises several mm higher than anterior. In average-sized adult, anterior calyx height is 7.0 mm, posterior height is 9.7 mm. Posterior side protuberant. Surface of plates covered with pits which do not penetrate plates. Pits commonly weathered or abraded; where evident, pits are round, ranging from four to six per mm. Sutures between plates sometimes impressed. In some specimens, small parallel ridges cross plate sutures at right angles to sutures; width of ridges same as diameter of pits; small grooves between ridges connect pits from adjacent plates. Ridges vary in length from .2 mm to 2.0 mm. Single specimens have ridges of varying size which fade out gradually into pitted plate area. Most sutures between plates are narrow, only slightly indented. Weathering affects appearance of pits and ridges to a greater or lesser degree.

Five pentagonal BB, subequal in size; CD interray B higher and wider than AE and AB interray BB. In average adult, CD interray B is 4.7 mm high and 4.1 mm wide; AE and AB interray BB are 3.8 mm high and 3.5 mm wide. The size of the BB decreases from the CD interray B which is the largest to the CB and DE interray BB which are intermediate in size to the AB and AE interray BB which are the smallest.

RR take up remaining half of calyx height. Four pentagonal RR and one hexagonal RA in RR circlet. D ray R is slightly higher and wider than A ray R. Average adult has A ray R 5.3 mm high and 4.7 mm wide; D ray R 5.5 mm high and 5.2 mm wide.

RA hexagonal, markedly convex; in average adult, 6 mm high, 5.6 mm wide. RA supports small, pentagonal C ray R on its right shoulder, and small quadrangular anal X on its left shoulder. C ray R widens slightly distally. Average size of these plates in adult is height and width of C ray R 4.8 mm by 4.9 mm, and height and width of anal X 3.0 mm by 3.4 mm.

The size of the plates in the RR circlet decreases from largest which is RA, next is D ray R, then B and E ray RR, and last A ray R. C ray R and anal X, which lie in distal part of RR circlet are smallest.

Plate thickness in single specimen roughly constant; BB become slightly thicker in proximal direction near axial canal; distal RR margin near arm facet also thickened. In a specimen 13.3 mm in cup height, with A ray R 7.4 mm high, and AB interray B 6.0 mm high, the plate thickness of the R and B is .4 mm. R thickens distally at arm facet to .6 mm; average plate thickness is 7% of its height. B thickens proximally near lumen to .5 mm; average thickness of B is 6% of its height.

Arm facets equal almost one-third width of R; protuberant and directed outward; deep ambulacral notch; semicircular outline, with slightly raised rim; inside rim, the articular face is slightly concave.

One incomplete specimen shows partial tegmen composed of four large OO with space for missing CD interray O. Outer margins of adjacent OO possess openings where axial or aboral nerves penetrated calyx. Ambulacral grooves continue from arm facet above sutures between OO. During life, covering plates were presumably present as in other hybocrinids. Sutures between adjacent OO deeply indented. Ambulacra and other tegmen structures unknown.

Stem facet small, 2 mm diameter in average adult; round, slightly concave, with low surrounding rim. Pentalobate axial canal; lobes interradial.

Arms and column unknown.

Remarks.—This species was originally described by Miller and Gurley (1895b, p. 83, pl. 5, figs. 8-13) on the basis of a single incomplete specimen (holotype, UC 6125). At the same time, Miller and Gurley erected the genus *Indianocrinus* for this one crinoid. According to those writers, the genus was characterized by four RR although the usual hybocrinid number is five. Their holotype is no doubt a normal hybocrinid with the anal X and the C ray R missing. Their figures (pl. 5, figs. 8-13) clearly show a dorsal cup with four large RR (A, B, D, and E) and the RA in place (also Pl. 4, fig. 1 of this paper). This condition is frequently encountered in *Hybocrinus punctatus* (Miller and Gurley) since the small anal X and the C ray R extend higher above the distal margin of the calyx than the other four RR. Consequently, these two plates are easily broken off and lost.

According to Kirk (see citation in Bassler and Moodey, 1943, p. 515), who examined the specimen, the Middle Silurian Laurel Limestone occurrence cited by Miller and Gurley was in error. This is correct, and the dark brownish color of the holotype clearly denotes that the crinoid was not collected from the Laurel Limestone where the crinoids are yellowish in color. Considering the morphology of the holotype and the localities from which Miller and Gurley obtained their collections, and proceeding by logical process of elimination, one concludes that the individual must have been collected from the Black River, in or near Knoxville, Tennessee.

The only other previously described hybocrinid with a pitted surface on the plates is *H. crinerensis* Strimple and Watkins (1949, p. 132, pl. 1, figs. 4-8) from the Bromide of Oklahoma. However, this form has a narrower and more symmetrical calyx than *H. punctatus*. The Bromide crinoid shows only a mild posterior protrusion while this bulge is pronounced in *H. punctatus*. Two other Bromide hybocrinids, *H. nitidus* Sinclair (1945, p. 713, pl. 2, figs. 1-4) and *H. pyxidatus* Sinclair (1945, p. 713, pl. 2, figs. 5-7), are less asymmetrical than *H. punctatus* but have smooth rather than pitted plates. These differ from each other in size, *H. pyxidatus* being larger and *H. nitidus* smaller.

Among the remaining asymmetrical forms, *H. conicus* Billings (1857, p. 274), the type species (Springer, 1911, pl. 5, figs. 6a, b), has smooth plates. *H. tumidus* Billings (1857, p. 275; Springer, 1911, pl. 5, figs. 1-5), a smaller form, shows minutely granular plates which are tumid in the center. In *H. pristinus* Billings (1859, p. 23, pl. 1, fig. 2a), the smallest of these three crinoids, the plates appear smooth but under magnification are seen to have small tubercles. The calyx shape of *H. tumidus* and *H. pristinus* is subglobular while that of *H. conicus* is steeply conical. These all differ from the pear-shaped calyx of *H. punctatus.*

The anal X of *H. tumidus* differs from that of *H. punctatus* in being highly elevated above the rim of the cup with a curved crenellated distal margin. In *H. punctatus,* the anal X is subquadrangular, only slightly elevated above the rim of the cup and lacks a crenellated distal margin.

Apart from the camerate *Diabolocrinus,* the most abundant "Benbolt" crinoid is *Hybocrinus punctatus* which is represented by 99 calyces and dorsal cups. These were obtained from almost all the collection sites ranging northeastward from Knoxville, Tennessee, to Hansonville, Virginia. Eighty specimens were found in the central part of this area ranging from Lutrell, Tennessee, to Evans Ferry, Tennessee. With the exception of the Knoxville crinoids (see later discussion), the distribution of morphological variants shows no correlation with geography or stratigraphic horizon. Clearly, the main population of the species was located in the central part of the range; peripheral individuals possibly represent immigrants from the main population.

There are five specimens from near Knoxville, Tennessee, for which Ulrich proposed the manuscript name of "*Hybocrinus recurvus*". Two of these specimens have smooth, abraded and weathered, or weathered plate surfaces and strangely asymmetrical cups which bend strongly at the base, so that the stem facet faces the posterior side and is almost parallel to the vertical axis of the cup. The remaining three individuals all show some traces of surface pitting, although these are somewhat weathered. The orientation of the stem facet in these three crinoids ranges from being parallel to the vertical axis of the calyx to possessing the normal structure of *H. punctatus* with the column facet slightly inclined with respect to the cup width. Thus it is clear that Ulrich's "*H. recurvus*" grades into the typical *H. punctatus* configuration; consequently, the Knoxville crinoids are considered conspecific. Probably the Knoxville individuals represent a small semi-isolated population showing, to some degree, a specialized adaptation to local conditions (unusually high current agitation ?). Probably extreme individuals of this type had recumbent stems which lay on the substrate like those of calcaeocrinids.

Types. — Holotype, UC 6125. Figured specimens, USNM 164110-164120.

Occurrence. — Benbolt Formation, localities 1a, 1f, 2a, 3a, and 5; Benbolt and Wardell Formations or Wardell Formation, localities 7 and 13; Wardell Formation or Witten Formation, locality 8a; questionably Wardell Formation, locality 8b; Benbolt Formation or Hogskin Member of Lincolnshire Formation; localities 9a, 9c, 10a, 10c and 10d; Hogskin Member of Lincolnshire Formation, according to Cooper (1956), localities 8c, 9b and 11; Ottosee Shale or Sevier Shale, localities 15a and 15e; questionably Red Knobs Formation, locality 17; Pierce Shale, locality 18.

Hybocrinus punctatocristatus, n. sp. Pl. 3, figs. 6a, 6b

Diagnosis. — A species of *Hybocrinus* with large, broadly conical calyx; calyx markedly asymmetrical with crestlike protuberance on RA. Plates pitted.

Description. — Species based on single specimen with C ray R, anal X, and distal portion of RA missing. Large asymmetrical conical cup, anterior side 38 mm high, posterior side incomplete. Both anterior and posterior sides expand widely from narrow base, but posterior side expands to a greater degree due to the crest on the RA. Plate sutures slightly incised. Where not abraded, plate surface shows five round pits per mm.

BB five, pentagonal, high, with higher and wider BB on posterior side. CD interray B 18.9 mm high and 13.4 mm wide; DE interray B 18.5 mm high and 13 mm wide. AE interray B shorter and narrower with dimensions of 18 mm height and 12.2 mm width. Both AB and BC interray BB partially missing. BB occupy about one half height of cup.

RR pentagonal, about one-half height of cup. Posterior RR higher and wider: D ray R 19 mm high, 16.5 mm wide; E ray R slightly smaller, 18 mm high, 14 mm wide; A ray R 17.5 mm high, 13.5 mm wide. B ray R incomplete, width is 16.5 mm. C ray R missing; shape of RA and D ray R indicates a small plate. Arm facets protuberant, located on short necklike extensions of distal RR margins. Extensions protrude upward and outward at an angle of about 30° from the horizontal. Facets elongate, narrow, horseshoe-shaped, approximately 5 mm wide and 7 mm long. Facet surface poorly preserved, smooth with distinct marginal rim. Ambulacral grooves narrow and deeply notched; extend beneath depressed sutures between adjacent OO.

Anal X missing. RA hexagonal, 20 mm high by 19 mm wide; largest plate in cup with prominent, longitudinal crestlike protuberance; narrowly incised articular sutures.

Tegmen shows four large triangular OO, with CD interray O missing. Sutures between OO indented, forming a ditch with steeply sloping sides. Ambulacral tracts under sutures. Other details unknown.

Arms and column unknown.

Stem facet round, 5.0 mm in diameter, slight rim around edge; pentalobate axial canal, lobes interradial.

Remarks. — This form is based on a single calyx which lacks the C ray R, anal X, and the left distal portion of the RA. The species is easily distinguished from most hybocrinids by the pitted ornamentation. Although the general nature of the pits in *H. punctatocristatus,* n. sp. is similar to that of the other two previously described pitted species, *H. punctatus* (Miller and Gurley) and *H. crinerensis* Strimple and Watkins (1949, p. 132, pl. 1, figs. 4-8), it differs from these in a number of characteristics.

The large size, conical shape and crested RA separate it readily from *H. punctatus* which is smaller, pear-shaped, and more asymmetrical with a convex noncrested RA.

The same characteristics distinguish the new species from the Bromide *H. crinerensis.* The latter also shows a somewhat conical calyx shape; however, the rounded base of the Bromide form is markedly distinct from the straight-walled base of the Benbolt crinoid. In addition, *H. crinerensis* is smaller and more symmetrical than *H. punctatocristatus,* n. sp.

Specific name. — *Punctatocristatus* in allusion to the pitted surface and crested RA.

Holotype. — USNM 164121.

Occurrence. — Benbolt Formation or equivalent part of Dryden Limestone, locality 4e.

Hybocrinus perperamnominatus, n. sp. Pl. 3, figs. 2-4

Diagnosis. — A species of *Hybocrinus* with small, slender, elongated dorsal cup. Calyx with little asymmetry. Surface pitted.

Description. — Long narrow, almost symmetrical calyx, 18 mm high and 9.3 mm wide at its greatest width (all measurements from holotype). Shape varies from narrow elongated cone with steeply sloping straight sides, to elongated barrel shape with sides outlining a long shallow curve. Plate sutures narrow, only slightly indented. Some sutures crossed by narrow ridges at right angles to sutures. Ridges alternate with depressions. Pits found in depressions and on surface of plates; about four to five round pits per mm; pits not penetrating through plates.

BB five, pentagonal, high, somewhat less than half the calyx height; in holotype, 7.2 mm high and 4.5 mm wide. As seen in longitudinal section, proximal half of B 1.6 mm thick at widest part, thinning slightly towards stem, forming a narrow canal which is continuous with the stem axial canal. Upper half of B thinner, narrowing to .5 mm where it articulates with the R. At thickest part of B, thickness equals 20% of its height.

R about .5 mm thick, with thickness equalling about 6% of height of R; gradually thickens distally toward arm facets, where plate thickness is about .6 mm and roughly equals 8% of height. Only D and C ray RR preserved in holotype. D ray R pentagonal, 7.5 mm high, occupying almost half height of cup; complete width not observed. C ray R roughly pentagonal, 3.2 mm high and 5 mm wide. Articular surfaces between plates usually smooth, narrowly depressed in some instances. Arm facets wide horseshoe-shaped, occupying less than one-third of the distal width of the R. Marginal rim present with concave articular surface.

RA in holotype hexagonal, slightly higher than wide, 7.4 mm high and 5.8 mm wide, slightly convex. Anal X on left shoulder of RA, quadrangular, 3.8 mm high and 3.4 mm wide. Small C ray R on right shoulder of RA, probably pentagonal, distal portion unknown.

Arms represented by three quadrangular IBrr in holotype, approximately 1.7 mm high and 2.5 mm wide. Surface pitted. Brr roughly round in cross section with narrow food groove.

Stem facet about 3.6 mm in diameter; slight marginal rim; axial canal pentalobate, lobes interradial.

Remarks.—This species is based on relatively poor material. The holotype is a longitudinally broken cup preserving the posterior side. The paratype consists of a cup with the posterior side buried in matrix. In addition, there are about 10 BB circlets also embedded in matrix, and one broken specimen. Several of these show articular surfaces and stem facets.

H. perperamnominatus, n. sp. differs markedly from the other pitted hybocrinids in the calyx shape. In the new species, the calyx sides are almost straight, and the cup is almost twice as high as wide. It is readily separated from the relatively broad and strongly pear-shaped *H. punctatus* (Miller and Gurley). The shape of *H. perperamnominatus* n. sp. is most similar to that of *H. crinerensis* Strimple and Watkins (1949, p. 132, pl. 1, figs. 4-8) and *H. punctatocristatus,* n. sp. However, in both the latter, the width of the calyx roughly equals the height, but in *H. perperamnominatus,* n. sp., the width equals about half the height. The new species is the narrowest and the most symmetrical hybocrinid yet found. Its RA lacks the marked convexity of the RA of *H. punctatus* and the crestlike protuberance of the RA of *H. punctatocristatus,* n. sp.

Specific name.—*Perperamnominatus* or incorrectly named, since it is not a hump-backed crinoid like most of the other species in *Hybocrinus* (*hybos,* hump backed).

Types.—Holotype, USNM 164122. Paratypes, USNM 164123 and 164124.

Occurrence.—Benbolt Formation, localities 1a and 1e.

Order CLADIDA Moore and Laudon, 1943

Suborder CYATHOCRINOIDEA Bather, 1899

Family **PALAEOCRINIDAE** Bather, 1899

Genus **PALAEOCRINUS** Billings, 1859 (p. 24)

Type species: Designated by Miller, 1889, page 267, *Palaeocrinus striatus* Billings, 1859, page 25, plate 1, figures 5a, b.

Diagnosis.—A genus of Palaeocrinidae with completely developed parallel ridges on plates, crossing sutures at right angles. Small, quadrangular RA and small anal X in line with RR. As presently defined, anal opening on tegmen surface or at the end of an anal tube. In the former case, five OO dominate the tegmen; CD interray O largest and perforated by a hydropore to form a madreporite.

Remarks. — *Palaeocrinus* differs from the other genera in this family in having fully developed parallel ridges across the plate surfaces at right angles to the plate sutures, in showing a small RA extending below the proximal border of the RR and a small anal X in line with the RR, and in tegmen structure.

The species presently assigned to *Palaeocrinus* fall into two groups, those lacking an anal tube and those possessing one. In *P. striatus* Billings, the type species, the anal opening is directly on the tegmen, located above the anal X. The large CD interray O has a perforation which is probably the hydropore. *P. chapmani* (Billings) (1858, p. 71), known only from isolated plates, is either closely related or, more likely, a synonym of *P. striatus* (Hudson, 1911, pp. 244-246, text-fig. 20).

P. angulatus (Billings) (1857, p. 269), on the other hand, possesses an anal tube, mentioned in Wilson (1946, p. 40, pl. 6, fig. 1) and observed by Brower. The anal tube of *P. pulchellus* Billings (1859, p. 46; see Wilson, 1946, p. 40, pl. 6, fig. 3) has not been seen, but this form is closely related to *P. angulatus* and probably belongs to the same group.

The tegmen of *P. rhombiferous* Billings (1859, p. 45; Wilson, 1946, p. 40, pl. 6, fig. 2) is unknown; consequently this crinoid cannot be placed in either group.

It seems probable that a separate genus should be erected for *P. angulatus* and *P. pulchellus*, the diagnostic characteristic of which should be the possession of an anal tube. This is not done here because all the pertinent material has not been studied.

Occurrence. — Middle Ordovician; North America.

Palaeocrinus planobasalis, n. sp. Pl. 5, figs. 5a, b; Pls. 6-8; Text-figs. 3, 6

1941. *Palaeocrinus* aff. *P. striatus* Billings, Butts, Virginia Geol. Sur., Bull. 52, pt. 2, p. 91, pl. 89, figs. 9-11.

Diagnosis. — A species of *Palaeocrinus* with small subglobular cup and flattened base; ornamentation consisting of fine ridges arranged in raised bundles forming rhomboids on cup; column round with pentalobate or pentagonal axial canal. Anal opening located on tegmen surface.

Description. — Based on holotype, USNM 97465, a typical adult individual. Cup subglobular with flattened base, 19 mm at greatest width, and 16.5 mm high. Cup covered with parallel ridges arranged in rhomboidal-shaped bundles disected transversely by plate sutures. Bundles placed so that the widest part of rhomboid overlies plate suture and pinches out toward the plate center. Longest and most upraised ridges in center of each bundle with ridge on either side parallel to it but placed lower on sloping sides of bundle and becoming shorter towards edges of bundle. Width of ridges approximately .19 mm, all ridges of same width regardless of length and size of crinoid. The longer the sutures between the plates, the greater the number of ridges crossing it. The ridges on adjacent IBB are subparallel to the sutures between them. There are no ridges crossing these sutures. The ridges covering each IB belong to the proximal part of two different bundles each of which runs from the proximal edge of the IB to the center of the two adjoining BB. The rhomboid shape of these bundles is somewhat distorted due to the convergence of the IB lateral margins toward the stem facet. See later discussion for details of suture length and ridge numbers.

IBB five, pentagonal, almost horizontal, 4.7 mm wide by 3.7 mm high. BB five, hexagonal, approximately 8.7 mm wide and 7.2 mm high.

RR basically pentagonal, averaging 9.2 mm wide by 7.2 mm high. Arm facets narrow, horseshoe-shaped, 4.6 mm wide by 3.7 mm high with deep ambulacral grooves. Prominent marginal rim around facet, with concave sides of articular surface sloping inward. Outer curve of facet sometimes has a small longitudinal groove which underlies the ambulacral groove axis and is parallel to long axis of facet. Both sides of arm facet sometimes have an irregular transverse ridge.

RA small, roughly quadrangular, 5 mm wide and 5.5 mm high, resting on shoulders of BC interray and CD interray BB, partly in line with RR. Anal X quadrangular, 6 mm wide by 5 mm high, in line with RR, resting on RA and CD interray B.

Flooring surface of tegmen preserved on S 5422. Composed of five OO; CD interray O largest with perforation in center, probably a hydropore. Anus on tegmen surface, between anal X and CD interray O. Food grooves in depressed areas between adjacent OO sutures, located on OO surfaces. Food grooves radiate from central mouth; arranged in trigonal pattern, with B and E ray food grooves branching to form those of C and D rays, respectively. Openings at outer ends of food grooves apparently represent places where aboral nerve cords run from IBrr into dorsal cup.

Tegmen surface preserved in holotype. Main food grooves five, occurring on OO. Near tegmen margin each food groove branches above IAx, with one branch going to each IIBr1. On outer sides of IIBrr1, parts of food grooves are partially floored by several large iAmbb which occur between dorsal cup and covering plates. One or two large iAmbb present between IIBrr1 food grooves of single ray. Food groove covering plates wedge-shaped with inner narrow sides interlocking. Covering plates generally arranged in biserial rows of two plates each. In a few places, four plates occur in a single row; outer two rows probably correspond to side covering plates of living crinoids; inner two rows equivalent to inner covering plates. Anal opening surrounded by arch of five plates; distal plate located between CD interray O and anus. Hydropore (?) surrounded by numerous small irregular plates, apparently located between an anal arch plate and CD interray O.

Column of holotype is 3.5 mm in diameter. Axial canal not well preserved but is seen to be pentalobate on another broken specimen, paratype USNM 97465. Axial canal may be pentagonal as in unnumbered specimen from Hansonville, Virginia, or obscurely pentagonal as in S 5423. Columnals round, composed of alternating nodals and internodals, narrow with crenelated sutures, axial canal pentalobate, as seen in paratype S 5421.

Arms possess an IBr1 which is axillary; triangular with distal apex, about 4.5 mm wide and 2.7 mm high. Nonaxillary IIBrr1 partially preserved in A and D rays, quadrangular, much wider than high.

Remarks. — This species is based on some 30 poorly preserved typical specimens and a number of isolated plates found throughout the outcrop belt from Hansonville, Virginia, to Louisville, Tennessee. Roughly 25 crinoids were collected in the central area around Luttrell, Tennessee, and five were located at the southwest and northeast ends near Louisville, Tennessee, and Hansonville, Virginia.

Species assigned to *Palaeocrinus* differ from each other in cup shape, surface ridges and column. Only those lacking an anal tube (see *Remarks* under genus) are considered here. *P. planobasalis,* n. sp. has a flattened base which gives the cup a subglobular shape; the rhomboidal groups of ridges are arranged in raised bundles and the column is round. *P. avonalensis,* n. sp. (described later) exhibits a cup-shaped calyx with flattened base as in *P. planobasalis,* n. sp. However, its rhombed-shaped ridged areas are not raised into bundles and possess fewer ridges than those of the latter. The arms of *P. avondalensis,* n. sp. contain two or three IBrr, in contrast to the single IBr of *P. planobasalis,* n. sp. In *P. striatus* Billings (1859, p. 25, pl. 1, figs. 5a, b; Hudson, 1911, pp. 217-244, text-figs. 4-19, pls. 5-7), the cup is subconical, the ridges are not elevated in bundles and a round column is present. *P. rhombiferous* Billings (1859, p. 45; Wilson, 1946, p. 40, pl. 6, fig. 2) possesses a small cup of conical shape, there are fewer ridges which do not occur in raised bundles, and the column is pentagonal.

Typical specimens of *P. planobasalis,* n. sp. have sharp ridge bundles with distinct individual external ridges. Another *P. planobasalis,* n. sp. variant, hereafter simply termed "variant", is represented by one poorly preserved weathered dorsal cup, USNM 164131 (Pl. 7, fig. 4); a crushed dorsal cup (MCZ 4162, Pl. 8, figs. 4a, b); five isolated BB (MCZ 4163a-c, Pl. 8, figs. 1-3); and one isolated R (MCZ 4164). These crinoids differ from typical *P. planobasalis,* n. sp. in several ways. The "variant" exhibits more internal ridges than in typical specimens. Tabulating loose BB for mature crinoids in the same size range discloses that typical plates bear from 31-43 internal ridges while "variants" are characterized by 45-62 total ridges. In typical *P. planobasalis,* n. sp., there is a one to one correspondence between the internal ridge canals and the surface ridges (see later discussion for more detail). In end-member specimens of the "variant", the external ridges which overlie many of the internal ridge canals are only visible near the plate margins. Toward the plate centers, the external ridges pinch out and grade into large roughly triangular upraised areas. Thus, away from the plate margins, each ridge canal is no longer associated with its own external ridge. Rather a series of adjacent ridge canals is overlain by one large swollen area which corresponds to the ridge bundles of typical crinoids. MCZ 4162 is somewhat transitional between typical and "variant" specimens. This crinoid has distinct individual external ridges near the plate margins, some of which can be traced about halfway from the plate margins to the center (Pl. 8, figs. 4a, b). A correlated feature is the plate thickness. "Variant" plates are somewhat thicker than those of typical individuals, and a partial gradational sequence can be arranged. The thinnest plates have the most numerous and distinct external ridges as seen in typical *P. planobasalis,* n. sp. Thick-plated "variants" only show distinct ridges at the plate margins. These considerations suggest that the "variants" were derived from normal specimens by accelerating the internal and external thickness growth vectors. The former would have served to thicken the floor of the rhomboidal chamber (see later discussion) while the latter filled in the spaces between adjacent external ridges resulting in a single large ridge bundle. During the process, the new ridge formation rate was also augmented in the "variants".

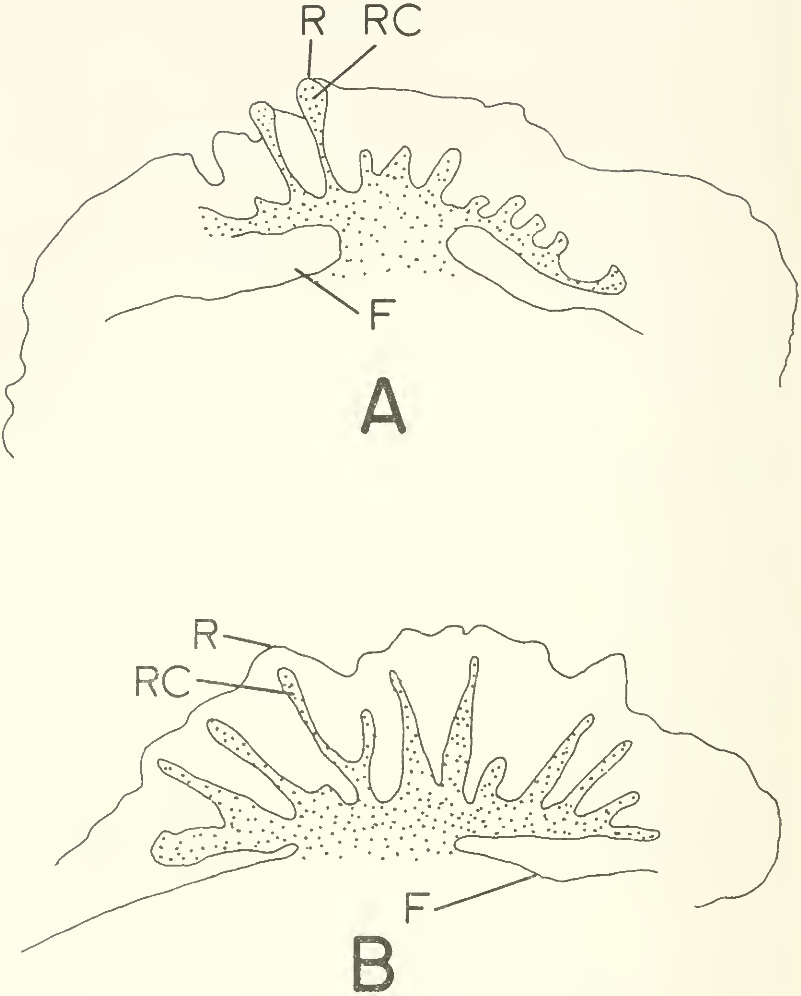
The taxonomic status of the "variant" is somewhat questionable. Possibly the "variant" could be considered as a new species, although this is not done here for several reasons. There is at least one transitional specimen with respect to plate thickness and the nature of the external ridges. The difference in internal ridges between typical crinoids and the "variant" is not large enough to be significant. Consequently the "variants" and typical *P. planobasalis,* n. sp. are considered to be conspecific.

Internal structure of plate ridges and bundles. — This discussion is largely based on typical specimens. The structure of "variants" is the same except that the external ridges are only visible near the plate margins. The external configuration of the *P. planobasalis,* n. sp. ridges was outlined under *Description.* The most interesting feature of this crinoid is the internal morphology of the ridges and the underlying plate. Three approaches to the study of the internal structure of the plates were used. First was examination of dorsal cups showing various degrees of weathering. Fresh or essentially unweathered crinoids illustrate the external configuration of the ridges. With progressive weathering, the interior of the ridges and the underlying structure can be observed. Study of isolated plates was second. Lastly, serial sections of bundles were made with one set of sections cut in a plane parallel to the surface of the plates and another at right angles to it and parallel to the plate suture. Observations were made at .2 mm intervals and camera lucida drawings prepared.

Combining the results of the above techniques, the following structure was revealed (Text-fig. 3, Pl. 5, figs. 5a, b, Pls. 6-8). A single arched bundle of ridges lies across the plate suture; the longest ridge occurs in the center with the other parallel ridges along both of the sloping sides of the bundle gradually becoming shorter. In cross section, the axial plane of the central ridge is seen to be vertical in relation to the cup surface while the outer edge of the other ridges dip outward towards the sides of the bundle.

The plate material roofing the ridges is thin and porous and commonly shows little black specks under high magnification (30 X - 80 X). These black specks represent the more or less carbonized organic matrix which filled the pores of the thin roof of the ridges during the life of the animal. In contrast to this, the plate material between the ridges is much thicker and seems to lack black specks. This suggests lower plate porosity and less organic matrix per unit volume of plate. Proceeding inward, the hollow "canals" under the ridges appear. These are seen in paratypes S 5421, S 5420, USNM 164128, USNM 164130 and in the isolated plates. At first, the "canals" are narrow and correspond in orientation, length and width to the overlying ridges; at this level, these are separated by thick plate material belonging to the depressed areas between the ridges as seen on the surface. Many of these underlying hollow "canals" are filled with dark brown or black material (*e.g.* paratype, S 5420). The black substance obviously represents the more or less carbonized organic material which occupied the canals while the brown material appears to be the same in a more oxidized state.

Continuing inward, the ridge "canals" expand slightly, and the bases of the "canals" open into a rhomb-shaped central chamber. In cross section, this chamber has an arched roof and a flat floor. The upper (outward) margin of the chamber corresponds to the general outline of the overlying ridge bundle. Plate material



Text-figure 3.—*Palaeocrinus planobasalis,* n. sp. Camera lucida drawings of typical "Benbolt" palaeocrinid isolated plate crossections; × 14.5. Symbols: R = external ridge. RC = ridge canal. F = floor of rhomboidal chamber. A. R, paratype USNM 164129. B. B, paratype USNM 124127.

separates each rhomboidal chamber from the adjacent chambers. Upon removal of the matrix in one of these cavities as seen in the isolated plates, a large opening is found in the center of the floor. The opening is located along the plate suture and underlies the center of the overlying bundle. The exact outline of the opening remains somewhat conjectural, as the floor of the chamber is commonly broken or weathered in the isolated plates. Clearly the opening is smaller than the floor of the rhomboidal chamber. Generally the openings are roughly elliptical with the long axis at a right angle to the suture as judged from the appearance of the camera lucida drawings made from serial sections of the bundles. Examination of two well-preserved isolated plates reveals along the edges of the plate, a cross section of the hollow chambers. The arched corrugated roof and the flat floor, open in the center, are clearly seen. One of these plates (Text-fig. 3a) is a R, 8.8 mm wide, in which a representative chamber has a floor which thins out from .6 mm near the junction with the roof to .4 mm near the central opening. The other plate is a B (Text-fig. 3b), 7.6 mm wide, with a floor of a representative chamber thinning out from .5 mm at the edge to .2 mm towards the center. Although the floors of the half chambers are not wholly preserved in either plate, there is a relatively complete floor under one of the chambers in the isolated R. This reveals the roughly elliptical shape of the pore with the long axis at right angles to the edge of the plate. It is approximately .7 mm wide at the widest and has a half length of 1.2 mm. This would indicate an opening of about 2.4 mm in length in a complete chamber floor.

In contrast to *Palaeocrinus planobasalis*, n. sp., *P. striatus* possesses a much smaller number of hollow plate ridges which are not grouped into raised bundles. The canals of these ridges communicate directly with a large sutural canal of cylindrical shape which opens into the interior of the calyx through a vertical canal (Hudson, 1911, pp. 221, 223). Recently *Porocrinus* and *Tribolo-porus* Kesling and Paul (1968, p. 13), were studied in detail by those authors. The following comparison is based on their discussion. In porocrinids, the ridges are endothecal with the folds extending into the calyx. The ridge "canals" which underlie the ridge surfaces open directly into the inside of the calyx. The ridge canals of *Palaeo-*

crinus, on the other hand, open inward into a hollow chamber which in turn opens into the calyx interior.

The function of the above structures was probably respiratory. The distribution of the organic material mentioned above shows that the internal body wall of the crinoid extended through the opening in the floor of the rhomboidal chamber, along the sides of this cavity, and into the hollow ridges. The whole ramifying hollow was no doubt filled with coelomic fluid. The internal body wall joined the overlying plate surface which comprised the ridge bundle. As previously mentioned, the thin-roofed ridges are highly porous. Presumably during life of the animal, these pores were filled with the organic matrix which secreted the plates. Conversely, the depressed areas between the ridges are thicker; probably, these were less porous and contained a smaller amount of organic matrix per unit plate volume. The epidermis, if present, overlay these plate surfaces.

In Recent echinoderms, respiration is accomplished by means of the epidermis and outpouchings of the water vascular system (for discussion of echinoderm respiration, see Farmanfarmaian, 1966). In crinoids, the water vascular outpouchings are represented by the tentacles and podia of the arms. Internally, the fluid filling the water vascular system is in continuous flow with the fluid of the body cavity. Movement of this coelomic fluid is accomplished by flagellated cells lining the body cavities and by movements of the internal organs such as the water vascular system and the alimentary canal. The diffusion of oxygen and carbon dioxide is sustained by the movement of sea water externally and coelomic fluid internally. In some living crinoids (Hyman, 1955, p. 48), the epidermal layer is not completely developed, and in these plates, the body wall and organic matrix within the plates is in contact with sea water. Possibly this condition was present in mature individuals of *Palaeocrinus planobasalis,* n. sp.

In the palaeocrinids under discussion here, the internal body wall area was extended due to being raised into the rhomboidal chambers and in having the top of the chamber developed into numerous extensions fitted into the hollow ridge "canals" near the plate surface. The rhomboidal chambers increased the total coelomic cavity volume while the hollow canals basically augmented the coelomic cavity area in close, albeit indirect, contact with the sea water.

The functioning of the *Palaeocrinus planobasalis,* n. sp. calyx respiratory structures is reconstructed by analogy with living forms. Only the flow of ingoing oxygen is discussed as an example; the path of outgoing substances, *e.g.*, carbon dioxide, was the reverse of oxygen. Assuming an epidermis was present, oxygen acceptance began with this tissue. If an epidermis was lacking, the initial contact occurred with the organic matrix within the plates. Oxygen then diffused through the organic matrix. The amount of material transferred in a given time interval was probably maximized across the thin roofed ridges. Lesser amounts traveled through the depressed areas lying between the ridges. This was due to two factors. The ridges are more porous and contained more organic matrix per unit plate volume. The ridge plate material is thinner than that of the associated depressions. Next, oxygen traveled through the interior body wall, which lined the rhomboidal chamber and the insides of the ridge canals, and into the coelom housed within the interior wall. Once in the coelom, oxygen was distributed throughout the animal by the mechanisms previously outlined for extant crinoids.

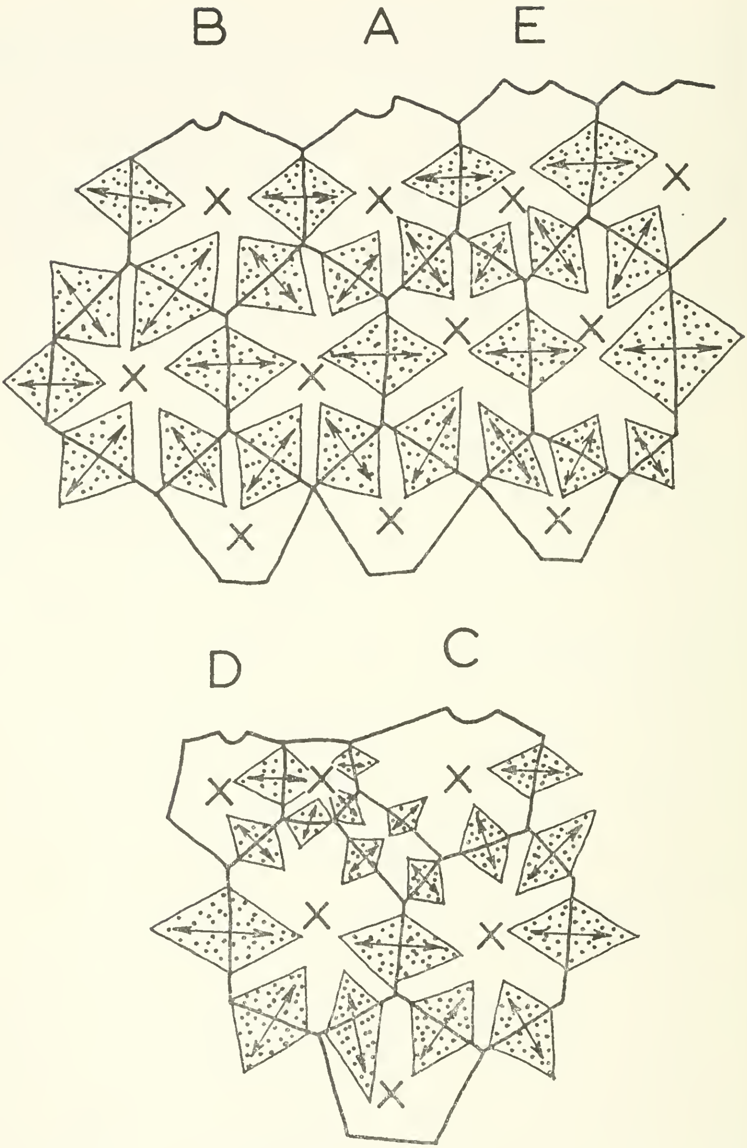
Calycinal respiratory structures also occur in other crinoids, *e.g., Porocrinus* and *Triboloporus* of the Porocrinidae (Kesling and Paul, 1968, p. 13). These two genera possess structures termed goniospires by Hudson (1915, p. 164), each of which consists of three sets of ridges located at the adjacent corners of three calyx plates. The internal folds between the ridges (ridge canals) are endothecal, that is they extend directly into the calyx without an intervening plate structure as in *Palaeocrinus.* Presumably the coelom extended directly into the internal folds. In *Porocrinus,* there are several folds at each plate corner, and in *Triboloporus* there is only one arranged in a triradiate pattern at the juncture of any three plates. One species, *T. cryptoplicatus* Kesling and Paul (1968, p. 13, pl. 1, figs. 1-8), is from the Benbolt Limestone near Hansonville, Virginia; the form is well described and will not be discussed further in this paper.

In *Palaeocrinus,* the internal respiratory structure is much more complex. As previously discussed, the coelom within the ridge canals was in direct contact with that of the rhomboidal chamber; the coelom of this chamber was linked to the main internal coelom by means of the opening at the base of the rhomboidal chamber. Functionally, the palaeocrinid structure seems far more complicated and indirect than the porocrinid type.

The external movement of sea water necessary to sustain the oxygen-carbon dioxide exchange did not necessarily follow the same path in all echinoderms with such internal respiratory structures. In the pectinirhombs of cystoids (Kesling and Paul, 1968, p. 8; Paul, 1968, p. 709), water is generally visualized as entering one end of a trough and exiting at the other. In cystoids, such a pattern seems reasonably efficient because pectinirhombs are not usually present along all sutures; rather, they are scattered over the theca. Consequently, the incoming (oxygenated) water currents would have been well separated from the outgoing (deoxygenated) water currents. The palaeocrinid situation is greatly different as the respiratory structures developed along all dorsal cup plate sutures. If the cystoid model is applicable to the palaeocrinids, at least some oxygenated and deoxygenated water currents were not hydraulically separated; in this case, the deoxygenated currents would often have fouled the oxygen bearing currents. Consequently, the writers postulate the following: In successful animals where hydraulics are important, generally the volume occupied by the inflowing water currents exceeds that of the outflowing water currents. Brachiopods and pelecypods are classic examples. Sponges appear to show the reverse (at least in the ascon type), and in the coral gullet region, the two current systems occupy about the same volume. Therefore, in the general case, elementary hydraulics dictates that the deoxygenated water current travel at a higher velocity than the oxygenated water one in order to ensure hydraulic separation and efficiency. The only way that this model may be applied to the palaeocrinids is to minimize the number of deoxygenated water or outgoing current locations. Consideration of palaeocrinid dorsal cup and respiratory system morphology indicates that the closest approach to this requirement is to have a single deoxygenated water exit in the center of each plate. By process of elimination, oxygenated water inflow would have occurred along the plate sutures (the periphery of each plate). If the model is applicable, the oxygenated water current flowed down along the plate sutures; when this point was reached, the current probably branched into two parts with each continuing along the ridge bundle troughs on each side of the suture and eventually exiting at the plate center (Text-figure 4). This would have resulted in the incoming oxygenated current occupying a larger volume and moving at a lesser velocity than the deoxygenated water current. Kesling and Paul (1968, pp. 8-9) reached the same conclusion about the most likely porocrinid pattern, apparently using similar reasoning. Presumably the currents, regardless of pattern, were activated by cilia along the surface of the epidermis.

The respiratory function of the plate structure is compatible with "Benbolt" palaeocrinid ontogeny (see later discussion) and with two other palaeocrinid morphological features. In many fossil crinoids, the anal tube is supplied with large pores (aside from the pore structure which housed the organic matrix within the plates) and probably functioned in a respiratory capacity (Ubaghs, 1953, p. 687). As previously mentioned, some species of *Palaeocrinus* including *P. planobasalis*, n. sp. lack anal tubes. In anal tube bearing palaeocrinids, this structure is short and represents a small area and volume. In Recent crinoids and doubtless in extinct forms, respiration is one of the main functions of the arms. However, in all *Palaeocrinus* species in which the arms are known, they are short. In crinoids possessing short arms relative to viscera size and mass, a device increasing the respiratory surface would have been of great physiological benefit. Such a device is probably found in the intricately ridged and hollowed calyx plates of *Palaeocrinus*.

Strangely enough, other similar criniods with short arms, *e.g.*, hybocrinids and carabocrinids (at least the Trenton forms examined by the writers) lack such respiratory devices. Among the carabocrinids from the Bromide of Oklahoma, some of the more deeply weathered ridges reveal a distinct longitudinal hollow canal. The structure beneath these canals is unknown. No explanation is apparent. Both carabocrinds and hybocrinids were moderately diversified in the Ordovician with 14 carabocrinid species in two genera and 19 hybocrinid species in five genera.



Text-figure 4. — *Palaeocrinus planobasalis,* n. sp. Schematic sketch illustrating inferred directions of external water flow. X's denote approximate plate centers and locations of probable outgoing water currents. Ingoing currents most likely occurred along the plate sutures with subsequent movement along the plate surfaces parallel to the external ridges.

For example, *Carabocrinus* was abundant in the Twin Cities area and fairly common in the Bromide of Oklahoma and the Trenton of Kirkfield, Ontario. Hybocrinids were abundant in the "Benbolt" and the Bromide (both Black River in age) and in the Trenton of Kirkfield and Kentucky. During the Middle Ordovician, carabocrinids appear to have been moderately successful, and hybocrinids somewhat more successful. When hybocrinids, palaeocrinids, and carabocrinids occurred together, the hybocrinid group was typically the most abundant. Clearly, the hybocrinids represented the most successful group. When carabocrinids and palaeocrinids are found together, sometimes the latter are more abundant ("Benbolt") and at other times the former were more successful (Trenton of the Twin Cities area).

Ontogeny of the ridges. — Five typical individuals of increasing size were examined to observe the ontogeny of the ridges and the underlying canals. The following measurements were made: dorsal cup volume, height and width of calyx, basic plate measurements (height and width of the IBB, BB, RR, anal X, and RA), length of sutures between all plates where preservation permitted measurement, and number of ridges per bundle crossing each suture. The length of the ridges was not measured as this is somewhat controlled by weathering, and the degree of weathering of the five crinoids is not comparable; the smallest specimen is more deeply weathered than the other crinoids. A statistical growth study is not presented because it has not been possible to gather complete sets of data from all five dorsal cups.

Inspection of Text-figures 5-7 and Plate 6 shows the following growth trends:

1. During ontogeny, the calyx plate structure remained stable, and no plates were added to the dorsal cup.

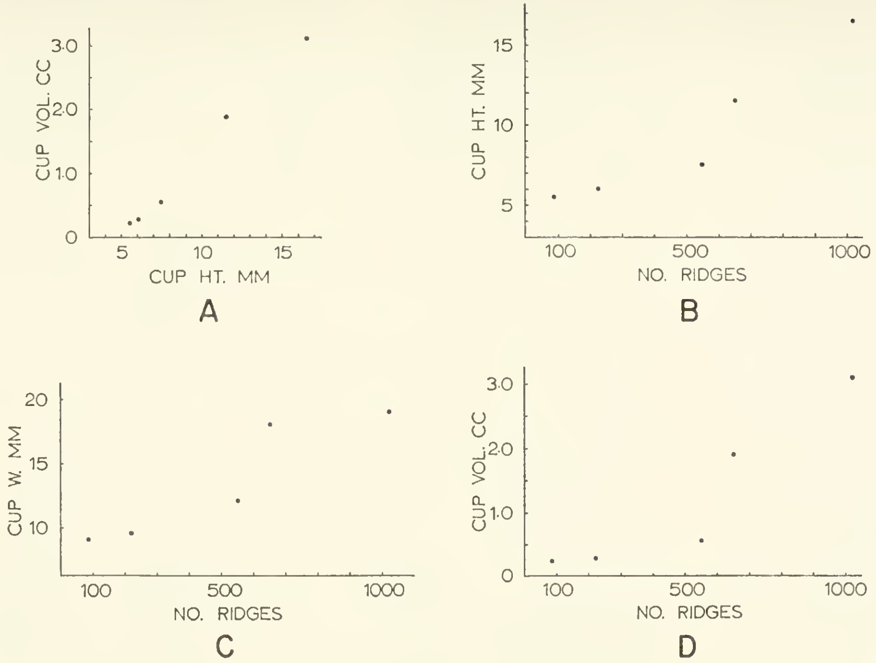
2. Dorsal cup size increased due to growth of the component dorsal cup plates. The dorsal cup volume was augmented at an exponentially increasing rate with respect to size (Text-fig. 5a). In this crinoid, viscera volume may be roughly approximated by external volume because of two reasons. The tegmen is almost flat. Therefore, the volume of the major part of the viscera equalled the external dorsal cup volume less the volume of the dorsal cup itself. A large part of each plate was penetrated by the coelom in the

form of the opening at the base of the rhomboidal chamber, the chamber itself, and the ridge "canals" while the remaining plate material is highly porous and was filled with organic matrix. In living crinoids, the porous fenestrated network occupies roughly 60% of the total plate volume. This figure can probably be extrapolated to fossil crinoids.

3. During ontogeny, the individual calyx plates increased in height and width; consequently the suture lengths were augmented also. The exact growth model for palaeocrinid cup plates is unknown but it seems similar to that postulated by Lane (1963, pp. 928-929), Meyer (1965), Macurda (1968), and Brower (1973) for camerate crinoids. In camerates, the major plate growth vectors equalled the lateral components (*e.g.*, height and width). Calcite laminae were deposited on the outside of the plate and covered up the lateral growth lines. In many camerates, growth lines and grooves which represent the calyx aboral nervous system may be seen on plate interiors. Thus it appears that no calcite deposition took place on the insides of camerate plates (see Brower and Macurda for further detail). This process is not conclusive in the palaeocrinids; it seems that the floor of the rhomboidal cavity was perhaps thickened during ontogeny although the responsible growth vector has not been determined. At any rate, growth of all calyx plates, calyx size and cup volume was a highly integrated and coordinated phenomenon as in the camerates studied by Brower and Macurda.

4. In the youngest individual (specimen No. 1), the smallest number of ridges (*i.e.*, ridges overlying the ridge canals) is present (one to three per suture). The sutures bearing three ridges are all located within the D ray R — E ray R — DE interray B area. Clearly, the ridges first developed here. Within the E ray R — D ray R group of three ridges, the central ridge formed first as this is the longest, then the proximal ridge and lastly the distal one. In the D ray R — DE interray B and the E ray R — DE interray B areas, the central ridge grew first, then the ones furthest away from the E ray R — D ray R — DE interray B junction, followed by the ones closest to this three plate junction.

Plate sutures containing only two ridges are peripheral to the three-ridge group. Toward the posterior, there are two ridges on



Text-figure 5.—*Palaeocrinus planobasalis,* n. sp. Graphs showing growth of calyx and respiratory structures. A. Cup volume versus cup height. B, C. Cup height and cup width versus total number of ridges. D. Cup volume versus total number of ridges.

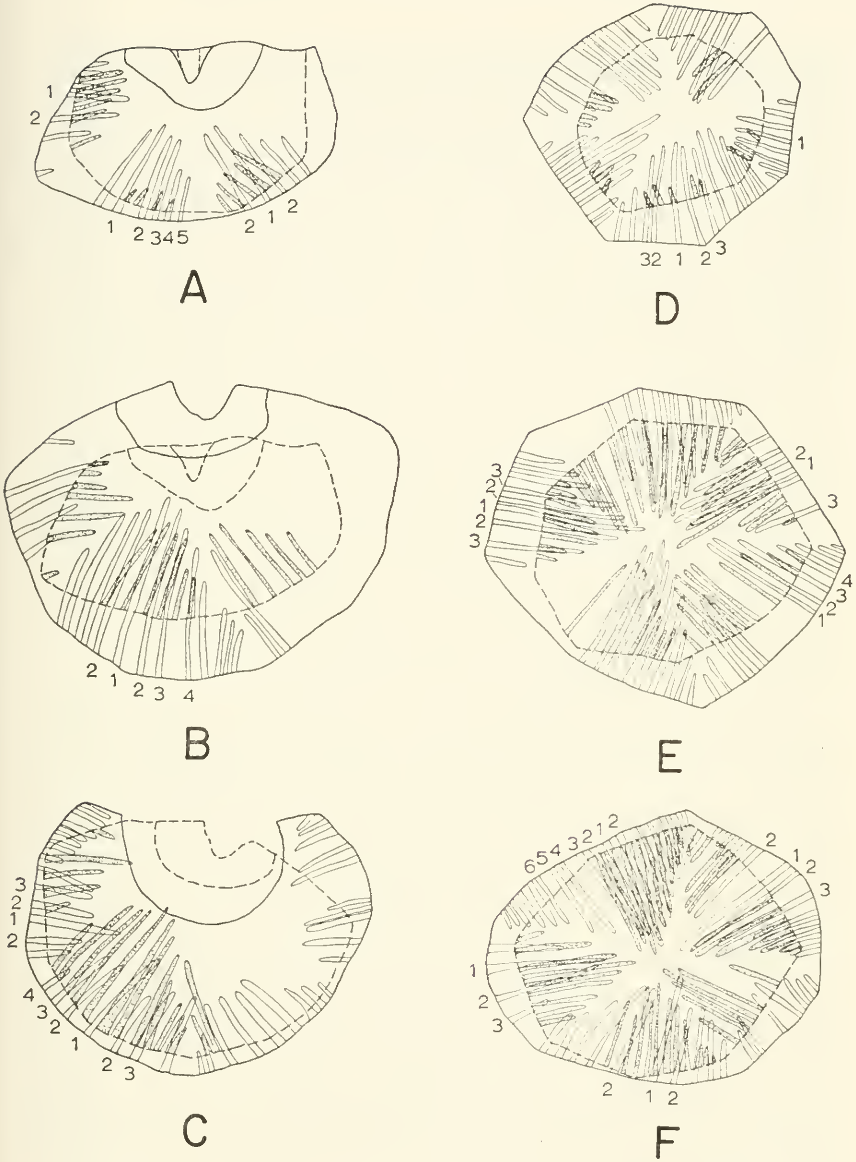
each of the following sutures: D ray R — CD interray B, anal X — D ray R, and CD interray B — anal X. Towards the anterior, there are two ridges on the A ray R — E ray R suture. The development order of single ridges within the two ridge group paralleled the above sequence. All other sutures have only one ridge each.

Thus within a single bundle, the central ridge formed first, following which the younger ridges developed on alternate sides of the central one. Consequently, the oldest ridges occur in the central part of the bundle, and the youngest occur at the two ends of the bundle.

In specimen No. 2, many more ridges are present along each suture although the plate suture lengths are roughly the same as in the younger individual. There are as many as nine ridge canals on the sutures between the RR, and from three to five ridge canals between the RR and the BB and between the BB and the IBB. This clearly denotes that once the ridges started to form they grew rapidly. Basically, the development order of the ridges within a bundle and adjacent bundles followed the pattern which is seen in embryonic form in the younger crinoid.

In the three largest crinoids, the sutures have many more ridges, and the order of development continued along the previous pattern. In specimen No. 3 there are 11 or 12 ridges on the sutures between the RR, from five to 12 ridges on the sutures between the RR and BB, from five to 13 on the sutures between the BB, and three to seven from the BB to the IBB. On the fourth specimen, the number of ridges on the sutures between the RR is 15, between the RR and the BB eleven to 16, between the BB five to 17, and on the sutures between the BB and IBB, there are eight or nine ridges. On the fifth and largest specimen, the number of ridges on the sutures between the RR ranges from nine to 22 and those between the RR and the BB from 13 to 20. The sutures between the BB and between the BB and the IBB contain from seven to 11 ridges.

5. In order to estimate the extent of the increased length of the ridges, the following procedure was used. Camera lucida drawings were prepared of the same R, B, and IB of each of the five specimens. Then the drawings of homologous plates from adjacent specimens in the ontogeny sequence were superimposed using the centers of the plates as constant topographic reference points (Text-fig. 6).



Text-figure 6.—*Palaeocrinus planobasalis*, n. sp. Plate superpositions for typical "Benbolt" palaeocrinids showing growth patterns. Numbers on external ridges and ridge canals refer to order of development. Number 1 is the oldest and first to form during ontogeny. Ridges and ridge canals of smaller plates are stippled. All figures × 6.1 unless otherwise stated. A. R of specimen No. 3/ R of specimen No. 2. B. R of specimen No. 4/ R of specimen No. 3. C. R of specimen No. 5/ R of specimen No. 4. D. B of specimen No. 3/ B of specimen No. 2. E. B of specimen No. 4/ B of specimen No. 3. F. B of specimen No. 5/ B of specimen No. 4, × 4.8.

For example, the specimen No. 3 R was placed over that of specimen No. 2. The geometry of ridge growth seems most consistent with this ontogenetic model because superimposition of the plates in this fashion gives the best fit of homologous ridges. The superimposed position of the IBB with respect to each other is not known with certainty as the control points (*i.e.*, the bundles and ridges thereof) only occur on the distal margins of these plates. Consequently, the location of the growth centers of these plates along the proximal-distal axis cannot be determined with any precision. However, the growth model cannot be verified because growth lines were not seen on the plate interiors of "Benbolt" palaeocrinids. The increase in the lengths of the ridges towards the center of the plate and towards the edge of the plate was noted for all superpositions. The smallest specimen was not included in these observations, because weathering greatly extended the apparent length of the ridges.

The results of the superimpositions of the various plates indicate that new ridges developed at the periphery of the bundle as previously outlined, and previously developed ridges were extended in length at both ends (*i.e.*, toward the plate suture and toward the inner margins of the bundles).

This indicates that two growth components were involved. Evidently the ridges first formed along both sides of the plate suture. During all ontogeny stages, ridge extension was at least partly inward towards the center of the ridge bearing plates; clearly this growth component was caused by resorption of previously deposited plate material. During ontogeny, the plate size increased due to lateral accretion; consequently, the suture between two adjacent plates "migrated outward" with respect to the initially formed parts of the plates involved. When the ridges developed, they were also extended outward due to these lateral growth vectors. Thus, if a ridge is examined, its latest formed parts lie along the plate margin near the middle of the bundle shared by the two adjacent plates and at the end of the bundle roughly at or near the center of the plate; the earliest portion of the ridge occurs somewhere in the middle.

The superimposition of the various plates also records the approximate amount of ridge growth due to resorption versus extension. As indicated in Text-figure 7a, the relation between the two components is most variable. In some cases, the augmentation greatly exceeded resorption, and vice versa; in other ridges, the two components were nearly equalized. Text-figures 7 b-g illustrate the amount of augmentation and resorption for individual plates; no systematic relation between relative augmentation and resorption can be detected. In addition, no consistent correlation between the location of a ridge within a single bundle and the two growth components can be seen (see numbers on data points in Text-figures 7d-g). The average increase in ridge length for sets of two plates is tabulated below:

	AE interray B		E ray R	
Specimens	Augmentation	Resorption	Augmentation	Resorption
No. 3/No. 2	.75 mm	.67 mm	.21 mm	.75 mm
No. 4/No. 3	.67 mm	.60 mm	1.20 mm	.42 mm
No. 5/No. 4	.54 mm	.56 mm	1.70 mm	.42 mm

Text figures 7 h-k illustrate the amount of peripheral plate growth (*i.e.*, accretion which equals the ridge augmentation component, termed growth front on the graphs) plotted against total ridge extension for the various superimposed plates. In specimen No. 3/specimen No. 2, the correlations are low; whereas in specimen No. 4/specimen No. 3, slightly higher correlations are observed which denote a more integrated and coordinated growth mechanism. A plot of specimen No. 5/specimen No. 4 shows less well integrated development than the above.

The overall growth pattern seems to indicate that in the ontogeny of an individual ridge, the two growth components were variable and poorly integrated with each other. It also appears that increase in ridge length was poorly integrated with the lateral accretion rates of the plates. Lastly, the total number of ridges, the sequence of ridge development, and presumably the rate of ridge addition was well integrated and coordinated with the ontogeny of dorsal cup plate size and calyx size and with volume growth (see later discussion).

6. The ridge bundles are vaguely defined in the youngest specimen. The bundle area is more obvious when there are three ridges

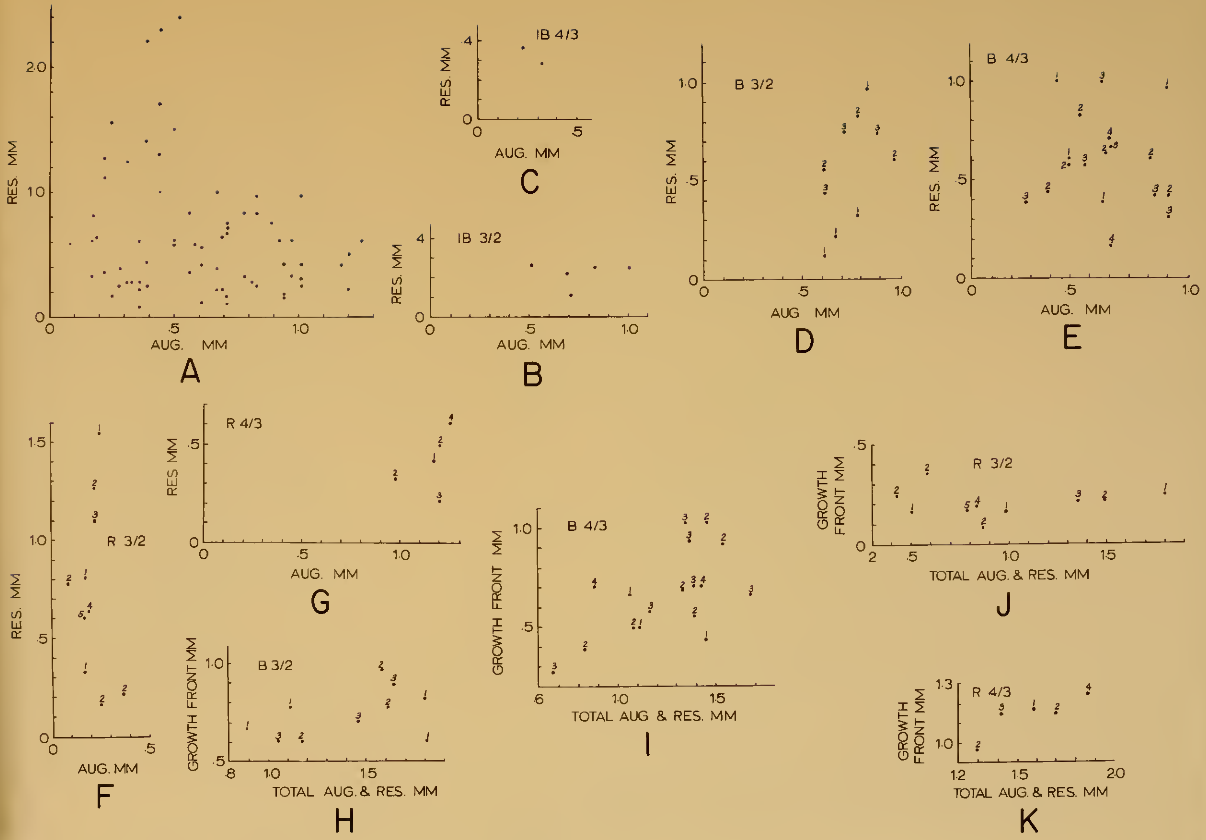
on a suture than when there are one or two. Throughout the rest of the sequence, the bundles became more prominent and larger as more ridges were initiated. This seems to denote that the rhomboidal cavity underlying the ridges progressively increased in size and volume at a rate which was closely related to the number and length of the ridges and to the area and volume occupied by them. Further details cannot be given as the size of the rhomboidal cavity cannot be measured directly.

7. As seen in Text-figure 5, calyx volume increased at the usual exponential rate with respect to dorsal cup size. In the case of ridge number versus calyx size or volume (see Text-figures 5b-d), the number of ridges grew at logarithmically decreasing rates relative to the calyx volume or size. The data are listed below:

Specimen number	Calyx height	Calyx volume	Number of ridges
No. 1	5.5 mm	.23 cc	85
No. 2	6.0 mm	.28 cc	220
No. 3	7.5 mm	.56 cc	550
No. 4	11.5 mm	1.90 cc	650
No. 5	16.5 mm	3.10 cc	1020

Probably, if ridge plus rhomboidal chamber volume were plotted versus calyx volume, a straight line relationship would be found.

Text-figure 7.—*Palacocrinus planobasalis,* n. sp. Superimposition of the plates (Text-fig. 6) records the approximate amount of ridge growth due to resorption and augmentation. The data point numbers refer to the order of ridge formation as in Text-figure 6. Figures A - G illustrate the amount of augmentation and resorption. Figures H - K show the amount of peripheral plate growth (growth front) plotted against the total ridge extension (augmentation plus resorption). In figures H and I, the scatter is high; in figures J and K, the scatter is slightly lower which denotes developing integration and coordination of the growth mechanism. A. Extent of resorption plotted against augmentation in all ridges measured. B. Resorption versus augmentation in E ray IB, No. 3/No. 2. C. Resorption versus augmentation E ray IB, No. 4/No. 3. D. Resorption versus augmentation in AE interray B, No. 3/No. 2. E. Resorption versus augmentation in AE interray B, No. 4/No. 3. F. Resorption versus augmentation in E ray R, No. 3/No. 2. G. Resorption versus augmentation in E ray R, No. 4/No. 3. H. Growth front versus total resorption and augmentation in AE interray B, No. 3/No. 2. I. Growth front versus total resorption and augmentation in AE interray B, No. 4/No. 3. J. Growth front versus total resorption and augmentation in E ray R, No. 3/No. 2. K. Growth front versus total resorption and augmentation in E ray R, No. 4/No. 3.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Although few data are available, the relationships between calyx size and volume and total number of ridges were most likely well integrated and coordinated.

As previously indicated, the ridge in the center of the suture formed first, then a proximal one, then a distal one, presumably alternating until a full bundle of ridges developed. In *Palaeocrinus striatus* Billings as discussed by Hudson (1911, p. 223), the initial ridge also occurred in the middle of the suture with new ridges added on either side. However, he postulated a spiral succession of ridge formation involving three adjacent plates (1911, fig. 10). There is some indication that the succession of ridges in *P. planobasalis*, n. sp. also followed a spiral path, but the material is too poorly preserved to be certain. The ridges of the *Porocrinus* goniospires grew in the opposite order (Kesling and Paul, 1968, p. 8). The first ridge lay at the plate corner and the succeeding ridges were added towards the middle of the sutures between plates.

Specific name. — *Planobasalis* in reference to the flat base of the calyx.

Types. — Typical specimens: Holotype, specimen No. 5, USNM 97465, which was figured by Butts (1941) as *P.* aff. *P. striatus* Billings. Paratypes; specimen No. 1, USNM 164125; specimen No. 2, USNM 164126; specimen No. 3, S 5421; specimen No. 4, S 5420; additional specimens number USNM 97465; USNM 164127 - 164130; and S 5421 - S 5423.

"Variant" specimens: USNM 164131; MCZ 4162, 4163a-e, 4164.

Occurrence. — Benbolt Formation, localities 1a, 1b, 2b and 3b; Benbolt Formation or equivalent part of Dryden Limestone, locality 4e; Benbolt Formation and or Wardell Formation, localities 7 and 13; Wardell Formation or Witten Formation, locality 8a; Benbolt Formation or Hogskin Member of Lincolnshire Formation, locality 9a; Hogskin Member of Lincolnshire Formation according to Cooper (1956), locality 11; Ottosee Shale or Sevier Shale, localities 15a and 15b; base of Sevier Shale, locality 16; unknown horizons, probably Black River in age, localities 12 and 14.

Palaeocrinus avondalensis, n. sp. Pl. 5. figs. 4a, 4b

Diagnosis. — A palaeocrinid with bowl-shaped cup and flattened base; fine ridges covering entire cup, located in rhomb-shaped areas which are not raised into bundles.

Description. — Based on holotype, an adult specimen. Bowl-shaped cup with flattened base, 17 mm high, by 21 mm wide. Entire surface covered with ridges arranged in flat rhomb-shaped areas; the plate sutures bisect the rhombic areas at right angles. Ten to 15 ridges on bundles between RR; five to 12 on bundles from RR to BB; between the BB, bundles possess from four to nine ridges; and from BB to IBB there are six to eight ridges per bundle.

IBB five, pentagonal, horizontally situated at right angles to stem, 4.7 mm wide and 4.3 mm high.

BB basically hexagonal, averaging about 10 mm in width and 8.5 mm in height.

RR pentagonal, approximately 8 mm high by 8 mm wide. Arm facets poorly preserved, narrow, horseshoe-shaped, approximately 2.7 mm wide and 3 mm high; rim around outside edge; deep food groove.

RA large, quadrangular, approximately 7.5 mm high by 7.5 mm wide, resting on shoulders of BC interray and CD interray BB, partly in line with RR. Anal X pentagonal, roughly 8 mm high and 8.5 mm wide, in line with RR, resting on RA and CD interray B.

Several Brr preserved. On D ray, two IBrr, second one axillary, approximately 4 mm wide by 1.5 mm high; two IIBrr, second one axillary, and one IIIBrr, all wider than high. On A ray, three IBrr, third one axillary, and one non-axillary IIBrr preserved.

Only proximal CD interray part of tegmen known; consists of numerous irregular plates. Anal opening partly preserved on tegmen surface of CD interray.

Column round, 1.7 mm in diameter. Columnals alternate slightly in height, ornamented with longitudinal ridges, sutures crenellated. Axial canal filled with numerous small irregular plates.

Remarks. — This species is based on one poorly preserved, crushed and flattened specimen. It resembles typical specimens of *P. planobasalis,* n. sp. in its flat-based cup-shaped calyx and ridges which cover its entire surface. The crinoid differs from all *P. planobasalis,* n. sp. in that the rhomb-shaped ridge bearing areas are not raised into bundles. The ridges are less numerous than those found in homologous rhomb-shaped bundles of equivalent sized mature typical *P. planobasalis*, n. sp. as tabulated below:

Suture	Number of ridges along listed plate suture	
	P. planobasalis, n. sp.	*P. avondalensis*, n. sp.
R-R	17 to 22	10 to 12
RA-CD interray B	15	7
RA-C ray R	14	6
RA-BC interray B	11	6
RA-Anal X	12	6

P. avondalensis, n. sp. possesses two or three IBrr in contrast to the single axillary IBr of the other "Benbolt" palaeocrinid.

Specific name. — *Avondalensis*, referring to the locality in which this specimen was found.

Holotype. — MCZ 603, collected by James Sprinkle and C. R. C. Paul.

Occurrence. — Benbolt Formation or Hogskin Member of Lincolnshire Formation, locality 9c.

Family **CARABOCRINIDAE** Bather, 1899

Genus **CARABOCRINUS** Billings, 1857 (p. 275)

Carabocrinus stellifer, n. sp. Pl. 2. figs. 7, 10

Diagnosis. — A species of *Carabocrinus* with flattened globose cup. Plates ornamented by wide, heavy, convex, radiating stellate-type ridges; each major ridge in the form of an elongated triangle leading from the plate center to the suture, apex of triangle at plate center, triangle base at suture; major ridges sometimes single, sometimes with two to four smaller grooves along their surfaces.

Description of adult specimen. — Dorsal cup flattened, globose, maximum width 29 mm, height 22 mm (all measurements from holotype). Plates strongly convex; sutures sometimes incised, sometimes not. Usual ornamentation composed of stellate ridges as follows: two broad triangular, grooved ridges on each IB, one to four grooves on each ridge, with base of each triangle meeting the basal triangles at the sutures between the IBB and the BB; six or seven grooved triangles on each B, one to three grooves on each ridge, apices meeting at center of plate, bases occur at sutures; five more or less clearly defined triangles on iRA, triangles ungrooved or with one groove; five clearly defined triangles on sRA, either ungrooved or with a single groove; four triangles on each R radiating from arm facet to each lateral and proximal suture, some triangles ungrooved, some with one and some with two grooves.

IBB five, subequal, irregularly pentagonal in shape, 8 mm high by 14.5 mm wide.

BB equidimensional, hexagonal with curved sutures, height and width about 14 mm, largest plates in cup.

RR pentagonal, A and E ray RR well preserved, about 6 mm high by 9 mm wide. C ray R smaller, too poorly known to measure. RR facets poorly preserved, elongated horseshoe-shaped with deep groove for ambulacral tract, width equals about one-third width of distal R edge. Facet surface not well enough preserved for complete description, but the one on the C ray R shows a smooth concave articulating surface surrounded by a raised rim; slight transverse ridge on left side of facet.

The iRA pentagonal, distal edge truncated, 7.6 mm high by 10 mm wide, rests on shoulders of C and D ray IBB. The sRA pentagonal, proximal edge truncated, 8 mm high by 10.1 mm wide. Anal X on left shoulder of sRA and right shoulder of DE interray B, too poorly preserved to measure but basically pentagonal.

Tegmen unknown.

Stem facet 4 mm in diameter, round with pentalobate axial canal, lobes in radial position.

Arms and stem unknown.

Remarks. — This form is based on six rather poorly preserved dorsal cups and several isolated plates. It differs from all other species of *Carabocrinus* in dorsal cup shape and surface ornamentation. Most carabocrinids have more or less numerous relatively fine plate ridges arranged in stellate patterns. Only *C. slocumi* Foerste (*in* Slocum and Foerste, 1924, p. 350, pl. 31, figs. 1-10; pl. 32, figs. 1, 7-9, 11-14, 26-29) and *C. stellifer*, n. sp. exhibit single large ridges which radiate from the plate centers. The single ridges of *C. stellifer*, n. sp. are the heaviest and cover most of the plate surface. They are roughly triangular in shape with the triangle apex at the plate center and the base of the triangle at the suture. Each of these heavy triangular ridges may be ungrooved or may possess one to four grooves with minor ridges between them.

One small specimen, S 5430, is tentatively referred to this form. The dorsal cup is about half as high as typical *C. stellifer,* n. sp. and the cup is higher relative to its width. The stellate ridges are much narrower and sharper than in specimens definitely placed in *C. stellifer,* n. sp. Possibly the small crinoid represents an undescribed species. However, until more and better material can be found, the specimen is questionably considered a growth variant of *C. stellifer,* n. sp.

In contrast to the globose cup of *C. stellifer,* n. sp., conical cups are characteristic of *C. slocumi* and *C. geometricus* Hudson (1905, p. 282, pl. 1, figs. 1, 2, text fig. 7).

Both *C. huronensis* Foerste (*in* Slocum and Foerste, 1924, p. 345, pl. 31, figs. 11, 13, 14) and *C. treadwelli* Sinclair (1945, p. 714, pl. 2, figs. 14-16) have obconical cups which are more slender than in the new species. Also the base is steeper and the stellate ridges are finer and more numerous than in *C. stellifer,* n. sp.

C. dicyclicus Sardeson (1925, p. 61, pl. 5, fig. 5) and *C. magnificus* Sardeson (1939, p. 33, pl. 2, figs. 1, 2) are large forms with much higher cups than in *C. stellifer,* n. sp. although the shape of the base is similar. The ornamentation includes tubercles as well as the typical carabocrinid radiating ridges.

The dorsal cup shape of *C. vancortlandi* Billings (1859, p. 32, pl. 2, fig. 4) and *C. ovalis* Miller and Gurley (1894, p. 25, pl. 2, figs. 20, 21) is oval in contrast to the flatter and more globose shape of *C. stellifer,* n. sp.

C. radiatus Billings (1857, p. 276) is compactly spherical which distinguishes it from the flattened globular cup of *C. stellifer,* n. sp. Three or four distinct ridges radiate from the plate center to each plate margin in *C. radiatus* in contrast to the single wide-grooved triangular ridge of the Benbolt crinoid.

C. esthonus Jaekel (1918, p. 50, text-fig. 38) from the Wassalem Limestone near Reval, Esthonia is remarkably similar to *C. radiatus* with respect to calyx shape, plate outlines, and ornamentation.

Specific name. — *Stellifer* in allusion to the star-shaped stellate ridge ornamentation on the plates.

Types. — Holotype, S 5424. Paratypes, S 5425 - S 5429.

Occurrence. — Ottosee Shale or Sevier Shale; locality 15a.

Carabocrinus micropunctatus, n. sp. Pl. 2, figs. 8-9

1941. *Echinosphaerites* sp. Butts, Virginia Geol. Sur., Bull. 52, pt. 2, p. 91, pl. 89, fig. 12.

Diagnosis. — A carabocrinid with a wide-rounded conical cup, numerous fine V-shaped ridges arranged in a stellate pattern; finely pitted plate surface.

Description. — Dorsal cup wide, maximum width at top of RR, with curved sides and narrow base, 27 mm maximum width, 20 mm high (all measurements from holotype). Plate surface covered with minute pits, about eight to ten pits per mm. Ornamentation consists of many fine V-shaped ridges arranged in stellate pattern; four V-shaped ridges on the IBB; from four to six ridges cross each B margin, apices of V-shaped ridges at or near the plate center; about four ridges cross from the BB to the RR, apices of V-shaped ridges located below or at the sides of the RR facets; several fine ridges on the iRA and sRA; anal X surface not well enough preserved to determine ornamentation.

IBB subequal, pentagonal, about 6.6 mm wide and 6 mm high.

BB hexagonal, largest plates in dorsal cup, slightly wider than high, 11.4 mm wide by 10.3 mm high.

RR basically pentagonal, much wider than high, about 13 mm wide and 8 mm high. R facet narrow, horseshoe-shaped, about one fourth the width of the R distal edge, poorly preserved, but shows some indication of a raised rim.

The iRA pentagonal, 6.5 mm wide and 5.7 mm high, truncated distally. The sRA pentagonal, truncated proximally, 8 mm wide by 7.2 mm high.

Anal X poorly preserved, approximately hexagonal, 8 mm wide by 8.2 mm high.

Stem facet 4.4 mm wide; axial canal pentalobate; lobes radial in position.

Stem and arms unknown.

Remarks. — This species is based on three dorsal cups. The wide cup with rounded walls and narrow base differentiates this crinoid from all other carabocrinids except *C. huronensis* Foerste (*in* Slocum and Foerste, 1924, p. 345, pl. 31, figs. 11, 13, 14) and *C. treadwelli* Sinclair (1945, p. 714, pl. 2, figs. 14-16). The walls of the "Benbolt" crinoid are less steep than those of the other two forms.

The ornamenting ridges of *C. micropunctatus,* n. sp. are finer and more numerous than those of *C. huronensis* and *C. treadwelli.*

Under a magnification of seven times, the plates are seen to be covered with many small pits. To the writers' knowledge, punctation is unknown in all other carabocrinids.

Specific name. — *Micropunctatus* in allusion to the fine pitting of the plate surfaces.

Types. — Holotype, S 5431. Paratypes, two specimens catalogued as USNM 97466, one of which was figured by Butts as *Echinosphaerites* sp.

Occurrence. — Benbolt Formation, locality 5; Benbolt Formation or equivalent part of Dryden Limestone, locality 4d; Benbolt Formation or Hogskin Member of Lincolnshire Formation, localities 9a and 9c.

Carabocrinus cf. **treadwelli** Sinclair

Remarks. — Several "Benbolt" crinoids consisting of partial dorsal cups and isolated plates are too poorly preserved to warrant full description. In overall appearance they resemble the Bromide *C. treadwelli* Sinclair (1945, p. 714, pl. 2, figs. 14-16). However, there are several differences. The "Benbolt" crinoids have keel-shaped ridges which are higher and sharper than in the Bromide species. Although the cup shape is poorly known in the "Benbolt" specimens, the base appears flatter and more rounded than that of *C. treadwelli.* Inasmuch as the "Benbolt" specimens are poorly preserved and the significance and consistency of the morphological differences are unknown, these crinoids are compared favorably with *C. treadwelli* for the present.

Mentioned specimens. — USNM 164132, 164133.

Occurrence. — Benbolt Formation or equivalent part of Dryden Limestone, locality 4b; Benbolt Formation or Hogskin Member of Lincolnshire Formation, locality 9a; Ottosee Shale or Sevier Shale, locality 15d.

Subclass CAMERATA Wachsmuth and Springer, 1885

Order DIPLOBATHRA Moore and Laudon, 1943

Family **RHODOCRINITIDAE** Bassler, 1938

Genus **ARCHAEOCRINUS** Wachsmuth and Springer, 1881 [p. 363(189)]

Type species: By subsequent designation of Wachsmuth and Springer, 1881, page 190, *Glyptocrinus lacunosus* (Billings), 1857, page 261.

Diagnosis. — A "rhodocrinitid" genus characterized by conical or globose cup; IBB low, not visible from side; lateral interrays composed of one iR, followed by two iBrr1, generally followed by three iBrr2; CD interray wider with usually one iR, the primanal followed by two CD interray iBrr1 and one anal series plate. Arms biserial, branching several times.

Remarks. — Lower Palaeozoic genera assigned by Moore and Laudon (1943, pp. 82-83) and Ubaghs (1953, pp. 735-737) to the Rhodocrinitidae and Archaeocrinidae are a highly diverse group with little degree of distinction between the two families. Consequently, the writers prefer to consider all genera assigned to these families as belonging to one heterogeneous group under the name Rhodocrinitidae which has nomenclatural priority. *Archaeocrinus* will not here be compared to the numerous and diverse genera assigned to the two families. Rather, the "Benbolt" genera will be discussed relative to the other "rhodocrinitids" which also occur in the Benbolt and allied units. *Archaeocrinus* compares as follows to the other "Benbolt" "rhodocrinitids":

1. *Pararchaeocrinus* Strimple and Watkins (1955, p. 351) has a short subglobular cup with the lateral interrays consisting of one iR followed by three iBrr1. The protruded CD interray is composed of two or three iRR (one of which is the primanal) in a single range, followed by three plates. The arms are uniserial and branch at least twice.

2. *Diabolocrinus* Wachsmuth and Springer (1897, p. 249) shows a depressed globular cup with lateral interrays formed by one iR followed by two iBrr1, usually with several small supplementary plates. The CD interray is wider, possessing a primanal and generally two CD interray iBrr1 with an anal series plate and several small sup-

plementary plates. The calyx differs markedly from that of *Archaeocrinus* in possessing a depressed globular shape, a wide, deep basal concavity and lobate arm bases which protrude from the calyx. There are two heavy biserial unbranched arms in each ray which are directed upward and outward.

3. *Archaeocrinus* differs from *Paradiabolocrinus,* n. gen. in much the same way that it does from *Diabolocrinus.* The differences between *Diabolocrinus* and *Paradiabolocrinus,* n. gen. will be discussed in more detail later.

4. *Archaeocrinus* differs obviously from *Wilsonicrinus* Springer (1926, p. 23) which exhibits a broad wheel-shaped calyx. The dorsal cup is characterized by one large iR (including the primanal) in each interray which is the largest plate in the cup. Ten separated arm openings are located above several wide IIBrr.

5. Archaeocrinids may be separated from *Rhaphanocrinus* Wachsmuth and Springer (1885, p. 320) by the presence of biserial arms. Rhaphanocrinid arms are uniserial.

Occurrence. — Middle Ordovician; North America.

Archaeocrinus peculiaris Miller and Gurley Pl. 9, figs. 2-8

1894. *Archaeocrinus peculiaris* Miller and Gurley, Illinois State Mus. Nat. Hist., Bull. 5, p. 17, pl. 2, figs. 1-3.
1897. *Archaeocrinus peculiaris* Miller, Second Appendix to North American Geol. and Palaeo., Cincinnati, p. 734, figs. 1299-1300.
1915. *Archaeocrinus peculiaris* Bassler, U.S. Nat. Mus., Bull. 92, p. 60.
1943. *Archaeocrinus peculiaris* Bassler and Moodey, Geol. Soc. America, Spec. Paper 45, p. 309.

Diagnosis. — An archaeocrinid with globose calyx, wider than high, lacking median-ray ridges; strongly depressed sutures between plates.

Description. — Calyx large, globose; width distinctly greater than height. Greatest diameter at top of IAxx, constricted below arm bases; median-ray ridges lacking. Plates convex, with deeply beveled sutures. Surface appears granular, but under magnification is seen to have small sinuous ridges. Basal concavity pentagonal, IBB hidden within it. BB hexagonal, higher than wide, truncated at distal margin by iR. Proximal part of BB located in basal concavity. BB invariably alternate in position with RR.

Four of the five RR pentagonal; D ray R hexagonal, largest plate in cup. IBr1 hexagonal, subequal to R; IBr2 axillary, pentagonal, smaller. IIBr1 small, irregularly hexagonal, usually non-axillary, sometimes axillary. IIBrr2 usually axillary, small, roughly hexagonal. IIBrr2 of same half-ray separated by one inter-half-ray iBr1, equal to them in size and shape. Generally IIBrr2 are followed by IIIBr1 and separated by two inter-half-ray iBrr2, subequal in size and shape to IIIBrr1. Usually 20 arm facets, rounded, smooth. In one individual IIBr2 is non-axillary and forms arm base.

Lateral interray composed of iR, irregularly heptagonal, subequal to R, placed between RR and IBrr1. Followed by two iBrr1, roughly hexagonal, about half the size of the iR, reaching to level of IIBr1; lastly are one or two ranges of two to four smaller, irregular-shaped plates leading into tegmen.

CD interray protuberant, with plates slightly larger and sometimes more numerous than those of lateral interrays. Two plate structures occur. In one type, primanal irregularly hexagonal, located at level of R and IBr1, largest iR in cup; followed by two iBrr1, irregularly heptagonal, occurring at level of IBrr1 and 2; next are three or four iBrr2, irregular in shape at IIBr1 level; highest range consists of small irregular plates leading into tegmen. In second CD interray type, an anal series can be distinguished. Primanal as above, at level of R and IBr1; followed by three iBrr1 at level of IBrr1 and 2 (central one, directly above primanal is part of the anal series); followed by three or four iBrr2 at IIBr1 level (the median plate is an anal series element); followed by small irregular plates leading into tegmen.

Tegmen and column unknown.

Remarks. — Thirty-five poorly preserved specimens of *Archaeocrinus peculiaris* were found throughout the length of the "Benbolt" area.

A. peculiaris differs from other archaeocrinid species in the following ways. *A. desideratus* W. R. Billings (see Wachsmuth and Springer, 1897, p. 257, pl. 10, figs. 4a, b) exhibits a large funnel-shaped basal concavity which is much wider than the column diameter and is deep enough to contain five or six columnals; the form also possesses median-ray ridges. *A. lacunosus* (Billings) (1857, p. 261; Billings, 1859, pl. 8, figs. 3a-e; Wachsmuth and Springer, 1897, p. 255, pl. 10, fig. 1) shows a narrower cup than *A. peculiaris* with median-ray ridges which are lacking in the latter.

A. microbasalis (Billings) (1857, p. 264; Billings, 1859, p. 63, pl. 6, fig. 2; Wachsmuth and Springer, 1897, p. 256, pl. 10, figs. 2a-c), and *Neoarchaeocrinus obconicus* (Slocum) (1924, p. 328, pl. 29, figs. 10-13) are obconical in contrast to the wider and more globose shape of *A. peculiaris* while *Neoarchaeocrinus pyriformis* (Billings) (1857, p. 262; Billings, 1859, p. 61, pl. 6, figs. 1a-d; Wachsmuth and Springer, 1897, p. 255, pl. 10, figs. 3a, b) is pear-shaped. *A. subovalis* Strimple (1953, p. 606, text-figs. 1-7) has a high calyx with a flattened base which easily distinguishes it from the subglobular shape of the "Benbolt" archaeocrinid; in addition, *A. subovalis* Strimple bears median-ray ridges.

Smooth biserial arm fragments are often associated with this species. Although not observed attached to calyces, the association frequency suggests that the arm fragments belong to *A. peculiaris*. The arms are heavy, smooth and biserial with long slender pinnules. Among the "Benbolt" "rhodocrinitids", the only other known arms are referred to *Diabolocrinus vesperalis* (White). The diabolocrinid arms are like those of the archaeocrinid except that they are more heavily ornamented.

Types. — Holotype, UC 6037. Figured specimens, USNM 164616, and S 5436 - S 5440.

Occurrence. — Benbolt Formation, localities 1 and 5; Benbolt Formation or Hogskin Member of Lincolnshire Formation, localities 9c and 10c; Hogskin Member of Lincolnshire Formation according to Cooper (1956), localities 8d, 9b and 11; Ottosee Shale or Sevier Shale, locality 15c.

Genus **PARARCHAEOCRINUS** Strimple and Watkins, 1955 (p. 351)

Types species: By original designation, *P. decoratus* Strimple and Watkins, 1955, page 351, figures 2b-f.

Diagnosis. — A "rhodocrinitid" genus characterized by a short subglobular cup; lateral interrays formed by one iR followed by a tier of three iBrr1; posterior ray protuberant with two or three iRR (one of which is primanal) in contact with CD interray B. Median-ray ridges may or may not be present. Arm bases not protuberant. Arms uniserial, two per ray, branching at least twice.

Occurrence. — Middle Ordovician; North America.

Pararchaeocrinus convexus, n. sp. Pl. 13, fig. 4

Diagnosis. — A pararchaeocrinid lacking median-ray ridges; plates convex with indented sutures; surface of plates granular.

Description. — Only known from lateral fragment of cup; low subglobular shape indicated. Plates convex with depressed sutures, surface covered with granules. IBB not visible from side, pentagonal, small, wide and short, about 2.7 mm wide by 2 mm high, located in basal concavity. BB hexagonal, truncated distally, about 5 mm high and 6.5 mm wide. RR irregularly hexagonal or heptagonal, about 5.6 mm high and 5.6 mm wide. IBr1 roughly hexagonal, about 3.5 mm high and 3.2 mm wide. IBr2 axillary, with six or seven sides, about 4.1 mm high and 3.1 mm wide. IIBr1 basically hexagonal, although up to eight sides may be present, about 2.6 mm wide by 2.7 mm high, fixed in cup. IIBrr2 basically pentagonal, smaller than IIBrr1. IIBrr3 are distal fixed-Brr, shape not known, possessess wide food groove. Inter-half-ray iBr1 between distal portion of IIBrr1 lateral margins, pentagonal, about 1.2 mm wide by 1.2 mm high. Inter-half-ray iBrr above iBr1 not well preserved, although one small inter-half-ray iBr2 between IIBrr2 and inter-half-ray iBr3 can be seen within the A ray.

Lateral interray with irregularly hexagonal iR, about 4.2 mm high by 5 mm wide, truncated distally, located at RR level, followed by three iBrr1. These are irregularly shaped with five to seven sides, slightly smaller than iR. Central iBr1 rests on iR and reaches level of IBr1. Lateral iBrr1 reach mid-height of IBr1. An arch of four or five iBrr2 is distal to the three iBrr1, irregular in shape and somewhat smaller than iBrr1; distal margins of this range terminate at mid-IAx level. Four still smaller irregular-shaped iBrr3 above these, at level of IBrr2. Two iBrr4 at IIBr1 level in BC interray; higher iBrr not preserved. In AB interray, three irregular iBrr4 at level of IIBr1; followed by four irregular iBrr5 at level of IIBr2; and then three irregular iBrr6 at distal level of IIBr2; iBrr unknown above this level.

Stem facet within basal concavity, pentagonal.

CD interray, tegmen, arms, and stem unknown.

Remarks. — This species is based on one dorsal cup fragment. Only three rays and three interrays are wholly or partly preserved.

The rays are probably the A, B and a small part of the C ray, whereas the interrays represent the AB and BC interrays with a small portion of the CD interray. The plates on the left side of the crinoid become noticeably larger and therefore probably belong to the protruded CD interray. This crinoid is partly silicified; consequently most of the granules covering the surface seem to be weathered beekite rings and not the original surface markings. However, the original surface probably was granular as indicated by the right side of the specimen.

Despite the fragmentary condition of the dorsal cup, it can nevertheless be assigned to *Pararchaeocrinus* because of the unique structure of the interrays and the short globose nature of the calyx.

P. convexus, n. sp. differs from the only other known pararchaeocrinid, *P. decoratus* Strimple and Watkins (1955, p. 351, text-figs. 2b-f, 9, 10) in the granular surface of the plates and the absence of median-ray ridges. In addition, the plates and sutures of *P. decoratus* are smooth, whereas the plates of *P. convexus,* n. sp. are strongly convex and the sutures depressed.

Specific name. — *Convexus* in allusion to the convex plates.

Occurrence. — Probably Wardell Formation or Witten Formation, locality 8a.

Genus **DIABOLOCRINUS** Wachsmuth and Springer, 1897 (p. 249)

Type species: By original designation and synonymy, *Rhodocrinus vesperalis* White, 1880, page 252, Plate 1, figures 11-12. (See discussion of *Diabolocrinus vesperalis*).

Diagnosis. — A "rhodocrinitid" genus with depressed globular cup; lobate and protuberant arm bases, two massive biserial unbranched arms to the ray; interray composed of one iR followed by two iBrr1, often with several supplementary plates; CD interray wider, with one iR followed by three plates and several additional supplementary plates.

Occurrence. — Middle Ordovician; North America and Great Britain.

Diabolocrinus vesperalis (White) Pls. 10, 11; Pl. 12, figs. 1-5

1850. *Gilbertsocrinus americanus* Troost (*nomen nudum*), American Assoc. Adv. Sci., Proc., 2, p. 61.

1880a. *Rhodocrinus vesperalis* White, U.S. Nat. Mus., Proc., vol. 2, p. 252, pl. 1, figs. 11-12.

1880b. *Rhodocrinus vesperalis* White, U.S. Geol. Sur., 12th Ann. Rep., p. 129, pl. 35, figs. 4a, b.
1882b. *Lyriocrinus sculptilis* Miller, Cincinnati Soc. Nat. Hist., Jour., vol. 5, p. 83, pl. 3, figs. 6, 6a, 6b.
1885. *Archaeocrinus sculptus* Wachsmuth and Springer, Rev. Palaeocrinoidea, Pt. 3, sec. 1, Philadelphia Acad. Nat. Sci., Proc., p. 98.
1889. *Archaeocrinus sculptus* Wachsmuth and Springer, Miller, North American Geol. and Palaeont., Cincinnati, p. 225, fig. 250.
1889. *Lyriocrinus sculptilis* Miller, North American Geol. and Palaeont., Cincinnati, p. 259.
1894. *Archaeocrinus asperatus* Miller and Gurley, Illinois State Mus. Nat. Hist., Bull. No. 5, p. 19, pl. 2, figs. 7-9.
1894. *Archaeocrinus parvus* Miller and Gurley, Illinois State Mus. Nat. Hist., Bull. No. 5, p. 21, figs. 26-28.
1895. *Archaeocrinus knoxensis* Miller and Gurley, Illinois State Mus. Nat. Hist., Bull. No. 6, p. 34, pl. 3, figs. 12-15.
1897. *Archaeocrinus asperatus* Miller and Gurley, Miller, Second Appendix, North American Geol. and Palaeont., Cincinnati, pp. 734, 741, figs. 1296-1297.
1897. *Archaeocrinus knoxensis* Miller and Gurley, Miller, Second Appendix, North American Geol. and Palaeont., Cincinnati, p. 734.
1897. *Archaeocrinus parvus* Miller and Gurley, Miller, Second Appendix, North American Geol. and Palaeont., Cincinnati, p. 734, fig. 1298.
1897. *Diabolocrinus hieroglyphicus* Wachsmuth and Springer, Mus. Comp. Zool., Mem., vol. 20, p. 252, pl. 10, figs. 5a-c.
1897. *Diabolocrinus perplexus* Wachsmuth and Springer, Mus. Comp. Zool., Mem., vol. 20, p. 250, pl. 11, figs. 1a, b.
1897. *Diabolocrinus vesperalis* (White), Wachsmuth and Springer, Mus. Comp. Zool., Mem., vol. 20, p. 251, pl. 11, figs. 1c, d.
1909. *Gilbertsocrinus americanus (nomen nudum)* Wood, U.S. Nat. Mus., Bull. 64, p. 104.
1915. *Diabolocrinus asperatus* Miller and Gurley, Bassler, U.S. Nat. Mus., Bull. 92, p. 403.
1915. *Diabolocrinus perplexus* Wachsmuth and Springer, Bassler, U.S. Nat. Mus., Bull. 92, p. 404.
1915. *Diabolocrinus vesperalis* (White), Bassler, U.S. Nat. Mus., Bull. 92, p. 404.
1941. *Diabolocrinus asperatus* ? (Miller and Gurley), Butts (in part), Virginia Geol. Sur., Bull. 52, pt. 2, p. 91, pl. 89, figs. 6-8, not figs. 4-5.
1941. *Diabolocrinus perplexus* Wachsmuth and Springer, Butts, Virginia Geol. Sur., Bull. 52, pt. 2, p. 91, pl. 89, figs. 1-3.
1943. *Archaeocrinus knoxensis* Miller and Gurley, Bassler and Moodey, Geol. Soc. America, Spec. Paper 45, p. 308.
1943. *Archaeocrinus parvus* Miller and Gurley, Bassler and Moodey, Geol. Soc. America, Spec. Paper 45, p. 309.
1943. *Diabolocrinus asperatus* (Miller and Gurley), Bassler and Moodey, Geol. Soc. America, Spec. Paper 45, p. 417.
1943. *Diabolocrinus perplexus* Wachsmuth and Springer, Bassler and Moodey, Geol. Soc. America, Spec. Paper 45, p. 417.
1943. *Diabolocrinus vesperalis* (White), Bassler and Moodey, Geol. Soc. America, Spec. Paper 45, p. 417.
1944. *Diabolocrinus perplexus* Wachsmuth and Springer, Moore and Laudon *in* Shimer and Shrock, Index Fossils of North America, p. 185, pl. 72, fig. 15.
1944. *Diabolocrinus vesperalis* (White), Moore and Laudon *in* Shimer and Shrock, Index Fossils of North America, p. 185, pl. 72, fig. 16.

Diagnosis. — A diabolocrinid with highly variable ornamentation consisting of sinuous ridges, stellate ridges, and nodes. These elements of ornamentation may be absent, or present in varying degrees, and in different combinations with each other. Depressed globular cup, lacking median-ray ridges.

Description. — Average size of mature compressed globular cup about 18 mm high by 25 mm wide. Plates ornamented variously by sinuous ridges, stellate ridges and nodes. These elements of ornamentation appear on all individuals in varying degrees. Ornamentation shows little correlation with size and age, except that stellate ridges appear more strongly on smaller individuals, and nodes are more prominent on larger individuals. Sutures between plates indented.

IBB pentagonal, short and wide, with width more than twice the height, hidden in basal concavity. BB hexagonal, almost as high as wide, truncated distally for reception of overlying iR or primanal.

RR pentagonal, truncated distally, a little wider than high. IBr1 hexagonal, higher than wide. IBr2 is primaxil, pentagonal, about twice as wide as high. IIBrr1 roughly quadrangular, about twice as wide as high. IIBrr2 wedge-shaped, wider than high. IIBrr3 irregular in shape, but wider than high, bearing elongated, narrow arm facets. IIBrr1, 2, and 3 form lobate protuberances from calyx wall. Arm facets on IIBrr3 face upward and outward at an angle of about 50° from the horizontal.

In lateral interray, iR is hexagonal, subequal to R, set between distal half of RR and proximal half of IBrr1. A varying number of plates may surround the iR. Two larger plates, directly distal to iR, are iBrr1; the remaining plates are supplementary. The two iBrr1 roughly pentagonal, smaller than iR, set between distal half of IBrr1 and proximal half of IBrr2. The iBrr2 smaller than iBrr1, irregular in shape, generally three in number. Small irregular plates distal to these grade imperceptibly into tegmen.

CD interray wider with larger plates, and often a greater number of supplementary plates. The primanal is irregularly heptagonal, located at the RR and IBrr1 level. The primanal may be surrounded by a varying number of plates, including the CD interray iBrr1; the latter are irregularly pentagonal, occurring at level of IBrr1 and proximal part of IBrr2. No distinct anal series. The iBrr2 and higher plates are as in the lateral interrays.

No correlation between ornamentation and number of supplementary plates. Although some of the individuals examined lack supplementary plates in the lateral interrays, the number varies from one to seven in those that do possess them; the number also varies in different lateral interrays of the same individual. For example, one crinoid shows no supplementary plates in one lateral interray and four in another; another specimen has two in one lateral interray and six in another. Only a few individuals lack supplementary plates in the CD interray. There may be as many as seven supplementary plates, exclusive of the iBrr1, surrounding the primanal. Not all supplementary plates are in contact with the primanal; the total number of supplementary plates in the CD interray ranges from none to nine.

Number of supplementary plates is not correlated with size either in the lateral or the CD interrays.

Tegmen plates continuous with distal interray plates; these are small, polygonal, of various sizes and shapes. Ambb areas lobate, iAmbb areas depressed. Tegmen composed of large regular plates with small supplementary plates interspersed among them. Ambb not clearly differentiated from iAmbb. Ambb usually arranged in irregular biserial ranges of two plates each, about five ranges in the adult crinoid Ambb area. In some cases, three Ambb occur in single range, in others only one large plate is present. OO not differentiated, although in some cases, they appear in base of anal tube. In one example, the iAmbb in AB and AE interrays are composed of three to five large plates, sometimes with additional supplementary plates. In BC and DE interrays, there are a greater number of iAmbb, usually at least five. Anal series continues distally along anal tube, which is subcentrally located and incompletely known; anal tube probably short, sometimes set at right angles to tegmen surface, but more commonly leans toward the A ray. Base of anal tube composed of plates similar to those of tegmen; distal portion unknown.

Arms massive, biserial, with ornamented hexagonal Brr. Each Br bears a long slender pinnule composed of about five pinnulars.

Stem facet pentagonal; on one well-preserved specimen, pentalobate axial canal observed. Stem fragment round, heteromorphic, composed of alternating nodals and internodals.

Remarks.—The diabolocrinids were found throughout the length of the "Benbolt" outcrop belt. The crinoids are most common at the southern end and are encountered less frequently towards the north. About 200 specimens in various states of preservation have been seen. Of these, some 75 were used for detailed study. The remaining crinoids are too broken, abraded, or encrusted to be useful.

Wachsmuth and Springer distinguished three species of *Diabolocrinus* on the basis of surface ornamentation and number of supplementary plates. These are, along with the diagnostic features listed by the authors: 1. *D. perplexus* Wachsmuth and Springer (see Pl. 12, fig. 3). Larger plates convex, possessing one or more conspicuous nodes; smaller plates with single central node. The iBrr and supplementary plates regularly arranged. Lateral interray supplementary plates range from none to two in smaller specimens up to a maximum of four to six in large crinoids. CD interray with about five to seven supplementary plates. 2. *D. vesperalis* (White) (holotype on Pl. 10, fig. 2). Slightly convex plates which are densely covered with wrinkles or indistinct striae. Supplementary plates irregularly distributed or absent, varying in number from none to seven. 3. *D. hieroglyphicus* Wachsmuth and Springer (syntype on Pl. 11, fig. 3). Irregularly elongated nodes and conspicuous sinuous and stellate ridges. Supplementary plates infrequent, when present, usually one, rarely as many as four. Strimple (1963, p. 76) noted that one of the snytypes figured by Wachsmuth and Springer (1897, Pl. 10, figs. 5a, b; see Pl. 11, fig. 3 of this paper) is not a typical *Diabolocrinus.* The specimen exhibits three high fixed IIBrr rather than the usual diabolocrinid short IIBrr with lobate arm bases. The second syntype of *D. hieroglyphicus* (Wachsmuth and Springer, 1897, pl. 10, fig. 5c) bears normal diabolocrinid arm bases. In addition, the writers have identified other calyces with lobate arm bases which fit Wachsmuth and Springer's diagnosis of *D. hieroglyphicus.* Therefore, the first mentioned syntype is considered an abnormal specimen with peculiar arm bases.

Miller and Gurley also recognized three diabolocrinid species based on surface ornamentation and structure of the interrays. 1. *D. asperatus* (Miller and Gurley) (syntype on Pl. 11, fig. 6). Plates highly convex with more or less sculptured granular or sinuous ridge covered surface. Stellate ridges on RR; central nodes on IBrr.

Lateral interray composed of one large iR (largest plate in cup) followed by an arch of five or six plates; here the two central larger plates are iBrr1 and the remaining three to four plates are supplementary; the last range is comprised of three or four plates. In the CD interray, there are two iRR, one smaller than the other; these are followed by a range of five supplementary plates, each of which is larger than the plates of the same lateral interray arch. 2. *D. parvus* (Miller and Gurley) (syntype on Pl. 10, fig. 1). A small form. Stellate ridges present on the proximal calyx plates; these are not interrupted at the sutures. Calyx plates have granular surfaces. Lateral interrays with one large iR followed by two iBrr1. The one large CD interray iR (primanal) is overlain by one iBr1 and two supplementary plates. 3. *D. knoxensis* (Miller and Gurley) (holotype on Pl. 11, fig. 8). Plates convex with beveled sutures and granular surfaces; stellate ridges lacking. Smaller plates with one central node; larger plates bear two or three nodes. Lateral BB do not have truncated distal margin. In lateral interrays, the large central iR is surrounded by seven or eight plates; here, the two central larger ones are iBrr1 and five or six are supplementary plates; the next range is composed of three or four plates. CD interray slightly wider and with a few more plates. The iR surrounded by eight plates, of which two are iBrr1 and six are supplementary. Four plates follow distally.

When Wachsmuth and Springer erected *Diabolocrinus* in 1897, they included *Rhodocrinus vesperalis* White (1880), as well as their newly described *D. perplexus* and *D. hieroglyphicus*. Evidently, they were unaware of the three species proposed by Miller and Gurley in 1894 and 1895 because these were not mentioned in their text.

Rhodocrinus vesperalis was proposed by White (1880) and redescribed by Miller in 1882 as *Lyriocrinus sculptilis*. In 1885, Wachsmuth and Springer assigned Miller's species to *Archaeocrinus*. In addition, they presented the name *A. sculptus* for Miller's *Lyriocrinus sculptilis* because the latter name was preoccupied by the *Rhodocrinus (Lyriocrinus) sculptilis* of Hall (1868, p. 368). This change was invalid at the time inasmuch as the two species were assigned to different genera. Wachsmuth and Springer (1897, p. 262) reexamined Miller's *Lyriocrinus sculptilis* (their *Archaeocrinus* *sculptus*) and assigned the crinoid to *Diabolocrinus*, considering it a synonym of *D. vesperalis*.

The synonymy of the other names is equally complex. For example Miller (1897, p. 741) considered the two species described by Wachsmuth and Springer as conspecific with *D. asperatus* (Miller and Gurley). Bassler and Moodey (1943, p. 417) also included *D. hieroglyphicus* Wachsmuth and Springer with *D. asperatus*.

In an attempt to evaluate the relations of the "species", 75 of the better adult crinoids were segregated into the following categories: *D. "vesperalis"*, *D. "perplexus"*, *D. "hieroglyphicus"*, *D. "asperatus"*, *D. "parvus"*, and *D. "knoxensis"*. The "diagnostic features" previously listed were used.

The authors encountered considerable difficulty when attempting to identify the specimens in terms of the described "species" due to the high degree of variability shown by the crinoids. Supposedly, *D. "perplexus"* is distinguished from the other species by one or more conspicuous nodes; however, both *D. "knoxensis"* and *D. "hieroglyphicus"* possess the same type of nodes. Sinuous ridges characterize *D. "vesperalis"* but also occur on *D. "asperatus"*. Stellate ridges are supposed to separate *D. "hieroglyphicus"* but are found on all other "species", and are strong on some individuals of *D. "asperatus"* and *D. "vesperalis"*.

The number of supplementary plates also varies to a much greater extent than the previously published descriptions of the different "species" lead one to expect. The authors relied on ornamentation more than on the number of supplementary plates in assigning the "Benbolt" diabolocrinids to the various "species". Invariably the number of supplementary plates differs in being both less and more numerous than the number given in the "diagnoses".

For example, large specimens of *D. "perplexus"* were described as possessing an iR surrounded by six plates in the lateral interray and by seven plates in the CD interray; these include the iBrr1. But the number of supplementary plates, exclusive of the iBrr1, was found to range from none to five in the lateral interrays and from none to six in the CD interray. Similar situations exist with the other "species".

Most specimens conform more or less to *D. "vesperalis"*. With the exception of the two syntypes, no *D. "parvus"* were identified.

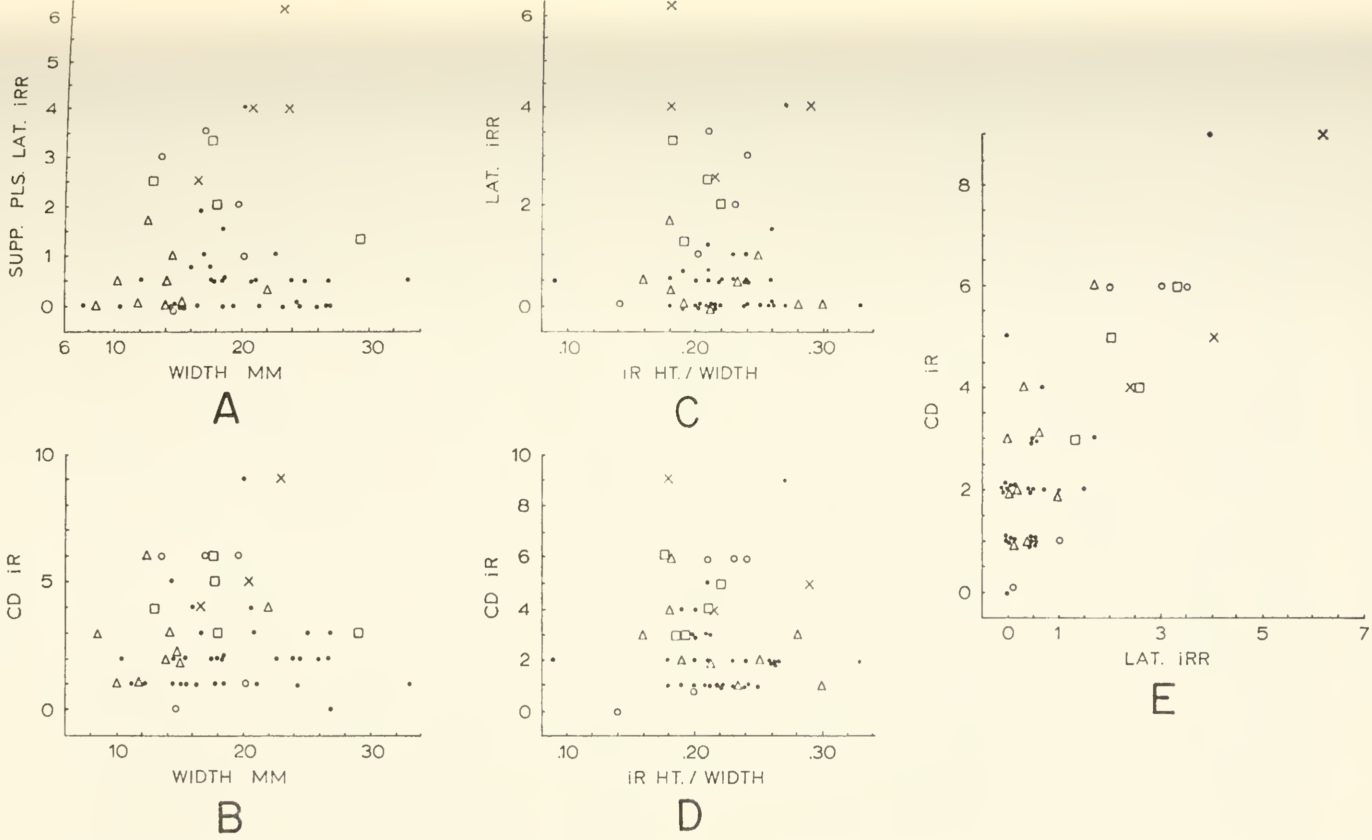
This form is clearly a young diabolocrinid. Inspection of the types and figures given by Miller and Gurley (1894, pl. 2, figs. 26-28) indicates that the crinoid is probably an immature *D. vesperalis.* Both syntypes (UC 6039; see Pl. 10, fig. 1 herein) have stellate ridges which reach the IBr1, iR, and in some interrays the iBr1 level. Above this, the crinoids are badly weathered, and the ornamentation cannot be clearly defined. In addition to the stellate ridges, there are small nodes and sinuous ridges. The cups possess 10 lobate protruding arm bases. The lateral interrays show one iR followed by two iBrr while the CD interray shows one iR followed by three iBrr. In the text, the authors (Miller and Gurley, 1894, p. 21) stated, "This species, though small and somewhat resembling *A. asperatus* is so distinct as to require no comparison to distinguish it."

The remaining four "species" were found to grade into *D. "vesperalis"*. Tentatively, 49 individuals were identified as *D. "vesperalis"*, nine as *D. "hieroglyphicus"*, seven as *D. "asperatus"*, eight as *D. "perplexus"* and four as *D. "knoxensis"*. As shown below, all the varying individuals of the "Benbolt" diabolocrinids are believed to constitute a single species.

Geographic distribution of the "Benbolt" diabolocrinids failed to reveal any grouping into the above "species". At every locality where they were found in any numbers, *e.g.*, Knoxville, Lutrell, Washburn, Red Hill (all in Tennessee), from two to five of the "species" occurred together.

In the next stage of the study, the adult crinoid distribution of each "diagnostic" character was plotted to determine the presence or absence of morphological discontinuities. These characters are the number of supplementary plates in the lateral and CD interrays, and ornamentation by nodes, and/or by stellate ridges, and/or by sinuous ridges. Basically, each character was treated as a single unit in this phase, regardless of its relation to the other characters.

In Text-figure 8a, the distribution of the number of supplementary plates in the mean lateral interray is plotted relative to calyx width. Where the number of supplementary plates differed on the several interrays of the same individual, the number plotted was the average. For example, if the number of supplementary plates varied from 0 to 1 in one individual, .5 was plotted. Variations from



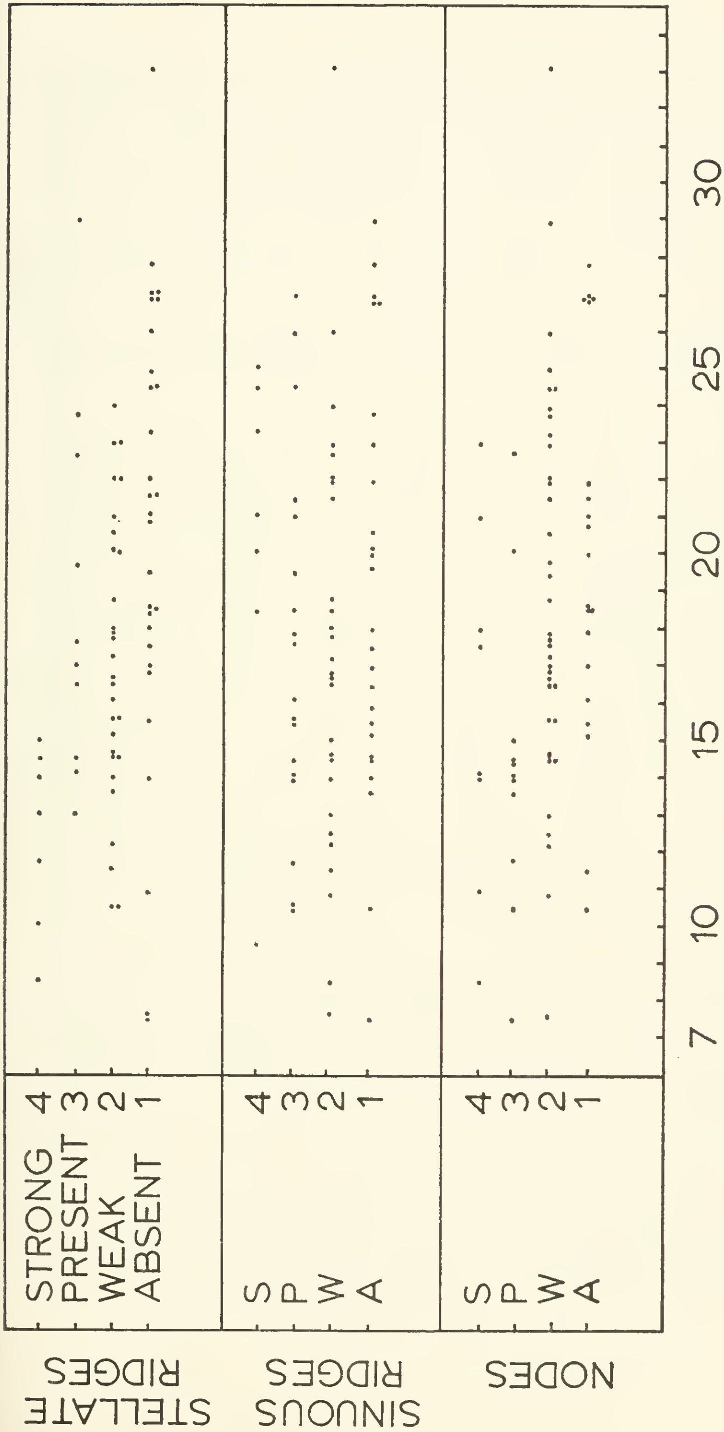
Text-figure 8.—*Diabolocrinus vesperalis* (White). Graphs showing variation. A. The number of lateral interray supplementary plates plotted against the calyx width. The "species" are indicated by the symbols listed below. B. Same as figure A for the CD interray supplementary plates. C. The number of lateral interray supplementary plates plotted against the iR height/calyx width. D. Same as figure C for the CD interray supplementary plates. E. The number of lateral interray supplementary plates plotted against that of the CD interray. "Species" symbols: *D. "vesperalis"* — black dots. *D. "perplexus"* — open circles. *D. "knoxensis"* — X's. *D. "hieroglyphicus"* — triangles. *D. "asperatus"* — squares.

none to seven were found in the lateral interrays. The different "species" are indicated on the data points; no morphological discontinuity appears. Text-figure 8b shows the same situation in the CD interray with the range of supplementary plates from none to nine.

In Text-figure 8c and 8d, the number of supplementary plates in the lateral and CD interrays, respectively, are plotted against the iR height/calyx width ratio (this constitutes a measure of the relative size of the plate). The "species" are identified by the use of symbols on the data points (see Text-figure 8 legend). According to Wachsmuth and Springer (1897, p. 251), in large specimens of *D. "perplexus"*, when "completely developed", the iR is surrounded by six plates in the lateral interrays and by seven plates in the CD interray. Presumably, they thought fewer supplementary plates occurred in "incompletely developed" individuals. As seen in the figures, neither *D. "perplexus"* nor any of the other "species" exhibits a morphological discontinuity, nor is there any relationship between number of supplementary plates and relative size of the iR.

In Text-figure 8e, the number of supplementary plates in the lateral interrays is plotted against the number in the CD interray. Although a positive correlation ($r = .83$) is seen, the relationship does not seem significant in taxonomy.

Text-figure 9 shows the distribution of the ornamentation elements plotted versus the size of the crinoids. In these crinoids, the ornamentation consists of three elements, stellate ridges, nodes, and sinuous ridges. Because it is impractical to measure any of these elements, each was broken down into four qualitative categories: 1. Absent. 2. Weak. 3. Present. 4. Strong. Each ornamentation element was treated as a single unit although one or more of these are often found on a single individual. In Text-figure 9, it appears that these unit characters do not exhibit any morphological discontinuities. At first glance, the "Benbolt" diabolocrinid ornamentation seems to be divided into two groups. First are specimens with strongly swollen and nodose plates. Smaller sharp nodes may occur on some plates. Heavy median-ray and stellate ridges, or stellate ridges are sometimes present. The second group includes calyces with flatter plates having fine sinuous ridges and stellate ridges, or



Text-figure 9.—*Diabolocrinus vesperalis* (White). Distribution of ornamentation elements plotted against calyx width. Note lack of morphological discontinuities.

stellate ridges. Actually these two types grade into one another in single specimens. For example, the center of a plate may be nodose and the sides flat with sinuous or fine stellate ridges. Similarly, different types of ornamentation may be found on the various plates of a single crinoid. Also, the elements are more or less growth independent. Stellate ridges do appear more strongly in smaller individuals, but the other ornamentation characters are not correlated with size.

Text-figure 10 shows the relationship among the three elements of ornamentation. Again, no discontinuities or groupings into "species" occur.

Text-figures 11a and 11b attempt to correlate the described "species" and their "diagnostic" ornamentation with the number of supplementary plates in the lateral and CD interrays, respectively. The specimens tentatively identified as *D. "vesperalis"* and bearing sinuous ridges occur with all variations of numbers of supplementary plates in the CD interray and with many variations in the lateral interrays. *D. "perplexus"* and *D. "knoxensis"*, with node type ornamentation, possess a different mean number of supplementary plates, but they overlap in both the lateral and CD interrays. The same situation is seen in *D. "hieroglyphicus"* and *D. "asperatus"*, supposedly with ornamentation of nodes and stellate and sinuous ridges. Each "species" shows a different average number of supplementary plates in both the lateral and CD interrays; however they intergrade. As shown above, nodes occur in *D. "perplexus"*, *D. "knoxensis"*, *D. "hieroglyphicus"*, and *D. "asperatus"*. Stellate ridges occur in all five "species" and are strong in some individuals of *D. "vesperalis"* and *D. "asperatus"*. The conclusion to be drawn is that the combined "diagnostic" features of ornamentation and the number of supplementary plates do not separate these diabolocrinids into distinct groups. The figures show no morphological discontinuities, and a continuous distribution is obviously present.

All data were analyzed by multivariate statistics; the following characters or variables were treated: Nature of nodes ($X1$), sinuous ridges ($X2$), stellate ridges ($X3$), number of supplementary plates in lateral interrays ($X4$), number of supplementary plates in the CD interray ($X5$), the size of the iR relative to the calyx, *i.e.*, iR height/calyx width ($X6$), and calyx width ($X7$). The ornamenta-

Text Figure 10

NODES	1	2	3	4
4	1 v 1 k 1 a	1 h	1 v 1 h	
3	1 v 1 p 1 a	1 v 1 h	2 v 3 h	1 p
2	1 p 1 a 1 k	14 v 2 p 2 a 3 h	5 v 1 a	3 v
1	12 v	2 v 2 a	5 v	3 v 3 p

SINUOUS RIDGES

NODES	1	2	3	4
4	2 p	2 v 1 k		2 h
3	1 a	2 v 2 p	2 v 1 h	1 v 3 h
2	10 v 1 a 2 p	11 v 2 h 1 a 1 k	1 v 1 p 2 k 1 a,1 h	1 a
1	16 v 1 a	5 v	1 v	

STELLATE RIDGES

SINUOUS RIDGES	1	2	3	4
4	8 v	1 p		
3	5 v	5 v 1 a	2 v 1 h	3 h 1 v
2	6 v 2 a 1 p	6 v 2 h 1 p	1 v 1 h	2 h 1 a
1	6 v 2 a 2 p	8 v 2 p 2 k	1 v 1 p 1 a 2 k	1 v

STELLATE RIDGES

v = "VESPERALIS"

p = "PERPLEXUS"

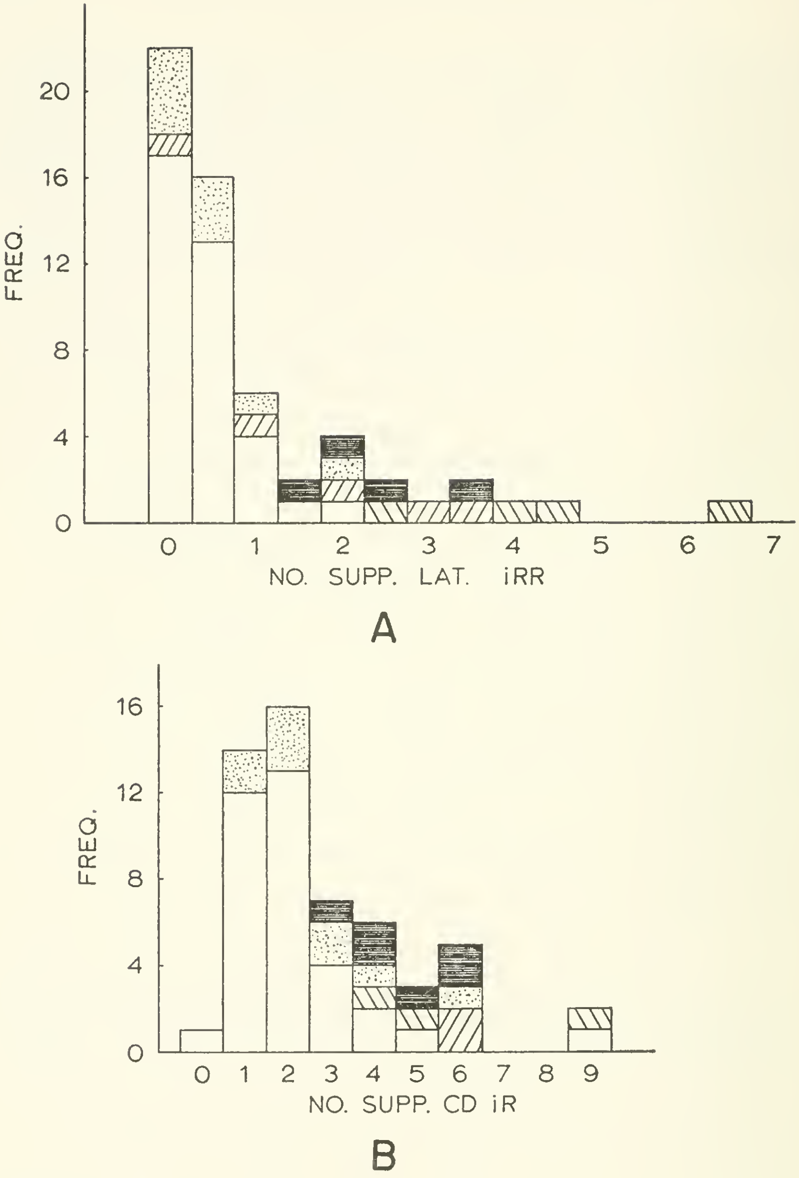
k = "KNOXENSIS"

h = "HIEROGLYPHICUS"

a = "ASPERATUS"

1 - absent
2 - weak
3 - present
4 - strong

Text-figure 10.—*Diabolocrinus vesperalis* (White). Relationships among the three ornamentation elements shown in tabular form. Note the lack of morphological discontinuities.



Text-figure 11.—*Diabolocrinus vesperalis* (White). Graphs showing variation of supplementary plates relative to "species". A. Frequency graph of number of lateral interray supplementary plates. "Species" are coded by the symbols listed below. B. Same as above for the CD interray. "Species" coding: *D. "vesperalis"* — blank. *D. "perplexus"* — ruling which dips to left. *D. "knoxensis"* — ruling which dips to right. *D. "hieroglyphicus"* — stippling. *D. "asperatus"* — black. In some cases, the mean number of supplementary plates within several "species" differs. However, all "species" show significant overlap. Such intergradation indicates no significant morphological discontinuity.

tion data were coded on the scales ranging from 1.0 to 4.0 as previously mentioned. The crinoids for which this data could be compiled were distributed among the "species" as follows: *D. "vesperalis"*, 30 crinoids; *D. "asperatus"*, four crinoids; *D. "knoxensis"*, three crinoids; *D. "perplexus"*, five crinoids; *D. "hieroglyphicus"*, nine crinoids.

The first stage of the analysis comprised extraction of principal components from a correlation coefficient matrix. The computer program used was BMD 01M which is outlined in Dixon (1970, pp. 150-158.) General discussions of principal components are available in Seal (1964, chapt. 6) and Morrison (1967, chapt. 7). Sokal and Rohlf (1969, chapt. 15) described correlation coefficients. The principal components show that most variables are independent of one another. However, two partial character packages exist. The number of supplementary plates in the lateral and CD interrays are positively correlated where the correlation coefficient (r) equals .83. Nevertheless, the coefficient of determination [$(1\text{-}r^2)$ times 100] is only 69%, demonstrating that 31% of the variance of one variable is independent of the other. Calyx width and the stellate ridge strength are inversely related with a –.56 correlation coefficient. This represents a growth trend in stellate ridge bearing specimens where the younger crinoids exhibit stronger ridges. All other variables are independent of overall size. The results of the principal components denote that all variables, including the above two character packages, are sufficiently independent so that all characters convey meaningful information. Consequently, the subsequent taxonomic analyses consider all seven previously listed variables.

The taxonomic evaluation consists of two stages. The first phase constituted numerical taxonomic analysis of squared distance coefficients (Sokal and Sneath, 1963, see appendix for the computational method). The data matrix treats the diabolocrinid specimens (OTU's) as variables and the characters or variables as observations. The characters are standardized so that each contributes equally to the similarity coefficients. The similarity coefficients selected were of the squared distance type. These are best visualized as squared Euclidian distances between OTU's in seven dimensional character space in which the lengths of the character axes are equalized. The relationships were extracted from the similarity coefficient matrix by average linkage cluster analysis. The computer program utilized was HGROUP (Veldman, 1967, pp. 308-319). The following reasoning was followed in the interpretation of results. There should be little or no morphological overlap between the "species" if they are valid. Where the diabolocrinids are found in any numbers, from two to all five "species" occur together. Thus, any one "species" should be separated from all others pooled together. In the cluster analysis, each "species" should form a single cluster if the "species" are distinct. The cluster analysis results are tabulated below for the five cluster stage.

Cluster I. Eleven *D. "vesperalis"*, one *D. "asperatus"*, two *D. "hieroglyphicus"*.
Cluster II. Six *D. "vesperalis"*, one *D. "asperatus"*, one *D. "knoxensis"*, three *D. "perplexus"*, four *D. "hieroglyphicus"*.
Cluster III. Eleven *D. "vesperalis"*, one *D. "asperatus"*.
Cluster IV. One *D. "vesperalis"*, three *D. "hieroglyphicus"*.
Cluster V. One *D. "vesperalis"*, one *D. "asperatus"*, two *D. "knoxensis"*, two *D. "perplexus"*.

The data clearly show that the different "species" intergrade and there are no morphological discontinuities between the "species".

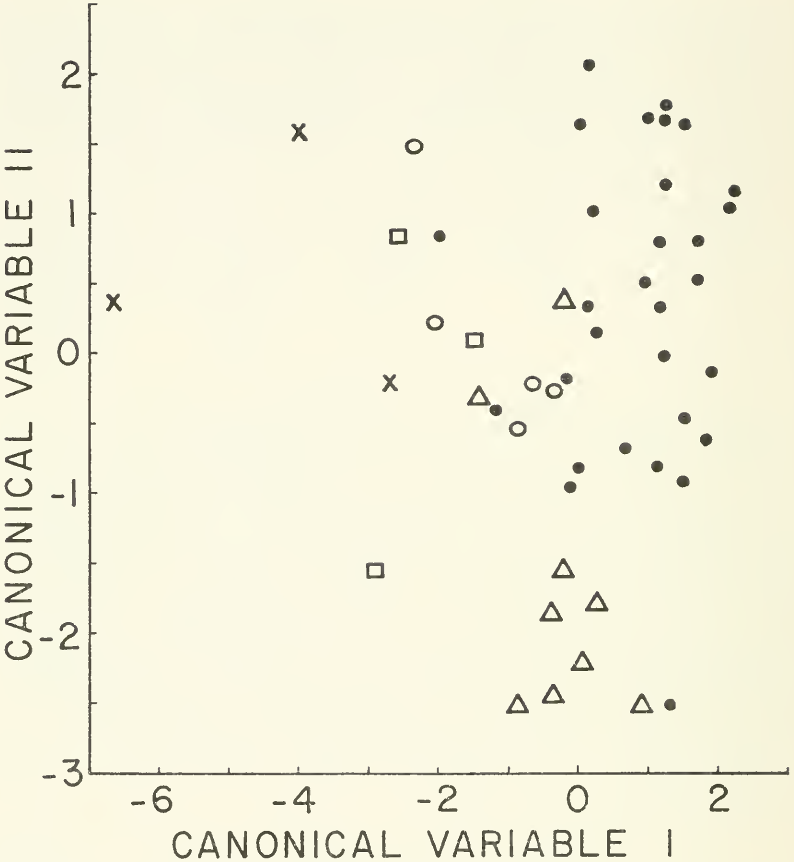
In the second stage of taxonomic analysis, the above conclusions were followed up by the one-way multivariate analysis of variance and canonical variables. A general outline of the method may be seen in Seal (1964, chapt. 7). The computer program used was BMD 07M (Dixon, 1970, pp. 214a-214t). Although all responses seem linear, the diabolocrinid data do not meet all assumptions of the analysis. The variance-covariance matrices of the "species" are not all equal; apparently, this reflects the disparity of sample sizes for the various "species" rather than any meaningful biological phenomena. Also the coded data, such as stellate ridges, are not normally distributed. Despite these problems, the results seem reasonable and they are certainly consistent with the cluster analysis. Two results of the program are of main interest here. F-ratios between all combinations of two "species" are listed in matrix form. These are easily compared because all have the same degrees of freedom, namely seven and 40 for the numerator and denominator, respectively. These F-ratios may be interpreted as distances, corrected for the number of variables and sample sizes, which are weighted inversely with respect to the pooled within groups variance-covariance matrix. The probabilities corresponding to the F-ratios range from greater than .25 to less than .005. The F-ratio matrix follows:

D. *"vesperalis"*	*D.* *"asperatus"*	*D.* *"knoxensis"*	*D.* *"perplexus"*	*D.* *"hieroglyphicus"*
—	3.57	9.70	2.99	4.01
	—	1.71	.522	2.42
		—	2.85	7.73
			—	2.61
				—

The BMD 07M program also calculates discriminant functions for each "species" versus the rest of the "species" pooled together. Each specimen is then assigned to the group or "species" with the highest probability of membership (see general discussion in Cooley and Lohnes, 1962, chapt. 7; Morrison, 1967, chapt. 4; Van de Geer, 1971, chapt. 18). An individual can be placed in the original group (a correct classification) or it could be misclassified into another group by the discriminant function. None or few misclassifications would indicate little or no group overlap; numerous misclassifications show much intergradation between groups. The classification matrix is listed below (the number of correct classifications for each "species" or group is underlined):

	D. *"vesperalis"*	*D.* *"asperatus"*	*D.* *"knoxensis"*	*D.* *"perplexus"*	*D.* *"hieroglyphicus"*
D. "vesperalis"	22	3	0	1	4
D. "asperatus"	1	2	0	1	0
D. "knoxensis"	0	1	2	0	0
D. "perplexus"	0	2	0	3	0
D. "hieroglyphicus"	2	0	0	0	7

The misclassifications within a single species range from 22 to 50%. The total misclassifications equal 29%. In this case, equal *a priori* classification odds were assumed. Under such ground rules, the maximum total misclassification percent comprises 50%, and the discriminant functions would be right half of the time. The high frequency of misclassifications shows that there are no significant



Text-figure 12.—*Diabolocrinus vesperalis* (White). Plot of first and second canonical variables. The eigenvalues are 2.28 and .680 and these account for 74 and 22% of the total dispersion, respectively. The canonical variable equations are (see list of variables in the text):

$$y_1 = -.21X_1 + .22X_2 - .56X_3 - 1.7X_4 + .47X_5 + .45X_6 - .031X_7$$

$$y_2 = -.22X_1 - .29X_2 - .88X_3 + .35X_4 - .21X_5 + .55X_6 + .048X_7$$

"Species" symbols: *D. "vesperalis"* — black dots. *D. "perplexus"* — open circles. *D. "knoxensis"* — X's. *D. "hieroglyphicus"* — triangles. *D. "asperatus"* — squares.

morphological discontinuities between the "species". A plot of the first two canonical variables is presented in Text-figure 12, and this confirms the conclusions drawn from the discriminant functions. The first canonical variable accounts for 74% of the sum of squares and crossproduct matrix variance. The main contributing variable is the number of supplementary plates in lateral interrays (X4). Canonical variable I tends to distinguish *D. "vesperalis"* from the other "species" although only poor separation is obtained. The second canonical variable is associated with about 22% of the variance and the most important characters are the stellate ridges (X3) and the iR height/calyx width (X6). This canonical variable attempts to isolate *D. "hieroglyphicus"* from the other "species". The overall impression obtained from the plot is little separation and great overlap between all "species".

One diagnostic feature of *D. "knoxensis"* was not treated statistically but can be discussed simply as follows. This form is supposed to be characterized by the possession of "untruncated" BB (*i.e.*, directly overlain by supplementary plates at the distal margin). Of 15 crinoids assigned by the writers to *D. "knoxensis"*, only four exhibited this feature. Eleven specimens of *D. "knoxensis"* had typical truncated BB, overlain by a large iR, and one specimen of *D. "verperalis"* was found to have one "untruncated" B.

The results of the graphs, statistical analyses and the observation of the geographical distribution of the specimens do not warrant the division of *Diabolocrinus* into the species indicated by Wachsmuth and Springer and by Miller and Gurley. Clearly, the crinoids represent a single interbreeding population with a high degree of variability with respect to surface ornamentation, disposition of interray plates and shape of the BB distal margin. Consequently, only a single species is recognized.

Integration of the previously mentioned F-ratios and the classification data suggest some pertinent information on statistical probabilities and species separation. The many diabolocrinid misclassifications are associated with F-ratio probabilities ranging from greater than .25 to less than .005. This suggests that probabilities of around .001 would be required to separate meaningful species in this case. This is consistent with our experience on other crinoid groups where we accept probability levels ranging from .01 to .001. At any rate, the .05 probability or 5% risk level accepted by many statisticians is too large and results in too many misclassifications to define meaningful and operational species.

Because *D. vesperalis* (White) has priority, it is retained as the species name. When Wachsmuth and Springer erected *Diabolocrinus,* they designated *D. perplexus* Wachsmuth and Springer (1897, p. 250, pl. 11, figs. 1a-c) as the type species. As indicated above, *D. perplexus* is a junior synonym of *D. vesperalis*. Consequently, the type species is currently *D. vesperalis* rather than *D. perplexus*.

There are several diabolocrinids that do differ from the "Benbolt" form at the specific level. The British *D. craigheadensis* Ramsbottom (1961, p. 27, pl. 8, figs. 5-9) shows an extremely low cup with the RR hidden from view; the cup sides are formed by the IBrr and IIBrr. The plates are smooth and convex with sunken sutures in distinction to the ornamented plates of the "Benbolt" diabolocrinid. The arrangement of the interray plates is variable.

Ramsbottom (1961, pl. 8, figs. 10-20) described *D. globularis* (Nicholson and Etheridge) (1880, p. 329, pl. 22, figs. 9-11) as having biserial arms, lacking supplementary plates and bearing median-ray ridges. The plates are usually smooth, convex and possess sunken sutures. Stellate ridges rarely occur. The median-ray ridges and usually smooth plates separate this crinoid from the "Benbolt" species.

Diabolocrinus, n. sp., found in the Pierce and described in more detail below, differs from *D. vesperalis* in its higher globular cup and in the lateral interrays which are formed by one small iR followed by three regular iBrr1. The plates appear smooth, but are badly weathered and abraded, or abraded.

A series of six "Benbolt" diabolocrinids, ranging in size from a calyx 2.5 mm high and 8.5 mm wide to a calyx of 7.0 mm in height and 26 mm in width, were examined for growth changes (see previous discussion for ontogeny of ornamentation). During ontogeny, the height growth rates of all major calyx plates (*i.e.*, BB, iRR, RR, IBrr and IAxx) exceeded those of width. In the IIBrr1 and 2, the height and width growth rates were about the same. In addition, the orientation of individual plates changed during development. The RR assumed a more horizontal position. More of the BB proximal margins were incorporated into the basal concavity. The arm facet on IIBr2 shifted in direction from an upward to an outward orientation.

As a result of these growth patterns, the calyx shape grew as follows. A deeper basal concavity developed. The calyx became wider with a flatter base. The arm bases were directed more horizontally, and the IIBrr formed lobate protuberances.

In addition, the diameter of the anal tube became narrower relative to the calyx size.

Types. — Holotype of *Rhodocrinus vesperalis* White, USNM 8032. Two plesiotypes of *Diabolocrinus vesperalis* (White), S 88. Four syntypes of *Gilbertsocrinus americanus* Troost, USNM 39970. Holotype of *Diabolocrinus perplexus* Wachsmuth and Springer, S 89. Specimen figured by Butts as *D. perplexus,* S 90. Holotype of *Archaeocrinus knoxensis* Miller and Gurley, UC 6085. Two syntypes of *Archaeocrinus parvus* Miller and Gurley, UC 6039. Two syntypes of *A. asperatus* Miller and Gurley, UC 6038. Specimen figured by Butts (1941, pl. 89, figs. 6-8) as *Diabolocrinus asperatus*, USNM 97464. The other specimen figured by Butts (1941, pl. 89, figs. 4-5) as *D. asperatus* is described later in this paper as *Paradiabolocrinus sinuorugosus,* n. gen., n. sp. Holotype of *Archaeocrinus knoxensis* Miller and Gurley, UC 6035. Specimens figured here as *Diabolocrinus vesperalis* (White), USNM 164617-164624; S 5541 - S 5544.

Occurrence. — Benbolt Formation or equivalent part of Dryden Limestone, localities 4c and 4d; probably Benbolt Formation or Wardell Formation, locality 13; Benbolt Formation or Hogskin Member of Lincolnshire Formation, localities 9c, 10b, 10c and 10d; Hogskin Member of Lincolnshire Formation according to Cooper (1956), localities 8c, 9b and 11; Ottosee Shale or Sevier Shale, localities 15a, 15c and 15e; base of Sevier Shale, locality 16.

Diabolocrinus, n. sp. Pl. 13, fig. 1

Remarks. — Only two badly weathered and abraded, or abraded specimens of this form were found. One is a dorsal cup with the B ray and part of the adjoining interrays missing. The other consists only of a dorsal cup base with a short column segment attached. The lateral interray structure differs from the other Benbolt diabolocrinids in several ways. The iR is smaller than in typical diabolocrinids. The iR of the lateral interrays and the primanal of the CD interray are followed by three iBrr1. The iBrr above these are irregular in size, shape, and number, although the CD interray possesses more plates than the lateral interrays. There are no distinctly smaller plates that could be designated as supplementary plates.

This is clearly a new species as characterized by the interrays and the high globular dorsal cup shape which contrasts with the depressed globular cup of the other "Benbolt" diabolocrinids. The crinoid is judged to belong to *Diabolocrinus* because of the similarity in the 10 lobate, protuberant arm bases, the constriction of the calyx proximal to the arm bases, and the small subcentral anal tube. However, the crinoid is not formally described here because the specimens are badly abraded or weathered, and the ornamentation cannot be completely determined.

Types. — Figured specimen, USNM 164625. Mentioned specimen, USNM 164626.

Occurrence. — Top of Pierce Shale, locality 18.

Genus **PARADIABOLOCRINUS**, n. gen.

Types species: By designation herein, *Paradiabolocrinus irregularis*, n. gen. n. sp.

Diagnosis. — A "rhodocrinitid" genus with a large cup which is either depressed globular in shape or widely conical below the arm openings. Median-ray ridges and BB stellate ridges commonly present. Tegmen with lobate ambulacral areas or smoothly convex. Short lobate arm bases support two arms per ray. Several inter-half-ray iBrr present. Lateral interrays composed of many irregularly shaped and irregularly placed iRR and iBrr. CD interray wider, containing a greater number of plates.

Description. — Dorsal cup large with flat subglobular or widely conical shape; tegmen gently convex or almost flat. Surface ornamentation consists of various sized nodes, or of sinuous ridges. Median-ray ridges and proximal stellate ridges commonly present. Arms grouped, two per ray, arm openings directed upward and outard; short lobate arm bases.

IBB five, small, hidden in basal concavity. BB hexagonal, truncated distally. RR basically pentagonal, truncated at distal edge. IBr1 and IAx polygonal. Inter-half-ray iBrr begin at IIBrr1 level.

Lateral and CD interrays consist of small irregular-shaped and irregularly placed plates. Plate number varies from 17 to 36, with CD interray wider and containing more plates than lateral interrays.

Tegmen low and flat with Ambb areas faintly lobate, or convex with Ambb and iAmbb areas not differentiated. Tegmen plates polygonal, of varying sizes.

Arms and column unknown.

Remarks. — The depressed cup shape of *Paradiabolocrinus*, n. gen. is closest in appearance to that of *Diabolocrinus* Wachsmuth and Springer (1897, p. 249). *Archaeocrinus* Wachsmuth and Springer [(1881), p. 363(189)] and *Rhaphanocrinus* Wachsmuth and Springer (1885, p. 320) exhibit a more slender shape with a narrower base, while *Pararchaeocrinus* Strimple and Watkins (1955, p. 351) has a higher globular shape. *Wilsonicrinus* Springer (1926, p. 23) is characterized by a broad wheel-shaped calyx.

Paradiabolocrinus, n. gen. is similar to *Diabolocrinus* in possessing two arms per ray which originate from lobate protruding arm bases. However, these arm bases are much smaller and less protuberant then in *Diabolocrinus*.

The other "Benbolt" "rhodocrinitids" (*Archaeocrinus, Pararchaeocrinus* and *Wilsonicrinus*) lack protuberant arm bases and the arms are not so strongly grouped.

The interray structure of *Paradiabolocrinus*, n. gen. is highly distinctive in the large number of iRR and iBrr. Only *Diabolocrinus* possesses supplementary plates in addition to the iR and iBrr, but at most, 10 lateral interray plates occur at and below the IIBrr level. In *Paradiabolocrinus*, n. gen. there may be from 17 to 36 interray plates reaching the same level. In the lateral interrays of the related "Benbolt" forms, *Archaeocrinus* shows one iR and, at most, three iBrr whereas *Pararchaeocrinus* has two or three iRR and three iBrr; *Wilsonicrinus* is characterized by one large iR which dominates the interray and is followed by one iBr.

Inter-half-ray iBrr are a distinguishing feature of *Paradiabolocrinus*, n. gen.; these are lacking in *Diabolocrinus*.

Generic name. — *Paradiabolocrinus* in allusion to the fact that this crinoid is closer to *Diabolocrinus* than to other "rhodocrinitids".

Occurrence. — "Benbolt" Formation, Tennessee.

Paradiabolocrinus irregularis, n. sp. Pl. 13, figs. 3a-c

Diagnosis. — A paradiabolocrinid with depressed globular cup, nodose plates; 36 plates in the lateral and CD interrays; tegmen with lobate ambulacral areas.

Description of holotype. — Large, flattened subglobular cup, approximately 40 mm wide and 23 mm high. Ornamentation composed of heavy stellate ridges on BB and proximal parts of RR; distally, these grade into coarse median-ray ridges which extend to the arm bases; irregular nodes commonly occur on and flanking the stellate and median-ray ridges; small sinuous ridges appear on distal median-ray ridges. Interray plates nodose; most larger plates with one large centrally located node, with or without smaller scattered nodes; smaller interray plates typically with a single central node; node diameter ranges from 1.3 to 2.5 mm. Plate sutures smooth. Arm bases grouped, two per ray.

IBB five, small, hidden in basal concavity. BB five, irregularly hexagonal, about 7 mm high and 9.1 mm wide. RR irregularly heptagonal with truncated distal edge, approximately 8.1 mm high and 7.1 mm wide. IBr1 polygonal, with eight or nine sides, approximately 5.4 mm high and 6.2 mm wide; followed by roughly pentagonal to heptagonal IAx, 4 mm high by 4.2 mm wide. Six sided IIBrr1 on each shoulder of IAx about 2 mm high by 3.5 mm wide. IIBrr2 with six sides; IIBrr3 and 4 with four sides. Protruding arm bases consist of IIBrr2, 3 and 4; these are low wide plates with height equalling about .7 mm and width ranging from 3.1 to 4.3 mm. Small arm facets with deep food grooves borne by IIBr4.

One polygonal inter-half-ray iBr1 about 2.1 mm high and 2.1 mm wide with a distinct node in center, at level of IIBrr1 and 2; followed by similar inter-half-ray iBr2 which reaches to level of arm bases.

Lateral interrays consist of small irregular-shaped and irregularly placed plates. No clear distinction between iRR and iBrr. Two or three of these plates in contact with BB; followed by an irregular tier composed of three or four plates, reaching approximately to the level of the RR distal margins; these are considered iRR. The iBrr arranged as follows: approximately 10 plates in two tiers at level of IBr1; six or seven in the following tier at level of IBr2; remaining plates varying greatly in size at the IIBrr level. Larger nodes on these plates covered with sinuous ridges. Number of plates in the interrays varies from about 21 to 36.

CD interray not preserved.

Tegmen low and flat. Ambb areas faintly lobate. The iAmbb areas not depressed. Tegmen composed of large regular plates interspaced with small supplementary plates. Distinct node on each plate. Ambb areas not clearly differentiated from iAmbb areas. Anal opening not preserved.

Stem facet about 3.4 mm in diameter.

Arms and stem unknown.

Remarks.—This species is based on three specimens: a cup with two rays and two interrays intact (holotype); another cup embedded in matrix with only the base exposed, and a rock fragment bearing several nodose plates.

Specific name.—*Irregularis* in allusion to the structure of the interrays.

Types.—Holotype, USNM 164627. Mentioned specimen, USNM 164630.

Occurrence.—Probably Benbolt or Wardell Formation, locality 13.

Paradiabolocrinus sinuorugosus, n. sp. Pl. 12, figs. 6a-c

1941. *Diabolocrinus asperatus* ? (in part) Butts, Virginia Geol. Sur. Bull. 52, pt. 2, p. 91, pl. 89, figs. 4-5, not figs. 6-8.

Diagnosis.—A paradiabolocrinid with smooth convex tegmen, cup widely conical with rounded sides below arm bases. Surface ornamentation consists of sinuous ridges.

Description.—Dorsal cup with convex tegmen, widely conical below arm bases. Width at arm openings 28 mm, height 19 mm. Deep basal concavity, 6 mm wide. Plates covered with sinuous ridges, sutures somewhat depressed. Median-ray ridges on RR and IBrr; these divide proximally with one ridge branch continuing onto each adjacent B; median-ray ridge grades distally into irregular convexities and concavities on IIBrr. Arm facets vary from IIBrr3 to 5; openings directed outward and upward.

IBB five, small, completely hidden in deep basal concavity. Column facet located above IBB, *i.e.*, deeper in basal cavity. BB hexagonal, truncated distally for reception of iRR, 4.5 mm high by 6 mm wide. RR basically pentagonal, but may have six to eight sides adjusted to join the numerous adjacent interray plates. Approximately 5.5 mm high by 6.2 mm wide. IBrr five- to six-sided, averaging 4 mm high by 4.1 mm wide. IAx six- to eight-sided, averaging 3.5 mm high by 3.8 mm wide. IIBrr1 shapes irregular, completely separated or separated distally by an inter-half-ray iBr1. IIBrr1 approximately 3.2 mm wide and 2.5 mm high. IIBrr2 irregular in shape and size, 2.5 mm in width and 2.6 mm in height. Arm facet location variable, ranging from IIBr3 to 5; these plates more or less wedge shaped, wider than high. Food groove not well preserved but seems shallow. On D ray, inter-half-ray iBr1 between IIBrr1 distal margins; inter-half-ray iBr2 between IIBrr2 and 3. On E ray, inter-half-ray iBr1 between IIBrr1; inter-half-ray iBr2 between IIBrr2 and 3 on one side and IIBrr3 and 4 on the other.

The iR basically hexagonal although they appear many-sided due to the small flanking iBrr, iRR average 3.2 mm wide by 3.5 mm high; located at RR and IBrr1 level. In DE interray, six relatively large iBrr arch around the iR at the IBrr and IIBrr level. About 10 smaller iBrr at the IIBrr level, none of which are small enough to be considered supplementary plates. AE interray not completely preserved; iR surrounded by six relatively large iBrr and two small supplementary plates. Approximately 13 iBrr at level of IIBrr.

CD interray wider with iR (primanal) measuring approximately 4.2 mm high by 4.2 mm wide, located at RR and IBrr level. Four relatively large iBrr arch around the iR at the IBrr1 and 2 level; about 14 irregular iBrr occur at higher levels. One or two small plates may be supplementary plates.

Tegmen convex, possessing polygonal plates of varying size and shape; not differentiated into Ambb and iAmbb; surface ornamentation of faint sinuous ridges.

Remarks. — This species is based on a single incomplete specimen consisting of a partial calyx which includes the D and E rays, the base and part of the tegmen. It is assigned to *Paradiabolocrinus,* n. gen. because of the large number of interray plates (17 to 19), the median-ray ridges and the presence of inter-half-ray iBrr. This crinoid may be separated from the only other described paradiabolocrinid by the following characters. Its smooth convex tegmen contrasts with the more lobate tegmen of *P. irregularis,* n. gen., n. sp. The *P. sinuorugosus,* n. gen., n. sp. dorsal cup is widely conical below the arm openings and convex above them while that of *P. irregularis,* n. gen., n. sp. is flatter in both regions. The sinuous ridge type ornamentation of this form differs from the nodose plates of *P. irregularis,* n. gen., n. sp.

Specific name. — *Sinuorugosus* in reference to the surface markings.

Holotype. — USNM 97463, figured by Butts as *Diabolocrinus asperatus* ?.

Occurrence. — Benbolt Formation or equivalent part of Dryden Limestone, locality 4a.

Genus **WILSONICRINUS** Springer, 1926 (p. 23)

Type species: By monotypy, *Wilsonicrinus discoideus* Springer, 1926, page 23, Plate 4, figures 6, 6a.

Diagnosis. — A "rhodocrinitid" genus characterized by a broad wheel-shaped cup. Interray formed by one large iR, largest plate in cup, reaches level of IIBr2, followed by iBr1 and/or fixed pinnules extending from Brr. No supplementary plates. Ten separated arm openings arise from IIBrr2. CD interray slightly distinguishable from lateral interrays.

Occurrence. — Middle Ordovician, Tennessee; Silurian, Laurel Limestone; Indiana.

Wilsonicrinus culmensinuosus, n. sp. Pl. 13, figs. 2a, b

Diagnosis. — A species of *Wilsonicrinus* characterized by sinuous ridge-covered plates.

Description. — Broad, flat dorsal cup with distal part missing; 20 mm wide above iRR. Plates covered with fine, sinuous ridges. IBB hidden in pentagonal basal concavity. BB 4.2 mm wide at widest part, 3.5 mm high, heptagonal, truncated distally, possesses reentrant angle at edge of basal concavity.

RR pentagonal, 5.6 mm wide and 3.2 mm high. IBr1 quadrangular and IAx pentagonal, about 4.9 mm wide by 2.3 mm high. IIBrr irregularly quadrangular or pentagonal, twice as wide as high, smaller than IBr2. Only B and D rays well preserved; IIBr2 bears fixed pinnular on interray side and IIBr3 on the opposite side; several small and irregularly shaped IIBrr4 present; fixed pinnular located at IIBr3 and 4 level; higher calyx structure not known. Arm facets not observed; presumably two arm openings per ray.

The iR polygonal, either with 11 to 13 sides, or roughly circular, approximately 5.5 mm in diameter, largest plate in cup, extending from level of RR to IIBrr2 and its fixed pinnular. In lateral interrays, iR is followed by one iBr1 about 2.2 mm high and 2.5 mm wide or slightly smaller, placed at level of IIBrr2 and 3.

CD interray iBr1 slightly larger, 2.3 mm high and 2.8 mm wide, located at same level at lateral interray iBr1.

Tegmen and arms unknown.

Stem facet pentagonal, 4.1 mm in diameter.

Remarks. — This species is based on an incomplete dorsal cup. *W. culmensinuosus*, n. sp. differs from the type and only other known species of *Wilsonicrinus* in the marked sinuous ridges on the plate surfaces and in the roughly quadrangular or pentagonal shape of the IIBrr. *W. discoideus* Springer (1926, p. 23, pl. 4, figs. 6, 6a) possesses smooth plates and cuneate shaped IIBrr.

The "Benbolt" wilsonicrinid bears a closer resemblance to the Middle Silurian *W. discoideus* than it does to any Ordovician "rhodocrinitid". This resemblance lies in the single large iR which dominates the dorsal cup, in the flat wheel-shaped calyx and in the identical shapes of the RR, iBrr1 and 2.

Specific name. — *Culmensinuosus,* referring to the sinuous ridges covering the plate surface.

Holotype. — USNM 164626.

Occurrence. — Hogskin Member of Lincolnshire Formation according to Cooper (1956), locality 11.

Genus **RHAPHANOCRINUS** Wachsmuth and Springer, 1885 [p. 98(320)]

Type species: By monotypy, *Glyptocrinus subnodosus* Walcott, 1883, page 208, plate 17, figure 3.

Diagnosis. — A "rhodocrinitid" genus characterized by erect dorsal cup in which the IBB are not visible from the side; lateral interray iR followed by two or three plates; primanal succeeded by three plates of which the central one is an anal series plate and the two flanking ones are CD interray iBrr1; iBrr large and regular; two or four unbranched uniserial arms per ray; IIBr3, rarely IIBr2, axillary in four armed rays.

Remarks. — *Rhaphanocrinus* is most closely allied to *Archaeocrinus* Wachsmuth and Springer [1881, p. 189(363)] and *Neoarchaeocrinus* Strimple and Watkins (1955, p. 348). Rhaphanocrinids exhibit uniserial arms in contrast to the branched biserial arms of archaeocrinids. The neoarchaeocrinid arms are not completely known although the proximal portions are biserial (see *N. pyriformis* illustrated by Wachsmuth and Springer, 1897, p. 255, pl. 10, figs. 3a, b). *Neoarchaeocrinus* possesses strongly erect IBB which can be seen from the side. Those of *Rhaphanocrinus* are usually confined to the basal concavity and cannot be viewed from the side.

Occurrence. — Middle Ordovician; North America and Great Britain. Upper Ordovician; North America.

Rhaphanocrinus simplex, n. sp. Pl. 1, fig. 1

Diagnosis. — A questionable rhaphanocrinid characterized by a conical dorsal cup with slightly rounded sides; IBB confined to BB concavity, not visible from side; moderately well-defined median-ray ridges present; remainder of plates smooth.

Description. — Species only known from holotype, a partial dorsal cup with the C, D, and E rays preserved. Dorsal cup conical with slightly rounded walls and small basal concavity; cup 12 mm high and 14 mm wide. Ornamentation consists of moderately well-defined median-ray ridges which die out below the middle of the RR; distally, the median-ray ridges divide on the IAx and on IIBr2. Dorsal cup plates smooth except for the median-ray ridges.

IBB five, small, pentagonal, much higher than wide, hidden in basal concavity. BB large, hexagonal, 2.6 mm high by 3.1 mm wide, proximal BB margins located in BB concavity. All ray plates wider than high. RR typically pentagonal although the C and D ray RR exhibit six sides, 3.2 mm high and 3.4 mm high. IBr1 always hexagonal, nearly as large as underlying R, 2.8 mm high by 3.2 mm wide. IAx pentagonal or six sided, smaller than iBr1, height and width equal 2.4 and 2.7 mm, respectively. IIBrr1 resting on distal IAx margins, septagonal or with six sides, much smaller than IAx, 1.8 mm high by 2.3 mm wide. Distal most FBrr seen comprise IIBrr2, IIBr2 with five or six sides, probably axillary, 1.5 mm high and 1.9 mm wide. Arm bases not preserved.

Lateral interrays composed of large regular plates which are usually higher than wide. Average plate size decreases distally. The iR is the largest plate, septagonal, 3.6 mm high and 3.4 mm wide; resting on truncated B and between the adjacent RR, iR terminates at the IBr1 mid-level. Two plates in iBrr1 range, each plate with five to seven sides, iBr1 heights and widths are 2.8 mm and 2.6 mm, respectively; iBrr1 end at IAx or the proximal IIBr1 level depending on the shapes of the associated ray plates. Two plates comprise the iBrr2 range, these with five or seven sides, terminating at IIBr1 level. The iBrr3 range composed of three plates which have five or six sides, range ends at IIBr2 or 3 level. Highest range is iBrr4 which bears two hexagonal or septagonal plates.

Inter-half-ray iBrr only represented by one hexagonal plate which is inserted between the IIBrr1 and 2 of a single ray.

CD interray wider and with more plates than in lateral interrays. Primanal hexagonal, largest CD interray plate, height 3.5 mm and width 3.3 mm; primanal rests on truncated CD interray B and between C and D ray RR, reaching RR mid-level; primanal followed by three plates of which the central one is an anal series plate and the two flanking ones are CD interray iBrr1. Preserved portion of anal series consists of three hexagonal plates arranged in a vertical row. CD interray iBrr ranges are composed of one plate each, plates bear from five to seven sides; CD interray iBr1 terminates at IBr1 level; CD interray iBr2 reaches the IIBr1 level. Distal portion of CD interray not preserved.

Column facet located in basal concavity, round with large round axial canal.

Arms, tegmen and column unknown.

Remarks. — This species is based on one specimen, a partial dorsal cup in which the tegmen, arms and stem are not preserved. The cup is broken off at the IIBr2 level. Probably, the IIBrr2 are axillary. If so each IIBr2 supported two arms which would group this crinoid with the four arms per ray *R. sculptus* (Miller) (1882a, p. 37, pl. 1, fig. 2; see Wachsmuth and Springer, 1897, p. 260, pl. 11, fig. 3). Alternatively, an *R. simplex,* n. sp. IIBr2 may have bourne an arm on one side and a large fixed pinnular on the other; this would place this form with rhaphanocrinids showing two arms in each ray. The distal IIBr2 margin is most suggestive of an axillary plate although this cannot be proven with the available material.

Due to the absence of the arms, the assignment of *R. simplex,* n. sp. to *Rhaphanocrinus* is somewhat questionable. However, the dorsal cup shape and plate structure are more similar to *Rhaphanocrinus* than to any other Ordovician "rhodocrinitid" genus and the "Benbolt" crinoid is placed here with little hesitation.

The British *R. basalis* (McCoy) (Ramsbottom, 1961, p. 25, pl. 7, figs. 1-7) exhibits the most similar cup shape. The English species differs in having erect IBB which are visible from the side and at least some specimens possess stellate ridges on the distal dorsal cup plates. The *R. simplex,* n. sp. IBB are confined to the basal concavity and all plates are smooth except for the median-ray ridges. The Chazyan *R. gemmeus* Hudson (1905, p. 280, pl. 2, figs. 1-5, text-fig. 6) shows characteristic plates which bear flat-topped nodes. The depressed suture areas are covered with small ridges oriented at right angles to the plate sutures. *R. sculptus* (Miller) is separated from the "Benbolt" form by the prominent stellate ridges on all calyx plates. *R. subnodosus* (Walcott) (Wachsmuth and Springer, 1897, p. 259, pl. 11, fig. 2) exhibits a wider calyx and column facet in conjunction with stellate ridges and nodes on the proximal cup plates.

Neoarchaeocrinus Strimple and Watkins (1955, p. 348; see illustrations of *N. pyriformis* in Wachsmuth and Springer, 1897, p. 255, pl. 10, figs. 3a, b) is characterized by erect IBB which can be viewed from the side. The *R. simplex,* n. sp. IBB are on the inside of the basal concavity.

The most closely allied *Archaeocrinus* species comprise *A. lacunosus* (E. Billings) (1857, p. 261; E. Billings, 1859, p. 61, pl. 8, figs. 3a-e; Wachsmuth and Springer, 1897, p. 255, pl. 10, fig. 1), and *A. microbasalis* (E. Billings) (1857, p. 264; E. Billings, 1859, p. 63, pl. 6, fig. 2; Wachsmuth and Springer, 1897, p. 256, pl. 10, figs. 2a-c). These forms are easily differentiated by their calyx shapes and ornamentation.

Specific name. — *Simplex* in allusion to the relatively plain and simple ornamentation compared to most allied forms.

Holotype. — MCZ 4165.

Occurrence. — Benbolt Formation or Hogskin Member of Lincolnshire Formation, locality 9c.

CRINOID ROOT

Pl. 9, figs. 1a, b

Remarks. — The most common "Benbolt" rooting device is a relatively heavy cirrus root. Typically the roots are massive irregular-plated structures with about four cirri; a star shaped axial canal is present. No roots were seen attached to calyces. These roots are consistently associated with certain forms, including *Diabolocrinus vesperalis* (White) and *Archaeocrinus peculiaris* Miller and Gurley. C. R. C. Paul (personal communication) has observed such roots near calyces of *Cleiocrinus* sp. This consistency of association implies that the roots belong to these species. If so, these taxa developed the same root form, perhaps in response to the "Benbolt" environment. Possibly many "Benbolt" camerates and maybe some inadunates were also characterized by this root type. This is consistent with the occurrences of calyces and roots although the association frequencies are not diagnostic. The figured specimen was found in a collection with *Diabolocrinus vesperalis* and *Archaeocrinus peculiaris.*

Figured specimen. — USNM 164615.

Occurrence. — Almost all localities.

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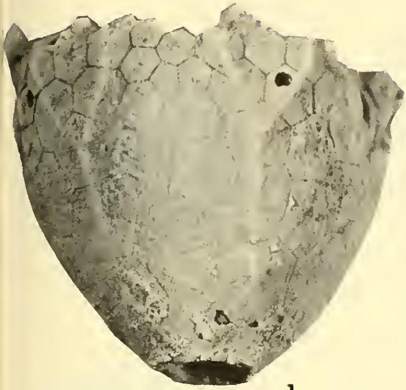

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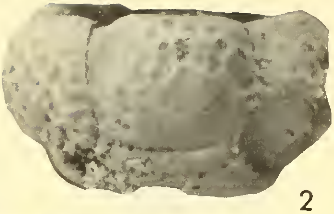

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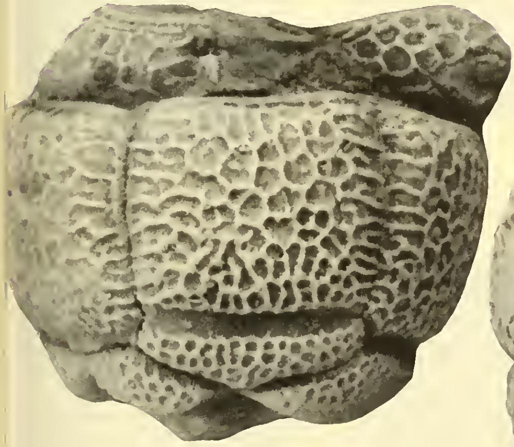

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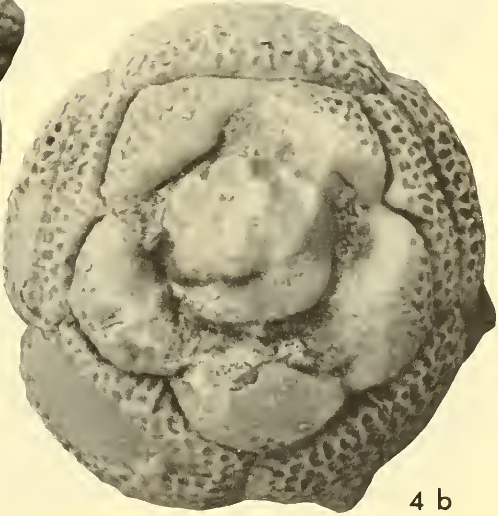

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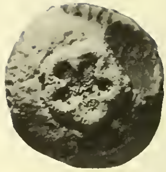
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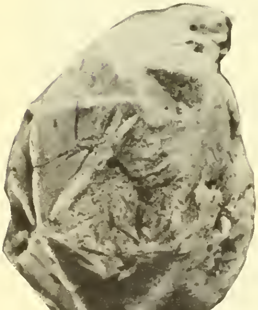
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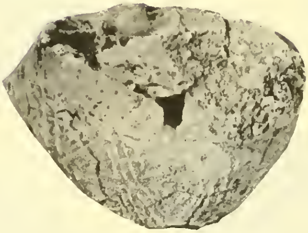
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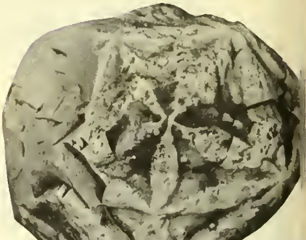
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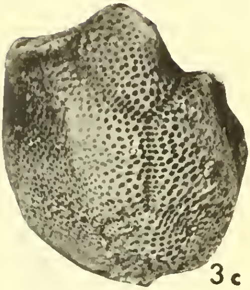

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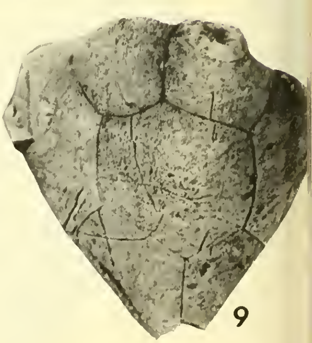

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EXPLANATION OF PLATE 4

Figure		Page
1-9.	**Hybocrinus punctatus** (Miller and Gurley)	30

1. Holotype UC 6125, CD interray of young, note loss of C ray R and anal X, unusually slender calyx with high BB, × 4.2, cup height 6.5 mm, Knoxville area, exact locality unknown.
2. Figured specimen USNM 164110, CD interray of strongly asymmetrical young with slightly weathered ornament, × 5.1, CD interray cup height 7.3 mm, locality 11 or 13.
3. Figured specimen USNM 164111, typical young, note fresh ornament and more symmetrical shape compared to Figure 2, A ray cup height 7.6 mm, C ray height 10 mm, locality 13. a. A ray, × 3. b. E ray, × 3. c. C ray, × 3.6.
4. Figured specimen USNM 164112, partially weathered and highly asymmetrical submature crinoid. A ray height 8.3 mm, C ray height 13 mm, locality 10a. a. A ray, × 2.8. b. B ray, × 3.3.
5. Figured specimen USNM 164113, AE interray of unweathered average-shaped submature cup, × 3, CD interray cup height 12 mm, locality 18.
6. Figured specimen USNM 164114, A ray of weathered submature crinoid, more symmetrical than Figure 5, × 2.2, A ray height 11 mm, locality 10a.
7. Figured specimen USNM 164115, B ray of partially crushed adult with fine ornament, × 2.3, A ray height 16 mm, CD interray height 20 mm, locality 7.
8. Figured specimen USNM 164116, CD interray of adult with fine ornament and typical shape, × 2.4, cup height 16 mm, locality 11.
9. Figured specimen USNM 164117, CD interray of typical weathered adult, × 2.9, A ray height 12 mm, CD interray height 14 mm, locality 7.

EXPLANATION OF PLATE 5

Figure Page

1-3. **Hybocrinus punctatus** (Miller and Gurley) 30

1. Figured specimen USNM 164120, strongly asymmetrical adult, compare weathered surfaces with normal plates, A ray height 12 mm, CD interray height 18 mm, locality unknown. a. CD interray, × 3.1. b. Tegmen, × 3.6. c. B ray, × 3.3. d. A ray, × 2.7.
2. Figured specimen USNM 164118, *H. "recurvus"* of Ulrich, CD interray of weathered crinoid with stem facet nearly parallel to the cup height axis, × 2, CD interray cup height 19 mm, A ray cup height 16 mm, locality 15e.
3. Figured specimen USNM 164119, close-up view of A ray of adult showing typical coarse pitted ornament, note slight asymmetry and slender calyx, × 5.3, CD interray height 16 mm, A ray height 14 mm, locality 1a.

4. **Palaeocrinus avondalensis,** n. sp. 59

Holotype MCZ 603, width 21 mm, height 17 mm, locality 9c. a. C ray, × 2.6. b. D ray, × 2.3.

5. **Palaeocrinus planobasalis,** n. sp. 38

Paratype USNM 164128, close-up views of typical specimen with sharp ridges, some ridges not fully developed and replaced by lines of elongate nodes, weathering has exposed several internal ridge canals, height 12 mm, locality 4e. a. BC interray, × 2.8. b. A ray, × 3.1.


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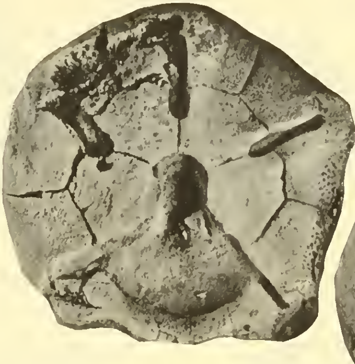
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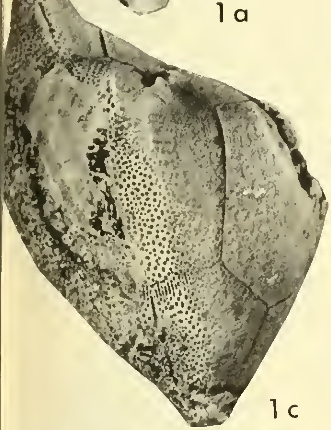
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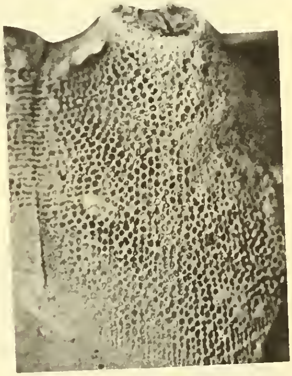
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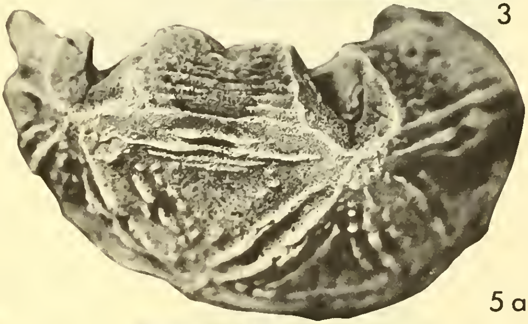
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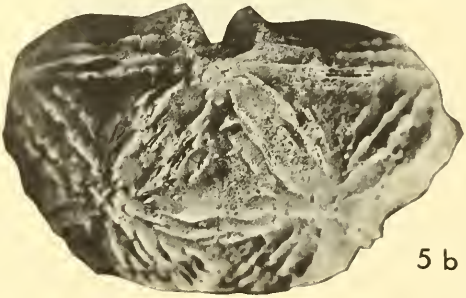
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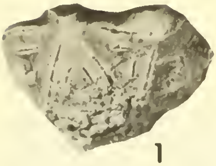

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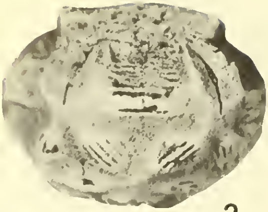

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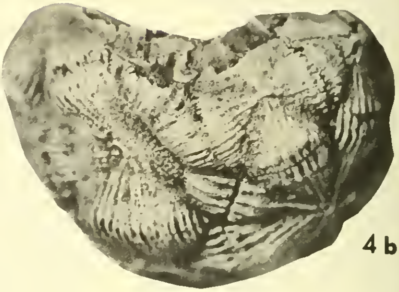

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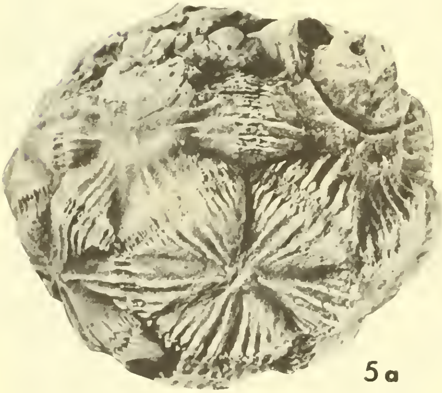

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7

EXPLANATION OF PLATE 6

Figure		Page
1-7.	**Palaeocrinus planobasalis,** n. sp.	38

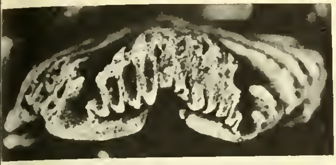
Typical specimens.
1-5. Growth sequence specimens.
1. Paratype USNM 164125, specimen No. 1, lateral ray, × 3.4, cup height 5.5 mm, locality 11.
2. Paratype USNM 164126, specimen No. 2, lateral ray, × 3.8, cup height 6 mm, locality 13.
3. Paratype S 5421, specimen No. 3, lateral ray, × 4, cup height 7.5 mm, locality 13.
4. Paratype S 5420, specimen No. 4, X 3.1, cup height 11.5 mm, locality 14. a. A ray. b. CD interray.
5. Holotype USNM 97465, specimen No. 5, × 2.8, cup height 16.5 mm, locality 4e. a. BC interray. b. Tegmen.
6. Paratype USNM 97465, basal view with relatively sharp ridges, × 2.7, maximum diameter 19 mm, locality 4e.
7. Paratype S 5422, tegmen with mouth in center and anus in lower right, the small opening between the mouth and anus is probably the hydropore, × 4.5, diameter 10 mm, locality 7 or 9a.

EXPLANATION OF PLATE 7

Figure Page

1-4. **Palaeocrinus planobasalis,** n. sp. 38

1. Paratype USNM 164129, isolated R of typical specimen, 8.8 mm wide, locality 9c. a. Edge, × 5.6. b. Interior, × 4.5. c. Exterior, × 4.5.
2. Paratype USNM 164127, isolated B of typical specimen, 7.6 mm wide, locality 9c. a. Edge, × 6.2. b. Another edge, × 6.2. c. Interior, × 6. d. Exterior, × 6.
3. Paratype USNM 97465, isolated B of typical specimen, 15 mm wide, locality 4e. a. Edge, × 4.5. b. Exterior, × 4. c. Interior, × 4.
4. Figured specimen USNM 164131, dorsal cup of "variant" crinoid, CD interray, × 3, cup height 10.5 mm, locality 16.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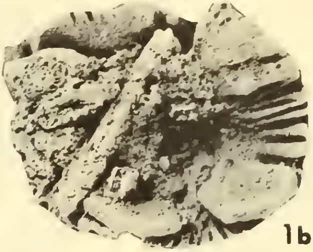
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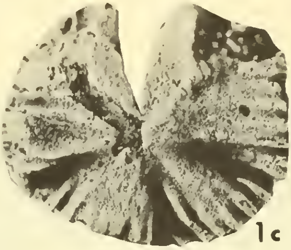
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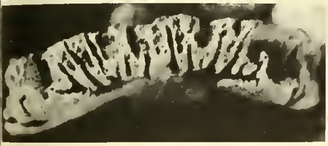
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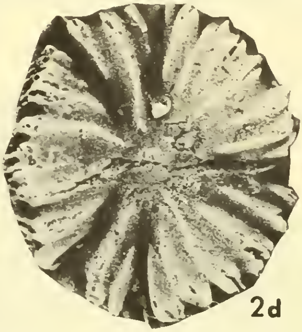
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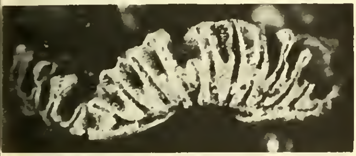
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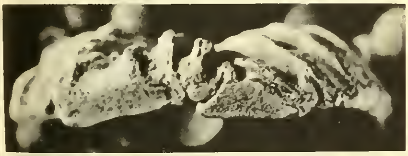
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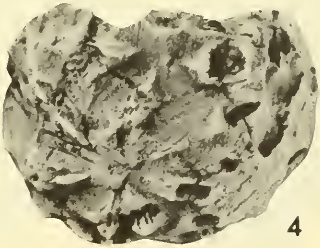
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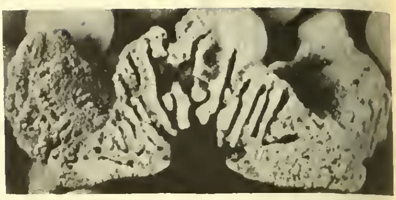

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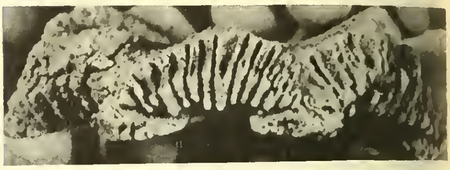

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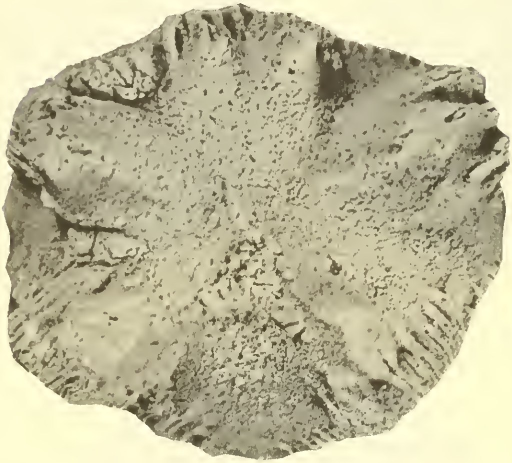

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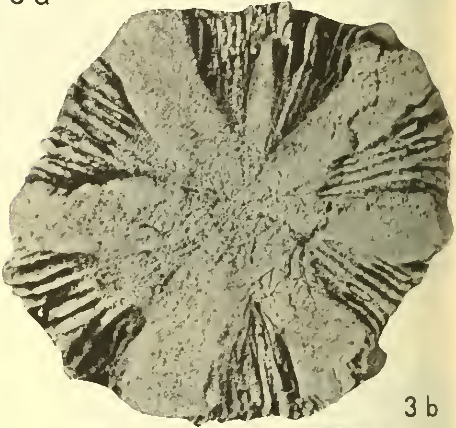

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4 b

EXPLANATION OF PLATE 8

Figure		Page
1-4.	**Palaeocrinus planobasalis,** n. sp.	38

"Variant" specimens.

1. Figured specimen MCZ 4163d, isolated B, 7.6 mm wide, ridge bundle width 2.5 mm, locality 2b. a. Edge, × 9. b. Exterior, × 8.
2. Figured specimen MCZ 4163b, edge of isolated B, × 7.6, ridge bundle width about 5.8 mm, locality 2b.
3. Figured specimen MCZ 4163c, isolated B, maximum width 9.7 mm, ridge bundle width 4.7 mm, locality 2b. a. Edge, × 7. b. Exterior, × 6.3.
4. Figured specimen MCZ 4162, crushed dorsal cup showing transitional ornament between extreme "variants", such as MCZ 4163, and typical specimens illustrated on the previous three plates, × 4.3, maximum height 17.5 mm, locality 2b. a. RR view, note comparatively long and well-defined external ridges. b. Opposite side showing column facet, IBB, BB and RA, the external ridges are shorter and less well defined than on the RR.

Explanation of Plate 9

Figure Page

1. "Benbolt" crinoid cirrus root **102**

Figured specimen USNM 164615, base of column showing cirrus roots and axial canal, column diameter 7.0 mm, locality 15a. a. Lateral view, × 2.7. b. Axial canal, × 4.6.

2-8. **Archaeocrinus peculiaris** (Miller and Gurley) 67

2. Figured specimen S 5436, cup with two plates following primanal, cup height 23 mm, locality 15c. a. C ray, × 1.1. b. Base showing IBB, × 1.4.
3. Figured specimen S 5437, CD interray with three plates above the primanal, × 1.3, cup height 20 mm, locality 15c.
4. Figured specimen S 5438, animal with relatively coarse ornament and primanal plus three plates, cup height 17 mm, locality 15c. a. C ray, × 1.8. b. CD interray, × 1.6.
5. Figured specimen S 5439, oblique B ray view of individual with comparatively fine ornament, × 1.2, cup height 28 mm, locality 15c.
6. Figured specimen S 5440, basal view, × 1.8, cup width 26 mm, locality 15c.
7. Holotype UC 6037, lateral view of animal with heavy surface sculpture, × 1.7, cup height 22 mm, Knoxville area, exact locality unknown.
8. Figured specimen USNM 164616, pinnulate arm fragments of this type are consistently associated with this form, × 1.9, length 25 mm, locality 11.


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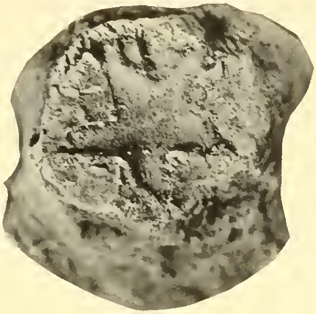
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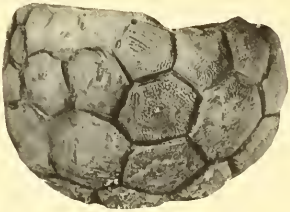
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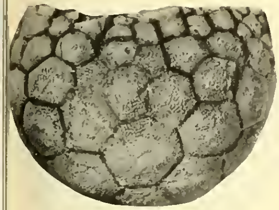
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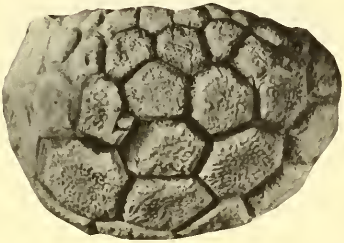
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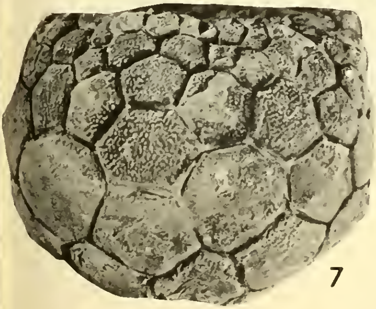
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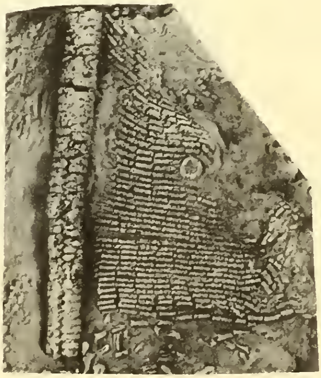
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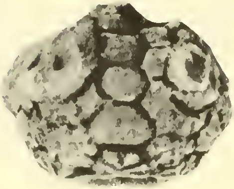

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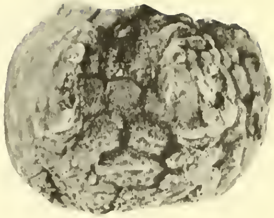

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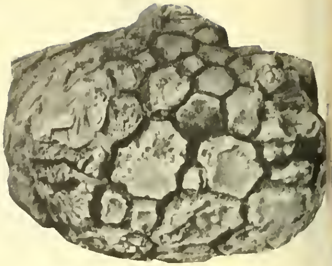

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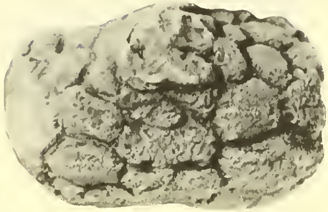

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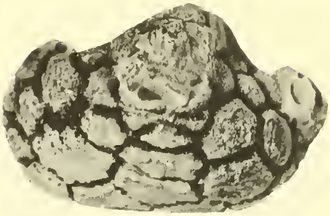

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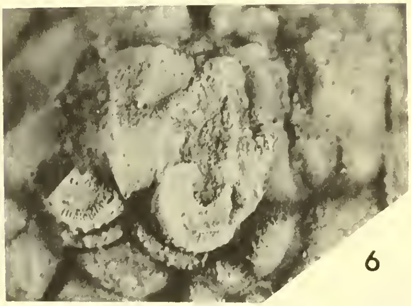

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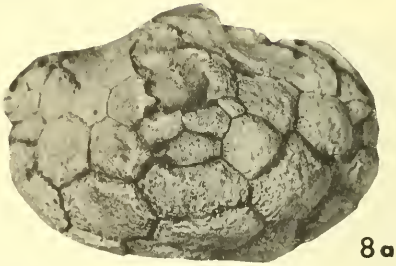

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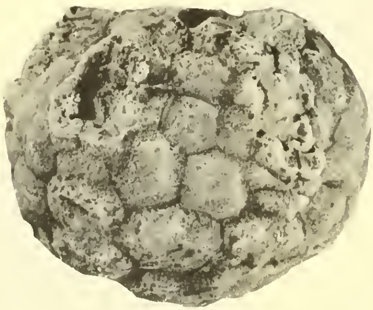

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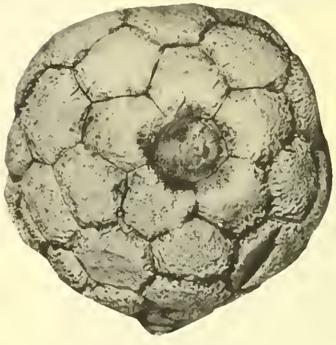


8b

EXPLANATION OF PLATE 10

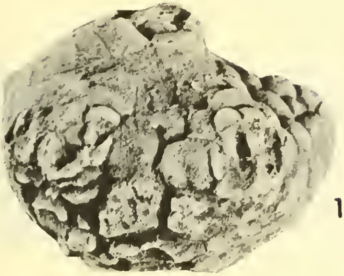
Figure		Page
1-8.	**Diabolocrinus vesperalis** (White)	71

1. Syntype of *Archaeocrinus parvus* Miller and Gurley, UC 6039, lateral interray with no supplementary plates, stellate ridges on proximal plates, finely granular plate surfaces, × 3, cup height 5.5 mm, Knoxville area, exact locality unknown.
2. Holotype of *D. vesperalis* (White), USNM 8032, lateral interray of calyx lacking supplementary plates, ornament of incised plate sutures and swollen plates covered with wrinkles and sinuous ridges, × 2.2, cup height 8.4 mm, probably locality 15a.
3. Figured specimen S 5441, CD interray, two supplementary plates on left of primanal, one above primanal, depressed plate sutures, flat plate surfaces covered with irregular nodes and sinuous ridges, × 1.8, cup height 12.5 mm, locality 15c.
4. Figured specimen S 5442, with no supplementary plates, incised plate sutures covered with small nodes, granules, and sinuous ridges, × 2.2, cup height 9.1 mm, locality 15c. a. B ray. b. C ray.
5. Syntype of *Gilbertsocrinus americanus* Troost, USNM 39970, lateral interray bearing two supplementary plates, one on each side of iR, nodose plates with granules and fine sinuous ridges, × 1.7, cup height 13 mm, probably locality 15c.
6. Figured specimen S 5443, close-up view of arm facet showing concave surface with crenulated margins, note large fixed pinnular Amb tract on interray side of right half-ray, × 5.4, cup height 8.3 mm, locality 15c.
7. Plesiotype of *D. vesperalis* (White) figured by Wachsmuth and Springer (1897), S 88, lateral interray of animal lacking supplementary plates, convex plates with incised sutures, proximal plates with weak stellate ridges, some plates have small sinuous ridges, × 2.5, cup height 13 mm, locality 15c.
8. Figured specimen S 5444, supplementary plates absent, incised plate sutures with flat or somewhat convex plates, heavy granules and small sinuous ridges present, × 1.8, cup height 11 mm, locality 15c. a. D ray. b. Base.

EXPLANATION OF PLATE 11

Figure		Page
1-8.	**Diabolocrinus vesperalis** (White)	71

1. *Archaeocrinus sculptus* Wachsmuth and Springer, holotype of *Lyriocrinus sculptilis* Miller, UC 6285, lateral interray with no supplementary plates, convex plates covered with fine granules or heavy sinuous ridges, × 2.5, cup height 7.2 mm, Knoxville area, exact locality unknown.
2. Figured specimen USNM 164617, lateral interray, calyx lacks supplementary plates, plate sutures deeply incised, plates flat or convex with heavy sinuous ridges and finer granules, traces of median-ray and stellate ridges on proximal plates, × 3.6, cup height 6.7 mm, locality 11.
3. Snytype *D. hieroglyphicus* Wachsmuth and Springer, S 90, lateral ray of cup, supplementary plates absent, proximal stellate ridges grade into distal median-ray ridges, many sinuous ridges on unweathered plates, cup height 12 mm, × 2.2, locality 15c.
4. Figured specimen USNM 164618, most interrays with four to six supplementary plates, cup plates highly convex, granular, often with one or more central nodes, sometimes with marginal sinuous ridges, cup height 8.6 mm, locality 15c. a. C ray, × 2. b. B ray, × 2.4.
5. Figured specimen USNM 164619, lateral ray of relatively flat calyx with highly nodose plates, proximal part of cup with heavy median-ray and stellate ridges, × 2, cup height 13 mm, locality 15c.
6. Syntype *Archaeocrinus asperatus* Miller and Gurley, UC 6038, lateral interray with no supplementary plates, plates convex, covered with irregular wrinkles, the crinoid is "atypical" because it does not agree with Miller and Gurley's description of the "species", × 1.8, cup height 12 mm, Knoxville area, exact locality unknown.
7. Figured specimen USNM 164620, lateral interray with four supplementary plates, two on each side of iR, plates convex, usually with prominent nodes, plate surfaces granular, some margins bear small sinuous ridges, × 2.6, cup height 7.8 mm, mm, locality 15a.
8. Holotype of *Archaeocrinus knoxensis* Miller and Gurley, UC 6035, lateral interray, one supplementary plate on left side of iR, two supplementaries on right of iR, plates convex, nodose with granules and some sinuous ridges, × 2.1, cup height 11 mm, Knoxville area, exact locality unknown.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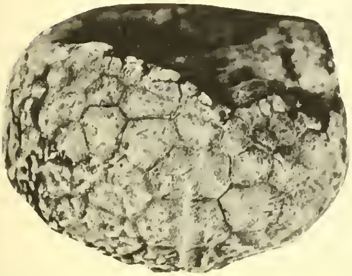
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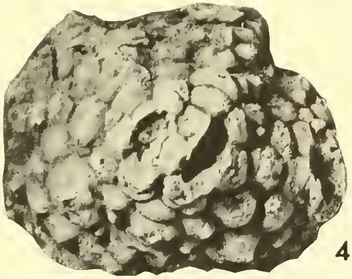
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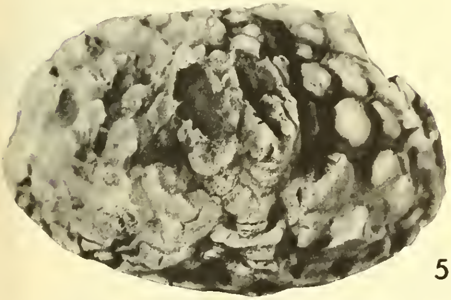
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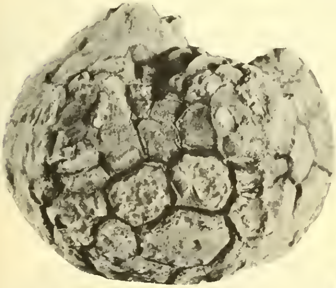
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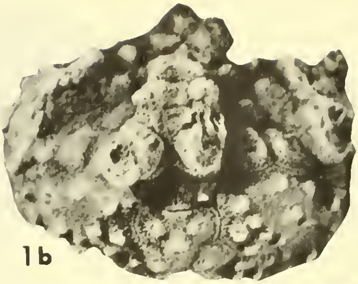
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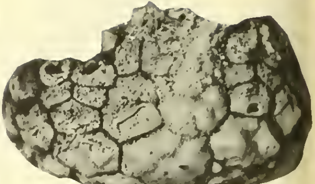
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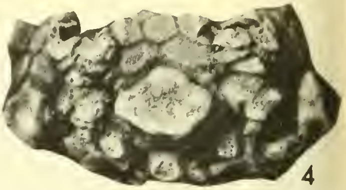
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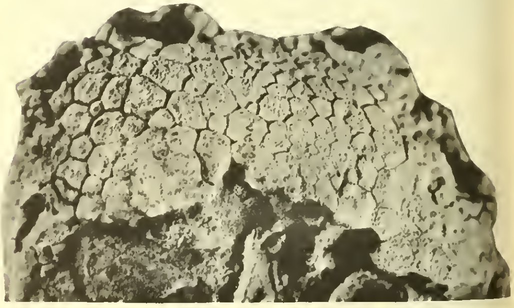
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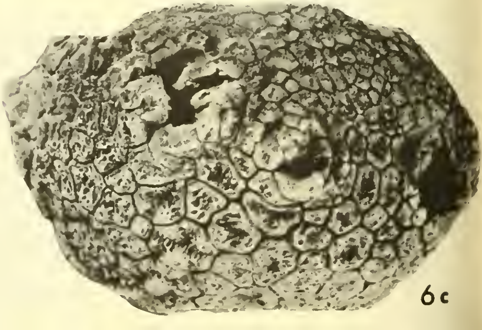
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EXPLANATION OF PLATE 12

Figure		Page
1-5.	**Diabolocrinus vesperalis** (White)	71

1. Figured specimen USNM 164621, small, no supplementary plates and numerous small nodes, cup height 5.2 mm, locality 13. a. Oblique view of arm base, × 3.3. b. Lateral ray, × 4.2.
2. Figured specimen USNM 164622, lateral interray, small supplementary plate on right side of iR and swollen plates covered with irregular, low nodes, × 2.6, cup height 9.4 mm, locality 13.
3. Holotype *D. perplexus* Wachsmuth and Springer, S 89, lateral interray of adult with four supplementary plates, two on each side of iR, plates nodose, highly convex, plate surfaces granular or with a few marginal sinuous ridges, × 2.3, cup height 8.0 mm, locality 15c.
4. Figured specimen USNM 164623, lateral interray of crushed cup with four or five supplementary plates surrounding the iR, plate sutures incised, most plates bear a single large node, fine granules and/or sinuous ridges also present, × 3, cup height 7.6 mm, locality 11.
5. Figured specimen USNM 164624, arm fragment probably belonging to crushed calyx of this species, × 5.7, maximum width of arm and pinnules 7 mm, locality 15a.

6. **Paradiabolocrinus sinuorugosus,** n. gen., n. sp. 95

Holotype, figured by Butts as *Diabolocrinus asperatus?*, USNM 97463, cup height 19 mm, 28 mm wide at arm bases, locality 4a. a. Portion of tegmen, × 2.7. b. Base, × 1.8. c. Lateral ray, × 1.8.

EXPLANATION OF PLATE 13

Figure		Page
1.	**Diabolocrinus,** n. sp. Figured specimen USNM 164625, DE interray, × 1.8, cup height 18 mm, locality 18.	91
2.	**Wilsonicrinus culmensinuosus,** n. sp. Holotype USNM 164626, × 2.4, cup height 10 mm, cup diameter 20 mm, locality 11. a. B ray. b. Base.	97
3.	**Paradiabolocrinus irregularis,** n. gen., n. sp. Holotype USNM 164627, cup height 23 mm, cup diameter 40 mm, locality 13. a. D ray, × 1.5. b. Base, × 2.0. c. Tegmen, × 1.8.	94
4.	**Pararchaeocrinus convexus,** n. sp. Holotype USNM 164628, C ray, × 1.8, cup height 20 mm, locality 8a.	70


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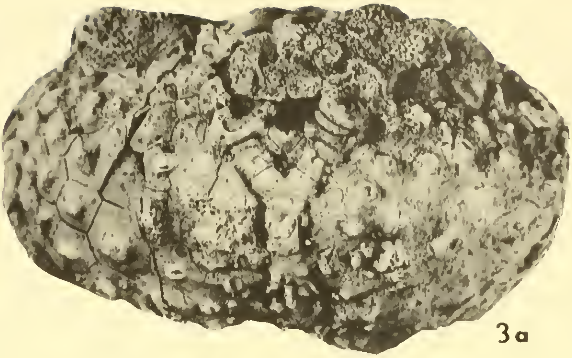
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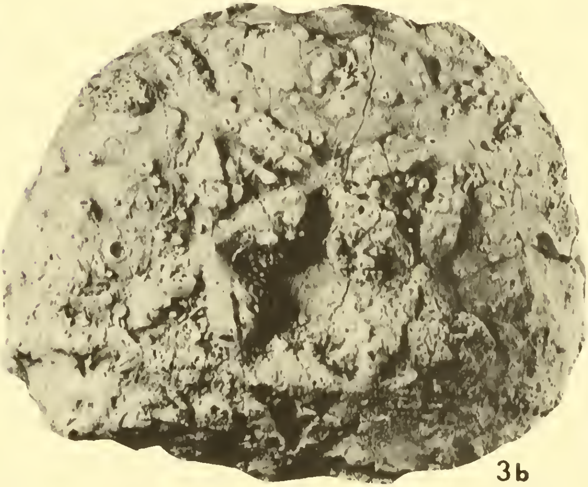
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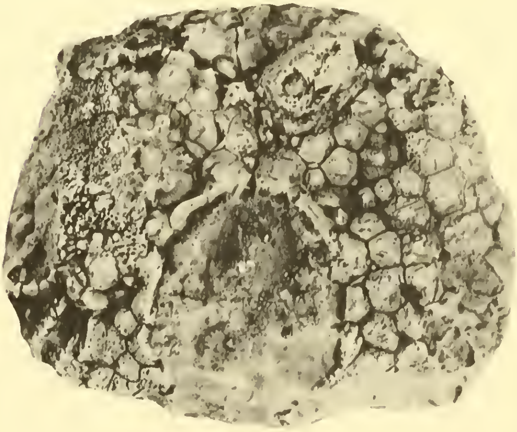
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By

J. Mark Erickson

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REVISION OF THE GASTROPODA OF THE FOX HILLS FORMATION, UPPER CRETACEOUS (MAESTRICHTIAN) OF NORTH DAKOTA

J. Mark Erickson

ABSTRACT

Nearly one hundred years have passed since F. B. Meek completed his monumental studies of invertebrate fossils in the Upper Cretaceous rocks of the Nebraska and Dakota Territories. The desire to examine molluscan distributions of the Western Interior in new ways has prompted a need for revision of the molluscan taxonomy and faunal lists of the "upper Missouri country."

The Fox Hills Formation (Maestrichtian) of North Dakota and South Dakota, a complex of nearshore and littoral, delta platform and lagoonal sandstones, siltstones, and clays, contains a moderately large molluscan faunal record of the closing marine event of the Mesozoic Era in that region. By the end of his career Meek had described approximately 25 gastropod species from the formation, only four of which were definitely taken from localities in North Dakota. The Bivalvia having been revised earlier by Feldmann, this revision updates the taxonomy and distribution of the gastropods of the Fox Hill Formation in North Dakota.

As described herein the fauna contains 37 species. These represent 24 genera in 18 families distributed among four orders and two subclasses of the Gastropoda. Five species, *Neritina loganensis,* n. sp.; *Piestochilus feldmanni,* n. sp.; *Hercorhyncus (Haplovoluta) hollandi,* n. sp.; *Remera? cvancarai,* n. sp.; and *Cancellaria siouxensis,* n. sp. are described. Eleven species in a like number of genera are newly reported from the Fox Hills Formation. *Goniocylichna bisculpturata* Wade and *Euspira rectilabrum* (Conrad) occur in common with the fauna of the Ripley Formation of the Mississippi Embayment, with which the Fox Hills Formation has its closest compositional affinity.

Paleogeographic distributions of Fox Hills genera clearly indicate that North Dakota was a region of overlap of Tethyan migrants (for discussion of Tethys see particularly Sylvester-Bradley *in* Adams and Ager, 1967) from the Gulf Coast region and a less prominent "boreal" or northern Pacific stock emigrating from the north and northwest. Southern genera show a reduction of ornamentation reflecting cooler conditions than those in the Tethyan Realm. True endemism, formerly considered predominant in the Fox Hills fauna, is actually not great, but was, and is, a manifestation of our still incomplete knowledge of distributions and stratigraphic occurrences of Gastropoda in the Cretaceous of the Western Interior.

Observations regarding stratigraphy and sedimentation of the formation indicate that major storms swept the midcontinental seas during the late Cretaceous and were responsible for several major sediment accumulations within the formation. In addition an as yet unnamed member was recognized high in the section. As a blanket sandstone it seems to owe its depositional origin to subsidence of the deltaic platform and resulting re-transgression of the generally regressive Fox Hills sea.

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the U.S. Geological Survey and the U.S. National Museum were examined through the courtesy of Norman F. Sohl and Frederick Collier. The latter also arranged for loan of Meek's types figured herein. The F. D. Hollands were gracious hosts during my visits to Washington. Bibliographic compilation was made easier and library loans were acquired more rapidly due to the professional library skills of Mary W. Scott and Helen Sweeney.

Conversations and discussions with F. D. Holland, Jr., Alan M. Cvancara, and Normal F. Sohl have greatly aided in development of the present work. They, along with E. A. Noble, J. K. Neel, and R. G. Fisher critically reviewed an early version of the manuscript. The final version benefited from examinations and suggestions by F. D. Holland, Jr., and Normal F. Sohl, and the editorial guidance of Katherine Van Winkle Palmer. All of their efforts in my behalf cannot be overstated. Lorraine Rose deserves my thanks for her skillful typing of the original manuscript.

Finally, I am pleased to acknowledge all my friends and associates from whom I learned so much during my stay in North Dakota. Nothing, however, would have been possible without the constant encouragement of my parents whose faith in the eventual outcome was a great strength.

INTRODUCTION

As this manuscript was written, it was 95 years ago that F. V. Hayden transmitted, on June 1, 1876, to the Secretary of the Interior a memoir by F. B. Meek entitled "A Report on the Invertebrate Cretaceous and Tertiary Fossils of the Upper Missouri Country" with the following statement:

> To the geologist who may hereafter study the various groups of sedimentary strata over our widely-extended western domain, this volume will prove indispensible. The different divisions or groups of the Cretaceous and Tertiary ages, especially of the former, were originally established by the invertebrate remains herein described, and it therefore forms the basis of our knowledge of two of the most important formations of the West (Meek, 1876, p. III).

The content of the gastropod fauna of the Fox Hills Formation (Maestrichtian) of the "Upper Missouri Country" has grown by the addition of only one species since that time, nearly a century ago. Only recently (Feldmann, 1967; Speden, 1970) has the bivalve fauna of the Fox Hills been reexamined and modernized. The Cephalopoda have not been restudied.

If ever a work could be said to have inhibited research in a particular discipline, surely Meek's monograph did. The fault, however, was not in any error in truth, but rather in its greatness — its utter completeness. Geology continued in the Dakotas but much of it was mineral exploration, and that was primarily in strata younger than the Fox Hills.

Thus it is that questions have begun to arise regarding Western Interior molluscan faunas which cannot be answered with the antiquated taxonomic and distributional data bequeathed to us by the paleontological giants of the nineteenth century. The questions pertain to faunal composition, diversity, ecology, and origin. They cannot be resolved without first modernizing the taxonomy. Consider with these data the fact that the gastropod fauna of the Fox Hills Formation in North Dakota never has been considered in any detail (only four of Meek's species probably were collected in North Dakota) and the problem becomes plain — to redescribe the Fox Hills gastropod fauna according to modern concepts of the Class.

The research presented herein is a contribution toward this modernization of Fox Hills gastropod taxonomy and of their distribution in North Dakota.

The Fox Hills Formation is a stratigraphic unit in the Upper Cretaceous section of North Dakota and South Dakota. The type area along the Moreau River and Grand River in north-central South Dakota has been studied in detail by Waage, who, in 1968, described 274 localities throughout that portion of the state. Most of these represent erosional exposures in badlands topography in which outcrops are extensive and units are readily traced.

Northward from the type area, along the Missouri River drainage into North Dakota, vegetational cover increases with a consequent decrease in badlands topography and its extensive outcrop area. Nevertheless, in southern Morton, Logan, Emmons, and Sioux counties, North Dakota, there are numerous scattered exposures representing various members of this formation (Text-figure 1). This is the major area of Fox Hills outcrop in the state.

During his study of the bivalve fauna, Feldmann (1967, p. 2) visited ". . . virtually every known outcrop of that unit in the state." The majority of Feldmann's outcrops were in the area of the counties mentioned, although he examined other portions of the state as well.

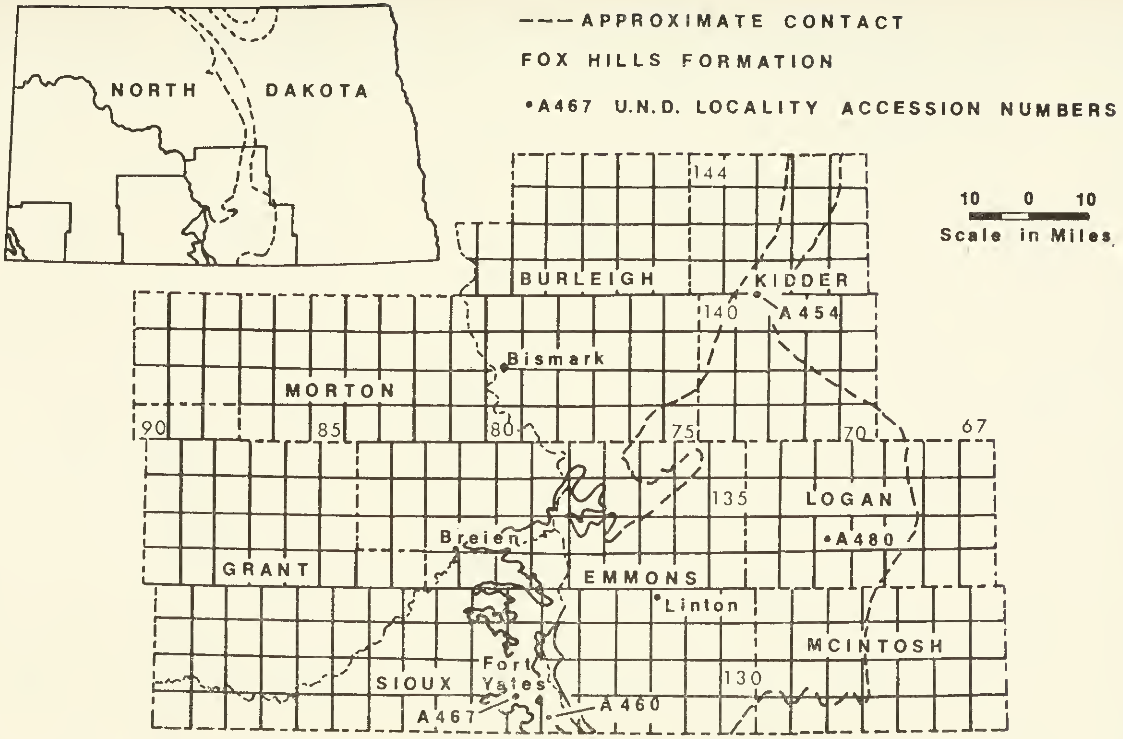
This work, being a parallel to that of Feldmann, was also concentrated in these areas of major Fox Hills outcrop. I re-examined most of his locateable outcrops, particularly those which had produced fossil gastropods during Feldmann's collecting. In addition, several very fossiliferous outcrops were newly discovered. This, in a few instances, was due to filling of Oahe Reservoir which brought about road construction and some slumping of the shoreline, both activities yielding fresh exposures. The same rising water also covered some very promising and some proven fossil localities which will never again be collected, an irreparable loss of historical record.

Northward from the area of major outcrop across the central part of North Dakota, the formation is principally a subcrop beneath Tertiary strata or Pleistocene and Holocene surficial deposits. It is occasionally documented on drillers logs, and an infrequent typical Fox Hills concretion is reported from glacial deposits, thus documenting the existence of the formation in glaciated areas. The approximate map boundaries of the formation in North Dakota as given by Carlson (1969) are presented in Text-figure 1. A complete list of collecting localities that have yielded gastropods for this study is given later in this report.

PREVIOUS WORK

Notes and research on rocks now considered part of the Fox Hills Formation have been accumulating since the explorations of Lewis and Clark more than a century and a half ago. Recounting these investigations would not be a difficult task but would in essence be paraphrasing similar accounts of several recent workers. Rather than do this I take pleasure in referring to the complete and absorbing historical summary presented by Feldmann in 1967 (pp. 5-25).

Rather than presenting this extensive account I instead summarize those major early works that are critical to our paleonto-



Text-figure 1. — Index and locality maps with detail of principal area of investigation for this study.

logical and stratigraphical understanding of the formation at present, and give a detailed account of the score, or so, of related publications that have appeared in the literature since Feldmann's research was culminated. Additional, older references will be cited in the sections of this study to which they pertain.

The occurrence of the Fox Hills Formation was first quantitatively defined in the scientific literature as the result of explorations by Dr. Fielding Bradford Meek and Dr. Frederick Vaniveer Hayden at the direction of James Hall, State Geologist of New York. In 1853 Hall sent Meek and Hayden into the upper Missouri country principally to collect vertebrate fossils from the Cretaceous and Tertiary strata of the area. These explorers noted the stratigraphy and invertebrate fossils in addition to making vertebrate collections. The first stratigraphic sections of the marine Upper Cretaceous rocks of North Dakota and South Dakota were published as a result of these explorations (Hall and Meek, 1856) and revised later (Meek and Hayden, 1857). Rocks of the Fox Hills Formation were termed unit "No. 5" of the series in these studies. These units were further refined and named by Meek and Hayden in 1861.

During the 1850's and early 1860's a series of publications by the above named workers described a large portion of the invertebrate fauna of the Pierre Formation and Fox Hills Formation. Evans and Shumard (1854, 1857) and Morton (1841, 1842) also contributed to studies of this large fauna, but the works of Meek and Hayden were fundamental. They were summarized by Meek's monographic volume on invertebrate Cretaceous and Tertiary fossils of the "Upper Missouri Country" in 1876. White (1876, 1879a, b, 1883a) and later Stanton (1893, 1910, 1914, 1921) studied fossils in this and related areas but their works were generally peripheral to those of Meek and Hayden in the type area of the formation.

Most major stratigraphic contributions were made after the turn of the century when the extent of Fox Hills-like deposits in Montana, Wyoming, and Colorado was realized. Leonard (1904, 1906, 1908) discussed stratigraphy of the formation in North Dakota, but no major divisions were made. Stanton (1910) gave information on regional extent and the upper contact of the formation as related to the "Lance" problem.

The first geologic maps of the major Fox Hills outcrop area in North Dakota were published by Leonard (1912) and Calvert, *et al.* (1914). An earlier publication by Calvert (1912) was the first to describe rocks of the Colgate Member and to apply that name to them. His work was done on the Cedar Creek Anticline and areas in Montana where he felt the units to be Tertiary rather than Cretaceous as we now know them.

Henderson in 1920(b) designated 100 to 150 feet of massive concretionary sandstone found in the base of the formation at Milliken Station in Weld County, Colorado, as the Milliken Member. His study was thorough and included a listing of invertebrate fossils as well. The unit he described, however, does not persist into South Dakota or North Dakota. No other major stratigraphic contributions were published from that time until 1945 when Morgan and Petsch proposed the terms Trail City and Timber Lake, after areas in South Dakota, for members of the formation. Fisher (1952) first used them in North Dakota when he mapped the geology of Emmons County.

The last member to be defined in the literature prior to 1960 was the Bullhead Member, formerly referred to as the "banded beds." These are thin-bedded, brown and gray silts and clays which were first mapped as "Bullhead" by Stevenson in 1956 when he produced the geologic map of the Bullhead Quadrangle in South Dakota.

This rapid summary of these works that had a major affect upon our present concept of the Fox Hills brings us to the 1960's when a flourish of new research in Fox Hills and related rocks of the northern Western Interior was begun. At the time Feldmann began work on the Bivalvia of the Fox Hills Formation in North Dakota, Waage and his students were carrying out an extensive examination of all aspects of the formation in its type area along the Moreau River in South Dakota. They eventually expanded the study to include most of the Fox Hills exposures in that state.

Waage first summarized his work in 1961 when he described general stratigraphy, paleoecology, and several assemblage zones based on molluscan accumulations in concretions. These accumulations were attributed to mass mortality of an unknown cause in quiet marine conditions. He considered these molluscan zones and the occurrence of concretions in more detail in 1964. A particular coleoid cephalopod, *Actinosepia canadensis* Whiteaves, was discussed in 1965.

In North Dakota, Feldmann (1964) published a preliminary description of the upper portion of the formation as it occurs in the region of Sibley Buttes, Kidder County, North Dakota. This was accompanied by a brief but fairly complete faunal list for the units exposed there. Later (1966) he summarized the geology of the Fox Hills Formation in Emmons County, North Dakota, in the light of Waage's work. Feldmann supported the earlier suggestion of Fisher (1952) that there should be a two-fold division of the formation in Emmons County because the Timber Lake and Trail City members become more and more similar to each other northward from their type localities, until they are frequently difficult to recognize in eastern Emmons County.

Relationships between the interfingering Fox Hills Formation and Hell Creek Formation were clarified in a paper by Frye (1964) who described marine tongues in the Hell Creek Formation. The lowest of these he termed the Breien Member for its exposures near Breien in Morton County, North Dakota. Frye later (1969) gave a complete account of Hell Creek stratigraphy in North Dakota.

In 1967 Waage again presented a synthesis of his faunal and stratigraphic studies as they related to the closing phases of the Cretaceous seaway in the Western Interior. Some of his conclusions regarding littoral and deltaic facies overlap those of Pettyjohn (1967). In the same year Pettyjohn described the Fairpoint Member and White Owl Creek Member. The former is a shale, silt, and sand squence 280 feet thick containing the "Stoneville coal facies," formerly termed a member, of Searight (1934). It is overlain by the White Owl Creek Member, 195 feet of silt, crossbedded sand and sandstone, and purple clay-shale which in turn is overlain by the Tertiary White River Group.

A major revision of Fox Hills stratigraphic nomenclature was proposed by Waage in 1968. He recognized the Trail City Member containing the Irish Creek lithofacies and the Little Eagle lithofacies; the Timber Lake Member containing a *Cucullaea* and a *Cymbophora-Tellina* assemblage zone, a *Tancredia-Ophimorpha* biofacies, and a Rock Creek lithofacies of restricted extent; and the Iron Lightning Member containing the Bullhead lithofacies and Colgate lithofacies (formerly members). He (p. 42) was not certain of the relationships of these units with Pettyjohn's Fairpoint Member and White Owl Creek Member which were described about 100 miles from the type area. Earlier, Black (1964) had discussed a change from typical marine facies to continental facies westward from the type area of the formation in the Bridger area of Haakon County. Black's brief conclusions were not discussed by Waage in 1968, nor were Feldmann's (1964, 1966) stratigraphic presentations considered.

Feldmann completed his revisions of the Fox Hills bivalve fauna and paleoecology in North Dakota in 1967 when he described a fauna of 42 species of bivalves. This fauna and the geology of the formation are discussed in Feldmann's (1972) synthesis. Speden (1970) completed a parallel study in South Dakota which included 58 species of bivalves and a revision of Waage's (1968) zonation terminology in view of systematic nomenclatorial changes. Feldmann's (1967) bivalve study led to his description of Fox Hills paleoecology of south-central North Dakota in 1968(b).

In addition to these major revisions there have been several recent works that, together, may influence stratigraphic and paleoecologic work yet to be done. These include Feldmann (1968a), Holland and Feldmann (1967), and Mello (1969).

More generally, Levington in 1970 considered the possibility that mollusk assemblages in the Fox Hills Formation might be the result of invasions of "opportunistic" species onto the shelf area of Fox Hills deposition. Hall (1967) and Norton and Hall (1967, 1969) made a comprehensive treatment of Cretaceous-Tertiary floras in eastern Montana. Their studies dealt with Bearpaw, Fox Hills, Hell Creek, Tullock and Lebo strata. New species of spores were described from the Colgate Member of the Fox Hills Formation (Hall, 1967), and the stratigraphic significance of the floras was outlined.

Stratigraphic and facies relationships of the formation were included in Weimer's (1965) synopsis of the stratigraphy and petroleum occurrences in the Almond Formation and Lewis Formations of Wyoming. Most recently Land (1972) interpreted the Fox

Hills Formation in the area of the Rock Springs Uplift of Wyoming as a shoreline-estuarine sequence, and Feldmann (1972) described the general stratigraphy and paleoecology of the formation in North Dakota.

Yet more remote, but pertinent to this study are two papers by Sohl. In 1967(a) he described a gastropod fauna from the Red Bird section of the Pierre Shale in Wyoming. Again in 1967(b) he gave an outline of the usefulness of gastropods for interpreting Upper Cretaceous paleogeography and faunal realms. He reiterated his strong belief in their utility in 1968 and again in 1969.

Jeletzky (1969) outlined a history of Cretaceous marine biotic provinces for western and northern Canada. He concluded the Canadian Cretaceous molluscan faunas indicated existence of two principal biotic provinces, a "North Pacific" province and a "Boreal Cretaceous" province (p. 890), the latter dominated by relatively few species compared with the former which had a Tethyan influence.

STRATIGRAPHY

The Fox Hills Formation in North Dakota is a series of marine and estuarine siltstones, sandstones, and clays representing the final deposition in the Maestrichtian sea within the Williston Basin. The lower contact with the Pierre Shale is gradational over a few to several feet in North Dakota and South Dakota (Meek and Hayden, 1861, p. 427; Feldmann, 1967; Waage, 1968, pp. 57, 58) and is generally marked by concentrations of jarosite. In North Dakota it can best be seen at locality A469 of this report where both the gradational increase in coarser clastics and the accumulations of jarosite are readily apparent.

The upper contact, that with the paleogeographically landward facies of the Hell Creek Formation, is less easy to document and is considerably more variable. The Hell Creek strata are mainly terrestrial, deltaic stream, swamp, and occasionally brackish, lagoonal marine deposits (Frye, 1969). This type of advancing deltaic complex overlapping a regressive marine lithofacies association of offshore silts, littoral and sublittoral beaches and bars, and back-beach, lagoon and estuarine muds and channel sands can produce more than 20 possible stratigraphic sequences between which the Fox

Hills-Hell Creek contact may be placed. Slight erosion of Fox Hills strata prior to Hell Creek deposition, a likely possibility in some areas, could increase this number. In view of this, it is no wonder that definitions have been troublesome and generally were only of local value.

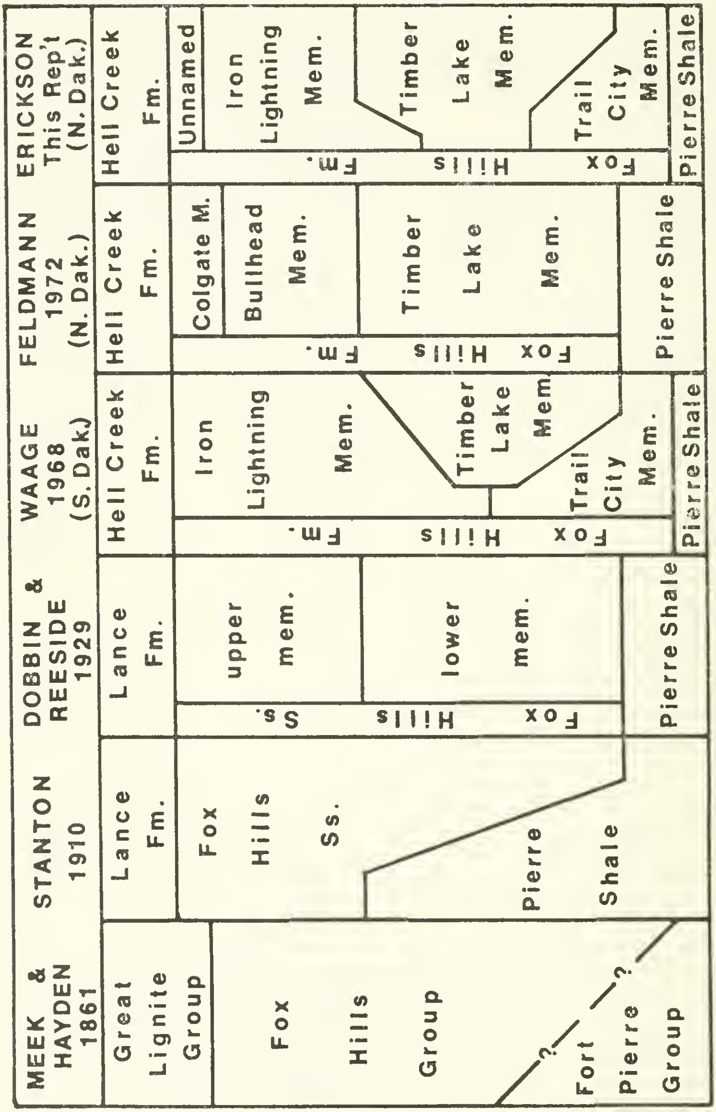
Most recently the contact was described by Frye (1969) and Waage (1968). Frye, after careful study, concluded that the contact shows both unconformable and transitional character depending upon geographic location. He said (p. 24):

> The writer believes that his and other investigator's results have shown that there are no simple conclusions to be made concerning this contract. Dobbin and Reeside's (1929) summary of the Fox Hills-Hell Creek contact appears to fit most of North Dakota and South Dakota. However, in eastern Montana, it has now been substantiated that the unconformities found between the Hell Creek and Fox Hills Formations are not local but very widespread.

Waage (1961, p. 238) indicated by use of fossil zonation that the upper contact of the formation is older to the west of the type area. In 1968 he described the contact in some detail (pp. 118-120). He indicated the most useful placement of the contact in the type area was that it be ". . . taken at the base of the first appreciably thick lignite or lignitic clay or shale." This is a general solution to a problem of transitional deposition to which I can offer no more specific solution.

A variety of names of member status have been applied to local lithologic units within the formation in several areas. I have discussed these elsewhere (Erickson, 1971) and will not detail them here. Of major import are the new concepts of the formation which resulted from Waage's (1968) detailed field work in the type area in South Dakota. In view of it and my field experience in North Dakota, I feel that a redefinition of the members occurring in North Dakota would be worthwhile because it serves to clarify both stratigraphic and paleoecologic concepts of the formation in the state.

The history of nomenclature as applied to members in the type area was given by Waage (1968, p. 41, fig. 4) and is included with my additions as shown in Text-figure 2. The terminology applied by Feldmann in 1967 is essentially that which is used by the South Dakota Geological Survey as in the same Text-figure. Feldmann, in



Text-figure 2. — Comparative nomenclature of members within the Fox Hills Formation.

addition, recognized the interfingering relationship of the units, much as Waage did, and he was the first to consistently apply the term "Bullhead" to silts and clays high in the formation in North Dakota.

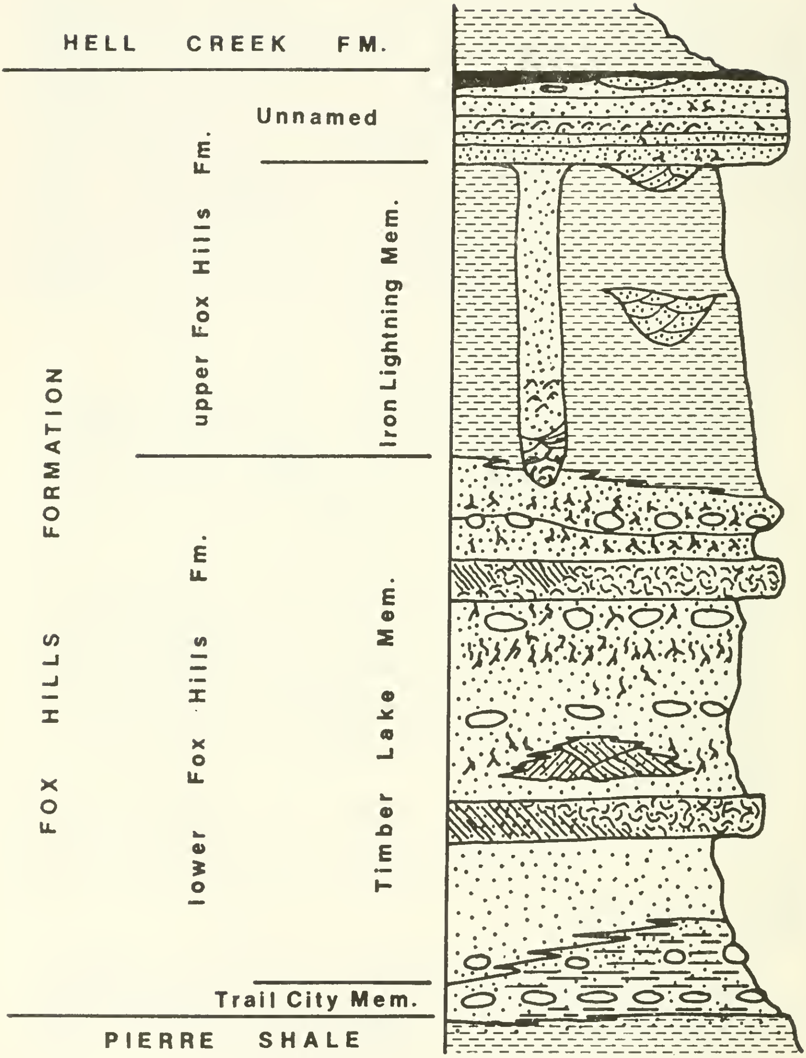
It is generally agreed that the formation in and northward from the type area is divisable into a lower and an upper portion (Fisher, 1952; Feldmann, 1966, 1967; Waage, 1968). Waage (p. 45) redefined the upper portion to include one member in two lithofacies. This Iron Lightning Member has its type section, a composite of several local exposures in the W½ sec. 33, T. 14 N., R. 19 E., U.S.G.S. Redelm NE quadrangle, Ziebach County, South Dakota (Loc. 74 of Waage, 1968). I have examined the member at this locality where it contains lithologies previously considered to be the Bullhead Member and Colgate Member. The reasoning behind Waage's action was expressed by the following statements (1968, pp. 45, 46):

> The concept of the type Fox Hills as a formation made up of four successive members is an oversimplification of fact. The four named members in use at the present time do indeed apply to four lithogenetically distinctive parts of the formation but these are neither uniformly successive nor are all of them continuous within the type area. Two of the four members (Bullhead and Colgate) are so intricately interrelated that their separation obscures rather than clarifies their true relationship. . .
>
> A broader, natural subdivision of the Fox Hills into lower and upper parts is afforded by its major environments of deposition. The Trail City and Timber Lake Members form a lower part of off-shore marine deposits and the Iron Lightning Member an upper part of nearshore marine and brackish-water deposits. In areas peripheral to the type Fox Hills, where one or more of the members begins to lose its identity, a twofold subdivision of the formation apparently remains obvious and might be useful in mapping. In describing the type area, adoption of the informal subdivisions lower and upper Fox Hills provides a means of organizing the stratigraphic data in an environmental framework.

In this revision there is no violation of the Stratigraphic Code, because this type of reassignment is not covered by the Code. His use of the terms Bullhead "lithofacies" and Colgate "lithofacies" is defined as follows (p. 46):

> In addition to the formal members of the Fox Hills Formation, informal units, here called lithofacies, are used to single out lithogenetic units essential for environmental reconstruction. As used in this report, a lithofacies is one or more bodies of sediment or sedimentary rock distinguished from enclosing deposits by noteworthy lithologic, organic and/or internal structural characters.

This usage is not in keeping with that of Sloss, *et al.* (1949), who express lithofacies in a statistical manner, but it might be called a "lithosome" in their terminology. Waage (p. 47) felt this statistical usage was too restrictive when discussing field and paleo-



Text-figure 3.— Schematic stratigraphic column of the Fox Hills Formation in North Dakota as used in this report.

environmental relationships, and I am inclined to agree with him. I have accepted his definition of the Iron Lightning Member containing a Bullhead and a Colgate lithofacies (informal) as indicated in Text-figure 3.

Below the Iron Lightning Member are fossiliferous, glauconitic, medium to fine-grained sandstones and silty sandstones of the Timber Lake Member. These are well developed in Sioux County and Emmons County, North Dakota. Their expression is essentially that described by Waage (1968) for the type area and the sandstones need not be re-discussed.

At the same time, Waage redefined the character of the Trail City Member to include two lithofacies, the Little Eagle lithofacies and Irish Creek lithofacies. The former is a homogeneous gray clayey silt and clayey sand containing abundant fossiliferous concretions and lacking much defined bedding due to bioturbation (Waage, 1968, p. 63). This unit occupies the basal position in the formation at outcrops in the eastern portion of the type area in South Dakota. The latter unit occupies a like position in the western portion of the type area with a lateral gradation between them. It is distinguished by a scarcity or absence of fossiliferous concretions and a more distinguishable bedding, although the sediments are generally of a composition similar to the Little Eagle.

At the present stage of Fox Hills stratigraphy in North Dakota these lithofacies are of little use. This is particularly true because the Trail City Member thins markedly to the north of the type area to the extent that it is frequently not recognizable in North Dakota (Feldmann, 1967; Waage, 1968). I consider the lower portion of the outcrop at locality A480 to represent this member, and it is present at localities A469 and A457 in Emmons and Sioux Counties as well, but nowhere does it expose the thicknesses (65-210 feet) reported by Waage (p. 58) from the type area.

There is apparently one unit in North Dakota that is not significantly persistent to the south to warrant separation there. At most exposures east of the Missouri River in North Dakota it is a butte-capping, highly resistant bed that seems to occupy a stratigraphic position at or near the top of the formation. It is generally a well-indurated, light to medium gray or gray-green, medium-grained sandstone. It often occurs in flaggy beds, parting on flat planes to produce slabs one half inch to upwards of six inches thick in some outcrops. The cement is often siliceous although carbonate cement is occasionally present. The rock often contains fragments of silicified wood, and units of brown to orange mud-flake conglomerate a few to several inches thick. The fauna where present, is also distinctive, containing *Crassostrea, Pachymelania, Corbicula, Anomia, Euspira,* and occasionally *Neritina,* often in that approximate order of abundance.

This unit has been recognized as distinct by several workers in Emmons, Logan and McIntosh Counties of North Dakota (Fisher, 1952; Clayton, 1962, p. 48). Feldmann (1967, pp. 41, 51) noted that it was probably a south-eastward expression of the Colgate Member (lithofacies), and he considered it as such, though he was aware of several distinctions (p. 50). These and other consistent deviations from the composition of the Colgate lithofacies have been discussed in detail elsewhere (Erickson, 1971). They are of sufficient significance to warrant designation of this as a separate member, a prospect that will be undertaken at a later time. For the sake of discussions to follow I have referred to these beds as an "unnamed member" of the formation in North Dakota.

Thus, at present, it seems most expedient to retain the name Trail City Member for the basal unit of the formation in North Dakota without conceptual change as it is generally poorly developed and poorly exposed in the state, thus not warranting subdivision. The Timber Lake Member is well developed along the Missouri River and is recognized as a major lithologic unit in the area covered by this report. Waage's (1968) definition of the Iron Lightning Member in the Colgate lithofacies and Bullhead lithofacies is deemed a useful contribution to the concept of the formation in North Dakota, and the application of these terms is encouraged. Finally, a new member, as yet unnamed, should be considered for outcrops high in the section which contain the *Crassostrea-Pachymelania* faunule and generally occur east of the Missouri River in North Dakota.

AGE AND CORRELATION

The Fox Hills Formation is the upper unit of the Montana

Group (Eldridge, 1896) and overlies the Pierre Shale, also of that group, together representing the latest phase of marine Cretaceous deposition in the Western Interior. Stratigraphy of this group, and a correlation were given by Stanton and Hatcher (1905, p. 63) who listed the Eagle, Clagget, Judith River, and Bearpaw Formations in central Montana as correlatives of the Pierre Shale in the South Dakota Section. Stebinger (1914) and Bowen (1915) refined the stratigraphy of the Montana group.

Cobban and Reeside (1952) considered the formation to be of Maestrichtian age. In Montana the approximate correlative units would be the Horse Thief Formation and Lennep Formation (Stebinger, 1914). On the Atlantic Coast it would be approximately equivalent to the Red Bank Sandstone of New Jersey, Delaware, and Maryland, and the upper Pedee Formation of North Carolina (Stephenson, 1923, pl. 8). Gulf Coast correlatives include the Corsicanna Marl and Kemp Formation according to Stephenson (1941, p. 33). These correlations were carried to the Mississippi Embayment by Sohl (1964, p. 160). Sohl considered the Corsicanna Marl to be older than the Fox Hills Formation.

Precise correlations are difficult. Gulf Coast Zonation has traditionally been based upon the bivalve genus *Exogyra* which is not present in the Western Interior where rocks are zoned instead upon occurrences of *Inoceramus* and ammonoid species. *Inoceramus* occurrence is often facies-determined (Sohl, 1967a), and it is rare in the littoral deposits of the Fox Hills Formation. The facies influence upon composition of the Fox Hills fauna was recognized in 1905 by Stanton and Hatcher who made the following statement (p. 66):

> Faunas similar to that of the Fox Hills sandstone have a great vertical range and are likely to be found at any horizon within the Montana group where a littoral or shallow-water facies is developed. The use of the term Fox Hills as a formation or horizon outside of the original area in South Dakota is therefore of doubtful propriety, as experience has shown.

A better understanding of this fact might clarify some attempted correlations at great distances from the type area such as those of Lovering, *et al.* (1932) or Henderson (1920a; 1920b) based largely upon fauna of the molluscan benthic communities in Colorado.

The use of benthic invertebrates in correlation is always tenuous on a continental scale. Ammonite zonation applied to these rocks has been more promising and the correlations given here have been examined in that light. *Sphenodiscus lenticularis* (Owen) is taken to be the best index to rocks of Fox Hills age, and correlations using *Sphenodiscus* have been given most weight. Stephenson (1923) reported it from the Peedee Formation which falls in the *Exogyra costata* Zone of eastern usage.

Cobban and Reeside (1952) noted that western portions of the Fox Hills Formation are included in the *Baculites ovatus* Zone and *B. clinolobatus* Zone which are in the Pierre Shale farther east. This increased age of the Fox Hills Formation westward from the type area has been demonstrated by those authors and by Waage (1961). One would expect a regressive littoral marine facies to transgress time in this manner. Perhaps after scaphitid ammonites of the Fox Hills Formation are better defined more refined correlation within the Western Interior and above the *Baculites clinolobatus* Zone may be accomplished with more assurance.

At present the gastropod fauna contains two species in common with the Coon Creek fauna of the Ripley Formation in the Mississippi Embayment. Both *Goniocylichna bisculpturata* Wade and *Euspira rectilabrum* (Conrad) were reported from the Coon Creek sediments of Tennessee by Sohl (1960, 1964). Several genera are likewise shared. Strictly on the basis of the gastropod fauna in North Dakota it would appear that the best regional correlation would thus be between the Fox Hills rocks and those of the Coon Creek Tongue of the Ripley Formation based largely on the occurrence of *G. bisculpturata* in both faunas. This seems to give the formation slightly greater age than is generally assumed, and I am not yet prepared to make this claim on the basis of gastropod occurrences.

The best gastropod similarities at the generic level on the Texas Gulf Coast seem to be with the Nacotoch Sandstone or the Kemp Clay, but these may be an artifact of publication.

The Escondido Formation contains a *Sphenodiscus lenticularis* fauna, and its potential correlation with the Fox Hills Formation has been recently noted by Cooper (1970). He cautions against use of *S. lenticularis* because it appears to have been a shallow water, benthic (?) species which may thus have sedimentologic as well as chronologic controls over its distribution. Correlation with the Escondido Formation of the Rio Grande Embayment is most likely in my opinion.

PALEOENVIRONMENT AND FAUNAL ORIGINS

Several statements describing paleoenvironmental conditions during deposition of Fox Hills sediments in North Dakota, South Dakota, and Wyoming are available (Feldmann, 1967, 1968b, 1972; Waage, 1967, 1968; Weimer, 1965; Land, 1972). All of these are in general agreement that the formation represents a complex of offshore, nearshore, strandline, and estuarine environments with the most detailed contribution to date being that of Land.

Preliminary data accumulated during this study substantiate these conclusions and have permitted more detailed speculations regarding depositional conditions in North Dakota than have previously been reported. Sediments in Emmons, Sioux, Logan, and McIntosh Counties as represented by the Trail City and Timber Lake Members were probably deposited on, and lateral to, the platform of one or more major deltas. Lagoonal conditions represented by the Iron Lightning Member prevailed lateral to, and eventually covered, much of the delta-platform sands and silts. These in turn were covered rather abruptly by a destructional, transgressive event representing either a major storm sequence as described by Ball (1971) or, more probably, a reaction to shifting of the riverine sediment source and consequent reworking of platform deposits by wave and tidal activity during delta compaction thus producing a sheetlike sandstone deposit such as that described by Hubert, *et al.* (1972) for similar deposits on the Cody-Parkman delta of Wyoming. This last event of Fox Hills deposition in North Dakota is preserved in the blanket sandstone of the "unnamed member" discussed previously in this report.

Additional ideas regarding the physical environment were generated during this study from limited outcrop data, but they are worth mentioning here. First, it is likely that the Maestrichtian sea, at least over large local areas in the region, became thermally stratified, periodically. Second, major storms occasionally swept the area, reworking the sediments and leaving a marked record in the physical character of the strata. Finally, the gastropod fauna has more southern than northern affinities and may be a response either to relatively warm (but much cooler than Gulf-Coastal latitudes) regional climatic conditions, or to prevailing directions of marine current flow from the south, or both. Each of these ideas is highly speculative. The physical parameters from which they were developed were discussed in some detail by Erickson (1971) and will not be reexamined here.

Faunal distribution with respect to the gastropods is germain to this report. Fossils described in this study were taken from death assemblages representing relatively gentle conditions of accumulation in unconsolidated sandy siltstones and high-energy accumulations in fine-to medium-grained indurated or friable sandstones, and from several types of concretions of undetermined origins. The gastropods were facies-sensitive, and their local distribution was governed by the local marine conditions during deposition. Likewise, they were dependent upon the existence of a relatively nearshore, shallow marine environment to allow latitudinal migration, and thus they are probably not the most desirable species for purposes of correlation. They are useful for paleogeographic reconstructions, however, and will be considered in this light.

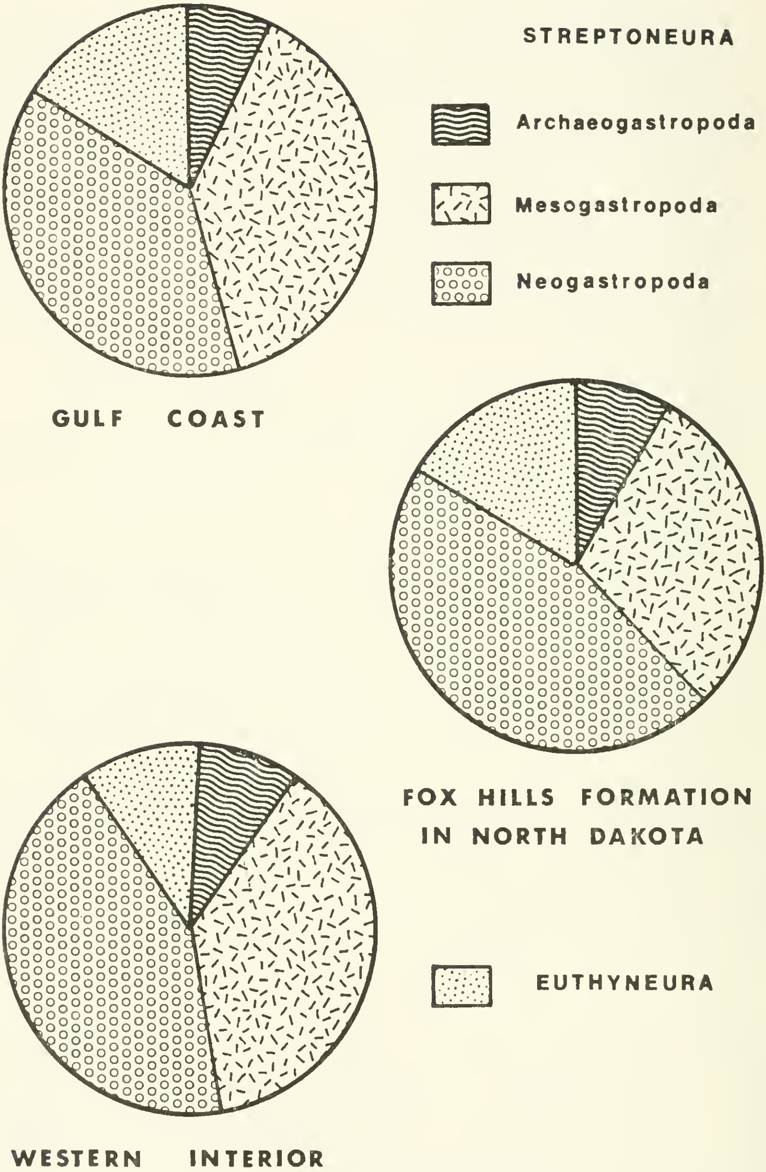
The composition of the Fox Hills gastropod fauna of North Dakota permits several comparisons with other North American Maestrichtian faunas. A list of Fox Hills species determined in this study is included here to acquaint the reader with the fauna for the discussion which follows.

Undetermined margaritinid
Neritina loganensis, n. sp.
Pachymelania wyomingensis (Meek)
P. insculpta (Meek)
Spironema tenuilineata (Meek and Hayden)
Syncera? sp.
Drepanochilus evansi Cossmann
D. nebrascensis? (Evans and Shumard)
Vanikoropsis nebrascensis (Meek and Hayden)
Euspira rectilabrum (Conrad)
E. obliquata (Hall and Meek)

E. subcrassa (Meek and Hayden)
E. ? dakotensis (Henderson)
Semitriton buccinoides (Meek and Hayden)
Rhombopsis subturritus (Meek and Hayden)
Graphidula culbertsoni (Meek and Hayden)
G. ? cretacea (Meek and Hayden)
Piestochilus feldmanni, n. sp.
P. scarboroughi (Meek and Hayden)
P. galpiniana (Meek and Hayden)
Hercorhyncus (Haplovoluta) hollandi, n. sp.
Serrifusus dakotaensis (Meek and Hayden)
Remera? cvancarai, n. sp.
?Cryptorhytis flexicostata (Meek and Hayden)
Pyropsis bairdi (Meek and Hayden)
Perissitys? sp. A
Perissitys? sp. B
Cancellaria siouxensis, n. sp.
Amuletum (Amuletum) minor (Evans and Shumard)
Amuletum (Lutema) sp.
Oligoptycha concinna (Hall and Meek)
Ellipsoscapha cf. *E. minor* (Meek and Hayden)
Cylichna scitula (Meek and Hayden)
C. volvaria? (Meek and Hayden)
Goniocylichna bisculpturata Wade
Goniocylichna sp.

Sohl (1967b) gave a compilation of Gulf Coast and Western Interior faunal compositions based upon his experience and faunas known at that time. He recognized 125 genera from the Western Interior but stated (p. 3) that, "A full taxonomic study would probably increase this number by some 5 to 10 percent." The present study has introduced 11 generic level taxa to Western Interior occurrence data. Several of these are due to subdivision of some long standing "form genera" such as *Fasciolaria sensu* Meek and Hayden (1856). Seven have never before been formally described from the area. These include *Syncera, Hercorhyncus, Remera, Perissitys, Cancellaria, Amuletum (Lutema),* and *Goniocylichna.* Of these Sohl (1967b, pp. 30-35) listed an undescribed form of *Hercorhyncus* sp. and an *Amuletum (Amuletum)* from older Western Interior deposits. Sohl's comparison with Gulf Coast faunas was presented graphically using percentage of genera found in various classes of the Streptoneura and in a composite of Euthyneura. I have presented his data in Text-figure 4 along with Fox Hills data from North Dakota. Examination indicates that the data are comparable except in the Euthyneura and the Mesogastropoda.

Euthyneuran genera compose nearly 17 percent of the fauna, more similar to Gulf Coast associations than Western Interior



Text-figure 4. — Comparison of generic compositions of midcontinent Upper Cretaceous gastropod faunas (data from Sohl, 1967b) with Fox Hills fauna in North Dakota. Arc length proportional to percentage of genera in each taxon.

faunas. This is due most probably to discovery during the present work of low energy shell accumulations of small species, not generally preserved in the sandy facies which contain most of the Western Interior gastropod faunas (Sohl, 1967b, p. 3). Secondly, it results from the introduction of a Mississippi Embayment genus, *Goniocylichna,* to the faunal lists of the Western Interior.

The substantially smaller number of mesogastropod genera is the result of reassignment of several naticid genera to *Euspira,* which group should be examined more critically in records of other areas. A reexamination would most likely cause similar reduction in those faunas as well. It is also a partial reflection of collecting since at least one genus, *Turritella* is known to occur in South Dakota but has not been collected in North Dakota as yet.

Dominance of the neogastropods within the Streptoneura, as opposed to dominance by archaeogastropods during the Triassic and by mesogastropods during the Jurassic and earlier in the Cretaceous noted by Sohl (1964, p. 152), is in keeping with most Maestrichtian faunas he examined. It is very similar to the faunal composition of both the Ripley and Navarro, although each of these has four or five percent fewer neogastropods.

These data also afford opportunities for increased understanding of paleogeographic relationships and origins of various components of the Fox Hills molluscan fauna. Sohl (1967b, 1971) called attention to the usefulness of gastropods for this type of interpretation in the Cretaceous of the Western Interior. Earlier Reeside (1957) discussed potential faunal sources and migration routes open to Western Interior mollusks. These included Gulf Coast and Arctic sources, or, at various times, both such sources. This resulted in a fauna with mixed origins in the Interior. He also noted that some Western Interior faunas had a large endemic aspect. The Fox Hills fauna has been considered by many to have the greatest such endemic character in the region. This study shows little indication of true endemism in the fauna. There are indications that generic groups which arrived early in the region underwent new directions of speciation in the Interior and subsequently migrated once more to their place of origin to produce new characteristics in that stock. The *Graphidula culbertsoni* group, probably followed this procedure.

The new data made available by this study are conclusive as to faunal origin. Of the Fox Hills gastropod genera only *Pachymelania* is endemic to the Western Interior and that only because it probably had a freshwater origin. Table 1 compares Fox Hills gastropod genera of North Dakota with occurrences of the same or closely related genera from other regions as compiled from the literature. These data show the strong influence of stocks from the Mississippi Embayment and Gulf Coast. They also demonstrate influx of some Arctic forms clearly. New records for *Perissitys* ?, *Remera* ?, *Amuletum, Hercorhyncus, Cancellaria, Syncera* ?, and *Goniocylichna* strongly enhance this interpretation. Their influences and origins are portrayed schematically in Text-figure 5.

The faunal contribution from the Ripley of Mississippi and Tennessee is very strong, but this may simply be an artifact of the excellent preservation of the Coon Creek molluscan fauna. Feldmann (1967, pp. 56, 57) noted a similar general relationship for the bivalve fauna, however.

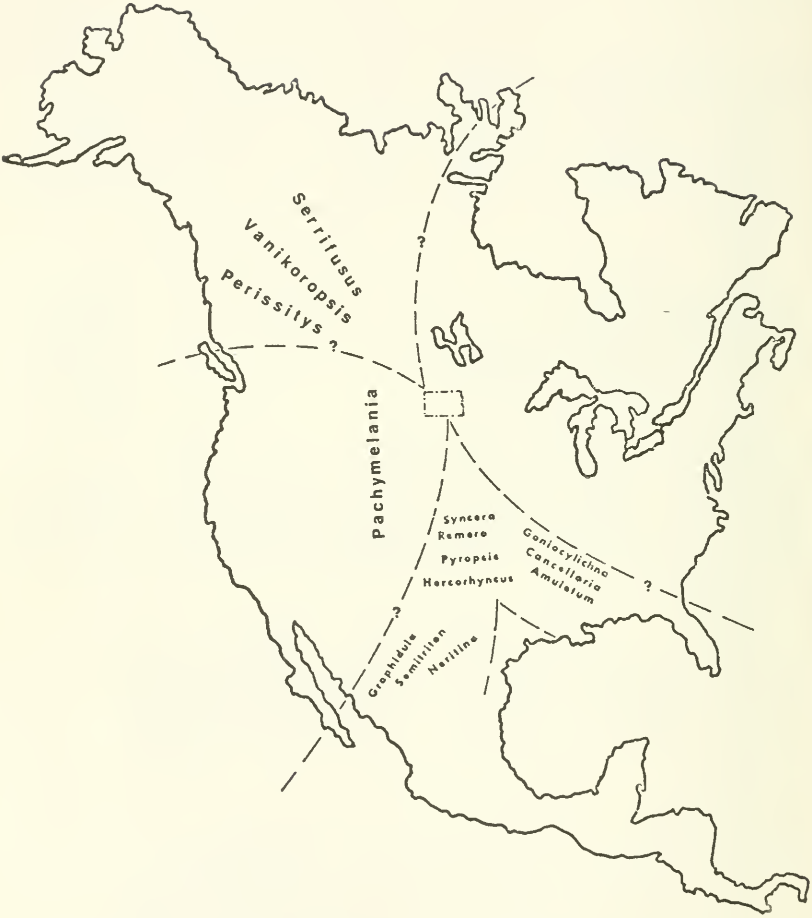
These data, interesting in themselves, have additional environmental significance when the appearance of the Fox Hills species is compared with southern relatives. Many of the southern genera are rather highly ornate in the southern rocks. Species of *Hercorhyncus, Pyropsis, Remera, Amuletum,* and *Rhombopsis* show nodes, tubercles, or complex raised rib and costae patterns of prosopon. In every case these are diminished, subdued, or absent entirely on the Fox Hills counterparts. Furthermore, the rarity of many of these forms creates the impression that they were existing close to the northern limits of their range and were frequently not abundant elements of the fauna, except perhaps at particularly favorable periods of short duration. Lack of complex ornament may be attributed to both high energy water conditions and colder water conditions, whereas range limitation indicates principally a latitudinal climatic, or temperature, gradient of marine conditions.

Presence of *Perissitys* ?, *Serrifusus,* and *Vanikoropsis* which have Pacific ranges are indicative of similar conditions. None seems to extend much farther southward into the Western Interior. *Serrifusus* is recorded from the Pierre Shale fauna of Wyoming (Sohl, 1967a), and Sohl (1967b) noted it from New Mexico. These are earlier occurrences then reported herein and may reflect previous

TABLE 1

COMPARISON OF FOX HILLS GASTROPOD GENERA WITH OCCURRENCES OF THE SAME, OR CLOSELY RELATED, GENERA FROM UPPER CRETACEOUS ROCKS OF CENTRAL AND WESTERN NORTH AMERICA

Wade (1926) Sohl (1960, 1964) Ripley Fm. Miss.-Tenn.	Stephenson (1941) Navarro Gp. Texas	This Report N. Dak.	White (1889) Whiteaves (1879, 1884, 1885, 1903) Vancouver Is.	Stewart (1927) Anderson (1958) California Pacific Coast
Margaritella	*Margaritella*	*Margaritinae*	*Solariella*	*Margarites*
Neritina	*Neritina*	*Neritina*	*Neritina?*	
Drepanochilus	*Drepanochilus*	*Drepanochilus*	*Anchura*	*Drepanochilus?*
Oligoptycha	*Oligoptycha*	*Oligoptycha*	*Cinulia*	*Oligoptycha*
Ellipsoscapha	*Ellipsoscapha*	*Ellipsoscapha*	*Haminea*	*(?=Scaphander)*
Goniocylichna		*Goniocylichna*	*(?=Trochacteon)*	
Euspira	*Euspira*	*Euspira*		*Euspira*
Cancellaria?	*Bonellitia?*	*Cancellaria*		
Remera	*Remera*	*Remera?*		
Amuletum	*Amuletum*	*Amuletum*		
Caveola	*Caveola*	*Semitriton*		
Rhombopsis	*Rhombopsis*	*Rhombopsis*	*(?=Pyrifusus)*	
Cryptorhytis?	*Cryptorhytis?*	*Cryptorhytis?*		
Hercorhyncus	*Hercorhyncus*	*Hercorhyncus*		
Graphidula	*Graphidula*	*Graphidula*		
Piestochilus	*Piestochilus*	*Piestochilus*		
Pyropsis	*Pyropsis*	*Pyropsis* spp.		
Spironema	*Spironema*	*Spironema*		
Cylichna	*Cylichna*	*Cylichna*		
		Serrifusus	*Serrifusus*	*Serrifusus*
		Perissitys?	*(=Perissolax)*	*Perissitys*
		Vanikoropsis	*Vanikoropsis*	
		Pachymelania		



Text-figure 5.—Map schematically illustrating probable areas of origin for selected gastropod genera in the Fox Hills Formation, North Dakota.

range extensions southward under more "boreal" marine temperatures. Since *Serrifusus* is a Pacific genus with closely related species in California, British Columbia, and Japan, I do not consider it endemic to the Western Interior and these range data are taken to represent extensions under optimum conditions for the genus.

Jeletzky (1969, p. 890) described aspects of the "Northern Pacific biotic province" which had a tethyan aspect and the "Boreal Cretaceous biotic province" with an arctic or northern Eurasian influence. His conclusions were based upon molluscan data, primarily ammonites, and I am not prepared to assign elements of the Fox Hills fauna to either province. I do feel that the work of both Sohl and Jeletzky enhance each other and that the data herein definitely show the influence of latitudinal, or some type of oceanic-current, effect upon Maestrichtian gastropod faunas of the northern Western Interior. North Dakota and South Dakota were areas of overlap of these two influences with the southern (Tethyan) influence somewhat more dominant during Fox Hills time. I have considered the paleogeographic implications of the gastropod fauna in greater detail elsewhere (Erickson, 1973).

Endemism, resulting from local isolation might be expected to be stronger in later faunas such as that of the Cannonball Formation (Paleocene) of North Dakota. A cursory comparison of the Fox Hills and Cannonball faunas indicates that this is the case. Only four species of Stanton's (1921) 31 gastropods overlap the boundary. At the generic level, after reassignment of his taxa in view of present taxonomy, there are only nine or ten which occur in both formations with certainty. Either the Cannonball fauna was influenced from a different source or it is distinctly more endemic than that of the Fox Hills.

ACCESSION AND LOCALITY DATA

The majority of field collecting for this study was carried out during July and August of 1969. Gastropods occurred much less commonly than bivalves, and good material was taken from only 45 localities. The most productive outcrops were revisited twice during the summer of 1970 and again during 1971.

Collections made by me augmented those made previously by R. M. Feldmann and A. M. Cvancara and housed at the University of North Dakota at Grand Forks. Specimens in the collection of the University of North Dakota are designated by numbers prefixed by UND while those specimens and types loaned from or donated to the U.S. National Museum are given here with a USNM prefix.

The following is a list of collecting localities as have been referred to in the text. Numbers refer to the University of North Dakota, Geology Department, Accession catalogue numbers which are given for location or stratigraphic horizon at a location.

1. A452: Prominent buttes (Shell Buttes), NW¼ sec. 26, T. 133 N., R. 73 W., Logan Co., N. Dak.
2. A454: Hillslope above site of abandoned Magnolia Dakota "A" well, NE¼ sec. 36, T. 141 N., R. 73 W., Sibley Buttes, Kidder Co., N. Dak. (= USGS loc. 16002).
3. A455: Scattered fossils in Timber Lake Member, SW side of paved road center sec. 35, T. 130 N., R. 80 W., ca. 3.5 miles SSW of Ft. Yates, Sioux Co., N. Dak.
4. A457: High cut face N. side of ND 24 where it turns N. toward Ft. Yates, center sec. 27, T. 130 N., R. 80 W., ca. 2½ miles SW of Ft. Yates, Sioux Co., N. Dak.
5. A458: Rip-rap under bridge on ND 24 ca. ¼ mile E. jct. with ND 6, center N. edge sec. 3, T. 129 N., R. 81 W., Sioux Co., No. Dak.
6. A459: Rd. cut W. side ND 24 on hill ca. ½ mile N. bridge, NE¼NW¼ sec. 15, T. 131 N., R. 80 W., ca. 6 mi. N. of Ft. Yates, Sioux Co, N. Dak.
7. A460: Ca. 3 ft. below top of section described in A461 is 6 inch zone of accumulation of mollusks; E. side of gravelled road near center sec. 21, T. 129 N., R. 79 W., ca. 8 miles SSW of Ft. Yates, Sioux Co., N. Dak.
8. A461: *Cucullaea* concretion zone near top of high road cut (15 ft. below top of exposed section) E. side of road near center sec. 21, T. 129 N., R. 79 W., ca. 8 miles SSW of Ft. Yates, Sioux Co., N. Dak.
9. A462: Fossils occurring in outcrop below prominent break in slope along S. face of valley wall SW¼ sec. 33, T. 130 N., R. 80 W., along Four-Mile Ck. valley, Sioux Co., N. Dak.
10. A463: Eroded pasture surface in SE¼ sec. 32, T. 130 N., R. 80 W., W. of gravelled farm road leading down to Four-Mile Ck., Sioux Co., N. Dak.
11. A464: UNIT 6 (Erickson, 1971) of section in cut bank exposure on Four-Mile Ck., NW¼NW¼ sec. 6, T. 129 N., R. 80 W., ca. 7 miles SW of Ft. Yates, Sioux Co., N. Dak.
12. A465: UNIT 7 of section in cut bank exposure on Four-Mile Ck., NW¼-NW¼ sec. 6, T. 129 N., R. 80 W., ca. 7 miles SW of Ft. Yates, Sioux Co., N. Dak.
13. A466: UNIT 8 of section in cut bank exposure on Four-Mile Ck., NW¼-NW¼ sec. 6, T. 129 N., R 80 W., ca 7 miles SW of Ft. Yates, Sioux Co., N. Dak.
14. A467: Cut bank on Four-Mile Ck., NW¼NW¼ sec. 6, T. 129 N., R. 80 W., ca. 7 miles SW of Ft. Yates, Sioux Co., N. Dak. This outcrop consists of well defined units of Timber Lake Member.
15. A468: Road cut at SE corner of Beaver Lake, E. of Burnstad, Logan Co., N. Dak.

14. A467: Cut bank on Four-Mile Ck., NW¼NW¼ sec. 6, T. 129 N., R. 80 W., side of Beaver Creek in Seeman Park (Linton Municipal Park), SW¼-SW¼ sec. 17, T. 132 N., R. 76 W., ca. 0.75 mi. SE of Linton, Emmons Co., N. Dak.
17. A470: Road cut E. side N-S gravelled road at jct. with E-W gravelled road, SW¼ sec. 6, T. 129 N., R. 78 W., Emmons Co., N. Dak.
18. A472: Road cut on E. side of N-S gravelled road and cut banks of associated stream drainage (E-W) NW¼NW¼ sec. 33, T. 130 N., R. 78 W., Emmons Co., N. Dak.
19. A473: Butte-capping sandstone at center sec. 10, T. 129 N., R. 78 W., Emmons Co., N. Dak.
20. A474: Outcrop in drainage, running NW-SE across E-W gravelled road ca. ¼ mile E. of farmhouse, SE¼ sec. 11, T. 129 N., R. 78 W., Emmons Co., N. Dak.
21. A475: Rd. cut E. side of gravelled road just N. of farm entrance, NW¼-SW¼ sec. 1, T. 133 N., R. 78 W., Emmons Co., N. Dak.
22. A476: Outcrop in road cut (primarily) at top of hill on W. side of drainage on N. and S. sides of E-W gravelled road at center sec. 1, T. 134 N., R. 79 W., Emmons Co., N. Dak.
23. A477: Cross-bedded sandstone outcrops of Timber Lake Member, N. side of small drainage, ca. ⅓ mile W. of gravelled road of E. edge sec. 35, T. 134 N., R. 79 W., Emmons Co., N. Dak.
24. A478: Road cut E. side of road, NW¼SW¼ sec. 15, T. 132 N., R. 75 W., Emmons Co., N. Dak.
25. A479: Road cut on farm rd. at jct. with E-W gravelled road, SE corner sec. 29, T. 131 N., R. 77 W., Emmons Co., N. Dak.
26. A480: Road cut on W. edge of glacial drainage, S. side of gravel road, center sec. 26, T. 134 N., R. 71 W., east of Burnstad, Logan Co., N. Dak.
27. A601: NE¼ sec. 12, T. 132 N., R. 79 W., Emmons Co., N. Dak.
28. A611: SE¼ sec. 32, T. 133 N., R. 75 W., Emmons Co., N. Dak.
29. A615: SW¼ sec. 34, T. 133 N., R. 76 W., Emmons Co., N. Dak.
30. A617: SW¼ sec. 27, T. 133 N., R. 76 W., Emmons Co., N. Dak.
31. A618: NE¼ sec. 21, T. 133 N., R. 76 W., Emmons Co., N. Dak.
32. A625: SW¼ sec. 26, T. 133 N., R. 77 W., Emmons Co., N. Dak.
33. A626: NE¼ sec. 35, T. 133 N., R. 77 W., Emmons Co., N. Dak.
34. A627: NW¼SW¼ sec. 27, T. 133 N., R. 77 W., Emmons Co., N. Dak.
35. A643: SW¼ sec. 36, T. 134 N., R. 77 W., Emmons Co., N. Dak.
36. A677: Charlie Whippli's ranch, NW¼ sec. 20, T. 130 N., R. 80 W., Sioux Co., N. Dak.
37. A684: E. rdcut. exposure, SE side Buffalo Lake, NE¼NW¼ sec. 12, T. 152 N., R. 72 W., ca 10¼ air mi. NNE Selz, S. Pierce Co., N. Dak.
38. A689: SE¼ sec. 7, T. 129 N., R. 78 W., Emmons Co., N. Dak.
39. A701: SW¼NW¼ sec. 3, T. 130 N., R. 78 W., roadcut on east and west sides of road, Emmons Co., N. Dak.
40. A706: NW¼ sec. 33, T. 130 N., R. 78 W., Emmons Co., N. Dak.
41. A719: NW¼ sec. 27, T. 130 N., R. 80 W., Sioux Co., N. Dak.
42. A720: S½ sec. 32, T. 130 N., R. 80 W., Sioux Co., N. Dak.
43. A726: SW¼SE¼ sec. 33, T. 131 N., R. 78 W., road cut on north side of road, Emmons Co., N. Dak.
44. A740: SW¼ sec. 24, T. 131 N., R. 80 W., roadcut on west side of N. Dak. 24, Sioux Co., N. Dak.
45. A747: SE¼ sec. 14, T. 132 N., R. 76 W., Emmons Co., N. Dak.

TERMINOLOGY

Terminology, particularly morphologic usage, employed herein is that applied by current workers in the field with a few exceptions.

Among the works consulted in this regard were Cox (1955, 1960), Powell (1961), and Sohl (1964, 1967a). Size distinctions between parallel terms such as costae and ribs, or chords and threads are empirical, and no attempt has been made to quantify them as they are often a function of the size (age) of the specimen in question.

Measurements have been made according to the practices of Sohl (1964, 1967a). Types of measurement are listed below along with their abbreviations as used in the text:

DPW: Diameter of the penultimate whorl measured normal to teloconch axis of coiling.
MD: Maximum diameter of the shell measured normal to teloconch axis of coiling.
H: Total height of the shell measured parallel to the axis of coiling.
HA: Height of the aperture measured to include canals.
HB: Height of the last ("body") whorl measured parallel to the axis of coiling at its maximum, generally at the aperture.
PA: Pleural angle of the spire, measured in degrees, tangent to the last few whorls of the shell.

SYSTEMATIC PALEONTOLOGY

MOLLUSCA

GASTROPODA

STREPTONEURA

ARCHAEOGASTROPODA

TROCHACEA

Family **TROCHIDAE**

Subfamily **MARGARITINAE**?

Genus and species uncertain Pl. 14, figs. 1-6

Material. — Five incomplete specimens extracted from sandstone concretions. These specimens, having been partially weathered prior to removal from the concretion, lack the outer shell layer carrying ornamentation and the early teloconch and protoconch whorls.

Discussion. — This species may belong to any of several genera including *Margarites, Margaritella, Atira,* and *Solariella* as indicated by the general size and trochoid aspect of the shell and by the pearly nacreous layer of shell, some of which is preserved. A faint trace of lineation on the whorls prior to preparation indicated that the shells may have been ornamented by collabral(?) grooves or striations, but none were definitely preserved. In general appearance the shells are small, trochoid, and deeply umbilicate. The periphery of the last whorl has a tendency to be acute anteriorly, producing a broad, convex, posterior slope and weak, anterior, carina-like flexure of the outer lip. The umbilicus does not seem to have been circled by any type of angular ridge or cord, but this type of prosopon is generally not reflected in lower shell layers, and because the ornamental layer is absent, the question of umbilical ornament is open.

A decision to place these specimens in *Margarites, Atira,* or *Solariella,* all common, Maestrichtian, Western Interior genera, would rest upon the character of umbilical ornament, whereas assignment to *Margaritella* would require presence of a noded ridge on the early teloconch whorls. When Meek discussed his *"Margarita" nebrascensis* (= *Atira nebrascensis*) in 1876 he illustrated several small forms assignable to that species but included (pl. 19, fig. 9b) one much larger form under the same name. His *A. nebrascensis* were from the Pierre Shale of South Dakota. The large form, which Sohl (1967a, p. B11) stated was an undescribed species lacking umbilical nodes and subsutural sculpture, is from the Fox Hills Formation at "Long Lake" (Meek, p. 299). The location of Long Lake (= *"Yanktonin"*), based upon the research of Waage (1968), is in North Dakota. My specimens resemble Meek's in general form, but without ornament they are indeterminate.

In general shape the specimens at hand resemble more closely *Solariella* (*Radiatula*?) *occidentalis* Whiteaves (1903, p. 368, pl. 43, figs. 5, 5a) as he illustrated it. Whiteaves' species cannot be placed to genus with any certainty from his figure or description, however, and may be a large *Atira.* Sohl (1967a, p. B11) stated that Meek's (1876) undescribed specimen lacks umbilical nodes but that is impossible to determine from Meek's figure 9b. If nodes are present, Meek's specimen may be conspecific with Whiteaves' *S.* (*R.*?) *occidentalis* and with my material. Well-preserved material must be located before the issue is resolved.

Types.—Hypotypes UND 13460, 13461.

Occurrence. — From concretions in the Timber Lake Member at localities A740 and A458.

Geologic range. — Maestrichtian?

Superfamily **NERITACEA**

Family **NERITIDAE**

Genus **NERITINA** Lamarck, 1816

Type species (by subsequent designation of Children, 1823, p. 111, *in* Kennard, *et al.*, 1931, p. 24): *Nerita pulliger* Linnaeus, 1767.

Generic diagnosis. — Subrhomboid, abruptly expanding, blunt-spired shells, generally having first whorl, or two, depressed and encircled by later whorls, last whorl being completely exposed. Surface smooth, sutures flush to slightly impressed, sides of whorl flat or gently convex; aperture crescentic; outer lip smooth or with interior weakly denticulate; inner lip thickened into callus completely covering umbilical region, and with or without teeth (*sensu* Sohl, 1960).

Remarks. — This diagnosis treats *Neritina* in the strict sense and does not consider forms now referred to *Velatella* Meek. *Neritina* is a widely reported Western Interior genus. It is generally taken to be indicative of estuarine or littoral conditions of deposition. Meek (1873, pp. 499-500), White (1879b, p. 308; 1883a, pp. 25-6), Stanton (1947, p. 63), Stephenson (1946, p. 181), and Sohl (1960, p. 63) have all described *Neritina* from the Cretaceous of the mid-continent, and most have alluded to the littoral and estuarine habitat preference of the genus.

Neritina is rare in the Fox Hills Formation of North Dakota. One "Fox Hills" record is that of White, 1879(b) (p. 309) from, "Cretaceous strata, Fox Hills Group; valley of Sulphur Creek, near Hilliard Station, Union Pacific Railroad, Wyoming" which is the type locality of *Neritina incompta* White. The exact correlation of these strata is uncertain because usage of the term "Fox Hills" has in the past been rather broad the farther a worker was from the type area in South Dakota. The report herein is the first documented occurrence of the genus in the Fox Hills Formation in its restricted sense.

Neritina loganensis, n. sp. Pl. 14, figs. 7-9

Diagnosis. — Shell high for genus; outer lip not expanding abruptly, smooth on interior; inner lip bearing three teeth, posterior tooth strongest, bent slightly toward middle tooth which bends toward it producing a mild, "bow-legged" appearance for the two; lowest tooth parallel to middle one. Ornament lacking save for very faint growth lines.

Description. — Shell subrhomboid, convex, spire blunt, early whorls almost completely hidden by last whorl. Outer lip not expanding or flaring outward abruptly as in many *Neritina,* free of denticles on inner surface, not thinning markedly at edge; inner lip forming a thick callus or boss covering base of columella and umbilicus completely, producing an anomphalous condition; midportion of inner lip bearing three strong teeth, posterior tooth largest, others slightly smaller and of equal size. Smaller teeth parallel, tilted slighty posteriorly; posterior tooth straighter, tilted slightly toward the anterior; aperture crescentic. Shell of holotype a uniform grayish brown with no color banding and ornamented only by very fine collabral growth lines; suture barely impressed. Pleural angle approximately 60 degrees. Protoconch worn on holotype, depressed.

Material. — One excellently preserved specimen lacking only protoconch. One badly decorticated specimen preserving only a portion of the last whorl and entire tooth bearing callus of inner lip.

Discussion. — This species resembles only one other Western Interior *Neritina, N. pisum* (= *N. pisiformis*) Meek from the Coalville Cretaceous of Utah which is Turonian in age. Meek (1873) originally considered *N. pisum* to have a smooth inner lip but, upon breaking it during extraction from concretionary matrix, he discovered its lip was ". . . provided there with four small denticles, the upper one of which is largest" (p. 500). Meek called the toothed form *N. pisiformis,* separating it from *N. pisum.* The holotype of *N. pisiformis* was later figured by White (1883a, pl. 12, figs. 9a, b, c). Stanton, upon cleaning the aperture of *N. pisum,* found it to be denticulate as well and placed *N. pisiformis* as a junior synonym of *N. pisum* (1893, p. 127).

I have examined the holotype of *N. pisiformis* (SNM 7885) at the U.S. National Museum where it is housed with *N. pisum.* It has a lower spire than *N. loganensis* and the posterior tooth seems to be more reduced. The teeth on Meek's holotype are difficult to interpret because his specimen is broken partially across them. The fourth tooth is difficult to interpret and it may well have been reduced in subsequent handling. None of his other specimens expose the dentition, and Stanton said nothing about the number of teeth in his discussion. For this reason I have relied upon Meek's original description to differentiate *N. loganensis* from *N. pisum* (= *N. pisiformis*).

This represents the first record of *Neritina* from the Fox Hills Formation near the type area and the first occurrence from North Dakota. It further reduces the endemic character often ascribed to the fauna generated by our previously incomplete knowledge of Fox Hills gastropods.

Etymology.—The species is named for Logan County, North Dakota, where the paratype was collected.

Types.—Holotype, USNM 180531; paratype, UND 13465.

Dimensions of holotype.—H = 0.9cm. MD = 0.8cm, PA = 60°.

Type locality.—The holotype is from USGS locality 16002: top of ridge ± 600 feet W. of township line in sec. 36, T. 141 N., R. 73 W., about 10 miles N. of Steele, in Kidder County, North Dakota (= UND locality A454); paratype from UND locality A480, center sec. 21, T. 134 N., R. 71 W., Logan County, North Dakota.

Occurrence.—The paratype was collected from fine sand and silt of the unnamed member at locality A480. I do not believe the animal lived in conditions represented by these deposits (see Rhoads, *et al.*, 1972) and its extremely worn condition, suggesting much transport, corroborates this conclusion. The label for U.S. Geological Survey locality 16002, where the holotype was collected, reads: "Fox Hills? A. Balban Ranch about 10 mi. N. of Steele, N. Dak. ± 600′ W. of township line in sec. 36, T. 141 N., R. 73 W. on south slope of high point on ridge, near top of ridge. June 19, 1931. R. W. Brown, J. Murata." Strata at this locality occupy a position in the upper, unnamed, buttecapping sandstone which contains a *Crassostrea-Pachymelania* "estuarine" faunule.

Geologic range.—Maestrichtian.

MESOGASTROPODA

CERITHIACEA

Family **THIARIDAE**

Genus **PACHYMELANIA** E. A. Smith, 1893

Type species (by monotypy): *Nerita aurita* Müller, E. A. Smith, 1893, Conchologist, vol. 2, pp. 141-2 (not *Pachymelania* White, 1895, U.S. Geol. Sur., Bull. 128, p. 50).

Generic diagnosis. — Shell high-spired, moderately thick; whorls strongly ribbed, with well-developed spiral ornament, or with strong carinae, tubercules, or nodes. Aperture not inflated, oval, slightly narrowed posteriorly as a sinus, with lip thicken anteriorly and around base of columella. Operculum thin, flat, paucispiral. (Modified from Wenz, 1938.)

Remarks. — Correct assignment of the two species here referred to *Pachymelania* has been in doubt since their original description by Meek in 1873 as emphasized by the passage below taken from his work:

> It is not probable that this shell belongs properly either to the genus *Melania* or *Goniobasis,* as those genera are now restricted by the best authorities in conchology; though I have little doubt that it will fall into *Melania,* as defined and understood by those who give greater latitude to genera. It is probable that when its aperture can be seen, it will be found to present characters that would warrant its separation under a new generic name. I suspect indeed, that some others of our fossil-shells of this kind, from the fresh and brackish water-beds of the Rocky Mountain region, will be found to belong to several undefined groups; but until better specimens can be obtained, we can only range them provisionally under the established genera to which they seem to be most nearly allied. Undoubtedly at some future time specimens will be found sufficiently well preserved to enable the paleontologist to classify them more correctly. It seems desirable, however, in the mean time to define them, so that they can be used by geologists in identifying strata, as it may be ages before perfect specimens can be found; while those we now have can be readily identified specifically by their ornamentation and other well-marked characters.

In 1876 White (p. 131) described *Melania larunda* which he later (1883b, p. 95) recognized as a synonym of Meek's *Melania wyomingensis.* At that time he figured two specimens (pl. 28, figs. 6a, b) neither of which appears to be the type now at the U.S.

National Museum and figured herein (Pl. 15, figs. 21, 22). He also made the following comment regarding generic placement (p. 96):

> This description [of *M. wyomingensis*] is drawn mainly from my type specimens of *M. larunda*, because they are much more perfect than Mr. Meek's types are, and more perfect than any others yet discovered. In its aspect and ornamentation this species is so much like an Old World *Melania* that I prefer to assign it to that species rather than to *Goniobasis*, with some forms of which it agrees in general characteristics.

Since these early workers there have been numerous references to these forms but no thorough treatment of the two species assigned to *Pachymelania* has been made. The uncertainty of their assignment has continually been reflected by many competent workers as this statement on *Melania* from Henderson (1935, p. 208) indicates: "Possibly some or all of these species should be assigned to some other genus, if not to some other family." In much of the present literature these forms are referred to as "*Melania*" to signify the generic uncertainty.

As here used, the genus is characterized principally by a deep broad sinus on the outer lip which is not characteristic of either *Goniobasis* or *Melania s.s.* (=*Thiara* in part?). The species included here have a wide geographic range from Canada to New Mexico and possibly into Mexico. *Pachymelania* includes *P. wyomingensis* (Meek) and *P. insculpta* (Meek) with the possibility that *Melania*? *whiteavesi* Stanton and Hatcher, 1905 (= *Goniobasis insculpta* Dawson, 1875, not Meek; *Melania insculpta* Whiteaves, 1885, not Meek) may belong here as well. Stanton and Hatcher's plate 13, figure 5 is suggestive of *P. insculpta*, but no growth lines can be seen to portray the aperture.

Recognition of a Holocene West African genus in the Western Interior Cretaceous without perfect material is not conducive to the greatest degree of confidence. There is some feeling that two genera *Pachymelania* and *Dircella* are present in the Fox Hills material. At present I feel that both North Dakota species here assigned are closely related and I cannot justify recognition of *Dircella*. The possibility that the Fox Hills forms are in fact representatives of an underscribed genus is strong and should be born in mind until more perfect material is collected.

Both *P. wyomingensis* and *P. insculpta* were brackish-water forms and are restricted to deposits in lagoonal facies of the upper Fox Hills Formation where they occur with *Crassostrea.* This *Crassostrea-Pachymelania* assemblage contains, in addition, such genera as *Corbicula, Anomia,* and *Neritina,* but there are never any truly fresh-water members present.

Geologic range. — Maestrichtian — Holocene.

Pachymelania wyomingensis (Meek), 1873 Pl. 14, figs. 19-22

1873. *Melania Goniobasis* (?) *wyomingensis* Meek, U.S. Geol. Sur. Terr., 6th Ann. Rept., p. 516.
1876. *Melania larunda* White, Geol. Uinta Mtns., Powell Rept., pp. 107, 131.
1883. *Melania wyomingensis* Meek, White, U.S. Geog. Geol. Sur. Terr., 12th Ann. Rept., pt. 1, p. 95, pl. 28, figs. 6a, b.
1893. *Melania wyomingensis* Meek, Stanton, U.S. Geol. Sur., Bull., No. 106, p. 42.
1897. *Melania wyomingensis* Meek, Stanton and Knowlton, Geol. Soc. America, Bull., vol. 8, pp. 144, 147.
1905. *Melania? wyomingensis* Meek, Stanton and Hatcher, U.S. Geol. Sur., Bull., No. 257, p. 121.
1935. *Melania wyomingensis* Meek, Henderson, Geol. Soc. America, Spec. Paper, No. 3, p. 210.
1968. *Melania wyomingensis* Meek, Waage, Yale Peabody Mus. Nat. Hist., Bull. 27, p. 128.

Diagnosis. — Shell attaining a rather large size, subterete, or very elongate-conical; volutions about nine or ten, the upper ones flattened-convex, and the lower two or three more prominent; suture well defined but not deep. Surface of upper volutions ornamented by small, regular, rather crowded, and slightly arched vertical costae, crossed by five or six regular revolving lines, that impart to them a granular or minutely nodular appearance; farther down, the vertical costae become less and less distinct, so as nearly or quite to disappear on the lower turns, while the revolving lines become proportionally stronger, especially one a little above the middle of each volution, which develops a revolving row of rather distinct nodes that are compressed from above and below, so as to become sharply prominent on the lower two volutions, thus giving them an angular appearance; though the last one is rounded below this angle. (Aperture unknown.) [Meek, 1873, p. 516].

Discussion. — The diagnosis given above is complete and I see no reason to alter it. The apertural characters are of generic significance and pertain both to this and the succeeding species.

Pachymelania wyomingensis is an "index" to the upper blanket sand unit of the Fox Hills Formation in North Dakota and South Dakota, a unit of wide regional extent deposited in an area of mixed fresh and salt water deposition, as discussed earlier. It occurs also in marine units of the Hell Creek Formation of North Dakota and its equivalent units (Lance) in Wyoming and Colorado. Further discussion will be included with that of *P. insculpta.*

Types. — Holotype (?) USNM 12490; Hypotypes, USGS locality 16002; UND 13449.

Type locality. — "Black Butte Station, Union Pacific Railroad, Wyoming Territory. Upper beds Bitter Creek series" (Meek, 1873, p. 516).

Occurrence. — *P. wyomingensis* occurs associated with the *Crassostrea-Pachymelania* "estuarine" faunule at localities A454, A480, A470, and A601 in a "salt and pepper," medium-grained, moderately indurated sandstone belonging to the upper, unnamed member of the Fox Hills Formation. It also occurs at numerous localities in the marine or brackish facies of the Hell Creek Formation in Morton, Sioux, and Emmons Counties, North Dakota.

Geologic range. — Maestrichtian.

Pachymelania insculpta (Meek), 1873 Pl. 14, figs. 15-18

1873. *Goniobasis? insculpta* Meek, U.S. Geol. Sur. Terr., 6th Ann. Rept., p. 515.
1876. *Goniobasis insculpta* Meek, White, Geol. Uinta Mtns., Powell Rept., p. 101.
1879. *Melania insculpta* Meek, White, U.S. Geog. Geol. Sur. Terr., 11th Ann. Rept., p. 221.
1883. *Melania? insculpta* Meek, White, U.S. Geog. Geol. Sur. Terr., 12th Ann. Rept., p. 94.
1910. *Melania insculpta* Meek, Stanton, Amer. Jour. Sci., 4th ser., vol. 50, p. 179.
1914. *Melania insculpta* Meek, Calvert, *et al.,* U.S. Geol. Sur., Bull., No. 575, p. 14.
1935. *Melania? insculpta* Meek, Henderson, Geol. Soc. America, Spec. Paper, No. 3, p. 208.
1968. *Melania* cf. *insculpta* Meek, Waage, Yale Peabody Mus. Nat. Hist., Bull. 27, p. 128.

Diagnosis. — Shell terete, or elongate-subconical, volutions apparently about ten, convex, or sometimes flattened-convex, increasing gradually in size; last one not much enlarged, and without an angle around the middle, sometimes slightly concave above in large specimens; suture well defined; aperture unknown. Surface ornamented by distinct, regular, nearly straight, or slightly arched vertical costae, about sixteen of which may be counted on each volution, while crossing these are smaller, regular, deep, revolving furrows that cut each rib into little transverse nodes, which, from the obsolescence of the vertical costae on the lower part of the last turn, become more or less continuous revolving lines on that part of the shell. [Meek, 1873, p. 515.]

Discussion. — All of the taxonomic conditions and morphologic variation that pertain to *P. insculpta* also hold for *P. wyomingensis.* The two are often found together, consequently the paleoecologic and paleogeographic comments above are similar and will not be repeated here.

It appears to me that there is yet some confusion, or lack of understanding, between *Pachymelania wyomingensis* and *P. insculpta* as figured herein. All except figure 17 are illustrations of U.S. National Museum types. In every way the sculpture of *P. insculpta* is identical with that on the early whorls of *P. wyomingensis* yet some attain a size as large as, or larger than, many spinose specimens of that species. It is possible that a complete series between the two forms exists, or that these specimens represent sexual or ecotypic variations of a single species.

To complicate this I have specimens of *P. insculpta* on which the ribs are straight with no subsutural opisthocline curve. The straight ribbed variety is not represented among the specimens in the U.S. National Museum collection. Thus, *Pachymelania wyomingensis* has been considered herein to be that form which loses ribs and developes spines on the later whorls, a feature common to the family. *P. insculpta* is considered as the ribbed form lacking spines or tubercles.

Types.—Holotype? (and paratype?) USNM 12491a and b; Hypotype UND 13449.

Type locality.—"Rock Spring, Wyoming, from a little above the main ten-foot bed of coal at that locality. Bitter Creek series" (Meek, 1873, p. 516).

Occurrences.—At localities A454, A470, A480, and A601.

Geologic range.—Maestrichtian.

Superfamily **LITTORINACEA**

Family **LITTORINIDAE**

Genus **SPIRONEMA** Meek, 1864

Type species (by original designation): *Turbo tenuilineata* Meek, 1864, Smithsonian Check-List North American Cretaceous fossils, p. 35.

> *Generic diagnosis.*—Shell turbinate or subovate, thin; spire rather prominent; suture channeled; axis perforated; aperture ovate, not modified by the body-volution above; peristome continuous; outer lip sharp; inner lip thin, not reflexed or flattened below, and only connected with the body-volution toward the upper part of the aperture; umbilical perforation small; surface with revolving lines and furrows. [Meek, 1876, p. 341.]

Remarks.—This monotypic genus was erected by Meek on the basis of a single specimen. It is very close in many ways to *Vani-*

koropsis, a lower spired, thick-shelled form (in the case at least of *V. tuomeyana,* the type species). *Spironema* was said to be distinguishable by its impressed suture, higher, terraced spire, free parietal wall at the umbilicus, descending anterior edge of outer lip, and thin shell. The holotype, USNM 270, is figured on Plate 16, figures 1 and 2 herein. Much of the unique character of this specimen is due to the condition of the sutures. It seems that the terraced appearance and deep sutures are caused in large part by preparation of the specimen and are artifacts of that process. Thus the impressed, or channeled, suture is probably not a good diagnostic character.

Specimens here referred to *Spironema tenuilineata* are done so on the basis of thin shell, tall spire (PA = 70-80 degrees), free anterior portion of the inner lip, and their being anteriorly produced. In these respects they conform to Meek's (1876, p. 342) description. Prosopon appears to be variable and close to that of *Vanikoropsis* making it less diagnostic. Further discussion of these genera will be found in the consideration of *Vanikoropsis* below.

Spironema tenuilineata (Meek and Hayden), 1856 Pl. 15, figs. 1-3

1856. *Turbo tenuilineatus* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 64.
1864. *Spironema tenuilineata* (Meek and Hayden), Meek, Smithsonian Check-List North American Cretaceous fossils, pp. 19, 35.
1876. *Spironema tenuilineata* (Meek and Hayden), Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 342, pl. 32, figs. 9a, b, c.

Diagnosis. — Shell obliquely subovate, comparatively thin; spire forming about half the entire length, apparently rather acute at the apex; volutions about five and a half, prominently convex, last one rounded and somewhat produced below; surface marked with fine lines of growth, which are crossed by stronger, irregular, revolving lines, about equaling the grooves between; much finer, obscure, revolving striae may also sometimes be seen by the aid of a magnifier, upon and between the larger lines. Aperture a little oblique, very nearly ovate, but a little straighter on the inner than the outer side; umbilicus small. [Meek, 1876, p. 342.]

Discussion. — As mentioned above the "excavated" suture and ornament are probably not diagnostic of this species. One other form *S. perryi* from the "Nacotoch Sand" of Texas was described by Stephenson (1941, p. 273). He distinguished the two species by the following comparison:

> Compared with *Spironema tenuilineata* Meek and Hayden, from the Fox Hills formation of the Western Interior, this shell is smaller, the spiral ribs are fewer, more regular, and more widely spaced, the suture is less deeply impressed, and the umbilicus is more nearly closed.

If a moderate variation of the prosopon of Meek's species is later demonstrated this species of Stephenson may prove to be synonymous with S. *tenuilineata.* This species has not been reported from North Dakota before.

Types. — Hypotype UND 902.

Type locality. — Fox Hills Formation along the Moreau River of South Dakota.

Occurrence. — Taken from concretions at locality A469 in the Trail City (?) Member where they are common along with *Vanikoropsis nebrascensis.*

Geologic range. — Maestrichtian.

Superfamily **RISSOACEA**

Family **SYNCERATIDAE**

Genus **SYNCERA**? Gray, 1821

Type species (by monotypy): *Nerita (Syncera) hepatica* (Gray), 1821, London Medical Repository, vol. 15, p. 239.

> *Generic diagnosis.* — Shell minute, turbinate or biconic. Whorls feebly or not at all convex. Surface usually smooth except for incrementals. Aperture holostomous, obliquely ovate or elliptical, angulated posteriorly, broadly and smoothly rounded anteriorly. Outer lip thin, sharp, simple. Inner lip formed by a heavy glaze that washes the parietal wall and reinforces the pillar. Umbilicus closed, or narrowly crescentic; the umbilical keel, if present, subacute or narrowly obtuse. [Gardner, 1947, p. 602].

Remarks. — The status of *Syncera* Gray is in some doubt. Thiele (1935, p. 169) made it a questionable synonym of *Assiminea* (Leach), Fleming, whereas Wenz (1938) considered it a nude name and placed it in synonmy with *Assiminea.* The latter usage is not well documented and seems drastic since Gardner (1947) quoted a portion of Gray's description of the animal. To compound the problem further, Wenz assigned eight subgenera to *Assiminea,* none of which seems to be in the sense of *Syncera* Gray as used by Gardner. Because I am comparing the Fox Hills form to *Syncera* as used by Gardner (1947), particularly as illustrated on her plate 57, figure 9, I am using the genus in the sense of her diagnosis as given above.

My material superficially resembles several Upper Cretaceous forms. It might be confused with members of *Creonella, Pyramidella, Tiberia,* and *Lacrimiforma* if good detail of the columella were lacking. All these genera possess one or more plaits, whereas the columella of *Syncera* is smooth. *Odostomia* Fleming is very close in form, but generally lacks a complete parietal and columellar glaze of callus encircling the entire appressed portion of the aperture as is present on the North Dakota material. Some *Odostomia* (*sensu* Wenz, 1938) also possess a parietal fold high on the columella, again not characteristic of *Syncera.*

Syncera ? sp. Pl. 15, figs. 21, 22

Material. — One specimen with early whorls missing and anterior portion of outer lip broken away. Slightly more than three whorls are preserved. No columellar plaits are visible and the entire shell except the aperture is filled by grains of fine sand. The shell is 2.6 mm high and 1.6 mm in maximum width.

Discussion. — This small shell, if correctly placed, represents the first record of *Syncera* from the Fox Hills Formation. There seem to be no other Cretaceous species comparable to it. Several small forms such as *Lacrimiforma secunda* from the Ripley Formation are similar, but as mentioned earlier all bear plaits on the columella contrary to the North Dakota specimen.

It is probable that the Fox Hills material represents an undescribed species, but additional, more complete material will be necessary before erection of a new taxon can be justified. Preservation of such a delicate specimen in the sandstone was fortuitous and additional material might be rare.

Types. — Figured specimen UND 13480.

Occurrence. — The shell was collected from butte-capping sandstone beds cropping out on Sibley Buttes at locality A454. It is from the top of the Fox Hills Formation.

Geologic range. — Maestrichtian.

Superfamily **STROMBACEA**

Family **APORRHAIDAE**

Genus **DREPANOCHILUS** Meek, 1864

Type species (by original designation): *Rostellaria americana*

Evans and Shumard, 1857, Acad. Sci. St. Louis, Trans., vol. 1, p. 42 (not *R. americana* d'Orbigny, 1842).

Generic diagnosis. — Medium-sized high-spired shells with round-sided whorls. Initial sculpture of fine spiral threads. Sculpture of spire commonly dominated by transverse ribs that virtually disappear on body whorl; body whorl sculpture dominated by two or three spiral cords or carinations with upper carination continuous over single narrow upturned spur of the expanded out lip. Anterior canal short to moderate length. [Sohl, 1967a, pp. B11-12.]

Remarks. — This is one of the most frequently observed genera from the marine Upper Cretaceous and Paleocene rocks of the Western Interior. It has been reported widely from the Pierre Shale, Fox Hills, and Cannonball Formations (Meek, 1876; Stanton, 1921; Sohl, 1960, 1967a; Cvancara, 1956; Brinster, 1970) as well as from strata of the Gulf Coast (Stephenson, 1941, 1952). According to Sohl (1967a) the genus is not common in rocks of the Mississippi Embayment and is lacking from the Atlantic Coast rocks of similar age. It is replaced in the latter province by *Anchura* and *Graciliala*. Aporrhaid generic occurrences were summarized by Sohl (1967a, p. B12, Table 2).

Drepanochilus evansi Cossmann, 1904 Pl. 14, figs. 10-13

1857. *Rostellaria americana* Evans and Shumard, Acad. Sci. St. Louis, Trans., vol. 1, p. 42 (*non R. americana* d'Orbigny, 1842).
1860. *Aporrhais americana* (Evans and Shumard), Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 423.
1860. *Aporrhais sublevis* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 178 (misprint *Aporrhais sublevata* appears on p. 428).
1876. *Anchura (Drepanochilus) americana* (Evans and Shumard), Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 324, pl. 32, figs. 8a, b.
1876. *Anchura? sublevis* (Meek and Hayden), Meek and Hayden, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 327, pl. 19, figs. 3a, b.
1879. *Anchura americana* (Evans and Shumard), White, U.S. Geol. Sur. Terr., 11th Ann. Rept., 1877, p. 185.
1885. *Anchura americana* (Evans and Shumard), Whiteaves, Canada Geol. Sur. Contr. Canadian Paleontology, vol. 1, pt. 1, pp. 48-9.
1904. *Arrhoges (Drepanochilus) evansi* Cossmann, Essais de paléoconchologie comparée, No. 6, p. 75.
1921. *Anchura (Drepanochilus) americana* (Evans and Shumard), Stanton, U.S. Geol. Sur., Prof. Paper 128, p. 37, pl. 6, fig. 13.
1938. *Drepanochilus (Drepanochilus) americanum* (Evans and Shumard), Gastropoda, *in* Schindewolf, O. H., Handbuch der Paläozoologie, vol. 6, pt. 4, p. 912, fig. 2683.
1944. *Drepanochilus americanum* (Evans and Shumard), Shimer and Shrock, Index Fossils of North America, p. 497, pl. 203, fig. 24.
1960. *Drepanochilus evansi* (Cossmann), Sohl, U.S. Geol. Sur., Prof. Paper 331-A, p. 100, pl. 11, figs. 23, 26.
1967. *Drepanochilus evansi* (Cossmann), Sohl, U.S. Geol. Sur., Prof. Paper 393-B, pp. B13-14, pl. 3, figs. 10-21.

Diagnosis. — Shell large for genus; body whorl strongly bicarinate, upper carina developing into long upturned pointed canal on flaring outer lip; lip becoming infilled and thickened in old age. Early whorls covered with threads crossing strong, almost evenly opisthocline ribs; on body whorls ribs are lost, seen only as nodes on upper carina, numerous small cords develop over body whorl as well. Pleural angle 25-30 degrees.

Discussion. — Because this is a common form from the Western Interior it has often been cited in the older literature and has thus developed an involved synonymy. It was a junior homonym of *Rostellaria americana* d'Orbigny a problem recognized and corrected by Cossmann in 1904 (p. 75) when he referred the species to *Arrhoges (Drepanochilus) evansi,* retaining Meek's (1864) subgeneric designation. *Arrhoges* as now used is a genus containing species with well-defined ribs on the last whorl and a blunt, broad outer lip to which *D. evansi* does not conform. It remains as the type of *Drepanochilus* which contains several Western Interior species that form a distinct evolutionary group in the midcontinent region. It was recorded from the Cannonball Formation by Stanton in 1921 (p. 37) and is not new to the state; Cvancara (1956) recorded it from the Fox Hills Formation.

Types. — Hypotypes UND 13448, 893, 13455.

Type locality. — "Moreau and Grand Rivers" (Evans and Shumard, 1857, p. 42); this is in the type area of the Fox Hills Formation in South Dakota.

Occurrence. — *D. evansi* is common at two localities; from concretions in the Trail City Member at locality A469 and from fine and medium-grained sandstone of the Timber Lake Member at locality A460.

Geologic range. — Maestrichtian-Paleocene.

Drepanochilus nebrascensis? (Evans and Shumard), 1854 **Pl. 14, fig. 14**

1854. *Rostellaria nebrascensis* Evans and Shumard, Acad. Nat. Sci., Philadelphia, Proc., vol. 7, p. 164.

1860. *Aporrhais nebrascensis* (Evans and Shumard), Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 423.

1876. *Anchura (Drepanochilus) nebrascensis* (Evans and Shumard), Meek (in part), U.S. Geol. Sur. Terr. Rept., vol. 9, p. 326, pl. 13, figs. 5a, b, c (figures questionably assigned to species).

1900. *Anchura nebrascensis* (Evans and Shumard), Knight, Wyoming Univ., Bull. 45, p. 154, pl. 9, fig. 7.

1904. *Arrhoges (Drepanochilus) nebrascensis* (Evans and Shumard), Cossmann, Essais de paléoconchologie comparée, No. 6, p. 77.
1967. *Drepanochilus nebrascensis* (Evans and Shumard), Sohl, U.S. Geol. Sur., Prof. Paper 393-B, p. B17, pl. 3, figs. 1-9.

Type locality. — "Sage Creek, Nebraska [= South Dakota]" (Evans and Shumard, 1854, p. 164).

Diagnosis. — Shells medium to small for genus; body with two strong carinae that lack nodes; ribs numerous, narrow, opisthocline with most flexure on posterior portion. Ridge on inner surface of outer lip close to and parallel with edge. Pleural angle 20 to 23 degrees.

Discussion. — Sohl (1967a, p. B17) discussed this species at some length. He indicated that specimens figured by Meek (1876, pl. 9, figs. 5a-c) appear to have weaker carinae than required and may belong to some undescribed form. Whitfield's (1880, p. 429) specimens assigned to this species were reassigned as *D. obesus* Sohl (1967a, p. B18).

D. nebrascensis is generally accepted as occurring from the *Didymoceras stevensoni* Zone upward to the *Baculites reesidei* Zone in the Pierre Shale of Wyoming and South Dakota (Sohl, 1967a). It has not been previously recorded as high as the Fox Hills Formation. Because the upper whorls of this specimen are masked by matrix, I have questioned my assignment, and thus questioned the provisional stratigraphic range extension beyond the Pierre Shale. If correct this is a new occurrence for the Fox Hills Formation. The *Drepanochilus* sp. of Brinster (1970, p. 42) from the Pierre Shale may be conspecific with it making this a second record from North Dakota.

Types. — Hypotype UND 13454.

Occurrence. — This specimen was taken from fine to medium-grained sandstone of the Timber Lake Member at locality A460.

Geologic range. — Campanian-Maestrichtian(?).

Superfamily **HIPPONIACEA**

Family **VANIKORIDAE**

Genus **VANIKOROPSIS** Meek, 1876

Type species (by original designation): *Natica tuomyana* [*sic*] Meek and Hayden, 1856, p. 270.

Generic diagnosis. — Shell subglobose, thick, and solid; body-volution large; spire depressed; aperture ovate; axis imperforated; outer lip simple, beveled; inner lip closely folded upon, and adhering to, the columella and the body-volution, very little thickened, and not flattened, toothed, notched, or serrated; surface with distinct revolving lines and furrows, and on the body-volution developing strong oblique folds or plications and furrows, parallel to the lines of growth. [Meek, 1876, p. 331.]

Above is Meek's original description of the genus; that below is of Sohl (1967a, p. B22): "Medium-sized thick naticiform shells. Sculpture dominated by strong broad spiral ribbons with transverse sculpture absent or as low and broad collabral rugosities. Umbilicus narrow."

Remarks. — Sohl (1967a) gave a good account of *Vanikoropsis* since Meek erected it in 1876. At that time he placed it in the Vanikoridae. Cossmann (1925) and later Wenz (1938) placed it in the Naticidae due to its supposed lack of an umbilicus. The holotype of *Vanikoropsis tuomeyana,* the type species, is an incomplete specimen with broken aperture, worn spire, and narrow umbilicus. It has coarse growth rugae. On the basis of similarity in shape, thickness of shell, prosopon and possession of a narrow umbilicus, Sohl (1967a, p. B22) assigned *Fossar? nebrascensis* Meek and Hayden (including *Natica ambigua* Meek and Hayden, *Natica haydeni* Cossmann, and *Natica praenominata* Cossmann) to *Vanikoropsis.*

As mentioned in previous discussion *Spironema* has a close resemblance to some forms assigned to *V. nebrascensis.* It appears to be higher spired, have more impressed sutures (an artifact of preparation of the holotype?) and a thin shell. *V. tuomeyana* is partially based on its thick shell. *V. nebrascensis* may have either a thick or thin shell and was originally defined (*Natica? ambigua* Meek and Hayden, 1856, p. 64) as having "thin lips." Both thin- and thick-shelled forms appear now to be included in *Vanikoropsis.* My illustration on Plate 16, figures 4, 5 is of a hypotype (Sohl, 1967a, pl. 5, figs. 14, 17) from the Fox Hills Formation in South Dakota identified by Sohl as *V. nebrascensis.* It is a thick-shelled, high-spired form. With a thinner shell and a complete aperture, it would compare well with the holotype of *S. tenuilineata* on Plate 15, figures 1, 2 herein.

Vanikoropsis is based on a single specimen of *V. tuomeyana* and has been expanded in the sense of Sohl by his Pierre Shale and Fox Hills forms of *V. nebrascensis. Spironema* is based on poorly defined material with shell thickness a principal character. If shell thickness and spire height should prove to be factors of sexual dimorphism after suitable material is found, *Spironema tenuilineata* will be a junior synonym of *Natica*? *ambigua* (= *Vanikoropsis nebrascensis*), based on previous pagination. If, as well, *V. nebrascensis* belongs in *Vanikoropsis* with *V. tuomeyana* (known from a single specimen) as Sohl assigned it, all must be assigned to the first defined genus based on a valid species — in this case *Vanikoropsis* (Meek, 1876, p. 331). Both *Spironema* and *Vanikoropsis* need to be redescribed on the basis of new material. These remarks have been aimed at that necessity but material for such redescription is not available.

Geologic range. — Late Campanian-Maestrichtian.

Vanikoropsis nebrascensis (Meek and Hayden), 1856 Pl. 15, figs. 4-7

1856. *Natica? ambigua* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 64 (*non* Morris and Lycett, 1854).
1860. *Fossar? nebrascensis* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 423.
1864. *Vanikoro ambigua* (Meek and Hayden), Meek, Smithsonian Misc. Coll., vol. 15, p. 18.
1876. *Vanikoro ambigua* (Meek and Hayden), Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 330, pl. 19, figs. 12a-d.
1880. *Vanikoro ambigua* (Meek and Hayden), Whitfield, U.S. Geog. Geol. Sur. Rocky Mtn. Region, p. 430, pl. 12, fig. 14.
1899. *Natica haydeni* Cossmann, Rev. critique paléozoologie, vol. 3, No. 3, p. 36.
1920. *Natica praenominata* Cossmann, Rev. geologie, vol. 1, No. 1, p. 69.
1925. *Vanikoro ambigua* (Meek and Hayden), Cossmann, Essais de paléoconchologie comparée, No. 13, p. 165.
1967. *Vanikoropsis nebrascensis* (Meek and Hayden), Sohl, U.S. Geol. Sur., Prof. Paper 393-B, p. B22, pl. 5, figs. 1, 5-10, 12, 14, 17.

Diagnosis. — Spire high and pleural angle low for genus. Transverse rugae uncommon. [Sohl, 1967a, p. B22.]

Discussion. — The synonymy of this species has been, and will continue to be, complicated. The following quotation from Sohl's (1967a, p. B23) excellent summary is complete:

> The synonymy of *Vanikoropsis nebrascensis* is complex. The combination *Natica ambigua* of Meek and Hayden (1856) is a homonym preoccupied by Morris and Lycett (1851) for a Jurassic species. In 1860, Meek and Hayden reassigned their species to *Fossar,* but as they pointed out, *Fossar ambigua* was preoccupied and they substituted the name *nebrascensis.* However, Meek in 1864 and later in 1876 reassigned the species to *Vanikoro* and resurrected the original name *ambigua.* This designation held until 1899 when Cossmann pointed out the homonymy of the original combination *Natica? ambigua* and substituted the name *Natica haydeni.*
>
> In 1920, Cossmann again pointed out that *Natica? ambigua* Meek and Hayden was a homonym of Morris and Lycett's species. Cossmann evidently forgot his previous substitution of *Natica haydeni* and pro-

posed the new name *Natica praenominata*. Later in 1925, Cossmann in his "Essais" again reassigned the species placing it in *Vanikoroa* (pro *Vanikoro*) and accepted the original name *ambigua*. In my opinion the first substituted name *nebrascensis* must stand for the species, and Cossmann's subsequent substitutions are invalid.

Because this species seems to contain both thick- and thin-shelled forms I earlier expressed concern that it, in part at least, may be synonymous with *Spironema tenuilineata*. Thickness is not always a useful character even at the specific level, and I have tried to assign specimens without prejudice as to thickness. The result included a variety of both forms in *V. nebrascensis*. There are no rugose forms that might suggest *V. tuomeyana* in the fauna. Several species, including two British Columbian forms, *V. suciensis* White and *Vanikoro pulchella* Whiteaves are probably not properly assigned (Sohl, 1967a, p. B22). At present, *Vanikoropsis* appears to be an endemic genus in the Pierre, Fox Hills, and equivalent faunas of the Western Interior where it remains poorly understood. After restudy of western Canadian material it may be shown to have northern affinities.

Types.—Hypotypes UND 13432 and USNM 132665.

Type locality.—The area of Glendive, Montana, on the Yellowstone River, 150 miles above its mouth; probably from the Pierre Shale.

Occurrence.—Specimens were taken from concretions in the Trail City Member at locality A469 and from concretionary sandstone of the Timber Lake Member at locality A677.

Geologic range.—Upper Campanian-Maestrichtian.

Superfamily **NATICACEA**

Family **NATICIDAE**

Subfamily **NATICINAE**

Assignment of Fox Hills genera.—Naticids are numerous from marine late Mesozoic and Cenozoic strata throughout the world. Nearly all of them look superficially alike when, as fossils, they lack characteristic colorations and opercula. Wrigley summed up the causes for many taxonomic problems in the family in 1948 (p. 10) as follows:

> The study of Tertiary fossil Naticidae is especially difficult for several reasons. Although specimens are abundant enough to show the

> range of specific variation, they differ slightly in their modes of preservation and in the degree to which they have been worn or corroded. In sandy strata like the Oldhaven and Blackheath beds sutural corrosion is almost universal, converting a moderately conic species into an apparently turreted one in a most deceptive way. Colour, which is so helpful in the discrimination of living species, is nearly always lacking in fossils and Naticids are almost without the specific sculpture found in so many other groups of gastropoda. If a large number of Recent Naticid shells, including many juveniles, were bleached and mixed it would be no easy task to classify them correctly. Sexual differences have been reported in Naticid shells, the females being less flat-sided or conic and more turreted than the smaller males, by having to accommodate a large egg sac, with a resultant swelling near the suture. I have not found this idea always helpful with fossils, for it sometimes leads to the absurdity of finding all the males of a supposed species living aeons before or after the females.

I have not condensed Wrigley's phraseology because I feel the British tendency for understatement characterizes the treatment of this group since its earliest recognition.

Present discussion revolves around four genera of import to the Fox Hills Formation and correlative units. These include *Polinices, Lunatia, Euspira,* and *Natica.* I am excluding *Gyrodes* and *Amauropsis* because they were not found in this study and are readily recognized when found.

The earliest comprehensive account of *Natica* that I have examined is the 1921 description by Harmer (p. 672) of Crag (Pliocene) forms. Species he referred to *Natica* possessed a calcareous operculum and some had an open umbilicus whereas in others it was covered by callus of the inner lip. He considered *Lunatia* Gray, 1847, a subgenus of *Natica* comprising those forms with non-calcareous opercula, many of which formerly had been in *Naticina* Guilding, 1834. The following was his feeling in regard to the concept of *Polinices* (p. 672): "A few Crag species are grouped with *Polinices,* more largely used in America, confined by P. Fischer to oval and elongated shells having the umbilicus closed by the funicular callosity." *Polinices* too was treated as a subgenus. *Euspira* was not considered.

Cossmann in 1925 was unclear in his usage since he described *Natica s. l.* with a calcareous operculum yet his subgenus *Polinices* (p. 125) was diagnosed with a corneous operculum, the latter also possessing one or more umbilical funicles. *Lunatia,* again a subgenus, was characterized as having an open umbilicus unlimited by callus formation within (p. 132). He considered *Euspira* to be a synonym of *Ampullina* as stated below (p. 133):

> C'est pourquoi, je ne puis admettre que *Lunatia* soit un Sous-Genre de *Polynices* [*sic*], comme l'a propose M. Dall (1908, Albatros Exped., t. II, p. 333) qui—en même temps—a fait une autre erreur en remplacant *Lunatia* par *Euspira* Ag. (1842, non 1837) interpretation à laquelle je ne puis me rallier, puisque le véritable *Euspira* est synonyme d'*Ampullina,* ainsi que je l'ai démontre ci-dessus.

Wenz (1944) erected two subfamilies, Polinicinae and Naticinae. The former had corneous opercula and an umbilical boss, or strong funicle, covering the umbilicus. *Lunatia* and *Euspira* were treated as genera of the Polinicinae and Naticinae respectively.

Gardner (1947) was aware of the problems produced by the large number of fossil naticids. Treating *Natica* and *Polinices* as distinct genera she (p. 549) distinguished them clearly by the following single paragraph summary: "The shell characters of *Polinices* are similar to those of *Natica;* however, the operculum of *Polinices* is corneous, and that of *Natica* is calcareous." She did recognize Cossmann's error in rejecting *Euspira* but she was not willing to place it in synonymy with *Lunatia,* although she acknowledged their similarity.

Wrigley (1948) made the following statement regarding *Euspira* and *Lunatia*:

> This genus [*Euspira*] is used for fossil species which resemble the living *Lunatia* Gray, 1847, which could be treated as a synonym of *Euspira,* except for the consideration that the animal of a living species is, or can be known, while that of a fossil is not [!] (p. 14).

He did, however, define and draw particular attention to umbilical structures in the family. *Natica* in Wrigley's sense consists of

> ". . . species whose umbilicus has a well defined middle plug which is present at all stages of growth. The known opercula are calcareous with a double rim at the outer periphery and a finely serrated edge on the columellar side [p. 11]."

In diagnosing *Euspira* (p. 14) he said, "There is a rear lobe and sometimes a middle lobe, but they are not continuously produced [during maturation?] so that no true umbilical plugs are present." There is no diagnosis given for *Polinices* but forms which he refers to that genus have a filled or nearly filled umbilicus.

Natica and *Polinices* at the generic level were distinguished by

Olsson, *et al.* (1953) in a manner similar to that of Wrigley with the added note that *Polinices* has a corneous operculum.

Sohl in 1960 placed both *Polinices* and *Euspira* in the Naticinae, explaining their differences as follows:

> *Euspira* differs from *Polinices* primarily by having an abutted or impressed rather than appressed suture, as well as being globose in outline instead of ovoid. Other differences rest in the filling of the umbilicus by callus, which in *Polinices* is usually complete [p. 121].

With regard to *Euspira* and *Lunatia* it is laudable, indeed, to note that after more than one hundred years of supposition and hedging by malacologists and paleontologists Sohl finally declared flatly ". . . I believe the names to be synonymous." He further attempted to define Western Interior species of *Euspira* in 1967(a).

This summary of four principal naticid genera is taxonomically superficial. The synonymies of nearly all are complex almost to absurdity and are discussed under the respective genera below. As many as 100 genera of naticids appear in the literature, many have fossil representatives as well as living ones. Most of the type species have been variously assigned to two or more genera, many to three or four. Opercula are seldom preserved and are thus poor taxonomic characters for paleontologic study. Sexual dimorphism is common. The naticid genera *Polinices*, *Euspira* (= *Lunatia* Gray), and *Natica* must be classified solely on conch morphology on the basis of numerous specimens where sexual differences are clearly documented. For that reason generic and specific taxonomy herein is based on that of Wrigley and of Sohl as used above.

Genus **EUSPIRA** Agassiz (*in* J. Sowerby), 1838

(= *Lunatia* Gray, 1847 = *Labellinacca* Cossmann, 1919)

Type species (by subsequent designation of Dall, 1915): *Natica glaucinoides* J. Sowerby, 1812.

> *Generic diagnosis.*—Medium- to large-sized globose shell, with abutting to impressed sutures; umbilicus open and small to medium sized and lacks a funicle. [Sohl, 1960, p. 122.]

Remarks.—The complex systematics of *Euspira* resulted partially from Cossmann's (1919) misinformation regarding the first date of Agassiz's publication of *Euspira* and partly from the refusal of many workers to place *Lunatia* and *Euspira* in synonymy without opercula being present, even after Cossmann's error was recognized. His 1919 erection of *Labellinacca* for Agassiz's forms was unnecessary, yet he continued to compound it in 1925 as I quoted earlier. Sohl summarized the history of Western Interior species of *Euspira* in 1960 and reassigned many forms in 1967(a).

This is one of the most common genera present in Upper Cretaceous rock units representing near shore depositional conditions. It is very common in the Gulf Coast, Mississippi Embayment, and Western Interior of North America. There are three species positively identified from Fox Hills rocks and a fourth is here questionably assigned. Western Interior species seem to reflect migratory routes from the south but several species easily tolerated whatever "boreal" climatic conditions may have existed in North Dakota Maestrichtian seas.

Euspira rectilabrum (Conrad), 1858 Pl. 15, figs. 8-11

1858. *Natica (Lunatia) rectilabrum* Conrad, Acad. Nat. Sci., Philadelphia, Jour., 2d ser., vol. 3, p. 334, pl. 35, fig. 28.
1923. *Lunatia carolinensis* Conrad, Stephenson, North Carolina Econ. Geol. Sur., vol. 5, p. 356, pl. 88, figs. 17, 18 [not 19].
1926. *Polinices (Euspira) halli* (Gabb), Wade, U.S. Geol. Sur., Prof. Paper 137, p. 163, pl. 56, figs. 11, 12.
1941. *Polinices rectilabrum* (Conrad), Stephenson, Texas Univ. Bull. 4101, p. 276, pl. 50, figs. 1, 6.
1955. *Polinices rectilabrum* (Conrad), Stephenson, U.S. Geol. Sur., Prof. Paper 274-E, p. 125, pl. 21, figs. 10-12.
1960. *Euspira rectilabrum* (Conrad), Sohl, U.S. Geol. Sur., Prof. Paper 331-A, p. 122, pl. 17, figs. 5-7, 12-14; Sohl, 1967, U.S. Geol. Sur., Prof. Paper 393-B, p. B27.

Diagnosis. — Shell medium-sized, subglobose, with impressed suture; whorls slightly shouldered; inner lip straight, thickened expanding into thickened pad of callus; umbilicus well defined, moderately narrow. Pleural angle 75-90 degrees. (Modified from Sohl, 1960, p. 122).

Discussion. — *E. rectilabrum* was discussed in detail by Sohl (1960, pp. 122-3) at which time he recorded several synonyms including *Lunatia halli* Gabb, *Lunatia carolinensis* Conrad, 1875, as figured by Stephenson (1923, pl. 88, figs. 17, 18, not 19), and *Polinices rectilabrum texanus* Stephenson. Stephenson (1941) assigned *E. rectilabrum* to *Polinices,* a position that cannot be justified because that genus is considered to possess a full or partial umbilical plug. The holotype of *Lunatia halli* in my opinion is a large specimen of *E. rectilabrum,* similar to my figures 9 and 10 on Plate 16. I concur with Sohl's other assignments as well.

In 1960 Sohl noted that this species was very common in a molluscan fauna containing many species predated upon by borers, but its shell was never bored. This same fact is strikingly true in Fox Hills units where *E. rectilabrum* is common. His suggestion (p. 124) that *E. rectilabrum* was a primary predator of many molluscan species is probably true.

This is the first record of *E. rectilabrum* from the Fox Hills Formation. An internal mold from the Pierre Shale was assigned to the species by Brinster (1970, p. 49, pl. 1, fig. 24) but it is high-spired and may be a male *E. obliquata.*

Types. — Hypotypes UND 13443 and UND 13479.

Type locality. — Owl Creek Formation at Owl Creek, Tippah County, Mississippi.

Occurrence. — This species has been collected from the Timber Lake Member at localities A455, A457, A465, A466, A467, A460, A462, and A474.

Geologic range. — Campanian-Maestrichtian.

Euspira obliquata (Hall and Meek), 1856 Pl. 15, figs. 12-15

1856. *Natica obliquata* Hall and Meek, (not Deshayes, 1866), Amer. Acad. Arts Sci., Mem., vol. 5, p. 389, pl. 3, figs. 1a,b.
1856. *Natica concinna* Hall and Meek, Amer. Acad. Arts Sci., Mem., vol. 5, p. 389, pl. 3, figs. 2a-d.
1856. *Natica moreauensis* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 64.
1860. *Natica (Lunatia) moreauensis* Meek and Hayden, Meek and Hayden Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 422.
1876. *Lunatia concinna* (Hall and Meek), Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, pp. 314, 315, pl. 32, figs. 11a-c.
1880. *Lunatia concinna* (Hall and Meek), Whitfield, U.S. Geog. Geol. Sur. Rocky Mtn. Region, p. 430, pl. 12, fig. 13.
1921. *Lunatia obliquata* (Hall and Meek), Stanton, U.S. Geol. Sur., Prof. Paper 128-A, p. 35, pl. 6, figs. 10a, b.
1925. *Crommium (Amauropsella) concinna* (Hall and Meek), Cossmann, Essais de paléoconchologie comparée, No. 13, p. 45.
1925. *Natica (Lunatia) concinna* (Hall and Meek), Cossmann, Essais de paléoconchologie comparée, No. 13, p. 134.
1960. *Euspira concinna* (Hall and Meek), Sohl, U.S. Geol. Sur., Prof. Paper 331-A, p. 123.
1967. *Euspira obliquata* (Hall and Meek), Sohl, U.S. Geol. Sur., Prof. Paper 393-B, p. B25, pl. 1, figs. 12-19.

Diagnosis. — *Euspira* with rather broad umbilicus, thin parietal callus, globose whorls with poorly defined shoulders. Pleural angle generally large (80-110 degrees). Sexual dimorphism produces males with taller spires (lower pleural angles).

Discussion. — This *Euspira* is also common in the Fox Hills fauna. As used herein it includes *Natica concinna* Hall and Meek and *N. moreauensis* Meek and Hayden which were determined to be synonyms of *E. obliquata* by Sohl in 1967a (p. B25). I have examined the holotype of *N. moreauensis* and hypotypes of *E. obliquata* at the U.S. National Museum and believe there is enough variation in the species to support Sohl's action. Meek in 1876 recognized the similarity between *Natica concinna* and *N. moreauensis* and placed them in synonymy. He felt (p. 315) that *Lunatia obliquata* was still distinct because his specimens had a "well-defined opercular groove along the columella, not seen in the original *E. concinna*. . ." According to Sohl the holotypes of both species are immature forms. Formation and preservation of the columellar groove, is not constant, and, after seeing the large amount of variation in this and other *Euspira* species, I am not surprised that these synonymous forms were described.

I have not found *E. obliquata* in the same outcrops with *E. rectilabrum.* It does occur in a thanatocoenosic accumulation with *E.? dakotensis.* Several shells of *E. obliquata* show naticid borings and at one locality many young snails appear to have been peeled open by some crustacean or other predator. In areas where it was preyed upon, it appears to have been populous.

E. obliquata occurs throughout the Western Interior in the Pierre, Bearpaw, and Clagget Formations and in the Bearpaw Shale of Canada (Sohl, 1967a, p. B28). It also is reported from the Fox Hills Formation of North Dakota (herein), South Dakota, and Colorado and was found by Stanton (1921) in the Cannonball Formation (Paleocene) of North Dakota. It seems to be close to *Polinices harrisii* Gardner, 1933 as figured on her plate 26, figure 15, from the Midway Group of Texas.

Types. — Hypotypes UND 13481, and UND 13482.

Type locality. — "Great Bend of the Missouri. From clay beds of division No. 4 [Pierre Shale] of section" (Hall and Meek, 1856, p. 315).

Occurrence. — This species occurs in concretions of the Trail

City Member at locality A469 and in very fine sand matrix at localities A460 and A480.

Geologic range. — Campanian and Maestrichtian-Paleocene.

Euspira subcrassa (Meek and Hayden), 1856 Pl. 15, figs. 19, 20

1856. *Natica subcrassa* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 87.
1860. *Natica (Lunatia) subcrassa* Meek and Hayden, Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 422.
1876. *Lunatia subcrassa* (Meek and Hayden), Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 316, pl. 39, figs. 3a-c.
1921. *Lunatia subcrassa* (Meek and Hayden), Stanton, U.S. Geol. Sur., Prof. Paper 128, p. 36, pl. 6, figs. 11a, b.
1967. *Lunatia subcrassa* (Meek and Hayden), Sohl, U.S. Geol. Sur., Prof. Paper 393-B, pl. 1, figs. 22-26.
1967. *Natica* [?] *subcrassa* (Meek and Hayden), Sohl, U.S. Geol. Sur., Prof. Paper 393-B, p. B25.

Diagnosis. — Thick-shelled, ovate, *Euspira* with large pleural angle (110 degrees) and sutures little impressed; lip thick, parietal callus strong but umbilicus clearly exposed; whorls generally with subshoulderal indentation of varying strength.

Discussion. — Meek and Hayden's (1856) original description mentioned strong growth lines causing imbricating wrinkles on the whorl surface but these are not characteristic of Fox Hills specimens in North Dakota and probably should not be considered diagnostic of the species.

The synonymy is brief, probably because the species ranges westward where less work has been done rather than to the east and south where faunas are better studied. Its brevity should not be deceiving as the species has been assigned to all the "usual" genera save *Polinices*. Meek in 1876 was first to perceive its probable correct assignment making the following cautious statement (p. 317): "It is possible that the names of this and the preceding species may have to be changed to *Euspira subcrassa* and *E. occidentalis;* that is, if *Euspira* is made to replace *Lunatia,* as already suggested." Hesitation to assign this species to *Euspira* was entirely justified and is summarized well by the following statement of Sohl's from his list of reassigned naticid species (1967a, p. B25):

> Subsequent authors have consistently assigned this species to *Lunatia.* The best preserved specimens of this species show a conspicuous shouldering of the whorl, a subshoulder constriction of the whorls, and a sharp-edged inner lip callus that evanesces anteriorly. These features are not typical of either *Euspira* or *Natica.*

I have here assigned this form to *Euspira* without hestitation for several reasons. *Natica* requires a funicle in the umbilicus (and a calcareous operculum). The thick shell is a response to environmental as much as biological factors. The subshoulderal constriction is not constant and may reflect sexual variation. *E. subcrassa* was a form inhabiting very shallow, perhaps estuarine, active environments as its presence in the characteristic faunule from this environment was shown to demonstrate earlier in this report.

The potential value of *E. subcrassa* in stratigraphic work was also shown earlier. It is a principal constituent of the fauna in the Colgate lithofacies and in the upper, unnamed, blanket sandstone, often incorrectly called "Colgate," at the top of the formation. It carried through into the Cannonball Formation as an endemic species in the Western Interior.

Types. — Hypotype UND 13442.

Type locality. — "Mouth of Judith River, on the Upper Missouri, where it occurs with other Cretaceous fossils in beds elsewhere found to hold a position at the horizon of the top of the Fox Hills group" (Meek, 1876, p. 317). According to Stanton, in 1921, (p. 87) and Sohl (1967a, p. B25) this locality is in the Clagget Shale.

Occurrence. — All specimens were taken from the unnamed or Colgate Members at localities A454, A611, A617, A625, A626, A627, A643, A701, A706, A684.

Geologic range. — Maestrichtian-Paleocene.

Euspira? dakotensis (Henderson), 1920 Pl. 15, figs. 16-18

1856. *Natica occidentalis* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 64.

1860. *Natica (Lunatia) occidentalis* Meek and Hayden, Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 422 (not Hall, 1845).

1876. *Lunatia occidentalis* (Meek and Hayden), Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 315, pl. 32, figs. 12a, b, c.

1920. *Natica dakotensis* Henderson [= *Natica (Lunatia) occidentalis* Meek and Hayden], Nautilus, vol. 33, p. 122.

1967. *Euspira? dakotensis* (Henderson), Sohl, U.S. Geol. Sur., Prof. Paper 393-B, p. B27.

Diagnosis. — Shell obliquely ovate; spire rather elevated; volutions four and a half to five, convex, and separated by a very distinctly defined suture; surface marked by fine lines of growth, crossed by numerous, fine, obscure, minutely flexuous, revolving striae; aperture obliquely ovate, nearly straight on the inner side, widest and rounded below, subangular above; outer lip sharp; inner lip slightly thickened, and a little reflexed on the body-volution above the small umbilical perforation. [Meek, 1876, pp. 315, 316.]

Discussion. — This species was known only from the holotype which is illustrated herein on Plate 16, figures 16, 17. Henderson pointed out in 1920(a) that *Natica occidentalis* Meek and Hayden was preoccupied by *Natica? occidentalis* Hall, 1845, which he felt was actually a fresh-water Tertiary species. Henderson (p. 122) proposed *N. dakotensis* to replace the homonym *N. occidentalis.*

This species is high-spired and somewhat thin-shelled when compared with other *Euspira.* It shows no parietal callus over the inner lip as is characteristic of the genus. The shell is smooth, ornamented with very fine threads and a secondary, faint, spiraling rugosity which may be a function of preservation. The fine threads are visible on my material whereas the rugosity is not. Sohl (1967a) realized that the spire and lip characters of *E.? dakotensis* were not consistent with the generic traits of *Euspira* but noted (p. B25) that "It appears to be closest to *Euspira* in most characters. . ."

Some of my specimens were examined earlier by Cvancara (1956) and were termed *Lunatia occidentalis* (=*Natica dakotensis*). I agree entirely with that identification of the North Dakota material although apertural characters are not visible.

My reference of these specimens to *Euspira? dakotensis* modernizes Cvancara's identification. It also indicates the same hesitation as Sohl's in assignment to *Euspira.* This is only the second reported occurrence of the species and its apertural traits are still too poorly known to warrant unquestioned placement.

Types. — Hypotype UND 890.

Type locality. — "Moreau River, [South] Dakota; from the Fox Hills group of the Upper Missouri Cretaceous series" (Meek, 1876, p. 316).

Occurrence. — All specimens are from the Trail City Member at locality A469 where they occur in concretions.

Geologic range. — Maestrichtian.

Superfamily **TONNACEA**

Family **CYMATIIDAE**

Genus **SEMITRITON** Cossmann, 1903

Type species (by original designation): *Plesiotriton dennanti,* Tate, Cossmann, 1903, Essais de paléoconchologie comparée, No. 5, p. 102, pl. 5, fig. 11.

Generic diagnosis. — Shell fusiform, with extremely obsolete varices, or none; aperture elongate, canal short, poorly developed, nearly straight, not markedly twisted. Outer lip feebly bordered, with denticulate interior; inner lip little callused, bearing two strong, oblique, median plaits on columella. Whorls convex with suture slightly impressed. Protoconch typically tritonoid. (Translated from Cossmann, 1903, p. 102 and slightly modified).

Remarks. — Cossmann erected *Semitriton* to hold *Plesiotriton dennanti* Tate which did not belong to that genus due to lack of callus wash on the columellar border and its broad, non-tapering and non-twisted anterior canal. His figure of *Semitriton dennanti* is nearly identical in every detail to the species here referred to *Semitriton* except it is about twice the size of the Cretaceous species. The author distinguished his genus from *Epidromus* and *Hilda* in the following manner:

> On ne peut rapprocher *Semitriton* d'*Epidromus* à cause de son dernier tour pus grand, ni de *Hilda* à cause de ses plis columellaires; comme j'en possède trois échantillons plus ou moins intacts, je ne pense pas que l'absence de bord columellaire soit le résultat de ce que ces individus net sont pas complètement adultes. [Cossmann, 1903, p. 103].

This is the first report of *Semitriton* from North America though several forms, particularly some in *Caveola* Stephenson (1941, p. 363), should be referred to this genus.

Semitriton buccinoides (Meek and Hayden), 1856 Pl. 16, figs. 1-3

1856. *Fasciolaria buccinoides* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 67.
1876. *Fasciolaria buccinoides* Meek and Hayden, Meek, U.S. Geol. Sur. Terr., vol. 9, pp. 358-359, pl. 1, figs. 8a, b, c, d.
1901. *Mazzalina buccinoides* (Meek and Hayden), Cossmann, Essais de paléoconchologie comparée, No. 4, p. 51.
1967. "*Fasciolaria*" *buccinoides* Meek and Hayden, Sohl, U.S. Geol. Sur., Prof. Paper 393-B, p. B29.

Diagnosis. — Shell small, rather short-fusiform; spire moderately elevated, composed of five to five and a half convex volutions; last turn somewhat gibbous, forming more than half the entire length, and contracting rather abruptly below into the rather short canal; suture distinct or slightly channeled; surface ornamented by fine, regular lines of growth, with sometimes small, obscure, vertical folds, which are crossed by rounded, little revolving bands or raised lines, equal to, or slightly broader than, the depressions between; on these bands, as well as in the intervening depressions, faint traces of very fine revolving striae may sometimes be seen by the aid of a lens; aperture narrow-oval, angular above, and tapering below; outer lip thin, but apparently thickened and crenulate within, at intervals of about three or four times to each turn of the spire; columella a little twisted, and provided

> with two well-defined, oblique plaits, that are so far around as not to be clearly seen when the aperture is filled with rocky material that cannot be removed. [Meek, p. 358.]

Discussion. — Meek and Hayden (1856a) and later Meek (1876) referred this species to *Fasciolaria.* This species does not possess the characters of that genus. It was assigned to *Mazzalina* Conrad by Cossmann in 1901 (p. 52) apparently on the basis of a photograph supplied to him by Stanton. No doubt the photo did not reveal the denticulate outer lip. In 1903 when he erected *Semitriton,* Cossmann referred no other species to the genus indicating that he had either forgotten this species, or that the photograph did not reveal its complete character.

In 1967(a) Sohl (p. B29), as part of his discussion of *Trachytriton vinculum,* made the following comments with regard to "*Fasciolaria*" *buccinoides*:

> Cossmann (1901, p. 51) assigned that species [*F. buccinoides*] to *Mazzalina* of the Fasciolariidae. It approaches that genus in several characters, but it has two columellar plications that are constant in strength and placement. More significantly there are nodes and teeth on the parietal wall and denticulations on the inner surface of the outer lip (pl. 6, figs. 5, 9) that were not noted by Meek. These features suggest placement of "*Fasciolaria*" *buccinoides* in the Cymatiidae of the Tonnaca [*sic*] rather than in the Fasciolariidae.

Although Sohl's higher assignments were certainly correct he made no suggestion of generic placement and there is no indication that he had any particular genus in mind.

I had originally intended to include the Fox Hills material in Stephenson's genus *Caveola,* but upon examination of earlier literature, it became apparent that these specimens were referrable to *Semitriton. Caveola* contains forms that do not belong there as Sohl (1964, p. 269) believed, and most of its species, including the type, should be referred to *Semitriton.*

The relationship of these two genera is important paleogeographically. *Semitriton* (= *Caveola* in part) is a geologically old genus, occurring in the Texas Upper Cretaceous. It has southern origins and does not seem to have reached the Western Interior until the appearance of *Semitriton buccinoides* in the Fox Hills Formation. North Dakota is probably close to the northern range of this group which does not seem to have Canadian relatives.

Because Meek (1876) recorded this species from Long Lake, I consider it to have been previously reported from North Dakota.

Types. — Hypotypes UND 933 and UND 13459.

Type locality. — "Moreau and Fox Hills" [South Dakota] (Meek and Hayden, 1856, p. 67.)

Occurrence. — In concretions at locality A469. Free on outcrop, A465.

Geologic range. — Maestrichtian.

Order NEOGASTROPODA

Suborder STENOGLOSSA

Superfamily **BUCCINACEA**

Family **MELONGENIDAE**

Genus **RHOMBOPSIS** Gardner, 1916

Type species (by original designation): *Fusus newberryi* Meek and Hayden, 1857, Acad. Nat. Sci., Philadelphia, Proc., vol. 9, p. 139.

> *Generic diagnosis.* — Pyriform shells of medium size, whorls moderately shouldered and posteriorly constricted to a broad subsutural collar or inclined ramp; aperture sublenticular, produced anteriorly to a moderately long, rather straight, siphonal canal; sculpture of discontinuous collabral ribs and numerous spiral lirae or cords. [Sohl, 1964, p. 198.]

Remarks. — Meek and Hayden described three species from the Western Interior including *Fusus newberryi, Fusus subturritus,* and *Fusus intertextus* which seemed to be closely related and which Meek (1864, p. 22) later placed in Conrad's genus *Pyrifusus.* Not convinced of their exact relationship to *Pyrifusus,* yet satisfied of their kinship with each other, Meek (1876, p. 344) divided *Pyrifusus* into two subgenera, *Pyrifusus* [*s.s.*] and *Neptunella,* the latter containing the Western Interior species.

Neptunella Meek was preoccupied by *Neptunella* Gray, 1853. For that reason Gardner (1916, p. 456) proposed the name *Rhombopsis* to replace it. In his monograph of the Upper Cretaceous gastropods of Tennessee and Mississippi, Sohl (1964) followed her precedent, recognizing *Pyrifusus* and *Rhombopsis* as distinct genera, with the latter, however, having a higher spire, lacking a strong posterior notch, and having a more sinuous growth line.

Sohl (pp. 198-9) further considered *Rhombopsis* to be closely allied to *Deussenia* if *R. orientalis* Wade is included in *Rhombopsis.* I have examined most of the types concerned in this discussion and typologically *Deussenia* and *Rhombopsis* do not appear closely related, because of ornament, posterior notch differences, subsutural collar distinctions, and differences in degree of straightness of the anterior canal. It should be noted that neither *R. subturritus* nor *R. intertextus* agree closely with the type species, as both have higher spires than *R. newberryi.* At present there is no genus known to me into which they might better be placed.

Rhombopsis subturritus (Meek and Hayden), 1857 Pl. 16, figs. 4-6

1857. *Fusus subturritus* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 9, p. 139.
1864. *Pyrifusus subturritus* (Meek and Hayden), Meek, Smithsonian Check-List N. American Cretaceous Fossils, p. 22 [not seen].
1876. *Pyrifusus (Neptunella) subturritus* (Meek and Hayden). Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 347, pl. 32, figs. 3a, 6.
1926. *Rhombopsis subturritus* (Meek and Hayden), Wade, U.S. Geol. Sur., Prof. Paper 137, p. 142.

Diagnosis. — Shell medium (2.5-4.5 cm) height and spire high for the genus, pleural angle approximately 53 degrees, shoulder angular, noded with approximately 12 elongated nodes; whorls lacking defined ribs on slopes; broad posterior ramp and marked anterior constriction producing nearly flat-sided appearance of last whorl; shell covered by broad ribbons, generally faint on anterior and posterior slopes.

Discussion. — Preservation of the prosopon and aperture of the material at hand is somewhat better than much of the type material. The North Dakota specimens, however, are immature — a factor that made comparison with the types more difficult. My material bears a resemblance to *Boltenella excellans* Wade differing from it only by the absence of both a posterior, subsutural cord and a slight posterior canal from *R. subturritus.*

R. subturritus was recorded only from the upper Pierre Shale of South Dakota by Meek (1876). The report herein, therefore, represents an extention of its range upward into the Fox Hills Formation and northward into North Dakota.

Types. — Hypotypes UND 13444, and UND 13440.

Type locality. — "Upper part of No. 4 [Pierre Shale], near Grand River [South Dakota]." (Meek and Hayden, 1857, p. 139).

Occurrence. — All specimens were taken from locality A480 from The Trail City Member.

Geologic range. — Maestrichtian.

Family FASCIOLARIIDAE

Subfamily FASCIOLARIINAE

Genus GRAPHIDULA Stephenson, 1941

Type species (by original designation): *Graphidula terebriformis* Stephenson, 1941, Texas Univ. Bull. 4101, p. 345, pl. 66, figs. 13, 14.

Generic diagnosis. — Medium-sized, slender, elongate, fusiform shells with spire usually longer than aperture; aperture lanceolate, posteriorly angulate; canal elongate and straight or curving slightly left. Pleural angle 20-35 degrees. Columella generally with one moderately strong plait at maturity, up to four plaits present in youth on some species. Prosopon ornate to plain, of either ribs or ribbons or both. (Modified from Sohl 1964, p. 211 and 1967a, p. B31.)

Remarks. — This genus, along with the closely related genus *Piestochilus* Meek, is common in the Upper Cretaceous rocks of the Gulf Coast and Western Interior. The two genera contain within them several as yet poorly understood groupings of species which, due primarily to lack of material, remain perplexing in the discussion of Pierre and Fox Hills gastropod faunas. They probably hold valuable stratigraphic and paleoecologic significance that can only be understood following a complete revision of both *Graphidula* and *Piestochilus* based on new collections from the Western Interior. Sohl (1964, p. 211) has begun to unravel them.

As used here *Graphidula* contains two species from the Fox Hills Formation of North Dakota, neither of which were assigned to the genus by their authors. All three remained assigned to *Fasciolaria* (*Piestochilus*) since 1876 until Sohl (1964) made his revision based upon *Graphidula terebriformis* Stephenson from the Nacatoch Sandstone of Texas.

The original description of *Graphidula* implied small apical angles (25 degrees) and two weak plaits on the columella. These traits are characteristic of some species assigned by Meek (1876) to *Fasciolaria* (*Piestochilus*). Sohl (1964) divided *Piestochilus* placing *P. culbertsoni*, *P. alleni*, and *P. cretacea* in *Graphidula* and leaving *P. scarboroughi*, the type species of *Piestochilus*, on the basis of its wider apical angle (45 degrees).

Without examination of numerous specimens of species in this genus, some of which are rare, I am obliged to follow the work of Sohl as latest reviser. I have collected two species of *Graphidula*, *G. culbertsoni* and *G.? cretacea* from North Dakota. The latter of these is of doubtful placement. In 1964 Sohl placed *Piestochilus cretacea* in *Graphidula* with doubt, due most probably to its possession of four plaits, whereas the type species has only two such plaits. In apical angle and ornament this species conforms to Stephenson's concept of the genus. Some hesitancy is justified with regard to this assignment, and future studies with more material may clarify its placement in the *Graphidula* group.

The full paleogeographical, paleoecological, and stratigraphic significance of the *Graphidula* group, or groups, cannot yet be deciphered due to lack of basic occurrence and systematic data. Sohl (1967b, pp. 10-11) considered that at least two species groups, a southern group and a northern, *Graphidula culbertsoni* group, are present in late Campanian and Maestrichtian rocks, and he considered the latter group to have migrated to the south. This may well be; nevertheless, the genus as now understood appears well developed in late Campanian rocks of the Gulf Coast, having forms distinct from those of the northern Western Interior. I would suggest that if *G. culbertsoni* and allied forms did push southward, they represented a re-invasion by a modified species group derived earlier from southern stock. There is the suggestion that *G. culbertsoni* may be related to *Piestochilus laevigatus* Nagao of Japan (Sohl, 1967b, p. 9) which might contradict my interpretation, or might reflect some other migratory route. No similar form has, to my knowledge, been recorded from the approximate correlative strata of Vancouver Island or northern California where other "boreal" forms from the Fox Hills fauna seem to have existed. Regardless of the veracity of this hypothesis it should be clear that better understanding of this and the genus next discussed will contribute much to our understanding of migratory routes and molluscan faunal provinces.

Graphidula culbertsoni (Meek and Hayden), 1856 Pl. 16, figs. 7, 8

1856. *Fusus culbertsoni* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 66.

1857. *Fusus haydeni* Evans and Shumard, Acad. Sci. St. Louis, Trans., vol. 1, p. 41.

1876. *Fasciolaria (Piestochilus) culbertsoni* (Meek and Hayden), Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 360, pl. 32, figs. 1a-f, text fig. 44.
1879. *Fasciolaria (Piestochilus) culbertsoni* (Meek and Hayden), White, U.S. Geol. Geog. Sur. Terr., 11th Ann. Rept., p. 185.
1901. *Cryptorhytis (Piestochilus) culbertsoni* (Meek and Hayden), Cossmann, Essais de paléoconchologie comparée, No. 4, p. 59, text-fig. 18.
1964. *Graphidula culbertsoni* (Meek and Hayden), Sohl, U.S. Geol. Sur., Prof. Paper 331-B, p. 211.
1967. *Graphidula culbertsoni* (Meek and Hayden), Sohl, U.S. Geol. Sur., Prof. Paper 393-B, p. B31, pl. 7, figs. 21-24, 29-31.

Diagnosis. — Shell large for the genus with whorls slightly to highly round-sided and with transverse ribs restricted to earlier growth stages. Pleural angle 25 degrees.

Discussion. — This is a common species in both the Pierre Formation and Fox Hills Formations of the Western Interior. It shows a great deal of morphologic variation. Several comments (Sohl, 1967a, p. B31) in this regard are noteworthy.

> The holotype . . . from the Fox Hills Sandstone is decidedly atypical. It possesses strong transverse ribs at a much later stage than most specimens. More typically, transverse ribs are restricted to only the first few whorls or may not be present at all. . . .
>
> The plaits of the columellar surface also vary. Near the aperture all specimens have only one weak plication; however, a range from none to three or four plaits may occur on the very earliest whorls. These variations all occur within suites of specimens from the same locality.

An additional variation is also present. The specimen shown herein on Plate 17, figure 7 shows two whorls of a robust form with constricted posterior slopes and slightly impressed sutures. Some specimens from locality A469 are yet more inflated than this. An unillustrated specimen, UND 13483, is a flat-sided form from the Pierre Shale at Glendive, Montana. On that specimen there is essentially no posterior constriction and sutures are not impressed. A third form, not illustrated, found in Fox Hills concretions on Whitehorse Ridge, South Dakota, has a very well-developed posterior constriction affecting a broad area of posterior half of each whorl and producing a marked ventricose appearance for the anterior half. In this variation, the holotype appears to lie between the flat-sided form and the highly-constricted, robust form. I have no doubt that a complex relationship is represented in this species as now broadly understood. It occurs widely in Montana, North Dakota, South Dakota, Wyoming, and Colorado (Sohl, 1967a, p. B32). Further studies of numerous examples from these areas will certainly show some specific or subspecific differentiation based on stratigraphic or ecotypic variation within *G. culbertsoni.*

Types. — Hypotypes UND 919, UND 921, and UND 13483.

Type locality. — "Moreau River [South Dakota]; from the Fox Hills group of the Upper Missouri Cretaceous series" (Meek, 1876, p. 362).

Occurrence. — This species is common in concretions at locality A469. It also occurs at locality A467 in sandstone. These localities represent collections from both Trail City Member and Timber Lake Member of the Fox Hills Formation.

Geologic range. — Maestrichtian. ". . . ranging from the *Baculites baculus* zone of the Pierre Shale through the Fox Hills Sandstone. . ." (Sohl, 1967a, p. B32).

Graphidula? cretacea (Meek and Hayden), 1856 Pl. 16, figs. 9-11

1856. *Fasciolaria cretacea* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 66.
1876. *Fasciolaria (Piestochilus) cretacea* (Meek and Hayden), Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 363, pl. 31, fig. 11a, b.
1964. *Graphidula cretacea* (Meek and Hayden), Sohl, U.S. Geol. Sur., Prof. Paper 131-B, p. 211 [assigned with doubt].

Diagnosis. — Shell small, fusiform; spire of five or six, moderately convex whorls, and about half the height of the shell. Columella slightly twisted, bearing four or five linear, oblique plaits which are not exposed when aperture is viewed directly. Ornament of ribbons and fine growth lines only. Pleural angle 29 degrees.

Discussion. — The specimens here described seem definitely to belong to *Fasciolaria cretacea* Meek and Hayden. I have questioned their generic assignment to *Graphidula* to which they conform in all characters excepting the number of plications on the adult columella. Sohl's (1964) assignment of this species to *Graphidula* was made with doubt for the same reason, but no more satisfactory placement is readily available.

It is possible that possession of four or five plaits is a juvenile character of the genus that is retained to maturity in this particular species. As noted above from Sohl's (1967a, p. B-31) comments, the juvenile whorls of *G. culbertsoni* often possess three or four plaits in their earliest stages, a fact which lends some credence to the idea. Further work is required to solve the problem. At present I follow Sohl's usage.

This is the first record of the species from North Dakota. It appears to be a form endemic to the Fox Hills Formation inasmuch as records do not list it, or even other closely related forms, from equivalent rocks of other areas. Small size and the rather delicate shell may have resulted in poor preservation or in its being overlooked during collection in these areas.

Types. — Hypotypes UND 13467 and UND 13466.

Type locality. — "Moreau River [South Dakota]; from the Fox Hills group of the Upper Cretaceous series" (Meek, 1876, p. 364).

Occurrence. — From silty sandstone of the Timber Lake Member at locality A460.

Geologic range. — Maestrichtian; as presently known, restricted to the Fox Hills Formation.

Genus **PIESTOCHILUS** Meek, 1876

Type species (by original designation): *Fusus (Pleurotoma?) scarboroughi* Meek and Hayden, 1857 [1858], Acad. Nat. Sci., Philadelphia, Proc., vol. 9, p. 139.

Generic diagnosis. — Fusiform shells of medium-size with convex whorls; columella with one or two strong plaits not visible from aperture. Sculpture generally of strong, collabral ribs and ribbons, the former occasionally subdued. Pleural angle 35 to 50 degrees.

Remarks. — The close relationship of *Piestochilus* to *Graphidula* has already been remarked upon in discussion of the latter. At first glance there would appear to be less complication in the present concept of *Piestochilus* after Sohl's (1964) revision of the two genera. This is not the case. Meek's original diagnosis is as follows:

> Shells of small size, with spire and canal produced; volutions flattened or moderately convex and finely spirally straited, sometimes with vertical folds; plait or plaits of columella not exposed in a direct view into the aperture, very oblique, and occupying a higher position than in either of the foregoing; outer lip smooth within. [Meek, 1876, p. 356.]

This broad definition includes such forms as *P. culbertsoni* and *P. cretacea* which Sohl referred to *Graphidula*. Meek designated *Fusus scarboroughi* Meek and Hayden as the type of *Piestochilus*. In his description of that species later in the same work (Meek, 1876, p. 359) he made no mention of columellar plaits, yet on plate 32, figure

4a he illustrated a specimen of *P. scarboroughi* with two good columellar plaits. I have seen the specimen, and it is as he illustrated.

Sohl (1964, p. 214) in his diagnosis of *Piestochilus*, stated that the columella bears one strong plait, a contradiction according to Meek's specimen and probably a misstatement, since *P. curviliratus* discussed on the same page, was said to have two plaits. Sohl's generic distinction was based principally upon whorl shape and apical angle by the following statement: "The columellar placement of these forms [*Piestochilus scarboroughi* and *Graphidula culbertsoni*] is similar and a distinction is only feasible on the basis of shape" (Sohl, 1964, p. 211). He quantified his shape values in 1967(a) (p. B31) when he indicated that *Graphidula* had an apical angle of 20-25 degrees whereas *Piestochilus* had an apical angle of 45 degrees. I have altered his diagnosis in each case to include forms that are at variance with his. As both genera are here understood, the columellar plaits are more nearly specific than generic characters, although they apparently may even vary within a species as in the case of *Graphidula culbertsoni*.

I have tried to follow usage of apical and pleural angles as the primary difference between these genera. At present Fox Hills forms here referred to *Graphidula* or *Piestochilus* probably represent four distinct species groups, but poor preservation and lack of large numbers of specimens prohibit further delineation of taxa at this time.

Two other species are recognized, *P. curviliratus* (Conrad) from the Ripley Formation and *P.? levis* Stephenson from the Kemp Clay of Texas. Other forms referred to *Piestochilus* were reassigned by Sohl (1964, p. 211) to various genera.

Piestochilus scarboroughi (Meek and Hayden), 1857 Pl. 16, figs. 12-14

1857. *Fusus (Pleurotoma?) scarboroughi* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 9, p. 139.
1876. *Fasciolaria (Piestochilus) scarboroughi* (Meek and Hayden), Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 359, pl. 32, fig. 4a, b, c, d.
1964. *Piestochilus scarboroughi* (Meek and Hayden), Sohl, U.S. Geol. Sur., Prof. Paper 331-B, p. 211.
1964. *Piestochilus scarboroughi* (Meek and Hayden), Sohl, 1967, U.S. Geol. Sur., Prof. Paper 393-B, p. B31.

Diagnosis. — Shell fusiform, of medium size, large specimens may reach 6.0 cm in height and 2.3 cm in width; whorls slightly convex, last whorl having a slight posterior constriction visible below the suture when outer lip is viewed dorsally. Curving of collabral growth lines reflect this trend; other prosopon of ribbons about as wide as interspaces and becoming finer anteriorly onto the rather straight canal. Columella with one or two plaits. Pleural angle about 40 degrees.

Discussion. — This species, while not previously recorded from North Dakota, is the most commonly observed neogastropod and one of the most common gastropods of the fauna. It is characteristic of the Timber Lake Member of the Fox Hills Formation but is not limited to that unit.

Shells of *P. scarboroughi* seem to show a slight variation in size of the last whorl. I predict that a study of many specimens will show a sexual or ecotypic dimorphism in which females will be larger and more swollen than males. Large shell size may be a response to a higher energy environment as well. The range of variation does not approach that mentioned for *Graphidula culbertsoni.*

Types. — Hypotypes UND 13437, UND 13441, and UND 13458.

Type locality. — "Butte au Gres, on the Missouri River [South Dakota]; in the Fox Hills group of the Upper Missouri Cretaceous series" (Meek, 1876, p. 360).

Occurrence. — This species was collected from concretionary sandstone ledges and concretions in the Timber Lake Member at localities A460, A462, A465, A479, A677, A719, and A720.

Geologic range. — Maestrichtian, presently restricted to the Fox Hills Formation.

Piestochilus feldmanni, n. sp. Pl. 16, figs. 15-21

Diagnosis. — Shell fusiform to subfusiform, (holotype approximately 3.8 cm high and 2.1 cm in maximum diameter), with spire nearly straight-sided; aperture sublanceolate. Prosopon of somewhat suppressed ribbons and clear collabral growth lines. Pleural angle varying from about 43 to 50 degrees, apical angle as high as 72 degrees. Columella with one broad plait not seen at the aperture. Protoconch not well known, probably of two smooth whorls.

Description. — This shell is of moderate size, generally subfusiform with straight-sided spire less than one-half shell height, and with last whorl that is ventricose as seen by shape of outer lip of the holotype on Plate 17, figures 15, 16. Sutures covered slightly by posterior portion of each succeeding whorl. Aperture sublanceolate, constricting gently into anterior canal; posterior quite angular. Outer lip broken on types; inner lip moderately callused, smooth. Prosopon of spiral ribbons as typical of the genus, but being subdued on the types; no heavy transverse ornament present, collabral growth lines prosocline, opisthocline, and becoming orthocline in sequence from posterior to anterior on last whorl. Columella strong, slightly twisted, and bearing one broad, low plait about midway along it and not visible from the aperture. The protoconch may be of two smooth whorls.

Material. — I have examined seven specimens of *P. feldmanni* one of which, the holotype, is in good condition. All others are in various stages of destruction, including one specimen which has been freed of outer shell to reveal the entire columella. Measurement for various specimens are given below:

	H	MD	HA	PA
Holotype USNM 180535	3.8 cm	2.1 cm	2.3 cm	45°
Paratype UND 13446	—	1.8	—	47°
Paratype USNM 180536	3.1+	—	—	43°

Discussion. — This species resembles a squat, flat-sided *Piestochilus scarboroughi* in growth line and ornament. It is clearly different from that species because of its generally larger pleural angle, lack of convexity of spire whorls, shorter overall height, and single broad plait on the columella. I am certain that it has been confused with *P. scarboroughi* in the past. As an example, at least one of the specimens illustrated by Waage (1968, pl. 12, fig. B) is probably *P. feldmanni* rather than *P. scarboroughi,* though I have not examined the specimen personally. *P. scarboroughi* is often cited as occurring in the Bullhead Member when most of these occurrences are probably *P. feldmanni,* the former species occurring predominately in the sandy facies of the Timber Lake Member.

The possibility that these two species are merely ecotypic morphotypes was considered and rejected on the basis of the several distinct differences noted above. The question of existence of several closely related species competing for the same niche in violation of

Gause's principle is not pertinent because *P. feldmanni* is clearly an inhabitant of siltier, quieter areas, less frequented by *P. scarboroughi. Graphidula culbertsoni* occupied yet deeper offshore waters and is more common in the Pierre Shale and lower concretion zones of the Fox Hills.

The species superficially resembles *P.? levis* Stephenson which also has a single plait. It, however, has convex whorls. I have examined the holotype of Stephenson's species from the Kemp Clay of Texas, and feel it to be distinct from *P. feldmanni.* There are no other forms that resemble *P. feldmanni.*

Etymology. — The species is named in honor of Rodney M. Feldmann who collected the holotype.

Types. — Holotype USNM 180535; Paratypes UND 13446, UND 13447, and USNM 180536.

Type locality. — Silty sandstone units of the unnamed member at locality A480, a roadcut on S. side of gravelled road in the center sec. 26, T. 134 N., R. 71 W., east of Burnstad in Logan County, North Dakota. Specimen from USGS locality No. 5961 (from collections made by T. W. Stanton, June 21, 1909) is included as USNM 180536.

Occurrence. — The UND specimens were collected from the unnamed member at locality A480 whereas the USGS specimens came from, "Shale between two principal beds of Fox Hills sandstone on South side of Grand River 1/2 mile below mouth of Dirt Lodge Creek, S. Dak." according to the field label accompanying the specimens in the USGS collections.

Geologic range. — Maestrichtian.

Piestochilus galpiniana? (Meek and Hayden), 1857 Pl. 16, figs. 22-24

1856. *Fusus galpinianus* Meek and Hayden, [1857], Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 65.
1876. *Fasciolaria (Piestochilus)? galpiniana* (Meek and Hayden), Meek, U.S. Geol. Geog. Sur. Terr., vol. 9, p. 362, pl. 32, figs. 2a, b.

Diagnosis. — Shell unequally fusiform; spire elevated, or apparently slightly exceeding the length of the aperture and canal; suture distinct; volutions about six, slightly convex, upper ones with apparently obscure traces of vertical folds; last or body volution contracting abruptly into the comparatively short, somewhat bent, canal; aperture a little obliquely lance-oval, being acutely angular above, and tapering into the narrow canal below; columella a little twisted and bent below, not showing any plaits externally; surface marked by regular, revolving, somewhat flattened, lines, a little wider than the linear furrows between them, and more or less strong lines of growth, that show by their curves that the outer lip is broadly sinuous above. [Meek, 1876, p. 362.]

Discussion.—I have given Meek's diagnosis of *P. galpiniana* because it is the most recent in the literature and my specimens can add nothing to it. When Sohl (1964) made his reassignment of members of *Piestochilus* and *Graphidula* he deferred on this species noting that it probably did not belong in either genus. This is probably the case based on the bent canal and uncertain occurrence of columellar plaits. I do not have material of sufficient quality to erect a new genus, and there does not appear to be a related genus already established. The low (28-32 degrees) apical angle is more suggestive of *Graphidula.* Rather than refer my material to that genus, an action unjustified by its condition, I have elected the conservative alternative of retaining Meek's (1876) assignment until such time as good material may warrant a change.

If my specimens are indeed *P. galpiniana,* this is the first documented occurrence of it in North Dakota. On Plate 17, figures 23, 24 I have illustrated the holotype (USNM 287) to enhance Meek's diagnosis as given herein.

Occurrence.—Taken from concretions at locality A689.

Types.—Holotype USNM 287; hypotype UND 13439.

Type locality.—"Moreau trading post [South Dakota]; No. 5 of the series" (Meek and Hayden, 1857, p. 65).

Subfamily **FUSININAE**

Genus **HERCORHYNCUS** Conrad, 1868

Type species (by monotypy): *Fusus tippanus* Conrad, 1860, Acad. Nat. Sci., Philadelphia, Jour., 2nd ser., vol. 4, p. 286, pl. 46, fig. 41.

Generic diagnosis.—Fusiform shells with a spire a little less than one-third total shell height. Whorls peripherally swollen, constricted above a tuberculated shoulder that is of variable strength, and rather strongly constricted below sinus on base of body. Ornament consists of coarse transverse ribs that are strongest at the shoulder but that die out below on periphery and on collar above; spiral ornament weak on collar, strong below. Aperture posteriorly notched, anteriorly drawn out to a narrow elongate siphonal canal; outer lip crenulate; inner lip rather heavily callused with an umbilical chink developing opposite the beginning of the siphonal canal. [Sohl, 1964, p. 220.]

Remarks.—*Hercorhyncus* is one of several Campanian and Maestrichtian genera including *Haplovoluta* Wade, *Euthriofusus*

Cossmann, and *Boltenella* Wade that appear to be closely related. These have been variously assigned as subgenera of *Euthriofusus* (Cossmann, 1925, p. 249; Wenz, 1944, p. 1247) and *Afer* Conrad (Wenz, 1944, p. 1306); the latter was a poor assignment based, no doubt, on the equally poor figure (p. 1306, fig. 3723) available to him.

Stephenson (1941, pp. 321-323) described five new species of *Hercorhyncus* from the Navarro Group of Texas. In his study of the Ripley, Owl Creek, and Prairie Bluff faunas, Sohl (1964, p. 220) discussed these assignments and concluded that two, *H. coronale* and *H. vadosum* were synonyms of *H. tippanus* (Conrad) and a third, *H. mundum,* was reassigned to *Pyrifusus.* As earlier workers had done, Sohl recognized the close affinities of *Hercorhyncus* and *Haplovoluta* Wade. He felt that the significant differences between them were at the subgeneric level and thus proposed *H. (Hercorhyncus)* for forms resembling *Hercorhyncus s.s.* and *Hercorhyncus (Haplovoluta)* for forms with well-developed, transverse prosopon, ornamented basal sulcus, and a wider umbilical chink as exhibited by *Haplovoluta bicarinata* Wade.

Subgenus **HAPLOVOLUTA** Wade, 1918

Type species (by original designation): *Haplovoluta bicarinata* Wade, 1918, Amer. Jour. Sci., 4th Ser., vol. 45, p. 334.

Diagnosis. — Fusiform shells with spire slightly less than one-third total shell height. Columella of medium to narrow thickness, twisted left; umbilical chink poorly to moderately well developed; anterior sulcus weak to moderate. Prosopon dominated by nodose peripheral carinae.

Hercorhyncus (Haplovoluta) hollandi, n. sp. Pl. 17, figs. 1, 2

Diagnosis. — A delicate *Hercorhyncus* with narrow umbilical chink; approximately 18 strong nodes per whorl on each of three ill-defined carinae, with entire whorl uniformly overlain by fine spiral cords. Anterior sulcus poorly developed; anterior slope with four well-defined spiral cords.

Description. — A fusiform shell, (holotype measures 4.12 cm high, 2.5+ cm wide), with pleural angle of the holotype varying from 85 degrees in early whorls to 80 degrees after approximately 4½ whorls. Spire about one-third total shell height with robust whorls constricting posteriorly toward suture and anteriorly into a fairly narrow canal, twisted to the left. Posterior notch present but missing from the holotype. Outer lip unknown, probably rather thin and crenulate; inner lip glazed with callus. Umbilical chink not present due to wear, probably very small, originating about 6 mm above tip of canal. Columella smooth. Prosopon of 18 transverse sets of three nodes, the strongest on shoulder of whorl, next strongest slightly more than halfway down, and weakest, though still well defined, set on anterior shoulder of whorl. Whorl uniformly covered by fine cords alternating with yet finer lirae all becoming finer on the sutural collar. Along with this delicate prosopon are four stronger cords dispersed over the anterior slope. Canal also covered by fine spiral prosopon. Growth lines orthocline over the whorl becoming opisthocline on posterior slope. Protoconch smooth, of 2½(?) whorls. Earliest teloconch whorls ornamented with transverse ribs producing nodes beginning on the second teloconch whorl, all but the shoulder nodes being covered by sutural collar of later whorls.

Material. — One well-preserved shell, lacking outer lip.

Discussion. — This species is an important addition to the gastropod fauna of North Dakota and the Western Interior. The genus is a southern one, no species having been previously recorded from the northern midcontinent. Sohl (1967b, p. 34) listed undescribed *Hercorhyncus* from Utah and Wyoming without documentation; these are given as being upper Coniacian to Campanian rather than Maestrichtian.

H. (Haplovoluta) hollandi appears to be a form from a Mississippi Embayment and Gulf Coast lineage that has extended its range northward into the northern midcontinent, offering additional evidence that this area was one of faunal overlap of northern and southern forms. The prosopon of *H. (H.) hollandi* is more conservative for the genus just as North Dakota species of *Amuletum, Pyropsis,* and *Remera*? tend to be, a character that has frequently been attributed to more "boreal" molluscan forms. In fact, in the less developed, ornamented, anterior sulcus, slight umbilical chink, and finer spiral prosopon the species is somewhat atypical of previous concepts of the morphology of the genus and subgenus. The nodes are diagnostic of *H. (Haplovoluta);* the narrower umbilical chink, height of spire and spiral prosopon, are more characteristic of *H.*

(Hercorhyncus). Due to this slight overlap of characters the subgeneric assignment herein reflects my personal judgement which is based on comparison of *H. (H.) hollandi* with types of both subgenera and their contained species in the collections of the U.S. National Museum.

Etymology. — This species is named in honor of F. D. Holland, Jr. — teacher, field companion, and friend.

Types. — Holotype USNM 180534.

Dimensions of holotype. — H = 4.1 cm, MD = 2.5+ cm, PA = 80°.

Type locality. — The exact locality where Feldmann collected the holotype is in slight doubt. It is clearly from the Timber Lake Member. An extra label was found among the specimens associated with this one in the UND collection. It indicated a locality in western Emmons County, North Dakota, where Timber Lake sandstones are commonly exposed. Feldmann (written communication, 1971) indicated independently, that an area in eastern Emmons County was the possible origin for the specimen. My experience would favor the locality implied by the extra label to be more likely than Feldmann's opinion. The exact locality remains undefined.

Occurrence. — Timber Lake Member of the Fox Hills Formation in western (?) Emmons County.

Geologic range. — Late Maestrichtian.

Genus **SERRIFUSUS** Meek, 1876

Type species (by original designation): *Fusus dakotaensis* Meek and Hayden, 1856, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 65.

> *Generic diagnosis.* — Shell short-fusiform; body-volution large, and bi- or tricarinate, with carinae more or less nodose; spire and canal moderate, the latter bent and more or less twisted; outer lip broadly but slightly sinuous in outline, between the upper carina and the suture. [Meek, 1876, p. 373.]

Remarks. — A review of the status of *Serrifusus* was given by Sohl (1967a, p. B29-30) in which he noted only two other forms that appeared correctly assigned, *S. joaquinensis* Anderson, 1958, and *S. dakotensis* var. *vancouverensis* Whiteaves, 1879, which Sohl felt was ". . . close to the type species." There is apparently also an undescribed *Serrifusus* from Wyoming (Sohl, 1967, p. 30). Sohl noted that *Serrifusus* has a western distribution, and I would add, probably northern as well, since related forms seem absent from Gulf Coast faunas.

Serrifusus dakotaensis (Meek and Hayden), 1856 Pl. 17, figs. 3, 4

1856. *Fusus dakotaensis* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 65.
1860. *Fusus (Neptunea) dakotensis* [*sic*] Meek and Hayden, Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 421.
1876. *Fusus? (Serrifusus) dakotensis* [*sic*] Meek and Hayden, Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 374, pl. 31, fig. 11; pl. 32, figs. 6a, c.
1876. *Fusus? (Serrifusus) goniophorus* Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 375, pl. 32, fig. 7a, b(?).
1879. *Serrifusus dakotensis* [*sic*], var. *vancouverensis* Whiteaves, Geol. Sur. Canada, Mesozoic Fossils, vol. 1, pt. 2, p. 119, pl. 15, fig. 5.
1901. *Serrifusus dakotensis* [*sic*] (Meek and Hayden), Cossmann, Essais de paléoconchologie comparée, No. 4, p. 8, pl. 7, fig. 7.
1941. *Fusinus (Serrifusus) dakotensis* [*sic*] (Meek and Hayden), Wenz, Gastropoda, *in* Schindewolf, O. H., Handbuch der Palaozoologie, vol. 6, pt. 5, p. 1262, fig. 3594.
1945. *Fusus dakotensis* [*sic*] Meek and Hayden, Morgan and Petsch, South Dakota Geol. Sur. Rept. Inv. 49, pl. 5, fig. 4; pl. 6, fig. 4.
1958. [?] *Serrifusus vancouverensis* (Whiteaves), Anderson, Geol. Soc. Amer., Mem. 71, p. 171.

Diagnosis. — "Strongly bicarinate whorls covered by finer spiral lirations." [Sohl, 1967a, p. B30.]

Discussion. — The specific name as used herein is spelled in the form as used in the original description of the species. The label on the holotype bears this spelling (in Meek's handwriting?) as well. He subsequently misspelled the specific name as "dakotensis" in 1860 and 1876. Sohl (1967a) in his synonymy cited the original spelling in this incorrect manner as well. According to the Code of Zoological Nomenclature, the original spelling must stand unless there is clear evidence of a copying or printing error in the original citation. Because the label of the holotype bears the same spelling as the original description, I assume that the authors' intent was to name the species "*dakotaensis*." In 1860 and thereafter Meek apparently forgot his original spelling and adopted the incorrect form as have others. There is no mention of an intentional emendation to the spelling in any of these references. For that reason all subsequent incorrect spellings must be considered "incorrect subsequent spellings" and can have no standing in the nomenclature.

Whiteaves (1879, pp. 119-20, pl. 15) illustrated a form which, as Sohl (1967a, p. 29) acknowledged, is close to the type species. In fact, as synonymous with this form Whiteaves listed a taxon which

Meek (1876, pp. 375-6) also felt to be different from his type. Meek termed it a varietal difference without making a nomenclatural designation but stated (p. 376) that, if it were later found to be a distinct species, it be designated "*Fusus? (Serrifusus) goniophorus.*" Whiteaves' figure is of a mature specimen whereas Meek's figure of the varietal form is of an immature shell (which I have examined), yet they are essentially identical. They both differ from the holotype by having a more complete posterior carina rather than one interrupted by nodes, perhaps a slight sexual dimorphism or a true subspecific difference.

Anderson (1958, p. 117) elevated Whiteaves' form to specific rank with the following comment: "This form is specifically distinct from Meek's genotype, though congeneric with it, and may represent the same age, namely early Maestrichtian." He neither illustrated new material nor made any attempt to justify or clarify this decision; for this reason I have left Whiteaves' form synonymous with that of Meek.

Regardless of the level of difference it should suffice to say that there is a form of *Serrifusus* common to both the Maestrichtian of North Dakota and the Upper Cretaceous (Maestrichtian?) rocks of the Vancouver Island area of British Columbia.

Another species, *Serrifusus joaquinensis* Anderson, 1958, is apparently valid (Sohl, 1967a, p. B29). It appears to represent an expansion of the posterior carina with concurrent loss of other carinae. Anderson said (p. 172): "In general form and ornamentation it is a southern analogue of, and is correlative with its congener [*S. vancouverensis*] described above."

S. dakotaensis has been reported from the Fox Hills Formation in North Dakota by Sohl (1967a).

Types. — Figured herein is the holotype, USNM 256.

Type locality. — Fox Hills Formation on the Moreau River, South Dakota.

Occurrence. — In concretions with *Cucullaea* at locality A462 Timber Lake Member, Fox Hills Formation, Sioux County, North Dakota.

Geologic range. — Maestrichtian.

Genus **REMERA** Stephenson, 1941

Type species (by original designation): *Remera microstriata*

Stephenson, 1941, Univ. Texas Bull. No. 4101, p. 344, pl. 65, figs. 3, 4.

Generic diagnosis. — Medium-sized fusiform shells having spire more than half the height of the shell; whorls generally flat-sided more rarely rounded; anterior canal moderately long and very slightly twisted; posterior canal lacking. Aperture lenticular to lanceolate, angulated posteriorly; inner and outer lips smooth, not thickened, columella smooth. Prosopon of collabral, transverse ribs and pronounced ribbons which become somewhat subdued when crossing ribs.

Remarks. — This genus strongly resembles *Exilia* Conrad, 1860. To this extent a note on the status of the genera *Exilia* and *Remera* is in order here. I have not seen the holotype of *E. pergracilis,* though I have seen several *Remera.* Conrad's original description of *E. pergracilis* appears below as quoted from Harris (1896, p. 90).

> Narrow-fusiform; volutions twelve, convex, with slightly curved, numerous, narrow ribs, and fine closely-arranged revolving lines; spire rather longer than apeture, first two whorls smooth; beak perfectly straight, minutely striated to the extremity.

No mention was made of a posterior notch on the type although this was described by Stewart (1927, p. 419). The notch may be indicated by the faint prosocline bend of the ribs on the posterior slope in Harris' figure (pl. 9, fig. 1). The outer lip of Harris' specimen is incomplete, and Stewart's conclusions may be unjustified. The presence or absence of this notch is crucial because it is a major factor in familial assignment and, therefore, generic placement. Lacking the notch *Exilia* might easily be placed in the Fasciolariidae whereas its presence causes the assignment to the Turridae as Stewart did. If *Exilia* is not notched, it may well be a fasciolarid making *Remera* most certainly a junior synonym of *Exilia.* Comparison of types is in order.

Other species referred to *Exilia,* namely *E. microptygma* (Gabb) and *E. diaboli* (Gabb) from California appear closely related to *Remera.* They each have spiral prosopon (a continuation of the ribbons from the anterior slope?) on the inner lip of the columella but this does not appear strong enough in Stewart's (1927, pl. 27, fig. 6a; pl. 39, fig. 10a) figures to obviate both from inclusion in *Remera.* They seemed to lack a posterior notch. It is possible that the diagnosis given above should be expanded yet further to encompass stronger columellar ornament as well.

Remera? cvancarai, n. sp. Pl. 17, figs. 7, 8

Diagnosis. — *Remera* with rounded whorls and broad ribs, and strong ribbons, coarsest on the shoulder and only slightly subdued where crossing ribs.

Description. — Incomplete holotype 17.5+ mm high and with maximum width of 6.2 mm. Height of last whorl 1.0 cm. Shell fusiform of at least five whorls, pleural angle approximately 30 degrees. Sutures slightly impressed; aperture lanceolate tapering rapidly into moderately long, slightly twisted canal. Inner lip smooth, thin, with some underlying prosopon showing through; outer lip missing, probably thin and simple. The columella appears to be smooth. Prosopon of broad, collabral, axial ribs which fade on the anterior slope; numerous flat-topped spiral ribbons (13 on penultinate whorl of the holotype) separated by grooves about half the ribbon width. Ribbons covering last whorl to tip of canal, coarsest across shoulder of each whorl with insertion occurring on both anterior and posterior slopes. Protoconch probably trochoid with three smooth whorls.

Material. — One specimen with well-preserved shell material but lacking outer lip, protoconch, and upper 1½ (?) whorls.

Discussion. — It has been exceedingly difficult to place this species with certainty. It conforms to the type of *Exilia* in many ways but is ornamented with ribbons over the entire spire unlike that species, nor does it show the slightest indication of a posterior notch or canal as it should to be allied with *E. pergracilis s.s.* Stewart, 1927. On the other hand the whorls are not nearly so flat-sided nor the axial ribs so strong as on most species of *Remera.*

The above discussion must convey some of my concern for this assignment, although no other genus can easily accommodate this species, and, rather than erect a new genus to hold it, I feel it wiser to modify *Remera* slightly to accommodate *R. cvancarai* which may simply be a more northern member of that predominantly southern genus.

Etymology. — This species is named in honor of Alan M.

Cvancara (pronunciation: Swûn shä rä i) who collected the specimen, and whose example and friendship I value highly.

Types. — Holotype USNM 180533.

Dimensions of holotype. — H = 1.75+ cm, MD = 0.62 cm, PA = 30°.

Type locality. — Concretion zone in base of Fox Hills Formation (Trail City Member) at cut bank exposure on Beaver Creek, Seeman Park, Linton, Emmons Co., N. Dak., SW1/4, SW1/4, sec. 17, T. 132 N., R. 76 W., .75 mi. SE of Linton.

Occurrence. — From concretion at locality A469.

Geologic range. — Maestrichtian.

Genus **CRYPTORHYTIS**? Meek, 1876

Type species (by original designation): *Gladius*? *cheyennensis*, Meek and Hayden, 1860, Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 422 (= *Rostellaria fusiformis* Hall and Meek, 1854, not *R. fusiformis* Pictet and Roux, 1848).

> *Generic diagnosis.* — Medium-sized fusiform shells with posteriorly constricted whorls, a relatively long siphonal canal, and several oblique plaits that occur relatively high on the columella but are not visible at the aperture. [Sohl, 1964, p. 231.]

Remarks. — By Meek's admission the concept of *Cryptorhytis* was uncertain at the time of its designation by virtue of the poor preservation of his original specimens of *C. cheyennensis*. Originally assigned to *Rostellaria* more than twenty years earlier, Meek finally removed enough matrix from the columella to find a plait; therefore he then placed the species in the Fasciolariidae as *Fasciolaria (Cryptorhytis) cheyennensis* (Meek, 1876, p. 356). It was one of two species upon which the subgenus was erected. Since that time the genus has accumulated a remarkable number of ill-defined, poorly preserved, or otherwise "homeless" species, many of them East Coast forms, from which Sohl (1964, p. 231) tried to make some order. The most recent suggestion by Sohl (1967a, p. B33) is that the low columellar plait, columellar constriction, and sinuous ribs give *Cryptorhytis* a strong resemblance to *Bellifusus* Stephenson which would become a junior synonym. Although these similarities exist, Sohl deferred action due to lack of quality material. The assignment and material herein do little to clarify the foggy generic concept of *Cryptorhytis*.

Cryptorhytis flexicostata? (Meek and Hayden), 1856 Pl. 17, figs. 5, 6

1856. *Fusus flexicostatus,* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 66.
1876. *Fasciolaria? (Cryptorhytis) flexicostata* (Meek and Hayden), Meek, U.S. Geol. Sur. Terr., vol. 9, p. 367, pl. 19, fig. 2.
1926. *Cryptorhytis flexicostata* (Meek and Hayden), Wade, U.S. Geol. Sur., Prof. Paper 137, p. 132.

Diagnosis. — Shell thin, short, fusiform, spire moderately high of six or seven whorls each constricted at the suture. Aperture lanceolate, constricting abruptly anteriorly into a slightly twisted canal. Columella with one broad fold nearly bordering canal. Prosopon of somewhat sinuous ribs, overlain by ribbons strengthening on anterior slope.

Discussion. — Meek's placement of this species, like his concept of the genus, was in doubt. Because it has not been discussed in the recent literature, and because this study has produced no material of suitable preservation to shed more light on the subject, no attempt will be made to resolve the dilemma here. If my identification is correct, it is the first record of *C. flexicostata* from the Fox Hills Formation and particularly that of North Dakota.

Types. — Hypotype UND 13457.

Type locality. — "Yellowstone River [Montana], 150 miles from its mouth; where it occurs in beds containing a blending of the fossils of the Fort Pieree and Fox Hills groups of the Upper Missouri Cretaceous." [Meek, 1876, p. 368.]

Occurrence. — All specimens were taken from locality A480 from lithology of the unnamed member. None occurred in concretions.

Geologic range. — Maestrichtian.

Family XANCIDAE

Subfamily VASINAE

Genus PYROPSIS Conrad, 1860

Type species (by monotypy): *Tudicla (Pyropsis) perlata* Conrad, 1860, Acad. Nat. Sci. Philadelphia, Jour., 2nd ser., vol. 4, p. 288, pl. 46, fig. 39.

Generic diagnosis. — Shells medium to large, subpyriform with low to very low spires; whorls peripherally expanded, moderately to strongly constricted anteriorly; spire with a smooth, pyriform appearance or, in forms with angular shoulders, with a steplike silhouette. Aperture thickened within; inner lip moderately to heavily callused, columella smooth with a broad, weak or strong swelling above the siphonal canal that may produce an umbilical fissure behind the columellar lip. Columella straight to gently flexed. Prosopon generally ornate, of nodose to spinose spiral chords; growth lines orthocline to mildly prosocline. Protoconch round-topped, of two whorls, slightly raised above plane of volution of teloconch.

Remarks. — The concept of this genus became confused after its proposal due to poor definition both of it and related genera, as well as to genetic proximity to several other taxa commonly present in Upper Cretaceous strata. Sohl (1964) partially modernized the concept of *Pyropsis* including in it Stephenson's (1941, p. 316) genus *Medionapus,* and thus Wade's (1926) genus *Trochifusus,* noting (p. 235) that:

> Although the type species of *Pyropsis* and *Medionapus* appear to be widely separated when compared, the other included species, variously assigned to *Pyropsis, Medionapus,* or *Trochifusus,* seem to fill in the gap between the two end members.

He, therefore, treated *Medionapus* as a junior synonym of *Pyropsis.* At the same time he accepted the generic distinction of *Tudicla,* in which *Pyropsis* was originally situated, and of Stephenson's genus *Napulus.* Sohl (1967a, p. B7, 8) gave much significance to the fact that *Pyropsis* can be traced readily through Upper Cretaceous rocks with several lineages definable both geographically and stratigraphically. It was his conclusion that isolation and re-invasion of various genetic units within the group reflected fluctuation of the Upper Cretaceous seaways over the Western Interior from the Cenomanian through the Maestrichtian. This hypothesis is justified and agrees with conclusions presented herein for other members of the Fox Hills neogastropod fauna. *Pyropsis* is a more "Tethyan" or southern genus. It has no analogs yet reported either from the marine Maestrichtian of Canada or from that of California. Once the Vasinae of the Western Interior are all clearly defined taxonomically and stratigraphically they may furnish a tool for paleogeographers and paleoecologists.

Pyropsis bairdi (Meek and Hayden), 1856 Pl. 18, figs. 1-6; Pl. 19, figs. 1-6

1856. *Pyrula bairdi* Meek and Hayden, Acad. Nat. Sci. Philadelphia, Proc., vol. 8, p. 66.

1856. *Busycon bairdi* (Meek and Hayden), Meek and Hayden, Acad. Nat. Sci. Philadelphia, Proc., vol. 8, p. 126.
1876. *Pyropsis bairdi* (Meek and Hayden), Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 369.
1964. *Pyropsis bairdi* (Meek and Hayden), Sohl, U.S. Geol. Sur., Prof. Paper 331-B, p. 235.

Diagnosis. — Shells large, pyriform, with spire elevated less than half the height of the aperture; whorls shouldered by a nodose carina. Suture impressed, formed below uppermost carina of each preceding whorl. Anterior canal long, bent slightly in youth, becoming straight after 3½ or 4 whorls. Aperture oval to suboval, contracting anteriorly to narrow canal; columellar lip and thickened, reflexed outer lip develop in maturity. Columellar lip swollen slightly into aperture at base of canal producing a smoothly-rounded parietal geniculation; columella smooth and umbilicate. Prosopon of faint, slightly prosocline, growth lines; three major spiral, nodose carinae and minor spiral threads, or cords (depending on age of specimen), approximately 20 on posterior slope of third and fourth whorls, a dozen or so on anterior slope, becoming stronger at maturity. Protoconch smooth, slightly raised, not deflected.

Discussion. — *P. bairdi* is the largest species of gastropod thus far reported from the Fox Hills Formation. As indicated in the discussion above the genus is a southern one. This species reflects the trend of many such immigrants in decreasing the degree of ornateness of the shell. The carinae and nodes are much subdued when compared with Mississippi or Texas species.

Meek (1876) designated *P. bairdi rotula* as a varietal form with stronger chords, more nodose carinae, and flatter posterior ramp. This is a more ornate form of *P. bairdi* as shown on Plate 19, figures 5, 6, and Plate 20, figures 4, 5, 6 herein, which illustrate the holotype (UNSM 252) and an immature specimen (USNM 180537) from USGS collections from South Dakota.

I would be inclined, because of the more bent anterior canal, convex, more carinate and nodose whorls, and free rather than adnate inner lip callus, to consider Meek's varietal form as a distinct species. It is rare and has not been found in North Dakota hence no reassignment is made herein. The possibility that these differences are the result of sexual dimorphism also exists.

Types. — Holotype USNM 252 *(P. bairdi* and *P. bairdi rotula)*; Hypotypes UND 13431, UND 13433, and USNM 180537.

Type locality. — "Moreau River and Fox Hills [South Dakota]. No. 5 of series" (Meek and Hayden, 1856, p. 66).

Occurrence. — Collected from concretionary sandstone lenses of the Timber Lake Member at locality A466 and A676 and from concretions in the same member at localities A457 and A461.

Geologic range. — Maestrichtian.

Genus **PERISSITYS** Stewart, 1927

Type species (by original designation): *Perisolax brevirostris* (Gabb), Stewart, 1927, p. 426, pl. 20, fig. 4.

Diagnosis. — Shell large, pyriform, appearing blunt due to thickening along sutures; teloconch expanding rapidly, whorls expanded, squat with last whorl having anterior slope expanded approaching the lip causing widening of posterior portion of the columella. Posterior portion of whorls a broad inclined ramp becoming a high collar overlapping the suture; shoulder moderately well to well developed. Aperture subcircular to subovate(?) narrowing into long anterior canal. Columella thick, long (may be longer than spire), twisted, having a wide fold bordering the canal. Inner and outer lips undescribed. Prosopon of weak costae producing strong nodes on shoulder. Five or six major carinae, the posterior most at the shoulder, distributed anteriorly onto anterior slope, frequently becoming cleft where crossing costae. Three or more cords distributed between carinae on whorl and present on ramp. Protoconch not well known. (Modified from Stewart, 1927.)

Remarks. — This genus is poorly covered in the literature since its description by Stewart from Gabb's (1864, p. 91, *in* Stewart, 1927, p. 426) species *Perisolax brevirostris*. Several species of Gabb's genus *Perisolax* (type by subsequent designation of Whitfield, 1892, p. 34) were proposed for East Coast and Ripley specimens by Weller (1907), Whitfield (1892), and Wade (1926). Stephenson (1941, p. 318) designated *Perisolax whitfieldi* (Weller) as the type of his genus *Napulus*. Forms of *Perisolax* have been distributed among or erroneously referred to *Pyropsis, Tudicla, Perissitys,* and *Cophocara*.

In this restudy of Gabb's material Stewart described both *Perissitys* and *Cophocara* from material previously considered to be *Perisolax brevirostris;* the main difference being that *Cophocara* contains a form which has a strong secondary sutural callus deposited over each previous whorl as new whorls are added. I suspect this is a gradational or ecotypic form and should not have generic standing, but further California specimens must be found to prove or disprove this. The Fox Hills species to be considered here is thought to belong to *Perissitys* in the sense of Stewart and of the diagnosis herein, which is my modification from his descriptions.

Perissitys ? sp. A Pl. 17, fig. 10

Material. — Fragments of three specimens collected by Feldmann from two localities. In two cases the apical whorls are present but badly eroded. Some whorl fragments preserve good ornament and secondary sutural deposits as diagnosed above for the genus. Two portions of columella are also present.

Discussion. — I have taken Stewart's (1927, p. 426) acceptance of Whiteaves (1897, p. 356, pl. 43, fig. 3) to signify the veracity of that identification. Whiteaves' specimen was *Perissitys brevirostris* from the Vancouver Island area. This indicates to me a northward range for the genus creating the strong possibility for its presence in Fox Hills rocks of North Dakota.

My material is not complete enough to make a positive identification of the generic much less the specific identification of the specimens. Nevertheless available portions indicate proper placement and also that the species represented is a new one. The shoulder nodes are weaker, carinae stronger, and posterior ramp at a slightly higher angle than in *P. brevirostris*. Cords on the anterior slope are much less developed as well. If this identification is correct it represents an extension of the genus from the West Coast into the Western Interior and is new to North Dakota. It resembles nothing previously described by early workers such as Meek and Hayden, White, or Morton.

Types. — Figured specimen UND 13453.

Occurrence. — Fragmental specimens collected from matrix of Timber Lake (?) Member at localities A726 and A618.

Geologic range. — Maestrichtian(?).

Perissitys ? sp. B Pl. 17, figs. 9, 11

Material. — One internal mold of 3½ whorls preserving, in matrix, a portion of the columella. Larger whorls show slight indication of costae but no spiral ornament. Sutures are deep and thick, and the columella twisted.

Discussion. — This steinkern might represent any of several genera. The secondary covering of the suture, twisted canal and size of the specimen support assignment to *Perissitys.* Lack of spiral ornament on the mold is of little concern as examination of the internal wall of material from the previous species shows that cords and carinae are not reflected on the interior of the shell. This specimen was taken from the same area as the last species. Until it is better known further speculation is fruitless.

Types. — Figured specimen UND 13436.

Occurrence. — From Timber Lake Member (possibly in concretion, at locality A615.

Geologic range. — Maestrichtian.

Suborder NEMATOGLOSSA

Superfamily **CANCELLARIACEA**

Family **CANCELLARIIDAE**

Genus **CANCELLARIA** Lamarck, 1799

Type species (by monotypy): *Voluta recticulata* Linnaeus, 1767.

Generic diagnosis. — Medium-sized, stout, low to moderately high spiral shells. Siphonal canal short, narrow and twisted; outer lip thick, lirate within; inner lip glazed by callus. Aperture lenticular; columella having two or three folds with posterior plait generally strongest. Umbilicus perforate to imperforate. Prosopon usually cancellate (modified from Sohl, 1964).

Remarks. — Until 1941 no members of this genus had been recognized from Mesozoic rocks. At that time Stephenson (1941, pp. 362-3) described *Cancellaria? matsoni* from the Kemp Clay (Maestrichtian) of Texas, a species not very reminiscent of later assigned Cretaceous members of the genus. Sohl (1964, pp. 268-9) described *Cancellaria? macnairyensis* from the Coon Creek Tongue of the Ripley Formation of Tennessee. Although Sohl questions his generic placement of the species, there is little doubt after seeing his specimen that it is a *Cancellaria.* The same is true for the North

Dakota material herein described. Stephenson's *C.? matsoni* remains uncertainly placed, in my opinion, since it apparently lacks the anterior-most columellar plait present on both *C. macnairyensis* and the North Dakota species.

Generic assignment of my specimens was made more difficult by their similarity to several cancellariid genera including *Admete* Moller, *Bonellitia* Jousseaume, and more superficially, *Paladmete* Gardner. The last possesses similar shell habit but lacks plaits on the columella. *Admete* may have two or more weak folds, but the anterior canal is imperforate and there is no fasciole. *Bonellitia* is the closest genus in general aspect; however, it is imperforate, often possesses varices, and has a fasciole on the anterior canal. Olsson (1964, p. 128) considered *Bonellitia* a subgenus of *Admete* to which it is closely related. Palmer (1947) considered it a distinct genus. *Bonellitia* is the only genus of these three which definitely ranges into the Cretaceous (Maestrichtian). Stephenson in 1952 reported a questionable occurrence of *Paladmete* ? from the Woodbine of Texas but his material consisting of two latex molds was indeterminate. Decision to assign the North Dakota material to *Cancellaria* is based on the weakly perforate anterior canal, possession of a weak fasciole, lack of varices, and well-developed anterior canal indicated.

A note on the subordinal assignment of *Cancellaria* herein is necessary. A recent examination of cancellariid radulae by Olsson (1970) showed that they are unlike those of any other group. He proposed (p. 19) to indicate this by erecting the order Nematoglossa to hold the Cancellariidae. Previously the family was assigned both to the Toxoglossa (Keen, 1963; Thiele, 1935) and the Stenoglossa as in Taylor and Sohl (1962). Olsson's work appears significant enough to justify removal of the Cancellariidae from the Stenoglossa and their placement in Nematoglossa, a taxon here treated at the subordinal rank in keeping with the format of Taylor and Sohl. The superfamilial assignment is made in the sense of Olsson (1964). It is clear that the cancellariids had begun their development by the late Cretaceous. Their radulae may be a refinement of the stenoglossate radula evolving toward its use in the manner of the toxoglossate radula. Not enough is yet known of present cancellariid feeding habits to attempt extrapolation of data toward paleo-feeding habits and thus toward feeding-based evolutionary trends.

Cancellaria siouxensis, n. sp. Pl. 20, figs. 1-5

Diagnosis. — Shell small for genus; spire about half total shell height; aperture constricted anteriorly to a short perforate canal; inner lip lightly callused; outer lip with six denticles; columella with three plications of nearly equal strength. Prosopon of spiral ribbons and narrow transverse ribs. Protoconch naticiform, of approximately 2½ whorls.

Description. — Shell small; spire about half total shell height; pleural angle about 47 to 53 degrees. Aperture broadly lenticular, widest approximately two-thirds of the distance posteriorly, constricting rapidly anteriorly to a short canal; whorls with rounded posterior shoulder. Inner lip glazed, smooth; outer lip not thickened, having six denticles recessed within the aperture and evenly spaced along the lip wall. Columella with three plaits, anterior-most slightly less well developed and very slightly oblique to the others. Umbilicus a well-developed slit on most mature specimens. Prosopon a combination of spiral ribbons and narrow, opisthocline, round-topped, transverse costae; about 24 ribbons on ultimate whorl, 8 on penultimate whorl. Spiral ribbons crenulate on posterior slope of each whorl. Costae approximately 20 on ultimate whorl, most strongly developed on the shoulder and fading out on anterior slope; secondary ribbons inserted between the five or six primary ribbons midway along the anterior slope. Protoconch about 2½ smooth naticiform whorls.

Material. — Twenty specimens, both mature and immature, most with aperture damaged, many with penultimate whorl bored by predators. All taken from friable, silty sandstone; none from concretions.

Discussion. — Specimens of this species were one of the most common forms represented at locality A460. As such it is known from more material than either *Cancellaria*? *macnairyensis* Sohl or *C.*? *matsoni* Stephenson for which only the respective holotypes are known. Both of the aforementioned species have stronger transverse prosopon than *C. siouxensis;* their apertures are thicker, and shells are shorter. *Cancellaria siouxensis* has closer, finer ornamentation, which is more subtle than the prosopon of either of the other Cretaceous species. In form and ornament it more closely resembles *C.? macnairyensis* from the Ripley Formation than it does *C.? matsoni*. This is true also in view of the columellar plaiting; *C.? macnairyensis* and *C. siouxensis* each possess three plaits whereas *C.? matsoni* has only two.

My material bears some resemblance to older and younger material from the Cenomanian of Texas and the Paleocene of North Dakota, respectively. An indeterminate specimen referred by Stephenson (1952, p. 192, pl. 43, figs. 38, 39) to *Cancellaria* ? sp. has a slight resemblance to *C. siouxensis* but the costae on the former are more narrow and curved and the anterior canal appears to have been longer and more twisted. His single specimen was too poorly preserved to determine, but his generic placement seems to be correct. In 1921 Stanton described two species from the Cannonball Formation (Paleocene) of North Dakota which are similar to *C. siouxensis*. *Fasciolaria lloydi* (p. 42) is larger than *C. siouxensis*, has a more reticulate prosopon, and lacks a strong anterior plait. *Fasciolaria ? cordensis* is closer in columellar structure but has finer prosopon and lacks the strong shoulder and posterior slope of the whorls that are present on *C. siouxensis*. Both of the species described by Stanton are probably referrable to the Cancellariidae as used herein and *Fasciolaria ? cordensis* is probably close to *C. siouxensis* and should be assigned to *Cancellaria*.

Cancellaria siouxensis is the first representative of that genus to be definitely assigned from the Cretaceous though many scattered, earlier, questionable assignments exist in the literature. It is the first record of any cancellariid genus from the Fox Hills Formation or from North Dakota rocks, exclusive of Stanton's incorrectly assigned species here assigned as *Cancellaria cordensis*. Additional work with the cancellariids of the northern Western Interior should demonstrate their paleoecologic, and perhaps stratigraphic, value. Their small size and rarity make both uses difficult to assess at present. They probably represent a southern stock which migrated northward and eventually remained isolated there to form part of the Cannonball marine fauna during the Paleocene.

Etymology.—The specific name was developed with three sources in mind: (1) the "Fighting Sioux" of the University of

North Dakota; (2) the Sioux Indian Nation on whose land the specimens were collected; and (3) Sioux County, North Dakota, in which that land is located.

Types. — Holotype USNM 180538; Paratypes USNM 180539, USNM 180540, UND 13471, UND 13474.

Dimensions of types. — The following list is a summary of measurements of the type material:

	H	MD	PA
USNM 180538 (Holotype)	.60 cm	.34 cm	47°
USNM 180539 (Paratype)	.83+	.42+	55°
USNM 180540 (Paratype)	.69	.40	47°
UND 13471 (Paratype)	.55+	.29+	48°

Type locality. — These specimens were collected from the Timber Lake Member of the Fox Hills Formation from a 6-inch thick zone of sparse shell accumulation approximately 3 feet below the top of a roadcut section near the center sec. 21, T. 129 N., R. 79 W., 8 miles SSW of Ft. Yates, Sioux County, North Dakota.

Occurrence. — Timber Lake Member, Fox Hills Formation, UND collecting locality A460, Sioux County, North Dakota. All from friable, very fine, silty sandstone.

Geologic range. — Maestrichtian.

Suborder TOXOGLOSSA

Superfamily **CONACEA**

Family **TURRIDAE**

Genus **AMULETUM** Stephenson, 1941

Type species (by original designation): *Turricula macnairyensis* Wade, 1926, U.S. Geol. Sur., Prof. Paper 137, p. 113, pl. 36, figs. 8, 9.

Generic diagnosis. — Small rather slender shells with a spire about half total shell height. Protoconch proportionally large consisting of 3 to 4 smooth whorls. Whorls rounded, slightly constricted posteriorly to a sloping subsutural collar. Transverse and spiral sculpture is sometimes nodose. Siphonal canal elongate, slender, and curved somewhat; outer lip with a rather shallow subsutural sinus. Columella lacks plications and narrows to a thin edge at the anterior extremity. [Sohl, 1964, p. 274.]

Remarks. — Several turrid genera, some closely related, others only distantly so, have been defined and redefined by numerous workers in attempts to clarify relationships within this large family. Many early forms were placed in *Turris* or *Pleurotoma* and later in *Turricula, Surcula, Exilia, Amuletum, Lutema, Beretra,* and *Remnita* as more and more material became available. The present understanding of the genus has evolved principally from Wade's (1926) work on the Coon Creek fauna and Stephenson's (1941) Navarro studies. Sohl (1964) carried Stephenson's work on a step further as the following discussion will illustrate.

Amuletum Stephenson is based on *Turricula macnairyensis* Wade, one of five new *Turricula* which Wade described in a fauna of seven turriculid species from the Coon Creek. In 1941 Stephenson (p. 369) noted with ample justification the following:

> The genus *Turricula,* to which Wade referred his species, is founded on the Recent *Turricula flamea* Schumacher (= *Murex javanus* Chemnitz, not Linné = *Murex tornatus* Dillwyn, not *Turris tornatum* Bolten), from the oriental seas. This species is a large, nearly smooth form having a spiral angle of about 35 degrees; it has a proportionately larger body whorl, a conspicuous constriction below the suture, and a pronounced shoulder; these characters seem to amply justify erecting a new genus for the Cretaceous shell. None of the species referred by Wade to *Turricula* belongs to that genus.

At the same time Stephenson described two new species of *Amuletum, A. curvocostatum* and *A. venustum.* He also erected the genus *Lutema* (Stephenson, 1941, p. 373) based on *L. simpsonensis;* the genus *Beretra* (p. 375) based on *B. firma* Stephenson; and the genus *Remnita* (p. 379) based on *Turricula biacuminata* Wade, referring *Turricula faceolata* Wade and *T. anomalocostata* Wade to *Remnita.* I have examined the types of these genera and many included species in the collection of the U.S. National Museum, and they do, in fact, seem to demonstrate valid differences, but they are closely related.

The present understanding of *Amuletum, Lutema* and *Remnita* follows the work of Sohl (1964) who noted that *Amuletum* and *Lutema* can be distinguished only on the type of sculpture on later whorls; *Remnita,* however, differs in nature of columellar lip, collar sinus, and spiral ornament. For these reasons he considers *Amuletum* to contain two subgenera, *Amuletum s.s.* and *Amuletum (Lutema)* retaining Stephensons's types for each. Sohl also noted that *A.*

curvocostatum Stephenson (in part) is a synonym of *A. ripleyana* (Wade) which in turn is synonymous with *A. macnairyensis.*

Apparently a great deal of variation occurred with *Amuletum* at this (Ripley) time. Sohl (p. 276) distinguished two subspecies of *A. (A.) macnairyensis* and one new species *A. (A.) dumasensis,* from the Ripley Formation. Thus there are five recognized species of *Amuletum s.s.* from the Ripley and, with his recognized species of *A. (Lutema) limbatum,* a total of six for *Amuletum s. l.* There are also three species of *Remnita* and three of *Beretra* in the Ripley fauna. Apparently these genera did not "blossom" in the northern Western Interior to the extent that they did in the Mississippi Embayment and Gulf Coast Cretaceous seas, since only *Amuletum* is known presently, and it is represented by two species at most in the North Dakota Fox Hills fauna. More work on Pierre Shale faunas may reveal others. Three forms recorded by Stanton (1920, pp. 45-46), including *Turris cordensis, Turris lloydi,* and perhaps *Turricula cincta* from the Cannonball Formation (Paleocene) in North Dakota, are referrable to *Amuletum* indicating a later expansion of the genus in northern waters.

Subgenus **AMULETUM** Stephenson, 1941

Type species: *Turricula macnairyensis* Wade, 1926, U.S. Geol. Sur., Prof. Paper 137, p. 113, pl. 36, figs. 8, 9.

Diagnosis. — *Amuletum* with poorly developed or no shoulder, well-developed spiral sculpture and non-nodose character of transverse ribs.

Amuletum (Amuletum) minor (Evans and Shumard), 1857 Pl. 20, fig. 6

1857. *Pleurotoma minor* Evans and Shumard, Acad. Sci. St. Louis, Trans., vol. 1, p. 42.
1860. *Turris minor* (Evans and Shumard), Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 41; Meek, 1864, Smithsonian Check-List North American Cretaceous Fossils, p. 22.
1876. *Turris minor* (Evans and Shumard), Meek, U. S. Geol. Sur. Terr. Rept. vol. 9, p. 384, pl. 31, figs. 9a, b, c.
1926. *Turricula minor* (Evans and Shumard), Wade, U.S. Geol. Sur., Prof. Paper 137, p. 113.
1941. *Pleurotoma minor* Evans and Shumard (= *Turris minor* Meek), Stephenson, Texas Univ. Bull. 4101, p. 370.

Diagnosis. — Slim, fusiform shells with moderately strong posterior constriction of whorls, ribs strong on posterior slope and across the shoulder and fading out rapidly on anterior portion of last whorl, one or two finer ribs between each major rib on later whorls; ribbons 10-12 on penultimate whorl, narrow on posterior slope, wider and stronger toward anterior.

Discussion. — In degree of coarseness of ribs and general aspect this species most nearly resembles *A. (A) dumasensis* Sohl and to a lesser extent *A. (A.) macnairyensis*, both from the Ripley Formation. With examination of a great many more Fox Hills specimens it is not inconceivable to me that *A. (A.) minor* might be shown to vary enough to overlap one of the above species. No such material is available to me at present, and the characters of the material at hand show it to be a distinct form of *Amuletum s.s.* as used by Sohl (1964).

A form described as *Surcula raricostata* by Gabb from the California Tertiary (Stewart, 1927) is probably an *Amuletum* and bears some resemblance to *A. (A.) minor.* Whiteaves (1879, pp. 116-117) described *S. raricostata* from the Vancouver Island area that closely fit Gabb's description save in a few details deemed by him to be of only varietal significance. The specimens, as figured by Stewart and Whiteaves, both show characters of *Amuletum* and both have a general resemblance to *Amuletum s.s.* in the Ripley Formation and Fox Hills Formation. It would seem that there is here food for thought regarding latitudinal affects on and dispersal directions of *Amuletum* during the Maestrichtian. Apparently it was more widely represented in southerly waters. Just where the origin of *Amuletum* was is still a question.

Types. — Hypotype, UND 994.

Type locality. — From Moreau and Grand River Valleys, South Dakota, apparently from Fox Hills rocks.

Occurrence. — Single specimen taken from concretions near base of the Fox Hills Formation at locality A469.

Geologic range. — Maestrichtian.

Subgenus **LUTEMA** Stephenson, 1941

Type species (by original designation): *Lutema simpsonensis* Stephenson, Sohl, 1964, U.S. Geol. Sur., Prof. Paper 331-B, p. 278.

> *Diagnosis.* — Medium sized fusiform to subfusiform *Amuletum* like [sic] shells that possess subdued ornament, with the transverse sculpture either suppressed or accentuated and having a tendency for stronger shouldering and a development of noding at the shoulder. [Sohl, 1964, p. 278.]

Amuletum (Lutema) sp. Pl. 20, figs. 7, 8

Material. — Two, probably immature specimens, one complete the other with outer lip broken away, are the sole representatives of this species in the UND collections.

Discussion. — These shells closely conform to Sohl's (1964) diagnosis of the subgenus as given above. They are also very close to, if not conspecific with, his undetermined *Lutema* (p. 279). The sculpture of transverse ribs on the second whorl is lost after the second teloconch whorl as he described. This occurrence marks a geographic extension of *Lutema* into North Dakota and a stratigraphic extension into the Fox Hills Formation. Adult material will be required for correct placement of the species. It does not agree perfectly with any described forms. *Surcula suciensis* Whiteaves (1879, pp. 115-116) from the Cretaceous deposits of the Sucia Islands, British Columbia, is probably an *A. (Lutema)* and may thus have affinities with this form, yet, because his species is so poorly figured, there is little way of ascertaining without seeing the type. This species, too, seems to indicate close relationships between southern and northern forms overlapping in North Dakota latitudes.

Types. — Figured specimen, UND 13463.

Occurrence. — From fine friable sandstones of the Timber Lake Member of the Fox Hills Formation only at locality A460.

Geologic range. — Maestrichtian?

Family UNCERTAIN

Genus and species uncertain Pl. 20, figs. 9, 10

Material. — One specimen which is badly decorticated and has broken outer lip and canal.

Discussion. — This single specimen is of a moderate-sized gastropod with robust whorls, impressed sutures covered by overlapping shell. Shell is thick and the columella smooth. It superficially resembles *Astandes* from the Pierre Shale and *Cantharus vaughni* from the Cannonball Formation. It is too large for *A. densatus* of the Pierre. *C. vaughni* would be the best suggestion, but the preservation is too poor to justify assignment. Until such time as more specimens are found it must remain an unassigned element of the Fox Hills gastropod fauna in North Dakota.

Types. — Figured specimen UND 13438.

Occurrence. — From concretionary sandstone unit at locality A467.

Subclass EUTHYNEURA

Order OPISTHOBRANCHIA

Superfamily **ACTEONACEA**

Family **RINGICULIDAE**

Genus **OLIGOPTYCHA** Meek, 1876

Type species (by original designation): *Actaeon concinnus*, Hall and Meek, 1854, p. 390.

Generic diagnosis. — Globose shell, spire depressed. Sculpture of incised spirals consisting of a series of chainlike links. Outer lip thickened to a rounded rim at mature stage, interiorly smooth to denticulate. Columella has a strong anterior fold and bears from zero to two weaker parietal folds." (Sohl, 1967a, p. B34.)

Remarks. — The history of this genus is long and in concept has become alternately clear, clouded, and clear again as collections are restudied. *Oligoptycha* was first proposed by Meek, 1876, p. 283, misspelled "Oligoptych") as a subgenus of *Cinulia* Gray along with *Cinulia s.s.* and *Avellana* (d'Orbigny). *Actaeon concinnus* (Hall and Meek) was designated as the type. *Oligoptycha* was given generic rank by Stewart (1927). After Meek's work several additional forms from North America were referred to *Cinulia* (*sensu* Gray) — *Cinulia* (*Oligoptycha*), *Oligoptycha, Avellana,* and *Eryptycha,* all closely related ringiculids. Wade (1926), and later Stephenson (1941) discussed *Oligoptycha americana* (Wade) of the Gulf Coast Cretaceous and Mississippi Embayment Cretaceous. Sohl (1964, pp. 295-6) refined the generic diagnoses to include characters of Coon Creek species of which *O. corrugata* was proposed as new.

In the same discussion Sohl (1964) attempted to outline weak phylogenetic trends but conceded that trouble arises when poorly understood Gulf Coast (and Pacific Coast) forms are considered. Several forms figured prominently in this confusion including *Avellana subincrassata* d'Orbigny, *O. obliqua* (Gabb) Stewart (1927, p. 436) and *Oligoptycha*? *popenoei* Allison (1955, p. 43). Sohl (p. 296) alluded to strong similarities between *A. subincrassata* and *Oligoptycha* but pointed out the facts that the parietal folds extend to the aperture, the columellar fold is weaker and is virtually horizontal in *A. subincrassata* as substantial evidence for maintaining generic distinction between *Avellana* and *Oligoptycha.* Popenoe (1957, p. 435) erected *Biplica* with *B. heteroplicata* as the type, a globose form with one columellar swelling (hardly a plait), an anteriorly produced canal, and thick outer lip, and reassigned *O. obliqua* to his genus. The placement of *O.? popenoei* Allison was in doubt at its original description due to lack of good material and remains tentatively assigned to that genus (Sohl, 1964, p. 296).

Sohl neglected several species which must figure in any phylogenetic or paleogeographic interpretation. Atlantic Coast forms *Cinulia (Oligoptycha) naticoides* (Gabb), Whitfield (1892, p. 161) and *Avellana bullata* (Morton) (see Richards, 1962, p. 92) are both important species, the latter having a strong resemblance to *O. concinna* as stressed by Whitfield (p. 161) but disregarded by later workers (Richards, 1962; Gardner, 1916; Weller, 1907). *Avellana bullata* in fact, probably is an *Oligoptycha. A. bullata* is of questionable assignment if judged by descriptions I have read, but without seeing material, and because it is beyond the scope of this report, it is left tentatively in that genus.

The final species to be considered here is *Cinulia pusilla* Whiteaves known from seven specimens in the Upper Cretaceous of the Vancouver Island area (Whiteaves, 1884, p. 217). Apparently all his material lacked well-defined columellar and parietal characters (due to lack of preservation?) although the superficial description and examination of Whiteaves' figures seem to indicate very close relationship to *Oligoptycha,* more than to any other ringiculid genus, the spire probably being too low to place it in *Cinulia s.s.* which is retained for higher-spired forms.

If future work on evolutionary trends in the Ringiculidae is to be undertaken, the generic-level taxa must be stabilized. The most logical synopsis of this family is probably that of Zilch (1960, pp. 20-23) with the exception that *Oligoptycha* as now understood, and as stressed by Sohl (1964, p. 295), should stand as a genus rather than remain of subgeneric rank where Zilch placed it.

Oligoptycha concinna (Hall and Meek), 1854 Pl. 20, figs. 11, 12

1854. *Actaeon concinnus* Hall and Meek, Amer. Acad. Arts Sci., Mem., vol. 5, p. 390, pl. 3, fig. 4.

1856. *Avellana subglobosa* (Meek and Hall), Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 8, p. 64.
1860. *Cinulia concinna* (Hall and Meek), Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 424.
1876. *Cinulia (Oligoptycha) concinna* (Hall and Meek), Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 284, pl. 31, figs. 6a, b, c.
1895. *Cinulia (Oligoptycha) concinnus* (Hall and Meek), Cossmann, Essais de paléoconchologie comparée, No. 1, p. 121, pl. 7, fig. 15.
1941. *Oligoptycha concinna* (Hall and Meek), Stephenson, Texas Univ. Bull. 4101, p. 390.
1964. *Oligoptycha concinna* (Hall and Meek), Sohl, U. S. Geol. Sur., Prof. Paper 331-B, p. 295.

Diagnosis. — *Oligoptycha* with a strong anteriorly inclined columellar plait low on the inner lip, and very slightly denticulated or nondenticulate inner surface of the outer lip (modified from Sohl, 1967a, p. B34).

Discussion. — Although published records do not acknowledge it, *Oligoptycha concinna* appears to be fairly common in the upper Pierre Shale and the Fox Hills Formation in North Dakota. It has been previously reported from North Dakota by Cvancara (1956) and Brinster (1970). The present study can add little to its morphology, yet a point of clarification might be made. Sohl (1964, p. 296) mentioned seeing specimens from the upper Fox Hills Formation of the Black Hills region which possess very faint denticles on the outer lip, yet his (1967a, p. B34) diagnosis fails to take this mild, occasional denticulation into account. One or two fragments seen in this study also seem to show a faint denticulation on the inner surface of the outer lip, an occurrence which has been considered in the diagnosis given above. Preservation and development of such denticulation is no doubt influenced by age of the individual at death and stage of development of the calloused outer lip which is not well developed until late maturity.

Types. — Hypotype UND 13464.

Type locality. — "The type specimens are from the upper part of the Pierre Shale on 'Sage Creek' South Dakota (*Baculites compressus* zone)" (Sohl, 1967a, p. B34). Meek (1876, p. 284) mentioned it also from the Fox Hills Formation on Moreau River, South Dakota.

Occurrence. — The species was found in sediments of the Trail City Member and in concretions from several horizons. Localities include A460, A480, and A469.

Geologic range. — Upper Campanian — Maestrichtian.

Superfamily **PHILINACEA**

Family **SCAPHANDRIDAE**

Genus **ELLIPSOSCAPHA** Stephenson, 1941

Type species (by original designation): *Cylichna striatella* Shumard, 1861, Boston Soc. Nat. Hist., Proc., vol. 8, p. 194.

Generic diagnosis. — Subelliptical, involute, tightly coiled shells with a moderately small apical pit. Sculpture of punctate spiral grooves. Aperture narrow and curving over upper surface and broadening below to a rounded anterior margin. Inner lip callused over columellar area and bears a low weak fold. [Sohl, 1967a, p. B35.]

Remarks. — Stephenson (1941) had a definite concept of *Ellipsoscapha* in mind when he separated these forms, namely elliptical, tightly coiled shells with nearly straight columella, having a gentle fold, and slight depression of the spire. In those characters it differs from *Scaphander* Montfort. It differs too from *Haminea* Gray because that genus is more openly coiled and nearly smooth. Three species, *Haminea occidentalis, H. subcyclindrica*, and *H. minor* from the Western Interior, erected by Meek and Hayden, were referred by Stephenson (p. 392) to *Ellipsoschapha.* Whiteaves (1879, p. 132) found *Haminea horni* Gabb from the Upper Cretaceous of the Vancouver Island area, but his illustration is not satisfactory to determine whether or not identification is correct. It is small, but may be an *Ellipsoscapha* since the ornament covers the entire whorl surface. The genus apparently had an extensive paleogeographic range if Gabb's is an *Ellipsoscapha.*

Ellipsoscapha cf. **E. minor** (Meek and Hayden), 1856 Pl. 20, fig. 13

Material. — One specimen collected from a concretion. The spire is damaged and preservation is as a mold of the interior.

Discussion. — This specimen was collected and described by Cvancara (1956, p. 52) with the same reservation that I feel. It agrees well with Meek's (1876, p. 273) description, but the prosopon is not perfectly preserved, nor are the aperture and spire available for examination. Without seeing the columella and spire, I hesitate to make an absolute determination.

I have compared it with material from Whitehorse Ridge in South Dakota where *E. subcyclindrica* was collected. *E. minor* is much shorter and proportionately more robust. If this identification is correct, this is its first report from North Dakota.

Types. — Hypotype UND 926.

Occurrence. — From concretion in Trail City Member at locality A469.

Geologic range. — Maestrichtian.

Family **ACTEOCINIDAE**

Genus **CYLICHNA** Loven, 1846

Type species (by subsequent designation of Herrmannsen, 1852, p. 42): *Bulla cylindracea* Pennant, 1777.

Generic diagnosis. — Small slender cylindrical shells. Spire involute, apically truncate, and perforate in early growth stages. Surface smooth or with fine incised spiral grooves. Aperture posteriorly narrow but expanding to a rounded anterior end; columellar lip with a low fold. [Sohl, 1964, p. 299.]

Remarks. — This is a geographically and stratigraphically wide-ranging genus in Upper Cretaceous rocks of the midcontinent region. It is made up of thin-shelled species which are often poorly preserved, lacking the ornament necessary to make proper specific assignment. Sohl (1964) recognized the tenuous nature of many assignments made to *Cylichna,* and I am here following his recommendations by using the broad concept of the genus.

Considering the active energy levels present in many depositional environments of the Fox Hills Formation, it is somewhat surprising that the genus is represented in my collections by such a large number of individuals (approximately 30 specimens). These are, however, mainly from two outcrops representing rather gentle conditions of shell accumulation. I have referred most shells to one species with one form questionably assigned to a second species. Badly worn shell surfaces do not permit assignment of many specimens which may be distinct forms, but here are referred to *C. scitula* because of close superficial morphologic similarity to that species.

Cylichna scitula Meek and Hayden, 1860 Pl. 20, figs. 14, 15

1860. *Cylichna scitula* Meek and Hayden, Acad. Nat. Sci., Philadelphia, Proc., vol. 12, p. 178.
1876. *Cylichna scitula* Meek and Hayden, Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 276, pl. 31, figs. 3a, and b.

Diagnosis. — Shell small, rather solid, narrow-subelliptical, approaching subcylindrical; summit truncated, and occupied by a comparatively large umbilicoid depression; aperture very narrow, arcuate, widening little below; umbilical region sightly impressed; inner lip reflexed and twisted, so as to form a small indistinct fold at its base; surface marked by fine, obscure lines of growth, which are crossed by impressed transverse striae, separated by spaces about two or three times their own breadth near the middle of the outer whorl, but becoming more closely crowded toward the extremities. [Meek, 1876, p. 276.]

Discussion. — There is little to be said regarding this occurrence. *C. scitula* has been known from the Fox Hills Formation of South Dakota since Meek and Hayden described it. Stanton (1921, p. 48, pl. 9, fig. 10) described a specimen from the Cannonball Formation (Paleocene) of North Dakota that he referred to the species with question. As figured his specimen is in matrix and somewhat crushed. I do not doubt that this common species might be found in the Paleocene as well, but I am not able to certify his identification and have excluded it from my synonymy. Additional collections from the Cannonball Formation may verify his identification.

Types. — Hypotype UND 13469.

Type locality. — "Moreau River; No. 5 of the Nebrasca section [Fox Hills Formation, South Dakota]." (Meek and Hayden, 1860, p. 178).

Occurrence. — This species is common at localities A460 and A480 from fine sandstone and siltstone of the Timber Lake and unnamed Members respectively. It also occurs at locality A611 and A469 (with question).

Cylichna volvaria? (Meek and Hayden), 1856 Pl. 20, figs. 21, 22

1856. *Bulla volvaria* Meek and Hayden, Acad. Nat. Sci., Philadelphia Proc., vol. 8, p. 69.
1876. *Cylichna? volvaria* (Meek and Hayden). Meek, U.S. Geol. Sur. Terr. Rept., vol. 9, p. 275, pl. 31, figs. 2a, b.

Diagnosis. — Shell thin, elongate-subovate, being widest below the middle, and tapering upward gradually, with moderately convex sides, to the summit, which is narrowly rounded, with apparently a very small central pit; lower extremity oblique and subangular, or narrowly rounded; aperture very narrow, gently arcuate, and not much expanded below, where it shows a faint oblique fold or ridge; surface marked by fine, obscure lines of growth, which are crossed by shallow, transverse striae, narrower than the spaces between, excepting on the upper and lower extremities, where they are more crowded, and more distinctly defined. [Meek, 1876, p. 275.]

Types. — Hypotype UND 13468.

Type locality. — "Moreau trading post. No. 5 of Section [Fox Hills Formation, South Dakota]" (Meek and Hayden, 1856, p. 69).

Occurrence. — From Timber Lake Member at locality A465.

Genus **GONIOCYLICHNA** Wade, 1926

Type species (by original designation): *Goniocylichna bisculpturata* Wade, 1926, U.S. Geol. Sur., Prof. Paper 137, p. 106.

Generic diagnosis. — Small to moderately small cylindrical shells have a low turreted spire. Protoconch small, heterostrophic. Whorls squarely truncate posteriorly, rounded anteriorly. Sculpture of short transverse ribs on posterior one-fifth and of incised spirals on anterior four-fifths of body. Aperture anteriorly expanded and rounded, posteriorly terminating in a shallow notch. Inner lip gently truncate below with columella bearing a distinct fold at top of columellar lip that begins just behind aperture. [Sohl, 1964, p. 302.]

Remarks. — As originally described by Wade this genus was not readily distinguished from *Retusa* Brown. In working with the type of *G. bisculpturata* Sohl (1964, p. 302) found that a plication was present high on the columellar lip left uncleaned by Wade. This plait is now heavily relied upon as a generic character. It should be noted that Cossmann (1895, p. 82) mentioned the infrequent occurrence of a faint columellar plait in some *Retusa.* Whether he was referring to specimens now assignable to *Goniocylichna* or not is worth questioning, but is not more than noted in the present study.

The genera *Retusa* Brown, *Goniocylindrites* Meek, and *Acteocina* are all deemed closely related by Sohl. Zilch (1959, pp. 45-6) considered *Retusa* to stand as a large genus with a wide range of basic morphologies which are recognized as nine subgenera; *Goniocylichna* was one such subgenus. This placement seems a bit confining to me since it neglects some apparently related forms (*Trochacteon*? and *Acteocina*) while combining forms with distinct morphologic dissimilarities such as *Cylichnina* and *Pyrunculus*, for which reason I follow Sohl's (1964) usage.

This is the first report of *Goniocylichna* from the Western Interior and thus also from North Dakota and the Fox Hills Formation. The occurrence strengthens the basis for similarity between Fox Hills faunas and those of the Mississippi Embayment from whence come the holotype, *G. bisculpturata,* and a second species, *G. elongata.* The North Dakota specimens fill a geographic gap between Tennessee and Vancouver Island where *Trochacteon semicostatus* Whiteaves was described. Wade originally referred that species to *Goniocylichna,* and indeed Whiteaves' figure would favor the move, but, as Sohl mentioned (1964, p. 303), there must be further information on occurrence of columellar plications in *T. semicostatus* before the new referral is justified. Until that time Whiteaves' form should be considered a closely allied species; the northwest extent of paleogeographic distribution of *Goniocylichna* is in North Dakota. This report does serve to reduce further the endemic character previously attributed to Western Interior molluscan faunas.

Goniocylichna bisculpturata Wade, 1926 Pl. 20, figs. 16-18

1926. *Goniocylichna bisculpturata* Wade, U.S. Geol. Sur., Prof. Paper 137, p. 106, pl. 34, figs. 15, 16.
1964. *Goniocylichna bisculpturata* Wade, Sohl, U.S. Geol. Sur., Prof. Paper 331-B, p. 303, pl. 49, figs. 32, 33, 37, 38.

Diagnosis. — Shell small (ca. 5 mm in height); protoconch partly submerged; spire very low; sculpture of transverse ribs covers posterior three-quarters of a millimeter of body whorl.

Discussion. — The occurrence of *G. bisculpturata*, a Ripley species, in the Fox Hills tempts one to over interpret the implications of these data. Because it has not been found on the Gulf Coast, nor on the Atlantic Coast for that matter, is the Ripley occurrence the southeastern range limit of a more "boreal" species having its origins in the north as indicated by *Trochacteon semicostatus* Whiteaves on Vancouver Island? It is one of several species in the Fox Hills fauna with similar distributions that might be cited to support the idea. This is the first record of the species in the Fox Hills Formation and in North Dakota.

Types. — Hypotypes, UND 13476 and UND 13477.

Type locality. — Ripley Formation, Dave Week's farm, Coon Creek, McNairy County, Tennessee.

Occurrence. — This species was collected from Timber Lake sediments at locality A460 and the unnamed member at locality A480.

Geologic range. — U. Campanian — Maestrichtian.

Goniocylichna ? sp. Pl. 20, figs. 19, 20

Material. — Two specimens, one merely the last whorl, the other nearly entire but badly worn, somewhat compressed, and lacking the anterior portion of the lip. Measurements for the nearly complete specimen (UND 13475) are as follows: H = 9.9 mm, MD = 5.3 mm.

Remarks. — Further preparation of the figured specimen was deemed unfeasible without its total destruction, thus no columellar plait is well exposed. A faint plait is indicated high on the columella, however. The prosopon is badly worn, as is the protoconch. The faint plait, the abrupt posterior shouldering of whorls, and indeed the general aspect of the shell have caused me to place it with reservation in *Goniocylichna.*

Both specimens are from an animal considerably larger than *G. bisculpturata* which is said to have a maximum height of 5.7 mm and maximum diameter of 3.0 mm (Sohl, 1964, p. 303), and, in fact, would more nearly approximate *G. elongata* (H = 11.6 mm, MD = 4.3 mm) if they were undamaged. The condition of the protoconch and eroded prosopon do not permit this assignment. The material may as easily represent remains of an undescribed *Goniocylichna.*

Type. — Figured specimen, UND 13475.

Occurrence. — One specimen each at localities A460 and A467, Timber Lake Member, Fox Hills Formation.

Geologic range. — Maestrichtian?

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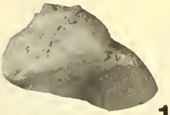
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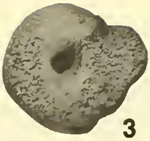
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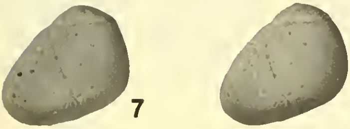
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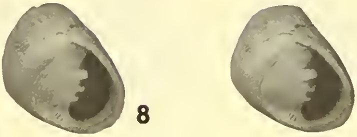
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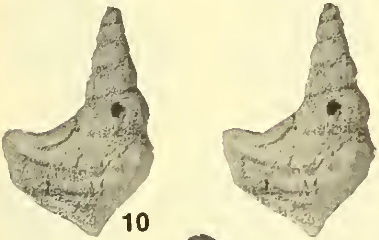
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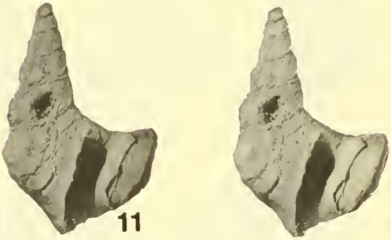
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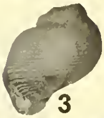
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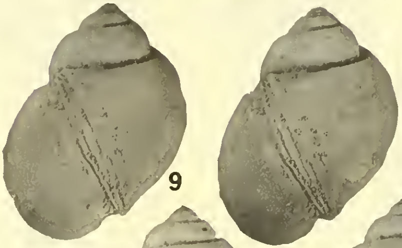
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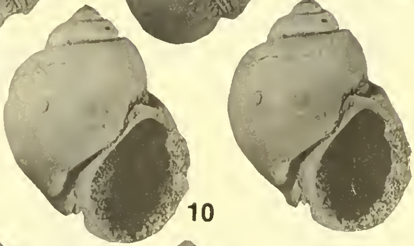
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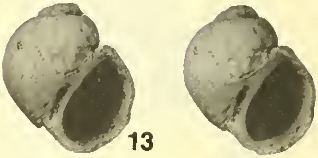
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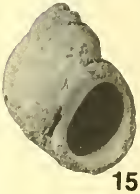
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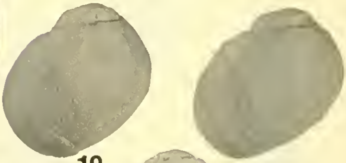
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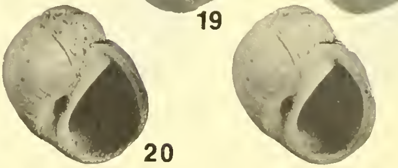
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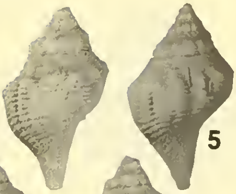
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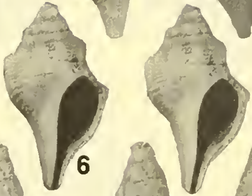
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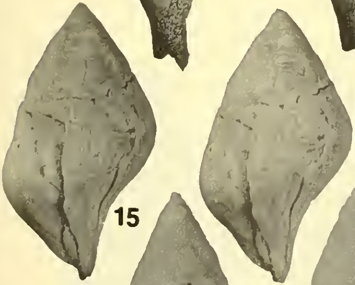
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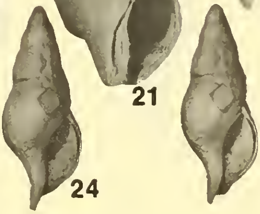
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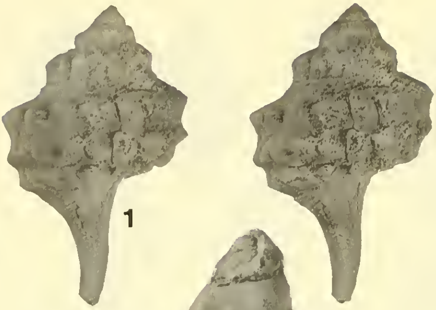
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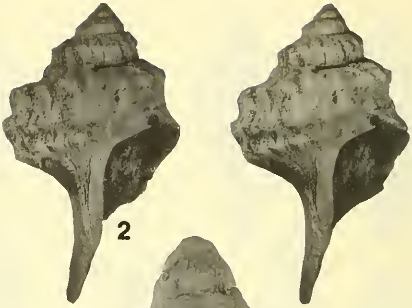
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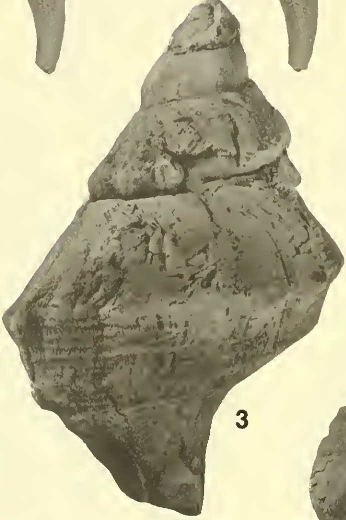
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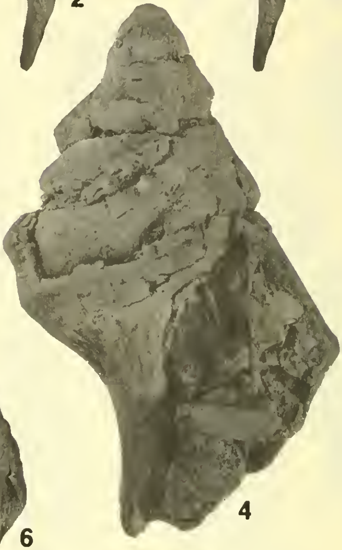
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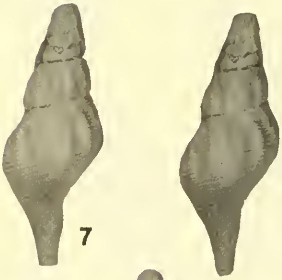
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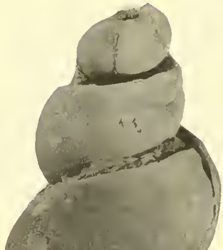
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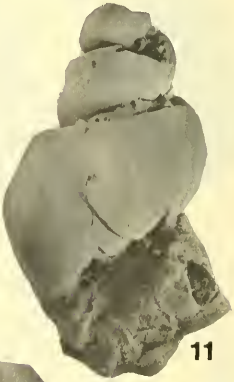
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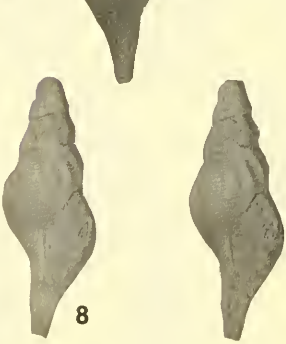
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1, 2. **Hercorhyncus (Haplovoluta) hollandi,** n. sp. 202
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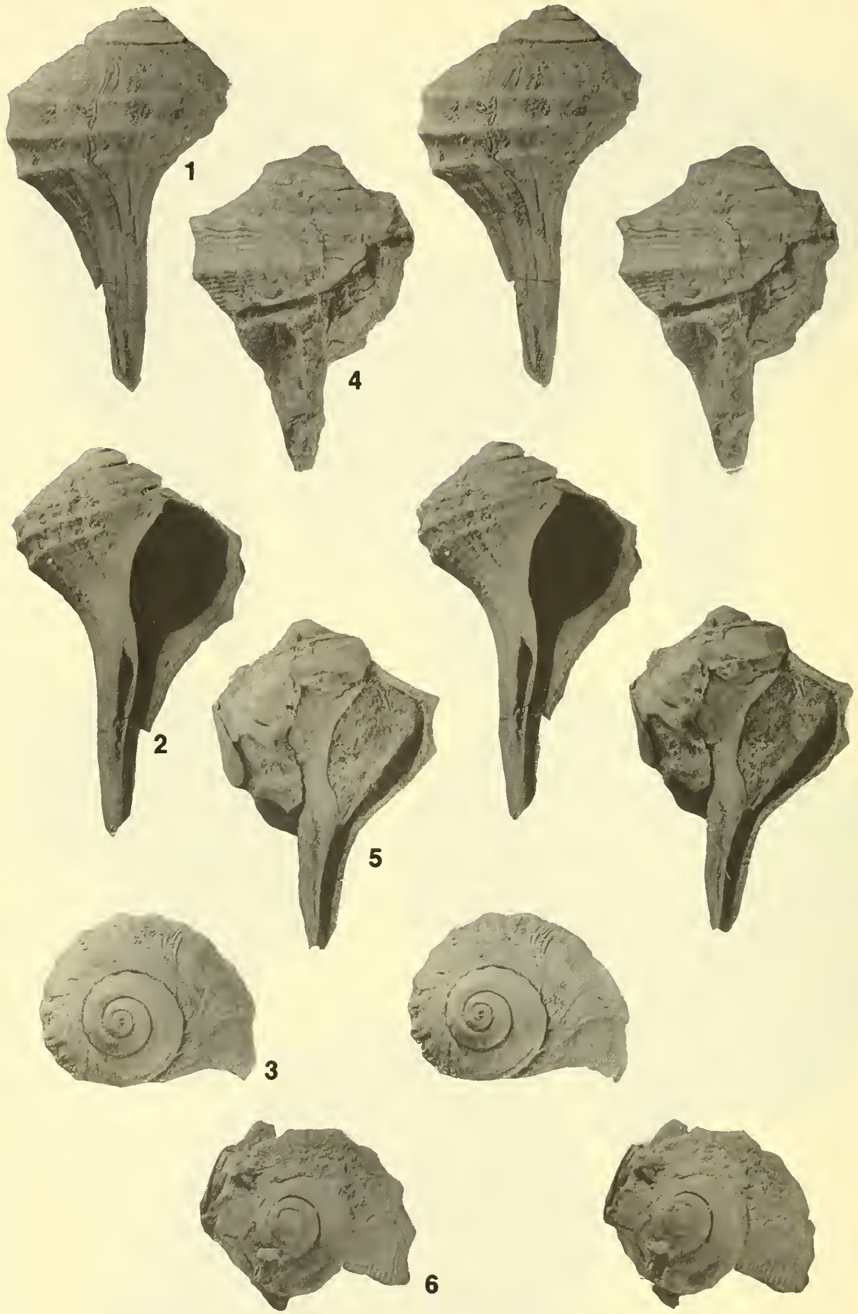
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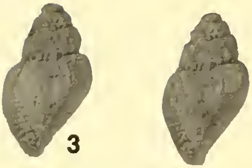
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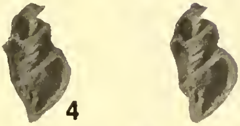
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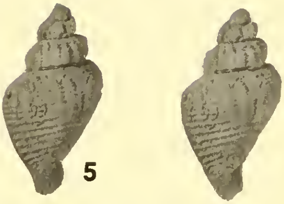
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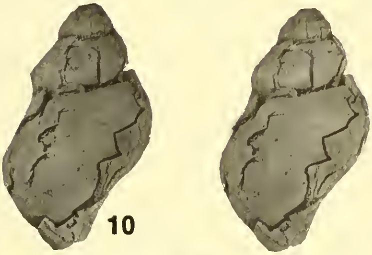
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By

Norman E. Weisbord

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By

NORMAN E. WEISBORD

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LATE CENOZOIC CORALS OF SOUTH FLORIDA

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ABSTRACT

Fifty-two late Cenozoic species of fossil corals are described from the following formations of South Florida: Pinecrest, Caloosahatchee, Glades, Fort Thompson, and Key Largo Limestone/Miami Oolite. Fifty-one of the species are in the order Scleractinia and one in the order Milleporina. Five new species are proposed, and these are *Diploria sarasotana, Thysanus floridanus, Dichocoenia caloosahatcheensis, Dichocoenia eminens,* and *Isophyllia ? desotoensis.* The salient characters of the several formations are depicted, and their ages, as determined by both biogeologic and radiometric dating, are analyzed and compared.

INTRODUCTION

This report deals with the taxonomy, synonymy, and distribution of 52 species of late Cenozoic fossil corals recorded from South Florida, as well as with the description and illustration of five species which are believed to be new. Most of the corals occur in the following formations: Pinecrest Sand, Caloosahatchee Marl, Unit "A" or Glades Formation, Fort Thompson Formation, Key Largo Limestone/Miami Oolite, and Holocene sands. These deposits are exposed here and there in peninsular Florida between 28° and 24°30′ north latitude, or from the vicinity of Eau Gallie in the north to Key West and the Tortugas in the south. The oldest formation is the Pinecrest, the youngest pre-Recent sands. The geologic age span is Mio-Pliocene to Holocene by biogeologic reckoning, late Pliocene to Holocene by radiometric dating. The Pinecrest Formation, which is believed by a number of paleontologists to be late Miocene or early Pliocene in age (or about 12 million years on the Holmes "absolute" scale), has been determined by Bender (1973) to be about 3.49 - 3.93 million years on the basis of radiometric dates obtained from Pinecrest corals. The Caloosahatchee Marl, which overlies the Pinecrest, is thought by geologists to be Pliocene or Plio-Pleistocene or late Pleistocene on biogeologic evidence, whereas radiometric dating of corals by Bender indicates that the He/U age of the Caloosahatchee Marl is 1.78 to 2.53 million years, or early Pleistocene on the Holmes Scale. Th-230/U-234 ratios of corals and oolites calculated by Osmond, *et al.* (1965) and by Thurber and Broecker (1965) suggest that the Key Largo Limestone/Miami Oolite was laid down at least as far back as 190,000 years ago. Hoffmeister and Multer (1968) reported the coral *Acropora palmata* at 18 ft. below the surface on Looe Key, and the radiocarbon date on that indicated an age of 1300 years. Most of the post-Caloosahatchee corals are living today, but a goodly number of Pinecrest and Caloosahatchee species are extinct, suggesting to me that both the Pinecrest and Caloosahatchee deposits are pre-Pleistocene in age.

The coral collections on which much of the present work is based are contained in the Department of Geology of Florida State University, in the Florida Bureau of Geology also in Tallahassee, and in the National Museum of Natural History (formerly U.S. National Museum) in Washington, D.C. During 1967, and again in 1970 I spent a number of profitable weeks studying the Tertiary and Recent corals in the National Museum. Then, late in 1972, the National Museum of Natural History, through the good offices of Dr. Maureen E. Downey and Ronald L. Larson, sent to me on loan, specimens of each of the 18 species listed by Vaughan (1919, p. 222) from the Caloosahatchee Marl, thus enabling me to study them at length and to have certain of the examples photographed for this report. The types of the new species described by me and contained in the NMNH collection remain with it in the Smithsonian Institution. Types of new species or figured specimens in the collections here at Florida State University and the Florida Bureau of Geology, are presently conserved in the Department of Geology.

The study of South Florida corals was begun in 1966, when, in conjunction with my work on the stony corals of Venezuela (Weisbord, 1968), it was determined that 13 of the 14 species occurring in the late Cenozoic of northern Venezuela also occur in the late Cenozoic of Florida. The Venezuelan research was supported by The National Science Foundation, and I wish to acknowledge with thanks that through its support the cost of the plates in this Bulletin was also funded by the Foundation.

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A number of geologists, paleontologists, biologists, and interested collectors have been kind enough to donate late Tertiary and Recent corals for the Florida State University collection or to furnish notes on taxonomy, stratigraphy, ecology, and other matters of interest. Among the contributors were: Noel Andress, Robert

Back, Joseph E. Banks, Leslie Dyet, Paul F. Huddlestun, Muriel E. Hunter, Lt. William F. Klose II, William R. McWilliams, Harbans S. Puri, Pieter J. Roos, Donald F. Squires, Mike Strong, William F. Tanner, Lyman D. Toulmin, Robert O. Vernon, John W. Wells, and Frank H. Wind.

An especially valuable source of unpublished data and faunal lists relating to the corals dredged or excavated from the Key Largo Limestone/Miami Oolite is contained in a seven page letter written by Lt. William F. Klose II on April 30, 1970, to Dr. Robert O. Vernon, then Chief Geologist of the Florida Geological Survey. This letter was sent to me by Dr. Vernon, and I have incorporated numerous details of it in this work. It is my understanding that all of the species listed in Klose's letter are in the Klose collection in Groton, Connecticut.

Dr. Katherine V. W. Palmer, Director of the Paleontological Research Institution, has attended to the publication of this paper in the Bulletins of American Paleontology, and I am indebted to her and to Doris C. Brann for that and for their many other amenities. I am also obliged to Gerrit Mulders of Tallahassee who photographed the corals.

STRATIGRAPHIC NOTES

PINECREST SAND

The name Pinecrest, taken from an old settlement on the Everglades road about one mile west of the Dade-Collier County line, was proposed by Olsson (*in* Olsson and Petit, 1964, pp. 516-518) "for certain strata composed largely of sand, barren or highly fossiliferous, encountered below a surface limestone in the general region of the 40 mile bend on the Tamiami Trail (Route 41) west of Miami in the western part of Dade County and extending across its boundary into Collier County, Florida". The section here was described by J. H. C. Martens *in* Mansfield (1931, p. 2) as follows:

Bed	Feet
3. Unconsolidated sand	2
2. Hard yellow limestone, containing many *Chione cancellata*	3
1. Unconsolidated medium-coarse sand with numerous shells;	
above water	1
below water about	6

Mansfield (1931, pp. 2-4) identified 55 species of mollusks from the lowest bed, ranging from 5 to 12 feet below the surface, and indicated in his list that perhaps 12 to 14 of the species occur in the Recent fauna: this means that 22 per cent of Mansfield's fossils have survived to Recent time and 78 per cent are extinct. Based in part on the extinction factor and in part on the occurrence of the species in distant formations of known age, Mansfield tentatively placed the fauna in the upper Miocene, recognizing, however, that it might represent a Miocene-Pliocene transition or Pliocene age.

Olsson was able to trace the Pinecrest beds intermittently in the shallow subsurface from the Everglades northward to Lake Okeechobee and westward into Charlotte County. In recent years Pinecrest sands have been recognized by geologists in Sarasota County in the Warren Brothers Pits. These pits are located a mile or so north and east of the easternmost limit of the city of Sarasota and about 145 miles northwest of the type locality. It is from the Warren Brothers Pits that the Pinecrest corals described in this paper were collected. The section in the pits was described by Harbans S. Puri (*in* Weisbord, 1971, p. 56) as follows:

Warren Brothers Pits — Sarasota, Fla.

Bed	Description	Thickness (Ft.)
4	Pleistocene Sand	+15
	Pinecrest Formation	
3	Oyster biostrome, as bed 1 (delicate) *Pecten* sp., *Ostrea haitensis* (Sowerby) mostly articulated valves, *Conus* sp.	4
2	Shell hash, sandy with few complete mollusks; top of the bed marked with *Mytiloconcha* sp. oriented as in life. Can be traced laterally around the pits.	1
1	Oyster biostrome Light gray to green shell hash, quartz sand with *Ostrea haitensis* (Sowerby), *Pecten eboreus darlingtonensis* Dall, *Cancellaria propevenusta* Mansfield, *Murex globosus* Emmons, *Conus adversarius* Conrad.	3

The Pinecrest beds were reported by Olsson to overlie the Tamiami Formation and to underlie the Caloosahatchee Marl, with the lower and upper contacts of the Pinecrest represented by disconformity or slight unconformity. Hunter (1968) suggested that the Pinecrest Sand is an upper member of the Tamiami Formation and that the Pinecrest Sand with the guide fossil *Pecten tamiamien-*

sis Mansfield is in a concurrent range zone with the Ochopee Limestone and Buckingham Limestone of Florida. Hunter further correlated the Upper Tamiami with the Jackson Bluff Formation of North Florida, the Duplin Marl of South and North Carolina, and the Yorktown Formation of Virginia. All of the formations up to a few years ago were considered upper Miocene largely on the character of benthonic invertebrates, their identity with, or similarity to species occurring in deposits elsewhere of the same given age, and particularly on the extinction ratio of the mollusks compared with living species. For example, the *extinct* species or those species not having survived to Recent time represent 80 per cent of the Jackson Bluff mollusks, 80 per cent of the Duplin Marl mollusks, and 83 per cent of the Yorktown mollusks. Present day assignment would place the Jackson Bluff Formation, on the basis of planktonic Foraminiferida, in the lower Pliocene (Akers, 1972) and the Pinecrest Formation in the upper Pliocene on the basis of radiometric dating by Bender (1973).

The Pinecrest corals identified by me and discussed in later pages were collected in the oyster biostromes of beds 1 and 3 in Warren Brothers Pits, and are the following:

Siderastrea dalli Vaughan
Siderastrea pliocenica Vaughan
Diploria sarasotana Weisbord, n. sp.
Solenastrea bournoni Edwards and Haime
Solenastrea hyades (Dana)
Astrangia leonensis Weisbord
Septastrea marylandica (Conrad)
Oculina sarasotana Weisbord
Isophyllia ? desotoensis Weisbord, n. sp.

Of the nine species listed above two, or 22 per cent have survived to Recent time. Among the remaining seven species, two are akin to living species, three have also been reported from the Caloosahatchee Marl, and two are from formations formerly regarded as upper Miocene. The corals thus seem to me to point to an early Pliocene age by biogeological deduction, or about 8 million years on the Holmes scale of 1965. This compares with a radiometric age of about 3.7 million years calculated by Bender for the corals of the Pinecrest Formation, or late Pliocene on the Holmes scale.

CALOOSAHATCHEE MARL

The Caloosahatchee Marl as used in this work refers to a group of sediments lying in the interval between the Tamiami Formation below and the Glades or Fort Thompson Formation above. The sediments of this interval consist predominantly of marls and sands, a number of them so richly fossiliferous they have been the source of important paleontological monographs. Among the megafossils, the mollusks are the most abundant and diverse, with more than 600 species having been reported by Dall (1903). Although few in number (25 species), corals of the order Scleractinia are also represented in the biota, and it is these corals, recorded from the Caloosahatchee Marl in Shell Creek and elsewhere in Charlotte County, as well as from the Caloosahatchee River in Hendry and Glades County, which are described in the present paper.

In the Caloosahatchee River, the Caloosahatchee Marl was divided into three members by DuBar (see Puri and Vernon, 1964, pp. 232-234), with the Fort Denaud Member (12 ft. thick) at the base, the Bee Branch Member (5 ft. thick) above that, and the Ayers Landing Member (12.5 ft. thick) at the top. Type exposures of these members are found along the Caloosahatchee River between Fort Denaud and Ortona Lock (see DuBar, 1958, figs. 9, 10), and the Formation underlies the southern part of De Soto County and much of Charlotte, Hendry, and Glades Counties, according to Cooke (1945, pp. 216-221).

All of the Caloosahatchee corals in Shell Creek that I have examined were sent to me from the National Museum of Natural History under the USGS number of 3300 which refers to a collection from "Shell Creek, Florida, De Soto County, 12 miles east of railroad bridge, collected for 6 miles along Creek." This locality is conjectured by me to cover columnar sections SC-1 to SC-13 of DuBar (1962, p. 9, fig. 4, pl. 1) and the same columnar sections in figure 36 of Puri and Vernon (1964) in the Cleveland and Bermont Quadrangles of Charlotte County.

According to DuBar (1962, pp. 10-14), exposures of the Caloosahatchee Marl in Shell Creek are restricted to the Bermont Quadrangle (SC-1 to SC-12), within a stream distance of approximately 4.5 miles. Typically, the Caloosahatchee sediments consist of unconsolidated sandy marl, marls, and hard sandy limestones, which are gray, tan, or cream in color. Wherever the base of Caloosahatchee Marl has been observed in Shell Creek it lies unconformably on the Tamiami Formation, and everywhere along the creek the Caloosahatchee is overlain unconformably by unfossiliferous sands of the Fort Thompson Formation. The maximum exposed thickness of the Caloosahatchee in any section along Shell Creek is not more than 15 feet, but a composite of creek sections indicates the formation is as much as 30.5 feet in thickness.

DuBar divided the Caloosahatchee Marl into six stratal units, from bottom to top, as follows:

A. Lower Limestone, resting unconformably on the Tamiami Formation. Maximum thickness 3 ft.

B. Lower Marl, lying conformably on A, 4 ft. thick, and abundantly fossiliferous.

C. Middle Limestone, 3 ft. thick, and also richly fossiliferous.

D. Middle Marl, 3-4 ft. thick, with numerous mollusks.

E. Upper Limestone, 1-2.5 ft. thick "is the most useful marker bed exposed along Shell Creek . . . Lithologically the limestone is sandy, hard, and gray, and contains an abundance of well preserved Caloosahatchee marine mollusks."

F. Upper Marl, estimated thickness 9 ft. Unconsolidated sandy, gray, marine shell marl. Made up largely of medium-sized grains of quartz and includes a few rounded, shiny black phosphorite grains.

Inasmuch as Unit F lies conformably on Unit E and is in turn unconformably overlain by unfossiliferous Fort Thompson sands, "there is little doubt that it is the uppermost Caloosahatchee unit on Shell Creek." (DuBar, 1962, p. 14).

Since precise locality or stratigraphic data are wanting on the specimen tags of all of the Caloosahatchee Marl specimens I have examined, I am unable to place the species in their particular member either in Shell Creek or the Caloosahatchee River, although each specimen considered in this report has been assigned to the Caloosahatchee Marl by the collector, donor, or paleontologist responsible for the data. In Shell Creek it is reasonable to assume that the Caloosahatchee corals were collected stratigraphically below the non-fossiliferous Fort Thompson Formation and stratigraphically above the Tamiami Formation. In the Caloosahatchee River, I suspect that a number of the corals donated by Mike Strong and collected by him "2 - 5 miles west of LaBelle", were obtained from the Ayers Landing Member and are therefore representative of the upper part of the Caloosahatchee Marl. With the foregoing proviso concerning the occurrence of the corals in the Caloosahatchee Marl *sensu lato,* the following species have been identified in that formation:

Siderastrea dalli Vaughan
Siderastrea pliocenica Vaughan
Porites divaricata Lesueur
Porites furcata Lamarck
Porites porites (Pallas)
Diploria clivosa (Ellis and Solander)
Diploria strigosa ? (Dana)
Thysanus floridanus Weisbord, n. sp.
Manicina areolata (Linnaeus)
Manicina cf. *M. gyrosa* (Ellis and Solander)
Cladocora johnsoni Gane
Solenastrea bournoni Edwards and Haime
Solenastrea hyades (Dana)
Astrangia floridana (Gane)
Phyllangia americana Edwards and Haime
Septastrea crassa (Holmes)
Septastrea marylandica (Conrad)
Oculina diffusa Lamarck
Oculina sarasotana Weisbord
Archohelia limonensis Vaughan
Meandrina maeandrites (Linnaeus)
Dichocoenia caloosahatcheensis Weisbord, n. sp.
Dichocoenia eminens Weisbord, n. sp.
Incertae *sedis* "a"
Incertae *sedis* "b"

Of the 25 species in the above list, two cannot be identified, three are new and possibly endemic, six occur in the Pinecrest Formation, eight occur in the Key Largo Limestone/Miami Oolite, and, including the two *Incertae sedis* forms (which are solitary corals and seem not to resemble living species), 12 occur in the Recent fauna. To me the important statistic is that 13 to perhaps 11 of the 25 species are extinct, and this means that 52 to 44 per cent have not survived to Recent time. This extinction ratio is much too high for the Caloosahatchee corals to be included in the Pleistocene, and I therefore consider the Caloosahatchee to be pre-Pleistocene, or Pliocene, on biological-geological grounds. It is interesting to note that Dall (1903, p. 1617) found that of the 639 mollusks identified in the Caloosahatchee Marl, 314 or 49 per cent occur in the Recent fauna. Similarly revealing is the finding by DuBar (1958, p. 137) who identified 341 species of mollusks from the type locality of the Caloosahatchee Formation, of which 39.5 per cent occur in the Recent fauna, and reciprocally 60.5 per cent are extinct.

Another reason for supporting the view that the Caloosahatchee Marl is of Pliocene age is the remarkable similarity of the coral fauna to that in the Carrizo Creek Formation of California. The corals of both formations were studied by T. Wayland Vaughan and determined by him to be Pliocene as early as 1917 in his paper on "The Reef-Coral Fauna of Carrizo Creek, Imperial County, California, and its Significance." In this paper Vaughan stated that the Carrizo Creek coral fauna was purely Atlantic and not Pacific in its affinities, the differentiation having taken place during Miocene time by the extinction of Pacific elements in the Atlantic area. Subsequent to the differentiation there was an interoceanic connection permitting the Atlantic fauna to extend across the Isthmian region of Mexico or farther south up to California. This connection existed during early Pliocene time and was closed off late in the Pliocene by diastrophic and other events.

The more than 400 specimens of corals in the Carrizo Creek Formation examined by Vaughan, were collected at the head of Barrett Canyon which flows south into Carrizo Creek from Fish Creek Mountain, and in Garnet and Alverson Canyons, the former flowing north into Carrizo Creek, the latter flowing south from a divide of Coyote Mountain in Imperial County. The corals and many other invertebrate fossils were obtained from the upper sandy phase of a basal conglomerate 120 to 130 feet thick, and in Barrett Creek from outcrops of basal sandstone and conglomerate not more than 10 feet thick. At one place in Barrett Creek a fossil coral reef lies on lavas isolated from all the other sedimentaries. The basal conglomerates of the Carrizo Creek Formation lie unconformably on Miocene volcanics, or on late Miocene marine beds, or on Mesozoic granitic rocks, depending on the local geologic setting.

The geologic age of the Carrizo Creek fauna was at first thought to be probably Cretaceous, then lower Miocene, and still later upper Miocene. However, as early as 1917 Vaughan (p. 368) wrote the following: "The Carrizo Creek species are so near species belonging to the same genera in the Pliocene Caloosahatchee marl of Florida and in Pleistocene and living reefs of Florida and West Indies that it seems to me they can scarcely be so old as Miocene; lower Pliocene appears to be the maximum age which may be assigned to the fauna".

As late as 1960 in the Lexicon of Geologic Names of the United States, the Carrizo Formation and Carrizo Creek Beds in the very area discussed above, were listed under Miocene. However, on the more recent Geologic Map of California, San Diego-El Centro Sheet, compiled by Rudolph G. Strand in 1962, the Carrizo Creek Beds in question are mapped as "'Pmi, Middle and/or lower Pliocene marine".

In contrast with the view of this writer and others who have preceded him that the Caloosahatchee Marl is Pliocene, is the opinion of DuBar (1969) who has steadfastly maintained for 15 years or so that the Caloosahatchee Marl is Pleistocene and that it was deposited in the Aftonian, or first interglacial stage of the Pleistocene epoch in North America. DuBar, who has done considerable stratigraphic and paleontologic work on the Caloosahatchee bases his Pleistocene diagnosis essentially on the evidence adduced from vertebrate fossils identified by a number of experts in the field of vertebrate paleontology.

Brooks (1969, p. 119) was of the opinion that "The Caloosahatchee Formation, restricted is Plio-Pleistocene in age", with the Fort Denaud Member being Pliocene and overlying beds being Pleistocene.

Olsson (1969, p. 126) continued to advocate a Pliocene age for the Caloosahatchee Marl, representing it as the youngest formation of his Group C interval which is given a late Neogene (Mio-Pliocene) time span.

Bender (1973) established a radiometric age range of the Caloosahatchee Marl of 1.78 to 2.53 million years on six specimens of corals, two of which (samples 21954 and 21955) were collected from the top of the Caloosahatchee (Ayers Landing Member?) and one (sample 21647) collected stratigraphically lower. If Bender's samples came from the Fort Denaud-Bee Branch-Ayers Landing sequence, his helium-uranium dating of the Caloosahatchee Marl corals would place them in the early Pleistocene or late Pliocene on the Holmes "absolute" scale of 1965 (p. 360).

In summary, the Caloosahatchee Marl may be Pleistocene, Plio-Pleistocene, or Pliocene in age. The Pleistocene age is adduced from vertebrate remains and is based in part on radiometric dating. The mollusks and corals, however, clearly point to a pre-Pleistocene age. The Plio-Pleistocene age is postulated by Brooks, and corroborated in part by Bender. The Pliocene age is indicated by the Mollusca, Foraminiferida (Cole, 1931), and scleractinian corals; by the stratigraphic position of the Caloosahatchee Marl below the Pleistocene Fort Thompson Formation and above the late Miocene or early Pliocene Tamiami Formation; by the correlation of the Caloosahatchee Marl with the Carrizo Creek Beds of California which are middle-lower Pliocene in age; and, doubtfully, by the radiometric date by Bender of the corals collected from the top of the Caloosahatchee Marl. Generally radiometry seems to yield later dates than biogeology, the former tending to support the Pleistocene assignment, the latter Pliocene or even Plio-Miocene. Generally, too, planktonic Foraminiferida also point to younger ages than do the benthonics, but virtually no planktonic forams were found by Paul F. Huddlestun in sand samples collected by Mike Strong 2 - 5 miles west of LaBelle.

A word or two about radiometric dating, versus geologic dating. Radiometric, or "absolute" dating deals with sidereal time whereas the divisions of the geological time scale are based on biological factors and stratigraphy. The biological factors take into consideration, among other concepts, the procession of life forms throughout geologic history, including genesis, proliferation, waning, and either extinction or evolution. Geologists need not be dismayed that radiometric dates as established at present disagree with their biogeologic dates, for radiometry is a *post hoc* refinement applied to an established biogeological system. During my lifetime the estimated age of the earth has been lengthened considerably, yet fundamentally the biogeologic concept for dating the Tertiary remains valid because it is as sound philosophically as radiometric dating will become when methods of analysis are standardized. What I think may evolve is a felicitous union of both principles, with some epochs (*i.e.* Pleistocene, Pliocene, Miocene, and so on) being lengthened in sidereal or "absolute" time and others shortened in sideral time. In the meanwhile this writer is a proponent for the biogeologic consideration of the Caloosahatchee Marl as Pliocene, which, according to Holmes ranges from 2-3 million to 12 million years in age span, and had a duration of 9 million to 10 million years.

UNIT "A" OR GLADES FORMATION

Unit "A" refers to a distinct stratigraphic and paleontologic entity first named by Olsson (*in* Olsson and Petit, 1964, pp. 521, 522), and described as "lying between the Caloosahatchee Marl below and the Fort Thompson above, and separated from both by sharp unconformable contacts, generally marked by deep solution channels and waved surface." According to Olsson, the Unit, also referred by him as the "Glades", was formerly considered as the upper part of the Caloosahatchee Marl with which it is generally closely associated. The contact between Unit "A" and the Caloosahatchee Marl has been observed in many places along the Caloosahatchee River and in Shell Creek, but the Unit has also been seen lying directly on the Pinecrest Sand or more rarely on the Tamiami Formation.

Typically, Unit "A" is a shell marl composed largely of the pelecypod *Chione cancellata* and several distinctive species of its own, as well as a few forms such as *Pyrazisinus,* which range upward from the Caloosahatchee Marl but become extinct in this Unit. At LaBelle, where the Unit "A" beds have been dug into, they may attain a thickness of 30 feet or more. Here, as well as at several other localities, the base of Unit "A" is marked "by a zone of oysters (*Ostrea virginica labellensis*) along an undulating surface contact with the Caloosahatchee marls below. At other places, such as at Ortona Locks and in several rock pits, its base is marked by a reefal bed of worm shells (*Vermicularia recta*) in erect colonial form" (Olsson, 1969, p. 128). The molluscan fauna is very rich with an estimated 600 species of which 70 or 80 per cent have survived to Recent time. Reciprocally, 30 to 20 per cent of the species are extinct, and this suggests a late Pliocene or early Pleistocene age. Olsson (1969, p. 129) stated that Druid Wilson favors earliest Pleistocene, but Olsson leans toward a late Pliocene age on the extinction ratio of the mollusks and the similarity of the geological setting with that of the type Coralline Crag of England.

The corals in the FSU collection, all collected and donated by Joseph E. Banks, seem to confirm the Plio-Pleistocene age indicated by the Mollusca. Ten species of scleractinian corals were collected in the Glades Formation in the town of South Bay and in a quarry at the south edge of Belle Glade, in Palm Beach County. The corals I have identified in the Banks collection are the following:

Siderastrea pliocenica Vaughan
Siderastrea radians (Pallas)
Siderastrea siderea (Ellis and Solander)
Manicina areolata (Linnaeus)
Cladocora arbuscula (Lesueur)
Solenastrea bournoni Edwards and Haime
Solenastrea hyades (Dana)
Astrangia floridana (Gane)
Oculina diffusa Lamarck
Archohelia limonensis Vaughan

Of the species listed above, only *Siderastrea pliocenica* and *Archohelia limonensis* do not occur in the Recent fauna, and this represents an extinction ratio of 22 per cent, or survival ratio of 78 per cent. Both of these species occur in the Caloosahatchee Marl, and *Archohelia limonensis* occurs in the Moín Formation of Costa Rica as well. The Moín Formation is given as Pliocene in some sources, Pleistocene in others. Three of the Glades species also occur in the Pinecrest Formation, and these are *Siderastrea pliocenica, Solenastrea bournoni,* and *Solenastrea hyades.*

FORT THOMPSON FORMATION

Only one species of coral — *Solenastrea hyades* (Dana) — has been reported from the Fort Thompson Formation, and this taxon ranges from Miocene to Recent in age.

The type locality of the Fort Thompson Formation is shown by DuBar (1958, fig. 1) as being on the south bank of the Caloosahatchee River, a little less than two miles east of LaBelle in Sect. 3, T 43 S, R 29 E (LaBelle Quadrangle), Hendry County. The name "Fort Thompson" was first coined by Sellards (1919, pp. 70, 71) to describe the upper part of a section exposed between LaBelle and Fort Thompson, of which he wrote as follows:

> At Fort Thompson this marl [Caloosahatchee] passes beneath later formations from which it is separated by a well marked unconformity

which is best seen in the exposures along the river between Labelle and Fort Thompson. The following section is seen at a cut-off between two bends in the river about one-half mile below Fort Thompson. The section as given here was made by the writer in 1908.

Section One-Half Mile Below Fort Thompson

8. Sand and soil at top of bank about 2 feet.
7. Shell marl in which *Chione cancellata* predominates 2 feet.
6. Shell marl in which fresh water gastropods predominate 2 feet.
5. Shell marl, marine shells 1/2 foot.
4. Unconformity
3. Calcareous stratum weathering rough on exposure containing Pliocene fossils 3 feet.
2. Shell marl with Pliocene fossils 1 foot.
1. Blue sandy clay marl with few fossils to the waters edge 3 feet.

The "Fort Thompson Beds" of Sellards (1919, p. 71) are exposed farther upstream in the Caloosahatchee River, about 7 miles or so northeast of LaBelle, "just below Goodno's Landing, Fort Thompson", probably a short distance west of Spillway 10 of Ortona Lock, in Sect. 27, T 42 S, R 30 E (Goodno Quadrangle), Glades County. Sellards described his Fort Thompson Beds here as follows:

3. Fresh water limestone 2 feet.
2. Marine shell marl 1/2 foot.
1. Fresh water shell marl 3 feet.

Most geologists consider the base of the "fresh water shell marl" of Bed 1 as representing a significant unconformity, as did Sellards, so that depending on locality, the amount of previous erosion, and the vagaries of deposition, the Fort Thompson may be seen to overlie any of the earlier formations, including the Glades or Unit A of Olsson (1969, pp. 126, 128, 129).

Today, the Fort Thompson is divided into a lower Okaloacoochee Member and an upper Coffee Mill Hammock Member by DuBar (1969, p. 33) and by Puri and Vanstrum (1971, p. 434). The Coffee Mill Hammock Member was regarded as a separate formation by Sellards (1919, p. 73) and is still so considered by Brooks (1969, pp. 114, 115). In any event, the original assignment of the Fort Thompson and Coffee Mill Hammock to the Pleistocene has been accepted without question since the days of Heilprin in 1887, and rightly so, for 70 of the 75 marine mollusks (93 per cent) identified by DuBar (1958, pp. 210-215) from the Fort Thompson Formation occur in the Recent fauna. The vertebrates of the Fort

Thompson Formation identified by Herbert Winters (*in* DuBar, 1958, p. 135) also indicate a Pleistocene age.

Formations younger than the Fort Thompson/Coffee Mill Hammock or possibly contemporaneous in part are the Key Largo Limestone and Miami Oolite. Younger than the latter is the Pamlico, and still younger in the Pleistocene Series is the Lake Flirt/Silver Bluff.

KEY LARGO LIMESTONE/MIAMI OOLITE

In their abstract on the "Geology and Origin of the Florida Keys", Hoffmeister and Multer (1968) summarized concisely the relationship of the Key Largo Limestone and Miami Oolite as follows:

> The Florida Keys form a crescentic chain of small limestone islands which extend from near Miami to Key West, a distance of about 150 miles. They are made of two main formations of Pleistocene age — the Key Largo Limestone and the Miami Limestone. The former, named and described by Sanford, is an elevated coral reef rock, and the latter, also described by Sanford, is an oölitic limestone in this area. The Key Largo Limestone is the surface rock of the Upper Keys, and the Miami Limestone covers the Lower Keys. A contact found at Big Pine Key shows that the oölitic limestone overlaps the Key Largo, and core borings show that the Key Largo underlies the oölitic cover for the entire area of the Lower Keys. The Key Largo, therefore, extends for the total length of the Keys. A core placed at Dry Tortugas, 70 miles west of Key West, encountered it at 30 feet below sea level. The Key Largo has a maximum thickness of over 200 feet.

According to determinations made by Osmond, Carpenter, and Windom (1965), radiometric dates of near surface corals from the Key Largo Limestone range from 101 ± 10 thousand years to 215 ± 35 thousand years, and radiometric dates of near surface samples of the Miami Oolite range from 112 ± 10 thousand years to 145 ± 10 thousand years. The ages calculated from the ratio Th-230/U-234 of near surface Key Largo corals and Miami oolites, calculated by Broecker and Thurber (1965) "clearly indicate periods of limestone formation at about 85,000, 130,000, and 190,000 years ago, indicating that the surface of the ocean was then close to its present level." How much farther back in time these formations were first deposited is not known. In the Florida Keys, the Key Largo Limestone, where fully penetrated by core borings, rests on a quartzose calcareous sand, the correlation of which has not yet been established. Nevertheless, the concensus is that both radiometrically and biogeologically the Key Largo Limestone and Miami Oolite are Pleistocene in age.

The species of corals reported from the Key Largo Limestone/Miami Oolite, all of them living today in Floridian waters, are the following:

Millepora alcicornis Linnaeus
Acropora cervicornis (Lamarck)
Acropora palmata (Lamarck)
Agaricia agaricites (Linnaeus)
Agaricia purpurea Lesueur
Helioseris cucullata (Ellis and Solander)
Siderastrea radians (Pallas)
Siderastrea siderea (Ellis and Solander)
Porites astreoides Lamarck
Porites divaricata Lesueur
Porites furcata Lamarck
Porites porites (Pallas)
Favia fragum (Esper)
Diploria clivosa (Ellis and Solander)
Diploria strigosa (Dana)
Manicina areolata (Linnaeus)
Colpophyllia natans (Müller)
Montastrea annularis (Ellis and Solander)
Montastrea cavernosa (Linnaeus)
Solenastrea hyades (Dana)
Meandrina maeandrites (Linnaeus)
Dichocoenia stokesi Edwards and Haime
Dendrogyra cylindrus Ehrenberg
Mussa angulosa (Pallas)
Isophyllia sinuosa (Ellis and Solander)
Mycetophyllia lamarckiana Edwards and Haime
Eusmilia fastigiata (Pallas)

Of the 27 species of corals from the Key Largo Limestone/Miami Oolite listed above, 27 of them, or 100 per cent, occur in the fauna living today in Florida waters. In formations successively older than the Key Largo, three of the 27 species have also been recorded from the "Pleistocene" or Fort Thompson, eight from the Glades, ten from the Caloosahatchee, two from the Pinecrest, one from the Chipola of North Florida, and one from the Tampa of Central Florida. The range of all the Late Cenozoic species of Florida discussed in this report is given on Table 1.

LOCALITY DATA

The collection localities as they appear on labeled specimens, are given in the body of this report. Supplemental notes, obtained

Table 1.

LATE CENOZOIC FOSSIL CORALS OF SOUTH FLORIDA
AND THEIR DISTRIBUTION IN FLORIDA

No.	Species	FORMATIONS Tampa	Chipola	Duplin or Jackson Bluff	Tamiami	Pinecrest	Caloosa-hatchee	Glades (Unit A)	Ft. Thompson; Pleistocene (undiff.)	Key Largo Ls. Miami Oolite	Recent	No.
1	Millepora alcicornis Linnaeus									x	x	1
2	Acropora cervicornis(Lamarck)									x	x	2
3	Acropora palmata (Lamarck)									x	x	3
4	Acropora prolifera (Lamarck)*										x	4
5	Agaricia agaricites (Linnaeus)									x	x	5
6	Agaricia fragilis (Dana)*										x	6
7	Agaricia purpurea Lesueur									x	x	7
8	Halioseris cucullata (Ellis and Solander)									x	x	8
9	Siderastrea dalli Vaughan					x	x					9
10	Siderastrea pliocenica Vaughan					x	x	?				10
11	Siderastrea radians (Pallas)							x		x	x	11
12	Siderastrea siderea (Ellis and Solander)							x		x	x	12
13	Porites astreoides Lamarck									x	x	13
14	Porites divaricata Lesueur						x			x	x	14
15	Porites furcata Lamarck						x		?	x	x	15
16	Porites porites (Pallas)						x			x	x	16
17	Favia fragum (Esper)									x	x	17
18	Diploria clivosa (Ellis and Solander)						x			x	x	18
19	Diploria labyrinthiformis (Linnaeus)									x	x	19
20	Diploria sarasotana Weisbord , n. sp.					x						20
21	Diploria strigosa (Dana						?			x	x	21
22	Thysanus floridanus Weisbord, n. sp.						x					22
23	Manicina areolata (Linnaeus)						x	x	x	x	x	23
24	Manicina cf. M. gyrosa (Ellis and Solander)						x				x	24
25	Colpophyllia natans (Müller)									x	x	25
26	Cladocora arbuscula (Lesueur)							x			x	26
27	Cladocora johnsoni Gane						x					27
28	Montastrea annularis (Ellis and Solander)									x	x	28
29	Montastrea cavernosa (Linnaeus	x	x							x	x	29
30	Solenastrea bournoni Edwards and Haime					x	x	x			x	30
31	Solenastrea hyades (Dana)					x	x	?	x	x	x	31
32	Astrangia floridana (Gane)				x		x	x				32
33	Astrangia leonensis Weisbord			x		x	?					33
34	Astrangia solitaria (Lesueur)								x		x	34
35	Phyllangia americana Edwards and Haime						x				x	35
36	Septastrea crassa (Holmes)			x			x					36
37	Septastrea marylandica (Conrad)			x		x	x	x				37
38	Oculina diffusa Lamarck			x			x	x	x		x	38
39	Oculina sarasotana Weisbord					x	x	x				39
40	Archohelia limonensis Vaughan						x	x				40
41	Meandrina maeandrites (Linnaeus)						x			x	x	41
42	Dichocoenia caloosahatcheensis Weisbord, n. sp.						x					42
43	Dichocoenia eminens Weisbord, n. sp.						x					43
44	Dichocoenia stokesi Edwards and Haime						x		x	x	x	44
45	Dendrogyra cylindrus Ehrenberg									x	x	45
46	Mussa angulosa (Pallas)									x	x	46
47	Isophyllia ? desotoensis Weisbord, n. sp.					x						47
48	Isophyllia sinuosa (Ellis and Solander)									x	x	48
49	Mycetophyllia lamarckiana Edwards and Haime									x	x	49
50	Eusmilia fastigiata (Pallas)									x	x	50
51	Incertae sedis "a"						x					51
52	Incertae sedis "b"						x					52

*No fossil record in Florida.

from Ronald J. Larson of the National Museum of Natural History and other sources, pertaining to the Caloosahatchee Marl in the Caloosahatchee River and in Shell Creek, are co-ordinated with the sections worked out by DuBar in 1958 and 1962, as follows:

CAL — (Florida State University collection). "Caloosahatchee Formation, 2 - 5 miles west of LaBelle, Hendry County." This stretch along the Caloosahatchee River lies between stations A-43 and A-23 of Dubar (1958, figs. 9, 10) and includes the Fort Denaud, Bee Branch, and Ayers Landing Members of the Caloosahatchee Marl.

I-1932 — (Florida Geological Survey collection). "Caloosahatchee River, 1 mile below Huggett's Landing, Hendry County. From below concretion bed. Caloosahatchee Formation. Sellards, 11/17/14." Huggett's Landing, also known as Rope Bend, is about 3 miles west of LaBelle and probably lies between stations A-34 and A-29 of DuBar (1958, figs. 9, 10). This stretch includes the type locality of DuBar's "Upper Caloosahatchee Shell Bed."

USGS — 2094 — (U.S. Geological Survey collection). "Caloosahatchee R., Florida, at 4-mile Hammock Bend between Fort Thompson and Denaud." This is conjectured to lie between DuBar's stations A-35 and A-31.

USGS — 2095 — "1/2 mile below canal at Fort Thompson." This is conjectured to lie between stations A-18 and A-16 of DuBar (1958, figs. 10, 11).

USGS — 3206 — "(3206 = 325299). Caloosahatchee Beds. No exact location."

USGS — 3300 — "Shell Cr. Fla., DeSoto Co. 12 miles east of Railroad bridge for six miles along creek." This is believed to include the columnar sections at stations SC-1 to SC-13 of DuBar (1962, fig. 4, pls. I, II) in Shell Creek, Charlotte County. From east to west these exposures are in Sections 28, 29, 30 of T 40 S, R 25 E, and in Sections 25, 26, 27 of T 40 S, R 24 E, spanning a little over 4 miles in a straight line from SC-7 on the east to SC-13 on the west, Bermont and Cleveland Quadrangles. According to DuBar, the Caloosahatchee Marl is exposed in Shell Creek between his stations SC-1 to SC-11 in the Bermont Quadrangle.

DESCRIPTION OF SPECIES

MILLEPORINA

MILLEPORIDAE

Millepora alcicornis Linnaeus Pl. 21, fig. 1

1707-1725. *Corallium asperum candicans* Sloane, A Voyage to the Islands of Madera, Barbados, Nieves, S. Christophers and Jamaica, pp. 17, fig. 1; pl. 18, fig. 1; pl. 19. [*Fide* Boschma, 1948, pp. 23, 25.]

1758. *Millepora alcicornis* Linnaeus, Systema Naturae, ed. 10, p. 791.

1771. *Millepora alcicornis* Linnaeus, Knorr, Deliciae Naturae, pl. A6, fig. 3. [*Fide* Boschma, 1948, pp. 23, 26.]

1790, 1796. *Millepora alcicornis* var. *digitata, corniculata, ramosa* Esper, Die Pflanzenthiere in Abbildungen, vol. 1, pt. 6, pp. 193-202; Esper, Fortsetzungen der Pflanzenthiere, *Millepora,* pls. 5, 6, 7. [*Fide* Deshayes and Edwards, *in* Lamarck, Hist. Nat. Anim. sans Vert., ed. 2, vol. 2, p. 308, 1836, and Boschma, 1948, pp. 23, 26.]

1816. *Millepora alcicornis* Linnaeus, Lamarck, Hist. Nat. Anim. sans Vert., vol. 2, p. 201.

1829-1843. *Millepora alcicornis* Linnaeus, Guérin-Méneville, Iconographie du Règne Animal de G. Cuvier, pl. 3, fig. 11.

1878. *Millepora alcicornis* Linnaeus, Rice, Amer. Jour. Sci., ser. 3, vol. 16 (116), No. 91, art. 16, pp. 180-182, figs. 1-20.

1880. *Millepora alcicornis* Linnaeus, Pourtalès, *in* Agassiz, Mus. Comp. Zool., Mem., vol. 7, No. 1, pl. 20, figs. 1-6.

1898. *Millepora alcicornis* Linnaeus, Hickson, Zool. Soc. London, Proc., pp. 252-256.

1901. *Millepora alcicornis* Linné, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, Pt. I, art. IV, pp. 182, 197, text-fig. 13.

1902. *Millepora alcicornis* Linnaeus, Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, pt. 2, p. 318, pls. 35-38.

1904. *Millepora alcicornis* Linnaeus, Greeley, *in* Branner, Mus. Comp. Zool., Bull., vol. 44, pp. 268, 270, 272.

1905-1906. *Millepora alcicornis* Linnaeus, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 12, art. II, pt. 4, pp. 118, 141, 188, pl. 30A, fig. 2, text-fig. 36.

1909. *Millepora alcicornis* Linnaeus, Hartmeyer, Meereskunde Berlin, Jahrg. 3, No. 2, pp. 17, 18, text-fig. 4.

1919. *Millepora alcicornis* Linnaeus, Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 225, 236, 507.

1921. *Millepora alcicornis* Linnaeus, Vaughan, Geol. Sur. Dominican Republic, Mem., vol. 1, p. 167.

1939. *Millepora alcicornis* Linnaeus, Butsch, Barbados Mus. and Nat. Hist. Soc., Jour., vol. 6, No. 3, p. 138, pl. 2, figs. 7, 8.

1948. *Millepora alcicornis* Linnaeus, Smith, Atlantic Reef Corals, pp. 62, 65, 100.

1948. *Millepora alcicornis* Linnaeus, Boschma, R. Mus. Nat. Hist. Leiden, Zool. Verhandel., No. 1, pp. 3, 6-9, 11-19, 23-28, 46-48, 54, 56, 58, 60, 61, 79-81, 100-102, 105, pl. 14, fig. 3; text-fig. 6. [Complete synonymy.]

1949. *Millepora alcicornis* Linnaeus, Boschma, Zool. Soc. London, Proc., vol. 119, pp. 661-663.

1949. *Millepora alcicornis* Linnaeus, Boschma, K. Nederland. Akad. Wetensch., Proc., Sect. Sci., vol. 52, No. 1, pp. 4, 5, pl. 1, figs. 1-5; text-figs. 2a, 2c, 4a, 4b.

1956. *Millepora alcicornis* Linné, Boschma, Treatise on Invertebrate Paleontology, Pt. F, Coelenterata, p. F94, fig. 76A.

1958. *Millepora alcicornis* Linnaeus, Squires, Amer. Mus. Nat. Hist., Bull., vol. 115, art. 4, pp. 227-229, 231-233, 237-240, 259, pl. 28, figs. 1, 2.
1959. *Millepora alcicornis* Linnaeus, Goreau, Ecology, vol. 40, No. 1, pp. 75, 76, 79, 80, 82, fig. 12.
1961. *Millepora alcicornis* Linnaeus, Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 82, 83, figs. 71, 72.
1963. *Millepora alcicornis* Linnaeus, Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 139-141, 144, 161, pl. IIa.
1964. *Millepora alcicornis* Linnaeus, Hoffmeister, *et al.,* Guidebook Geol. Soc. Amer. Convention, Field Trip No. 3, pp. 17, 22, pl. 2, fig. 3.
1966. *Millepora alcicornis* Linnaeus, Chevalier, Inst. Français Afrique Noire, Bull., sér. A, vol. 28, No. 4, pp. 1390, 1392.
1966. *Millepora alcicornis* Linnaeus, Laborel, Postilla, No. 107, pp. 12, 13.
1968. *Millepora alcicornis* Linnaeus, Hoffmeister and Multer, Geol. Soc. Amer., Bull., vol. 79, No. 11, p. 1493.
1968. *Millepora alcicornis* Linnaeus, Weisbord, Bull. Amer. Paleont., vol. 55, No. 246, pp. 16-21, pl. 1, figs. 1-4. [Numerous references, 1707-1964.]
1970. *Millepora alcicornis* Linnaeus, Klose, *in* letter to R.O. Vernon 30 April 1970, p. 3.
1971. *Millepora alcicornis* Linné, Olivares and Leonard, Inst. Oceanogr. Univ. Oriente, Bol., vol. 10, No. 1, pp. 49, 52, 59, 69, table 1, pl. 5, figs. c, d.
1971. *Millepora alcicornis* Linnaeus, Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 2, 28, 31-33, 36-39, 43, 44, fig. 14, pl. II.
1971. *Millepora alcicornis* Linné, Olivares, Inst. Oceanogr. Univ. Oriente, Bol., vol. 10, No. 2, pp. 73, 74, table 1.
1972. *Millepora alcicornis* Linnaeus, Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 547, 549, 557, 578, fig. 1, pl. 3C.
1972. *Millepora alcicornis* Linnaeus, Scoffin, Science, vol. 178, No. 4076, pp. 1280, 1281.

The specimen figured in this work (FMG-3a) is a somewhat flattened and medially compressed stem from which smaller branchlets diverge at the distal end. The color of the corallum is dull yellow.

Measurements. — Specimen FMG-3a: length of main stem 65 mm, diameters at base 8 mm × 7 mm, diameters at middle 5.3 mm × 5 mm.

Locality. — Recent, off west coast of Florida on Florida Middle Ground, Gulf of Mexico.

Range and distribution. — In the Western Atlantic - Caribbean, *Millepora alcicornis* is recorded from Bermuda to Brazil. In the Eastern Atlantic it occurs off the Senegal coast of Africa and in the Cape Verde Islands. The geologic range is Pliocene (?) to Recent.

Pliocene (?) — Venezuela (Cubagua Formation).

Pleistocene — Florida (Key Largo Limestone/Miami Oolite dredged between Stock Island and Cow Key, Monroe County);

Panama Canal Zone (Mt. Hope); Dominican Republic (Provincia Barahona, along road between San José and Lake Enriquillo and on road between Duvergé and Palma Dulce).

Recent — Bermuda (patch reefs; Harrington Sound); Bahamas (Abaco Island; Great Bahama Bank; Moselle Bank; Turtle Rocks; Rabbit Cay); Florida (southeastern reef tract and Florida keys; Soldier Key; Sand Key; Tortugas; Florida Middle Ground); Cuba; Jamaica (Ocho Rios on back reef, reef crest, and seaward slope; Pelican Cay); Mexico (Alacran Reef); British Honduras (Lighthouse Reef, Glover's Reef, Rendezvous Cay); Haiti; Puerto Rico (Cabo Rojo: La Parguera; Cayo Icacos; Mayagüez; Culebra); St. Thomas; Antigua; Anguilla; Guadeloupe; Martinique; Tobago; Barbados (off west coast, 2 - 6 fathoms); Trinidad; Netherlands Antilles: Curaçao (Caracasbaai). Bonaire (Boca Bartól, Plaja Sarna, Blauwe Pan-Witte Pan, Lac, Slagbaai, Klein Bonaire). St. Martin (Point Blanche Bay, Guana Bay). Saba (Cove Bay). St. Eustatius (Cocoluth Bay-Jenkins Bay, Gallows Bay); Columbia (Isla del Rosario; Cartagena); Venezuela (Higuerote, Edo. Miranda; Bahía de Mochima, Edo. Sucre at Isla Sta. Ana, Isla Huevito, Isla Redonda, Isla Larga, Ensenada Pozo del Isleño, E. Cabruta, E. El Inglés, E. Piedra Pelona, E. del Vallecillo, E. Toporo, E. Toporito, E. Mangle Quemao, E. Camaiguana, E. Honda, E. Los Reyes, E. Garrapata, E. El Aguirre, E. Burgao, E. Tía María, E. Guatacaral, E. Baradero, E. Baraderito, E. El Báquiro, E. Taguapire, E. Taguapirito, E. Mosquito, E. Maestranza, E. El Chorro, E. La Aguada, E. Carenero, E. Botella, Morro de La Garrapata, Costica Mano E'Piedra, Costa El Amparo, Costa Cenicero, Costa Maringinia, Playa Blanca de Guaiguá, Playa Piedra, Playa Boca del Rio, Punta Gorda, Punta Piedra, Punta Maestranza, Punta Gruesa, Punta El Amparo, Punta Aceite de Palo, Punta Las Maritas, Punta de León, Punta Mangle Seco, Punta La Palmita, Punta Las Morochas, Punta Cementerio, Punta La Señidura; Golfo de Cariaco, Zonas A - I); Brazil (Cabo de São Roque south to Cabo Frio: Candeias; Pernambuco; Maceio; Bahia; Rio Formoso)

SCLERACTINIA

ACROPORIDAE

Acropora cervicornis (Lamarck) Pl. 22, fig. 1; Pl. 23, figs. 1, 2

1707-1725. *Corallium album* Sloane, A Voyage to the Islands of Madera, Barbados, Nieves, S. Christofers and Jamaica, vol. 1, p. 51, pl. 18, fig. 3. [*Fide* Lamarck, 1836, p. 449.]

1758. *Corallum cornu cervini formae* Seba, Locupletissimi Rerum Naturalium Thesauri, vol. 3, pl. 114, fig. 1. [*Fide* Edwards and Haime, 1860, pp. 136, 137.]

1758. *Millepora muricata* (*pars*) Linnaeus, Systema Naturae, ed. 10, p. 792.

1767. ?*Madrepora muricata* (Linnaeus), Knorr, Deliciae Naturae, pl. A11, fig. 1. [*Fide* Vaughan, 1902, p. 313.]

1816. *Madrepora cervicornis* Lamarck, Hist. Nat. Anim. sans Vert., vol. 2, p. 281.

1836. *Madrepora cervicornis* Lamarck, Lamarck, Hist. Nat. Anim. sans Vert., ed. 2, vol. 2, p. 449.

1860. *Madrepora cervicornis* Lamarck, Edwards and Haime, Histoire Naturelle des Coralliaires ou Polypes proprement dits, vol. 3, pp. 136, 137.

1877. *Madrepora cervicornis* Lamarck, Arango y Molina, R. Acad. Cienc. Médicas, Físicas y Naturales Habana, An., vol. 14, p. 282.

1880. *Madrepora cervicornis* Lamarck, Pourtalès, *in* Agassiz, Mus. Comp. Zool., Mem., vol. 7, No. 1, pl. 18, figs. 1-9.

1893. *Madrepora (Eumadrepora) muricata* forma *cervicornis* Lamarck, Brook, Catalogue of the Madreporarian Corals in the British Museum (Natural History), vol. I. The Genus *Madrepora,* pp. 24, 25, 27-30.

1899. *Madrepora cervicornis* (Lamarck), Duerden, Inst. of Jamaica, Jour., vol. 2, pp. 621, 622.

1902. *Isopora muricata s.s.* = *cervicornis* (Lamarck), Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, pt. 2, p. 313, pl. 21; pl. 22, fig. 2.

1902. *Acropora muricata* (*pars*) (Linnaeus), Duerden, Nat. Acad. Sci., Washington, Mem., vol. 8, pp. 543-549, pls. 1-3, figs. 1-27.

1912. *Acropora muricata* (= *cervicornis*) (Lamarck), Vaughan, Carnegie Inst. Washington, Yearbook No. 11, p. 156.

1914. *Acropora muricata* (*cervicornis*) (Lamarck), Vaughan, Carnegie Inst. Washington, Yearbook No. 13, pp. 224, 225.

1915. *Acropora cervicornis* (Lamarck), Vaughan, Carnegie Inst. Washington, Yearbook No. 14, p. 228.

1915. *Acropora cervicornis* (Lamarck), Vaughan, Washington Acad. Sci., Jour., vol. 5, No. 17, p. 597.

1919. *Acropora muricata* (Linnaeus) and *A. cervicornis* (Lamarck), Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 225, 234, 255, 256, 481-483.

1921. *Acropora muricata* (Linnaeus), Vaughan, Geol. Survey Dominican Republic, Mem., vol. 1, p. 167.

1924. *Acropora muricata* (Linnaeus), Vaughan, *in* Woodring, Geol. Survey Republic of Haiti, p. 251.

1929. *Acropora cervicornis* (Lamarck), Felix, Fossilium Catalogus I: Animalia, pars 44, pp. 606, 607.

1932. *Acropora muricata* (Linnaeus), Wells, Carnegie Inst. Washington, Yearbook No. 31, p. 291.

1939. *Acropora muricata* var. *cervicornis* (Lamarck), Butsch, Barbados Mus. and Nat. Hist. Soc., Jour., vol. 6, No. 3, p. 137, pl. 2, fig. 3.

1940. *Acropora muricata* (Linnaeus), Rutten, K. Nederlandsche Akad. Wetensch., Proc., vol. 43, No. 7, pp. 824, 826.

1943. *Acropora cervicornis* (Lamarck), Vaughan and Wells, Geol. Soc. Amer., Spec. Pap., No. 44, p. 300, pl. 8, fig. 1.

1948. *Acropora cervicornis* (Lamarck), Smith, Atlantic Reef Corals, pp. 60, 66, 75, pl. 2.

1949. *Acropora cervicornis* (Lamarck), Lyman, Shell Notes, vol. 2, Nos. 7-9, p. 134, pl. 3, fig. 2.

1957. *Acropora cervicornis* (Lamarck), Newell and Rigby, Soc. Econ. Paleont., Spec. Publ., No. 5, pp. 42, 58, pl. 3, fig. 2.

1958. *Acropora cervicornis* (Lamarck), Squires, Amer. Mus. Nat. Hist., Bull., vol. 115, art. 4, pp. 221, 237.
1959. *Acropora cervicornis* (Lamarck), Goreau, Ecology, vol. 40, No. 1, pp. 70, 72, 74, 75, 76, 79, 81-83, 85, 88, figs. 13, 16, 17.
1960. *Acropora cervicornis* (Lamarck), Buisonjé and Zonneveld, Nieuwe West-Indische Gids, No. 40, pp. 136, 137, photos 10-12.
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The original description of, and comments on this species by Lamarck (1836, p. 449) are as follows:

> 8. Madrépore corne de-cerf. *Madrepora cervicornis.*
> *M. ramosa; ramis subsimplicibus, teretibus, acutis, crassis, varie curvis; papillis stelliferis, brevibus.*
> Habite les mers d'Amérique. Mon cabinet. Ce Madrépore et le suivant n'ont pas leurs branches couvertes de ramuscules courts et nombreux comme le précèdent. Celui-ci a des branches simples ou peu divisées, cylindriques, épaisses, pointues, scabres, à papilles courtes, sans étoiles superficielles dans les interstices.

A later and more complete description of *Madrepora cervicornis* by Edwards and Haime (1860, pp. 136, 137) of Lamarck's "type" was the following:

> 3. Madrepora cervicornis.
> Polypier arborescent, à branches cylindriques, subulées, très-grosses vers leur base, mais diminuant graduellement de diamètre et se terminant en pointe, courbées d'une manière un peu tortueuse et naissant en général très-loin les unes des autres. Calices latéraux, subnariformes, arrondis, faiblement striés, très-serrés et ne différant que peu entre eux; calices apicaux médiocres. Coenenchyme irrégulièrement reticule, peu abondant. Grosseur des branches maîtresses, environ 2-1/2 ou 3 centimètres; les branches terminales ayant souvent plus de 2 centimètres à leur base et environ 4 millimètres à leur sommet. Diamètre des calices latéraux, environ 2 millimètres.
> Mers des Antilles.
> Cette description a été faite d'après l'échantillon étudié par Lamarck, et conservé dans la galerie zoophylogique du Muséum, et nous sommes portés à croire que M. Dana a pu avoir sous les yeux une autre espèce, car il dit que les calices sont fortement striés à l'extrémité, caractère qui n'existe pas ici.
> M. Dana considère la *Heteropora cervicornis* de M. Ehrenberg (*op. cit.*, p. 110), comme s'éloignant beaucoup de la précédente; mais, après avoir exexaminé l'échantillon d'origine inconnue qui se trouve au Musée de Berlin, et qui a été décrit par ce dernier naturaliste, nous sommes portés à croire que c'est bien un *M. cervicornis* de Lamarck, dont les calices seraient mieux conservés, et par conséquent plus saillants que dans la plupart des examplaires du Musée de Paris.

The specimen described below (FLX-15a) is a Recent one from Florida, the precise locality not known.

The corallum of FLX-15a, broken off from an originally large arborescent example, is branching, the branches elongate and diverging from the common stem at nearly right angles. The branches are subcircular in cross section and taper gradually to the distal ends, in each of which is a terminal or axial corallite. Around the branch are series of radial corallites arranged in rows, with 18 such rows in a branch 60 mm in length, and about 12 corallites in each row. The rows and corallites are a little unequal and seem to traverse the branch in a slight ascending spiral. Individual corallites are protuberant, most of them leaning or arched toward the axis of the branch and subacute at their calicular end. The length or height of these radial corallites varies from 3.7 mm to 1.4 mm depending on size and position on the branch.

The calices are more or less circular in outline and have broad rounded summits. The terminal calice on one of the branches of FLX-15a is larger than any of the radial ones, and bears two cycles of septa, with a number of minor ones barely projecting from the wall at the rim of the calice. The summit of the calice proper is flattish and porose. The outer diameter of the terminal calice is 4 mm, the diameter of the calice itself 1.9 mm. The six primary septa are much larger than the six secondary septa, the former extending to and joining the columella, the latter narrower and extending only part way down the wall. The margins of the septa are entire or minutely dentate, and the sides are plain or with an occasional short spinulose vestige of the synapticulae. Between each septum of the terminal calice there is at least one very small minor septum of gnarled appearance projecting into the calice from the upper part of the wall. There are 48 costae on the terminal corallite and these are laminar and nearly equal in size. The costae, which are simple to occasionally minutely granulate on the crest, extend down the wall to the valleys between adjacent corallites where they develop into and merge with the compressed and pointed echinulations of which the coenosteum is composed. Between the costae are dissepiments numbering about seven to the millimeter.

The radial corallites and calices are similar to those in the termini of the branches but are smaller and recumbent, with the calicular opening facing the slope of the corallite in front of it, and with the lower rim of the calice often abutting, and occasionally immersed in, the coenosteum. The radial calices vary from 0.5 mm to 1.0 mm in diameter. There are two cycles of septa only, and the margins of the primary ones are more strongly serrulate than the primary septa of the axial corallites. The costae are also like those of the axial corallite and there are about 24 of them, or double the number of septa.

The columella is very small and deep, and consists of the innermost ends of some of the principal septa joining the center and forming a linear connection between opposite septa to produce a directive lamina.

Measurements. — Specimen FLX-15a: length of main branch from crotch to distal end, 60 mm; diameter at base (including radial corallites), 11 mm; diameter at distal end 7 mm. Diameter of main stem at base of corallum 14 mm × 12 mm. Span between branches, 81 mm.

Locality. — FLX-15a: Recent, from Florida, exact locations not known.

Range and distribution. — In the Western Atlantic the geographic range of *Acropora cervicornis* extends from Florida to the Islands of Tortuga and Blanquilla off the north coast of Venezuela. In the Eastern Atlantic the species is reported from the Gulf of Guinea. The geologic range is Pliocene to Recent.

Pliocene — Costa Rica (Moín Formation).

Pleistocene — Florida (Key Largo Limestone and Miami Oolite, the latter dredged at Key West); Cuba (terraces along Guantánamo Bay at elevations of 50 ft., 200-275 ft., and 500 ft. above sea level); Costa Rica (Monkey Point); Panama Canal Zone (Mt. Hope); Dominican Republic (Provincias de Macoris, Sto. Domingo, and Barahona); Haiti (Port-de-Paix; Môle St.-Nicolas; Arrondissement Port-au-Prince, Cateaux, and Jacmel at elevations of 1 m to 6 m above sea level); Guadeloupe (Formation Madréporique); St. Eustatius (Mollusk Bed I); Barbados (submerged reefs; elevated reefs of the Bath Reef Series, 150 ft. - 165 ft.; Chelston Quarry, St. Michael, 100 ft.; Prospect, St. James, 70 ft.; Black Rock, 20 ft.).

Recent — Florida (along southeast coast; Elliot Key; Tortugas at Golding Cay and Fort Jefferson); Bahamas (Abaco Island; Great Bahama Bank); Cuba; Jamaica (shore to 17 m; Bluefields Bay; Pigeon Island; Ocho Rios); Mexico (Alacran; Isla de Lobos; Blanquilla Reef; Yucatan Shelf); Panama (San Blas); Haiti; Puerto Rico (Cayo Icacos; Gallardo Bank); Virgin Islands (south of Virgen Gorda depths 22 m - 74 m; St. Thomas); St. Kitts; Barbados; Tobago; Netherlands Antilles: Curaçao (Westpuntbaai above 8 m, Plaja Kalki, Sta. Martha Baai, Portomaribaai, Daaibooibaai, Spaanse Water, Klein Curaçao, Sint Michielsbaai). Aruba (Barcadera, Mangel Altu). Bonaire (Boca Bartól, Jan Doran, Barcadera, Ruin, Hato, Klein Bonaire, Plaja Sarna, Baca, Vierkant, Blauwe Pan, Witte Pan, Oranje Pan, Slagbaai, Palu Lechi). St. Martin

(Burgeux Bay). St. Eustatius (Cocoluch Bay, Jenkins Bay, Tumbledown Dick Bay); Venezuela (Tortuga; Blanquilla).

Acropora palmata (Lamarck) Pl. 22, fig. 2

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Acropora palmata is an important reef coral which flourishes in a strong surf, and provides a framework for the accumulation of detrital material. It is one of the best known and most widely dispersed species in Atlantic and Caribbean waters. It has not yet been found in the Key Largo Limestone of Florida in surface exposures, core holes, or dredgings to 50 feet but has been found in the Limestone at the seaward edge of the Florida platform at a depth of 58 ft. below the present sea level.

Measurements. — The specimen illustrated herein is a Recent one by Roos (1971, pl. XIIb) from Caracasbaai, Curaçao. The span between margins of the fronds is estimated at a little over 510 mm.

Range and distribution. — The geographic range of *Acropora palmata* is from Florida to Venezuela; the geologic range is Pleistocene to Recent; the radiometric or radiocarbon ages range from Pleistocene to Holocene, or 190,000 to 1,300 years.

Pleistocene — Florida (Key Largo Limestone); British Honduras (Glover's Reef, radiocarbon age 8,500-7,500 years at 150 meters below present sea level); Panama Canal Zone; Costa Rica (Monkey Point); Dominican Republic (Provincia Santo Domingo, at elevations of 36 m and 80 m above sea level between Santo Domingo and San Cristobal); Haiti (Môle St.-Nicolas; Légoane; Grand'Anse); Puerto Rico; St. Eustatius (Mollusk bed 1); Guadeloupe (Formation Madréporique); Dominica (Coral-Point Formation); Barbados (submerged reefs; Bath-Reef Series).

Recent — Florida (reef tract and keys; patch reefs; Soldier Key in Biscayne Bay; Tortugas at Golding Cay); Bahamas (Bimini; Abaco Island; Bahama Bank; Turtle Rocks); Cuba; Jamaica (shore to 17 m; Bluefields Bay; Ocho Rios; South Cay, Port Royal); Pedro Bank; British Honduras (Rendezvous Cay, Turneffe, Lighthouse Reef, Glover's Reef); Mexico (off Vera Cruz at Isla de Lobos and Blanquilla; Alacran; Yucatan Shelf); Puerto Rico (Mayagüez; Culebra; Cayo Enrique; Cayo Caballo Ahogado; Cayo Turrumote; Cayo Icacos; Cabo Rojo); St. Thomas; Antigua; Dominica; Guadeloupe; Barbados (west coast); Netherlands Antilles: Aruba (Cudarebe, Arashi, Boca Catalina, Malmok, Eagle Beach-Palm Beach, Mangel Altu, Andicuri). Curaçao (Plaja Kalki, Westpuntbaai, Plaja Abao, Plaja Chikitu, Boca Santa Marta, Daaibooibaai, Spaanse Water, Oostpunt, St. Joris Baai, Caracasbaai). Bonaire (Boca Bartol, Plaja Frans, Goto, Jan Doran, Barcadera, Baca, Klein Bonaire, Punt Vierkant, Blauwe Pan, Witte Pan, Oranje Pan, Plenchi, Slagbaai). St. Martin (Anse des Pères, Baie Rouge, Mullet Pond Bay, Mahó Bay, Burgeux Bay, Simson Bay, Cay Bay, Great Bay, Point Blanche Bay, Guana Bay, Gibbs Bay, Babit Point). Saba (Ladder Bay, Cove Bay, Fort Bay). St. Eustatius (Cocoluch Bay, Jenkins Bay-Tumbledown Dick Bay, Gallows Bay, Compagnie Baai, Schildpadden Baai); Venezuela (Bahía de Mochima, Edo. Sucre at Ensenada Piedra Pelona, Ensenada Los Aceites, Ensenada El Inglés, Ensenada El Aguirre, Ensenada Burgao, Ensenada Cabruta Roja, Ensenada Garrapata, Morro de la Garrapata, Playa Blanca de Guiaguá, Ensenada Las Maritas, Punta Las Maritas, Costica Mano E'Piedra; Golfo de Cariaco (Zona A).

Acropora prolifera (Lamarck) Pl. 23, fig. 3

1707-1725. ?*Corallium porosum album* Sloane, A Voyage to the Islands of Madera, Barbados, Nieves, S. Christofers and Jamaica, vol. 1, p. 53, pl. 17, fig. 2. [*Fide* Lamarck, 1836, p. 449.]

1767. ?*Madrepora muricata* (Linnaeus), Knorr, Deliciae Naturae, pl. A11, fig. 1. [*Fide* Lamarck, 1836, p. 450.]

1794. *Madrepora muricata* var. *2* Esper, Fortsetzungen der Pflanzenthiere, vol. 1, pl. 50, figs. 1, 2. [*Fide* Lamarck, 1836, p. 450.]

1816. *Madrepora prolifera* Lamarck, Hist. Nat. Anim. sans Vert., vol. 2, p. 281.

1827. *Madrepora prolifera* Lamarck, Eudes-Deslongchamps, Encyclopédie Méthodique, pt. 2, p. 504.

1834. *Madrepora prolifera* Lamarck, Blainville, Manuel d'Actinologie ou de Zoophytologie, p. 390.
1834. *Heterophora prolifera* (Lamarck), Ehrenberg, Akad. Wiss. Berlin, Phys. Abhandl. 1832, pp. 336, 337.
1836. *Madrepora prolifera* Lamarck, Lamarck, Hist. Nat. Anim. sans Vert., ed. 2, vol. 2, pp. 449, 450.
1846. *Madrepora prolifera* Lamarck, Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, p. 480.
1860. *Madrepora prolifera* Lamarck, Edwards and Haime, Histoire Naturelle des Coralliaires ou Polypes proprement dits, vol. 3, p. 139.
1877. *Madrepora prolifera* Lamarck, Lindström, K. Svenska Vetensk-Akad., Handl., vol. 14, No. 6, p. 24.
1880. *Madrepora prolifera* Lamarck, Pourtalès, *in* Agassiz, Mus. Comp. Zool., Mem., vol. 7, No. 1, pl. 19, figs. 1-9.
1886. *Madrepora prolifera* Lamarck, Quelch, Voyage H. M. S. Challenger 1873-76, Rept. Sci. Results, vol. 16, pt. 46, pp. 10-12, 149.
1893. *Madrepora prolifera* Lamarck and *Madrepora muricata* forma *prolifera* Lamarck, Brook, Catalogue of the Madreporarian Corals in the British Museum (Natural History), vol. 1, The Genus *Madrepora*, pp. 24-27.
1902. *Isopora muricata* forma *prolifera* (Lamarck), Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, pt. II, pp. 290, 313, pl. 22, fig. 1; pls. 23-25.
1909. *Madrepora muricata* forma *prolifera* Lamarck, Hartmeyer, Meereskunde Berlin, Jahrg. 3, p. 10, pl. 1, fig. 2.
1912. *Acropora prolifera* (Lamarck), Vaughan, Carnegie Inst. Washington, Yearbook No. 11, p. 156.
1915. *Acropora prolifera* (Lamarck), Vaughan, Carnegie Inst. Washington, Yearbook No. 14, p. 228.
1915. *Acropora prolifera* (Lamarck), Vaughan, Washington Acad. Sci., Jour., vol. 5, No. 17, p. 597.
1939. *Acropora muricata* var. *prolifera* (Lamarck), Butsch, Barbados Mus. and Nat. Hist. Soc., Jour., vol. 6, No. 3, p. 137, pl. 2, fig. 2.
1944. *Acropora prolifera* (Lamarck), Wells, Jour. Paleont., vol. 18, No. 5, p. 446.
1948. *Acropora prolifera* (Lamarck), Smith, Atlantic Reef Corals, pp. 60, 76.
1959. *Acropora prolifera* (Lamarck), Goreau, Ecology, vol. 40, No. 1, pp. 70, 74, 75, 85.
1961. *Acropora prolifera* (Lamarck), Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 9, 12, 13, figs. 1, 2.
1963. *Acropora prolifera* (Lamarck), Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 136, 137, 142, 146, 161, pl. Va.
1964. *Acropora prolifera* (Lamarck), Rivero, Geos [Venezuela], No. 11, p. 113.
1967. *Acropora prolifera* (Lamarck), Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 446.
1968. *Acropora prolifera* (Lamarck), Weisbord, Bull. Amer. Paleont., vol. 55, No. 246, pp. 21-24, pl. 2, figs. 1-3. [Numerous references, 1707-1964.]
1971. *Acropora prolifera* (Lamarck), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 3, 28, 33, 53-55, 104, fig. 9, pl. XI.

Specimen FLX-16a, herein tentatively referred to *Acropora prolifera,* is a distal branch broken off presumably from a corallum of large size. The branch is gently tapering, and subcircular in cross section. The radial corallites are rather crowded and tublar, projecting obliquely from the coenosteum and inclined, but not bent, toward the corallites above. The length of individual corallites varies from 1.7 mm to 3.1 mm, and there are seven rows of them in the length of 24 mm, and about eight corallites to the row around the circumference of the larger end of the branch. The tubular corallites tend to flare slightly at the calicular margin. The calices are circular and deep, and are fairly constant in their diameter of 1.4 mm or so.

The septa of the radial corallites occur in one cycle, but in some calices the second cycle is also represented. The septa are unequal in size, the largest emplaced at that point where the lower rim of the calice abuts the coenosteum. This septum, which is the directive, is relatively narrow, laminar, often highly erose at the margin, and non-granulate on the sides. Where well displayed, this principal septum is aligned with and connected at the columella with the slightly smaller septum at the opposite rim of the calice; more often the other primary septa are rudimentary and are arrayed in linear columns consisting of small, often separated spicules projecting slightly from the wall, their number variable.

The axial corallite of FLX-16a is worn down but reveals six primary septa and a rudimentary secondary septum between each of the principals. The primary septa of the axial corallite are thin, relatively broad laminae descending steeply to the columella which itself is a short thin ribbon connecting the directive septa. The primary septa extend so far toward the center of the calice that the columella area is considerably reduced. The primary septa are non-granulate on the sides and are simple to slightly erose or denticulate on the margin. The septa are not quite equal in size, the directive a little larger than the other primaries. The secondary septa are very thin and narrow, and are minutely spiculate along the margin.

There are about 20 costae on each radial corallite; they are thin (0.1 mm) but well developed, elevated (0.15 mm) and prominent, about equal in size, and separated by deep interspaces about 0.15 mm apart. The crest of the costae is simple but in places may be minutely scalloped. The dissepiments between the costae are membranous and divide the costal interspaces into three or four elliptical cells to the millimeter. The columella is deep and small, and consists of a short lamina connecting the directive septa. The coenosteum is porose, the variably-sized openings bounded, where unweathered, by upright triangular plates or laminae produced from the fragmentation of the costae where they join the coenosteum in the spaces between the corallites.

Measurements. — FLX-16a: branch length 24 mm, diameter at larger end (including projecting corallites) 9.2 mm, diameter at smaller end 6 mm.

Locality. — Specimen FLX-16a is a Recent one from Florida, but the exact locality is not known.

Comparison. — Following are some notes I once made on Recent specimens of *Acropora cervicornis* and *Acropora prolifera* from Pigeon Island, Jamaica.

Acropora cervicornis	*Acropora prolifera*
1. Corallites taper toward and close in on calice.	1. Corallites tubular and tend to flare out at calicular margin.
2. Corallites slant upward and are appressed toward corallites above.	2. Corallites slant upward but are straight and do not bend toward corallites above.
3. Calices bevelled obliquely.	3. Calices nearly normal to corallite axis.
4. Costae high, strong, thin, and straightish.	4. Costae high, strong, thin, and in places a little vermicular.
5. Coenosteum between corallites granulose.	5. Coenosteum porose or made up of short pointed plates.
6. Corallum with long tapering branches, subcircular in cross section, generally straight.	6. Corallum with broad base, branches numerous, diverging, rather short, somewhat irregular.

Range and distribution. — The recorded geographic range of *Acropora prolifera* is Florida to Venezuela; the geologic range is Pleistocene to Recent, but so far as I am aware the species is not reported as a fossil from Florida.

Pleistocene — Bahamas (Fresh Creek fossil reef, Andros Island).

Recent — Florida (Tortugas at Golding Cay); Bahamas; Jamaica (north coast, shore to 30 m; Ocho Rios; Discovery Bay; Runway Bay; Portland Bight; Pigeon Island); Pedro Bank; British Honduras (Rendezvous Cay); Mexico (off Vera Cruz); Puerto Rico (Culebra; Cayo Turrumote); St. Thomas; Barbados (west coast 1 f - 8 f); Bonaire (Boca Bartól, Lac); Curaçao (Caracasbaai); Venezuela (Higuerote, Edo. Miranda; Puerto La Cruz, Edo. Anzoategui).

AGARICIIDAE

Agaricia agaricites (Linnaeus) Pl. 21, fig. 2

1755. *Agaric,* Dezallier d'Argenville, Hist. nat. éclaircie . . . l'oryctologie . . , p. 362, pl. 22, fig. 7. [*Fide* Edwards and Haime, 1851, p. 127.]
1758. *Agaricus seu Fungus quercinus* Seba, Locupletissimi Rerum Naturalium Thesauri, vol. 3, p. 203, pl. 110, No. 6c. [*Fide* Edwards and Haime, 1851, p. 127.]
1758. *Madrepora agaricites* Linnaeus (*pars*), Systema Naturae, ed. 10, p. 795.
1766. *Madrepora agaricites* Linnaeus, Pallas (*pars*), Elenchus Zoophytorum, pp. 287-289.
1767. *Madrepora agaricites* Linnaeus, Systema Naturae, ed. 12, vol. 1, pt. 2, p. 1274.
1786. *Madrepora agaricites* Linnaeus, Ellis and Solander, Natural History of . . . Zoophytes, p. 159, pl. 63.
1789. *Madrepora agaricites* Linnaeus, Esper, Die Pflanzenthiere in Abbildungen, vol. 1, pts. 3-4, pp. 132-135, pl. XX, figs. 1, 2.
1791. *Madrepora agaricites* Linnaeus, Gmelin, Systema Naturae, ed. 13, p. 3759.
1801. *Pavonia cristata* Lamarck, Syst. Anim. sans Vert., p. 372. [*Fide* Edwards and Haime, 1851, p. 127.]
1815. *Undaria agaricites* (Linnaeus), Oken, Lehrbuch der Naturgeschichte, vol. 1, p. 69.
1821. *Pavonia agaricites* (Linnaeus), Lamouroux, Exposition Méthodique . . . Polypiers, p. 53, pl. 63. Also *Agaricia agaricites* (Linnaeus), p. 54, pl. 40.
1824. *Pavonia agaricites* (Linnaeus), Eudes-Deslongchamps, Encyclopédie Méthodique, pt. 2, p. 604.
1825. *Pavonia agaricites* (Linnaeus), Blainville, Dictionnaire des Sciences Naturelles, vol. 38, p. 167.
1829. *Pavonia agaricites* (Linnaeus), Eichwald, Zoologia Specialis, vol. 1, p. 185.
1830. *Pavonia agaricites* (Linnaeus), Blainville, Dictionnaire des Sciences Naturelles, vol. 60, p. 330.
1834. *Pavonia agaricites* (Linnaeus), Blainville, Manuel d'Actinologie ou de Zoophytologie, p. 365.
1834. *Pavonia cristata* Lamarck, Ehrenberg, K. Akad. Wiss. Berlin, Phys. Abhandl. 1832, p. 328.
1846. *Agaricia (Mycedia) agaricites* (Linnaeus), Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, p. 342.
1847. *Agaricia cristata* (Lamarck), Duchassaing, Soc. Géol. France, Bull., sér. 2, vol. 4, p. 1097.
1851. *Agaricia agaricites* (Linnaeus), Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 15, pp. 127, 128.
1860. *Agaricia agaricites* (Linnaeus), Edwards and Haime, Histoire Naturelle des Coralliaires ou Polypes proprement dits, vol. 3, p. 81.
1861. *Agaricia agaricites* [?Linnaeus], (Pallas), Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 19, p. 356. Also *Mycedium lessoni, M. danai,* and *M. vesparium* Duchassaing and Michelotti, p. 357. [*Fide* Vaughan, 1901, p. 65.]
1863. *Agaricia agaricites* (Linnaeus), Duncan, Geol. Soc. London, Quart. Jour., vol. 19, p. 437.
1864. *Agaricia agaricites* (Edwards and Haime), Verrill, Mus. Comp. Zool., Bull., vol. 1, No. 3, p. 55.
1866. *Mycedium Sancti-Johannis* Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 25, p. 187, pl. 10, fig. 11.

1868. *Agaricia agaricites?* (Edwards and Haime), Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 1, pt. 2, art. V, No. 4, p. 352.
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1870. *Agaricia agaricites* (Linnaeus), Duchassaing, Revue des Zoophytes et des Spongiaires des Antilles, p. 31.
1871. *Agaricia agaricites* (Edwards and Haime), Pourtalès, Mus. Comp. Zool., Mem., vol. 2, No. 4, p. 82.
1875. *Agaricia agaricites* (Lamarck), Pourtalès, *in* Gabb, Geol. Mag., decade 2, vol. 2, p. 545.
1877. *Agaricia agaricites* (Pallas), Lindström, K. Svenska Vetensk.-Akad., Handl., vol. 14, No. 6, p. 23.
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1927. *Agaricia agaricites* (Linnaeus), van der Horst, Bijdr. Dierk. Amsterdam, vol. 25, pp. 160, 161. Also *A. crassa* Verrill.
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1971. *Agaricia agaricites* (Linnaeus), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 3, 16, 18-39, 56-58, 95, 103, figs. 7, 8, 21, pls. 14a, b; 15.
1971. *Agaricia agaricites* (Linnaeus), Olivares, Inst. Oceanogr. Univ. Oriente, Bol., vol. 10, No. 2, pp. 73, 74, 75.
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The description of *Madrepora agaricites* by Linnaeus (p. 795) was the following:

> Agaricites-o. M. composita acaulis sulcata sulcis carinatis, stellis concatenatis.
> *Habitat in* O. Indico.
> *Lapis constans lamellis variis divergentibus semiorbiculatis, exaratis urinque sulcis plurimis repandis.* Fundo *stellis concatenatis.*

The form herein described and illustrated as *Agaricia agaricites* is a Recent one from Looe Key, Florida. The corallum is encrusting, hemispherical, openly foliaceous and flower-like, with widely separated fronds that are high, erect, and concave upward. The fronds arise, and diverge from deep valleys, the height of the fronds varying from 14 mm to 29 mm; the summits of the fronds are acute, and the distance from summit to summit across the valleys varies from 21 mm to 39 mm; the average thickness of the fronds (including the collines) is about 10 mm. The base of the corallum is wedge-shaped, and shows evidence of having been attached.

Both faces of the fronds are beset by small, deep, subrectangular to vaguely polygonal calices arranged in parallel groups separated by thin, slightly projecting walls. The calices range from 1.7 mm to 3.6 mm in long diameter; their depth from the top of the wall to the fossa is about 1.5 mm to 2.2 mm. Depending on the size of the calice, there are about 20 to perhaps a maximum of 40 septa; the septa are thin, lamellar, and narrow, and alternate rather regularly in size, the major ones a little higher and better developed than the subsidiaries. The principal septa are finely serrulate along the margin and are finely spinulose on the sides. The synapticulae between the septa are well developed, and there are four of them in one millimeter of length. The costae are conterminous with the septa, and like the septa are denticulate on the crest and minutely spinose on the sides.

The collines are prominent and are 1.5 mm to 2.5 mm apart, with six rows of them on the largest frond. Most of them are more or less parallel with the crest of the frond, but some are transeverse or oblique; all of them, however, are sharp at the summit, and are about 1.5 mm in height. The collines are not quite normal to the plane of the frond but slope slightly toward the crest.

The development of the calices and collines on the under side of the fronds is less pronounced than on the upper side; the costae, however, are somewhat more pronounced on the lower surface than on the upper.

Measurements. — Specimen FLK-1a: corallum length 104 mm, width 84 mm, height 75 mm.

Locality. — Specimen FLK-1a is labeled Looe Key, Florida, in the FSU collection. It was collected by Noel Andress and donated by him to the Department of Geology, Florida State University.

Comparisons. — The following taxa, cited in the synonymy above, are considered by a number of authors to be the same as *Agaricia agaricites* or ecological variants thereof: *Agaricia cristata* (Lamarck); *Mycedium lessoni, M. danai, M. vesparium,* and *M. sancti-johannis* Duchassaing and Michelotti; and *Agaricia crassa* Verrill. Among all of the illustrated taxa, specimen FLK-1a is closest to the *Agaricia agaricites s.s.* of Vaughan and Wells (1943) and of Smith (1948); it also resembles the *A. agaricites* var. *crassa* of Squires (1958) and of Almy and Carrión-Torres (1963).

Range and distribution. — The geographic range of *Agaricia agaricites* is Florida to Brazil; the geologic range is Miocene to Recent, excepting the Pliocene.

Miocene — Guadeloupe (Tuf Blanc); Dominican Republic (Nivaje Shale); Trinidad (?).

Pleistocene — Florida (Key Largo Limestone/Miami Oolite dredged off Stock Island, and excavated from marl pits alongside Card Sound bridge, Monroe County); Bahamas (Bimini); Costa Rica; Panama Canal Zone (Mt. Hope); Puerto Rico; Dominican Republic.

Recent — Florida (reefs along southeast coast; Tortugas at Golding Cay, Fort Jefferson, and Loggerhead Key); Bahamas (Nassau, New Providence; Great Bahama Bank; Abaco Island; Bimini; Turtle Rocks; Rabbit Cay); Jamaica (Ocho Rios; 3 m to 45 m);

Mexico (Alacran Reef; Yucatan Shelf); St. Thomas; St. Bartholomew; Haiti; Puerto Rico (Cayo Icacos); Barbados (west coast); Netherlands Antilles: Aruba (Cudarebe, Arashi, Malmok, Eagle Beach, Palm Beach, Barcadera, Mangel Altu, north of Pitch Field). Curaçao (Westpuntbaai, Plaja Abao, Lagun, Sta. Martha Baai, Portomaribaai, Vaarsenbaai, Sint Michielsbaai, Kaap Malmeeuw, Spaanse Water, Klein Curaçao). Bonaire (Boca Bartól, Plaja Frans, Jan Doran, Barcadera, Ruin, Klein Bonaire, Plaja Sarna, Baca, Blauwe Pan-Witte Pan, Lac). St. Martin (Baie Rouge, Mahó Bay, Burgeux Bay, Cay Bay, Little Bay, Great Bay, Gibbs Bay, Babit Point). Saba (Cove Bay). St. Eustatius (Cocoluth Bay-Jenkins Bay, Gallows Bay, Compagnie Baai). Venezuela (Bahía de Mochima, Edo. Sucre at Ensenada Cabruta Roja, E. Tía Maria, E. Baraderito, E. San Agustin, E. Garrapata, E. Burgao, E. El Inglés, E. Carenero, E. Cabruta, E. La Aguada, E. Toporito-Toporo, Punta Toporo, Punta Mero Mañoso, Punta Las Maritas, Punta Las Morochas, Punta Piedra, Playa Piedra, Punta Aceite de Palo, Barranca de Mochima, Playa de Reyes, Playita Mangle Quemao, Costa y Punta El Amparo, Costica Mano E'Piedra, Costa Maringina, Lance Manguillas, Peña Azul; Golfo de Cariaco, Zonas A, D, I); Brazil? (Maceio coral reef; Abrolhos; Parcel de Paredes; Santo Aleixo; Rio Formoso).

Agaricia fragilis Dana Pl. 24, figs. 1, 2

1846. *Agaricia (Mycedia) fragilis* Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, p. 341.
1860. *Mycedia fragilis* Dana, Edwards and Haime, Histoire Naturelle des Coralliaires ou Polypes proprement dits, vol. 3, p. 83.
1864. *Mycedium fragile* Dana, Verrill, Mus. Comp. Zool., Bull., vol. 1, No. 3, p. 55.
1866. *?Mycedium cailleti* Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 23, p. 187. [*Fide* Gregory, 1895, p. 281.]
1870. *Mycedium cailleti ?* Duchassaing and Michelotti, Duchassaing, Revue des Zoophytes et des Spongiaires des Antilles, p. 31.
1871. *Mycedium fragile* Dana, Pourtalès, Mus. Comp. Zool., Mem., vol. 2, pp. 48, 82.
1877. *Mycedium fragile* Dana, Arango y Molina, R. Acad. Cienc. Médicas, Físicas y Naturales Habana, An., vol. 14, p. 281.
1880. *Mycedia fragilis* Dana, Agassiz and Pourtalès, Mus. Comp. Zool., Mem., vol. 7, No. 1, pl. 11, figs. 1-10 (young specimens); pl. 13, figs. 1-5; pl. 14, figs. 1-9.
1886. *Agaricia fragilis* Dana, Quelch, Voyage H.M.S. Challenger 1873-1876, Rept. Sci. Results, Zoology, vol. 16, pt. 46, pp. 10-12, 116, 117.
1888. *Mycedia fragile* Dana, Ortmann, Zool. Jahrb., Abt. Syst., vol. 3, p. 181.
1890. *Mycedia fragile* Dana, Ortmann, Zeitschr. f. Wiss. Zool. Leipzig, vol. 50, pt. 2, p. 288.

1895. *Agaricia elephantotus* Pallas (*pars*), Gregory, Geol. Soc. London, Quart. Jour., vol. 51, pp. 280, 281. [*Fide* Verrill, 1901, p. 142.]
1900. *Mycedium fragile* Dana, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 10, art. XVII, p. 592.
1901. *Agaricia fragilis* Dana, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. II, pt. I, art. III, pp. 134, 140-145, 151; art. IV, p. 181, pl. 26. figs. 1a-1d.
1901. *Agaricia fragilis* Dana, Vaughan, Rijksmus. Geol. en Mineral., Samml., ser. 2, vol. 2, No. 1, pp. 9, 12, 67, 68.
1902. *Agaricia fragilis* Dana, Duerden, Nat. Acad. Sci., Washington, Mem., vol. 8, pp. 592-594, pls. 24, 25, figs. 161-164.
1906. *Agaricia fragilis* Dana, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 12, art. II, pt. 4, pp. 141, 187, 245-247, figs. 101, 101a.
1929. *Agaricia fragilis* Dana, Felix, Fossilium Catalogus I: Animalia, pars 44, p. 558.
1948. *Agaricia fragilis* Dana, Smith, Atlantic Reef Corals, pp. 60, 67, 77, 78.
1954. *Agaricia fragilis* Dana, Fontaine, Inst. of Jamaica, Ann. Rept. 1953-1954, p. 24.
1954. *Agaricia fragilis* Dana, Smith, U.S. Fish and Wildlife Serv., Fish. Bull., vol. 55, No. 89, p. 293.
1958. *Agaricia fragilis* Dana, Zans, Geol. Survey Dept. Jamaica, W.I., Bull., No. 3, p. 31.
1959. *Agaricia fragilis* Dana, Zans, Geonotes, vol. 2, No. 1, pp. 28, 34.
1959. *Agaricia fragilis* Dana, Goreau, Ecology, vol. 40, No. 1, pp. 70, 75, 85.
1960. *Agaricia fragilis* Dana, Lewis, Canadian Jour. Zool., vol. 38, No. 6, pp. 1134, 1139, 1140.
1960. *Agaricia fragilis* Dana, Lewis, Barbados Mus. and Nat. Hist. Soc., Jour., vol. 28, p. 11.
1961. *Agaricia fragilis* Dana, Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 9, 22, 23, figs. 11, 12.
1962. *Agaricia fragilis* Dana, Stoddart, Atoll Res. Bull., No. 87, p. 19.
1963. *Agaricia agaricites* var. *fragilis* Dana, Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 1-2, p. 147, pl. VIb.
1964. *Agaricia fragilis* Dana, Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 20, No. 81, pp. 9, 24, 27, 32, 47.
1965. *Agaricia fragilis* Dana, Neumann, Bull. Marine Sci., vol. 15, No. 4, p. 1004.
1966. *Agaricia fragilis* Dana, Rigby and MacIntire, Brigham Young Univ. Geol. Studies, vol. 13, pp. 36, 41.
1966. *Agaricia fragilis* Dana, Laborel, Mus. Nat. Hist. nat., Paris, Bull., sér. 2, vol. 38, No. 3, pp. 282-284, 290, 296, 297, 299, pl. 1, figs. 3, 4, text-figs. 3, 6, 7.
1967. *Agaricia fragilis* Dana, Laborel, Postilla, No. 107, pp. 2, 5.
1967. *Agaricia fragilis* forma *fragilis* Dana, Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 447.

Agaricia fragilis Dana is not reported as a fossil in Florida although the living species occurs in the Tortugas and off the west coast in the Gulf of Mexico. The specimen (FMG-2a) described and illustrated herein is from the "Florida Middle Ground" in the Gulf of Mexico.

The corallum is a single thin salver-shaped frond spreading out from an off-centered pedicelled base. The outer edge of the frond is broadly scalloped and nearly paper-thin; toward the growth center the thickness of the frond increases to about 3 mm. At one end of the frond the edges bend down but at the other end they are flat, although overall the frond is gently but irregularly concave upward. At several places on the upper surface there are small humps and projections which represent imbedded or penetrated organisms, some of them tubular, covered wholly or in part by the encrusting growth of the coral.

The frond is unifacial, with the calices occurring on the upper surface only. The calices are small and subcircular to oval, the former about 1.4 mm in diameter, the latter up to 2.8 mm from margin to margin. They are arranged more or less continuously in longish rows between low concentric collines, in the valleys of which they are rather deeply immersed. There are fewer septa (14-16) in the circular calices than in the oval ones (up to 24) and they alternate in size, the major septa subequal and more prominent than the subequal minors. The septa are exsert and regularly arched over the calicular margins where they are characteristically stellate in appearance. Within the calice the septa descend rather steeply, the principals extending to and joining the base of the columella. The free margins of the septa are finely serrate, and on the sides of the septa there are small pointed granulations or spinules, one tier of which occurs at and alongside the free margin. The columella area is small and where the columella can be seen at all it is substyliform or papillate. On the upper surface of the frond the costae are conterminous with the septa and are similar in appearance, arrangement, and ornamentation.

The collines are low, rounded, subparallel and concentrically arranged to conform more less to the contour of the frond margin. They are 2.5 mm to 4.5 mm apart, the spacing greater near the edges of the frond. The septo-costae are extensions of, and continuations from the calices.

The under surface of the frond is smoothish and non-calicular, although it is marked by low concentric growth ridges of unequal spacing and magnitude, and by faint but numerous minute radial costae of which there are six in one millimeter of width near the periphery; the costae are finely granular along the sharp crest. The pedicel is suboblong and is 31 mm long, 15 mm or so in width, and 8 mm in height.

Measurements. — Specimen FMG-2a: frond length 172 mm, maximum width 107 mm, minimum width 61 mm.

Locality. — Florida Middle Ground off the west coast of Florida at about Long. 87° W and Lat. 28°15′ N. Collected and donated by Robert Back, 1972.

Range and distribution. — Pleistocene to Recent.

Pleistocene — Barbados (low level reefs near Bridgetown); Curaçao (elevated reefs at Plantersrust).

Recent — Bermuda (Harrington Sound; Castle Harbor); Florida (Tortugas, 36 f - 43 f, and Loggerhead Key; Florida Middle Ground); Cuba (near Habana); Jamaica (3 m - 40 m); Pedro Bank; Mexico (Isla de Lobos); St. Thomas; Puerto Rico; Curaçao (Piscaderabaai; Lagun); Barbados (west coast); Brazil (Abrolhos).

Agaricia purpurea (Lesueur) Pl. 26, fig. 1

1821. *Agaricia purpurea* Lesueur, Mus. Hist. Nat. Paris, Mém., vol. 6, pp. 276, 277, pl. 15, figs. 3a, 3b, 3c.
1846. *Agaricia (Mycedia) purpurea* Lesueur, Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, p. 340.
1860. *Agaricia purpurea* Lesueur, Edwards and Haime, Histoire Naturelle des Coralliaires ou Zoophytes proprement dits, vol. 3, p. 84.
1861. *Mycedium purpureum* "Dana," Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 19, p. 357.
1864. *Agaricia purpurea* Lesueur, Verrill, Mus. Comp. Zool., Bull., vol. 1, No. 3, p. 55.
1871. *Agaricia purpurea* Lesueur, Pourtalès, Mus. Comp. Zool., Mem., vol. 2, No. 4, p. 82.
1886. *Agaricia purpurea* Lesueur, Quelch, Voyage H.M.S. Challenger, Rept. Sci. Results, Zoology, vol. 16, pt. 46, p. 12.
1895. *Agaricia purpurea* Lesueur, Gregory, Geol. Soc. London, Quart. Jour., vol. 51, p. 280.
1901. *Agaricia purpurea* Lesueur, Dana, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, pt. I, art. III, pp. 135, 145, 149, pl. 27, figs. 4a, 4b.
1914. *Agaricia purpurea* Lesueur, Vaughan, Carnegie Inst. Washington, Yearbook No. 13, pp. 224, 225.
1915. *Agaricia purpurea* Lesueur, Vaughan, Carnegie Inst. Washington, Yearbook No. 14, p. 228.
1915. *Agaricia purpurea* Lesueur, Vaughan, Washington Acad. Sci., Jour., vol. 5, No. 17, p. 597.
1919. *Agaricia agaricites* var. *purpurea* Lesueur, Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 232, 233, 427.
1921. *Agaricia purpurea* Lesueur, Vaughan, Geol. Survey Dominican Republic, Mem., vol. 1, p. 167.
1924. *Agaricia agaricites* var. *purpurea* Lesueur, *in* Woodring, Geol. Survey Republic of Haiti, p. 243.
1929. *Agaricia purpurea* Lesueur, Felix, Fossilium Catalogus I: Animalia, pars 44, p. 558.

1930. *Agaricia purpurea* Lesueur, Yonge, Great Barrier Reef Exped. 1928-29, Sci. Rept., vol. 1, p. 44.
1948. *Agaricia purpurea* Lesueur, Smith, Atlantic Reef Corals, p. 76.
1958. *Agaricia agaricites* var. *purpurea* Lesueur, Squires, Amer. Mus. Nat. Hist., Bull., vol. 115, art. 4, pp. 227-229, 232, 237, 238, 248, pl. 32, fig. 3.
1959. *Agaricia agaricites* var. *purpurea* Lesueur, Zans, Geonotes, vol. 2, No. 1, pp. 28, 34.
1961. *Agaricia agaricites* var. *purpurea* Lesueur, Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 9, 20, 21, figs. 9, 10.
1961. *Agaricia agaricites* var. *purpurea* Lesueur, Westermann and Kiel, Natuurwetensch. Studiekring Suriname en de Nederlandse Antillen, No. 24, p. 136.
1963. *Agaricia agaricites* var. *purpurea* Lesueur, Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, p. 147, pl. VIa.
1964. *Agaricia agaricites* forma *purpurea* Lesueur, Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 20, No. 81, pp. 8, 24, 25, 27, 28, 38, 41.
1964. *Agaricia agaricites* var. *purpurea* Lesueur, Storr, Geol. Soc. Amer., Spec. Pap., No. 79, pp. 82-85.
1967. *Agaricia agaricites* forma *purpurea* Lesueur, Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 446.
1970. *Agaricia agaricites purpurea* Lesueur, Klose, *in* letter to R. O. Vernon 30 April 1970, p. 6.
1971. *Agaricia agaricites purpurea* Lesueur, Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 56-58.
1972. *Agaricia agaricites purpurea* Lesueur, Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 547, 551, 561, 577, pl. 4.

Lesueur's original description of *Agaricia purpurea* was as follows:

> I. Agarice pourpre. *Agaricia purpurea* (nobis).
>
> Polypier foliacé à expansions ondulées, tranchantes sur les bords, recouvrant tous les corps qu'il rencontre. Surface supérieure couverte de cellules profondes, tantôt sérialaires dans des vallons, tantôt groupées, et formant par leur inégalité et celle contournée des vallons, un réseau trés-irrégulier. Collines composées de lames entières, libres au sommet, denticulées, les intermédiaires plus petites; cellules sérialaires partagées entre elles par plusieurs lames placées dans le sens de la longueur des vallons, et opposées à celles des collines; surface inférieure finement striée, croisée par des ondulations concentriques.
>
> Animal à expansions gélatineuses, sans tentacules apparens; ouverture centrale allongée, plissée intérieurement, bordée d'un cercle jaune, et un peu plus loin par huit points jaunes, desquels naissent des lignes étant aussi d'un jaune pâle, et se prolongeant jusqu'au rebord. Il y en à d'autres plus légères, intermédiaires, qui se divisent en deux et trois. A chacun de leur point de division est une tache jaunâtre.
>
> La couleur générale est d'un beau pourpre au centre, qui passe à une teinte foncée d'un roux de terre de Sienne, vers les bords de l'animal.
>
> Cet animal est très-délicat, joli à voir. Quand son polypier à tous ces animaux développés, l'oppostion des lignes jaunes avec la couleur pourpre et celle foncée de terre de Sienne fait un assez joli contraste; les points jaunes des divisions varient de six, huit, jusqu'à douze; les expansions sont de cinq, six à huit pouces, encroûtant et recouvrant tout ce qui se recontre sur leur passage.

> Les lames qui composent les collines sont entières, et les traversent de chaque côte; elles ne sont point, comme dans les méandrines, réunies a leur sommet par un ligne en zigzag.
>
> Il y en a une variété entièrement verte que je n'ai pas eu le temps d'examiner.
>
> Habite Saint-Thomas.

Although I have not seen this species in the Florida State University collection, it is included in this work because of its occurrence in the Key Largo Formation (Pleistocene) of Florida. According to Verrill (1901), *Agaricia purpurea* usually forms broad, thick unifacial fronds, generally attached near the middle or else partly encrusting. The collines are narrow, acute, and short, and are often irregular and reticulated. The calices are large, deeply sunken, open, and angular. The septa are thin and narrow, alternately larger and smaller, and there are 24 to 36 of them. In the thicker parts of the calices there are well-formed dissepiments. The columella where visible is small, solid, and papilliform. The costae of the under side are fine, subequal, and regularly disposed.

Measurements. — The specimen from the Bahamas (AMNH No. 3299) illustrated by Squires (1958) is 104 mm in length and 89 mm in width.

Comparisons. — *Agaricia purpurea* is considered an ecologic variant of *A. agaricites* by some authors and a distinct species by others. Typically, *A. agaricites* is bifacial, whereas *A. purpurea* is unifacial as stated in Lesueur's original description. On the other hand both *A. purpurea* and *A. fragilis* are unifacial, although *A. purpurea* differs from *A. fragilis* in its thicker fronds, much larger calices, and particularly in its shorter, more irregular, and often reticulated collines.

Range and distribution. — Pliocene to Recent. Florida to Venezuela.

Pliocene — Haiti (Hinche Formation).

Pleistocene — Florida (Key Largo Limestone at Card Sound Bridge, Monroe County); Panama Canal Zone (Mt. Hope); St. Eustatius (Sugar Loaf and White Wall); Dominican Republic (Provinces of Macoris and Barahona).

Recent — Florida (Tortugas at Fort Jefferson and Loggerhead Key); Bahamas (Abaco Island; Turtle Rocks; Rabbit Cay); Cuba; Jamaica (1 m - 7 m); Panama (Colon); Haiti; Puerto Rico (Cayo

Icacos); St. Thomas; Curaçao (Lagun, Sta. Martha Baai, Kaap Malmeeuw, Spaanse Water); Venezuela (Bahía de Mochima, Edo. Sucre at Ensenada Cabruta and Barranca de Mochima).

Helioseris cucullata (Ellis and Solander) Pl. 25, figs. 1, 2

1776. Not *Madrepora elephantotus* Pallas, Elenchus Zoophytorum, p. 290. [*Fide* Verrill, 1901, pp. 133-135.]
1786. *Madrepora cucullata* Ellis and Solander, Natural history of . . . Zoophytes, p. 157, pl. 42, both figs.
1794. *Madrepora cucullata* Ellis and Solander, Esper, Fortsetzungen der Pflanzenthiere, vol. 1, p. 83, pl. LXVII, both figs. copied from Ellis and Solander.
1801. *Agaricia cucullata* (Ellis and Solander), Lamarck, Syst. Anim. sans Vert., p. 373.
1815. *Mycedium cucullata* (Ellis and Solander), Oken, Lehrbuch der Naturgeschichte, Theil 3, Zool., Abt. 1, p. 69.
1816. *Agaricia cucullata* (Ellis and Solander), Lamarck, Hist. Nat. Anim. sans Vert., vol. 2, p. 242.
1821. *Agaricia cucullata* (Ellis and Solander), Lamouroux, Exposition Méthodique . . . Polypiers, p. 54, pl. 42, figs. 1, 2.
1824. *Agaricia cucullata* (Ellis and Solander), Lamouroux, Encyclopédie Méthodique, vol. 2, pl. 484.
1834. *Agaricia cucullata* (Ellis and Solander), Blainville, Manuel d'Actinologie ou de Zoophytologie, p. 360, pl. 56, fig. 3.
1836. *Agaricia cucullata* (Ellis and Solander), Lamarck, Hist. Nat. Anim. sans Vert., ed. 2, vol. 2, p. 380.
1846. *Mycedia cucullata* (Ellis and Solander), Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, p. 339.
1851. ?*Mycedium elephantotus* Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 15, pp. 131, 132.
1860. ?*Mycedium elephantotus* Edwards and Haime, Histoire Naturelle des Coralliaires ou Polypes proprement dits, vol. 3, p. 74.
1866. ?*Mycedium elephantotus* Edwards and Haime, Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 23, p. 186.
1877. ?*Mycedium elephantotus* Oken, Arango y Molina, R. Acad. Cienc. Médicas, Físicas y Naturales Habana, An., vol. 14, p. 282.
1886. ?*Agaricia (Mycedium) elephantotus* Edwards and Haime, Quelch, Voyage H.M.S. Challenger 1873-76, Rept. Sci. Results, Zoology, vol. 16, pt. 46, p. 116.
1895. *Agaricia cucullata* (Ellis and Solander), Gregory *pars,* Geol. Soc. London, Quart. Jour., vol. 51, p. 281.
1901. ?*Agaricia elephantotus* (Edwards and Haime), Vaughan, Rijksmus. Geol. en Mineral. Leiden, Samml., ser. 2, vol. 2, No. 1, pp. 9, 67.
1901. *Mycedium cucullata* (Ellis and Solander), Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, Pt. 1, art. III, pp. 135, 140.
1901. *Agaricia nobilis* Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, Pt. 1, art. III, pp. 150, 151, pl. 28, figs. 1, 2. [*Fide* Goreau and Wells, 1967, p. 447, footnote.]
1902. ?*Agaricia elephantotus* (Edwards and Haime), Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, Pt. 2, p. 310, pl. 17, fig. 1.
1919. *Agaricia nobilis* Verrill, Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 429, 430.
1948. *Agaricia nobilis* Verrill, Smith, Atlantic Reef Corals, pp. 60, 68, 77, 78.
1954. *Agaricia nobilis* Verrill, Smith, U.S. Fish and Wildlife Serv., Fish. Bull., vol. 55, No. 89, p. 293.

1958. *?Agaricia nobilis* Verrill, Zans, Geol. Survey Dept. Jamaica, W.I., Bull., No. 3, p. 31.
1959. *Agaricia nobilis* Verrill, Zans, Geonotes, vol. 2, No. 1, pp. 28, 34.
1959. *Agaricia nobilis* Verrill, Goreau, Ecology, vol. 40, No. 1, pp. 70, 75, 85.
1960. *Agaricia nobilis* Verrill, Lewis, Barbados Mus. and Nat. Hist. Soc., Jour., vol. 28, No. 1, p. 11.
1960. *Agaricia nobilis* Verrill, Lewis, Canadian Jour. Zool., vol. 38, No. 6, pp. 1134, 1140.
1961. *Agaricia nobilis* Verrill, Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 9, 22.
1962. *Agaricia nobilis* Verrill, Stoddart, Atoll Res. Bull., No. 87, pp. 17-19.
1963. *Agaricia cucullata* (Ellis and Solander), Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 142, 148, 161, pl. VII b.
1964. *Agaricia nobilis* Verrill, Storr, Geol. Soc. Amer., Spec. Pap., No. 79, pp. 39, 46, 47.
1967. *Helioseris cucullata* (Ellis and Solander), Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 447.
1970. *Agaricia nobilis* Verrill, Klose, *in* letter to R. O. Vernon 30 April 1970, p. 4.
1971. *Agaricia cucullata* (Ellis and Solander), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, p. 57.

The original description of *Helioseris cucullata* by Ellis and Solander was as follows:

> "25. Madrepora cucullata.
>
> Tab. 42.
>
> Madrepora *foliacea explanata concatenata, stellis subserialibus profundis, ambulacris acute carinatis subflexuosis.*
>
> Tab. 42
>
> Primo intuitu M. Licheni Similis, distinctissima autem quod subtus absque stellis subtilissme striata."

Measurements. — Ellis and Solander's figures on their plate 42 are about 97 mm in length and 95 mm in width.

Recognizing that *Madrepora elephantotus* Pallas was an East Indian species and distinct from its Antillean counterpart, Verrill (1901) named and described the Antillean taxon as *Agaricia nobilis,* designating the type from Turks Island as No. 850 in the Museum of Yale University. Goreau and Wells (1967) in their revision of the shallow-water Scleractinia of Jamaica listed *Helioseris cucullata* (Ellis and Solander) as the prior name for the *Agaricia nobilis* of Jamaica. It is my understanding that Wells has continued work on the corals of Jamaica and that publication of the results is in the offing. In the meanwhile I have gone through the literature and drawn up the synonymy cited above which is based on the statement by Goreau and Wells that *Agaricia nobilis* is the same as *Helioseris cucullata.*

Range and distribution. — The living *Helioseris cucullata* and its congeners ranges from Florida to Barbados, and is reported from the following localities: Florida Keys; Bahamas (Abaco Island); Turks Island (Lat. 21°30′ N., Long. 71°07′ W.); Cuba; Jamaica (Ocho Rios; 3 m - 90 m); Pedro Bank; British Honduras (Rendezvous Cay); Puerto Rico (off Culebra, 16 fathoms); Barbados (west coast), Netherlands Antilles?

The Pleistocene form of *Helioseris cucullata* has been recorded (as *Agaricia nobilis*) in Florida by Klose (1970) in the Miami Oolite dredged off the eastern tip of Stock Island, Monroe County.

Observations. — In discussing the variability of *Agaricia agaricites* (Linnaeus), Roos (1971, pp. 57, 58, 103) stated: "*Agaricia cucullata* (= *A. nobilis*) is placed in the synonymy of *Agaricia agaricites,* because of the occurrence of parts of *A. agaricites* var. *purpurea,* which closely resemble Verrill's *Agaricia nobilis* (Pl. 15)."

Ellis and Solander's illustrations of *Madrepora cucullata* represent the under and upper sides of the same specimen. The under side is devoid of calices, and on the upper the calices are much subdued, and in places absent. Verrill's illustrations of *Agaricia nobilis* represent only the upper side, and this is "loosely covered with rather large, deep, prominent, appressed, stellate calices." Judging from the illustrations and description of both taxa, it does seem that the *A. nobilis* of the Netherlands Antilles is closer to the *A. agaricites* stock than to *H. cucullata.* On the other hand, the illustrations by Almy and Carrión-Torres (1963, p. 148, pl. VIIa) of the upper (?) side of *Agaricia cucullata* from Puerto Rico does indeed resemble the *H. cucullata* of Ellis and Solander.

SIDERASTREIDAE

Siderastrea dalli Vaughan Pl. 26, figs. 2, 3; Pl. 27, figs. 1-5

1919. *Siderastrea dalli* Vaughan, U.S. Nat. Mus., Bull., vol. 103, No. 9, pp. 222, 223, 232, 233, 437, 438, 450, 451, 517, pl. 119, figs. 1, 1a, 2.

1929. *Siderastraea dalli* Vaughan, Felix, Fossilium Catalogus I: Animalia, pars 44, p. 560.

1958. *Siderastrea dalli* Vaughan, DuBar, Florida Geol. Sur., Geol. Bull., No. 40, p. 121.

1969. *Siderastrea dalli* Vaughan, Wells, *in* DuBar, Gulf Coast Assoc. Geol. Soc., Soc. Econom. Paleont. and Mineral. Sect. Ann. Meet., Field Trip Number 4, p. 141.

Vaughan's original description of *Siderastrea dalli* was as follows:

> Corallum forming a mass rounded above. The type has a length of about 122 mm. and is 75 × 82 mm. in diameter in its median part.
>
> The corallites are large, hexagonal or pentagonal in shape. The usual diameter is from 5 to 6.5 mm.; a large corallite is 5.75 by 8 mm. in diameter. Wall between corallites usually distinct, thin. Calices, shallow.
>
> Septa, rather thin, or fairly thick, very crowded. There are four complete cycles, and a fair number of the members of a fifth cycle. The large calice, 5.75 × 8 mm. in diameter has 68 septa. The septal grouping need not be described, as it is that common for the genus. Septal dentations fine, compressed transversely to the septal planes, finely frosted, from seventeen to twenty or more teeth on the members of the first cycle. No compound or double dentations were seen. The septal faces, closely granulate; perforations similar to those in *S. pliocenica.*
>
> Synapticulae in three or four vertical rows — in the outer portion of the interseptal loculi, there may be even more. Very thin, nearly horizontal dissepiments present. The wall is similar to that of *S. pliocenica,* but thinner.
>
> Columella papillary. The papillae are fine, more delicate than in *S. pliocenica.*
>
> *Locality and geologic occurrence.* — Florida, station No. 3300, Shell Creek, collected by F. Burns (type); station 2094, Caloosahatchee River, Florida, collected by W. H. Dall; Pliocene.
>
> *Type.* — No. 325196, U.S.N.M.
>
> This species is separated from *S. pliocenica* by its generally more delicate structure, more numerous septal dentations, and more numerous septa. It differs from *S. siderea* (Ellis and Solander) by its larger and shallower calices.
>
> The closely crowded, transversely compressed, and finely frosted septal dentations of *S. dalli* give it an appearance very different from any other American species of *Siderastrea.* The number of septa is in corallites of the same diameter about the same as in specimens of *S. silecensis.*

In the Florida State University collection there are 20 specimens or so of *Siderastrea dalli* from the Pinecrest Formation in the Warren Brothers Pits east of Sarasota. The coralla are generally broadly oval in outline, with a hemispherical to domal head which in configuration is fairly even to undulatory to bumpy. The head may consist of a thick convex slab or is built up by several slabs draped over one another. The base, which was the attachment surface, occupies nearly the whole of the underside, is concentrically lamellate, and convex upward, reflecting the substrate to which it was adherent. Two specimens of *Siderastrea dalli* are attached to the outer surface of a thick-shelled oyster very close to *Ostrea tamiamiensis monroensis* Mansfield.

The calices are closely united, relatively shallow, widely open, and diversely polygonal, with no two of them the same in outline; they are generally longer than wide, hexagonal, pentagonal, or rarely quadrilateral in perimeter, and are bounded by a thin zigzag wall, the united thickness of which is about 0.12 mm.

The septa are moderately coarse and occur in four cycles, although in the largest calices there are five cycles, the fifth about one-third complete at most. The number of septa varies from 32 in a calice 2.4 mm × 2.3 mm in diameter to 64 in a calice 6.4 mm × 4.2 mm in diameter. There is a gradual diminution in size of the septa according to the order of insertion: the primaries are only slightly larger than the secondaries, and join each other just before the columella; the tertiaries join the secondaries a short distance from the columella, and the quaternaries join the tertiaries about a third of the distance in from the wall toward the calicular center. The septa are of narrow breadth (the primaries about 1 mm), and descend uniformly and gently to the small fossa, with perhaps a very slight convexity upward of the margins. The margins are strongly and closely dentate, the dentations varying from about 11 in number on a principal septum 1.3 mm in length to about 22 on a primary septum 2.8 mm in length. The dentations where weathered are low and compressed transversely to the septal plane, but where well preserved they are discrete, erect, and frondose to acute. The longitudinal rows of trabeculae descending down the faces of the septa from the dentations are coarse, and consist of prominent pointed or tubular projections, whereas between the rows there are numerous very small pointed granulations. Only rarely are the faces of the septa seen to be perforated.

The columella is small and papillate, and around it are one or two circlets of papillary denticles or paliform nodes at the ends of the principal septa.

The synapticulae are prominent, and there are perhaps four rows of them to the millimeter. The endothecal dissepiments are thin and there are about seven of them in a millimeter of length.

Measurements.—The largest corallum (SP-6a) in the collection is 135 mm × 109 mm in diameter at the head, and 81 mm high. SP-6b: 76 mm × 68 mm, height 66 mm. SP-6c: 95 mm × 78 mm, height 69 mm. SP-6d: 78 mm × 70 mm, height 47 mm: SP-6e: 68 mm × 53 mm, height 34 mm. SP-6f: 65 mm × 40 mm, height 27 mm. Paratype (USGS-325195), (corallum broken in half): diameters of calicinal surface 70 mm × 59.5 mm, height of half corallum 36 mm.

Details concerning the number of septa in calices of various sizes, and the number of dentations on primary septal margins of varying length, are given in the table below:

Septal measurements of *Siderastrea dalli* Vaughan

Sample No.	*Diameters of calice (mm)*	*No. of septa*	*Length of septal margin*	*No. of dentations on margin*
1	6.4 × 4.4	64	2.8	22
2	5.5 × 5.5	56	2.1	15
3	5.0 × 4.4	46	2.4	16
4	5.7 × 3.1	48	2.4	17
5	4.6 × 4.5	52	2.4	16
6	3.6 × 3.0	40	1.5	12
7	2.4 × 2.3	32	1.3	11
Paratype (USGS-325195)	5.0 × 4.4	55	1.8	15

Locality. — Warren Brothers Pits, 4 miles east of U.S. 301, Sarasota, Florida, just off Newburn Road 0.4 miles north of its intersection with 17th Street. Collectors and donors: Joseph E. Banks, Leslie Dyet, and Harbans S. Puri.

Range and distribution. — Caloosahatchee Marl (Pliocene); Pinecrest Formation (upper Miocene - Pliocene).

Comparison. — *Siderastrea dalli* Vaughan is differentiated from *S. pliocenica* Vaughan only by its thiner walls and more numerous septa per unit area of calice. *S. dalli* also resembles *Siderastrea conferta* (Duncan) from the Oligocene or lower Miocene of Antigua, Anguilla, Puerto Rico, and the Panama Canal Zone, but the number of septa per unit area of calice far exceeds that of *S. dalli.* The main differences between *S. dalli* and the Miocene to Recent *Siderastrea radians* (Pallas) are the smaller and deeper calices, the rounded collines, and the deeply sunken fossa of *S. radians.*

One specimen in the FSU collection — CAL-5a — is a wholly globular corallum with no particular attachment area but whose surficial details are so similar to those of *Siderastrea dalli,* that it is referred to that species. It occurs in the "Caloosahatchee Marl", 2-5 miles west of LaBelle, Hendry County, Florida, and was collected by Mike Strong, 2 December 1969. The specimen is 35.5 mm long, 32 mm wide, and 28 mm high.

Siderastrea pliocenica Vaughan Pl. 28, figs. 1-5

1919. *Siderastrea pliocenica* Vaughan, U.S. Nat. Mus., Bull., vol. 103, No. 9, pp. 222, 232, 437, 441, 442, 450, 517, pl. 118, figs. 2, 2a, 2b, 3.

1929. *Siderastraea pliocenica* Vaughan, Felix, Fossilium Catalogus I: Animalia, pars 44, p. 560.
1972. *Siderastrea pliocenica* Vaughan, Weisbord, Tulane Studies Geol. Paleont., vol. 10, No. 1, pp. 59-64, figs. 1-5.

The following is the original description of *Siderastrea pliocenica* by Vaughan:

> Twelve specimens, all of them excellent, serve as the basis of the following specific diagnosis. One is designated as the type in the collection.
>
> The corallum usually forms a rather small rounded head, but a few are elongate, and one is flattish, sublaminate. The heads attain a diameter of between 45 and 50 mm. About a third of the specimens show signs of having been attached or have not calices uniformly distributed over the whole outer surface of the corallum.
>
> The corallites are rather large, and are rather uniformly hexagonal or pentagonal; usual diameter is 4.5 to 5 mm.; intercorallite wall distinct and zigzag in plan. The calices are shallow or superficial.
>
> Septa thick, usually in almost four complete cycles, the fourth cycle is as a rule absent in one or two systems. Septal margins dentate, each dentation rounded, corresponding to the upper termination of a septal trabecula, the number of dentations on a septum of the first cycle varies from 8 or 9 to 13. The length of such a septum is almost 2.5 mm. Septal grouping is as usual in the genus, the members of the first cycle are continued directly to the columellar space and do not form part of septal groups; the members of the second cycle, also, are continued directly to the columellar space, but each member of this cycle is the middle of a septal group, the members of the third cycle bend toward it, and the members of the fourth bend toward the included member of the third. Along the course of each trabecula is a regular row of granulations which are compressed in a plane transverse to the longitudinal course of the trabecula. Septal perforations are frequent near the inner margins of the septa, usually occurring in the intertrabecular spaces, but in places a large perforation interrupts a trabecular course. The perforations become rarer as the wall is approached. Completely imperforate septa are very rare or do not exist at all.
>
> Both synapticulate and dissepimental endotheca is present. In places as many as four or five vertical rows of synapticulae can be distinguished. Very thin dissepiments are abundant. The wall is formed by synapticulae that are so elongated in a vertical row that they fuse and produce a continuous wall with only an occasional perforation.
>
> The columella is papillary, about two papillae being larger than the others. In worn specimens it is very prominent, appearing compressed styliform.
>
> *Locality and geological occurrence.* — Florida, Caloosahatchee River, collected by W. H. Dall; Shell Creek, Florida, collected by Doctor Griffith; Pliocene.
>
> *Type.* — No. 325184, U.S.N.M.
>
> *Paratype.* — No. 325185, U.S.N.M.
>
> The most striking differences between *S. pliocenica* and *S. radians,* to which it probably has the greatest affinity, are its larger and much shallower calices. *S. californica* Vaughan from the Pliocene of Carizo [*sic*] Creek, California, is a newly related species.

There are five specimens of *S. pliocenica* in the Florida State University collection. The locality of one of them — FLX-12a — is not known, although from its "lithology" it may have been collected from the Caloosahatchee Marl. Three other specimens of *E. pliocenica* (SP-5a-c) were collected in the Pinecrest Formation in Warren Brothers Pits, east of Sarasota, Florida.

The corallum of FLX-12a is massive and low hemispherical, with an undulatory head and irregular subfoliate base. The corallites are closely united on the surface, and in plan view are diversely polygonal. The calices are shallow, relatively small to relatively large, and assume a variety of outlines, with no two being identical. The calices are generally longer than wide, most of them hexagonal, but some pentagonal, and an occasional one quadrilateral. The margin of the calices is faintly nodulous, rendered so by the thickening there of the septa.

The septa are moderately crowded and fairly thick, the full complement arranged in four complete cycles, with a few in the fifth. The number of septa varies from 32 in a calice with a long diameter of 3 mm to a maximum of 52 in a calice 5.7 mm in length and 4.5 mm in width. The fourth cycle is rarely complete with 48 septa, the number falling somewhat short of that in calices of average size. The septa are often perforate near the summit, the perforations distinct but sparse. The septal grouping is as usual for the genus and the same as that described by Vaughan for the species. The free margin is dentate, with about eight denticles in 2.2 mm of length on the primary septa. The slope of the margin is rather uniform throughout — moderately steep off the wall but very gentle within and slightly concave upward before the columella. The walls separating the calices are solid, sturdy, tightly appressed, and a little elevated at the calicular margin where they have a combined thickness of about 0.4 mm.

The synapticulae are well developed and there are five of them in one millimeter in length. The faces of the septa are also minutely granulate.

The columella is a prominent plug, composed of three to nine fused papillae.

Embedded in specimen FLX-12a are at least ten shells of the barnacle *Ceratoconcha neogenica* (Weisbord) (1972).

Measurements. — FLX-12a: diameters of head 52 mm × 45 mm; height of corallum 29 mm. SP-5a: diameters of head 62.5 mm

× 51 mm; height of corallum 30 mm. SP-5b: diameters of head 34.5 mm × 25.5 mm; height of corallum 17 mm. SP-5c: diameters of head 28 mm × 26.5 mm; height of corallum 18 mm. USNM-7893 (corallum split in half): diameters of calicinal surface 65 mm × 61.5 mm; height of half-corallum 35 mm. Ort-la: globular corallum 77 mm × 69 mm × 69 mm.

Localities. — FLX-12a: not known, but possibly from the Caloosahatchee Marl in the Caloosahatchee River. SP-5: Warren Brothers Pits, 4 miles east of U.S. 301, Sarasota, just off Newburn Road, 0.4 miles north of its intersection with 17th Street. Collectors: Joseph E. Banks, Leslie Dyet, and Harbans S. Puri. USNM-7893: "St. Lucie Canal, Fla., Hays." The locality in the canal (which traverses Martin County from Lake Okeechobee to the Atlantic coast) is not known. Encountered along it are the Caloosahatchee Marl, "Glades" Formation; Fort Thompson Formation, and Anastasia Formation. Ort-la: Ortona Locks in the Caloosahatchee River east of LaBelle, Glades County. Exposed are the Caloosahatchee Marl, "Glades", and Fort Thompson Formation.

Comparison. — Specimen FLX-12a is so close to Vaughan's *Siderastrea pliocenica* as illustrated on his plate 18, figure 3, that there is little doubt of its identity even if the locality of FLX-12a is not known. The three specimens (SP-5a, 5b, and 5c) from the Pinecrest Formation (Mio-Pliocene) are also referable to *S. pliocenica.* Strangely enough *Siderastrea pliocenica,* which is a late Tertiary species, closely resembles *Siderastrea scotica* Wells (1945, pp. 1, 6, pl. 2, fig. 1) of Eocene age from the Upper Scotland Formation of Barbados; apparently, however, *S. pliocenica* differs from *S. scotica* in its more prominent columella, thicker septa, and sturdier walls. As pointed out by Vaughan (1919, p. 451), *S. pliocenica* also resembles *S. dalli* Vaughan, both of which occur together in the Caloosahatchee Marl and in the Pinecrest Formation east of Sarasota. *S. dalli* is separated from *S. pliocenica* "by its generally more delicate structure, more numerous septal dentations, and more numerous septa", but in some instances the two are difficult to distinguish. It may be noted also that *Siderastrea californica* Vaughan (1917, p. 375, pl. CII, figs. 2, 2a, 3, 4) from the Pliocene of Carrizo Creek, California, is a related species according to Vaughan.

Siderastrea radians (Pallas) Pl. 29, figs. 1, 2

1766. *Madrepora radians* Pallas, Elenchus Zoophytorum, pp. 322-323.
1791. *Madrepora galaxea* Ellis and Solander, Natural History of . . . Zoophytes, p. 168, pl. 47, fig. 7.
1794. *Madrepora astroites* Linnaeus, Esper, Fortsetzungen Pflanzenthiere, vol. 1, pp. 12-16, pl. 35.
1821. *Astraea galaxea* (Ellis and Solander), Lesueur, Mus. Nat. Hist. nat., Paris, Mém., vol. 6, p. 285, pl. 16, fig. 13.
1821. *Astraea galaxea* (Ellis and Solander), Lamouroux, Exposition Méthodique des . . . Polypiers, p. 60, pl. 47, fig. 7.
1846. *Siderina galaxea* (Ellis and Solander), Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, pp. 218-220, pl. 10, figs. 12, 12b.
1880. *Siderastrea galaxea* "(Milne-Edwards and Haime) and (Blainville)," Pourtalès, *in* Agassiz, Mus. Comp. Zool., Mem., vol. 7, pt. 1, pl. 11, figs. 14-21; pl. 15, figs. 1-12.
1895. *Astraea radians* (Pallas), Gregory, Geol. Soc. London, Quart. Jour., vol. 51, pp. 277-278, 285.
1901. *Siderastrea radians* (Pallas), Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, Pt. I, art. III, pp. 88, 152-155, art. IV, pp. 181, 186, pl. 30, fig. 1.
1902. *Siderastrea radians* (Pallas), Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, pt. 2, p. 309, pl. 15; pl. 16, fig. 2.
1904. *Siderastrea radians* (Pallas), Duerden, Carnegie Inst. Washington, Publ. No. 20, pp. 1-130, pls. 1-11, text-figs. 1-13.
1909. *Siderastrea radians* (Pallas), Gravier, Inst. Océanogr. Paris, Ann., vol. 1, pp. 4, 5, 17-24, pl. 5, figs. 16-20; pl. 6, figs. 24-27; pl. 7, figs. 28-33; pl. 8, figs. 34-38; pl. 9, fig. 39.
1910. *Siderastrea radians* (Pallas), Vaughan, Carnegie Inst. Washington, Publ. No. 133, Pap. Tortugas Lab., vol. 4, pp. 109, 177.
1919. *Siderastrea radians* (Pallas), Vaughan, U.S. Nat. Mus, Bull. 103, No. 9, pp. 225, 232, 300, 436, 437, 439-442, 444, 516, pl. 114, fig. 1.
1921. *Siderastrea* sp. aff. *S. radians* (Pallas), Vaughan, Geol. Survey Dominican Republic, Mem., vol. 1, p. 152.
1924. *Siderastrea radians* (Pallas), Vaughan, *in* Woodring *et al.*, Geology of the Republic of Haiti, p. 217.
1935. *Siderastrea radians* (Pallas), Yonge, Carnegie Inst. Washington, Publ. No. 452, Papers Tortugas Lab., vol. 29, pp. 201-208, pl. 1, figs. 1-4.
1940. *Siderastrea radians* (Pallas), Gerth, *in* Rutten, K. Nederlandsche Akad. Wetensch., Proc., vol. 43, No. 7, p. 840.
1943. *Siderastrea radians* (Pallas), Vaughan and Wells, Geol. Soc. Amer., Spec. Pap., No. 44, pp. 55, 68, 126, 294, 305, pl. 2, fig. 3; pl. 12, figs. 2, 3.
1948. *Siderastrea radians* (Pallas), Smith, Atlantic Reef Corals, pp. 60, 72, 78, pl. 6.
1949. *Siderastrea radians* (Pallas), Lyman, Shell Notes, vol. 2, Nos. 7-9, p. 134, pl. 3, fig. 5.
1956. *Siderastrea (Siderastrea) radians* (Pallas), Wells, Treatise on Invertebrate Paleontology, Pt. F, Coelenterata, p. F384, fig. 276, 1a.
1958. *Siderastrea radians* (Pallas), Squires, Amer. Mus. Nat. Hist., Bull., vol. 115, art. 4, pp. 227, 229, 230, 232, 233, 237-241, 248, 249, pl. 35, figs. 1-4; pl. 36, fig. 3.
1958. *Siderastrea* cf. *S. radians* (Pallas), Bonet, Asoc. Mexicana Geól. Petrol., Bol., vol. 10, Nos. 9-10, pp. 565, 569.
1959. *Siderastrea radians* (Pallas), Goreau, Ecology, vol. 40, No. 1, pp. 70, 73, 75, 76, 82, 85, fig. 7.
1961. *Siderastrea radians* (Pallas), Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 10, 72, 73, figs. 61, 62.

1962. *Siderastrea radians* (Pallas), Kornicker and Boyd, Amer. Assoc. Petrol. Geol., Bull., vol. 46, No. 5, pp. 655, 656, 668, fig. 16 (13), table 3.
1962. *Siderastrea radians* (Pallas), Stoddart, Atoll Res. Bull., No. 87, pp. 17, 19, 21, 22, fig. 11.
1963. *Siderastrea radians* (Pallas), Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 136, 139, 141, 142, 148, 162, pl. VIIb.
1964. *Siderastrea radians* (Pallas), Storr, Geol. Soc. Amer., Spec. Pap., No. 79, pp. 60, 67, 80.
1964. *Siderastrea radians* (Pallas), Hoffmeister, *et al.,* Guidebook Geol. Soc. Amer. Convention, Field Trip No. 3, p. 23.
1964. *Siderastrea radians* (Pallas), Rivero, Geos [Venezuela], No. 11, p. 112.
1966. *Siderastrea radians* (Pallas), Stanley, Amer. Assoc. Petrol. Geol., Bull., vol. 50, No. 9, p. 1931, pl. 1, fig. 10.
1966. *Siderastrea radians* (Pallas), Rigby and MacIntire, Brigham Young Univ. Geol. Studies, vol. 13, pp. 23, 44.
1966. *Siderastrea radians* (Pallas), Chevalier, Inst. Français Afrique Noire, Bull., sér. A, vol. 28, pp. 1359-1365, 1392, pl. 8, fig. 1, text-fig. 23.
1966. *Siderastrea radians* (Pallas), Cerame-Vivas and Gray, Ecology, vol. 47, No. 2, p. 263.
1966. *Siderastrea radians* (Pallas), Laborel, Mus. Nat. Hist. nat., Paris, Bull., sér. 2, vol. 38, No. 3, pp. 282, 284, 287, 290, 296.
1967. *Siderastrea radians* (Pallas), Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 447.
1968. *Siderastrea radians* (Pallas), Hoffmeister and Multer, Geol. Soc. Amer., Bull., vol. 79, No. 11, p. 1490.
1968. *Siderastrea radians* (Pallas), Yonge, Roy. Soc. London, Proc., ser. B, vol. 169, p. 339.
1968. *Siderastrea (Siderastrea) radians* (Pallas), Weisbord, Bull. Amer. Paleont., vol. 55, No. 246, pp. 28-33, pl. 2, figs. 4, 5. [Numerous references, 1786-1967.]
1969. *Siderastrea radians* (Pallas), Stoddart, Biol. Rev., vol. 44, pp. 443, 445, 458, 462.
1970. *Siderastrea (Siderastrea) radians* (Pallas), Klose, *in* letter to R. O. Vernon, 30 April 1970, pp. 2-6.
1970. *Siderastrea radians* (Pallas), Mesolella, Sealy, and Matthews, Amer. Assoc. Petrol. Geol., Bull., vol. 54, No. 10 (Pt. I of II), p. 1905.
1971. *Siderastrea radians* (Pallas), Olivares and Leonard, Inst. Oceanogr. Univ. Oriente, Bol., vol. 1, No. 1, pp. 49, 51-53, 59, 67, 69, table 1, pl. 10, figs. A, B.
1971. *Siderastrea radians* (Pallas), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 4, 16, 18-21, 23, 25, 27, 28, 33, 34-39, 52, 63, fig. 6, pls. XX, XXI.
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A fossil representative of *Siderastrea radians* is BG-2a from the Glades Formation. The corallum is an incrustation 7.5 mm thick, draped over a large broken gastropod. The calices are moderately deep, variously polygonal to angularly rounded, their greater diameter ranging from 4.3 mm with 34 to 36 septa to 6.1 mm with 40 to 46 septa. The septa are broadly and gently rounded at the calicular margin forming a low colline over the wall; farther within, the margins slope steeply toward the columella where they are nearly vertical. The septa of adjoining calices abut one another and obscure the wall. The margins of the septa are coarsely dentate, with eight rounded denticles on a principal septum 1.6 mm in length. The trabeculae on the faces of the septa are finely granulate, the granulations disposed in short close columns. The columella is small and papillate.

Measurements. — Specimen BG-2a: corallum length 53 mm, maximum width 40 mm, approximate height 28 mm. Specimen AB-1a: asymmetrically hemispherical, with a flattish base; diameters of head 75 mm × 58 mm, height 59 mm; base 73 mm in length, 53 mm maximum width. Specimen BAH-2a: domal corallum with globular head and flattish base; diameters of head 32.5 mm × 32.5 mm; base 51 mm × 46 mm.

Localities. — BG-2a: south side of Belle Glade, Palm Beach County in Belle Glade Rock Company excavation along Florida state road 80. Donated by Joseph E. Banks, 1 July 1968. Glades Formation. AB-1a: Apalachee Bay, 10 miles southeast of St. Marks Lighthouse, 10-12 ft. of water. Recent. BAH-2a: Bucaroon Bay, Great Abaco Island, Bahamas; living in less than 7 ft. of water.

Comparison. — This species is often found in association with *Siderastrea siderea* (Ellis and Solander) in both living and fossil assemblages, and may be confused with it. However, the distinction between them is important because of their preference in habitats. Concerning the distinction between *S. radians* and *S. siderea*, Squires (1958, p. 279) wrote as follows:

> *Siderastrea radians* may be characterized by having fewer than four complete cycles of septa (fewer than 48), while *S. siderea* generally has four complete cycles (48 or more septa). The calices of *S. radians* are generally smaller than those of *S. siderea* although there is overlap in this measurement between the two species. *Siderastrea siderea,* because of its more numerous septa, appears to have more crowded calices, while those of *S. radians* are more open. In addition, and an aid in collecting, there is a color differentiation between the two species, as *S. radians* has brown tentacles, the portions of the polyp out of the calicular cup are lighter, often light tan or cream in color, while *S. siderea* is lilac to reddish brown. Sometimes specimens of *S. radians* have a faint red overtone, often concentrated in the calices, giving them a reddish brown appearance, but the color is never so intense as in *S. siderea.*

Range and distribution. — The geologic range of *Siderastrea radians* is upper Miocene to Recent. In the Americas the living form is reported from Bermuda to Venezula. Elsewhere it is recorded from the Cape Verde Islands, the Red Sea, and off the islands of San Thomé, Annobon, and Fernando Po in the Gulf of Guinea.

Miocene — Dominican Republic (Mao Adentro Limestone); Haiti (Arrondissement St.-Marc.)

Pliocene — Mexico (Bacalar Formation of Quintana Roo).

Plio-Pleistocene — Florida (Unit A, or Glades Formation).

Pleistocene — Florida (Key Largo Limestone/Miami Oolite in Monroe County on Torch Key; alongside Card Sound Bridge; dredged from north end of Raccoon Key, the eastern tip of Stock Island, in the channel between Stock Island and Cow Key, and at Old Fort Taylor, Key West. Also dredged from the bottom of Lake Okeechobee); Bahamas (Fresh Creek fossil reef); Mexico (Bacalar Formation, Quintana Roo); Panama Canal Zone (Mt. Hope); Curaçao; Barbados (low level reefs).

Recent — Bermuda (Gallows Island, North Rock, The Boilers, Ferry Reach, Harrington Sound); Bahamas (Bimini, Turtle Rocks, Rabbit Cay, Cavelle Pond, Bucaroon Bay on patch reef less than 7 ft. deep, collected by W. R. MacWilliams, December 1969); Florida (Spanish Harbor; Tavernier Key, collected by Gunter and Martens, November 1927; outer reef of east coast; Biscayne Bay; Virginia Key; Tortugas at Bird Key Reef, Loggerhead Key, Fort Jefferson; Apalachee Bay, about 10 miles southeast of St. Marks Lighthouse in 10-12 ft. of water, collector Lyman D. Toulmin; St. George's Sound; off Lanarck, Franklin County); Mexico (Vera Cruz, Isla Verde, Isla de Lobos, Alacran Reef); Panama; British Honduras (Rendezvous Cay, Turneffe); Cuba; Jamaica (tide zone to 32 m; Ocho Rios); Kingston (5 ft. to 6 ft.); Puerto Rico (tide pools, back-and-patch reefs, cays); St. Thomas; Guadeloupe; St. Kitts; Antigua; Netherlands Antilles: Curaçao (Westpuntbaai, Sint Jorisbaai, Piscaderabaai, Punta Caballero, Sint Michielsbaai, Spaanse Water, Awa di Oostpunt, Portomaribaai). Bonaire (Slagbaai, Boca Bartól, Plenchi, Lac, Cai, Lagun). St. Martin (Great Bay, Anse des Pères, Anse des Sables, Little Bay, Mullet Pond Bay, Point Blanche Bay, Burgeux Bay, Guana Bay, Gibbs Bay, Babit Point, Oyster Pond). Saba (Ladder Bay, Fort Bay). St. Eustatius (Billy's Gut, Cocoluch Bay, Jenkins Bay, Tumbledown Dick Bay, Compagnie Baai, Schildpadden Baai, Oranjestad Baai, Gallows

Bay). Aruba (Cudarebe, Arashi, Boca Catalina, Malmok, Palm Beach, Eagle Beach, Spaans Lagoen, St. Nicolaasbaai, Klein Lagoen, off Pitch Field, Andicuri); Tobago; Venezuela (Higuerote, Edo. Miranda; Isla Margarita; Bahía de Mochima, Edo. Sucre at Ensenada Mangle Quemao, E. Cabruta Roja, E. El Muerto, E. Las Maritas, E. de Vallecillo, E. Taguapiritu, E. San Agustin, E. de Centeno, E. Garrapata, E. El Inglés, E. Botella, E. Carenero, E. de Punta León, E. La Aguada, E. Báquiro, Playa Blanca de Guaiguá, Punta Botella, P. Las Maritas, P. La Trampa, P. Cementerio, P. Las Morochas, P. Gruesa, P. San Agustin, P. Aceite de Palo, P. de León, P. Mero Mañoso, P. Toporo, P. Piedra, P. Mangle Seco, Playa de Los Reyes, Costa Maringinia, Costa El Amparo, Punta El Amparo, Peña Azul, Playita Mangle Quemao, Morro Garrapata, Lance Manguillas; Golfo de Cariaco, Zonas A-C, E-I); Barbados (West coast); Brazil ? (not confirmed by Laborel, 1967).

Siderastrea siderea (Ellis and Solander) Pl. 30, fig. 1

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The original description of *Siderastrea siderea* by Sir John Ellis was as follows:

> 66. Madrepora siderea
> Madrepora *aggregata, stellis confertis rotundis subangulatisque, parietibus crassi convexiusculis, lamellis alternis margine subconnatis, centris simplicibus.*
> Tab. 49, Fig. 2

The original drawing of *Siderastrea siderea* is stylized and the description generalized, but thanks to subsequent workers the characters of the species are now well known.

The fossil specimen (BG-1a) illustrated in this paper is from Belle Glade, Florida, and is referable to *Siderastrea siderea* although due to corrosion the calices are not so deep and the calicular margins less rounded than on well-preserved examples of the species.

BG-1 is a wholly spheroidal corallum, with a hardly perceptible attachment area. The calices, which are corroded, are shallow and variously polygonal in outline, with their greater diameters ranging from about 4.8 mm to 7.5 mm. In mature calices there are four complete cycles of septa, and in some of them a number in the fifth. The septa are dentate on the margin, granulate on the sides, and are arranged as usual in the genus, with the smaller ones joining the next larger. Perforations on the faces of the septa are not uncommon and are often present between the synapticulae which themselves are prominent and occur in three to five rows. The columella is small, often fused, and in places papillary.

Measurements.—Specimen BG-1a: corallum height 60 mm, length 72 mm, width 63 mm.

Locality.—South edge of Belle Glade, Palm Beach County, in Belle Glade Rock Co. excavation at Florida state road 80. Donated by Joseph E. Banks, 1 July 1968. Glades Formation.

Range and distribution.—The geologic range of *Siderastrea siderea* is upper Miocene to Recent. In the Western Atlantic the living form is reported from North Carolina south to Venezuela. The living species also is found in the Red Sea, the Cape Verde Islands, the Gulf of Guinea, and the Island of San Thomé.

Miocene — Cuba; Jamaica (Bowden Formation); Vieques Island; Haiti (upper Miocene), Thomonde Formation; Dominican Republic (upper Miocene) in the Gurabo Hills, Rio Cana, Arroyo Las Lavas, Rio Yaque del Sur; Trinidad (lower-middle Miocene).

Pliocene — Haiti (Rivière Gauche Formation); Venezuela (Playa Grande Formation).

Plio-Pleistocene (?) — Florida (Glades Formation); Dominican Republic (Provincia de Monte Cristi).

Pleistocene — Florida (Miami Oolite in Monroe County at Old Fort Taylor; between Stock Island and Cow Key; eastern tip of Stock Island; and in channel at north end of Raccoon Key; Key Largo Limestone at Port Everglades, Broward County; Bermuda; Bahamas; Panama Canal Zone (Mt. Hope); Costa Rica; Cuba; Jamaica; Dominican Republic (Barahona); St. Eustatius; Curaçao; Aruba; Barbados in reefs up to 480 feet in elevation.

Recent — North Carolina (Onslow Bay, 22 m, 10.6°C., temperature of bottom in winter); Florida (Tortugas; off southeast coast; Biscayne Bay; patch reefs); Bermuda; Bahamas (Rabbit Cay, Turtle Rocks, Great Bahama Bank); Mexico (Blanquilla and Alacran Reefs, Isla de Lobos off Vera Cruz); Panama; British Honduras (Rendezvous Cay, Lighthouse Reef, Glover's Reef); Pedro Bank; Jamaica (0.5 m to 70 m; Ocho Rios); Puerto Rico (Culebra; Cayo Turrumote; Cayo Icacos); St. Thomas (22 m to 74 m); Anguilla (37 m to 47 m); St. Bartholomew (36 m to 48 m); Montserrat (33 m to 40 m); Netherlands Antilles: St. Eustatius (Jenkins Bay, Tumbledown Dick Bay, Gallows Bay). Aruba (Boca Catalina-Malmok, Mangel Altu). Curaçao (Westpuntbaai, Plaja Abao, Boca Santa Marta, Daaibooibaai, Vaarsenbaai, Sint Michielsbaai, Piscaderabaai, Spaanse Water, Awa di Oostpunt). Bonaire (Boca Bartól, Plaja Frans, Goto, Jan Doran-Barcadera, Ruin, Hato, Klein Bonaire, Plaja Sarna, Baca, Blauwe Pan, Witte Pan, Oranje Pan, Lac, Lagun). St. Martin (Baie Rouge, Mullet Pond Bay, Mahó Bay, Burgeux Bay, Simson Bay, Cay Bay). Saba (Cove Bay); Barbados (west coast 2 to 24 m); Venezuela (Puerto La Cruz, Edo. Anzoategui; Tortuga; Bahía de Mochima, Edo. Sucre at Ensenada

Cabruta Roja, E. Cabruta Blanca, E. El Muerto, E. El Aguirre, E. El Inglés, E. Taguapirito, E. San Agustin, E. de Centeno, E. Garrapata, E. Carenero, Barranca de Mochima, Morro Garrapta, Punta Botella, P. Aguirre, P. Garrapata, P. León, P. El Amparo, P. San Agustin, P. Aceite de Palo, P. Las Maritas, P. Mero Mañoso, Playa de Los Reyes, Playita Mangle Quemao, Costa El Amparo, Peña Azul, Lance Manguillas); Golfo de Cariaco, Zonas A-G, I.

PORITIDAE

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Lamarck's original description of this species was the following:

> 3. Porite astréoïde. *Porites astreoides.*
> *P. incrustans, undato-gibbosula; stella parvis, profundis, continguis; parietibus lamelloso-striatis, denticulatis; margine scabro.*

As we do not have a fossil form of *Porites astreoides* in our Florida collection, the description below is based on a well-preserved Recent specimen (BAH-1a) from the Bahama Islands.

The corallum is dull yellowish brown, porose, massive, and gibbous on the surface, the gibbosites elevated, roundish, and contiguous. The calices are small, polygonal in outline, and relatively deep, their size ranging from 1 mm to 1.6 mm for an average of 1.3 mm; the average depth is about 0.9 mm. There are 12 subequal septa in two cycles, the septa thin and lamellar, strongly erose or serrulate along the margins, and smoothish to faintly corrugate on the sides. The pali on the inner ends of the principal septa are indistinct and styliform. The central area of the calices is small and deep, and arising from it there may be a small erect styliform columella. Small perforations are numerous and are present in the walls, on the summits of contiguous calices, and sometimes through the septa.

Measurements. — Specimen BAH-1a. corallum length 81.5 mm, width 65 mm, height 47 mm.

Locality. — Bucaroon Bay, Great Abaco Island, Bahamas. Living in less than 7 feet of water in a patch reef. Collected by W. R. McWilliams of the Biology Department of Florida State University, 14-25 December 1969.

Comparisons. — As noted by Vaughan (1917, p. 376), *Porites carrizensis* Vaughan from the Carrizo Creek Beds of Imperial County, California, of lower-middle Pliocene age, has the same growth form, the same diameter of calices, and the same kind of septal margins as *P. astreoides* of Florida and the West Indies. "The calices of *P. carrizensis* seem shallower and the pali better developed than in *P. astreoides*, but the two are remarkably alike." Seven other Pliocene to Recent corals of Florida are so close in specific affinities to the Carrizo Creek corals that it seemed to Vaughan (1919, p. 223) the Carrizo Creek Beds "can scarcely be so old as Miocene; lower Pliocene appears to be the maximum age which may be assigned to the [Carrizo Creek] fauna."

As suggested as early as 1902 by Vaughan (1902, p. 317), it is now thought by Laborel (1967, p. 4) to be "completely impossible to draw a line between *P. astreoides* Lamarck and *P. verillii* Rehberg, [and] their provisional reunification seems justified."

Range and distribution. — The geographic range of *Porites astreoides* Lamarck is Bermuda to Brazil; the reported geologic range is Oligocene to Recent, with the Oligocene to Pliocene occurrences yet to be verified.

Oligocene — Puerto Rico (Cibao Marl ? and San Sebastian Formation ?).

Miocene — Cuba (La Cruz Marl); Haiti (Arrondissement Mirebelais ?); Dominican Republic (Rio Gurabo ? and Arroyo Las Lavas ?); Trinidad (St. Croix ?).

Pliocene — Haiti (Arrondissement Léogane ?).

Pleistocene — Florida (Miami Oolite or Key Largo Limestone dredged off Key West, Cow Key, Stock Island, Raccoon Key; excavated in marl pits alongside Card Sound Bridge); Panama Canal Zone (near Mt. Hope); St. Kitts (Brimstone Hill); Dominican Republic (Provincias de Macoris, Santo Domingo, and Barahona); Trinidad; Barbados (submerged coral reefs along west coast; low-level reefs near Bridgetown and 1 mile north of Bath, elevation 165 ft; high-level reefs, Castle Grant, elevation 1070 ft.).

Recent — Bermuda (Harrington Sound; North Rock; Castle Harbor); Bahamas (Nassau; Bucaroon Bay, Great Abaco Island; Bimini; Rabbit Cay; Turtle Rocks; Moselle Bank); Florida (Dry Tortugas; Key West; Spanish Harbor; Biscayne Bay; outer reefs and patch reefs off the southeast coast); Cuba; Jamaica (Ocho Rios; 0.2 m - 70 m); Pedro Bank; Mexico (Blanquilla off Vera Cruz; Alacran Reef); British Honduras (Rendezvous Cay, Turneffe, Lighthouse Reef, Glover's Reef); St. Thomas (22 m to 39 m); St. Bartholomew; Montserrat (33 m to 42 m); St. Lucia (32 m to 68 m); Guadeloupe; Puerto Rico (Cayo Icacos); Barbados (west coast, 15 m to 24 m); Netherlands Antilles: Aruba (Cudarebe-Arashi, Boca Catalina, Malmok, Eagle Beach-Palm Beach, Barcadera, Mangel Altu, St. Nicolaasbaai, Punta Basora, Andicuri). Curaçao (Westpuntbaai, Plaja Abao, Portomaribaai, Daaibooibaai, Vaarsenbaai, Kaap Malmeeuw, Sint Michielsbaai, Spaanse Water, Awa di Oostpunt, Sint Jorisbaai, Klein Curaçao). Bonaire (Boca Bartol, Plaja Frans, Goto, Jan Doran, Barcadera, Ruin, Lont, Klein Bonaire, Plaja Sarna, Baca, Punt Vierkant, Blauwe Pan, Witte Pan, Oranje Pan, Plenchi, Lac). St. Martin (Anse des Pères, Anse des Sables, Baie Rouge, Mullet Pond Bay, Mahó Bay, Burgeux Bay, Simson Bay, Cay Bay, Little Bay, Great Bay, Point Blanche Bay, Guana Bay, Gibb's Bay, Babit Point). Saba (Ladder Bay, Fort Bay, Cove Bay). St. Eustatius (Cocoluth Bay - Jenkins Bay - Tumbledown Dick Bay, Gallows Bay, Compagnie Baai); Venezuela (Golfo de Cariaco, Zonas A-I); Bahía de Mochima, Edo Sucre (Isla Larga, Punta Garrapata, Playa de Los Reyes, Playita Mangle Quemao, Costica Mano E'Piedra, Lance Manguillas, Costa Maringinia, Isla Huevito, Ensenada Cabruta Blanca, Isla Santa Ana, Isla Redonda, Ensenada Cabruta Roja, Ensenada de Vallecillo, Ensenada Taguapirito, Ensenada San Agustin, Ensenada Piedra Pelona, Ensenada Garrapata, Ensenada Las Maritas, Ensenada Los Aceites, Ensenala El Inglés, Ensenada La Aguada, Ensenada Toporo-Toporito, Ensenada Báquiro, Ensenada El Muerto, Ensenada El Aguirre, Morro de Garrapata, Punta Cementerio, Punta Las Morochas, Punta Gruesa, Punta Las Maritas, Punta de León, Punta Mero Mañoso, Punta Mangle Seco, Ensenada Burgao, Barranca de Mochima, Playa Blanca de Guaguá, Ensenada Botella); Brazil (Rio Grande do Norte sandstone reef, Pernambuco sandstone reefs, Maceio coral reef, Cape Bacoparý, Mamanguape, Goyanna, Abrolhos and Lixa reefs, Candeias, Tamandare, Rio Formoso, Maria Farinha, Parahyba do Norte).

Porites divaricata Lesueur Pl. 31, figs. 1, 2

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1827. *Porites divaricata* Lesueur, Eudes-Deslongchamps, Ecncyclopédie Méthodique, pt. 2, p. 441.

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1970. *Porites divaricata* Lesueur, Klose, *in* letter to R. O. Vernon 30 April 1970, p. 5.

Lesueur's original description of *Porites divaricata* was as follows:

> 3. Porite étendue. *Porites divaricata.*
>
> Rameaux grêles, écartés, subcomprimés, divergens renversés sur les côtes, bilobés aux extrémités.
>
> Animaux ne couvrant que les extrémités supérieures, mais descendant plus bas que dans le précédente espèce.
>
> Celle-ci, que je ne connois que morte, diffère, de l'autre par la disposition de ses rameaux, qui sont divergens et obliques, au lieu d'ètre ramassés en groupes droits comme dans la précédente. Sa hauteur est de deux pouces au plus. Elle est tré-délicate.
>
> Habite la Guadeloupe.

Although *Porites divaricata* has been reported from the Pliocene and Pleistocene of Florida, I have not seen the fossil form. However, what I believe may be the Recent form of the species occurs off the west coast of Florida in Florida's "Middle Ground", and is described and illustrated herein.

The "Middle Ground" corallum is porose and branching, the branches few in number, subcircular in cross section, and small in girth, the diameters varying from 5.5 mm to 6.5 mm. The calices are low and shallow, obtusely polygonal in outline, and intimately connected; their average diameter is about 1.75 mm. There are two cycles of septa, the septa subequal and echinulate, with the margins and sides beset with minute spinules and tubules. The secondary septa join the primaries before the columella, and at the inner ends of each of the primaries there is a stellate and echinulate palus, the pali disposed in an irregular ring around the columella. The columella, or center of the columellar circlet is often styliform and erect, and resembles in every respect the individual palus.

Small perforations are ubiquitous throughout.

Measurements. — FMG-1a: corallum height 83 mm, maximum span between branch ends 46 mm. FMB-1b: corallum height 45 mm, maximum span between branch ends 26 mm.

Locality. — Florida Middle Ground, in Gulf of Mexico, off the west coast of Florida. Specimens FMG-1a, b were collected by Robert Back of Florida State University, and donated by him 7 December 1972.

Comparison. — Specimen FMG-1b is virtually identical with the forms of *Porites divaricata* illustrated by Vaughan (1902) and Squires (1958), from Puerto Rico and the Bahamas, respectively.

Range and distribution. — Pliocene to Recent. Florida to Barbados.

Pliocene — Florida (Caloosahatchee Marl).

Pleistocene — Florida (Miami Oolite, dredged from northern end of Stock Island, Monroe County; species encountered in well at Delray, Palm Beach County, at depth of 118 feet.

Recent — Florida (Middle Ground); Bahamas (off South Bimini); British Honduras (Rendezvous Cay, Turneffe); Jamaica (Ocho Rios; 0.1 m to 47 m); St. Thomas; Puerto Rico (off Culebra, 15-1/2 fathoms); Guadeloupe; Barbados (west coast).

Porites furcata Lamarck Pl. 30, fig. 2; Pl. 31, fig. 3

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1821. *Porites recta* Lesueur, Mus. Nat. Hist. nat., Paris, Mém., vol. 6, p. 288, pl. 16, fig. 16. [*Fide* Felix, 1929, p. 614.]
1846. *Porites furcata* Lamarck, Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, p. 555.
1851. *Porites furcata* Lamarck, Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 16, pp. 25, 26, pl. 1, figs. 1, 1a, 1b, 1c.
1880. *Porites furcata* Lamarck, Pourtalès, *in* Agassiz, Mus. Comp. Zool., Mem., vol. 7, No. 1, p. 12, fig. 7; pl. 16, figs. 13-20.
1888. *Porites furcata* Lamarck, Rathbun, U.S. Nat. Mus., Proc., vol. 10, pp. 361-364, pl. 15, figs. 1-3; pl. 17, fig. 1.
1895. *Porites furcata* Lamarck, Gregory, Geol. Soc. London, Quart. Jour., vol. 51, pp. 283, 284.
1901. *Porites polymorpha* Verrill (*pars*), Connecticut Acad. Arts and Sci., Trans., vol. 11, Pt. I, art. III, p. 158. [*Fide* Vaughan, 1919, p. 499.]
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1939. *Porites clavaria* Lamarck, Butsch, Barbados Mus. and Nat. Hist. Soc., Jour., vol. 6, No. 3, p. 138, pl. 2, fig. 4.
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Two specimens, USGS-3300 from Shell Creek and PG-1a from 3.5 miles southeast of Punta Gorda, Charlotte County, both reported to occur in the Caloosahatchee Marl, were examined. The former was identified by Vaughan, and PG-1a, although corroded and broken, is also thought to be referable to the same species.

The weathered corallum of PG-1a is a porose appressed stem from which diverge two branches snubbed off at their ends. The calices are shallow and subpolygonal in outline, varying from 1.3 mm to 1.8 mm in greater diameter, for a median of 1.5 mm. There are 12 septa in two cycles, the septa more or less the same in size. The margins of the septa are coarsely dentate and erose, and the faces, which bear fine pointed granulations, are also perforate, the perforations sparse but relatively large. On the inner ends of the septa there are three to five pali, the latter number probably being the usual one on specimens in good condition. The columella is small and nondescript.

Measurements. — Specimen PG-1a: corallum length 35.5 mm, width across ends of branches 14 mm, diameter of main stem at middle 11 mm × 8 mm, diameters of branches at crotch 6.4 mm × 5.7 mm and 5 mm × 5 mm (reconstructed). Specimen USGS-3300: corallum length 50.5 mm, maximum width 29.6 mm, diameters at middle of stem 11 mm × 13 mm, diameters of larger branch 11.2 mm × 13 mm.

Locality. — PG1-a: about 3.5 miles southeast of Punta Gorda, Charlotte County, on road to Punta Gorda airport, 1.4 miles south of the entrance to Tee and Green Estates. Collector: Leslie Dyet, 16 February 1968. "Caloosahatchee Marl".

Range and distribution. — The geologic range of *Porites furcata* is Oligo-Miocene to Recent; geographically the taxon is reported from Florida to Venezuela.

Oligo-Miocene — Haiti ? (Arrondissement de Mirebelais).

Miocene — Haiti ? (Las Cahobas Formation); Dominican Republic (Mao Adentro Limestone).

Pliocene — Florida (Caloosahatchee Marl).

Pleistocene — Florida (Miami Oolite dredged from channel at northern end of Raccoon Key); Costa Rica (Moín); Panama Canal Zone; Dominican Republic; Curaçao; Barbados.

Recent — Florida (Tortugas, Middle Ground, Caesar's Creek, and Cape Florida in Gulf of Mexico, and Key West, Salt Pond Key, Stock Island, and Spanish Harbor in Atlantic waters; Bermuda; Great Bahama Bank; Jamaica (0.2 to 50 m; Lime Cay; Rockham Cay; Ocho Rios in back reef, lagoon, reef crest, seaward slope); Mexico (off Vera Cruz; Alacran Reef); British Honduras (Rendezvous Cay, Turneffe, Lighthouse Reef, Glover's Reef); Puerto Rico (La Parguera); Barbados; Netherlands Antilles: Aruba (Arashi, Malmok, Eagle Beach, Palm Beach, Barcadera, St. Nicolaasbaai, Pitch Field). Curaçao (Plaja Abao, Portomaribaai, Vaarsenbaai, Sint Michielsbaai, Piscaderabaai, Spaanse Water, Awa di Oostpunt, Boca Plaja Canoa, Sint Jorisbaai, Klein Curaçao). Bonaire (Boca Bartól, Plaja Frans, Lont, Ruin, Klein Bonaire, Plaja Sarna, Willemstoren, Plenchi, Lac). St. Martin (Simson Bay, Great Bay, Guana Bay, Gibb's Bay). Saba (Fort Bay, Cove Bay). St. Eustatius (Jenkins Bay, Tumbledown Dick Bay, Gallows Bay, Compagnie Baai); Venezuela (Playa Grande Yachting Club, Distrito Federal; Bahía de Mochima, Edo. Sucre, at Ensenada Garrapata, Ensenada El Muerto, Ensenada El Aguirre, Ensenada Botella, Ensenada Mangle Quemao, Ensenada Cabruta Blanca, Ensenada Los Aceites, Ensenada Cabruta Roja, Morro de la Garrapata, Punta Botella).

Porites porites (Pallas) Pl. 31, fig. 4

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The specimen here described is labeled *Porites porites* (Pallas) and is one of three fossil fragments contained in the collection of the U.S. National Museum; a tag in the same tray bears the following notation: "1/593. Dredged from St. Lucie Canal, Fla., 1 mile from L. Okeechobee."

The corallum of the largest specimen is branching but the terminal character of the subsidiary branches is not known. The calices are low, tightly appressed, pentagonal or hexagonal in outline, and range from 1.7 mm to 2.1 mm in greater diameter. There are 12 alternating septa in two cycles, the primaries much larger than the secondaries, the latter joining the principals near the columella. The margins of the septa are erose and echinulate, the sides spinulose and often perforate, with generally one large perforation through a principal septum. Normally there is an echinulate palus at the end of each primary, and where fully developed there are six subequal pali surrounding the tuberculate and minutely spinose columella. However, a number of calices show five pali because of poor preservation or arrested growth.

Measurements.—USNM 1/593: corallum of largest specimen, length 36 mm, maximum width 25 mm, diameters of main stem 15.5 × 13.5 mm, diameters of larger branch 14.5 mm × 12 mm, diameters of smaller branch 11 mm × 9 mm.

Locality.—USNM 1/593: Dredged from St. Lucie Canal, 1 mile from Lake Okeechobee, Martin County. This locality is imprecise, but since the area around Lake Okeechobee in the vicinity of the St. Lucie Canal and Okeechobee Waterway is mapped as the Fort Thompson Formation by Puri and Vernon (1964, pl. 2), it is inferred that specimen 1/593 is Pleistocene in age.

Comparison.—Although the type of *Porites porites* was not recognized by Bernard (1905, 1906) and the species *sensu stricto* not even listed by Rathbun (1888b) as occurring in the Western Atlantic, the name seems again to be meeting with favor among many of today's writers. The species is similar to *Porites furcata* Lamarck, but is distinguished from that, according to Smith (1948, p. 81), by its somewhat larger calices, by the swollen rather than gently tapered ends of the branches, and by the six rather than five pali of *Porites furcata*.

Range and distribution.—The geographic range of *Porites porites* is recorded from Bermuda to Venezuela, and the geologic range from Miocene to Recent. In the Eastern Atlantic, the living species is reported from the Cape Verde Islands.

Miocene—Cuba (La Cruz Marl); Haiti (Arrondissement St.-Marc?); Trinidad (?).

Pliocene — Florida (Caloosahatchee Marl); Haiti (Arrondissement Légoane?).

Pleistocene — Florida (Miami Oolite/Key Largo Limestone dredged from channel between Stock Island and Cow Key; Specimen USNM-1/593 Lake Okeechobee); Panama Canal Zone (Mt. Hope); Dominican Republic (Provinces of Macoris and Barahona); Barbados (submerged and low level land reefs); Curaçao (low level reefs).

Recent — Bermuda (Castle Harbor); off Ledge Flats; Bahamas (Bimini); Florida (Spanish Harbor; Key Largo; Tortugas); Cuba; Mexico (Isla de Lobos; Alacran Reef); Jamaica (0.5 to 10 m; Lime Cay, Rockham Cay; Ocho Rios in the back reef, lagoon, reef crest, and seaward slope); Puerto Rico (Cayo Icacos); British Honduras (Rendezvous Cay, Turneffe, Lighthouse Reef, Glover's Reef); Netherlands Antilles: Aruba (Arashi, Boca Catalina, Malmok, Eagle Beach-Palm Beach, Barcadera, Mangel Altu, St. Nicolaasbaai). Curaçao (Westpuntbaai, Plaja Abao, Daaibooibaai, Vaarsenbaai, Sint Michielsbaai, Piscaderabaai, Spaanse Water, Kaap Malmeeuw, Awa di Oostpunt, Plaja Canoa, Sint Jorisbaai, Caracasbaai). Bonaire (Hato, Klein Bonaire, Plaja Sarna, Plenchi, Lac). St. Martin (Baie Rouge, Simson Bay, Little Bay, Great Bay, Guana Bay, Gibb's Bay, Babit Point). Saba (Fort Bay, Cove Bay). St. Eustatius (Cocoluch Bay, Jenkins Bay, Gallows Bay, Compagnie Baai); Barbados (west coast); Venezuela (Golfo de Cariaco, Zonas A-I; Bahía de Mochima, Edo. Sucre at Isla Huevito, Isla Larga, Isla Redonda, Isla Santa Ana, Ensenada El Muerto, E. Taguapirito, E. San Agustin, E. Garrapata, E. El Inglés, E. Carenero, E. Cabruta, E. Báquiro, E. Los Aceites, E. El Aguirre, E. Guatacaral, E. Baradero, E. Baraderito, E. Burgao, E. Toporo, E. El Isleño, E. Taguapire, E. La Aguada, E. Camaiguana, Punta Gruesa, Punta Aceite de Palo, Punta de León, Punta Mero Mañoso, Punta Toporo, Punta Mangle Seco, Punta Botella, Playa de Los Reyes, Piedra Ahogado, Peña Azul, Playita Mangle Quemao, Morro Garrapata, Lance Manguillas, Punta Cementerio, Punta Las Morochas).

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Favia fragum (Esper) Pl. 31, fig. 5

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The specimen described and illustrated (BAH-3a) is a Recent one from Bucaroon Bay in the Bahamas.

The corallum is subhemispherical with a flat encrusting base. The calices are subcircular, oval, subovate, or elliptical, varying in diameter from 4.3 mm, with 26 septa to 7.4 mm, with 52 septa, as measured from margin to margin. The average depth of the calices is about 2 mm. The calices are united and the margins rounded into low collines which are shallowly grooved where the septa come together. The corallites are obtusely polygonal at the surface.

The septa occur generally in four cycles, the primaries the largest, the others decreasing in size according to the order of insertion, the youngest much smaller than the ones adjoining. The septa are exsert in varying degree at the summit where they are gently arched and broad, then sloping steeply and narrowing toward the columella. The margins of the septa are irregularly dentate or serrate, and the sides are sparsely and finely spinulose, the spinules aligned in rays on the broader and larger ones. At their inner ends, the larger septa bear an erect and frondose palus resulting from a deep and narrow excavation near the base of the septum. The costae are conterminous with, and slightly thicker than their corresponding septa. Like the septa, the costae are coarsely granulose, and where the septo-costae of adjacent calices meet along the midline of the colline, the granulations may become detached. The columella is large and spongy, and usually forms a flat or slightly concave bottom. The outer or upper edge of the columella is distinctly denticulate and in places forms erose pillars at the pali.

Measurements. — Specimen BAH-3a: corallum length 28 mm, width 24 mm, height 15 mm; width of columella 1.0 mm to 1.4 mm. Specimen I-638a: corallum length 49.5 mm, maximum width 33 mm, height 31 mm.

Localities. — Specimen BAH-3a: Bucaroon Bay, Great Abaco Island, Bahamas. Living on patch reefs in less than 7 feet of water. Collector: W. R. McWilliams, December 1969. I-638a: Tavernier, Monroe County, Florida. Collectors: H. Gunter and J. H. C. Martens, Nov. 1927.

Range and distribution. — In the Western Atlantic the living *Favia fragum* is found from Bermuda to Venezuela. It has been reported farther south on Fernando de Noronha, Brazil (as *Favia ananas*) by authors, but this is not confirmed by Laborel (1967) who lists *Favia gravida* Verrill and *Favia leptophyllia* Verrill as the two species occurring in Brazil. In the Eastern Atlantic, *Favia fragum* is reported from the Azores, Cape Verde Islands, Senegal, and in the Gulf of Guinea. Geologically, *Favia fragum* is recorded from lower Miocene to Recent, but I have not seen a record of it from the Pliocene.

Lower Miocene — Guadeloupe (Tuf Blanc).

Upper Miocene — Dominican Republic (Yaque Group).

Pleistocene — Florida (Miami Oolite/Key Largo Limestone dredged off Old Fort Taylor on Key West; off the eastern tip of Stock Island; between Stock Island and Cow Key; and alongside Card Sound Bridge, Key Largo, Monroe County); Costa Rica (Monkey Hill); Panama Canal Zone (Mount Hope); Dominican Republic; Guadeloupe (Formation Madréporique); Dominica; Barbados (low-level reefs near Bridgetown).

Recent — Bermuda (North Rock; Castle Harbour); Florida (Tavernier, Biscayne Bay, Spanish Harbor, Elliot Key, Key West, Tortugas at Ft. Jefferson and Golding Cay); Bahamas (Rabbit Cay; Turtle Rocks; Bimini, Great Bahama Bank; Bucaroon Bay); Cuba (Cojímar); Jamaica (0.2 m - 30 m; Ocho Rios; Discovery Bay); Mexico (Alacran Reef, Campeche Bank; Yucatan Shelf); British Honduras (Rendezvous Cay, Turneffe, Lighthouse Reef, Glover's Reef); Panama (San Blas); Haiti; Puerto Rico (La Parguera; Cayo Turrumote; Cabo Rojo; Cayo Icacos; Playa de Ponce); St. Vincent; Barbuda; Dominica; Martinique; Tobago; Barbados (along west coast); Netherlands Antilles: Aruba (Cudarebe-Boca Catalina-Arashi, Malmok, Palm Beach, Barcadera, Mangel Altu, St. Nicolaasbaai, Klein Lagoen, Punta Basora, Pitch Field, Andicuri, Paardenbaai). Curaçao (Playa Kalki, Westpuntbaai, Plaja Abao, Boca Santa Marta, Portomaribaai, Daaibooibaai, Vaarsenbaai, Sint Michielsbaai, Kaap Malmeeuw 20 m - 30 m; Piscaderabaai, Caracasbaai, Punta Caballero, Spaanse Water, Awa di Oostpunt, Klein Curaçao). Bonaire (Boca Bartól, Plaja Frans, Goto, Jan Doran, Barcadera, Ruin, Hato, Klein Bonaire, Binnenklip, Plaja Sarna, Baca, Vierkant, Blauwe Pan, Witte Pan, Lac, Cai, Lagun, Slagbaai). St. Martin (Anse des Pères, Anse des Sables, Burgeux Bay, Simson Bay, Cay Bay, Great Bay, Point Blanche Bay, Gibb's Bay, Babit Point. Saba (Fort Bay, Cove Bay). St. Eustatius (Oranjestad Baai, Gallows Bay, Compagnie Baai); Venezuela (Los Roques; Bahía de Mochima, Edo. Sucre, at Ensenada El Aguirre, Punta Aguirre, Punta Garrapata, Punta León, Punta Las Maritas, Peña Azul, Playita Mangle Quemao, Ensenada Piedra Pelona, E. Garrapata, E. Burgao, E. La Ballena, E. El Inglés, E. Las Maritas, E. Cabruta, Morro Garrapata, Costica Mano E'Piedra, Lance Manguillas, Costa Maringinia; Golfo de Cariaco, Zonas A, B, C, D, E, G, I).

Diploria clivosa (Ellis and Solander) Pl. 32, fig. 1; Pl. 33, fig. 1

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1966. *Diploria clivosa* (Ellis and Solander), Stanley, Amer. Assoc. Petrol. Geol., Bull., vol. 50, No. 9, pp. 1931, 1937, pl. 1, fig. 3.
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The original description of *Diploria clivosa* by Ellis and Solander was the following:

> 45. Madrepora clivosa
>
> Madrepora *conglomerata, anfractibus basi angustatis, dissepimentis subexesis aequalibus, ambulacris simplicibus crassiusculis, lamellis alternis abbreviatis.*
>
> Habitat in Oceano Indiae occidentalis.
>
> *Corallium* rotundatum, nodulis magnis inaequale.

Esper (1789) illustrated the taxon under the name of *Madrepora filograna,* a species which is regarded by later authors to be the same as that first described by Ellis and Solander. The fossil specimen (2696) from the Caloosahatchee Marl is similar to Esper's drawing of the Recent form, and agrees well with other illustrations and specimens I have seen. The following description of *D. clivosa* is based on specimen 2696 (I-1013) contained in the collection of the Florida Bureau of Geology. The specimen was collected in 1914 by Dr. E. H. Sellards in the Caloosahatchee River, 5 miles below LaBelle, Hendry County.

The corallum is a spreading mat slightly convex to hummocky on the calicinal surface; the non-calicinal surface is wholly adherent to the exterior of the flared outer lip of the large gastropod *Strombus leidyi* Heilprin. The valleys are discontinuous and relatively narrow, their width 5.5 mm to perhaps 9 mm from colline to colline. Most of the valleys are long and slightly winding, but those on the hummocky portion of the upper surface are shorter and roughly elliptical in outline, and nearly entirely closed except for a small breach. The collines are subacute at the summit and rise 3.5 mm to 4 mm above the valley floor or columella. The septa are thin, 22 to 26 of them in one centimeter, and are arranged in an alternating series of principals and subsidiaries. The principal septa descend steeply, then broaden and curve slightly at the columella where they are raised into short, somewhat thickened paliform lobes. The subsidiary septa are very narrow, short and uniform. The margins of all the septa are erose or dentate, and the sides are granulose, the granulations small and pointed. The septa are a little exsert, the ends continuous over the colline. The trabecular columella is well developed, continuous and more or less uniform, with an average width of 1.7 mm or 1.8 mm.

The Florida fossil specimens have fewer septa in one centimeter than the Recent ones described by Matthai, but in other respects they are virtually identical.

Measurements. — FBG specimen I-1013 (2696): corallum length 136 mm, width 114 mm, maximum thickness through hummock 52 mm. Specimen USNM-3695: corallum length 77 mm, width 53 mm, thickness 33 mm.

Localities. — Specimen I-1013 (2696): Caloosahatchee River, 5 miles below LaBelle, Hendry County in Caloosahatchee Marl. Specimen USNM-3695: labeled by Vaughan "*Maeandra clivosa* (Ell. & Sol.), St. Marks, Fla. (Ballast?)". Because of Vaughan's statement that the USNM-3695 specimens may have been discarded ballast, the correct locality and stratigraphic position are not known.

Range and distribution. — The reported geographic range of *Diploria clivosa* in the Western Atlantic is from Florida to Venezuela. In the Eastern Atlantic it occurs off Senegal and the Cape Verde Islands. The geologic range is Miocene to Recent.

Miocene — Nivaje Shale of the Dominican Republic.

Pliocene — Caloosahatchee Marl, Florida.

Plio-Pleistocene. — Guadeloupe.

Pleistocene — Key Largo Limestone and Miami Oolite of Florida; Costa Rica (Monkey Point). "This species is general in the elevated Pleistocene reefs and in the areas of living reefs in the Caribbean region and in Florida." (Vaughan 1919, p. 420).

Recent — Florida (Biscayne Bay and the Florida reef tract, and in the Tortugas at Ft. Jefferson, Golding Cay, Loggerhead Key); Bahamas (Turtle Rock, Bimini, Freeport, and Abaco Island); Cuba; Jamaica (Ocho Rios; near shore to 35(?) meters); Mexico (Blanquilla Reef; Alacran; Isla de Lobos); British Honduras (Rendezvous Cay and Glover's Reef); Pedro Bank; Puerto Rico (Cabo Rojo; Cayo Icacos); St. Bartholomew (36 m to 38 m); Virgin Islands (22 m to 39 m southeast of Virgen Gorda); Netherlands Antilles: Curaçao (Westpuntbaai, Plaja Abao, Portomaribaai, Vaarsenbaai, Piscaderabaai, Spaanse Water, Boca Plaja Canoa, Sint Jorisbaai, Oostpunt, Klein Curaçao, Kaap Malmeeuw). Aruba (Cudarebe-Arashi, Boca Catalina, Malmok, Eagle Beach-Palm Beach, Barcadera, Pitch Field, Andicuri). Bonaire (Boca Bartol, Plaja Frans, Goto, Jan Doran-Barcadera, Ruin, Hato, Klein Bonaire, Plaja Sarna, Blauwe Pan, Witte Pan, Oranje Pan, Willemstoren, Lac). St. Martin (Anse de Pères, Baie Rouge, Mullet Pond Bay, Mahó Bay, Burgeux Bay, Simson Bay, Cay Bay, Little Bay, Great Bay, Point Blanche Bay, Guana Bay, Gibb's Bay, Babit Point). Saba (Ladder Bay, Fort Bay, Cove Bay). St. Eustatius (Cocoluch Bay-Jenkins Bay, Tumbledown Dick Bay, Oranjestad Baai, Gallows Bay, Compagnie Baai, Schildpadden Baai); Venezuela (Bahía de Mochima, Estado Sucre at Playa Blanca de Las Maritas, Ensenada Cabruta Roja, Ensenada Aguirre, Ensenada Los Aceites, Ensenada Piedra Pelona, Ensenada Burgao, Punta Aceite de Palo, Morro Garrapata; Golfo de Cariaco, Zonas A, B, C, F).

Diploria labyrinthiformis (Linnaeus) Pl. 32, fig. 2; Pl. 37, fig. 1

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As described by Verrill (1901), Matthai (1928), and Smith (1948), the corallum of this species is hemispherical, with an evenly convex calicinal surface. The valleys are very sinuous and almost continuous, tending to become straight at the periphery of the head. The average width of the valleys is 5 mm (up to 8 mm), and their depth 5 or 6 mm. The collines are vesicular and thick, up to 22 mm (average 5 mm), and up to 22 mm in depth (average 6 mm or 7 mm), and are invariably grooved, the grooves sometimes broader and much deeper than the valleys.

There are 14 to 17 septa in one centimeter, most of them (13-15) extending to the columella. The principal septa are more or less equal, the upper half or two-thirds narrowing toward the paliform lobes which are broad. The septal margins are serrated into closely spaced bluntly-pointed teeth, the uppermost ones the longest and directed obliquely upward. The faces of the septa are sparsely covered with small pointed granulations. The subsidiary septa are few and rudimentary. The principal septa are exsert about 1 mm, the arched summits sloping down to the costae. The costae are narrow but distinct, of even width, meeting at the bottom of the groove when the latter is shallow. Like the septa, the costae are toothed, the dentations conical or spiniform. The columella is well developed, composed of closely twisted thin trabeculae, and thickened at the centers which are 4 mm to 5 mm apart.

Diploria labyrinthiformis (Linnaeus) is widespread and abundant; it often occurs with, but is differentiated from *Diploria strigosa* (Dana), by the much more prominent groove in the collines of the former.

Measurements.—According to Matthai, the type figure of *Madrepora labyrinthiformis* Linnaeus is the one reproduced by Matthai (pl. 70, fig. 1), the diameters of which are 111.5 mm × 82.5 mm across the upper surface. The form of Linnaeus illustrated by Matthai (pl. 69, fig. 1) is, as stated by Linnaeus, the same as *M. labyrinthiformis.* The natural size of that specimen is 79 mm × 63.5 mm across the calicinal surface. Lamarck's type of *Meandrina cerebriformis* is more or less hemispherical, with an evenly convex calicinal surfaces. The corallum of that is 60 mm in height, and the diameters of the head 100 mm × 100 mm (Matthai, p. 69).

Range and distribution.—The geographic range of *Diploria labyrinthiformis* is from Bermuda to Venezuela; the geologic range is Oligocene? to Recent.

Oligocene?—Dominican Republic (near summit of Sierra Prieta, Provincia de Samaná).

Miocene—Dominican Republic (Cercado Formation ? in Rio Gurabo; Rio Amina ?; Mao Adentro Limestone; Provincia de Azua).

Pliocene—Haiti (west slope of Tapion du Petit-Goave, about 100 m above sea level, Arrondissement Léogane).

Plio-Pleistocene—Dominican Republic (Provincia de Monte Cristi, between Copey and Dajabon).

Pleistocene—Florida (Key Largo Limestone/Miami Oolite dredged in channel at Old Fort Taylor, Key West; channel between Stock Island and Cow Key; channel off eastern tip of Stock Island; channel at northern end of Raccoon Key; alongside Card Sound Bridge, Key Largo); Dominican Republic ? (Provincia de Santo Domingo, elev. 57 m); Puerto Rico; Montserrat (cliff 1500 yds. northwest along coast from Roche Bluff); Guadeloupe (Grande-

Terre); Curaçao (Westpunt); Bonaire; Barbados (low-level reefs near Bridgetown; high-level reefs at Castle Grant 1070 ft.; Mt. Misery 1053 ft.; Russia Gully, St. Thomas, 720 ft.; Orange Hill Plantation, St. Peter's, approximately 600 ft.; Scotland, St. Andrews; Bath-Reef Series near Bath 150 ft. - 165 ft.; Charles Rose Gully, St. George 160 ft.; Prospect, St. James 80 ft.; Grazettes, St. Michael 70 ft.; Sandy Lane, St. James 40 ft.).

Recent — Bermuda (Great Sound; Castle Harbour; North Rock; Green Flat; Ferry Reach); Bahamas (Abaco Island; Great Bahama Bank; Bimini; Andros Island; Nassau); Florida (patch reefs along southeast coast and at Golding Cay, Tortugas; Cuba; Jamaica (Ocho Rios; shore to 43 m); Pedro Bank (on all larger cays); Panama (San Blas?); British Honduras (Rendezvous Cay, Turneffe, Glover's Reef); Mexico (Yucatan Shelf; off Vera Cruz and Isla de Lobos; Alacran Reef; Blanquilla Reef); Puerto Rico (Cayo Turrumote; Cayo Icacos); St. Thomas; Barbados (west coast); Netherlands Antilles: Aruba (Eagle Beach-Palm Beach, Barcadera, Mangel Altu). Curaçao (Plaja Kalki, Westpuntbaai, Plaja Abao, Portomaribaai, Vaarsenbaai, Sint Michielsbaai, Spaanse Water, Caracas Baai, Sta. Martha Baai, Piscaderabaai). Bonaire (Plaja Frans, Jan Doran-Barcadera, Ruin, Hato, Klein Bonaire, Plaja Sarna, Baca, Vierkant, Blauwe Pan, Witte Pan, Oranje Pan, Slagbaai). St. Martin (Baie Rouge, Mullet Pond Bay, Simson Bay, Little Bay). Saba (Fort Bay). St. Eustatius (Cocoluth Bay-Jenkins Bay-Tumbledown Dick Bay, Oranjestad Baai); Venezuela (Bahía de Mochima, Edo. Sucre at Punta El Aguirre and Punta Garrapata).

Diploria sarasotana, new species Pl. 35, figs. 1, 2; Pl. 36, fig. 1

The corallum (SP-4a) is broken around the perimeter in such fashion that it gives the impression of being short conical in form. However, judging from the calicinal surface which is gently convex and meandroid, and from the base which is an irregular, flattened area, it is inferred that the corallum originally was large, hemispherical, more or less rounded in outline, and attached.

The valleys are moderately short and serpentine or looped like the letter "S", or are moderately long and sinuous. All of the valleys are breached in one place or another, and are interconnected by the continuous columellas of adjacent calices. The collines are singly ridged by virtue of the protrusion of the septothecal wall, and by the steep slope of the septa therefrom to the valley floor. However, in one localized area at the edge of the corallum, the colline is rounded and about 2 mm thick. Here the opposing septa of the neighboring calice are conterminous and arched over the colline, with the exsert ends elevated about 1 mm and notched at their crest down to the top of the wall. From colline to colline the width of the valleys varies from 8 mm to 13 mm; the depth of the valleys from the crest of the collines to the top of the columella is 5 mm to 6 mm.

There are 9 to 13 principal septa, for a median of 10, per centimeter of length, and 11 to 18 principal plus minor septa, for a median of 14 per centimeter of length. The minor or subsidiary septa do not alternate regularly with the principals. The latter are a little exsert and tabular, and are thicker at the wall (0.5 mm) than farther within (0.3 mm). They are relatively narrow and descend steeply, their margins straight to slightly convex upward. Before reaching the columella, a number of the principal septa are excavated at the margin to form thickened paliform lobes, whereas the inner ends of other septa are upturned at, and merge with the columella. The margins of the septa are dentate, the denticles large and blunt, with 10 or 11 of them on a septum 4.8 mm in length; of these four or five are on the margin of the paliform lobe. Each denticle represents the terminus of a thin column of simple trabeculae on the face of the septum, the trabeculae consisting of strong pointed granulations or smaller spinules. The innermost ends of the septa are twisted and tangle with the columella which is prominent, spongy, and continuous, branching into the valleys of all calices. The width of the columella varies from about 1.5 mm to 3 mm, and there is a trabecular linkage between centers.

The endothecal dissepiments are very thin to membranous.

Measurements. — Holotype (SP-4a): corallum length 79 mm, width 70 mm, height 49 mm; attachment area at base 26 mm × 21 mm.

Locality. — Warren Brothers Pits, 4 miles east of US 301, Sarasota, Sarasota County, Florida on Newbern Road, 0.4 miles north of 17th Street. Collector: Leslie Dyet, 20 April 1969.

Formation. — Pinecrest.

Comparison. — This species is characterized by its coarse septa, subacute collines, and unclosed or breached valleys in which the *Manicina*-like columella is prominent and continuous from one calice to the other. Its nearest relative is the Pliocene to Recent *Diploria strigosa* (Dana), and may perhaps be a forerunner of that. However, the new taxon *Diploria sarasotana* differs from *D. strigosa* in having fewer septa per centimeter of length (9 - 18 versus 15 - 20), in having no closed valleys (*D. strigosa* has a number of them), and in having some narrower collines between which the valleys are a little wider than in *D. strigosa.*

Diploria strigosa (Dana) Pl. 32, fig. 3; Pl. 33, figs. 2, 3

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1964. *Diploria strigosa* (Dana), Rivero, Geos [Venezuela], No. 11, p. 113.
1964. *Diploria strigosa* (Dana), Hoffmeister, *et al.*, Guidebook Geol. Soc. Amer. Convention, Field Trip No. 3, pp. 9, 22.
1964. *Diploris strigosa* (Dana), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 20, No. 81, pp. 11, 23-33, 35, 43, 47, fig. 14.
1966. *Diploria strigosa* (Dana), Laborel, Mus. Nat. Hist. nat., Paris, Bull., sér. 2, vol. 38, No. 3, pp. 282, 288, fig. 3CC.
1966. *Diploria strigosa* (Dana), Stanley, Amer. Assoc. Petrol. Geol., Bull., vol. 50, No. 9, pp. 1929-1931, 1937, 1938, pl. 1, fig 2.
1966. *Diploria strigosa* (Dana), Rigby and MacIntire, Brigham Young Univ. Geol. Studies, vol. 13, pp. 3, 22, 31, 33-35, 39, 40, 41, 43-45, pl. 7, fig. 4; pl. 8, fig. 1.
1967. *Diploria strigosa* (Dana), Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 448.
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1971. *Diploria strigosa* (Dana), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 4, 16, 18-32, 34, 35-39, 69, 70, 71, figs. 6, 7, 31, pls. 29a, b.
1971. *Diploria strigosa* (Dana), Olivares, Inst. Oceanogr. Univ. Oriente, Bol., vol. 10, No. 2, pp. 73, 74, table 1.
1972. *Diploria strigosa* (Dana), Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 548, 553, 567, 578, pl. 7C.

Specimen FWK-1a is a worn and broken one from Windley Key, and is illustrated to show the nature of the fossil corals obtained from the indurated Key Largo Limestone.

The upper and lower surfaces of the fractured corallum are marked by short and sinuous, but in places, elongated valleys, the former averaging 6.5 mm in width, the latter 9 mm to 11 mm. The crests of the collines are beveled down, many to the bottom of the valley, and are 1.5 mm to 2.5 mm in width.

There are an average of 18 septa in one centimeter, most of them principals, these thinly tabular, dentate on the margin, with small pointed granulations on the sides, and with paliform lobes below.

Measuremens. — Corallum FWK-1a: length 100 mm, width 75 mm, height 61 mm. Corallum BAH-2a: length 81 mm; width 72 mm, height 32 mm. Recent; Freeport, Bahamas. Collector: Noel Andress.

Locality. — FWK-1a: quarry on Windley Key, Monroe County. Collector Dr. Lyman D. Toulmin, November 1964.

Range and distribution. — The recorded geographic range of *Diploria strigosa* is from Bermuda to Barbados; the geologic range is Miocene to Recent.

Miocene — Dominican Republic (Mao Adentro Limestone).

Pliocene — Florida (Caloosahatchee Marl ?).

Pleistocene — Florida (Key Largo Limestone/Miami Oolite in quarry on Windley Key; dredged off Old Fort Taylor, Key West; off eastern tip of Stock Island; off Card Sound Bridge, Key Largo, Monroe County; dredged at Port Everglades, Broward County); Bermuda (Devonshire Formation, 120,000-130,000 years); Bahamas (Fish Creek fossil reef); Mexico (Quintana Roo); Costa Rica (Monkey Point in slightly elevated reefs); Dominican Republic; St. Eustatius (White Wall); Curaçao (Westpunt); Bonaire (Fontein); Aruba (Daimarie); Barbados (St. Johns Church, St. John 700 ft.; Bath-Reef Series near Bath 150 ft. - 165 ft.; Colleton, St. Lucy Parish 40 ft.).

Recent — Bermuda (North Rock); Florida (Miami area, Florida Keys, Tortugas); East Flower Bank south of the Louisiana coast; Bahamas (Abaco Island; Great Bahama Bank; Freeport; Rabbit Cay, 15 ft. or more); Cuba; Jamaica (Ocho Rios; shore to 40 m.); Mexico (Alacran Reef, Campeche Bank; off Vera Cruz, Isla de Lobos; off Quintana Roo; Blanquilla Reef); British Honduras (Rendezvous Cay, Turneffe, Lighthouse and Glover's Reefs); Puerto Rico (Cayo Turrumote; Cabo Rojo; Cayo Icacos; Mayagüez); St. Thomas; St. Bartholomew; Antigua; Netherlands Antilles: Curaçao (Westpuntbaai, Plaja Kalki, Plaja Abao, Plaja Chikitu, Boca Santa Marta, Santa Martha Baai, Portomaribaai, Daaibooibaai, Vaarsenbaai, Sint Michielsbaai, Kaap Malmeeuw, Piscaderabaai, Spaanse Water, Awa di Oostpunt, St. Joris Baai, Klein Curaçao). Aruba (Cudarebe-Arashi, Boca Catalina, Malmok, Eagle Beach-Palm Beach, Barcadera, Mangel Altu, St. Nicolaasbaai, Andicuri). Bonaire (Boca Bartól, Plaja Frans, Goto, Jan Doran, Barcadera, Lont, Ruin, Klein Bonaire, Plaja Sarna, Baca, Vierkant, Blauwe Pan, Witte Pan, Oranje Pan, Willemstoren, Lac). St. Martin (Baie Rouge, Mullet Pond Bay, Mahó Bay, Burgeux Bay, Simson Bay, Cay Bay, Little Bay, Great Bay, Point Blanche Bay, Guana Bay, Gibb's Bay, Babit Point. Saba (Ladder Bay, Fort Bay, Cove Bay). St. Eustatius (Cocoluch Bay, Jenkins Bay, Oranjestad Baai, Compagnie Baai, Schildpadden Baai). Barbados (west coast); Venezuela (Puerto La Cruz, Edo. Anzoategui; Bahía de Mochima, Edo. Sucre at Ensenada Botella, E. Cabruta Blanca, E. Cabruta Roja, E. Los Aceites, E. Garrapata, E. El Inglés, E. El Muerto, E. El Aguirre, E. San Agustin, E. de Centeno, E. Piedra Pelona, E. Garrapata, E. Ballena, E. Las Maritas, E. Carenero, Mangle Quemao, Morro de Garrapata, Punta Botella, Barranca de Mochima, Playa Blanca de Guaiguá, Punta San Agustin, P. de León, P. Aceite de Palo, P. Las Maritas, P. Mero Mañoso, P. Toporo, Costica Mano E'Piedra, Lance Manguillas, Costa Maringinia, Playa y Punta Piedra; Golfo de Cariaco, Zonas A, B, C, D, F, I.

Thysanus floridanus, new species Pl. 34, figs. 1-3

1919. *Thysanus species* Vaughan, *nomen nudum*, U.S. Nat. Mus., Bull., vol. 103, No. 9, p. 222.

The holotype — 3300 USNM from Shell Creek, Florida — is broken near the pedicillate area but is otherwise rather well preserved. The corallum is simple, flabelloid or boatshaped, with low, obtusely sloping sides, and a broadly rounded bottom which is traversed lengthwise by a low but prominent medial keel. The slope of the bottom is very gentle on the longer end of the corallum, but at the pedicelled end the bottom is subangular. The pedicel itself is broken away. The keel is in effect a long, continuous, somewhat wavy costa, finely granulate on the sides and minutely serrate to denticulate along the axis. Radiating away from the keel and curving toward the pedicillate end of the corallum are the true costae, each of which is well developed and conterminous with, but coarser than its corresponding septum. The costae alternate in two series of larger and smaller size, are strongly and somewhat irregularly granulose on the crest but minutely and sparsely so on the sides, and are separated by deep interspaces. Before curving away from the axial keel, a number of the costae are parallel and contiguous with it for a short distance. Near the long end of the bottom, the keel is interrupted for a fraction of a millimeter and then joins one of the small terminal costae, which in turn connects with the axial septum of the calice. The terminal costae at this end of the corallum are subequal, short, and crowded, and there are three or four of them on either side of the axial.

The calice is moderately deep (about 4.2 mm from the crest of the larger septa to the base of the columella), narrowly elongate and elliptical in outline, and with a longer end which is acutely but evenly rounded, and a pedicillate end which is presumed to be short and a little wider than the other. The columella is narrow (about 1.4 mm at the base) parietal below, but lamellar and interrupted above, the latter forming a long axial septum which joins the axial costa of the keel. All of the septa are lamellar and thin, and are exsert at the margin of the calice, the largest one rising 1.6 mm above the summit of the wall, the smallest one about 0.2 mm. The wall is thin, about 0.15 mm. There are 90 septa in the incomplete calice of the type specimen, and it is estimated there would be about 120 septa were the calice whole. The septa are separated by deep interspaces and alternate variously in size, a larger septum next to a smaller one, but in several rhythms of insertion. All of the larger septa are curved toward the pedicillate end of the corallite, and only the principal ones extend to the base of the columella which they join by means of a small terminal process. The margins of the septa are finely serrate or minutely denticulate, these characters produced from the slight protrusion of the ends of the trabeculae. The faces of the septa are beset by pointed granulations or faint, elongated, and granulose ridges aligned in rows along the narrow trabeculae. The larger septa are lobate, rather evenly so above the wall, but then, after a slight depression in the margin, broadening within to near the columella where the margin abruptly descends vertically to the base of the columella. The largest septum measured is 4.8 mm in width and 4.2 mm in height. A number of the principal septa are perceptibly flexed along their inner course. No internal lobes are present.

The columella indicates colony formation was by intramural linear budding.

Measurements. — Holotype, 3300 USNM: corallum (broken at pedicelled end) length 22.5 mm, width near middle 9.3 mm, height at pedicel 7.5 mm, height near middle about 4.7 mm.

Locality. — Shell Creek, Charlotte County, Florida. Collector Frank Burns. Label reads Pliocene.

Comparisons. — Following are the species of *Thysanus* from the circum-Caribbean area, all of them reported from the Miocene, lower to upper.

Thysanus excentricus Duncan (1863, p. 439, pl. 16, figs. 3a-3c). Jamaica; Dominican Republic; Cuba.

Thysanus corbicula Duncan (1863, p. 430, pl. 15, figs. 3a, 3b). Dominican Republic.

Thysanus elegans Duncan *in* Duncan and Wall, (1864, p. 10, pl. 2, figs. 2a, 2b). Jamaica.

Thysanus hayesi Vaughan (1919, p. 424, pl. 77, figs. 3, 3a, 3b). Cuba.

Thysanus crassicostatus Vaughan and Hoffmeister (1925, p. 326, pl. 3, figs. 5-8). Dominican Republic.

Thysanus species, juv. Vaughan and Hoffmeister (1926, p. 124). Trinidad.

The nearest, perhaps, of the above listed species to *Thysanus floridanus,* n. sp. is the late Miocene *Thysanus excentricus* Duncan, but that possesses internal lobes before the principal septa whereas on *T. excentricus* internal lobes are lacking.

Manicina areolata (Linnaeus) Pl. 33, figs. 4, 5; Pl. 34, figs. 4, 5; Pl. 36, figs. 2, 3; Pl. 37, figs. 2, 3; Pl. 38, fig. 1; Pl. 39, fig. 1

1788. *Madrepora areola* Linnaeus, Esper, Die Pflanzenthiere in Abbildungen,

1786. *Madrepora areolata* Linnaeus, Ellis and Solander, Natural History of Zoophytes, p. 161, pl. 47, figs. 4, 5. [*Non* fig. 4, *fide* Gregory, 1895, p. 264.]

1788. *Madrepora areola* Linnaeus, Esper, Die Pflanzenthiere in Abbildungen, vol. 1, pl. 4, figs. 1, 2; pl. 5, figs. 1-4. [*Fide* Matthai, 1928, p. 80.]

1821. *Maeandrina areolata* (Linnaeus), Lesueur, Mus. Nat. Hist. nat., Paris, Mém., vol. 6, pp. 283-285, pl. 16, fig. 11.

1821. *Maeandrina areolata* (Linnaeus), Lamouroux, Exposition Méthodique des . . . Polypiers, p. 55, pl. 47, figs. 4, 5.

1841. *Manicina areolata* (Linnaeus), Leuckart, Observationes Zoologicas de Zoophytis Coralliis, p. 61, pl. 3, figs. 3, 4.

1846. *Manicina areolata* (Linnaeus), Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, pp. 191-194, pl. 9, fig. 3. Also *M. hispida* Ehrenberg

M. praerupta Ehrenberg, M. dilatata Dana. [*Fide* Matthai, 1928, pp. 80, 81.]

1868. *Manicina areolata* (Linnaeus), Duncan, Geol. Soc. London, Quart. Jour., vol. 24, pp. 16, 23.

1877. *Manicina areolata* (Linnaeus), Lindström, K. Svenska Vetensk.-Akad., Handl., vol. 14, No. 6, p. 22.

1880. *Manicina areolata* Ehrenberg, Pourtalès, Mus. Comp. Zool., Mem., vol. 7, No. 1, pls. 5, 6.

1888. *Manicina areolata* (Linnaeus), Wilson, Jour. Morph., vol. 2, No. 2, pp. 191-252, pls. 1-7.

1900. *Manicina areolata* (Linnaeus), Vaughan, U.S. Geol. Sur., Mon., vol. 39, pp. 39-40, 48, 210, pl. 1, figs. 2, 3.

1900. *Manicina pliocenica* Gane, U.S. Nat. Mus., Proc., vol. 22, No. 1193, pp. 192, 193.

1901. *Maeandra areolata* (Linnaeus), Verrill, Connecticut Acad Arts and Sci., Trans., vol. 11, Pt. I, art. III, pp. 81-84, pl. 11, figs. 1, 2; pl. 12, figs. 1-3. Also *M. hispida* Edwards and Haime, *M. confertifolia, M. laxifolia, M. columellaris* Verrill. [*Fide* Matthai, 1928, p. 81.]

1902. *Manicina areolata* (Linnaeus), Duerden, Nat. Acad. Sci., Washington, Mem., vol. 8, pp. 502-508, 520, 577-579, figs. 13a-e, 14a-c, pls. 18, 19, figs. 129-137.

1902. *Manicina areolata* (Linnaeus), Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, Pt. 2, pp. 291, 305, pl. 4, figs. 2. 3 Also *Manicina pliocenica* Gane.

1909. *Manicina areolata* (Linnaeus), Hartmeyer, Meereskunde Berlin, Jahrg. 3, No. 2, pp. 12, 13, figs. 1, 2.

1910. *Maeandra areolata* (Linnaeus), Vaughan, Carnegie Inst. Washington, Publ. No. 133, Papers Tortugas Lab., vol. 4, p. 109.

1912. *Maeandra areolata* (Linnaeus), Vaughan, Carnegie Inst. Washington, Yearbook No. 10 for 1911, p. 156, pl. 4, figs. 5, 6; pl. 5, figs. 1-4.

1919. *Manicina areolata* (Linnaeus), Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 214, 215, 225, 419. Also *Maeandra pliocenica* (Gane), 1900, p. 222.

1921. *Maeandra* sp. aff. *M. areolata* (Linnaeus) and aff. *M. pliocenica* (Gane), Vaughan, Geol. Survey Dominican Republic, Mem., vol. 1, p. 152.

1926. *Manicina areolata* (Linnaeus), Matthai, Roy. Soc. London, Philos. Trans., ser. B, vol. 214, pl. 26, figs. 1, 2; pl. 27, figs. 15, 16, 18, 19; pl. 28, figs. 1-3.

1928. *Manicina areolata* (Linnaeus), Matthai, Catalogue of the Madreporarian Corals in the British Museum (Natural History), vol. 7, pp. 8, 15, 55, 80-91, 92, 97, 99, 104, 108, 109, 160, 162, 167, 168, pl. 20, figs. 1-10; pl. 21, figs. 1-9; pl. 53, figs. 1-4; pl. 55, figs. 10, 14; pl. 63, fig. 7; pl. 64, fig. 6; pl. 68, figs 3, 4; pl. 69, figs. 4-7.

1929. *Meandra areolata* (Linnaeus), Boschma, Carnegie Inst. Washington, Publ. No. 391, Papers Tortugas Lab., vol. 26, pp. 129-147, 9 figs.

1935. *Maeandra areolata* (Linnaeus), Yonge, Carnegie Inst. Washington, Publ. No. 452, Papers Tortugas Lab., vol. 29, pp. 185-198, pls. 1-3.

1939. *Maeandra areolata* (Linnaeus), Butsch, Barbados Mus. and Nat. Hist. Soc., Jour., vol. 6, No. 3, p. 136, pl. 1, fig. 3.

1943. *Manicina areolata* (Linnaeus), Smith, Florida Acad. Sci., Quart. Jour., vol. 6, No. 1, p. 46.

1943. *Manicina areolata* (Linnaeus), Vaughan and Wells, Geol. Soc. Amer., Spec. Pap., No. 44, pp. 1, 25, 26, 171, 296, pl. 4.

1948. *Manicina areolata* (Linnaeus), Smith, Atlantic Reef Corals, pp. 61, 69, 86, 87, 111, pls. 19-21.

1949. *Manicina areolata* (Linnaeus), Lyman, Shell Notes, vol. 2, Nos. 7-9, p. 132, pl. 2, fig. 2.

1956. *Manicina areolata* (Linnaeus), Wells, Treatise on Invertebrate Paleontology, Pt. F, Coelenterata, p. F403, fig. 299, 1.
1958. *Manicina areolata* (Linnaeus), Squires, Amer. Mus. Nat. Hist., Bull., vol. 115, art. 4, pp. 227-232, 238, 239, 241, 242, 244, 255, pl. 37, figs. 1-3.
1958. *Manicina areolata* (Linné), DuBar, Florida Geol. Survey, Geol. Bull., No. 40, p. 121.
1959. *Manicina areolata* (Linnaeus), Goreau, Biol. Bull., vol. 116, No. 1, pp. 63-66.
1959. *Manicina areolata* (Linnaeus), Goreau, Ecology, vol. 40, No. 1, pp. 70, 73, 75, 85.
1961. *Manicina areolata* (Linnaeus), Goreau, Endeavour, vol. 20, pp. 35, 36.
1962. *Manicina areolata* (Linnaeus), Moore and Gunter, Bull. Marine Sci. Gulf and Caribbean, vol. 12, No. 1, p. 69.
1963. *Manicina areolata* (Linnaeus), Jones, Bull. Marine Sci. Gulf and Caribbean, vol. 13, No. 2, p. 284.
1963. *Manicina areolata* (Linnaeus), Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 139, 141, 142, 152, 161, pl. XIb.
1964. *Manicina areolata* (Linnaeus), Storr, Geol. Soc. Amer., Spec. Pap., No. 79, pp. 45, 46, 78, 80, 84, 86.
1964. *Manicina areolata* (Linnaeus), Hoffmeister, *et al.*, Guidebook Geol. Soc. Amer. Convention, Field Trip No. 3, p. 23.
1964. *Manicina areolata* (Linnaeus), Hoskins, Amer. Assoc. Petrol. Geol., Bull., vol. 48, No. 10, pp. 1690, 1699, pl. 2, fig 13.
1967. *Manicina areolata* (Linnaeus), Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 448.
1968. *Manicina areolata* (Linnaeus), Weisbord, Bull. Amer. Paleont., vol. 55, No. 256, pp. 52-57. [Numerous references 1785-1964.]
1968. *Manicina (Maeandra) areolata* (Linnaeus), Yonge, Roy. Soc. London, Proc., ser. B, vol. 169, pp. 338, 341.
1969. *Manicina areolata* (Linnaeus), Logan, Amer. Assoc. Petrol. Geol., Mem. 11, pp. 149, 185, pl. 10, fig. 5.
1969. *Manicina areolata* (Linnaeus), Stoddart, Biol. Rev., vol. 44, pp. 445, 458, 462, 464.
1969. *Manicina areolata* (Linné), Wells, *in* DuBar, Gulf Coast Assoc. Geol. Soc., Soc. Econ. Paleont. and Mineral. Sect., Ann. Meet., Field Trip No. 4, p 141.
1970. *Manicina areolata* (Linnaeus), Wise, Science, vol. 169, p. 978.
1970. *Manicina areolata* (Linnaeus), Klose, *in* letter to R. O. Vernon 30 April 1970, pp. 4, 6.
1971. *Manicina areolata* (Linné), Olivares and Leonard, Inst. Oceanogr. Univ. Oriente, Bol., vol. 10, No. 1, pp. 49, 52, 58, table 1, pl. 4, figs. C, D.
1971. *Manicina areolata* (Linné), Olivares, Inst. Oceanogr. Univ. Orient, Bol., vol. 10, No. 2, pp. 73-75, table 1.
1971. *Manicina areolata* (Linnaeus), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 4, 18, 34, 72, fig. 33, pl. XXXVa, b.
1972. *Manicina areolata* (Linnaeus), Macintyre, Amer. Assoc. Petrol. Geol., Bull., vol. 56, No. 4, p. 731.
1972. *Manicina areolata* (Linnaeus), Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 548, 552, 568, 578, pl. 7.
1972. *Manicina areolata* (Linnaeus), Wise, Biomineralization Res. Repts., vol. 6, p. 162, pl. 4, fig. 3.

The fossil and living forms of *Manicina areolata* from Florida exhibit a variety of shapes, often from the same locality or formation and may be due to differences in size, degree of maturity, or environment of growth. One aspect of the species is exemplified by specimens of CAL-3 from the Caloosahatchee Marl, 2-5 miles west of LaBelle in the Caloosahatchee River. The coralla are subflabellate and oval in outline, with the ends somewhat attenuated. The calicinal surface, or head of the corallum, is slightly convex and tapers abruptly to a short conical base, with the underside between the base and head being gently convex upward. On the calicinal surface there is a main sinuous central valley traversing the long axis of the corallum into which enter shorter side valleys. The underside is veneered by a thin but well-developed epitheca extending upward from the stalk to near the margin of the corallum where it is neatly delimited. There are 10 or 11 alternating septa in one centimeter.

Specimens of *Manicina areolata* (BG-3) from the "Glades" Formation which overlies the Caloosahatchee Marl, are suboval to ovate in outline, moderately convex on the upper surface, and flat at the base with a very small stalk or pedicel in the center. The epitheca is prominent and extends from the pedicel to near the periphery of the base where it is sharply delimited. On the surface there is a small central valley crossing larger transverse ones to about two-thirds the distance in from the attenuated end where it abuts against a main transverse valley near the blunt end of the head. The collines are subacute to subrounded. There are 10 or 11 subequal to alternating septa in one centimeter.

In the National Museum of Natural History collection there are two specimens (USNM 243222), labeled *Manicina pliocenica* Gane, which seem to me to be identical with variants of *Manicina areolata*. One of them is flat and epithecate at the base, and the valley plan like that of BG-3. The other is similar to CAL-3, with a subflabellate corallum, a short conical epithecate base, and a principal elongated valley, with smaller lobular valleys leading into the main one. There are 10 alternating larger and smaller septa in one centimeter on the larger flat-based form, and 15 alternating septa on the smaller stalked form.

LO-1a, dredged from Lake Okeechobee, and probably Pleistocene in age, is suboblong in outline, with blunt ends and a flattish base possessing a rudimentary pedicel near the center; the base is weathered but evidences of epitheca are present. The collines are flattened and are 1 mm to 5 mm in width. The valleys vary from

16 mm to 24 mm in width from colline to colline, and their depth from colline to columella is 10 mm to 14 mm. The columella is linear and trabecular, averaging 1.4 mm in width. There are 20 alternating septa in one centimeter.

All of the specimens mentioned above bear the imprint of *Manicina areolata s. l.* The coralla are meandroid, varying in outline from elongate ovate to oval to elliptical to suboblong. The upper surface is nearly flat to slightly convex to hemispherical. The noncalicinal surface is subflabelloid to subturbinate and stalked, or is flattened, the latter generally with a small pedicel or attachment process near the center. The valleys are straight to winding to lobular, 10 mm to 24 mm across from colline to colline, and 9 mm to 14 mm in depth. The collines are acute to obtuse, the latter with a narrow groove, their width 2 mm to 8 mm. The septa are lamellar, exsert, and alternating, and there are 10 to 20 of them to the centimeter. The exsert ends of the septa meet or are offset in notches in the middle of the colline producing a groove effect. The principal septa extend to the columella; the upper two-thirds are narrow, the lower part raised into high, broad, paliform lobes. So abrupt and regular is the demarcation of the lobes that they often form a sraight shelf above and parallel with the columella. The margins of the septa are regularly dentate, the sides spinulose, the spinules arranged in close transverse rows. The costae are thin, more or less equal in size, and granulose. The epitheca, which is always present, is thin but prominent, extending upward from the base of subflabelloid or subturbinate coralla to near the calicular margin of the corallites, or outward from the center of the base to near its periphery where the coralla are flat. In all instances the upper or outer limit of the epitheca is sharply and neatly defined. The columella is linear and trabecular, its average width 1.3 mm.

Many of the fossil forms from Florida seem to have fewer septa (10 to rarely up to 20) in one centimeter than do living forms (15-20).

Measurements. — Following are the measurements of a number of fossil and Recent coralla of *Manicina areolata* (Linnaeus) in the collections of Florida State University and the National Museum of Natural History. See Table 2.

Range and distribution. — The geographic range of *Manicina*

Table 2.

Manicina areolata (Linnaeus)

Specimen No.	Formation	Length (mm)	Width (mm)	Height (mm)	No. of septa in 1 cm	Form of underside	Form of calicinal surface or head	Outline of corallum
USNM-2094	Caloosahatchee Marl	72	49	54	14	Subturbinate	Slightly convex	Suboval; plump
USNM-2094	Caloosahatchee Marl	73	35	35	13	Subflabelloid	Flattish; long central valley	One end blunt, the other attenuated
USNM-2094	Caloosahatchee Marl	75	35	44	11	Subflabelloid	Slightly convex; long central valley	One end subrounded, the other attenuated
CAL-3b	Caloosahatchee Marl	89.5	49.5	48	10	Appressed-conical	Convex; lobular; sinuous central valley	Subovate
FBG-19726	Caloosahatchee Marl[1]	101.5	47	49	11	Short conical	Slightly convex; wide valleys	Narrowly ovate
USNM-243222 (#11)	Labeled *Manicina pliocenica* Gane. Glades Formation.	67	32	30	15	Subflabelloid	Slightly convex; long central valley	Both ends attenuated
USNM-243222 (#23)	Labeled *Manicina pliocenica* Gane. Glades Formation.	92	67	40	10	Flattish-concave; small central pedicel	Hemispherical; lobular	One end blunt, the other attenuated
BG-3a	Glades	146	117	75	10-11	Flat, with small central pedicel	Convex; prominent transverse valleys	One end blunt, the other narrowly rounded
BG-3b	Glades	109	84	53	14	Flattish-concave with central pedicel	Convex; collines acute	Oval
LO-1a	Lake Okeechobee. Pleistocene.	113	90	47	20	Flat with central pedicel	Convex; collines flattened	Suboblong
BYB-1a	Recent. Bahamas, Yellow Bank.	55.5	22.5	38.5	16	Subflabelloid-attenuate	Single sinuous central valley	Narrowly elliptical
BBB-1a	Recent. Bahamas, Bucaroon Bay.	64	40	39	17	Subturbinate	gently convex; globular	Subovate; plump
CAL-2a	Caloosahatchee Marl	35	13-15.5	20	16	Subflabelloid	Single calice compressed at middle forming figure 8	One end attenuated, the other asymmetric
LO-2a	Clewiston. Pleistocene.	57.5	22-28	37.5	10	Subflabelloid	Single calice compressed at middle forming figure 8	One end subrounded, the other asymmetric

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areolata is from Bermuda to Venezuela; the geologic range is upper Miocene to Recent.

Upper Miocene — Dominican Republic (Mao Adentro Limestone, Province of Santiago).

Pliocene — Florida (Caloosahatchee Marl).

Plio-Pleistocene — Florida (Glades Formation, Belle Glade Rock Co. quarry, Belle Glade, Palm Beach County).

Pleistocene — Florida (near Clewiston, Hendry County; dredged from Everglades; Key Largo Limestone/Miami Oolite dredged from channel off eastern end of Stock Island; excavated from marl pits alongside Card Sound Bridge, Monroe County); Bahamas; Panama Canal Zone.

Recent — Bermuda; Florida (Pine Channel; Biscayne Bay; Virginia Key; outer reefs and patch reefs along southeast coast; Tortugas); Bahamas (Rabbit Cay; Turtle Rocks; South Bimini; Yellow Bank in 15 ft. of water; Bucaroon Bay off Great Abaco Island in 7 ft. of water); Cuba (Gulf of Batabanó); Jamaica (depth range from shore to 43 m; Ocho Rios); Mexico (Isla de Lobos; Yucatan Shelf); Haiti; Puerto Rico (Ensenada Honda; Cayo Enrique; Mayagüez; Aguadilla); St. Thomas, 24 m to 65 m; Sail Rock 20 to 23 fathoms; St. Bartholomew; east of St. Lucia (34 m); Barbuda; Martinique; Aruba; Curaçao; Bonaire; St. Martin; Venezuela (Los Roques; Bahía de Mochima, Edo. Sucre at Ensenada Cabruta, Ensenada El Aguirre, Playita Mangle Quemao, Costa Maringinia, Playa Piedra, Punta Piedra; Golfo de Cariaco, Zonas C, E, F, G, H, I).

Manicina cf. M. gyrosa (Ellis and Solander) Pl. 38, fig. 2; Pl. 39, fig. 2

1758. *Fungus marinus*, . . . Seba, Locupletissimi rerum naturalium Thesauri, vol. 3, p. 201, pl. 109, fig. 10. [*Fide* Edwards and Haime, 1849, pp. 266, 267.]

1786. *Madrepora gyrosa* Ellis and Solander, Natural History of . . . Zoophytes, p. 163, pl. 51, fig. 2.

1791. *Madrepora gyrosa* Ellis and Solander, Gmelin (*pars*), Systema Naturae, ed. 13, vol. 1, pt. 6, p. 3763.

1795. *Madrepora gyrosa* Ellis and Solander, Esper, Fortsetzungen der Pflanzenthiere, vol. 1, pts. 3-4, pp. 100, 101, pl. 80, fig. 1.

1815. *Madrepora gyrosa* Ellis and Solander, Oken, Lehrbuch der Naturgeschichte, p. 70.

1816. *Meandrina gyrosa* (Ellis and Solander), Lamarck, Hist. Nat. Anim. sans Vert., vol. 2, p. 247.

1821. *Meandrina gyrosa* (Ellis and Solander), Lamouroux, Exposition Méthodique . . . Polypiers, pp. 55, 56, pl. 51, fig. 2.

1823. *Meandrina gyrosa* (Ellis and Solander), Blainville, Dictionnaire des Sciences Naturelles, vol 29, p. 376.

1824. *Meandrina gyrosa* (Ellis and Solander), Eudes-Deslongchamps, Encyclopédie Méthodique, vol. 2, p. 508.

1830. *Meandrina gyrosa* (Ellis and Solander), Blainville Dictionnaire des Sciences Naturelles, Zoophytes, vol. 60, p. 323.

1834. *Meandrina gyrosa* (Ellis and Solander), Blainville, Manuel d'Actinologie ou de Zoophytologie, p. 357.

1834. *Manicina gyrosa* (Ellis and Solander), Ehrenberg, K. Akad. Wiss. Berlin, Phys. Abhand. 1832, p. 326. Also *Manicina maeandrites* Ehrenberg, *non* Esper.

1847. *Meandrina gyrosa* (Ellis and Solander), Duchassaing, Soc. Géol. France, Bull., sér. 2, vol. 4, pt. 2, p. 1095.

1848. *Mussa gyrosa* (Ellis and Solander), Dana, U.S. Exploring Exped. 1838-1842, Zoophytes, vol. 7, p. 186.

1848. *Meandrina gyrosa* (Ellis and Solander), Schomburgk, History of Barbados, p. 562.

1848. *Colpophyllia gyrosa* (Ellis and Solander), Edwards and Haime, Acad. Sci. Paris, C. R., vol. 27, p. 492.

1849. *Colpophyllia gyrosa* (Ellis and Solander), Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, pp. 266, 267. [*Fide* Gregory, 1895, p. 267.]

1850. *Meandrina gyrosa* (Ellis and Solander), Duchassaing, Animaux Radiaires des Antilles, p. 16.

1851. *Colpophylla gyrosa* (Ellis and Solander), Edwards and Haime, Mus. Nat. Hist. nat., Paris, Arch., vol. 5, p. 84.

1855. *Meandrina gyrosa* (Ellis and Solander), Duchassaing, Soc. Géol. France, Bull., sér. 2, vol. 12, pp. 754, 756.

1857. *Colpophyllia gyrosa* (Ellis and Solander), Edwards and Haime, Histoire Naturelle des Coralliaires ou Polypes proprement dites, p. 384.

1861. *Colpophyllia gyrosa* (Ellis and Solander), Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 19, p. 349. [*Fide* Vaughan, 1901, p. 41.]

1864. *Colpophyllia gyrosa* (Ellis and Solander), Verrill, Mus. Comp. Zool., Bull., vol. 1, No. 3, p. 49.

1866. *Colpophyllia gyrosa* (Ellis and Solander), Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 23, p. 174.

1870. *Colpophyllia gyrosa* (Ellis and Solander), Duchassaing and Michelotti, Revue des Zoophytes et des Spongiaires des Antilles, p. 29.

1875. ?*Colpophyllia gyrosa* "Edwards and Haime", Pourtalès, *in* Gabb, Geol. Mag., decade 2, vol. 2, p. 545.

1877. ?*Colpophyllia gyrosa* (Ellis and Solander), Lindström, K. Svenska Vetensk.-Akad., Handl., vol. 14, No. 6, p. 22.

1881. ?*Colpophyllia gyrosa* (Ellis and Solander), Quenstedt, Petrefactenkunde Deutschlands, vol. 6, No. 1, p. 1011, pl. 182, fig. 49.

1886. ?*Colpophyllia gyrosa* (Ellis and Solander), Quelch, Voyage H. M. S. Challenger 1873-76, Rept. Sci. Results, Zoology, vol. 6, pt. 46, p. 12.

1890. *Colpophyllia gyrosa* (Ellis and Solander), Ortmann, Zeitschr. f. Wissensch. Zool., Leipzig, vol. 50, p. 305. [*Fide* Gregory, 1895, p. 267.]

1895. *Colpophyllia gyrosa* (Ellis and Solander), Gregory, (*pars*), Geol. Soc. London, Quart. Jour., vol. 51, pp. 266, 267.

1901. *Colpophyllia gyrosa* (Ellis and Solander), Vaughan (*pars*), Rijksmus. Geol. en Mineral. Leiden, Samml., ser. 2, vol. 2, No. 1, pp. 7, 9-11.

1901. *Manicina gyrosa* (Ellis and Solander), Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, Pt. I, art. III, pp. 84, 85.

1902. *Colpophyllia gyrosa* (Ellis and Solander), Vaughan, *in* Spencer, Geol. Soc. London, Quart. Jour., vol. 58, No. 20, p. 349; No. 21, p. 361.

1902. *Colpophyllia gyrosa* (Ellis and Solander), Duerden (*pars*), Nat. Acad. Sci., Washington, Mem., vol. 5, pp. 580, 581, pl. 22, fig. 148.
1912. *Manicina gyrosa* (Ellis and Solander), Vaughan, Carnegie Inst. Washington, Yearbook No. 10 for 1911, p. 154.
1914. *Manicina gyrosa* (Ellis and Solander), Vaughan, Carnegie Inst. Washington, Yearbook No. 13, pp. 224, 225.
1915. *Manicina gyrosa* (Ellis and Solander), Vaughan, Washington Acad. Sci., Jour., vol. 5, p. 596.
1916. *Manicina gyrosa* (Ellis and Solander), Vaughan, Carnegie Inst. Washington, Yearbook No. 14, p. 227.
1919. *Manicina gyrosa* (Ellis and Solander), Vaughan, U.S. Nat. Mus., Bull., vol. 103, No. 9, pp. 225, 232, 255, 422, 423.
1921. *Manicina gyrosa* (Ellis and Solander), Vaughan, Geol. Survey Dominican Republic, Mem., vol. 1, p. 167.
1926. *Colpophyllia gyrosa* (Ellis and Solander), Matthai, Roy. Soc. London, Philos. Trans., ser. B, vol. 214, p. 316, pl. 26, figs. 4, 8.
1928. *Manicina gyrosa* (Ellis and Solander), Matthai, Catalogue of the Madreporarian Corals in the British Museum (Natural History), vol. 7, A Monograph of the Recent meandroid Astraeidae, pp. 91-95, pl. 24, figs. 1-3; pl. 25, fig. 3; pl. 56, fig. 1; pl. 63, fig. 6.
1943. *Meandrina gyrosa* Lamarck, Vaughan and Wells, Geol. Soc. Amer., Spec. Pap., No. 44, p. 171. Also *Madrepora gyrosa* Ellis and Solander.
1948. *Manicina gyrosa* (Ellis and Solander), Smith, Atlantic Reef Corals, p. 87. Also *Manicina mayori* (Wells), pp. 61, 69, 87.
1954. *Manicina gyrosa* (Ellis and Solander), Fontaine, Inst. of Jamaica, Ann. Rept. 1953-1954, p. 25.
1956. *Manicina gyrosa* (Ellis and Solander), Hoffstetter, Lexique Stratigraphique International, vol. 5, Amérique Latine, fasc. 2b, Antilles (Hispaniola), p. 396.
1966. *Colpophyllia gyrosa* (Ellis and Solander), Chevalier, Inst. Français Afrique Noire, Bull., sér. A, vol. 28, No. 4, p. 1400.
1968. *Manicina gyrosa* (Ellis and Solander), Weisbord, Bull. Amer. Paleont., vol. 55, No. 246, pp. 52, 53.

The original description of *Manicina gyrosa* (Ellis and Solander) was as follows:

> 44. Madrepora gyrosa.
>
> Tab. 51
>
> Madrepora *conglomerata, cellulosa, ambulacris duplicatis foliaceis, dissepimentis simplicibus, lamellis foliaceis aequalibus.*
>
> Tab. 51
>
> Seb. Mus. 3. tab. 109. fig. 9, 10.
>
> *Corallium* caeteris laevius, cellulis numerosis cavernosum.

Later descriptions and illustrations by Matthai (1928), Wells (1936), Smith (1948), and Almy and Carrión-Torres (1963) indicate that *Manicina gyrosa* is close to *Manicina areolata* (Ellis and Solander), differing perhaps from the latter in lacking a central stalk, in having a thin rather than prominent epitheca, and in its wide, well-developed groove on the collines.

The corallum of specimen CAL-7a is large, meandroid, and suboblong in outline, the ends not narrowing but blunt. The calicinal surface is convex. The base is flattish or slightly undulatory, without a central stalk and without epitheca; whether the absence of a stalk and of epitheca on the non-calicinal surface is due to the considerable corrosion of the specimen or is natural, I cannot determine.

A number of the larger valleys run normal to the long axis of the corallum, but these are joined or crossed by the other longitudinal or oblique valleys. The valleys are deep and wide, up to 14 mm in depth, and as much as 28 mm across from colline to colline. Generally, the head or upper surface of the corallum resembles that of *Manicina areolata* except that all of the collines of CAL-7a are shallowly grooved or channeled. These channels are not superficial for they persist upward from the base of the corallite, as shown on Plate 39, figure 2. The collines represent the walls of abutting calices; the channels or grooves result from the exsert ends of opposing septa arching over their respective side of the colline and terminating on it. Some of the septa are continuous over the colline but even these are bowed down at the crest of the colline. The collines vary from 1.5 mm to 5 mm in width.

There are generally ten or eleven septa in one centimeter; of these eight or nine are nearly equal in size and extend to the columella, and two are rudimentary and short. However, there is no alternating series of very narrow septa as in *M. areolata,* although like that species the margins of the septa are dentate and the faces spinulose. Also, as in *M. areolata,* the principal septa are raised below into paliform lobes, and so abrupt is the demarcation of the lobes that they are often aligned in a regular shelf above the columella. The columella is continuous, trabecular and narrow, with a fairly constant width of about 1.5 mm. At points where the columella diverges around or crosses that of neighboring calices, sharp angulations are formed, resulting in a pronounced zigzag pattern along the course of the columella.

The costae are narrow, about equal in size, and denticulate. The endothecal dissepiments are membranous, slightly arched, and unequally spaced, with about seven cells in 3 centimeters of length.

Measurements. — Specimen CAL-7a: corallum length 184 mm, width 120 mm, height 75 mm. CAL-7a is the host of the barnacle *Ceratoconcha prefloridana* (Brooks and Ross) and is invaded by numerous boring organisms, among them the pelecypod *Rocellaria hians* (Gmelin).

Locality. — Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County, Florida. Collector Mike Strong, donated 2 December 1969.

Comparison. — This fossil coral (CAL-7a) is so close to the living *Manicina gyrosa* from the Tortugas, Florida, as described and illustrated by Matthai (1928), that it must be considered the same species. According to Smith (1948), *Manicina gyrosa* is synonymous with the later-named *Manicina mayori* (Wells). However, in a letter to me dated 1 December 1972, Wells wrote: "About *Manicina 'mayori'*. I've never been happy about this thing, for it may only be overgrown, outsize *M. areolata.*" References to *Manicina mayori* (Wells) are the following:

1936. *Podasteria mayori* Wells, Amer. Jour. Sci., ser. 5, vol. 31 (231), No. 182, pp. 125, 126.
1948. *Manicina mayori* (Wells), Smith, Atlantic Reef Corals, pp. 61, 69, 87.
1954. *Manicina mayori* (Wells), Smith, U.S. Fish and Wildlife Serv., Fish. Bull., vol. 55, No. 89, p. 293.
1958. *Manicina mayori* (Wells), Zans, Geonotes, vol. 2, No. 1, pp. 28, 35.
1960. *Manicina mayori* (Wells), Brooks and Ross, Crustaceana, vol. 1, pp. 353, 354, pl. 6, fig. 1.
1963. *Manicina areolata* (Linnaeus) var. *Manicina mayori* (Wells), Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 152, 153, pl. XI, b3.
1967. *Manicina areolata forma mayori* (Wells), Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 448.
1968. *Manicina mayori* (Wells), Weisbord, Bull. Amer. Paleont., vol. 55, No. 246, pp. 52, 53.
1970. *Manicina mayori* (Wells), Klose, *in* letter to R. O. Vernon dated 30 April 1970, p. 5.
1972. *Manicina mayori* (Wells), Weisbord, Tulane Studies Geol. Paleont., vol. 10, No. 1, p. 63.

The range of *Manicina mayori,* as reported by the authors listed above, is Pliocene to Recent. The Pliocene form occurs in the Bee Branch Member of the Caloosahatchee Marl (Brooks and Ross). The Pleistocene form occurs in the Miami Oolite in the channel on the north end of Raccoon Key, near Stock Island, Monroe County, Florida (Klose). The Recent form is reported from the Dry Tortugas, Florida; Puerto Rico (Cayo Turrumote on calcareous bottom in 8 ft. of water, by Almy and Carrión-Torres); and Jamaica (depth range between 0.5 meters and 65 meters, by Goreau and Wells).

According to Matthai's diagnosis, *Manicina gyrosa* (Ellis and

Solander) is differentiated from *Manicina areolata* (Ellis and Solander) by 1) the blunt, rather than narrowed ends of the corallum; by 2) its broader and channeled collines; by 3) the absence of alternating series of very narrow septa; by 4) the absence of a central stalk on the base; and, on specimen CAL-7a, by 5) the possible absence of epitheca on the under side (which is so well developed on all specimens of *Manicina areolata* I have seen).

Range and distribution. — In Florida *Manicina gyrosa s.s.* is found in the Pliocene (CAL-7a) and Recent. Imbedded in specimen CAL-7a is the pelecypod *Rocellaria hians* (Gmelin) which also occurs in the Pliocene sand dredged at Pinellas Park, North St. Petersburg, and at Fort Thompson (Pleistocene) on the Caloosahatchee River. *Rocellaria hians* is a later name given for *Gastrochaena cuneiformis* Spengler as used by Olsson and Harbison (1953, p. 151). The barnacle *Ceratoconcha prefloridana* (Brooks and Ross), also imbedded in CAL-7a, occurs in the coral *Manicina mayori* which was collected by Brooks in the Bee Branch Member of the Caloosahatchee Marl. The Recent *Manicina gyrosa* is found only in the Tortugas, according to Matthai.

Elsewhere, Duchassaing (1847) reported *Colpophyllia gyrosa* from the Tuf Blanc (lower Miocene) of Guadeloupe, as did Vaughan *in* Spencer (1902) from the Gravel Series (Plio-Pleistocene of Dominica at an elevation of 165 ft., and from the Pleistocene of Barbados on the terrace one mile north of Bath, at an elevation of about 50 ft. Vaughan (1921) listed *Manicina gyrosa* from the Pleistocene of the Dominican Republic. *Colpophyllia gyrosa* was recorded also by Chevalier (1966, p. 1400) who stated that Cagel "signale la présence, sur une ancienne terrasse marine élevée à + 3 m, de *Colpophyllia gyrosa*, espèce actuelle des Antilles, d'ailleurs inconnue de nos jours sur les côtes d'Afrique." I take it that the marine terrace mentioned by Chevalier, which is in the Selvagem Islands north of the Canaries in the Eastern Atlantic, is Pleistocene in age.

Colpophyllia natans (Müller) Pl. 39, figs. 3, 4

1772. *Madrepora meandrites natans* Houttuyn, Natuurlyke Historie . . . vol. 1, No. 17, p. 124. [*Fide* Bayer, *in* Olivares and Leonard, 1971, p. 53.]
1775. *Madrepora natans* Müller, Carol von Linne . . . Natursystem, vol. 6, pt. 2, p. 681.
1789. *Madrepora natans* Müller, Esper, Die Pflanzenthiere in Abbildungen, vol. 1, pts. 3-4, pp. 140-143; pl. XXIII (1794).

1791. *Madrepora natans* Müller, Gmelin, Systema Naturae, ed. 13, vol. 1, pt. 1, pt. 6, p. 3760.

1807. *Maeandrina gyrosa* Fischer von Waldheim, Museum Demidoff, vol. 3, p. 298. [*Fide* Matthai, 1928, p. 101.]

1834. *Manicina fissa* Ehrenberg, K. Akad. Wiss. Berlin, Phys. Abhandl. 1832, p. 326. [*Fide* Matthai, 1928, p. 101.]

1846. *Manicina fissa* Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, pp. 190, 191.

1848. *Meandrina gyrosa* Edwards and Haime, Acad. Sci. Paris, C. R., vol. 27, p. 492. non *Madrepora gyrosa* Esper, nec *Meandrina gyrosa* Lamarck. [*Fide* Matthai, 1928, p. 101.]

1849. *Colpophyllia gyrosa (?), C. breviserialis, C. fragilis,* and *C. tenuis* Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 11, pp. 266, 267. [*Fide* Matthai, 1928, p. 101.]

1851. *Colpophyllia gyrosa* and *C. fragilis* Edwards and Haime, Mus. Nat. Hist. nat., Paris, Arch., vol. 5, pp. 84, 85.

1857. *Colpophyllia gyrosa, C. fragilis, C. tenuis,* and *(?) C. breviserialis* Edwards and Haime, Histoire Naturelle des Coralliaires ou de Polypes propremant dits, vol. 2, pp. 384, 385.

1861. *Colpophyllia astreaeformis* Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 19, p. 349. [*Fide* Matthai, 1928, p. 101.]

1866. *Colpophyllia gyrosa, C. fragilis, C. tenuis, C. astreaeformis,* and *Leptoria fragilis* Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 23, pp. 174, 176.

1871. *Colpophyllia gyrosa* Pourtalès, Mus. Comp. Zool., Mem., vol. 2, No. 4, p. 74.

1880. *Colpophyllia gyrosa* Pourtalès, Mus. Comp. Zool., Mem., vol. 7, No. 1, pl. 8, figs. 1-5; pl. 9, figs. 13-16.

1890. *Colpophyllia gyrosa* Ortmann, Zeitschr. f. Wiss. Zool., Leipzig, vol. 50, pt. 2, p. 305.

1895. *Colpophyllia gyrosa* Gregory, *pars,* Geol. Soc. London, Quart. Jour., vol. 51, p. 267.

1901. *Colpophyllia gyrosa* Vaughan, Rijksmus. Geol. en Mineral. Leiden, Samml., ser. 2, vol. 2, No. 1, pp. 41-45.

1928. *Colpophyllia natans* (Müller), Matthai, Catalogue of the Madreporarian Corals of the British Museum (Natural History), vol. 6, pp. 15, 101-108, pl. 26, figs. 2, 3; pl. 61, fig. 2; pl. 65, figs. 5, 7; pl. 67, figs. 1, 2; pl. 71, figs. 8b, 9; pl. 72, fig. 7b.

1944. *Colpophyllia natans* (Müller), Wells, Jour. Paleont., vol. 18, No. 5, p. 446.

1948. *Colpophyllia natans* (Muller), Smith, Atlantic Reef Corals, pp. 61, 69, 86, pl. 18.

1954. *Colpophyllia natans* (Muller), Fontaine, Inst. of Jamaica, Ann. Rept. 1953-1954, p. 24.

1954. *Colpophyllia natans* (Muller), Smith, U.S. Fish and Wildlife Serv., Fish. Bull., vol. 55, No. 89, p. 293.

1956. *Colpophyllia natans* (Müller), Wells, Treatise on Invertebrate Paleontology, Pt. F, Coelenterata, p. F403.

1958. *Colpophyllia natans* (Muller), Zans, Geol. Survey Dept. Jamaica, W.I., Bull. No. 3, p. 32.

1958. *Colpophyllia natans* (Muller), Zans, Geonotes, vol. 1, No. 2, p. 23.

1959. *Colpophyllia natans* (Muller), Zans, Geonotes, vol. 2, No. 1, pp. 29, 33.

1959. *Colpophyllia natans* (Muller), Goreau, Ecology, vol. 40, No. 1, pp. 70, 76, 79, 85.

1959. *Colpophyllia natans* (Muller), T. F. Goreau and N. I. Goreau, Biol. Bull., vol. 17, No. 2, pp. 239, 242, 243, 248, 249.

1960. *Colpophyllia natans* (Muller), Lewis, Barbados Mus. and Nat. Hist. Soc., Jour., vol. 28, No. 1, p. 11.

1960. *Colpophyllia natans* (Muller), Lewis, Canadian Jour. Zool., vol. 33, No. 6, pp. 1134, 1137, 1138, 1140, 1142.
1961. *Colpophyllia natans* (Muller), Westermann and Kiel, Natuurwetensch. Studiekring Suriname en de Nederlandse Antillen, No. 24, p. 136.
1961. *Colpophyllia natans* (Muller), Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 9, 26, 27, figs. 15, 16.
1962. *Colpophyllia natans* (Muller), Stoddart, Atoll Res. Bull., No. 81, pp. 17, 19, 28.
1962. *Colpophyllia natans* (Muller,) Kornicker and Squires, Limnology and Oceanography, vol. 7, No. 4, pp. 447-449, table 1.
1963. *Colpophyllia natans* (Muller), Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 142, 153, pl. XIIb.
1964. *Colpophyllia natans* (Muller), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 20, No. 81, pp. 11, 22-30, 32, 35, 44, 47, fig. 15-6.
1964. *Colpophyllia natans* (Muller), Rivero, Geos [Venezuela], No. 11, p. 113.
1967. *Colpophyllia natans* (Muller), Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 448.
1967. *Colpophyllia natans* (Muller), Roos, Growth and Occurrence of the Reef Coral *Porites astreoides* Lamarck, pp. 10, 12.
1970. *Colpophyllia natans* (Muller), Klose, *in* letter to R. O. Vernon 30 April 1970, pp. 2, 4, 6.
1971. *Colpophyllia natans* (Houttuyn), Olivares and Leonard, Inst. Oceanogr. Univ. Oriente, Bol., vol. 10, No. 1, pp. 52, 53, pl. II, figs. A, B.
1971. *Colpophyllia natans* (Muller), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 4, 18, 19, 20, 22, 23, 25-32, 34, 36, 38, 39, 73, 94, 100, pl. XXXIIIa, b, text-figs. 8-6, 34.
1971. *Colpophyllia natans* (Muller), Olivares, Inst. Oceanogr. Univ. Oriente, Bol., vol. 10, No. 2, pp. 73, 74, table 1.
1972. *Colpophyllia natans* (Muller), Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 548, 553, 556, 578, pl. 7L.

The following description of the Recent *Colpophyllia natans* is taken from Matthai (1928, pp. 102, 104) and Smith (1948, p. 86).

The corallum is large, massive, and light in weight. The calicinal surface is slightly to very convex, and the non-calicinal surface converges toward the base which is not stalked. The valleys are sinuous, usually continuous, sometimes discontinuous, their width 15 mm to 20 mm up to 30 mm to 40 mm at the edges of the colony; the average depth of the valleys is 10 mm to 12 mm but may be up to 18 mm, the depth beween centers reduced to 8 mm or 9 mm owing to vesicular deposition. The walls are grooved.

There are usually eight or nine septa in one centimeter, of which five or six extend to the columella. The upper two-thirds of the principal septa usually slope down to lower one-third where they curve inward toward the columella center. The lower part of the principal septa is sometimes differentiated from the upper part by a notch and simulates a paliform lobe; there are 16 to 18 principal septa around each columellar center. The margins of the septa are finely dentate and the sides are provided with horizontal ridges, those of opposite sides facing each other, a pair of such ridges terminating in a septal tooth. The columella is rudimentary or absent, the centers represented by principal septa curving inward and about 10 mm apart. Adjacent columellar centers are sometimes connected by a thin-toothed lamella of septal origin. The costae are narrow and thin and converge toward the center of the non-calicinal surface.

Measurements. — Esper's figured specimen, illustrated by Matthai (1928, pl. 67, figs. 1, 2) is 65 mm in height and 125 mm × 105 mm in diameter.

Remarks. — This species is one of the lightweight "floating corals" discussed by Kornicker and Squires (1962), a condition resulting from the entrapment of air in the vesicles.

Localities. — The Florida localities of the Pleistocene *Colpophyllia natans* given by Klose (1970) are Key West, Stock Island, and Key Largo, Monroe County.

Range and distribution. — The reported geographic range of *Colpophyllia natans* is from Bermuda to Venezuela; the geologic range is Pleistocene to Recent.

Pleistocene — Florida (Key Largo Limestone/Miami Oolite dredged off Fort Taylor, Stock Island, and alongside Card Sound Bridge on Key Largo); St. Kitts (Brimstone Hill).

Recent — Bermuda; Florida (Tortugas at Bush Key and Long Key); Texas (Padre, Mustang, and St. Joseph Islands); British Honduras (Rendezvous Cay and Glover's Reef); Pedro Bank; Jamaica (Ocho Rios; 0.5 m to 55 m); St. Thomas; Montserrat (33 m to 40 m); Barbados (off west coast 15 m to 24 m); Netherlands Antilles: Aruba (Boca Catalina-Malmok, Barcadera, Mangel Altu). Curaçao (Westpuntbaai, Plaja Kalki, Plaja Abao, Portomaribaai, Daaibooibaai, Vaarsenbaai, Piscaderabaai, Spaanse Water, Klein Curaçao, St. Martha Baai, St. Michiels Baai). Bonaire (Boca Bartól, Plaja Frans, Goto, Jan Doran-Barcadera, Ruin, Hato, Klein Bonaire, Plaja Sarna, Baca). St. Martin (Baie Rouge, Point Blanche Bay). Saba (Cove Bay). St. Eustatius (Cocoluth Bay-Jenkins Bay-Tumbledown Dick Bay, Oranjestad Baai, Gallows Bay). Venezuela (Puerto La Cruz, Edo. Anzoategui; Bahía de Mochima, Edo. Sucre at Ensenada Cabruta Blanca, E. San Agustin, E. El Inglés, E. Carenero, E. de Punta León, E. Cabruta Roja, E. Aceites, E. Garrapata, E. El Muerto, E. El Aguirre, E. Burgao, E. Botella, Morro de la Garrapata, Barranca de Mochima, Punta San Agustin, Punta Aceite de Palo, Punta Toporo, Punta y Playa Piedra, Costica Mano E'Piedra, Lance Manguillas; Golfo de Cariaco, Zonas B, D, I.

Cladocora arbuscula (Lesueur) Pl. 40, figs. 1, 2

1820. *Caryophyllia arbuscula* Lesueur, Mus. Nat. Hist. nat., Paris, Mém., vol. 6, p. 275, pl. 15, fig. 2

1820. *Caryophyllia solitaria* Lesueur, Mus. Nat. Hist. nat., Paris, Mém., vol. 6, p. 273, pl. 15, fig. 4. [*Fide* Edwards and Haime, 1849, p. 307.]

1824. *Caryophyllia solitaria* Lesueur, Lamouroux, Encyclopédie Méthodique, vol. 2, p. 171.

1834. *Caryophyllia solitaria* Lesueur, Blainville, Manuel d'Actinologie ou de Zoophytologie, p. 384.

1834. *Cladocora cespitosa* var. *B* ?; *C. microstoma,* p. 310; and *C. candelabrum,* p. 311, Ehrenberg, K. Akad. Wiss. Berlin, Phys. Abhandl. 1832, pp. 310, 311.

1836. *Caryophyllia arbuscula* Lesueur, Lamarck, Hist. Nat. Anim. sans Vert, ed. 2, vol. 2, p. 354.

1846. *Caryophyllia arbuscula* Lesueur, Dana, U.S. Exploring Expedition 1838-1842, vol. 7, Zoophytes, p. 281, fig. 24.

1849. *Cladocora arbuscula* (Lesueur), Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 11, p. 307.

1850. *Caryophyllia arbusculum* Lesueur, Duchassaing, Animaux Radiaires des Antilles, p. 15.

1857. *Cladocora arbuscula* (Lesueur), Edwards and Haime, Historie Naturelle des Coralliaires ou Polypes proprement dits, vol. 2, p. 595.

1861. *Cladocora unipedalis* Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 19, p. 355, pl. 10, fig. 5, 6. [*Fide* Vaughan, 1902, p. 298.]

1861. *Cladocora arbuscula* (Lesueur), Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 19, pp. 354, 355.

1864. *Cladocora arbuscula* (Lesueur), Verrill, Mus. Comp. Zool., Bull., vol. 1, No. 3, p. 47.

1866. *Cladocora arbuscula* (Lesueur), Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 23, p. 184.

1866. *Cladocora parvistella* Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 23, p. 185, pl. 10, figs. 1, 2. [*Fide* Vaughan, 1902, p. 298.]

1870. *Cladocora arbuscula* (Lesueur), Duchassaing, Revue des Zoophytes et des Spongiaires des Antilles, p. 31.

1871. *Cladocora arbuscula* (Lesueur), Pourtalès, Mus. Comp. Zool., Mem., vol. 2, No. 4, p. 30.

1877. *Cladocora arbuscula* (Lesueur), Lindström, K. Svenska Vetensk.-Akad., Handl., vol. 14, No. 6, p. 23.

1880. *Cladocora arbuscula* (Milne-Edwards and Haime), Agassiz and Pourtalès, Mus. Comp. Zool., Mem., vol. 7, No. 1, pl. 3, figs. 1-7.

1881. *Cladocora arbuscula* (Milne-Edwards and Haime), Moseley, Voyage H.M.S. Challenger, Rept. Sci. Results, Zoology, vol. 2, pt. 7, p. 184 (*pars*?)

1886. *Cladocora arbuscula* (Lesueur), Quelch, Voyage H.M.S. Challenger, Rept. Sci. Results, Zoology, vol. 16, pt. 46, pp. 11, 12, 13, 70.

1890. *Cladocora arbuscula* (Lesueur), Heilprin, Acad. Nat. Sci., Philadelphia, Proc., vol. 42, p. 308.
1901. *Cladocora arbuscula* (Edwards and Haime), Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, Pt. I, art. IV, p. 182.
1902. *Cladocora arbuscula* (Lesueur), Duerden, Nat. Acad. Sci., Washington, Mem., vol. 8, pp. 501, 502, 558-563, pl. 6, figs. 47-52; pl. 7, figs. 53-58; pl. 8, figs. 59-63.
1902. *Cladocora arbuscula* (Lesueur), Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, pt. 2, 298, pl. 2, figs. 3, 3a.
1907. *Cladocora arbuscula* (Lesueur), Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 12, art. II, pt. 5, p. 209.
1913. *Cladocora arbuscula* (Lesueur), Brown and Pilsbry, Acad. Nat. Sci., Philadelphia, Proc., vol. 65, p. 497.
1919. *Cladocora arbuscula* (Lesueur), Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 225, 228, 362.
1919. *Cladocora arbuscula* (Lesueur), Felix, Fossilium Catalogus I: Animalia, pars 44, p. 548.
1943. *Cladocora arbuscula* (Lesueur), Vaughan and Wells, Geol. Soc. Amer., Spec. Pap., No. 44, p. 321, pl. 29, fig. 4.
1948. *Cladocora arbuscula* (Lesueur), Smith, Atlantic Reef Corals, pp. 61, 66, 87, 88, 111, pl. 22.
1954. *Cladocora arbuscula* (Lesueur), Smith, U.S. Fish and Wildlife Serv., Fish. Bull., vol. 55, No. 89, p. 293.
1956. *Cladocora arbuscula* (Lesueur), Wells, Treatise on Invertebrate Paleontology, Pt. F (Coelenterata), p. F404, fig. 302, 1a, 1b.
1956. *Cladocora arbuscula* (Lesueur), Menzel, Oceanograph. Inst. Florida State Univ., Contrib., No. 61, p. 2.
1959. *Cladocora (Cladocora) arbuscula* (Lesueur), Zans, Geonotes, vol. 2, No. 1, pp. 29, 35.
1959. *Cladocora arbuscula* (Lesueur), Goreau, Biol. Bull. Woods Hole, vol. 116, No. 1, pp. 64, 67, 69.
1959. *Cladocora arbuscula* (Lesueur), Goreau, Ecology, vol. 40, No. 1, pp. 70, 75, 81, 85.
1961. *Cladocora arbuscula* (Lesueur), Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 9, 24, 25, figs. 13, 14.
1962. *Cladocora arbuscula* (Lesueur), Stoddart, Atoll Res. Bull., No. 87, pp. 17, 19.
1963. *Cladocora arbuscula* (Lesueur), Jones, Bull. Marine Sci Gulf and Caribbean, vol. 13, No. 2, p. 284.
1963. *Cladocora arbuscula* (Lesueur), Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 153, 154, pl. 12a.
1964. *Cladocora arbuscula* (Lesueur), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 20, No. 81, p. 47.
1967. *Cladocora arbuscula* (Lesueur), Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 448.
1969. *Cladocora arbuscula* (Lesueur), Stoddart, Biol. Rev., vol. 44, p. 458.
1971. *Cladocora arbuscula* (Lesueur), Olivares, Inst. Oceanogr. Univ. Oriente, Bol., vol. 10, No. 2, pp. 73, 74, 75, table 1, pl. I, figs. A, B.
1971. *Cladocora arbuscula* (Lesueur), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 4, 65, pls. 22a, 22b.

The following description of *Cladocora arbuscula* pertains to specimen SB-3a from South Bay, Florida.

The corallum is phaceloid and the corallites are branching. The main branches are 2.7 mm to 5 mm in height, 3 mm to 4 mm in diameter at the middle, and flare out somewhat at the margin of the calice. The calices are funnel-shaped, varying from 2.8 mm to 4.5 mm in diameter, and with a depth of up to 4.5 mm. Smaller extratentacular buds project from the main branches a little below the calicular margin.

Usually there are 36 septa in four cycles, the fourth cycle half complete. The septa are exsert and lobate at the calicular margin, serrate or dentate along the steeply sloping free margin, and spinulose on the sides. The primary septa are slightly larger than the secondaries, the secondaries a little larger than the tertiaries, and the quaternaries the smallest and least developed. Deep within the calice the quaternaries unite with tertiary septa. Drusy paliform lobes are present at the inner ends of the principal septa and merge with the small papillose columella.

The costae are conterminous with the septa and are nearly equal to alternating in size, unlike the septa which are differentiated into four size-groupings. The costae are relatively large and coarse, granulate on the surface, and continuous from the calicular margin down the sides of the corallite and on to the spaces between the corallites where they join and become confluent with the costae of neighboring branches.

Measurements.—Specimen SB-3a: corallum length 24.5 mm, width 17.2 mm, height 22 mm. CPT-1a: length 33.5 mm, width 28.5 mm, height 25 mm.

Locality.—Pit at South Bay water plant, South Bay, Palm Beach County, Florida. Collected by Joseph E. Banks in Unit A (Glades) of Olsson, Plio-Pleistocene (SB-3a).

Comparison.—This species is distinguished from *Cladocora johnsoni* Gane by its much deeper funnel-shaped calices and more numerous septa (normally 36 for *C. arbuscula* compared with 24 for *C. johnsoni*).

Range and distribution.—The geologic range of *Cladocora arbuscula* is recorded in the literature as Pleistocene to Recent. The living *C. arbuscula* ranges from Florida south to Curaçao in the Netherlands Antilles, and Venezuela.

The only Pleistocene occurrence (other than in the Plio-Pleistocene at South Bay, Florida) is in the Isthmus of Panama, in oyster shell layers from Black Swamp near Mt. Hope (Monkey Hill).

In Florida, the Recent *C. arbuscula* has been found at the following localities: Tortugas; Apalachee Bay; 10 miles southeast of St. Marks lighthouse in 10-12 ft. of water, collected by Lyman D. Toulmin; 20 miles south of St. Marks in 48 ft. of water, gift of C. P. Townsend, 19 May 1968; 40 miles southeast of St. Marks lighthouse, in 30 ft. of water, collected by Lyman D. Toulmin; 3-4 miles southwest of Longboat Key, Manatee County, in 5-6 fathoms; southeast Florida on patch reefs in 13 fathoms.

Other Recent occurrences are recorded from the Bahama Islands; Jamaica (0.5 m to 15 m; Ocho Rios); Mexico (off Vera Cruz); British Honduras (Rendevous Cay); Cuba; Puerto Rico (off Parguera in 70 ft. of water); St. Thomas; St. Bartholomew; St. Kitts (Frigate Bay); Guadeloupe; Curaçao; Klein Curaçao ?; Bonaire ?; Venezuela (Golfo de Cariaco, Zona I).

Cladocora johnsoni Gane Pl. 40, figs. 3, 4

1895. *Cladocora johnsoni* Gane, Johns Hopkins Univ. Circ., vol. 15, No. 121, p. 10.
1900. *Cladocora johnsoni* Gane, U.S. Nat. Mus., Proc., vol. 22, No. 1193, pp. 192, 197, pl. 15, figs. 10-12.
1919. *Cladocora johnsoni* Gane, Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, p. 222.
1929. *Cladocora Johnsoni* Gane, Felix, Fossilium Catalogus I: Animalia, pars 44, p. 549.

Gane's original description in 1900 was as follows:

> Corallites slender, somewhat flexuous, and cylindrical. When found fossil they are detached from the parent colony. Walls of moderate thickness. Costate granular, well developed, and close set; those corresponding in position to the septa of the first and second cycles of the same size, and larger than those corresponding the members of the third and fourth cycles. With the exception of a few costae of the fourth cycle, all reach to the base of the corallite. Calices circular *with a shallow fossa.* There are six systems of three complete cycles, with occasionally a few rudimentary septa of an incompleted order of a fourth cycle. Septa exsert, the primaries more prominently so, rounded and very finely granulated laterally, giving the laminae a slightly striated appearance; primaries thicker and broader then secondaries, which, in turn, have a similar relation to the tertiaries. In sections of a corallite below the calice, the septa of the third cycle approach and midway between the theca and columella unite with those of the preceding cycle. Either true pali or paliform lobes are present before all but the last cycle of septa. Columella coarsely papillary but rather narrow. Gemmation lateral and often in pairs at the same height on the stem.
>
> The nearest related form to this Pliocene coral seems to be the *Cladocora debilis* Edwards and Haime, Recent at Madeira, but owing

> to its meager descriptions the writer can not speak definitely on this point, as he has not had an opportunity of examining specimens of the species.
>
> The present form is named after Mr. Charles W. Johnson, of Philadelphia, who has added so much to our knowledge of the Neocene paleontology of the South.
>
> *Dimensions.* — Height of the largest specimen, 12 mm.; breadth of calice, from 2 to 2.8.
>
> *Geological horizon.* — Pliocene.
>
> *Locality.* — Waccamaw River, South Carolina.
>
> *Collections.* — Wagner Free Institute of Science (type), Johns Hopkins University. The type specimens were collected by Mr. C. W. Johnson.

There are three broken and somewhat corroded specimens in the collection of the National Musum of Natural History from Locality 3300, labeled (in Vaughan's handwriting ?) "*Cladocora johnsoni* Gane, Pliocene, Shell Creek, Fla., Burns." These Shell Creek coralla are relatively slender branches from which project smaller buds. The main branches are subcircular in cross section, 3 mm to 4 mm in diameter and 8.5 mm to 11.5 mm in height. The calices are more or less circular, varying from as little as 1.7 mm in diameter on buds to as much as 3.7 mm on the axis of the branch. The true depth of the calices is not ascertainable but is presumed to be fairly shallow.

The normal number of cycles seems to be three, with 24 septa in calices 2.4 mm to 2.8 mm in diameter; however, there are 22 septa in a calice 1.7 mm in diameter, and as many as 34 in an axial calice 3.7 mm in diameter. The septa seem originally to have been a little exsert and are decreasingly smaller according to the order of insertion: the primary septa are the largest, the secondaries somewhat smaller but larger than the tertiaries, and if present, the quaternaries which are the smallest and least developed. In some truncated calices, minor septa are seen curving into and joining the next larger to produce a three-pronged candelabra effect. The principal septa extend to the columella, and in one calice, at least, seem to be paliform. The septa are dentate along the free margin and finely spinulose on the sides.

The costae are coarse, rugged, subequal and granulose; a number of them on the upper half of the corallite are divided along the middle by a fine superficial suture, produced I think, by surface weathering. The costae continue down the sides of the corallite to the base where they become confluent with the costae of neighboring corallites.

The columella where preserved is seen to be papillate.

Measurements. — Specimen USNM 3300 (a): single branch height 8.5 mm, diameter at middle 3 mm. Specimen USNM 3300 (b): branching corallum height 9 mm, maximum width 8.5 mm. Specimen USNM 3300 (c): branch with buds, height 11.5 mm, maximum width 6 mm.

Locality. — Shell Creek, Charlotte County, Florida. Collector: Frank Burns.

Comparison. — In referring the Shell Creek examples to *Cladocora johnsoni*, I am assuming that the calices are shallow. This character, which was stressed by Gane as a distinguishing one, cannot be ascertained on the specimens available for study.

Range and distribution. — Pliocene in Waccamaw River of South Caroline, and Pliocene (Caloosahatchee Marl) in Shell Creek, Florida.

Montastrea annularis (Ellis and Solander) **Pl. 41, fig. 1**

1786. *Madrepora annularis* Ellis and Solander, The Natural History of . . . Zoophytes, p. 169, pl. 53, figs. 1, 2.

1816. *Astrea annularis* (Ellis and Solander), Lamarck, Hist. Nat. Anim. sans Vert., vol. 2, p. 259.

1821. *Astrea annularis* (Ellis and Solander), Lamouroux, Exposition Méthodique des . . . Polypiers, p. 58, pl. 53, figs. 1, 2.

1827. *Astrea annularis* (Ellis and Solander), Bory de St. Vincent, Encyclopédie Méthodique, pt. 2, pl. 486, figs. 1, 2.

1846. *Astrea (Orbicella) annularis* (Ellis and Solander), Dana, U.S. Exporing Exped. 1832-1842, vol. 7, Zoophytes, p. 214, pl. 10, fig. 6.

1880. *Orbicella annularis* Dana, Pourtalès, Mus. Comp. Zool., Mem., vol. 7, No. 1, pl. 4, figs. 1-10.

1890. *Orbicella annularis* (Ellis and Solander), A. Agassiz, Mus. Comp. Zool., Bull., vol. 20, No. 2, p. 61, pls. 1, 2.

1900. *Orbicella annularis* Dana, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 10, art. XIV, pp. 552, 553.

1901. *Orbicella annularis* (Ellis and Solander), Dana, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, Pt. I, art. III, pp. 94-96, pl. 15, fig. 1.

1902. *Orbicella acropora* (Linnaeus) var. Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, pt. 2, pp. 301, 302, pls. 6, 7.

1906. *Orbicella annularis* Dana, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 12, art. II, pt. 5, p. 233, fig. 86.

1919. *Orbicella annularis* (Ellis and Solander), Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 214, 215, 223, 228, 253-256, 362-376, 380, 396, 398, 400, 420, 510, pl. 80, figs. 7, 7a, 7b; pl. 81, figs. 1, 2; pl. 82, figs. 1, 2; pl. 83, figs. 1, 2, 3, 3a; pl. 84, figs. 1, 2, 3, 3a.

1920. *Orbicella annularis* (Ellis and Solander), Coryell and Ohlsen, New York Acad. Sci., Scientific Survey of Porto Rico and the Virgin Islands, vol. 3, pt. 1, pp. 194, 195, pl. 28, fig. 2.

1921. *Orbicella annularis* (Ellis and Solander), Vaughan, Geol. Survey Dominican Republic, Mem., vol. 1, pp. 152, 157, 167.
1924. *Orbicella annularis* (Ellis and Solander), Vaughan, *in* Woodring, Geol. Survey Republic of Haiti, pp. 217, 225, 243.
1939. *Orbicella annularis* (Ellis and Solander), Butsch, Barbados Mus. and Nat. Hist. Soc., Jour., vol. 6, No. 3, pp. 136, 137, pl. 1, fig. 6.
1943. *Montastrea annularis* (Ellis and Solander), Vaughan and Wells, Geol. Soc. Amer., Spec. Pap., No. 44, p. 321, pl. 29, fig. 5.
1948. *Montastrea annularis* (Ellis and Solander), Smith, Atlantic Reef Corals, pp. 61, 72, 89, 90, pls. 25, 26.
1955. *Montastrea annularis* (Ellis and Solander), G. Voss and N. Voss, Bull. Marine Sci. Gulf and Caribbean, vol. 5, No. 3, p. 224.
1958. *Montastrea annularis* (Ellis and Solander), Bonet, Asoc. Mexicana Géol. Petrol., Bol., vol. 10, Nos. 9-10, pp. 565, 567-570.
1958. *Montastrea annularis* (Ellis and Solander), Squires, Amer. Mus. Nat. Hist., Bull., vol. 115, art. 4, pp. 227-229, 232, 237, 238, 256, pl. 40, fig. 3; pl. 41, figs. 1, 2.
1959. *Montastrea annularis* (Ellis and Solander), Kornicker, Bonet, Cann, and Hoskin, Inst. Marine Sci. Univ. Texas, Publ., vol. 6, pp. 17, 19.
1959. *Montastrea annularis* (Ellis and Solander), T. F. Goreau and N. I. Goreau, Biol. Bull., vol. 117, No. 2, pp. 246, 248, 249.
1959. *Montastrea annularis* (Ellis and Solander), Goreau, Ecology, vol. 40, No. 1, pp. 70, 73-76, 79, 81, 85, figs. 4, 5, 7, 9, 12, 13, 15, 17.
1960. *Montastrea annularis* (Ellis and Solander), T. F. Goreau and N. I. Goreau, Biol. Bull., vol. 119, No. 3, p. 421.
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The original description of Ellis and Solander's *Madrepora annularis* was as follows:

> 69. Madrepora annularis.
>
> Tab. 53.
> Fig. 1, 2.
>
> Madrepora *aggregata, stellis teretibus aequalibus margine elevatis, interstitiis plano-concavis radiatis.*

The Pleistocene specimen (I-641b) described and illustrated herein is re-deposited with, or recrystallized by calcium carbonate.

The corallum, which is part of an originally large specimen, is tabular, and has a flat upper surface. The corallites are long, slender, and cylindrical. The calices are subcircular and have a starry appearance by virtue of the prominence of the principal septa on the calicular margin, which is thickened and raised. The diameter of the calices from summit to summit ranges from 2.3 mm to 3.9 mm, and their depth is 1 mm to 3 mm. The septa occur in three complete or nearly complete cycles, the primaries the largest, the secondaries a little smaller but also extending to the columella, and the tertiaries the smallest with their inner edges free. The principal septa are a little exsert at the calicular margin, the secondaries less so. The septal margins are dentate, the faces finely granulate. The costae are conterminous with the septa but are thicker and subequal, the larger alternating with the somewhat smaller, and meeting those of adjoining calices in the space between them. The crests of the costae are granulose. The columella is everywhere so calcified that the details cannot be made out, although it is inferred to be developed from the interlacing septal processes.

Measurements. — Specimen I-641b: corallum length 68.5 mm, width 57 mm, thickness 26 mm.

Locality. — Upper Matecumbe Key, Monroe County, Florida. Pleistocene. Collected by H. Gunter and J. H. C. Martens, Nov. 1927.

Range and distribution. — The recorded geographic range of *Montastrea annularis* is from Bermuda to Brazil; the geologic range is Oligo-Miocene to Recent.

Oligo-Miocene — Puerto Rico (Ponce Limestone).

Miocene (lower) — Puerto Rico (Quebradillas Limestone); Florida (Tampa Formation).

Miocene (upper) — Dominican Republic (Mao Adentro Limestone and Yaqui Group); Haiti (Arrondissemant Mirebalais ?; Arrondissement Léogane).

Pliocene — Mexico (Quintana Roo); Costa Rica (Limon); Haiti (west slope of Tapion du Petit-Goave).

Pleistocene — Florida (Key Largo Limestone/Miami Oolite Key West, Stock Island, Key Vaca, Big Pine Key, Upper Matecumbe Key, Key Largo; Port Everglades); Mexico (Quintana Roo); St. Eustatius; St. Kitts; Montserrat; Dominican Republic (Provinces of Macoris, Sto. Domingo, and Barahona); Barbados at the following elevations: 1043 ft. Hart Hill, St. Joseph Parish; 845 ft. Parris Hill, St. Joseph Parish; 747 ft. Market Hill, St. George Parish; 720 ft. Russia Gully, St. Thomas Parish; 707 ft. Haynesfield, St. John Parish; 480 ft. Locust Hill, St. George; 360 ft. Small Ridge, Christchurch; 300 ft. Skeens Hill, Christchurch and Codrington Quarry, St. Michael; 80 ft. Prospect, St. James; 70 ft. Grazettes, St. Michael; 40 ft. Sandy Lane, St. James.

Recent — Bermuda (North Rock; Ledge Flats; North Lagoon); Bahamas (Great Bahama Bank; Abaco Island; Coconut Point; Hogg Island); Florida (Tortugas; Key West; Big Pine and Newfound Harbor Keys; Ft. Taylor; Loggerhead Key; Hawk Channel; Margot Fish Shoal; Tavernier; Virginia Key; Biscayne Bay); Cuba; Mexico (Blanquilla Reef, Alacran Reef, Isla de Lobos, Yucatan Shelf off Progreso); British Honduras (Rendezvous Cay, Turneffe, Lighthouse Reef, Glover's Reef); Panama ?; Pedro Bank; Jamaica (Ocho Rios; 0.3 m - 80 m); Puerto Rico (La Parguera, Guanica, Ensenada, Mayagüez); St. Lucia; St. Thomas (22 m - 39 m); Guadeloupe (26 m - 34 m); Barbados (west coast, 15 m - 24 m); Netherlands Antilles: Curaçao (Playa Kalki, 1.5 m - 10 m; Westpuntbaai, along shore; Playa Abao, shore to 8 m.; Playa Chikitu, in shallow water with sandy bottom; Sta. Martha Baai, 15 m - 45 m); Portomaribaai, shore to 8 m; Vaarsenbaai, shore to 8 m; St. Michiels Baai, shore to 15 m; Kaap Malmeeuw, 20 m; Piscaderabaai, 3 m - 35 m; Spaanse Water, shore to 30 m; Klein Curaçao 4 m - 6 m; Caracasbaai). Bonaire (Plaja Frans, Goto, Jan Doran, Barcadera, Lont, Hato, Klein Bonaire, Plaja Sarna, Baca, Punt Vierkant, Blauwe Pan, Witte Pan, Oranje Pan, Lac). St. Martin (Mullet Pond Bay, Simson Bay, Cay Bay, Little Bay, Great Bay, Point Blanche Bay, Gibb's Bay, Babit Point). Saba (Ladder Bay, Fort Bay, Cove Bay). St. Eustatius (Cocoluch Bay, Jenkins Bay, Tumbledown Dick Bay, Compagnie Baai). Aruba (Arashi-Boca Catalina, Malmok, Eagle Beach, Palm Beach, Barcadera, Mangel Altu, St. Nicolaasbaai, Klein Lagoen, north of Pitch Field). Venezuela (Puerto La Cruz; Bahía de Mochima, Edo. Sucre at Playa Blanca de Guaiguá, Ensenada San Agustin, E. Piedra Pelona, E. Burgao, E. Carenero, Ensenada Mangle Quemao, Ensenada Cabruta Roja, Ensenada Cabruta Blanca, Ensenada de Punta León, Ensenada Los Aceites, Ensenada Garrapata, Lance Manguillas, Ensenada El Muerto, Ensenada El Aguirre, Morro de la Garrapata, Ensenada El Inglés, Punta Botella, Punta San Agustin, P. de León, P. Mero Mañoso, P. Hoporo, Ensenada Botella). Brazil (Bahía de Camamú).

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1971. *Montastrea cavernosa* (Linné), Olivares, Inst. Oceanogr. Univ. Oriente, Bol., vol. 2, No. 2, pp. 73-75, table 1.
1972. *Montastrea cavernosa* (Linnaeus), Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 548, 554, 570, 571, 578, fig. 10, pl. 7K.
1972. *Montastrea cavernosa* (Linnaeus), Macintyre, Amer. Assoc. Petrol Geol., Bull., vol. 56, No. 4, pp. 730-732.
1972. *Montastrea cavernosa* (Linnaeus), Scoffin, Science, vol. 178, No. 4067, p. 1280.

In Florida, the fossil *Montastrea cavernosa* is often recrystallized by calcium carbonate as shown in specimen I-641 figured herein. The specimen is broken and imperfect but it does display the internal character of the corallites, and in places, the outer rim of the calices. The corallum is massive and plocoid, the corallites long and cyclindrical. The calices are subcircular, large, relatively deep, and more or less elevated, their greater diameter 8 mm to 11 mm. There are four cycles of septa, alternating in the order of their insertion. The septa are narrow, serrulate along the margins, and smoothish on the sides. The costae, which are conterminous with the septa, are well developed coarsely dentate, and subequal in size.

Measurements. — Specimen I-641a, Florida Bureau of Geology: corallum length 62 mm, width 52.5 mm, height 50 mm.

Locality. — Upper Matecumbe Key, Monroe County, Florida. Collected by Herman Gunter and James H. C. Martens, November 1927.

Range and distribution. — *Montastrea cavernosa* (Linnaeus) is a long-ranged and far-flung species, extending from Bermuda to Brazil, and from Oligocene time to the present. In the eastern Atlantic, it is reported living in the Gulf of Guinea off the west coast of Africa.

Oligocene — Puerto Rico (San Sebastian Shale).

Oligo-Miocene — Puerto Rico (Ponce Limestone).

Miocene (lower) — Florida (Tampa Formation; Chipola Formation); Guadeloupe ("Tuf Blanc").

Miocene (upper) — Dominican Republic (Nivaje Shale, Mao Adentro Limestone, Yaque Group).

Pliocene — Mexico (doubtfully identified in the Pliocene of Quintana Roo).

Plio-Pleistocene — Guadeloupe (Formation Madréporique); Dominican Republic (Provincia Monte Cristi); Dominica (Morne Daniel Formation; elevated reefs near Rousseau, 1,000 ft. elevation).

Pleistocene — Bermuda (Devonshire Formation); Florida (Miami Oolite or Key Largo Limestone at Key West; in channel between Stock Island and Cow Key; Upper Matecumbe Key; marl pits alongside Card Sound Bridge; and Port Everglades); Mexico (doubtfully identified in the Pleistocene of Quintana Roo); St. Croix; St. Eustatius (Sugar Loaf); St. Kitts (Brimstone Hill); Guadeloupe; Montserrat (on coast 1,500 yds. northwest of Roche Bluff); Dominican Republic (Provincia Macoris; Barahona); Antigua; Barbados (low level reefs near Bridgetown and Ceres; high land reefs at Spring Estate, St. Andrews; Locust Hill, St. George, 780 ft.; Bissex Hill; Farmer's Shaft No. 3 in nearby gully; Welsh Town Gully, 600 ft.; Mt. Hillaby, 780 ft.; Bath Reef Series north and south of Bath, 150-165 ft.; submerged coral reefs along west coast); Trinidad.

Recent — Bermuda (North Rocks); Florida (Tortugas at Golding Cay, Ft. Jefferson, and Loggerhead Key; Biscayne Bay; Virginia Key; patch reefs along southeast coast, 2-15 fathoms); Bahamas (Rabbit Cay, Turtle Rocks, Abaco Island, Great Bahama Bank); Cuba; Mexico (Isla de Lobos, Alacran, Blanquilla Reef, Yucatan Shelf); Pedro Bank; Jamaica (0.5 m - 90 m.; Ocho Rios; Bluefields Bay); British Honduras (Rendezvous Cay, Turneffe, Lighthouse Reef, Glover's Reef); St. Thomas (22 m - 65 m); St. Bartholomew (36 m - 38 m); Guadeloupe (26 m - 34 m); Anguilla (37 m - 47 m); Antigua; Trinidad; Barbados (along west coast); Netherlands Antilles off the following islands: Aruba (Boca Catalina, Malmok, Barcadera, Mangel Altu). Curaçao (Plaja Kalki, Westpuntbaai, Plaja Abao, Lagun, Chikitu, Portomaribaai, Vaarsenbaai, St. Michiels Baai, Piscaderabaai, St. Martha Baai, Spaanse Water, Klein Curaçao). Bonaire (Boca Bartol, Goto, Barcadera, Ruin, Hato, Klein Bonaire, Plaja Sarna, Baca, Punt Vierkant, Blauwe Pan, Witte Pan). St. Martin (Mullet Pond Bay, Mahó Bay, Simson Bay, Cay Bay, Great Bay, Point Blanche Bay, Guana). Saba (Fort Bay, Cove Bay). St. Eustatius (Cocoluch Bay-Jenkins Bay, Tumbledown Dick Bay, Gallows Bay, Compagnie Baai); Venezuela (Puerto La Cruz, Edo. Anzoátegui; Golfo de Cariaco, Edo. Sucre, Zonas B, F; Bahía de Mochima, Edo. Sucre, at Ensenada Cabruta Blanca, E. Cabruta Roja, E. San Agustin, E. Centeno, E. Piedra Pelona, E. Garrapata, E. Burgao, E. La Ballena, E. Carenero, E. de Punta León, E. Mangle de Quemao, E. Los Aceites, E. El Inglés, E. El Muerto, E. El Aguirre, E. Botella, Punta San Agustin, Punta Aceite de Palo, Punta Botella, Punta de León, Punta Mero Mañoso, Costica Mano E'Piedra, Lance Manguillas, Costa Maringinia); Brazil (Barro Grande, 30 fathoms; Pernambuco; Long. 38°W, Lat. 12°S; Long. 34°49′ W, Lat. 9°7′ S.; Lagôa de Camamú, Bahia).

Solenastrea bournoni Edwards and Haime
Pl. 42, figs. 1-5; Pl. 44, figs. 4, 5

1849. *Solenastrea Bournonii* Milne Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 12, pp. 121, 122.

1861. *Heliastrea abdita* Duchassaing and Michelotti. [*Fide* Felix, 1927, p. 325]; *Cyphastrea oblita, Plesiastrea carpinetti, Solenastrea Ellisii, Solenastrea micans, Leptastrea caribaea* Duchassaing and Michelotti, R.

Accad. Sci. Torino, Mem., ser. 2, vol. 19, pp. 352-354. [*Fide* Vaughan, 1919, p. 398.]

1864. *Plesiastraea distans* Duncan and *P. globosa* Duncan, Geol. Soc. London, Quart. Jour., vol. 20, pp. 37, 38, pl. IV, figs. 4a, 4b, 5. [*Fide* Vaughan, 1919, p. 39.]

1901. *Solenastrea Bournoni* Edwards and Haime, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, Pt. I, art. III, p. 104.

1917. *Solenastrea bournoni* Milne Edwards and Haime, Vaughan, U.S. Geol. Sur., Prof. Paper 98-T, pp. 368, 372, 374, pls. XCIX, C.

1919. *Solenastrea bournoni* Milne Edwards and Haime, Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 219, 222, 223, 225, 230, 374, 377, 387, 398-401.

1921. *Solenastrea bournoni* Milne Edwards and Haime, Vaughan, Geol. Survey Dominican Republic, Mem., vol. 1, pp. 97, 115, 134, 158, 163, 167.

1923. *Solenastrea bournoni* Milne Edwards and Haime, Vaughan, Washington Acad. Sci., Jour., vol. 13, No. 14, p. 312.

1924. *Solenastrea bournoni* Milne-Edwards and Haime, Vaughan, *in* Woodring, Geol. Survey Republic of Haiti, pp. 173, 178, 203, 217, 243, 250.

1927. *Cyphastraea Bournoni* (M. Edwards and Haime), Felix, Fossilium Catalogus I: Animalia, pars 35, pp. 325, 326.

1929. *Cyphastraea Bournoni* (M. Edwards and Haime), Felix, Fossilium Catalogus I: Animalia, pars 44, p. 516.

1943. *Solenastrea bournoni* Edwards and Haime, Vaughan and Wells, Geol. Soc. Amer., Spec. Pap., No. 44, pp. 174, 321, pl. 29, figs. 7, 7a.

1948. *Solenastrea bournoni* Edwards and Haime, Smith, Atlantic Reef Corals, pp. 61, 71, 88.

1956. *Solenastrea bournoni* Milne Edwards and Haime, Wells, Treatise on Invertebrate Paleontology, Pt. F, Coelenterata, p. F406, fig. 303, 4b.

1961. *Solenastrea bournoni* Milne Edwards and Haime, Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 10, 76, 77, figs. 65, 66.

1962. *Solenastrea bournoni* Milne Edwards and Haime, Kornicker and Squires, Limnol. and Oceanogr., vol. 7, No. 4, pp. 447, 448, 450.

1963. *Solenastrea bournoni* Milne Edwards and Haime, Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 142, 154, 162, pl. 13b.

1964. *Solenastrea bournoni* Edwards and Haime, Roos, Studies on the Fauna of Curaçao and other Caribeban Islands, vol. 20, No. 81, pp. 11, 23, 25, 32, 35-37, 39, 40, 42, 48, figs. 9-13.

1968. *Solenastrea* cf. *S. bournoni* Edwards and Haime, Weisbord, Bull. Amer. Paleont., vol. 55, No. 246, pp. 60-62, pl. 12, figs 1-3. [Numerous references. 1849-1964.]

1971. *Solenastrea bournoni* Edwards and Haime, Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 4, 25, 67, figs. 7, 8, 28, pls. 24a, 25a.

1971. *Solenastrea bournoni* Edwards and Haime, Olivares, Inst. Oceanogr. Univ. Oriente, Bol., vol. 1, No. 2, pp. 73, 74, 75, table 1, pl. 1, figs. C, D.

1972. *Solenastrea bournoni* Edwards and Haime, Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 548, 569, 579, pl. 7H.

The original description of this species was as follows:

2. SOLENASTREA BOURNONII

> Cette espèce est très voisine de la *S. Hemprichiana;* elle en diffère par des côtes moins développées encore, une exothèque plus abondante, des murailles plus minces, des calices un peu plus grands et moin profonds, un columelle plus marquée, et des cloisons de troisième ordre plus développées. Diamètre des calices, 2 millimètres a 2 millimètres 1/2; leur profondeur, 1-1/2.

> Patrie inconnue. — Coll. M. (de Bournon).
> C'est peut-être auprès de cette espèce qu'il faut placer la *Madrepora pleiades,* Ellis et Solander, *Zooph.,* p. 169, tab. LIII, fig. 7 et 8 (1786).

It would be difficult to identify this species on the above description by Edwards and Haime were it not for Vaughan (1917, pls. XCIX, C) who procured photographic negatives of the type from Dr. Charles Gravier of the Muséum National d'Histoire naturelle, Paris. Vaughan's plates are excellent, and from them, as well as from the work of others, it is possible to determine that the SP-7 specimens from the Pinecrest Formation are referable to *Solenastrea bournoni.*

The SP-7 coralla are diverse in their growth pattern: SP-7a is hemispherical, with low non-uniform gibbosities on the head and an upwardly convex base or attachment area; SP-7b is tall, subcylindrical, and erect in growth, with the sides alternately broadly swollen and appressed; SP-7c is also upright and resembles a plump fig which is asymmetrically swollen, with a thick, somewhat prolonged stalk at the base; the largest specimen (SP-7e, 280 mm × 250 mm) has an asymmetrically convex and subrounded head, with broad, slightly elevated gibbosities on the calicinal surfaces and sides.

A few well-preserved corallites on the under side of SP-7a indicate that whereas the calices are more or less circular in outline, the corallites at the level of the coenosteum are variously polygonal in outline, most of them pentagonal, some hexagonal, and an occasional one diamond-shaped. Separating the contiguous corallites is a narrow impressed suture. The costae, which are short, thick, subequal to alternating, and minutely granulose on the surface, extend to, and terminate at the suture or in the narrow valley between the corallites. The coenosteum or exotheca on this fresh surface of the corallum is also granulose, but only sparsely vesicular or blistered. On the head proper, which is weathered, the exotheca is nearly entirely vesicular.

The calices are subcircular and small, varying from 2.0 mm to 2.8 mm in diameter for a median of 2.3 mm. The calicular margins are slightly elevated — about 0.5 mm or so — and a little nodulose, rendered so by the thickening there of the septa where they are conterminous with the costae.

The septa are thin and occur in three cycles, the primary ones slightly larger than the secondaries but both considerably larger than the 12 tertiary septa which alone do not extend to the columella, and project minimally from the wall. The principal septa are paliform before the columella, the pali thin to papilliform, the papillae often forming several rings around the columella. The margins of the septa are serrulate to dentate, the dentations becoming papillae near the columella in a goodly number of calices. The faces of the septa are narrow, imperforate, and granulate, the granulations pointed to tubulose.

The columella is a small polygon formed from the inner ends of the primary septa, with, in a few places, a small erect papilla at each corner. In many calices the columella itself is papillate, and is encircled by a ringlet or two of the papillae at the termini of the principal septa.

Measurements. — SP-7a: length 129 mm, maximum width 101 mm, height 98 mm. SP-7b: height 80 mm, diameter of the basal attachment area (which is part of a thick-shelled oyster) 62 mm × 39 mm, diameter of head 55 mm × 51 mm, diameter just above base 63 mm, and the diameter of the appressed waist 54 mm. SP-7c: base 34 mm × 29 mm, height 115 mm, diameter of lower middle (which is asymmetrically swollen 78 mm. SP-7d: broken corallum height 110 mm, diameters of calicinal surface 85 mm × 53 mm. SP-7e: this is split through the underside; the height unreconstructed is 155 mm, diameters of head 280 mm × 36 mm, base 47 mm × 34 mm.

Locality. — SP-7 specimens were collected by Joseph E. Banks, Leslie Dyet, and Harbans S. Puri in the Pinecrest Formation in the Warren Brothers Pits east of Sarasota, Sarasota County.

Comparison. — The Pinecrest specimens closely resemble the syntype ("cotypes") of *Solenastrea bournoni* illustrated by Vaughan (1917) and the *S. bournoni* from Piscaderabaai, Curaçao, illustrated by Roos (1971).

Also occurring in the Warren Brothers Pits is the Miocene to Recent *Solenastrea hyades* (Dana). *S. bournoni* differs from *S. hyades* in its generally smaller calices, in its more highly vesicular coenosteum on weathered surfaces and in having more rudimentary tertiary septa which usually do not curve into and join the secondary septa as in *S. hyades*. Nevertheless there are certain intergrading examples that are difficult to separate, such as specimens PG-3a from the Caloosahatchee Marl and SP-6a, 6b from the Pinecrest Sand, which are intermediate between *S. bournoni* and *S. hyades*.

Range and distribution. — The reported geographic range of *Soleanstrea bournoni* is from Florida to Venezuela. The reported geologic range is Miocene to Recent.

Miocene — Cuba (La Cruz Marl); Haiti (Las Cahobas Formation, and at St.-Marc); Dominican Republic (Cercado Formation in Rio Gurabo and Rio Cana; Gurabo Formation in Rio Mao and Rio Gurabo; Yaque Group in Rio Yaque, Provincia Azua); Vieques Island (at Cucuracha Light).

Mio-Pliocene — Florida (Pinecrest Formation); Dominican Republic (Cerros de Sal Formation).

Pliocene — Florida (Caloosahatchee Marl in Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County, and in Shell Creek, Charlotte County); Haiti (west slope of Tapion du Petit-Goave ?); Venezuela (Mare Formation).

Plio-Pleistocene — Florida (near Belle Glade, Palm Beach County, No. 243222 USNM. Collected by J. E. Ayers 1962).

Pleistocene — Panama Canal Zone; Haiti (Arrondissement Port-au-Prince); Dominican Republic (coast limestone at Cabral, Provincia Barahona).

Recent — Texas (Padre, Mustang, and St. Joseph Islands); Florida (Tortugas, 8-9 fathoms); Bahamas; British Honduras (Rendezvous Cay); Jamaica; Puerto Rico (Caballo Ahogado, 5 ft., and Bahía de Boquerón, 4 ft.); Vieques; St. Thomas; Martinique; Curaçao (Piscaderabaai, 20 meters, Caracasbaai, and Sta. Martha Baai, 10-45 meters); Bonaire (Slagbaai); Venezuela (Bahía de Mochima, Edo. Sucre at Playa Blanca de Las Maritas; Golfo de Cariaco, Zonas A, E-I).

Solenastrea hyades (Dana) Pl. 43, figs. 1-6; Pl. 44, figs. 1-3

1846. *A[strea] Orbicella hyades* Dana, U.S. Exploring Expedition 1838-1842, Zoophytes, vol. 7, p. 212, pl. 10, fig. 15.

1846. *A[strea] Orbicella excelsa* Dana, *ibid.*, p. 212, pl. 10, fig. 16. [*Fide* Vaughan 1919, pp. 395-398.]

1901. *Solenastrea hyades* (Dana), Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, Pt. I, art. III, pp. 97-100, 104-106, pl. 15, figs. 5, 5a, 5b.

1902. *Solenastrea hyades* (Dana), Duerden, Nat. Acad. Sci., Washington, Mem., vol. 8, pp. 567-569, pl. 10, figs. 74-79; pls. 11-13, figs. 80-91.
1910. *Cyphastrea hyades* (Dana), Vaughan, Carnegie Inst. Washington, Publ. No. 133, Pap. Tortugas Lab., vol. 4, p. 176.
1917. *Solenastrea hyades* (Dana), Vaughan, U.S. Geol. Sur., Prof. Paper 98-T, pp. 368, 472, 374, pl. XCVIII, figs. 1-3.
1919. *Solenastrea hyades* (Dana), Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 211, 219, 222, 223, 230, 395-398.
1921. *Solenastrea hyades* (Dana), Vaughan, Geol. Survey Dominican Republic, Mem., vol. 1, p. 134.
1925. *Solenastrea hyades* (Dana), Vaughan, *in* Woodring, Geol. Survey Republic of Haiti, pp. 203, 217, 222, 243, 250.
1948. *Solenastrea hyades* (Dana), Smith, Atlantic Reef Corals, pp. 66, 88, 89, pls. 23, 24.
1949. *Solenastrea hyades* (Dana), Lyman, Shell Notes, vol. 2, Nos. 7-9, p. 130, pl. 1, fig. 2.
1958. *Solenastrea hyades* (Dana), Bonet, Asoc. Mexicana Geól. Petrol., Bol., vol. 10, Nos. 9-10, pp. 565, 567-569, 570.
1959. *Solenastrea hyades* (Dana), Goreau, Ecology, vol. 40, No. 1, pp. 70, 75, 85.
1961. *Solenastrea hyades* (Dana), Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 10, 78-79, figs. 67, 68.
1964. *Solenastrea hyades* (Dana), Hoffmeister, *et al.*, Guidebook Geol. Soc. Amer. Convention, Field Trip No. 3, p. 23.
1964. *Solenastrea hyades* (Dana), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 20, No. 81, p. 48.
1967. *Solenastrea hyades* (Dana), Goreau and Wells, Bull. Marine Sci., No. 2, p. 448.
1968. *Solenastrea hyades* (Dana), Weisbord, Bull. Amer. Paleont., vol. 55, No. 246, pp. 8, 57-60, pl. 8, figs. 4-8; pl. 9, figs. 1-4. [Numerous references, 1846-1962.]
1969. *Solenastrea hyades* (Dana), Wells, *in* DuBar, Gulf Coast Assoc. Geol. Soc., Soc. Econom. Paleont. and Mineral. Sect., Ann. Meet., Field Trip Number 4, p. 140.
1969. *Solenastrea hyades* (Dana), Macintyre and Pilkey, Science, vol. 166, No. 3903, pp. 374, 375, fig. 2.
1969. *Solenastrea hyades* (Dana), Logan, Amer. Assoc. Petrol. Geol., Mem. 11, p. 71.
1970. *Solenastrea hyades* (Dana), Klose, *in* letter to R. O. Vernon, 30 April 1970, p. 5.
1972. *Solenastrea hyades* (Dana), Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 548, 555, 569, 579.

Floridan fossils of *Solenastrea hyades* assume a variety of forms — moderately convex, thumb-shaped, pear-shaped, high-domal, low domal, head-shaped, and saddle-shaped. Larger specimens are often nodose or bumpy, and elongated ones seem to have grown upward from a relatively small base.

The calices are nearly circular to subcircular or broadly oval; their average diameter is 3.4 mm, their depth 1 mm to 2 mm, and their height above the level of the coenosteum or exotheca 0.5 mm to 1 mm. In places the calicular margins are in contact, but more often they are separated, the intervals varying from 0.4 mm to nearly 3 mm. The exotheca is smooth to vesicular.

There are normally three complete cycles of 24 septa in mature calices, but here and there on the corallum is a larger calice with four cycles of septa, these incomplete to nearly complete; an example of the latter is seen on specimen PG-4a in which there are 38 septa in a calice 4.5 mm in diameter. The six primary septa are about the same in size as the secondaries, and these 12 principal septa extend to the columella. The septa of the third cycle are a little less wide and smaller than the principals, and the majority of them bend toward and join the secondary septa about midway between the wall and the columella. The pattern thus formed is that of six three-pronged candelabras or tridents with the outer tines curved, and this is the chief character distinguishing *S. hyades* from *S. bournoni* Edwards and Haime. On either side of each triad is a principal septum. The free margin of the septa is denticulate, the denticulations blunt and compound. The faces of the septa are beset by pointed granulations and tubules. All of the septa thicken at the calicular margin and are conterminous there with the costae which are robust, subequal, and minutely granulose. The paliform lobes of the principal septa are small and thin before the columella.

The columella is small and composed of small twisted processes from the inner ends of the primary septa. Below the tangle, the base of the columella is distinctly papillate.

Measurements. — Specimen I-628: corallum pear-shaped, height 76 mm, max. diameter 60 mm.; average calice diameter 3.3 mm, 24 septa; largest calice diameter 5.1 mm × 4.4 mm, 44 septa. Specimen TEL-1a: corallum worn and high-domal, height 132 mm, diameter at middle 89.5 mm × 77 mm, base 119 mm × 96 mm. Specimen PG-4a: corallum saddle-shaped, length 98.5 mm, max. width 92 mm, height of valley 38.5 mm, height of sides 67 mm, 56 mm. Specimen CAL-6a: corallum asymmetrically convex, length 40 mm, width 36 mm, height 20.5 mm.; average calice diameter 3.4 mm, 24 septa; largest calice diameter 5.4 mm × 5.1 mm, 44 septa. Specimen CAL-6b: corallum thumb-shaped, height 49 mm, diameter at middle 25 mm × 21.5 mm.; average calice diameter 3.1 mm, 24 septa. Specimen CAL-6c: weathered corallum large domal, length 111 mm, width 93.5 mm, height 91 mm. Specimen SP-8a:

corallum large with gibbosites, height or length 148 mm, width 91 mm. Specimen 2795 USNM: diameters of calicinal surface 124 mm × 130 mm, height of corallum 74 mm. (Identified by Vaughan.) Specimen SP-8a: height 148 mm, maximum diameter of head 118 mm, minimum 92 mm.

Localities. — The Floridan localities of *Solenastrea hyades* mentioned in this report are the following:

PG — 3.5 miles southeast of Punta Gorda, Charlotte County, on road to Punta Gorda airport 1.4 miles south of the entrance to Tee and Green Estates. Collector: Leslie Dyet, 16 February 1968 and 11 March 1968. Caloosahatchee Marl.

TEL — Borrow pit 18 miles east of Punta Gorda, Charlotte County, just south of Florida state road 74, Sec. 3, T 41 S, R 26 E, Telegraph Swamp Quadrangle NW. Caloosahatchee Marl.

1/1031 — 1/4 mile above Goodno's Landing, Caloosahatchee River. "Said to have come from Caloosahatchee Marl (Pliocene). E. H. Sellards 1914." Specimen 2795 USNM. Caloosahatchee Marl or Ft. Thompson Formation.

I-628 — In Caloosahatchee River below Lock No. 3, Glades County. (Lock No. 3 is 6.5 miles west of Ortona Lock and 5.5 miles east of LaBelle.) Collectors: C. W. Cooke and D. S. Mossom, 16 February 1927. Pleistocene.

CAL — Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. Collector: Mike Strong, December 1969. Caloosahatchee Marl.

SP — Warren Brothers Pits, 4 miles east of US 301 Sarasota, Sarasota County, just east of Newburn Road, 0.4 miles north of its intersection with 17th Street. Collector: Harbans S. Puri, 29 January 1970. Pinecrest Formation.

Comparison. — *Solenastrea hyades* may be confused with *Solenastrea bournoni* Edwards and Haime with which it sometimes occurs both living and fossil. Typically, however, the calices of *S. hyades* are larger, the exotheca more solid, and the tertiary septa wider, often bending toward and joining the secondary septa. The tertiary septa of *S. bournoni* on the other hand, are rudimentary, project slightly from the wall, and extend but part way down it.

Range and distribution. — The geographic range of *Solenastrea* *hyades* is from North Carolina to Venezuela; geologically the range is Miocene to Recent.

Miocene — Mexico (Bacalar Formation of Quintana Roo); Cuba (La Cruz Marl in eastern Cuba, and at Cienaga, near Habana); Haiti (Las Cahobas Formation; and at St.-Marc, Mirebalais, and in the Arrondissement of Port-au-Prince); Dominican Republic (Mao and Gurabo Formations).

Mio-Pliocene — Florida (Pinecrest Formation).

Pliocene — Florida (Caloosahatchee Marl); Mexico (Carillo Puerto Formation of Quintana Roo); Haiti (west slope of Tapion du Petit-Goave ?); Venezuela (Mare Formation; Guaiguaza Clay).

Pleistocene — Florida (Vero; "Glades" ? Formation between LaBelle and Ortona; Miami; Key Largo Limestone/Miami Oolite in the channel at the north end of Raccoon Key); Mexico (Territorio de Quintana Roo); Haiti (Arrondissement of Port-au-Prince); Montserrat.

Recent — North Carolina (Onslow Bay, 22 meters, winter temperature of 10.6° C); Bahamas; Florida (Florida Keys; near Miami; Caesar's Creek and near Osprey, Cedar Keys); Yucatan Shelf; Cuba; Jamaica (Ocho Rios; 3 m to 23 m): St. Thomas; Curaçao; Venezuela (Bahía de Mochima at Punta El Aguirre and Barranca de Mochima).

RHIZANGIIDAE

Astrangia floridana (Gane) Pl. 41, figs. 4-6; Pl. 45, figs. 1-5

1895. *Phyllangia floridana* Gane, Johns Hopkins Univ. Circ., vol. 15, No. 121, p. 9.

1900. *Phyllangia floridana* Gane, U.S. Nat. Mus., Proc., vol. 22, No. 1193, pp. 191, 198, pl. 15, figs. 7-9.

1902. *Phyllangia floridana* Gane, Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, pt. 2, p. 299.

1919. *Phyllangia floridana* Gane, Vaughan, U.S. Nat. Mus., Bull. 103, vol. 9, p. 222.

1929. *Phyllangia floridana* Gane, Felix, Fossilium Catalogus I: Animalia, pars 44, p. 551.

1947. *Astrangia floridana* (Gane), Wells, Bull. Amer. Paleont., vol. 31, No. 123, p. 169.

Following is Gane's original description of *Phyllangia floridana.*

> Colony encrusting, consisting of subturbinate corallites arising from the basal expansion. Individuals generally free above but somewhat closely united at their base. Walls thin at the calicular edge, thicker below. Costae low, subequal, minutely granulated, reaching the base, but more prominent at the calicular margin and at the swellings

just beneath the constrictions in the walls of the corallites. About on a level with the bottom of the fossa, the diameter of the corallite is least, the walls being here somewhat constricted, beneath which constriction they are again frequently swelled to a diameter equal to that at the calicular margin. Calices somewhat expanded, widely open, deep, narrow at the bottom. Septa crowded, in six systems of four complete cycles, lacking a few septa of the fifth order; primaries and secondaries more exsert, thicker and broader than the septa of the following cycles, quarternaries least exsert, thinnest and narrowest; sides of the septa sharply granulated and the edges of all but the fourth cycle rounded superiorly and subentire in their upper parts, the lower two-thirds of the septal edges being strongly lobate or dentate, the uppermost tooth being the most prominent and similar in shape to a true paliform lobe. Columella papillary occupying a very limited area; the line of separation between the papillae of the columella and the lowest teeth of the septa being indistinguishable. Gemmation by budding from the basal expansion of the wall of a parent corallite.

This form in its general size and mode of growth very much resembles the *Astrangia lineata* (Conrad) of the Virginia Miocene deposits.

Dimensions. — Breadth of calice, from 4 to 6 mm.

Geologic horizon. — Pliocene, Caloosahatchie beds.

Locality. — Alligator Creek, Monroe County, Florida.

Collections. — U.S. National Museum. The type specimen was collected by Mr. Joseph Willcox, of Philadelphia.

As two coralla in the Florida State University collection donated by Mr. Strong are exceptionally well preserved, the following description of *Astrangia floridana* complements that of Gane.

The colony is encrusting and plocoid, and consists of a clump of subcylindrical to subturbinate corallites arising as much as 7 mm from the basal expansion. Individuals are slightly divergent, generally free above, but somewhat closely united at their base. Many of the corallites are a little constricted around the middle, but swollen broadly above the constricted area and narrowly below it. The maximum diameter of the corallite is just below the calicular margin. The costae are moderately pronounced, generally alternating in size, the larger ones subequal, the smaller ones lower and very fine. The costae extend down the walls to become confluent with the costae of adjacent corallites. On the broad costae there are two columns of granulations, and on the narrower ones a single column. The calices are broadly and regularly oval to nearly circular, somewhat expanded, widely open, deep, and of small diameter at the columella. There are four cycles of septa, the number varying from 44 in a calice 6 mm in long diameter to 30 in a circular calice with a diameter of 3.4 mm. The primary and secondary septa are more exsert, thicker, and broader than the septa of the third and fourth cycles, the quaternaries being the least exsert, thinnest, and narrowest. In the upper part of the calice the septa are straight, but deep within, septa of the third cycle may join a septum of the second cycle in a candelabra effect. The sides of the septa are granulated by small pointed tubercles, and the free margins are denticulate. The principal septa are rounded superiorly and subentire in their upper parts; their free margins descend precipitously, and on the lower two-thirds are fronted by erect columns of coarse paliform denticles, with three to five arborescent pali to the column. The columella is deep, very small and papillose, the papillae hardly distinguishable from the lowest pali.

Measurements. — Specimen CAL-1a (consisting of 15 corallites in varying sizes): corallum length 20 mm, width 17 mm, height 15 mm.; corallite height 6 mm, diameter of the middle 5 mm, diameters of calice 6 mm × 5 mm. Specimen I-1932a: corallum length 26 mm, height 16.2 mm, width of base 11.2 mm. Specimen USNM-3300(a): corallum length 14.5 mm, height 12.5 mm, width 10.5 mm. Specimen USNM-3300(b): length of base 12 mm, height 12 mm. Specimen USNM-3300(c): length of base 10 mm, height of corallite 4 mm, diameter of calice 5.1 mm.

Localities. — The CAL-1 specimens were found along the south bank of the Caloosahatchee River, 2 to 5 miles west of LaBelle, Hendry County, Florida, by Mike Strong and reported by him to occur in the Caloosahatchee Formation. Examples of the same species were collected in 1914, by Dr. Sellards of the Florida Geological Survey, at Huggett's Landing on the Caloosahatchee River, 3 miles west of LaBelle; and in the National Museum of Natural History there are numerous specimens labeled *Astrangia floridana* from Shell Creek in Charlotte County. These Shell Creek corals were found in Alligator Creek, Monroe County, Florida, in the "Pliocene Caloosahatchie beds", some 80 miles or so southeast of Strong's locality in the Caloosahatchee River. The Everglades of Monroe County are underlain by the Tamiami Formation. There is another Alligator Creek in Charlotte County, Florida (Sec. 26, R 23 E, T 41 S) about 30 miles northwest of CAL-1a, in which J. R. DuBar (1958, p. 31 fig. 5) measured and described a 4-foot interval of Caloosahatchee resting unconformably on the Tamiami Formation. I have also identified the CAL form of *Astrangia floridana* collected in a pit at South Bay water plant, Palm Beach County, Florida. The coral was donated by Joseph E. Banks and stated by him to pertain to Unit A of Olsson (1968, pp. 69, 72, 76).

Comparisons. — As pointed out by Gane, there is considerable resemblance in size and mode of growth between *Astrangia floridana* (Gane) and *Astrangia lineata* (Conrad) from the Chesapeake Group of Virginia. However, the Virginian form may be distinguished by its trabecular columella and widely funneled calice. The Pleistocene to Recent *Astrangia solitaria* (Lesueur) is characterized by more tubular corallites than *A. lineata, A. floridana* or *A. leonensis* (Weisbord).

Remarks. — Under the heading "Pliocene, Caloosahatchee Marl, Florida," Vaughan (1919, p. 222) listed 19 species of corals, and stated that "The foregoing list is complete for the Caloosahatchee corals from the Caloosahatchee River and Shell Creek, Florida, except one species of whose genus I am not sure." One of the corals in Vaughan's list was *Phyllangia floridana* Gane, and it would thus appear, inasmuch as it was also collected from the "Caloosahatchee" in the Caloosahatchee River, that specimen CAL-1a is indeed the *P. floridana* of Gane. It should be mentioned, however, that Gane neither described nor illustrated the fine, beaded, interstitial costae that are often present between the broader costae, and if this alternation is significant it might be appropriate to consider Strong's form a subspecies of the *Astrangia floridana* from Monroe County. I have not seen the type of *A. floridana,* but inasmuch as the character of the costae is often variable on different specimens of the same species, and inasmuch as the forms from Hendry County and Charlotte County seem otherwise similar to that of Gane from Monroe County, the name *Astrangia floridana* is retained for them.

Age and distribution. — *Astrangia floridana* occurs in the Tamiami Formation (upper Miocene - Pliocene), in the Caloosahatchee Marl (Pliocene), and in Unit A which is considered late Pliocene by some geologists, early Pleistocene by others.

Astrangia leonensis Weisbord Pl. 46, figs. 1, 2

1971. *Astrangia leonensis* Weisbord, Florida Bur. Geol., Geol. Bull. No. 53, pp. 9, 11, 41, 43, 44, 80, pl. 10, figs. 1-6.

The two small specimens from Sarasota referred to this species are solitary but were undoubtedly united to other individuals by the coenosteum of the basal expansion which is missing. The corallites SP-4a and SP-4b seem to be identical with those of the type of *Astrangia leonensis* (JBC-6a) from Jackson Bluff in Leon County about 250 miles northwest of the Sarasota locality.

Measurements. — Specimen SP-4a: height of corallite 6.1 mm, diameter at base of corallite 3.4 mm; diameters of calice (oval) 5.1 mm × 4.4 mm; number of septa 36. Specimen SP-4b: height of corallite 4.7 mm, diameter at flared base of corallite 4.0 mm, diameter at waist of corallite 2.8 mm; diameter of calice (subcircular) 3.8 mm; number of septa 40.

Locality. — Warren Brothers Pits, 4 miles east of U.S. 301, Sarasota, Florida, just off Newbern Rd. 0.4 miles north of 17th Street. Collector and donor Joseph E. Banks.

Comparison. — As stated in my original description, *Astrangia leonensis* is very close to *Astrangia floridana* (Gane) and may perhaps be a geographic variant of it. However, compared with typical examples of *Astrangia floridana* in the National Museum of Natural History from the Caloosahatchee River one mile below Hugget's Landing, Hendry County, the corallites of *Astrangia leonensis* are shorter, the calices shallower, and the costae broader and more uniform in size.

Range and distribution. — *Astrangia leonensis* Weisbord is now known from the Jackson Bluff Formation of North Florida and the Pinecrest Sand of South Florida. The age of these two deposits is believed to be late Miocene or early Pliocene. Other corals occuring in both the Jackson Bluff beds and Pinecrest beds are *Oculina sarasotana* Weisbord and *Septastrea marylandica* (Conrad).

Astrangia solitaria (Lesueur) Pl. 46, fig. 3

1817. *Caryophyllia solitaria* Le Sueur, Acad. Nat. Sci., Philadelphia, Jour., vol. 1, p. 179, pl. 8, fig. 10.
1820. *Caryophyllia solitaria* Le Sueur, Le Sueur, Mus. Nat. Hist. nat., Paris, Mém., vol. 6, p. 274, pl. 15, fig. 1.
1846. *Caryophyllia solitaria* Lesueur, Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, p. 383.
1857. *Caryophyllia solitaria* Lesueur, Edwards and Haime, Histoire Naturelle des Coralliaires ou Polypes proprement dits, vol. 2, p. 595. [As a synonym of *Cladocora arbuscula*.]
1861. *Astrangia neglecta* and *Astrangia granulata* Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 19, p. 355, pl. 10, figs. 3, 4 (*A. neglecta*); pl. 9, figs. 13, 14 (*A. granulata*). [*Fide* Vaughan, 1902, p. 298.]

1864. *Astrangia solitaria* (Lesueur), Verrill, Mus. Comp. Zool., vol. 1, No. 3, p. 47.
1866. *Astrangia neglecta* and *Astrangia granulata* Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 23, p. 185.
1866. *Astrangia phyllangioides* Duchassaing and Michelotti, R. Accad. Sci. Torino, ser. 2, vol. 23, pp. 185, 186, pl. 10, figs. 3, 4. [*Fide* Pourtalès, 1871, p. 31.]
1870. *Astrangia neglecta, A. granulata, A. phyllangioides* Duchassaing and Michelotti, Duchassaing, Revue des Zoophytes et des Spongiaires des Antilles, p. 31.
1871. *Astrangia solitaria* (Lesueur), Pourtalès, Mus. Comp. Zool., Mem., vol. 2, No. 4, pp. 31, 79, 80.
1877. *Astrangia neglecta* Duchassaing and Michelotti, Lindström, K. Svenska Vetensk.-Akad., Handl., vol. 14, No. 6, p. 23.
1880. *Astrangia solitaria* Verrill, Pourtalès, Mus. Comp. Zool., Mem., vol. 7, No. 1, pl. 12, figs. 8-12.
1886. *Astrangia granulata, A. neglecta, A. phyllangioides* Duchassaing and Michelotti, Quelch, Voyage H.M.S. Challenger 1873-76, Rept. Sci. Results, Zoology, vol. 16, pt. 46, p. 12.
1886. *Astrangia solitaria* (Lesueur), Quelch, Voyage H.M.S. Challenger 1873-76, Rept. Sci. Results, Zoology, vol. 16, pt. 46, p. 12.
1890. *Astrangia solitaria* (Lesueur), sp., Duncan, *in* Ridley, Linnean Soc. London, Jour., Zoology, vol. 20, p. 569.
1901. *Astrangia solitaria* (Lesueur), Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, Pt. I, art. IV, pp. 183, 194.
1902. *Astrangia solitaria* (Lesueur), Duerden, Nat. Acad. Sci., Washington, Mem., vol. 8, pp. 553-555, pl. 5, figs. 43-45; pl. 6, fig. 47.
1902. *Astrangia solitaria* var. *portoricensis* Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, pt. 2, pp. 298, 299, pl. 1, figs. 6, 6a, 6b.
1904. *Astrangia solitaria ?* Edwards and Haime, Greeley, *in* Branner, Mus. Comp. Zool., Bull., vol. 44, Geol. Ser., vol. 7, p. 266. [= *Astrangia brasiliensis* Vaughan, U.S. Nat. Mus., Proc., vol. 30, No. 1447, pp. 848, 849, pl. 77, figs. 3-6, 1906.]
1906. *Astrangia solitaria* (Lesueur), Vaughan, U.S. Nat. Mus., Proc., vol. 30, No. 1477, p. 848. Also *Astrangia braziliensis* Vaughan, p. 848, pl. 77, figs. 3-6. [*Fide* Wells, 1972a, p. 4.]
1909. *Astrangia solitaria* (Lesueur), Vaughan, Florida State Geol. Survey, Second Ann. Rept. 1908-9, p. 151.
1927. *Astrangia solitaria* (Lesueur), van der Horst, Bijdr. Dierk. Amsterdam, vol. 25, p. 159.
1929. *Astrangia solitaria* (Lesueur), Felix, Fossilium Catalogus I: Animalia, pars 44, p. 550.
1948. *Astrangia solitaria* (Lesueur), Smith, Atlantic Reef Corals, pp. 61, 65, 91.
1954. *Astrangia solitaria* (Lesueur), Fontaine, Inst. Jamaica, Ann. Rept. 1953-1954, p. 25.
1954. *Astrangia solitaria* (Lesueur), Smith, U.S. Fish and Wildlife Serv., Fish. Bull., vol. 55, No. 89, p. 293.
1956. *Astrangia solitaria* (Lesueur), Menzel, Oceanogr. Inst. Florida State Univ., Contrib., No. 61, p. 2.
1959. *Astrangia solitaria* (Lesueur), Goreau, Ecology, vol. 40, No. 1, pp. 71, 75, 85.
1959. *Astrangia solitaria* (Lesueur), Zans, Geonotes, vol. 2, No. 1, pp. 29, 35.
1960. *Astrangia solitaria* (Lesueur), Lewis, Canadian Jour. Zool., vol. 38, No. 4, p. 1135.
1963. *Astrangia solitaria* (Lesueur), Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 143, 155, 156, 161, pl. 15a.

1964. *Astrangia solitaria* (Lesueur), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 20, No. 81, p. 48.
1966. *Astrangia* cf. *A. solitaria* (Lesueur), Laborel, Mus. Nat. Hist. nat., Paris, Bull., sér. 2, vol. 38, No. 3, p. 282.
1967. *Astrangia solitaria* (Lesueur), Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 448.
1971. *Astrangia solitaria* (Lesueur), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 4, 74, pl. XXXIVa, b.
1972. *Astrangia solitaria* (Lesueur), Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 548, 549, 571, 577, pl. 8-0.
1972a. *Astrangia solitaria* (Lesueur), Wells, Postilla, No. 156, pp. 1, 2-4, figs. 1-5.

Lesueur's original description of *Astrangia solitaria* is as follows:

> Caryophyllia *solitaria.* (Plate VIII, fig. 10) *Cellules* cylindric, generally insulated, radiated in the centre, furrowed on the exterior; *animal* diaphanous, ornamented with twenty-two *tentacula,* which are thick and short, and covered with white *spots,* twelve of these tentacula are annulated with red at their extremity; aperture of the *mouth* linear, marked with three black bands on each side, those of the middle largest.
>
> Whilst the animal is expanded, it rises partly out of its habitation, and elevates its mouth beyond its tentacula.
>
> Inhabits the madreporic rocks of Guadaloupe.

The following description is based on a specimen in the National Museum of Natural History from Honduras.

The corallum is composed of clusters or solitary corallites, the former fused near their bases in groups of three or more, the latter separated and connected with others by incrustations of the peritheca. The corallites are 5 mm to 10 mm in height and 3 mm to 5 mm in diameter; in form they are subcylindrical and slightly expanded at the calicular margin. The calices are subcircular in outline, and deep and tubular within, the inner margins of the septa descending vertically. A typical calice some 5 mm or so in diameter bears 34 to 36 septa in four cycles, the fourth about half complete. The septa are moderately robust, a little thicker at the wall, and slightly exsert, the septa of the first two cycles a little higher than the others at the wall and reaching the columella in the interior. The margins of all septa are denticulate or crenate, and the sides faintly papillate. Well within the calice, fourth cycle septa fuse to those of the third, and third cycle septa fuse to those of the second. Pali are present before the septa of the first three cycles; the pali are erect, compound, more or less united, and consist of connected frondose denticulations. The columella is small and porose.

For each septum there is a costa, the costae subequal, broad, and low, except at the margin of the calice where they may be narrower and a little more elevated. The costae are densely granulate and extend down from the calicular margin to near the base of the corallite. The color of the corallites on the Recent Honduran corallum is dull tan and dull white, with bright pink organisms adherent here and there.

Measurements. — Hond-1a: average corallite height 4.6 mm, diameter of calice 3.8 mm × 3.6 mm, number of septa 34. Corallum length 20 mm, width 14.7 mm, height 10 mm.

Range and distribution. — The geographic range of *Astrangia solitaria* is possibly from Bermuda southward to Venezuela and doubtfully to Brazil; the geologic range is Pleistocene (one report) to Recent.

Pleistocene — The only record of Pleistocene is by Vaughan (1902) who recorded the species in a "white Pleistocene sand", 4 miles west of Eau Gallie, Brevard County, Florida.

Recent — Bermuda (North Rock; Haversack West); Florida (Florida reef along southeast coast; Double-Headed Shot Key in 315 fathoms; Apalachee Bay in 30 - 50 ft. on a rocky, shelly, or sandy substrate; Bahamas; Cuba; Jamaica (0.2 m to 43 m; Ocho Rios); Honduras; Panama; Haiti; St. Thomas; Puerto Rico; Guadeloupe; Curaçao (Spaanse Water); Bonaire (Palu Lechi); Barbados (west coast); Venezuela (Bahía de Mochima, Edo. Sucre, at Ensenada Botella, Ensenada Cabruta Roja, Ensenada Las Maritas); Brazil ? (Island of Fernando Noronha off Natal).

The *Astrangia solitaria* ? reported by Greely *in* Branner (1904) on the coast of mainland Brazil was redescribed by Vaughan (1906) as *Astrangia brasiliensis,* and confirmed by Laborel (Postilla, No. 3, 1967). Concerning the *Astrangia solitaria* recorded by Duncan (1890, p. 569) from Fernando Noronha, Brazil, these are his remarks:

> A specimen much covered with Nullipores. The corallites smaller than the Florida types, and the so-called "pali" not united before the second and third cycles of septa. The form is allied to *Astrangia Danae* and to *A. Michelini.* It may be considered as a small variety of the Floridan species.

On the typical *Astrangia solitaria* (Lesueur) from Honduras, the paliform denticles before the septa of the first, second, and third cycles, are generally united. The Fernando Noronha occurrence of *A. solitaria* was confirmed by Wells in his 1972 paper.

Phyllangia americana Edwards and Haime Pl. 46, figs. 4, 5

1849. *Phyllangia americana* Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 12, p. 182.
1857. *Phyllangia americana* Edwards and Haime, Histoire Naturelle des Coralliaires ou Polypes proprement dits, vol. 2, p. 616.
1861. *Phyllangia americana* Milne-Edwards and Haime, Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 19, p. 356.
1871. *Phyllangia americana* Milne-Edwards and Haime, Pourtalès, Mus. Comp. Zool., Mem., vol. 2, No. 4, pp. 30, 79.
1902. *Phyllangia americana* Milne-Edwards and Haime, Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, pt. 2, p. 299.
1902. *Phyllangia americana* Milne Edwards and Haime, Duerden, Nat. Acad. Sci., Washington, Mem., vol. 8, pp. 555-558, pl. 5, fig. 46.
1947. *Phyllangia americana* Edwards and Haime, Wells, Bull. Amer. Paleont., vol. 31, No. 123, p. 169, pl. 11, fig. 6.
1956. *Phyllangia americana* Milne-Edwards and Haime, Wells, Treatise on Invertebrate Paleontology, Pt. F, Coelenterata, p. F409, fig. 307, 5.
1959. *Phyllangia americana* Milne-Edwards and Haime, Goreau, Ecology, vol. 40, No. 1, pp. 70, 75, 85.
1963. *Phyllangia americana* Milne-Edwards and Haime, Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2, 3, pp. 143, 156, pl. 15b.
1967. *Phyllangia americana* Milne-Edwards and Haime, Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 448.
1968. *Phyllangia americana* Edwards and Haime, Weisbord, Bull. Amer. Paleont., vol. 55, No. 246, pp. 68-71, pl. 10, fig. 3; pl. 11, fig. 1. (Numerous references, 1849-1964).
1969. *Phyllangia americana* Milne-Edwards and Haime, Macintyre and Pilkey, Science, vol. 166, No. 3903, p. 375.
1971. *Phyllangia americana* Milne-Edwards and Haime, Olivares and Leonard, Inst. Oceanogr. Univ. Oriente, Bol., vol. 1, No. 1, pp. 49, 52, 59, 64, table 1, pl. 8, figs. C, D.
1971. *Phyllangia americana* Milne-Edwards and Haime, Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 4, 74, pl. 36a, b.
1971. *Phyllangia americana* Milne-Edwards and Haime, Olivares, Inst. Oceanogr. Univ. Oriente, Bol., vol. 1, No. 2, pp. 73, 74, 75, table 1.
1972. *Phyllangia americana* Edwards and Haime, Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 548, 550, 572, pl. 8.

Although this species was named and described in 1849 it was not until 1947 that it was adequately illustrated by Wells. The original description by Edwards and Haime was the following:

1. Phyllangia Americana

Polypiérites très rapprochés et très inégaux, à muraille finement granulée et costulée. *Côtes* très peu distinctes à la base, droites, fines, serées, inégales et un peu saillantes dans leur partie supérieure. *Calices* subcirculaires ou subovalaires, à fossette grande et très profonde. *Columelle* représentée seulement par de petits lobules irréguliers et denticulés qui se séparent du bord interne des cloisons. Quatre cycles: très souvent dans quelques systèmes, les cloisons du quatrième cycle ne se dévelopment pas. *Cloisons* inégales suivant les ordres, débordantes, à bord fortement arqué en haut; les primaires et les secondaires un peu épaisses en dehors, graduellement amincies en dedans, à bord entier; les autres cloissons plus minces, à bord très finement denticulé; celles de quatrième ordre plus développées que les tertiaires vers lesquelles elles se courbent; celles de cinquième ordre presque rudimenaires. Les faces des cloisons sont couvertes de grains assez gros et très serrés. *Traverses* simples, légèrement convexes, très peu nombreuses. Hauteur des polypiérites, 10 à 15 millimètres; largeur des calices, 10; leur profondeur, 6; les cloisons primaires débordent de 2.

Habite la Martinique (Plée). — Coll. M.

The single fossil specimen (CAL-4a) in the collection bears 66 septa in four complete cycles and part of the fifth. The six primary septa are the largest, the six secondaries slightly smaller, the others decreasing in size according to the order of their insertion; quaternary septa are thin, and deep within the calice often unite with a tertiary septum at the periphery of the columella; the quinaries are rudimentary. All of the septa are thickest at the wall and more or less exsert, the larger ones hooked over the calicular margin and lobate in form, with the upper part broad and rounded, the margin steeply inclined within. The faces of the septa are rather densely spinulose, the free margins denticulate.

The calicular margin of CAL-4a is bent outward a little, and at the margin the costae are decidedly thickened. There is one costa for each septum, and just below the subnodulous margin to the base of the corallite all of the costae are narrow, finely granulose, and nearly equal, in contrast with unequal sizes of the septa with which they are conterminous.

The calice is oval and deep, and the columella is trabecular.

Measurements. — Specimen CAL-4a: height of corallite 10.5 mm, diameter at base 10 mm, diameters of calice 13.5 mm × 10.5 mm.

Locality. — Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. Specimen donated by Mike Strong.

Formation. — Caloosahatchee.

Range and distribution. — Pliocene and Recent. This is the second report of *Phyllangia americana* as a Pliocene fossil, the first having been recorded by this writer (Weisbord, 1968) in the Playa Grande Formation of Venezuela. The living form was reported from Winslow Bay, off North Carolina, to as far south as Brazil. Intermediate localities are the Bahamas; Florida (Alligator Point, Franklin County; St. George's Sound; Elbow Key, 315 fathoms); Florida

Straits; Gulf of Campeche (N 20°02′, W 91°58′); Jamaica (0.3 m-17(?) m; Ocho Rios); Curaçao (Spaanse Water); Bonaire (Slagbaai); Venezuela (Bahía de Mochima, Edo. Sucre at Ensenada San Agustin) Ensenada Garrapata, Ensenada Burgao, Ensenada Cabruta, Ensenada Botella, Lance Manguillas, Punta de León; Golfo de Cariaco, Zonas A B, D, E, F); Brazil (sandstone reefs north of Pernambuco).

Septastrea crassa (Holmes) Pl. 46, fig. 6; Pl. 47, figs. 1, 2

1858. *Astraea crassa* Holmes, Post-Pleiocene Fossils of South-Carolina, p. 2, pl. 1, figs. 3, 3a.
1904. *Septastrea marylandica* (Conrad), ?, Vaughan, *pars*, Maryland Geol. Sur., Miocene, Syst. Paleont., pl. 129.
1911. *Septastrea crassa* (Holmes), Veatch and Stephenson, Geol. Sur. Georgia, Bull. 26, p. 378.
1919. *Septastrea crassa* (Tuomey and Holmes), Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 220, 222.
1927. *Septastrea crassa* (Holmes), Hoffmeister, *in* Mansfield, U.S. Geol. Sur., Prof. Paper 150, p. 140.
1927. *Septastrea crassa* (Holmes), Felix, Fossilium Catalogus I: Animalia, *pars* 35, p. 339.
1936. *Astraea crassa* Holmes (*A. marylandica* Conrad), Richards, Geol. Soc. Amer., Bull., vol. 47, pt. 2, p. 1647.
1956. *Septastrea crassa* (Holmes), Wells, *in* Moore, Treatise on Invertebrate Paleontology, Pt. F (Coelenterata), p. F410, figs. 306, 7a, 7b.
1971. *Septastrea crassa* (Holmes), Weisbord, Florida Bur. Geol., Geol. Bull., No. 53, p. 52.

The original description of *Astraea crassa* by Holmes was as follows:

> Corallum thick, not encrusting; stars orbicular, sometimes polygonal, irregular, deep. Lamellae about twelve, rough denticulated.
>
> The cells of this coral resemble *A. Marylandica* of Conrad; but unlike that species, it is thick and not encrusting.

The specimens referred to *Septastrea crassa* (Holmes) in this paper are large, thick, heavily calcified when mature, and branching. The branches are jagged in form, elliptical in cross section, often large and thick and hollowish to "pithy" within. On some coralla the heavy branches diverge slightly then converge and unite above, leaving a large opening in the area thus surrounded. Mature coralla are generally heavily calcified, but in the core of the branches the calices may be thin and closely resemble those of *Septastrea marylandica* (Conrad) except for the greater number (often the full complement of 12) of third-cycle septa.

The corallites are irregularly polygonal in outline: some are hexagonal, others pentagonal, a few quadrilateral or diamond-shaped, and an occasional one triangular. In the fully developed corallum the walls are thick, tightly appressed, the line of fusion between adjoining calices marked by a distinct groove, the average thickness of the wall at the calicular margin is 0.4 mm. The calicular margins, the inner surface of the wall between the septa, the sides and margins of the septa, and the columella are covered by crowded microscopic granules.

The calices are suborbicular to suboval in outline, and subequal to unequal in size. The margin of the calices is strongly nodulated, with one elongated nodule or costa at the intercept of each septum, the nodules themselves about equal in size and all of them larger than the septa with which they are conterminous. One exceptionally well-preserved specimens the inner wall of some of the calices is seen to be vertical on one side and less steep on the other. On the far side of the gentler slope the nodules or costae may curve markedly and become confluent, albeit in greatly diminished strength, with the costae of adjacent calices in the intercorallite areas. The septa on the gentler slope are actually the longer and impart a pronounced rayed or starry effect within that region of the calice.

The septa are arranged in three cycles. The 12 principal septa of the first two cycles are nearly equal in size and generally extend to the outer rim of the columella; the tertiary septa are much the smaller and project but slightly from the wall, their number varying from the full complement of 12, or one between each major, to but a few. With maturity the corallum becomes heavily calcified thereby obscuring the details of ornamentation, but even in thickened calices an occasional pair of tertiary septa may be seen to curve toward and join a secondary septum, or a secondary to join a primary just before the columella. The columella is sunken and composed of the denticulated ends of the principal septa. These become fused into a dense flattish calcareous boss which is strewn with a number of small papillae.

Endothecal dissepiments are sturdy, lamellate, somewhat inclined, and, on specimen ABD-1a, are 1.7 mm apart.

Measurements. — Specimen ABD-1a (Alum Bluff): branch length 32.5 mm, maximum diameter 26.5 mm; diameters of average calice 4.7 mm × 4.3 mm. Specimen I-2584a (Alum Bluff): branch length 30.5 mm, width 23 mm, breadth 17 mm; diameters of average calice 4.3 mm × 4.2 mm. Specimen DSD-1a (Dismal Sink): corallum height 196 mm, maximum width across branches 62 mm, diameters of main stem 30 mm × 22 mm; diameters of average calice 5.7 mm × 4.3 mm. DSD-1b: corallum length 107 mm, width 75 mm, diameters of branch 31 mm × 25 mm. Fragments from DeLeon Springs, Volusia County, in USNM collection: corallum (a) 13 mm × 11.5 mm × 7.5 mm.; corallum (b) 21 mm × 18 mm × 13 mm; corallum (c) 21.5 mm × 18.5 mm × 6.5 mm. IW-1a (Intracoastal Waterway, S.C.): corallum length 127.5 mm, max. width 85 mm, max. thickness 24 mm.

Comparison. — The immature *Septastrea crassa* is difficult to distinguish from the heavily calcified form of *Septastrea marylandica* (Conrad), yet typically the two species are distinct despite the fact that they are often found together and seem to have the same geologic range. *S. marylandica* is thin, broadly encrusting or enveloping, is light in weight, abrasive to the touch, and has sharp-rimmed calices in which there are two full cycles of septa, with only a few or no septa in the third cycle. *S. crassa*, on the other hand, although attached at the base of the corallum, is non-encrusting, thickly branched and heavy, very finely granulated on all surfaces, and has three cycles of septa, the third cycle partially to wholly complete.

Localities. — *Septastrea crassa* (Holmes) has been reported from Maryland to Florida to Louisiana within the arc of the coastal plain. It is probable that some of the forms identified as *Septastrea marylandica* in Maryland and Virginia should be referred to *S. crassa*.

North Carolina

Wilmington (No. 305 USGS) and Walter Bluff, in USNM.

Hopwood farm, south bank of Neuse River, 1 mile downstream from James City, Craven County. Collector: Frank Stapor, 28 August 1970. Yorktown Formation.

Pamlico Formation (Richards).

South Carolina

Little River. Waccamaw Formation.

Intersection of U.S. 501 and Intracoastal Waterway, 3 miles northwest of Myrtle Beach. Collector: Vernon A. Taylor.

Tilley's Lake, Waccamaw River, Horry County. No. 4400, Burns collection, USNM.

Georgia

Brunswick, Glynn County. Dredged from Brunswick River. From Miocene underlying thin Quaterary cover. Reported by Veatch and Stephenson (1911).

Florida

ABD-1a, 1b. Top of Alum Bluff, Liberty County. Duplin Marl (*Ecphora* Zone).

I-2584a, Florida Bureau of Geology. Alum Bluff, Liberty County. Choctawhatchee Miocene. Collectors: Herman Gunter and Gerald Ponton, 1928.

DeLeon Spring, Volusia County. USNM.

DSD-1a, 1b. Dismal Sink, Leon County. Duplin Marl (?) above Tampa Limestone.

Caloosahatchee Marl. Reported by Vaughan (1919).

Louisiana

From well at 2600 ft., 5 miles south of Montegut, probably upper Miocene. Occurs together with *Septastrea marylandica* (Conrad). USNM.

Range and distribution.—Late Miocene to Pleistocene. Miocene of Maryland and Virginia; Miocene, Pliocene, and Pleistocene of North Carolina; Pliocene and Pleistocene of South Carolina; Miocene and Pliocene of Florida; Miocene of Louisiana.

Septastrea marylandica (Conrad) Pl. 47, fig. 3

1837. *Astrea* sp. W. B. and H. D. Rogers, Amer. Philos. Soc., Trans., n.s., vol. 5, art. 14, pp. 338, 339, footnote.

1841. *Astrea marylandica* Conrad, Acad. Nat. Sci., Philadelphia, Proc., vol. 1, p. 33.

1845. *Columnaria (?) sexradiata* Lonsdale and *Astraea hirtolamellata* Michelin ?, Lonsdale, Geol. Soc. London, Quart. Jour., vol. 1, pp. 497-500, figs. a, b (p. 497), fig. a (p. 500).

1846. *Astroitis sexradiata* (Lonsdale), Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, p. 722.

1847. *Astraea marylandica* Conrad, Lonsdale, Amer. Jour. Sci., ser. 2, vol. 4 (54), art. XXX, p. 359.

1857. *Astrea marylandica* Conrad, Tuomey and Holmes, Pleiocene Fossils of South Carolina, p. 2, pl. 1, figs. 2, 2a.

1887. *Glyphastraea forbesi* (Edwards and Haime), Duncan, Geol. Soc. London, Quart. Jour., vol. 43, pp. 29-32, pl. III.

1888. *Septastrea forbesi* Edwards and Haime, Hinde, and *Septastrea sexradiata* (Lonsdale), Hinde, Geol. Soc. London, Quart. Jour., vol. 44, pp. 218-222, pl. 9, figs. 1-17.

1900. *Coenangia marylandica* (Conrad), Gane, U.S. Nat. Mus., Proc., vol. 22, No. 1193, pp. 190, 191, 194.

1904. *Septastrea marylandica* (Conrad), Vaughan, Maryland Geol. Sur., Miocene, Systematic Paleontology, pp. 444-447, pl. CXXVI, figs. 1a, 1b, 2; pl. CXXVII, figs. 1-3.

1919. *Septastrea marylandica* (Conrad), Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 220, 222, 411, 412.
1919. *Septastrea matsoni* Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 230, 411, 412, 511, pl. 86, figs. 6, 6a.
1932. *Septastrea marylandica* (Conrad), Roberts, Virginia Geol. Sur., Bull. 37, Educ. Ser. No. 2, pp. 31, 32, pl. 16, fig. 1.
1942. *Astrangia marylandica* (Conrad), Richards and Harbison, Acad. Nat. Sci., Philadelphia, Proc., vol. 94, pp. 178, 224.
1962. *Septastrea matsoni* Vaughan, Moore and Gunter, Bull. Marine Sci. Gulf and Caribbean, vol. 12, No. 1, p. 69.
1971. *Septastrea marylandica* (Conrad), Weisbord, Florida Bur. Geol., Geol. Bull. No. 53, pp. 47-52, pl. 12, figs. 1-7. [Numerous references 1837-1956.]

The coral illustrated (SP-2d) occurs as a thick veneer adherent to a gastropod from the Pinecrest Formation.

As originally suggested by Vaughan, it is probable that his *Septastrea matsoni* is the same as Conrad's *Septastrea marylandica*, thereby extending the range of the latter as far south as the Republic of Colombia.

Measurements. — Specimen SP-2d: length 45 mm, width 33 mm, height 31.5 mm, thickness of coral veneer about 6 mm. Collector and donor, Leslie Dyet 14 July 1969.

Locality. — Warren Brothers Pits, 4 miles east of Sarasota (U.S. 301) just off Newburn Road, 0.4 miles north of 17th Street, Sarasota County. Pinecrest Formation.

Range and distribution. — The geographic range of *Septastrea marylandica* is New Jersey to Louisiana, U.S.A., and Colombia, S.A. The geologic range is late Miocene to Pliocene and possibly to Pleistocene.

New Jersey — Sea Isle City well at Fiftieth St., 600-700 ft. depth.

Maryland — Calvert Cliffs; St. Mary's Formation, St. Mary's River.

Virginia — James Peninsula; Yorktown Formation at Bellefield, Yorktown, and many places on James River; Urbana, Rappahannock River (No. 3915 USNM); Petersburg ?, Williamsburg, Evergreen.

North Carolina — See Richards and Harbison, 1942.

South Carolina — See Richards and Harbison, 1942; Darlington District; Specimen No. 4000 in USNM, 5 miles south of Mayesfield, Sumter County; No. 4400 USNM. Tilley's Lake, Waccamaw River, Horry County; Grahamville (see Nixonville Quadrangle).

Florida — Pinecrest Formation in Warren Brothers Pits, collector Joseph E. Banks; USNM No. 243222, J. E. Ayers collection, Sarasota, Sarasota County; Jackson Bluff Formation (Weisbord, 1971); spoil bank at pump station 65D near Ft. Bassinger, and at Brighton, both in Highlands County, collected by Joseph E. Banks; Caloosahatchee Marl (I-1932 FBG), 1 mile below Hugget's Landing, Caloosahatchee River, Hendry County. Collector E. H. Sellards, 17 Nov. 1914.

Louisiana — In well at 2600 ft., 5 miles south of Montegut (USNM). Probably late Miocene.

Colombia, S.A. — Gatun Formation 0.5 km west of Usiacurí, Depto. Atlantico.

OCULINIDAE

Oculina diffusa Lamarck Pl. 47, figs. 4, 5

1816. *Oculina diffusa* Lamarck, Hist. Nat. Anim. sans Vert., vol. 2, p. 285.
1846. *Oculina diffusa* Lamarck, Dana, U.S. Exploring Expedition 1838-1842, vol. 7, Zoophytes, pp. 397, 398.
1877. *Oculina diffusa* Lamarck, Lindström, K. Svenska Vetensk.-Akad., Handl., vol. 14, No. 6, p. 14.
1880. *Oculina diffusa* Lamarck, Pourtalès, *in* Agassiz, Mus. Comp. Zool., Mem., vol. 7, No. 1, pl. 3, figs. 10-12.
1900. *Oculina diffusa* Lamarck, Vaughan, U.S. Geol. Sur., Mon. 39, pp. 49, 116, 117, pl. 2, fig. 5.
1901. *Oculina diffusa* Lamarck, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 11, pt. 1, art. IV, p. 175.
1902. *Oculina diffusa* Lamarck ? var. Vaughan, U.S. Fish Comm., Bull., vol. 20 for 1900, pt. 2, pp. 291, 294.
1902. *Oculina diffusa* Lamarck, Duerden, Nat. Acad. Sci., Washington, Mem., vol. 8, pp. 585-588, pl. 22, fig. 149.
1943. *Oculina diffusa* Lamarck, Vaughan and Wells, Geol. Soc. Amer., Spec. Pap. No. 44, pp. 180, 181, 325, pl. 33, fig. 2.
1948. *Oculina diffusa* Lamarck, Smith, Atlantic Reef Corals, pp. 62, 66, 91, pl. 28.
1956. *Oculina (Oculina) diffusa* Lamarck, Wells, Treatise on Invertebrate Paleontology, Pt. F, Coelenterata, p. F140, fig. 308, 4.
1958. *Oculina diffusa* Lamarck, Squires, Amer. Mus. Nat. Hist., Bull., vol. 115, art. 4, pp. 229, 232, 238, 256-257, pl. 38, fig. 4.
1959. *Oculina diffusa* Lamarck, Goreau, Ecology, vol. 40, No. 1, pp. 70, 75, 81, 85.
1960. *Oculina diffusa* Lamarck, T. Goreau and N. Goreau, Biol. Bull. Woods Hole, vol. 119, No. 3, p. 424.
1961. *Oculina diffusa* Lamarck, Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 9, 60-61, figs. 49, 50.
1963. *Oculina diffusa* Lamarck, Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 143, 156, 162, pl. 16a.
1966. *Oculina diffusa* Lamarck, Laborel, Mus. Nat. Hist. nat., Paris, Bull., sér. 2, vol. 38, No. 3, pp. 282, 292, 299.
1967. *Oculina diffusa* Lamarck, Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 448.
1968. *Oculina diffusa* Lamarck, Weisbord, Bull. Amer. Paleont., vol. 55, No. 246, pp. 62-65, pl. 8, figs. 1-3. [Numerous references, 1816-1967.]

1970. *Oculina diffusa* Lamarck, Mesolella, Sealy, and Matthews, Amer. Assoc. Petrol. Geol., Bull., vol. 54, No. 10, p. 1905.
1971. *Oculina diffusa* Lamarck, Olivares and Leonard, Inst. Oceanogr. Univ. Oriente, Bol., vol. 1, No. 1, pp. 49, 50, 52, 64, 67, 69, table 1, pl. 8, figs. A, B.
1971. *Oculina diffusa* Lamarck, Olivares, Inst. Oceanogr. Univ. Oriente, Bol., vol. 1, No. 2, pp. 73, 74, 75, 78, table 1.
1971. *Oculina diffusa* Lamarck, Weisbord, Florida Bur. Geol., Geol. Bull. No. 53, pp. 9, 11, 53-55, 86, pl. 12, fig. 8; pl. 13, fig. 1.
1972. *Oculina diffusa* Lamarck, Scoffin, Science, vol. 178, No. 4067, p. 1280.
1972. *Oculina diffusa* Lamarck, Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 548, 572, 573, 578, pls. 2, 8.

Four specimens (5B-2a to 2d) from Unit A are identified as *Oculina diffusa* Lamarck. The coralla are irregular branches diverging from a compressed stem. The calices are more or less circular to broadly oval, about 3.2 mm in average diameter, and of moderate depth (about 1 mm). The calicular margins are slightly elevated, somewhat thickened, and a little rounded, a few of them nearly touching each other, but most of them separated by intervals varying from 0.5 mm to 5.5 mm. There are 24 septa in three cycles; the septa are not quite equal in size, the primary ones a trifle larger than the secondaries, and the secondaries a mite larger than the tertiaries, the last often uniting with the secondaries just before the columella. The septa are serrulate or dentate on the free margin and finely spinulose on the sides. At the inner end of each principal septum there is a low palus. The costae, which are conterminous with the septa, are short, prominent, and subequal, extending down the calice to its base but rarely across the space between the corallites. The surface of the costae and that of the coenosteum which is dense, is finely and closely granulate. The columella is calcified, and from it arise pseudopapillae, suggesting that originally the columella was stamen-like.

Measurements. — SB-2a: length of corallum 21 mm, maximum width 8.5 mm, diameters of branch 5 mm × 5 mm. SB-2b: length of corallum 20 mm, maximum width 8.5 mm, diameters of branch 7 mm × 6.5 mm. SB-2c: length of corallum 35.5 mm, maximum width 28 mm, diameters of branch 7.5 mm × 6.5 mm. SB-2d: length and width of corallum 28.5 mm, diameters of stem 16 mm × 8 mm. CAL-8a: length of corallum 41 mm, maximum width 27.5 mm.

Locality. — Pit at South Bay water plant, South Bay, Palm Beach County, Florida. Unit A (Glades Formation). Collected by Joseph E. Banks, donated 28 October 1969.

Comparison.—The calices of the fossil specimens are not so deep as, and the septa are a little thicker than in the living *O. diffusa* inhabiting the waters around Key West, Florida. However, making allowances for the normal variation of the species plus fossilization and consequent modification, the South Bay specimens seem referable to this species. At South Bay, *Oculina diffusa* Lamarck occurs together with *Archohelia limonensis* Vaughan.

Range and distribution.—The geologic range of *Oculina diffusa* is Mio-Pliocene to Recent; the geographic range is from Bermuda in the north to Venezuela in the south.

Mio-Pliocene—Florida (Jackson Bluff Formation); Venezuela (Cubagua).

Pliocene—Florida (dredged at North St. Petersburg, Pinellas County, 900 ft. east of 9th Street and a short distance south of 7th Avenue; in Caloosahatchee River at Hugget's Landing, 3 miles west of LaBelle, Hendry County, and 2-5 miles west of LaBelle, collector Mike Strong).

Plio-Pleistocene—Florida (South Bay, Palm Beach County).

Pleistocene—Florida (St. Lucie County ?); Bahamas (Bimini); Panama Canal Zone; Barbados; Venezuela (Abisinia Formation).

Recent—Florida (St. Andrews Bay, Bay County; Bald Point, Gulf County; Alligator Point, Franklin County; Tortugas; Key West, Monroe County; off Miami, Dade County); Bahama Islands; Bermuda (Ferry Reach; North Lagoon); Mexico (off Vera Cruz); British Honduras; Pedro Bank; Jamaica (3 m to 15 m; Ocho Rios); Panama; Cuba; Puerto Rico (10 to 16 fathoms); St. Thomas; Martinique; Barbados (west coast); Venezuela (Puerto La Cruz, Edo. Anzoategui; Bahía de Mochima, Edo. Sucre at Lance Manguillas, Costa Maringinia, Punta Gruesa, Punta Garrapata, Punta Las Maritas, Playa Blanca de Las Maritas, Playa Blanca de Guaiguá, Ensenada Mangle Quemao, Ensenada El Aguirre, Ensenada Carenero, Ensenada El Inglés, Ensenada Botella, Barranca de Mochima; Golfo de Cariaco, Zonas A-I).

Oculina sarasotana Weisbord Pl. 48, figs. 1-4

1971. *Oculina sarasotana* Weisbord, Florida Bur. Geol., Geol. Bull. 53, pp. 55-57, pl. 12, fig. 8; pl. 13, figs. 2-5.

A single specimen (PG-5a), collected from the "Caloosahatchee Marl" southeast of Punta Gorda, Charlotte County, is referred to this species. The corallum, a large divaricating branch, oval in cross section and representing the remnant of an originally much larger oculinid, is much the same as the type of *Oculina sarasotana* (SP-1a) from the Pinecrest Formation in Sarasota County.

The corallites are variously polygonal in outline (mostly pentagonal and hexagonal) and tightly appressed to each other, the line of demarcation between them indicated by a linear valley. The calices are shallow and subcircular, averaging about 2.4 mm in greater diameter but attaining as much as 3.3 mm, and separated one from the other by spaces of 0.5 mm to 1.3 mm. The calicular margins are slightly elevated and costate, the costae short, thick and nearly equal in size. There is one costa for each septum, but all of them are thicker than their corresponding septa. The costae are finely granulose on the surface as is the coenosteum between the corallites.

As in the type of *O. sarasotana,* specimen PG-5a normally bears 24 septa in three complete cycles. The primary and secondary septa are nearly equal in size, and extend to the columella; the 12 septa of the third cycle are considerably smaller and project only slightly from the wall. The principal septa are a little exsert, granulose on the sides, dentate along the free margin, and paliform near the columella. At the inner ends, the pali are often papillar and become part of the columella which itself is papillate and often fused.

Measurements.—Specimen PG-5a: corallum (branch) length 132 mm, diameters at ends of main branch 24.5 mm × 19.5 mm and 21.5 mm × 14.5 mm. Specimen TEL-2a: corallum (basal branches) length 90 mm, maximum width 39 mm, maximum thickness 27 mm.

Locality.—PG-5a, about 3.5 miles southeast of Punta Gorda, Charlotte County, on road to Punta Gorda airport, 1.4 miles south of entrance to Tee and Green Eastates. Collected by Leslie Dyet 18 June 1971. TEL-2a, 18 miles due east of Punta Gorda, Sect. 3, T41S, R26E Telegraph Swamp Quadrangle NW. Collector Frank H. Wind, August 1972.

Range and distribution.—*Oculina sarasotana* is now known from the Caloosahatchee, the Pinecrest, and the Jackson Bluff Formations in Charlotte, Sarasota, and Leon Counties over a distance of about 288 miles.

Archohelia limonensis Vaughan Pl. 47, figs. 6, 7

1919. *Archohelia limonensis* Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 222, 223, 228, 352-354, 510, pl. 80, figs. 1, 1a, 1b, 2, 3.
1929. *Archohelia limonensis* Vaughan, Felix, Fossilium Catalogus I: Animalia, pars 44, p. 601.
1943. *Archohelia limonensis* Vaughan, Vaughan and Wells, Geol. Soc. Amer., Spec. Pap., No. 44, p. 181.
1964. *Arcohelias* [*sic*] *limonensis* Vaughan, Olsson and Petit, Bull. Amer. Paleont., vol. 47, No. 217, p. 521.

The original description of *Archohelia limonensis* by Vaughan was the following:

> Corallum composed of relatively slender branches. The following are measurements of the cotypes:
>
> *Dimensions in millimeters of cotypes of Archohelia limonensis.*

Branch	Length	Diameter		Calices	
		Lower end	Upper end	Diameter	Exsert
1	25	4.5	4	2.5-3	1-3.5
2	31	4.5	4	2-2.6	0.5-3.5
3	33	4	3.5	2.3-3	1-7

> The cavity of the axial corallite is about 2.25 in diameter. The foregoing tables give the dimensions and amount of the projection of the radial calices — the diameters stated are as measured from the outside of the walls. The distance between adjacent calicular margins is about 2.5 mm. on branch No. 2; in extreme cases it ranges up to as much as 7 mm., as between some calices on branch No. 3. The arrangement is in more or less definite spirals. Subequal or slightly alternating costae, with closely granulate surfaces, correspond to all septa just below the calicular edges; lower down on the corallite limbs they flatten and become subequal; they may continue on the coenenchymal surface or disappear. The calicular cavities are excavated; moderately deep, about 1.5 mm.
>
> Septa normally in three complete cycles; primaries as a rule slightly larger than the secondaries, both cycles reach the columella, and have subequal, slighty exsert upper margins; tertiaries smaller than the secondaries and have lower upper margins. Inner edges of the tertiaries free, but in some systems they fuse to the sides of included secondary septa. Single or double paliform teeth on the inner ends of the primaries and secondaries. Septal faces closely granulate.
>
> Columella papillate.
>
> Coenenchyma dense; with or without costal prolongations from the calicular peripheries; fine granulations scattered over its surface.
>
> *Localities and geologic occurrence.* — Costa Rica, Limon, as follows: Station 2692, collected by R. T. Hill; Moin Hill, Niveau *d* and No. 461, collected by H. Pittier; station 5884*b*, Moin Hill, collected by D. F. MacDonald. The geologic horizon seems to be Pliocene.
>
> Florida, station 3300 in the Pliocene Caloosahatchee marl of Shell Creek, collected by Frank Burns.
>
> *Cotypes.* — No. 324809, U.S.N.M. from Niveau *d*, Moin Hill, Port Limon (3 specimens). [Syntypes.]

In the Florida State University collection, three specimens collected from Unit A, or the Glades Formation, are also referred to *Archohelia limonensis* as they accord very well with the types (U.S. Geological Survey 135643 and 2692 Limon) from Costa Rica. The Unit A coralla (SB-1a, 1b, 1c) are single slender branches (one of them tapering) bearing radial corallites which project outward in varying amount, and possess an axial corallite at both ends of the branch. The height of the corallites above the level of the coenosteum varies from 0.6 mm to 5.2 mm (on SB-1c), the average elevation being 2 mm or so. The calicular diameter of the axial corallite ranges from 2 mm to 3 mm. The corallites are separated, the distance between them varying from 0.1 mm to 2.4 mm at their base, and from 1.3 mm to 4.4 mm at the margins of the calices. The calices are more or less circular at their circumference, and range in diameter from 2.1 mm to 2.7 mm for an average of about 2.3 mm, and a depth of 0.9 mm.

The septa are laminar and exsert, and normally there are 24 of them in three complete cycles. The primary septa are the largest, and are exsert about 0.33 mm.; the secondary septa are a little smaller and slightly lower, and are exsert about 0.22 mm; the tertiary septa are the smallest and lowest, and are exsert about 0.11 mm. The septa of the first two cycles extend to the columella, and there are single to occasionally double paliform lobes on the inner ends. The margins of the septa are serrulate or dentate, and the faces are finely and closely granulate.

The costae are conterminous with the septa, but unlike them are subequal in size. Just below the calicular margin the costae are discrete and granulate to subspinose on the surface; farther down on the corallite limbs where they flatten, they are closely granulate and disappear to merge with the equally granular coenosteum.

The columella is distinctly papillate, the papillae drusy or frondose.

Measurements. — Specimen SB-1a: corallum branch length 15.3 mm, maximum width including projecting corallites 8 mm, average diameter of branch proper around middle 3.5 mm. The measurements in the same sequence as the foregoing are 21.7 mm, 9 mm, and 4.6 mm on SB-1b, and 23.5 mm, 9.8 mm, and 4.9 mm on SB-1c. Specimen USNM-135643: length 29.5 mm, diameter of branch at middle 5.6 mm.

Locality. — In pit at South Bay water plant, South Bay, Palm Beach County, Florida. Collected by Joseph E. Banks, and indicated by him that the corals occur in Unit A. Olsson (1969), who described the unit, suggested it is upper Pliocene or lower Pleistocene in age.

Range and distribution. — This species is now known from the Caloosahatchee Marl (Pliocene) and Unit A (Plio-Pleistocene) of Florida, and from the Pliocene and Pleistocene (?) of Costa Rica.

MEANDRINIDAE

Meandrina maeandrites (Linnaeus) Pl. 49, figs. 1, 2

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1972. *Meandrina meandrites* (Linnaeus), Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 548, 552, 574, 578, fig. 11, pl. 9.

The following is a description of USNM specimen 325303, identified by Vaughan as *Meandrina maeandrites* (Linnaeus), from the "Caloosahatchee Pliocene, Florida."

The corallum is large, meandroid, and short conical, with a flattish subcircular upper surface, asymmetrically tapering sides, and a smallish base. Most of the valleys are long, slightly sinuous here and there, and interconnected, radiating away from a "central" area which is much nearer one side than the other. The valleys in the off-centered region are small and "U"-shaped, and such smaller valleys diverge from the main ones. The collines are acute at the crest, but widened and porose where weathered. The main valleys, from colline to colline, vary from 8 mm to 13 mm in width and 6 mm to 11 mm in depth. As shown in end view, the corallites are tall and tightly appressed, their width gradually increasing upward. Some of the corallites are bifurcate near the middle of their course, others near their summit. The exterior of the corallites is traversed longitudinally by numerous slightly vermicular costae which are finely serrate or granulate along the crest.

Depending on where the measurements are made, there are 8 to 16 septa in one centimeter of length. In some places all of the septa are subequal, but in others they alternate in size. The septa normally are laminar, a little exsert, and conterminous with the costae at the wall, over which they are arched. The summits of the principal septa are often flexed or slightly breached to form the barest trace of a groove along the crest of the colline; however, where weathered the groove is widened and deepened. About half of the septa are principal ones and extend to the columella where they curve perceptibly before joining or becoming part of it. A number of the principals bend toward each other near the columella, with one minor septum between them; other principals bend in the same direction for a short distance to be followed in the same series by a few bending toward the former. The faces of the septa are minutely but distinctly granulate. The margins of the septa have a nearly vertical slope, and by virtue of the granulations on the faces being close to them, the margins appear faintly denticulate.

The columella is laminar in stretches and is a continuation of the lower end of certain septa which curve markedly in the columellar area. In other stretches the columella consists of twisted trabeculae or of two or three more or less continuous parallel laminae; elsewhere the columella may be discontinuous, rudimentary, or seemingly absent.

Measurements. — Corallum of USNM 325303, diameters of upper surface 160 mm × 150 mm, height 85 mm, area of base about 25 × 24 mm.

Locality. — Probably Shell Creek, Charlotte County, Florida. Collector: Dr. Griffith. Formation: Caloosahatchee Marl.

Comparison. — USNM specimen 325303, which is the largest I have seen recorded in the literature, meets the diagnosis of *Meandrina meandrites sensu stricto* except perhaps for its short conical form which I think is an individual rather than specific character, dependent on growth conditions. The species is not to be confused with *Meandrina brasiliensis* (Edwards and Haime) which is also conical below but plumper and possessing a short true stalk. The valleys of *M. brasiliensis* (re-named *M. meandrites danae* by Goreau and Wells, 1967, p. 448, footnote 5) are also interconnected as in *M. meandrites,* but in *M. brasiliensis* there is a single lengthwise central valley with side valleys opening off from the main one.

Range and distribution. — The geologic range of *M. meandrites* is upper Miocene to Recent; the geographic range is from Bermuda to Venezuela.

Upper Miocene — Dominican Republic (Mao Adentro Limestone).

Pliocene — Florida (Caloosahatchee Marl).

Pleistocene — Florida (Key Largo Limestone); Dominican Republic ("coast limestone at Cabral, Provincia de Barahona"); Guadeloupe ?; Curaçao; Barbados (low level reefs near Bridgetown; Chelston Quarry, St. Michael Parish, elevation 100 ft.).

Recent — Bermuda (North Rock; The Boilers); Bahamas (Nassau; Bimini; Abaco Island); Florida (Florida reef tract); Cuba; Jamaica (0.5 m to 70 m; Ocho Rios); Mexico (Isla de Lobos); Pedro Bank; British Honduras (Rendezvous Cay, Turneffe, Lighthouse Reef, Glover's Reef); Puerto Rico (off Culebra; Cayo Icacos, back reef); St. Thomas (Sail Rock, 24 m to 74 m); St. Bartholomew; Guadeloupe; Martinique; Netherlands Antilles: St. Eustatius. Bonaire (Boca Bartól, Lont, Ruin, Klein Bonaire, Plaja Sarna, Baca, Blauwe Pan). Curaçao (Plaja Abao, Boca Santa Marta, Portomaribaai, Daaibooibaai, Vaarsenbaai, Piscaderabaai, Westpuntbaai, Zaquito, Spaanse Water, Kaap Malmeeuw). Aruba (Malmok, Barcadera); St. Martin (Baie Rouge, Mullet Pond Bay, Mahó Bay, Great Bay); Panama (San Blas); Barbados (west coast), (15 m to 24 m); Venezuela (Bahía de Mochima, Edo. Sucre, at Ensenada Cabruta, Ensenada Cabruta Roja, Ensenada El Aguirre, Ensenada de Centeno, Ensenada El Inglés, Ensenada Cabruta Blanca, Ensenada, Botella, Punta Aguirre; Puerto La Cruz, Edo. Anzoategui).

Also reported from Florida is *Meandrina brasiliensis* (Edwards and Haime) which is said to occur in the Recent fauna but not as a fossil. No examples of *M. brasiliensis* are contained in the Florida State University collection, but for comparative purposes there is appended below all of the references I have been able to find on this species, as well as the original descriptions of *Ctenophyllia brasiliensis* and the synonymous *Ctenophyllia danae* by Edwards and Haime.

Meandrina brasiliensis (Edwards and Haime)

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1848. *Ctenophyllia Danae* Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 10, p. 279. [*Fide* Goreau and Wells, 1967, p. 19.]
1848. *Ctenophyllia fissa* (non *Manicina fissa* Ehrenberg), *C. quadrata, C. brasiliensis, C. danae* Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 10, pp. 278, 279, pl. 6, fig. 7. [*Fide* Matthai, 1928, p. 167.]
1851. *Pectinia Brasiliensis* (Edwards and Haime), Mus. Nat. Hist. nat., Paris, Arch., vol. 5, p. 57.
1851. *Pectinia sebae, P. quadrata, P. brasiliensis, P. danae* (Edwards and Haime), Mus. Nat. Hist. nat., Paris, Arch., vol. 5, p. 57. [*Fide* Matthai, 1928, p. 167.]
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1928. *Pectinia brasiliensis* (Milne Edwards and Haime), Matthai, Catalogue of the Madreporarian Corals in the British Museum (Natural History), vol. 7, A Monograph of the Recent meandroid Astraeidae, pp. 159, 160, 162, 167-169, pl. 42, figs. 1-4; pl. 62, fig. 16.
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1960. *Meandrina braziliensis* (Milne Edwards and Haime), Lewis, Canadian Jour. Zool., vol. 38, No. 6, pp. 1135, 1139.
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1961. *Meandrina braziliensis* (Edwards and Haime), Goreau, Endeavour, p. 34, fig. 3.
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1967. *Meandrina meandrites* forma *danae* (Edwards and Haime), Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 448, footnote 5.
1972. *Meandrina brasiliensis* (Edwards and Haime), Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 542, 548, 573, 574, 578.

The original description of *Ctenophyllia* [*Meandrina*] *brasiliensis* by Edwards and Haime was the following:

> 4. Ctenophyllia Brasiliensis.
>
> (Pl. 6, fig. 7)
>
> *Polypier* en cône comprimé, pédicellé, et devenant libre les progrès du développement. *Plateau* commun, montrant dans sa moitié supérieure seulement des côtes formées par de grosses granulations bien séparées. La principale série de polypiérites est en zig-zag. Les murailles minces en certain points, mas très épaisses dans d'autres, et présentant en dessus des granulations crépues très fortes et irrégulières. Les valées son étroites et profonds. *Cloisons* un peu débordantes, médiocrement épaisses, à faces couvertes de grains très nombreux et saillants, à bord présentant quelques denticulations d'une excessive finesse; elles sont très inégales, et paraissent appartenir à trois cycles.
>
> Hauteur de nos exemplaires, 6 centim.; largeur des séries, 15 ou 20 millim.; leur profondeur es un peu moindre.
>
> Habite les côtes du Brésil. — Coll. M. et Michelin.
>
> Peut-être l'espèce que M. Ehrenberg a nommée *Manicina praerupta* (*Corall.*, p. 103), et qu'il cite comme provenant des Antilles, est-elle identique avec celle-ci; mais elle est trop imparfaitement décrite pour que nous puissions décider cette question.

The original description of *Ctenophyllia (Meandrina) danae* by Edwards and Haime is the following:

> 5. Ctenophyllia Danae.
>
> *Polypier* ayant la forme générale de la *C. Brasiliensis.* Les côtes du plateau commun son recouvertes inférieurement par un épithèque plus développée que dans les autres espèces, et ne sont distinctes qu'en haut, où celles sont peu saillantes, et non granulées. La principale vallée sensiblement droite, et les valées dérivées lui étant perpendiculaires. Murailles un peu épaisses, a ligne de faîte présentant un sillon superficiel. *Cloisons* paraissant appartenir à trois cycles. Les principales épaisses, très fortes, un peu débordantes. Hauteur du polypier, 6 centim.; largeur des séries, de 25 à 30 millim.; profundeur des valées, 18. On compte quatorze cloisons grandes et petites dans une largeur d'un centimètre.
>
> Habite. . . . . — Coll. M.

So far as I am aware, *M. brasiliensis* (or *M. meandrites danae*) has not been reported as a fossil. The Recent form is recorded as ranging from Brazil northward to Florida as follows: Brazil, from south to north, (Vitoria, State of Espirito Santo; Recife de Lixo near Abrolhos in 2 feet of water at low tide; Itaparica Island in Bahia Bay; on beach between Rio Manguába and Rio Camaragibe, State of Alagoas); Venezuela (Bahía de Mochima, Edo. Sucre, 4 meters to 15 meters, at Punta Garrapata, Punta Aguirre, Punta Barranca, Ensenada Aguirre); Barbados; Jamaica (8 meters to 80 meters); Cuba; Florida; Bahamas.

Dichocoenia caloosahatcheensis, new species Pl. 48, fig. 5; Pl. 50, fig 1; Pl. 51, fig. 1; Pl. 52, figs. 1, 2

1919. *Dichocoenia* new species Vaughan, *nomen nudum,* U.S. Nat. Mus., Bull., vol. 103, No. 9, p. 222.

The following description applies to two specimens of 325299 (#3206) in the National Museum of Natural History labeled *Dichocoenia caloosahatcheensis* Vaughan, from the Caloosahatchee River, Florida. The taxon seems to have been labeled by Dr. Vaughan, and it is conjectured the name was meant to replace *Dichocoenia,* new species Vaughan (1919, p. 222) which itself is a *nomen nudum.* So far as I am aware the description of *D. caloosahatcheensis* was never published and is done so in this report to validate the name.

The larger corallum of 325299 is tall and pear-shaped, the underside rounded before merging into an irregular peduncular area of substantial proportion. The peduncle proper is not complete, most of it having been broken away, but it seems to have been swollen immediately below the base of the corallum itself. The smaller corallum of 325299 is hemispherical with an evenly convex head and an eroded base, the original character of which is indeterminate.

Despite the difference in size and form of the coralla, the calices of both specimens have roughly the same measurements and distribution. The calices are mono-, di-, and tri-stomodaeal, the monostomodaeal ones subcircular or oval, the distomodaeal ones elliptical with compressed sides, and the tri-stomodaeal ones trilobate or, in one instance, substellate. The subcircular calices are the smallest, measuring 4.5 mm in diameter, and with 24 septa; a typical oval calice measures 6 mm × 5 mm, with 30 septa; an average compressed elliptical calice is 10 mm in length, 5 mm across the middle and 6 mm or so near the ends, and bears 38 septa; the longest calice is a narrow tristomodaeal one, 15 mm in length, 2 mm to 2.5 mm in width at the narrowest sides, and about 4 mm in width across the wider ends, with 54 septa. A few of the calices are united but the calicular margins of most are separated, the distances varying from less than one millimeter to as much as 6 mm. All of the calices on the two coralla are weathered down, and as they now appear they are only slightly elevated, averaging 1.4 mm in height above the coenosteum, and are shallow, averaging about 0.7 mm in depth. The wall is thin at the calicular margin, about 0.15 mm, but considerably thicker at the level of the coenosteum where it is about 1.5 mm.

In the average monostomodaeal calice there are 28 to 30 septa in four cycles, the fourth cycle always incomplete and barely represented. The primary septa are a little larger than the secondaries, the secondaries considerably larger than the tertiaries, and the tertiaries slightly larger than the few quaternaries. The primary septa descend to unite with the columella, just before which the primaries are joined by the secondaries. The tertiary septa in turn join the secondaries higher within the calice, whereas the quaternaries are rudimentary and extend only part way down the wall. The septa are only slightly exsert and are arched at the wall where they are conterminous with the costae. The principal septa broaden below to become lobate, although the character of the inner lobes cannot be discerned. The septa are alternately thick and thin, the former meeting the columella, their septal margins rather coarsely dentate and descending steeply before rising into paliform lobes. The faces of the septa are granulate, the granulations aligned in short tiers on the trabeculae.

The costae are conterminous with the septa, are subequal to alternating, and are coarsely granular; they descend down the sides of the corallites to the base, but generally do not continue on to the valley floor between them. However, near the base of the corallum proper, the costae continue as a stream on to the under sides and over the pedicel below.

The endothecal dissepiments are membranous, dividing the interior into narrow rectangular cells. The exothecal laminae are coarse and crinkled, subequal to unequal in size, and connect adjoining corallites; there are four to six of them to the centimeter. The columella is composed of a few twisted trabeculae, and is about one millimeter in breadth in a monostomodaeal calice. In polystomodaeal calices the individual columellas may be connected by a single directive septum or lamina.

Measurements. — Holotype (USNM 325299a): corallum height 140 mm, width below middle 107 mm × 91 mm; pedunculate area 55 mm × 47 mm. Paratype (USNM 325299b): corallum height 52 mm, diameter of head 60 mm × 55 mm. USGS specimen 325300 (3300): corallum fragment, height 65 mm, diameter of head 45 mm × 35 mm.

Localities. — Caloosahatchee River and Shell Creek, Florida. The Shell Creek locality for *D. caloosahatcheensis* is for USGS specimen 325300 (3300), collected by Frank Burns, and labeled *Dichocoenia stokesi* M. Edw. & H. but with the specific name *stokesi* crossed out.

Comparisons. — This species is so similar to *Dichocoenia stokesii* Edwards and Haime *sensu lato* that it might be considered the same or a variant thereof under its broad taxonomic latitude. However, I have neither seen nor gathered from the literature that *D. stokesii* is peduncular and for that reason plus the fact that Vaughan, who had many good specimens of *D. stokesii* in the U.S. National Museum to compare it with, thought *D. caloosahatcheensis* was distinct, also persuade me to consider *D. caloosahatcheensis* as a new species. Another species closely related to, if not identical with *D. caloosahatcheensis* is *Dichocoenia merriami* (Vaughan) (1917, pp. 370, 371, pl. XCIV, figs. 1, 1a) from the Carrizo Creek Formation of California. In discussing *D. merriami*, Vaughan (1917, p. 371) stated: "A closely related species is found in the Pliocene Caloosahatchee marl of Florida, but descriptions and figures of it have not been published." The Florida taxon referred to by Vaughan is *D. caloosahatcheensis*, n. sp., and although I see little to differentiate the two, Vaughan must have been able to separate them, possibly taking into account the vast distance separating the two similar taxa.

Compared with the peduncular *Barysmilia intermedia* Duncan (1863, pp. 431, 432, pl. 15, fig. 4) from the upper Miocene of the Dominican Republic and with the peduncular *Dichocoenia eminens*, n. sp. from the Pliocene Caloosahatchee Marl of Florida, *D. caloosahatcheensis* is distinguished by its smaller, closer, and considerably less elevated calices.

Dichocoenia eminens, new species

Pl. 53, figs. 1-3; Pl. 54, figs. 1, 2; Pl. 55, figs. 1-3

1919. *Dichocoenia* new species Vaughan, *nomen nudum,* U.S. Nat. Mus., Bull., vol. 103, No. 9, p. 222.

This species is described from two specimens in the Florida State University collection (PG-2a and FLX-14a) and from two specimens in the collection of the National Museum of Natural History (325293 #4995 and 325305 #3206).

The adult corallum is large, plocoid, low conical to ellipsoidal, and massive, with an evenly rounded hemispherical head. Below, specimen PG-2a has irregularly bulging sides which converge to a robust pedunculate base. Specimen FLX-14a is also pedunculate. USNM specimen 325293, however, is not now pedunculate, having a slightly convex base with a central concave area covered by corallites like those on the evenly hemispherical upper surface. It is inferred that this specimen was originally pedunculate, but that the pedicel was broken off, and that calicular growth continued over the scarred area. Specimen USNM 325305 is a large hemispherical form, the lower portion of which has been sectioned.

The corallites on the head are erect and protuberant in marked degree, their elevations varying from 12 mm to 18 mm on the upper surface to as much as 37 mm on the sides. The summits of the corallites conform with the arc of sphericity so that the top of the corallum is evenly convex. The corallites are rather regularly distributed and arise in discrete series of twos and threes from their bases, the bases separated 4 mm to 6 mm from their nearest neighbors. The coenosteum between the corallites is thick and granular.

The calices, whose long axis is in no definite direction, are oval or narrowly elliptical and compressed on the sides, or trilobate. The oval calices are generally monostomodeal, the elliptical ones distomodaeal, the trilobed ones tristomodaeal. The wall of the calices is thin at the calicular margin but thickens progressively to the base where it may attain a thickness of nearly 2 mm. A typical oval calice measures 7 mm × 5.5 mm and bear 30 septa; an average elliptical calice measures 14 mm in length, 5 mm across the compressed sides, and 6 mm in width near each end, with a total of 66 septa; an average calice with three centers measures 11 mm × 9 mm, with 64 septa. The longest calice is an elliptical one 16 mm in length with 72 septa in a corallite 17 mm high. The calices are moderately deep, 3 mm to 5 mm.

The character of the septa is well displayed in a young cluster growing out of the side of specimen PG-2a. In one typical oval calice 8.5 mm × 4.5 mm, with 70 septa and a depth of 3.5 mm in a corallite 4.3 mm in height above the coenosteum, all of the septa are laminar and a little exsert. The septa occur in four cycles and are inserted in two alternating series of thicker and thinner ones. The septa of the first cycle are a little larger and slightly more exsert than the secondaries, the secondaries are perceptibly larger than the tertiaries, and the tertiaries larger than the quaternaries which are the thinnest of all and extend only part way down the wall. The larger septa are of moderate breadth and descend rather steeply to some distance before the columella where the margins of most are notched to form pronounced paliform lobes. The lobes are normally narrow, erect, and frondose, and are thick where they merge with the columella. The margins of the septa are faintly beaded, and the faces of the septa are set with small pointed granulations.

The costae are conterminous with, and by virtue of the veneer of peritheca, somewhat thicker than the septa. They extend down the full length of the wall to the edge of the coenosteum on which they dissipate into granulations. There is one costa for each septum, but are alternately thicker and thinner in one series rather than corresponding to the varying thicknesses of the four-cycled septa. The costae are granular as is the peritheca. The endothecal dissepiments are relatively thin and short and are roughly one millimeter apart in long rectangular cells. The exotheca is well developed, the dissepiments wide and crinkled and alternating in size, about 5 of them to the centimeter.

The columella is trabecular and spongy, and averages 0.5 mm in width.

The two USNM coralla 325293 and 325305, which were labeled "cotypes" of *Dichocoenia eminens* by Vaughan, represent an invalid species the description of which I believe was to have been incorporated in a work contemplated by Dr. Vaughan but never brought to fruition in published form. It is further suggested that *Dichocoenia eminens* was applied by Vaughan to replace his *Dichocoenia,* new species Vaughan (1919, p. 222) which itself is a *nomen nudum.* Nevertheless the name *Dichocoenia eminens* is so appropriate it is retained in the presnt paper, with the holotype designated as PG-2a, the paratype as FLX-14a, and the "cotypes" as USNM 325293 and 325305.

Measurements. — Holotype (PG-2a): corallum width 96 mm, height (maximum) 80 mm, diameter of base or attachment area 50 mm × 40 mm; embedded young corallum, length 31 mm, width 21 mm, height 15 mm. Paratype (FLX-14a): corallum head, including projecting corallites 144 mm × 127 mm, height 115 mm, diameter of base or attachment area 34 mm × 20 mm. "Cotype" 325293; length 162 mm, width 155 mm, height 104 mm. "Cotype" 325305: corallum length 206 mm, width 185 mm, height above cut section 136 mm.

Localities. — The locality of PG-2a is 3.5 miles southeast of Punta Gorda, Charlotte County, Florida, 1.4 miles south of the entrance to Tee and Green Estates, on the road to the Punta Gorda airport. Collected by Leslie Dyet, 16 February 1968. The locality of FLX-14a, which is the best preserved of the four specimens, is not known but presumed to have been collected in the Caloosahatchee Marl in the Caloosahatchee River or in Charlotte County. "Cotypes" 325293 and 325305 are reported to have come from the Caloosahatchee River.

Comparisons. — The new dichocoenid, *Dichocoenia eminens,* is distinguished by, among other characters, its unusually long protuberant corallites, its prominent costae, and in some specimens its large pedunculate base. It may be compared with *Dichocoenia porcata* (Lamarck), *Dichocoenia stokesii* Edwards and Haime, *Barysmilia intermedia* Duncan, and *Dichocoenia tuberosa* Duncan. The latter two species were synonymized with *Dichocoenia stokesii* by Gregory (1895, pp. 268, 269).

On the type of *Dichocoenia porcata* (Lamarck), as described and illustrated by Matthai (1928, pp. 197-199, pl. 45, fig. 2), the corallites although indeed protuberant are not nearly so much so as on *D. eminens;* also, the calices of *D. porcata* are far more diverse and in greater disarray, and the base not peduncular as on *D. eminens*. The corallites of *Dichocoenia stokesii* are even less elevated than those of *D. porcata,* and *D. stokesii* has a flattish rather than pediculate base. *Barysmilia intermedia* Duncan (1863, pp. 431, 432, pl. 15, fig. 4), with its trunklike basal prolongation and elevated calices, is similar to *D. eminens,* but the calices are lower, larger, and broader, the costae finer, and the columella rudimentary. Like *B. intermedia, Dichocoenia tuberosa* Duncan (1863, p. 432, pl. 15, figs. 5a, 5b) is also from the upper Miocene of the Dominican Republic and resembles both *Barysmilia intermedia* and *Dichocoenia stokesii,* but Vaughan (1919, p. 360) implied that neither *D. tuberosa* nor *D. stokesii* is peduncular as is *D. eminens,* the new species.

Because all of the known species mentioned above have been synonymized with *Dichocoenia stokesii* Edwards and Haime by one author or another, it may be appropriate to list the references to *D. stokesii,* which follow:

Dichocoenia stokesii Edwards and Haime

1816. *Astrea porcata* Lamarck, Hist. Nat. Anim. sans Vert., vol. 2, p. 260. *non Madrepora porcata* Esper, Fortsetzungen der Pflanzenthiere, vol. 1, p. 88, pl. 71, 1797; *non Astraea porcata* Esper, Dana, U.S. Exploring Exped. 1838- 1842, vol. 7, Zoophytes, p. 225, pl. 2, fig. 5, 1848; *nec Favia porcata* Ehrenberg, K. Akad. Wiss. Berlin, Abhandl. 1832, p. 318. [*Fide* Matthai, 1928, p. 198.]

1824. *Astrea porcata* Lamarck, Lamouroux, Encyclopédie Méthodique, vol. 2, p. 132.

1836. *Astrea porcata* Milne Edwards, *in* Lamarck, Hist. Nat. Anim. sans Vert., ed. 2, vol. 2, pp. 406, 407.

1848. *Dichocoenia Stokesii* Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, vol. 10, p. 307, pl. 7, figs. 3, 3a.

1857. *Dichocoenia porcata* and *D. Stokesii* Milne Edwards and Haime, Histoire Naturelle des Coralliaires ou Polypes proprement dits, vol. 2, pp. 199, 200, pl. D1, fig. 10.

1861. *Dichocoenia Stokesi* M. Edwards and Haime, Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem. ser. 2, vol. 19, p. 341.

1861. *Dichocoenia cassiopea* and *D. pulcherrima* Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 19, pp. 341, 342. [*Fide* Gregory, 1895, p. 268.]

1863. *Barysmilia intermedia* Duncan, Geol. Soc. London, Quart. Jour., vol. 19, pp. 431, 432, pl. 15, fig. 4. [*Fide* Gregory, 1895, p. 269.]

1863. *Dichocoenia tuberosa* Duncan, Geol. Soc. London, Quart. Jour., vol. 19, p. 432, pl. 15, figs. 5a, 5b. [*Fide* Gregory, 1895, p. 268.]

1866. *Barysmilia intermedia* Duncan, Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 23, p. 165. [*Fide* Gregory, 1895, p. 269.]

1866. *Dichocoenia Stokesi* M. Edwards and Haime, Duchassaing and Michelotti, R. Acad. Sci. Torino, Mem., ser. 2, vol. 23, pp. 166, 167.

1866. *Dichocoenia cassiopea, pulcherrima, aequinoxialis, elliptica, pauciflora* Duchassaing and Michelotti, R. Acad. Sci. Torino, Mem., ser. 2, vol. 23, pp. 166, 167, pl. 9, figs. 5, 6, 9-12. [*Fide* Matthai, 1928, p. 198.]

1866. *Dichocoenia tuberosa* Duncan, Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 23, p. 168.

1868. *Barysmilia intermedia* Duncan and *Dichocoenia tuberosa* Duncan, Geol. Soc. London, Quart. Jour., vol. 24, p. 23.

1870. *Dichocoenia cassiopea, pulcherrima, aequinoxialis, elliptica, tuberosa,* phytes at des Spongiaires des Antilles, p. 27.

1870. *Dichocoenia cassiopea, pulcherrima, aequinoxialis, elliptica, tuberosa,* Duchassaing, *ibid,* p. 27.

1871. *Dichocoenia stokesi* Edwards and Haime, Pourtalès, Mus. Comp. Zool., Me., vol. 2, No. 4, p. 68.

1877. *Dichocoenia Stokesi* Edwards and Haime, Lindström, K. Svenska Vetensk.-Akad., Handl., vol. 14, No. 6, p. 22.

1880. *Dichocoenia porcata* (*non auct.*) Pourtalès, Mus. Comp. Zool., Mem. vol. 7, No. 1, pl. 10, figs. 1-15. [*Fide* Gregory, 1895, p. 269.]

1881. *Dichocoenia Stokesi* Edwards and Haime, Quenstedt, Patrefactenkunde Deutschlands, vol. 6, p. 992, pl. 181, fig. 45.

1886. *Dichocoenia pauciflora* Duchassaing and Michelotti, Quelch, Voyage H. M. S. Challenger, Rept. Sci. Results, Zoology, vol. 16, pt. 46, p. 12.

1895. *Dichocoenia Stokesi* M.-Edwards and Haime, Gregory, Geol. Soc. London, Quart. Jour., vol. 51, pp. 268, 269, 285.

1898. *Dichocoenia stokesi* Edwards and Haime, Vaughan, *in* Hill, Mus. Comp. Zool., Bull., vol. 28, p. 275.

1900. *Diploria Stokesi* Edwards and Haime, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 10, art. XIV, p. 552.

1901. *Dichocoenia stokesi* Milne Edwards and Haime, Vaughan, Rijksmus. Geol. en Mineral. Leiden, Samml., ser. 2, vol. 2, No. 1, p. 9.

1902. *Dichocoenia stokesi* Milne Edwards and Haime, Duerden, Nat. Acad. Sci., Washington, Mem., vol. 8, pp. 572, 573, pl. 16, figs. 117-120.

1902. *Dichocoenia Stokesi* M.-Edwards and Haime, Vaughan, *in* Spencer, Geol. Soc. London, Quart. Jour., vol. 58, No. 21, p. 361.

1907. *Dichcoenia Stokesi* Edwards and Haime, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 12, art. II, pt. 5, p. 209.

1909. *Dichocoenia stokesi* Edwards and Haime, Vaughan, Carnegie Inst. Washington, Yearbook No. 7 (for 1908), p. 132.

1917. *Dichocoenia stokesi* Edwards and Haime, *Dichocoenia tuberosa* Duncan, and *Barysmilia intermedia* Duncan, Vaughan, U.S. Geol. Sur., Prof. Paper 98-T, p. 371, pl. XCIV, figs. 2, 2a.

1919. *Dichocoenia stokesi* Edwards and Haime, Vaughan, U.S. Nat. Mus., Bull. 103, No. 9, pp. 223, 360.

1921. *Dichocoenia stokesi* Edwards and Haime, Vaughan, *in* Vaughan *et al.,* Geol. Survey Dominican Republic, Mem., vol. 1, pp. 163(?), 167.

1927. *Dichocoenia Stokesi* M. Edwards and Haime, Felix, Fossilium Catalogus I: Animalia, pars 35, p. 305.
1927. *Dichocoenia porcata* Milne Edwards and Haime, van der Horst, Bijdr. Dierk. Amsterdam, vol. 25, p. 159.
1928. *Dichocoenia Stokesii* Milne Edwards and Haime, Matthai, Catalogue of the Madreporarian Corals in the British Museum (Natural History), vol. 7, pp. 198-201, pl. 44, fig. 1; pl. 45, figs. 2, 5; pl. 72, fig. 8a.
1944. *Dichocoenia stokesi* Milne-Edwards and Haime, Wells, Jour. Paleont., vol. 18, No. 5, p. 446.
1948. *Dichocoenia stokesii* Edwards and Haime, Smith, Atlantic Reef Corals, pp. 62, 70, 93, 94, pl. 31.
1954. *Dichocoenia stokesii* Edwards and Haime, Fontaine, Ann. Rept. Inst. Jamaica 1953-1954, p. 25.
1954. *Dichocoenia stokesii* Edwards and Haime, Smith, U.S. Fish and Wildlife Serv., Fishery Bull., vol. 55, No. 89, p. 293.
1956. *Dichocoenia (Dichocoenia) stokesi* Edwards and Haime, Wells, Treatise on Invertebrate Paleontology, Pt. F, Coelenterata, p. F415, fig. 315, 1b.
1958. *Dichocoenia stokesi* Milne-Edwards and Haime, DuBar, Florida Geol. Survey, Geol. Bull., No. 40, p. 121.
1958. *Dichocoenia stokesii* Edwards and Haime, Zans, Geol. Survey Dept. Jamaica, W.I., Bull., No. 3, p. 32.
1958. *Dichocoenia stokesi* Milne-Edwards and Haime, Squires, Amer. Mus. Nat. Hist., Bull., vol. 115, art. 4, pp. 227, 228, 232, 238, 257, pl. 34, fig. 4.
1959. *Dichocoenia stokesi* Milne Edwards and Haime, Zans, Geonotes, vol. 2, No. 1, p. 29.
1959. *Dichocoenia stokesii* Milne Edwards and Haime, Goreau, Ecology, vol. 40, No. 1, pp. 70, 75, 79, 85.
1960. *Dichocoenia stokesii* Milne Edwards and Haime, Lewis, Barbados Mus. and Nat. Hist. Soc., Jour., vol. 28, No. 1, p. 12.
1960. *Dichocoenia stokesii* Milne Edwards and Haime, Lewis, Canadian Jour. Zool., vol. 38, No. 5, pp. 1135, 1140.
1961. *Dichocoenia stokesi* Edwards and Haime, Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 9, 30, 31, figs. 19, 20.
1961. *Dichocoenia stokesi* M. Edwards and Haime, Westermann and Kiel, Natuurwetensch. Studiekring Suriname en Nederlandse Antillen, No. 24, pp. 131, 136.
1962. *Dichocoenia stokesii* Milne-Edwards and Haime, Stoddart, Atoll Res. Bull., No. 87, pp. 18, 19, fig. 12.
1963. *Dichocoenia stokesii* Milne-Edwards and Haime, Almy and Carrión Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 143, 157, 161, pl. 17, fig. a.
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1967. *Dichocoenia stokesii* (Edwards and Haime), Roos, Growth and Occurrence of the Reef Coral *Porites astreoides* Lamarck, pp. 10, 12.
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1971. *Dichocoenia stokesi* Edwards and Haime, Olivares, Inst. Oceanogr. Univ. Oriente, Bol., vol. 10, No. 2, pp. 73, 74, table 1.

1971. *Dichocoenia stokesii* Milne-Edwards and Haime, Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 4, 16, 18, 19, 22-36, 38, 39, 77, 78, pls. 41-43, text-fig. 38.

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Range and distribution. — The geologic range of *Dichocoenia stokesi* is Mio-Pliocene ? to Recent and the geographic range from Florida to Venezuela.

Mio-Pliocene — Dominican Republic ? (Cerros de Sal Formation, Provincia de Barahona).

Pliocene — Florida (Caloosahatchee Marl).

Pleistocene — Florida (dredged from harbor at Port Everglades, Broward County; Key Largo Limestone/Miami Oolite dredged in the Florida Keys, Monroe County in main ship channel in front of Old Fort Taylor; in channel between Stock Island and Cow Key; off eastern tip of Stock Island; in northern end of Raccoon Bay); Dominican Republic; St. Eustatius; St. Kitts; Montserrat; Barbados (low level terraces near Bridgetown).

Recent — Florida (southeastern patch reefs); Bahamas (Bimini; Andros Island; Hogg Island; Rabbit Cay; Turtle Rocks); Tortugas; Cuba; Jamaica (2 m to 40 m; Ocho Rios); Pedro Bank; British Honduras (Rendezvous Cay, Lighthouse Reef); Puerto Rico (in back reef in water deeper than 5 ft.); St. Thomas (24 m to 74 m); St. Bartholomew (36 m to 38 m); Montserrat (33 m to 40 m); Guadeloupe (26 m to 34 m); Dominica; Anguilla; Barbados (west coast); Netherlands Antilles: Aruba (Cudarebe, Arashi, Boca Catalina, Malmok, Barcadera). Bonaire (Goto, Jan Doran, Barcadera, Plaja Sarna, Baca, Blauwe Pan, Witte Pan, Oranje Pan, Lagún). Curaçao (Westpuntbaai, Plaja Abao, Portomaribaai, Daaibooibaai, Vaarsenbaai, Sint Michielsbaai, Piscaderabaai, Spaanse Water, Klein Curaçao). Saba (Fort Bay). St. Eustatius (Gallows Bay). St. Martin (Mullet Pond Bay, Mahó Bay, Great Bay); Venezuela (Puerto La Cruz, Edo. Anzoategui; Bahía de Mochima, Edo. Sucre at Playa Blanca de Las Maritas, Punta Blanca de Guaiguá, Ensenada Guaiguá, Ensenada Cabruta Blanca, Ensenada Cabruta Roja, Ensenada Mangle Quemao, Ensenada El Aguirre, Ensenada El Inglés, E. Carenero, E. de Centeno, E. Piedra Pelona, E. Garrapata, E. La Ballena, E. Las Maritas, Barranca de Mochima, Playa Blanca de Guaiguá, Punta San Agustin, Punta Aceite de Palo, Punta Las Maritas, Punta Botella, Punta de León, Costica Mano E'Piedra, Lance Manguillas, Costa Maringinia; Golfo de Cariaco, Zonas B, C, D, I).

The original description of *Dichocoenia stokesii* by Edwards and Haime is as follows.

> 3. Dichocoenia Stokesii.
> (Pl. 7, fig. 3, 3a.)
>
> *Polypier* en masse légerement convexe, très largement fixé, à plateau commun nu et finement strié. *Calices* très écartés en général subelliptiques, ne s'élevant que peu ou point au-dessus du coenenchyme, qui offre unie surface fortement granuleuse et chagrinée. *Côtes* très peu marquées. *Fossettes* assez profondes. *Columelle* peu développée, subpapilleuse. Trois cycles complets. *Cloisons* peu débordantes, très épaisses, peu inégales, à bord entier et fortement arqué, à faces granulées et striées près du bord. On voit des palis devant les primaires et les secondaires, et même devant les tertiaires. Largeur des calices, de 5 a 8 millim; leur profondeur, 2 ou 3.
>
> Habite Cuba. — Coll. Stokes.

Dendrogyra cylindrus Ehrenberg Pl. 56, fig. 1

1834. *Maeandra (Platygyra) spatiosa, M. (Dendrogyra) cylindrus,* and *M. (D.) caudex* Ehrenberg, K. Akad. Wiss. Berlin, Phys. Abhandl. 1832, pp. 324, 325. [*Fide* Matthai, 1928, p. 170.]

1846. *Meandrina cylindrus* (Ehrenberg), *M. caudex* (Ehrenberg), and *M. (Platygyra) spatiosa* (Ehrenberg), Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, pp. 255, 256.

1848. *Dendrogyra cylindrus* and *D. caudex* Ehrenberg, Milne Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 10, pp. 280, 281, pl. 6, figs. 9, 9a.

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1857. *Dendrogyra cylindrus, D. caudex,* and *D. spatiosa* Ehrenberg, Milne Edwards and Haime, Histoire Naturelle des Coralliaires ou Polypes proprement dits, vol. 2, p. 202.

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1871. *Dendrogyra cylindrus* Ehrenberg, Pourtalès, Mus. Comp. Zool., Mem., vol. 2, No. 4, p. 69.

1895. *Dendrogyra cylindrus* Ehrenberg, Gregory, Geol. Soc. London, Quart. Jour., vol. 51, p. 263.

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1906. *Dendrogyra cylindrus* Ehrenberg, Verrill, Connecticut Acad. Arts and Sci., Trans., vol. 12, art. II, pt. 5, p. 209.
1928. *Dendrogyra cylindrus* Ehrenberg, Matthai, Catalogue of the Madreporarian Corals in the British Museum (Natural History), vol. 7, pp. 111, 169-171, pl. 43, fig. 6; pl. 49, fig. 3; pl. 51, fig. 1; pl. 64, figs. 7, 9; pl. 65, figs. 6, 9; pl. 66, fig. 1.
1943. *Dendrogyra cylindrus* Ehrenberg, Vaughan and Wells, Geol. Soc. Amer., Spec. Pap., No. 44, pp. 189, 329, pl. 37, figs. 5, 5a.
1948. *Dendrogyra cylindrus* Ehrenberg, Smith, Atlantic Reef Corals, pp. 62, 69, 94, 95, pls. 32, 33.
1954. *Dendrogyra cylindrus* Ehrenberg, Smith, U.S. Fish and Wildlife Serv., Fish. Bull., vol. 55, No. 89, p. 293.
1956. *Dendrogyra cylindrus* Milne Edwards and Haime, Wells, Treatise on Invertebrate Paleontology, Pt. F, Coelenterata, p. F415, fig. 315, 2a, 2b.
1959. *Dendrogyra cylindrus* Milne Edwards and Haime, Zans, Geonotes, vol. 2, No. 1, pp. 29, 34.
1959. *Dendrogyra cylindrus* (Ehrenberg), Goreau, Ecology, vol. 40, No. 1, pp. 70, 75, 79, 85, fig. 16.
1960. *Dendrogyra cylindrus* Ehrenberg, Lewis, Canadian Jour. Zool., vol. 38, No. 6, pp. 1135, 1140.
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1961. *Dendrogyra cylindrus* Ehrenberg, Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 9, 28, 29, figs. 17, 18.
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1963. *Dendrogyra cylindrus* Ehrenberg, Almy and Carrión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 137, 141, 143, 157, 161, pl. XVIIb.
1964. *Dendrogyra cylindrus* Ehrenberg, Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 20, No. 81, pp. 13, 23-28, 32, 35, 41, 48.
1967. *Dendrogyra cylindrus* Ehrenberg, Roos, Growth and Occurrence of the reef coral *Porites astreoides* Lamarck . . . p. 21.
1967. *Dendrogyra cylindrus* Ehrenberg, Goreau and Wells, Bull. Marine Sci., vol. 17, No. 2, p. 448.
1970. *Dendrogyra cylindrus* Milne Edwards and Haime, Klose, *in* letter to R. O. Vernon 30 April 1970, pp. 2, 4.
1971. *Dendrogyra cylindrus* Ehrenberg, Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 37, No. 130, pp. 3, 18, 19, 22-24, 26, 28-30, 32, 76, 77, figs. 4-4, 37, pls. 38, 39.
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According to Matthai (1928, p. 170), Ehrenberg's type specimen (No. 4445 in the Berlin Museum), is a branch broken off a colony, forked at the free end and bearing three humps. The corallum rises into more or less cylindrical branches up to 30 cm in height, but the base of attachment is broad. There is a great variation at the extremities of the two arms of the fork, where the colline, columella, and septa are considerably attenuated. On the flattened region between the two arms, the valleys have become straight and narrow. Often the valleys are short, occasionally somewhat straight, 3 mm to 6 mm in width and 2.5 mm to 3 mm in depth. Several single corallites are also present. The collines are 3 mm to 5 mm in thickness, the upper surface granular and usually with a median shallow groove.

There are seven to ten septa in one centimeter; the thicker ones (1 mm) extend to the columella, and are exsert up to 1.25 mm, the exsert ends arched, usually with sharp margins, terminating at the edge of the colline groove. The columella is solid, about 1 mm thick, the centers not marked. Where the columella is absent, opposing broader septa sometimes meet across the bottom of the valley.

Smith (1948, p. 94) added that the septa are not dentate at the margin but are granular on the sides.

Measurements. — The type, which is broken, measures 300 mm in height, with diameters of 95 mm × 55 mm.

Localities. — The fossil *Dendrogyra cylindrus* occurs in the Pleistocene of Florida in the Keys where it was excavated by dredging.

Range and distribution. — Pleistocene to Recent; Florida to Barbados.

Pleistocene — Florida (Miami Oolite/Key Largo Limestone dredged off Old Fort Taylor on Key West, and off the eastern tip of Stock Island, Monroe County); Barbados (low level reefs).

Recent — Florida (Florida reef along southeast coast); Bahamas (Nassau, New Providence; Andros Island); British Honduras (Rendezvous Cay, Turneffe, Lighthouse Reef, Glover's Reef); Jamaica (Ocho Rios; 2 m to 20 m); Puerto Rico (Cayo Turrumote; Cayo Icacos); Guadeloupe; Barbados (15 m to 24 m, off west coast); Netherlands Antilles: Aruba (Barcadera). Curaçao (Playa Kalki, Westpuntbaai, Plaja Abao, Portomaribaai, Vaarsenbaai, St. Michielsbaai, Piscaderabaai. Bonaire (Plaja Frans, Jan Doran-Barcadera, Klein Bonaire, Blauwe Pan-Witte Pan).

MUSSIDAE

Mussa angulosa (Pallas) Pl. 57, figs. 1, 2

1758. *Fungus marinus, etc.* Seba, Locupletissimi Rerum Naturalium Thesauri, vol. 3, p. 201, pl. 109, Nos. 2, 3. [*Fide* Edwards and Haime, 1849, p. 245.]

1766. *Amaranthus saxeus* Knorr, Deliciae Naturae, vol. 1, p. 15, pl. A3, fig. 1. [*Fide* Edwards and Haime, 1849, p. 245.]

1766. *Madrepora angulosa* Pallas, Elenchus Zoophytorum, pp. 299, 300.

1786. *Madrepora angulosa* Pallas, Ellis and Solander, The Natural History of . . . Zoophytes, pp. 152, 153, pl. 34.

1786. *Madrepora carduus* Ellis and Solander, The Natural History of . . . Zoophytes, p. 153, pl. 35. [*Fide* Matthai, 1928, p. 204.]

1788. *Madrepora angulosa* Pallas, Esper, Die Pflanzenthiere in Abbildungen, pp. 92-95, pl. 7.

1789. *Madrepora lacera* (*pars*) Esper, Die Pflanzenthiere in Abbildungen, p. 148, pl. 25, figs. 1, 2(?).

1791. *Madrepora angulosa* Pallas, Gmelin, Systema Naturae, ed. 13, vol. 1, pt. 6, p. 3781.

1815. *Mussa angulosa* (Pallas), Oken, Lehrbuch der Naturgeschichte, Theil III, Abt. 1, p. 73.

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1830. *Lobophyllia angulosa* (Pallas), Blainville, Dictionnaire des Sciences Naturelles, vol. 60, p. 321.

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1836. *Caryophyllia angulosa* (Pallas), *Caryophyllia sinuosa* Lamarck, and *Caryophyllia carduus* (Ellis and Solander), Edwards, *in* Lamarck, Hist. Nat. Anim. sans Vert., ed. 2, vol. 2, pp. 55-57.

1846. *Mussa angulosa* (Pallas), Dana, U.S. Exploring Exped. 1838-1842, vol. 7, Zoophytes, p. 176, pl. 8, fig. 4.

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1851. *Mussa angulosa* (Pallas), Edwards and Haime, Mus. Nat. Hist. nat., Paris, Arch., vol. 5, p. 78.

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1866. *?Lithophyllia lacera* (Pallas), *?L. cubensis* M. Edwards and Haime, *Mussa carduus* (Ellis and Solander), *Mussa angulosa* (Pallas), *Mussa (Caryophyllia) sinuosa* Lamarck, *?Lithophyllia argemone, ?L. dubia, ?L. cylindrica, ?L. multilamella, ?L. radians* Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 23, pp. 171, 172, 173, pl. 8, figs. 3, 4, 12. [*Fide Matthai*, 1928, p. 205.]

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1871. *Mussa angulosa* (Pallas), Pourtalès, Mus. Comp. Zool., Mem., vol. 2, No. 4, p. 72.

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1877. *Lithophyllia cubensis* M.-Edwards and Haime, *L. argemone?, L. cylindrica* Duchassaing and Michelotti, Arango y Molina, R. Acad. Sci. Médicas, Físicas y Naturales Habana, An., vol. 14, p. 276.

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1948. *Mussa angulosa* (Pallas), Smith, Atlantic Reef Corals, pp. 62, 67, 96, pls. 34, 35.
1954. *Mussa angulosa* (Pallas), Smith, U.S. Fish and Wildlife Serv., Fish. Bull., vol. 55, No. 89, p. 293.
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1960. *Mussa angulosa* (Pallas), Lewis, Canadian Jour. Zool., vol. 38, No. 6, pp. 1135, 1138, 1140.
1961. *Mussa angulosa* (Pallas), Duarte Bello, Acuario Nac. Marianao [Cuba], ser. Educac., No. 2, pp. 9, 56, 57, figs. 45, 46.
1962. *Mussa angulosa* (Pallas), Stoddart, Atoll Res. Bull., No. 87, pp. 18, 19, 28.
1963. *Mussa angulosa* (Pallas), Almy and Carión-Torres, Caribbean Jour. Sci., vol. 3, Nos. 2-3, pp. 143, 158, 162, pl. XVIIIa.
1964. *Mussa angulosa* (Pallas), Roos, Studies on the Fauna of Curaçao and other Caribbean Islands, vol. 20, No. 81, pp. 13, 15, 16, 23, 25, 27, 29, 32, 37, 38, 43, 48, pl. VIII, figs. 14-6, 44-3.
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1972. *Mussa angulosa* (Pallas), Campos Villarroel, Soc. Venezolana Cienc. Nat., Bol., vol. 29, Nos. 122-123, pp. 549, 551, 575, 578, fig. 13, pl. 10C.

The following description is adapted from that of Matthai (1928, p. 205) and Smith (1948, p. 96).

The corallum is more or less conical and convex on the upper surface, with heavy branching corallites diverging upward from a smallish base and terminating in large calices expanded at the margin. The calices or valleys are up to 120 mm in length, 40 mm to 50 mm in maximum width, and about 20 mm in width between centers. In outline, the calices are rarely subcircular, more often oval to elliptical and compressed at the sides, and sometimes subpolygonal. There are one, two, or three columellar centers, and the valleys are constricted between these centers. The walls are 6 mm to 8 mm in thickness, and are often angular.

There are about eight septa in one centimeter, four or five of them principals, sloping to meet the columella. The margins of the septa are provided with eight to ten conspicuous bluntly-pointed teeth, broad at the base and directed obliquely upward, the upper ones the larger, up to 4 mm or 5 mm in length and 3 mm in width at the base. The sides of the septa are spinulose. The summits of the septa are considerably exsert, the principal ones about 6 mm or 7 mm, the exsert ends with two teeth. The principal septa are much broader and thicker (about 2 mm) than the subsidiaries, and this contrast is a distinguishing character of the species. The columella is well developed, the centers 4 mm or 5 mm in width, composed of thin closely interlaced trabeculae. The costae are prominent (up to 4 mm in height at the corallite rim), conterminous with the exsert ends of the septa, extending down the wall, with teeth obliquely directed upward, and decreasing in length from above downward.

Measurements. — The specimen illustrated is the one shown by Roos (1964, pl. VIII) which was collected "live" from Piscaderabaai, Curaçao. The actual diameters of the head of this specimen are about 167 mm × 158 mm, and the height of the corallum about 330 mm.

Range and distribution.—The recorded geographic range of *Mussa angulosa* is Florida to Venezuela; the geologic range is Pleistocene to Recent.

Pleistocene—Florida (Miami Oolite/Key Largo Limestone dredged off the eastern tip of Stock Island, and excavated from marl pits alongside Card Sound Bridge, Key Largo, Monroe County); Dominican Republic (coast limestone at Barbacoa, Provincia Barahona).

Recent—Florida (Florida Keys; Tortugas); Bahamas; Cuba; Jamaica (1.5 m - 59 m; Ocho Rios); Pedro Bank; British Honduras (Rendezvous Cay, Glover's Reef); Mexico (Isla de Lobos; Alacran Reef; Yucatan Shelf); Puerto Rico (Cayo Enrique, Cayo San Cristobál, Cayo Caballo Ahogado); St. Thomas; Martinique; Barbados (west coast); Curaçao (Plaja Kalki, Vaarsenbaai, Sint Michielsbaai, Piscaderabaai 10 m - 25 m, Sta. Martha Baai, Spaanse Water); Bonaire (Slagbaai); Venezuela (Bahía de Mochima, Edo. Sucre, at Playa Blanca de Maritas, Ensenada El Muerto, Ensenada El Aguirre, Ensenada Las Maritas, Ensenada Burgao, Ensenada Ballena, Ensenada El Inglés, Ensenada Carenero, Ensenada Cabruta, Costa Maringinia, Barranca de Mochima, and Punta Aguirre; Golfo de Cariaco).

Isophyllia ? desotoensis, new species Pl. 52, figs. 3, 4

The single incomplete corallum is small, depressed, and irregularly suboval in outline, with a slightly convex calicinal surface and a flattish, undulatory base which seems to have been the attachment area. The calices are relatively large for the small size of the corallum, and are horseshoe-shaped, oval or sinuously elongate. The valleys widen toward the rim and several of them have a radial arrangement away from the elongated one traversing the middle of the calicinal surface. Some of the valleys are continuous but at least one is completely closed and there may be others such on a larger corallum. The collines are well rounded and grooved along the crest, the groove produced by a notch or flexure or slight offset in the exsert summit of conterminous septa as they arch over the crest.

The average width of the collines is 4.5 mm and their height about 3.5 mm. The average width of the valleys from colline to colline is 7.5 mm. The columella is narrow, trabecular, and spongy, and varies in width from 0.5 mm to 1.7 mm.

There are 14 to 16 septa per centimeter of which eight or more are the principals, and six or more the subsidiaries. The larger septa are continuous over the collines albeit flexed or slightly severed at the crest. In one place near the edge of the corallum there is a smooth expanse of thickened coenosteum or ambulacra through which the columnar denticles of the septal margin protrude. The principal septa are subequal, exsert (up to 1.8 mm), and sturdy, a number of them thicker at the wall than at the columella, rendering them cuneate or wedge-shaped. The septa are broadly arched over the crest of the colline but below the arch the margins slope steeply to the columella where the inner ends of the septa merge with it. Here and there the septal margin is indented before the columella but no true paliform lobes are recognizable. The minor septa are thinner than the majors and extend part way down the wall; however, they too are denticulate along the margin and bear minute spiny granulations on the sides. On the margins of the principal septa, from the exsert summit to the columella, there are 10 to 15 denticles: 10 on a septum 2.8 mm in length, 11 on a septum 3.4 mm in length, and 15 on a septum 4.5 mm in length. On the exsert portion of the septum these dentations may be discrete, elongated, and columnar, somewhat like those on the comb of a fowl, but farther down the margin they are blunt and rounded. On the faces of the principal septa are small pointed granulations arranged in tiers, each tier represented at the margin by a considerably larger dentation.

Locally there are vestiges of epitheca over the non-calicinal surface.

Measurements. — Holotype (SP-3a): corallum length 26.5 mm, width 21 mm, height 11.5 mm.

Locality. — Warren Brothers Pits (in spoil) 4 miles east of US 301, Sarasota, Sarasota County, Florida, on Newbern Road 0.4 miles north of the intersection with 17th Street. Collector and donor: Joseph E. Banks. Pinecrest formation.

Comparison. — This species is akin to the Pleistocene and Recent *Isophyllia sinuosa* (Ellis and Solander). However, *I. desotoensis* differs from *I. sinuosa* in having nearly double the number of septa per centimeter, in having much narrower valleys, and in having more robust dentations on the septal margins. Nevertheless the Recent *I. sinuosa* is such a variable species that the fossil form here described under the name of *I. desotoensis* may fall within the limits of that variability. If it does, the range of *I. sinuosa* can be extended back to the Mio-Pliocene, although more specimens of the newly created *I. desotoensis* are needed for confirmation. Superficially *I. desotoensis* also resembles *Diploria sarasotana* Weisbord, n. sp., but it differs from that in having three fewer septa in one centimeter, and in having grooved and rounded collines compared with the acute collines of *D. sarasotana.*

The literature referring to *Isophyllia sinuosa* (Ellis and Solander) is the following:

Isophyllia sinuosa (Ellis and Solander)

1786. *Madrepora sinuosa* Ellis and Solander, The Natural History of . . . Zoophytes . . ., pp. 160, 161.
1791. *Madrepora sinuosa* Ellis and Solander, Gmelin, Systema Naturae, ed. 13, vol. 1, pt. 6, p. 3761.
1846. *Mussa dipsacea* and *Mussa fragilis* Dana, U.S. Exploring Expedition 1838-1842, vol. 7, Zoophytes, pp. 184-186, pl. 8, figs. 7, 9. [*Fide* Matthai, 1928, p. 297.]
1848-49. *? Caryophyllia australis; Oulophyllia ? spinosa* Edwards and Haime, Ann. Sci. Nat. Paris, sér. 3, Zoologie, vol. 11, pp. 239, 269; vol. 10, pl. 8, fig. 2. [*Fide* Matthai, 1928, p. 237.]
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Range and distribution. — The geologic range of *Isophyllia sinuosa* (Ellis and Solander) is Pleistocene to Recent; geographically the species extends from Bermuda to the Netherlands Antilles.

Pleistocene — Florida (Key Largo Limestone/Miami Oolite dredged off eastern tip of Stock Island, Monroe County); St. Eustatius (Mollusk bed 1c on Sugar Loaf).

Recent — Bermuda (North Rock, Bluchs Point, Ferry Reach, Tuckers Island, Harrington Sound, Walsingham Bay, Bethel's Island, The Boilers, Ledge Flats, Green Flat inner reef); Bahamas (Rabbit Cay, Turtle Rocks, Bimini, Coconut Point); Florida (reef along southeast coast and Tortugas, Gulf of Mexico); British Honduras; Pedro Bank; Cuba; Jamaica (1 m to 10 m; Ocho Rios); Puerto Rico (Cayo Icacos); St. Thomas; Montserrat (33 m to 40 m); St. Bartholomew; Guadeloupe; Barbados (west coast); Netherlands Antilles: Aruba (Arashi, Boca Catalina, Malmok, Eagle Beach, Palm Beach). Bonaire (Boca Bartól, Plaja Frans, Baca, Punt Vierkant, Blauwe Pan, Witte Pan). Curaçao (Westpuntbaai). Saba (Fort Bay, Cove Bay). St. Martin (Baie Rouge, Mahó bay, Burgeux Bay, Simson Bay, Cay Bay, Great Bay, Point Blanche Bay, Guana Bay, Gibb's Bay, Babit Point). St. Eustatius (Cocoluth Bay, Jenksins Bay, Tumbledown Dick Bay, Gallows Bay, Compagnie Baai, Schildpadden Baai).

Mycetophyllia lamarckiana Edwards and Haime Pl. 53, figs. 4, 5

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1866. *Mycetophyllia lamarckii* and *M. danai* Edwards and Haime, Duchassaing and Michelotti, R. Accad. Sci. Torino, Mem., ser. 2, vol. 23, p. 173.
1870. *Mycetophyllia lamarcki* and *M. danai* Edwards and Haime, Duchassaing, Revue des Zoophytes et des Spongiaires des Antilles, p. 29.
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Descriptions of this species may be summarized as follows:

The corallum is subturbinate, platy, or encrusting, with an almost flat to convex calicinal surface. The valleys are long and sinuous and interconnecting, their width 12 mm to 15 mm, their depth about 10 mm. The collines of young coralla are 2 mm to 5 mm in thickness, and ridged or slightly grooved; on older coralla, the collines are much more subdued. The under side of the corallum may be pediculate or completely encrusting.

There are eight to ten septa in one centimeter, four or five of them the principals and extending farthest inward. The margins of the larger septa bear seven to nine teeth, directed obliquely upward. The ends of the septa are slightly exsert and are continuous over the colline or meet in the groove. The faces of the septa are smoothish to spinulose.

The columellar centers are 8 mm to 10 mm apart, adjacent ones connected by about three lamellae which are acutely serrated along their margin, as shown to excellent advantage by Roos (1971, pl. 49). The costae are distinctly visible at the edge and side of the corallum where they are granular and slightly vermicular (Matthai, pl. 61, fig. 5). A thin epitheca is present on the under surface to within a short distance of the periphery.

Measurements. — According to Matthai, the type of *Mycetophyllia lamarckiana* is 50 mm high, 140 mm long, and 70 mm wide. The natural size of one of Edwards and Haime's syntypes (see Matthai, pl. 61, fig. 5) is about 129 mm in long diameter and 81 mm, height. Specimen BM 28.3.1.110 British Museum (N. H.), from Coconut Point in the Bahamas (Matthai, pl. 54, fig. 4) measures 86 mm × 70 mm across the calicinal surface; specimen BM 28.3.1.109 also from Coconut Point (Matthai, pl. 54, fig. 5) measures 80 mm × 65 mm.

Range and distribution. — The geographic range of *Mycetophyllia lamarckiana* is from Bermuda to Barbados; the geologic range is Pleistocene to Recent.

Pleistocene — Florida (Key Largo Limestone/Miami Oolite dredged alongside Card Sound Bridge, Key Largo, and off the eastern tip of Stock Island); Bermuda (Devonshire Formation); Dominican Republic (coastal limestone at Barbacoa, Provincia de Barahona); Barbados (low-level reefs and submerged reefs, west coast).

Recent — Florida (patch reefs along southeast coast; Looe Key; Key West, 5 f); Bahamas (Abaco Island; Coconut Point, Andros Island); Cuba; Jamaica (Ocho Rios; 1 m - 75 m); Pedro Bank; British Honduras (Rendezvous Cay, Turneffe, Lighthouse Reef, Glover's Reef); Mexico (Blanquilla Reef); Puerto Rico (Cayo Icacos); St. Thomas; Guadeloupe (26 m - 34 m); Barbados (along west coast, 15 m - 24 m); Netherlands Antilles: Aruba (Mangel Altu). Curaçao (Plaja Kalki, Kaap Malmeeuw 30 m, Piscaderabaai 15 m - 40 m, St. Michiels Baai, Sta. Martha Baai, Spaanse Water). Bonaire (Boca Bartól, Jan Doran-Barcadera, Ruin, Klein Bonaire, Plaja Sarna, Slagbaai).

CARYOPHYLLIIDAE

Eusmilia fastigiata (Pallas) Pl. 52, fig. 5

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1767. *Madrepora fastigiata* Pallas, Linnaeus, Systema Naturae, ed. 12, vol. 1, pt. 2, p. 1280.
1786. *Madrepora fastigiata* Pallas, Ellis and Solander, The Natural History . . . of Zoophytes, p. 152, pl. 33.
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1792. *Madrepora fastigiata* Pallas, Gmelin, Systema Naturae, ed. 13, vol. 1, pt. 6, p. 3777.
1797. (?) *Madrepora capitata* Esper, Fortsetzungen der Pflanzenthiere, pp. 102, 103, pl. 81, fig. 1; pl. 82 (copy of Ellis and Solander's pl. 33). [*Fide* Matthai, 1928, p. 190.]
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1847. *Caryophyllia fastigiata* (Pallas), Schomburgk, The History of Barbados, p. 562.
1848. *Eusmilia fastigiata* (Pallas), *E. knorii* (*pars*), *E. alticostata* Edwards and Haime, Ann. Sci. Nat., Paris, sér. 3, Zoologie, vol. 10, pp. 264-265, pl. 5, figs. 1, 2. [*Fide* Matthai, 1928, p. 191.]
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This hermatypic coral consists of large, relatively short, subconical corallites branching upward from a narrow base. The calices are flared at the margin, and are generally oval in outline, with mono-, di-, and tri-stomodaeal centers. The valleys are up to 35 mm in length, 8 mm to 13 mm in width, and 8 mm or 9 mm in depth. The wall is 2 mm thick, and has a sharp rim over which the septa are notably arched.

There are 15 to 18 septa in one centimeter; the maximum breadth of the principals is 3.5 mm to 4 mm and they thicken toward the wall to as much as 1.25 mm; at their summit they are exsert to

2.5 mm. The subsidiary septa are thin, less exsert than the principals, and narrower. The margins of the septa are entire or nondentate, and the sides are marked by small granular striae.

The costae are conterminous with the septa, the primary ones much the largest, the secondaries and tertiaries successively smaller, all of them irregularly toothed, and extending down the greater length of the corallites. The columella is composed of closely twisted septal trabeculae, about 1 mm in width, and usually sharply ridged above, the ridge wavy and often continuous.

Measurements.—The natural size of the *Eusmilia fastigiata* illustrated by Vaughan and Wells (1948, pl. 47, fig. 1) from the Dry Tortugas of Florida, is 53 mm across the long diameter of the calicinal surface and about 37 mm in height.

Range and distribution.—The geographic range of *Eusmilia fastigiata* is from Florida to Barbados; geologically it is recorded from Miocene to Recent.

Miocene—Guadeloupe (Tuf Blanc).

Plio-Pleistocene—Dominica.

Pleistocene—Florida (Miami Oolite/Key Largo Limestone dredged off Old Fort Taylor, Key West, between Stock Island and Cow Key, off the eastern tip of Stock Island, and alongside Card Sound Bridge, Key Largo, Monroe County); Panama Canal Zone (Mt. Hope); Costa Rica (Monkey Point); Dominican Republic (Provincia de Barahona between Duvergé and Palma Dulce); Barbados (submerged reefs along west coast; low-level reefs near Bridgetown; high-level reefs at Castle Grant 1050 ft.; Bath-Reef Series near Bath 150 ft. - 165 ft.).

Recent—Florida (reefs along southeast coast; Looe Key; Tortugas at Ft. Jefferson and Loggerhead Key); Bahamas (Nassau; Andros Island; Abaco Island); Cuba; Jamaica (Ocho Rios; 1 m to 65 m); Mexico (Alacran Reef); Panama (San Blas?) British Honduras (Rendezvous Cay, Glover's Reef); Puerto Rico; St. Thomas (22 m to 26 m); Martinique; Dominica; Netherlands Antilles: Aruba (Boca Catalina-Malmok, Barcadera, Mangel Altu). Curaçao (shore to 30 m.; Plaja Kalki, Westpuntbaai, Plaja Abao, Spaanse Water, Piscaderabaai, St. Michiels Baai, Kaap Malmeeuw, Punta Caballero, Vaarsenbaai). Bonaire (Plaja Frans, Jan Doran-Barcadera, Ruin, Klein Bonaire, Plaja Sarna, Blauwe Pan-Witte Pan, Slagbaai). St. Eustatius (Cocoluth Bay-Jenkin's Bay); Venezuela (Los Roques; Puerto La Cruz, Edo. Anzoategui; Bahía de Mochima, Edo. Sucre at Ensenada Los Aceites, Punta Garrapata, Punta Aguirre; Cumaná); Barbados (along west coast, 15 m to 24 m).

INCERTAE SEDIS

Incertae sedis "A" Pl. 56, figs. 2, 3

Specimen CAL-9a is an internal mold of a solitary coral, two-thirds or so of which is conserved. The corallum is naviculate or subflabellate in outline, with a bowlike distal end and a rather sharp, slightly undulating keel. The calice is completely filled with limestone and flat on top, and is regularly elliptical with nearly parallel sides.

Counting the slits on the surface of the mold, there are 74 septa or an estimated 96 in the formerly complete calice. From a rubberoid impression of the surface it is seen that the septa are lamellar and that their size decreases successively according to the order of insertion, with the primaries the largest, the secondaries next, and so on. Twenty-four of the septa extend to the columella and it is presumed that there would be 36 of these in the entire calice. On the rubberoid cast the septa seem vaguely to be dentate along the margin, and minutely granulose on the faces.

The columella is laminar and possibly interrupted.

Measurements. — CAL-9a: internal mold length 23 mm, height 14.5 mm, width at side 14.5 mm.

Locality. — Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. Collector Mike Strong, 2 December 1969. "Caloosahatchee Marl".

Incertae sedis "B" Pl. 56, figs. 4, 5

Specimen CAL-10a is an internal mold, the conformity of which is flabellate. The calcular cavity is subelliptical in outline and completely filled with limestone. One side of the corallum is slightly appressed near the middle, the other side gently convex. The slits in the sides of the mold represent septa, and there are about 92 of them. The columella is elongate-elliptical and spongy.

A rubberoid impression taken of the exterior of the mold indicate that the septa are graded in size according to the order of their insertion, with the primaries being the largest, the secondaries somewhat smaller, the tertiaries still smaller, and the subsidiaries the smallest. The septa, especially the principals, are strongly dentate along the margin, and the faces beset with regularly disposed granulations, the latter appearing as punctations on the interseptal fillings, aligned in arcuate rows of trabeculae.

Measurements. — CAL-10a: corallum length 27 mm, height 19 mm, width at sides 18.5 mm.; columella length 10 mm, width at middle 2.2 mm.

Locality. — Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. "Caloosahatchee Marl". Collector Mike Strong, 2 December 1969.

Comparison. — Although this taxon superficially resembles *Incertae sedis* "A" it is at once distinguished from it by its spongy rather than laminar columella.

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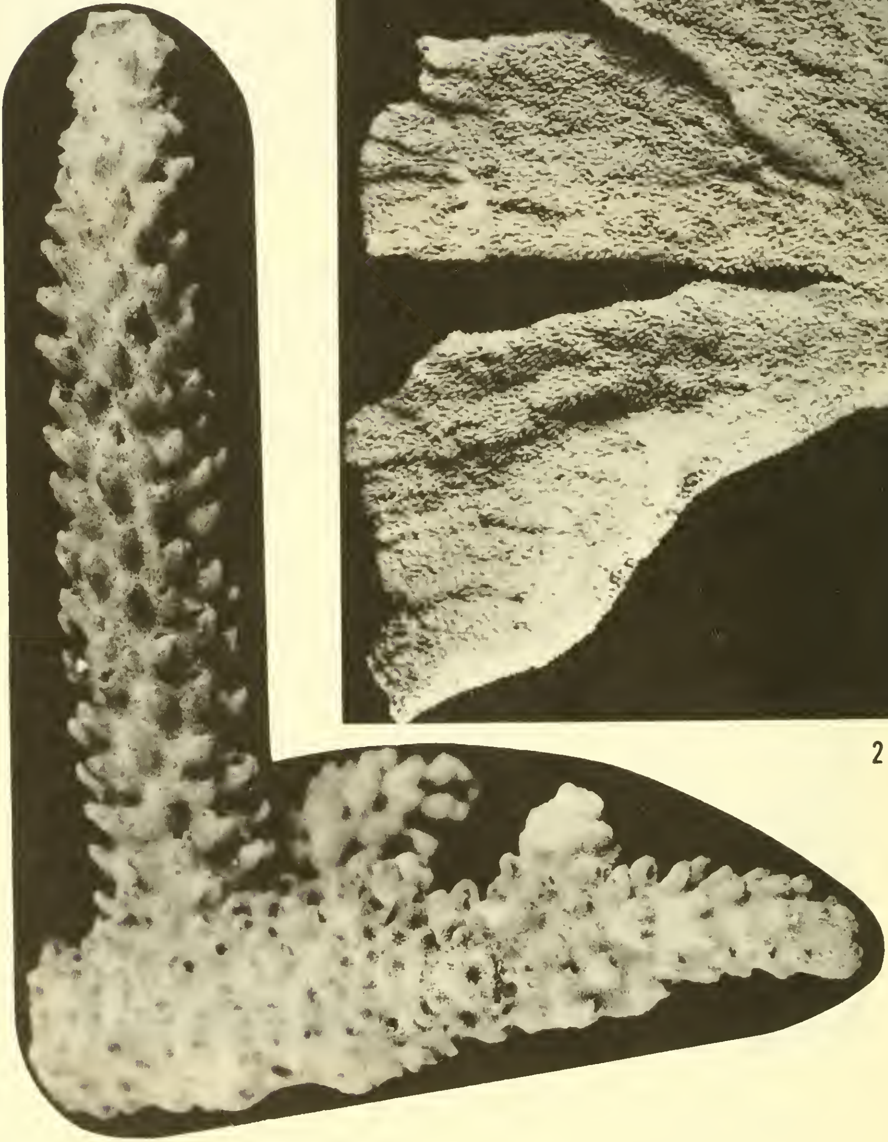

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2. **Acropora palmata** Lamarck Recent, Caracasbaai, Curaçao. Illustration from Roos (1971, pl. XIIb). × 0.28.	284

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1, 2. **Acropora cervicornis** (Lamarck) 278

Specimen FLX-15a. Recent, Florida.
1. Enlarged portion of shorter branch of specimen on Pl. 22, fig. 1. Illustration × 4. 2. Enlarged portion of longer branch of specimen on Pl. 22, fig. 1. Illustration × 4.

3. **Acropora prolifera** (Lamarck) 288

Specimen FLX-16a. Recent, Florida. Length of branch 24 mm. Illustration × 4.

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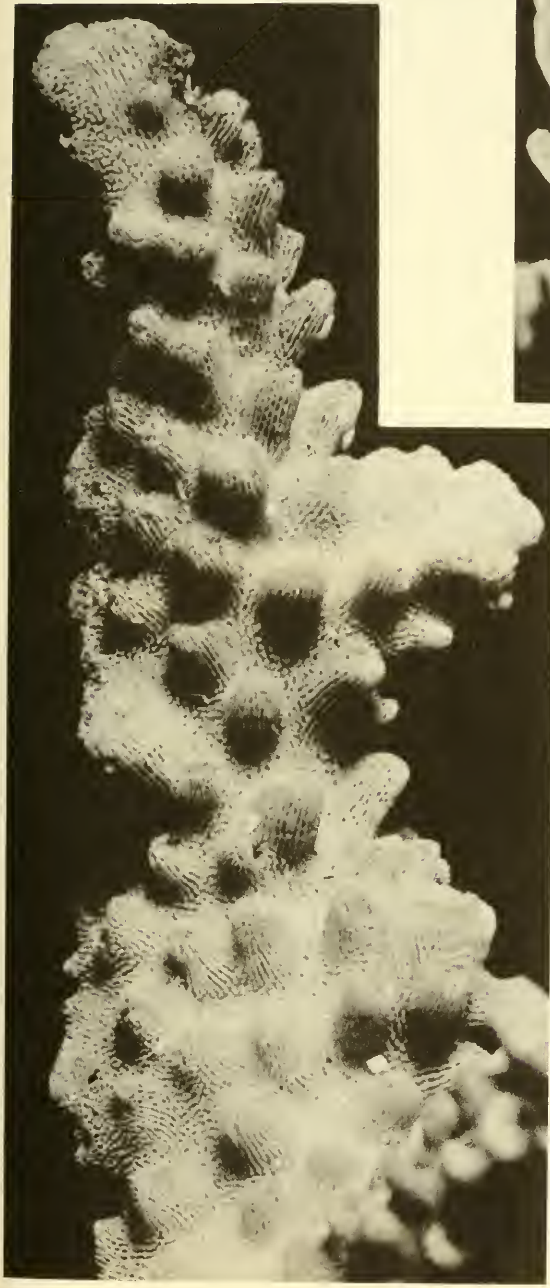

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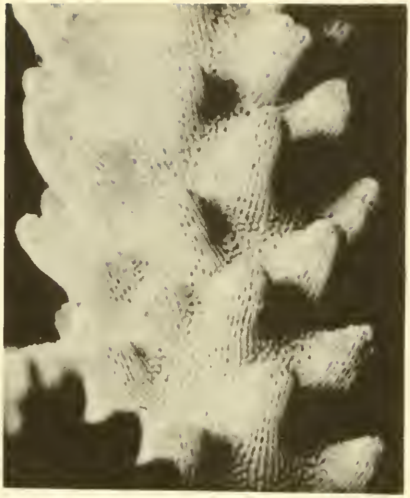

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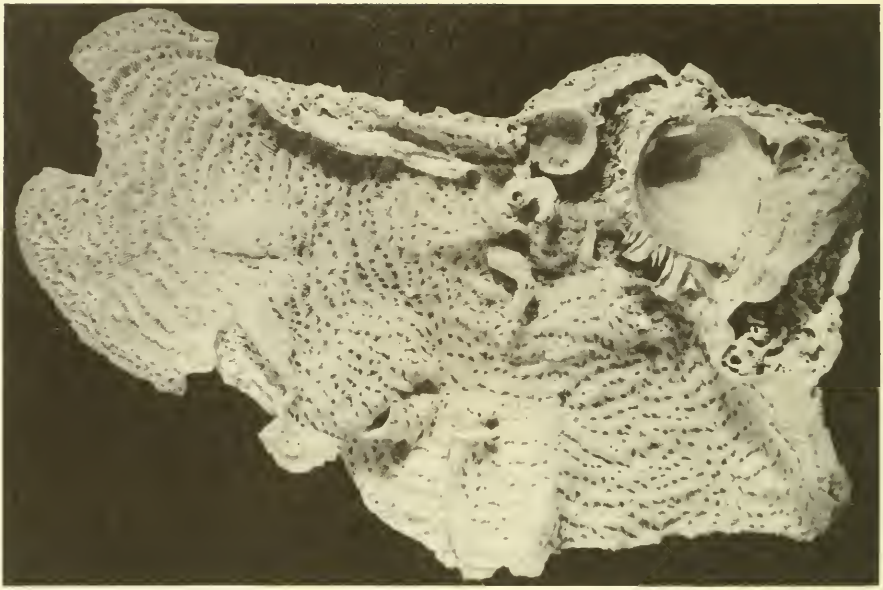

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Specimen FGM-2a. Recent, Florida Middle Ground, Gulf of Mexico. Frond length 172 mm; × 0.75.
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Reproduction of original illustrations of *Madrepora cucullata* Ellis and Solander (1786, p. 157, pl. 42, both figures). Frond measurements on pl. 42 of Ellis and Solander, 97 mm × 95 mm.

1. Lower surface of frond. 2. Upper surface of frond.

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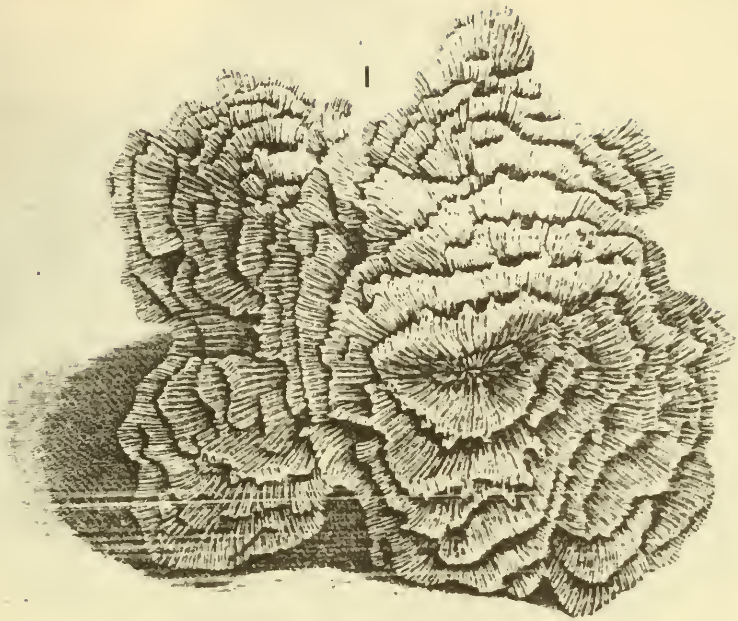

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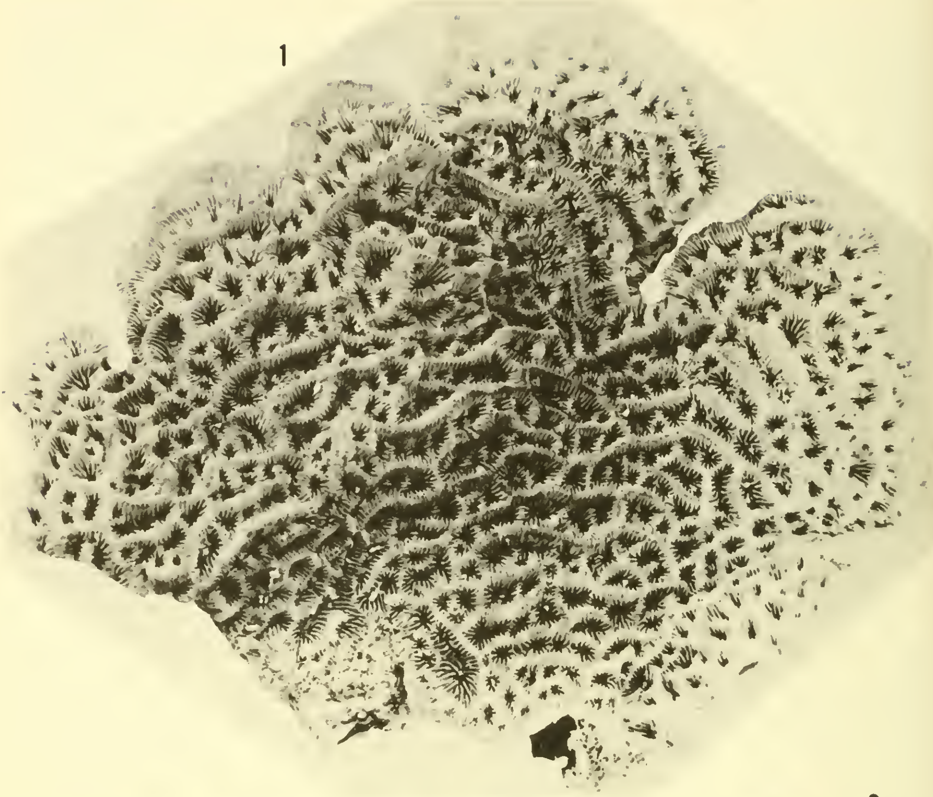

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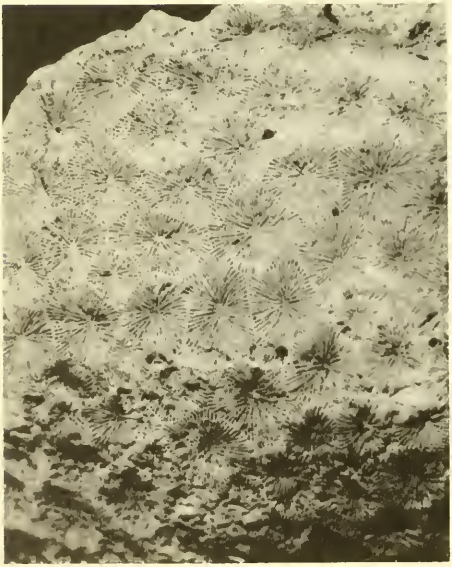

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Specimen SP-6c. Pinecrest Formation. Corallum length 95 mm, width 78 mm, height 69 mm. 1. Calicinal surface × 1.4. 2. Base × 0.8. 3-5. Calices × 3.2.

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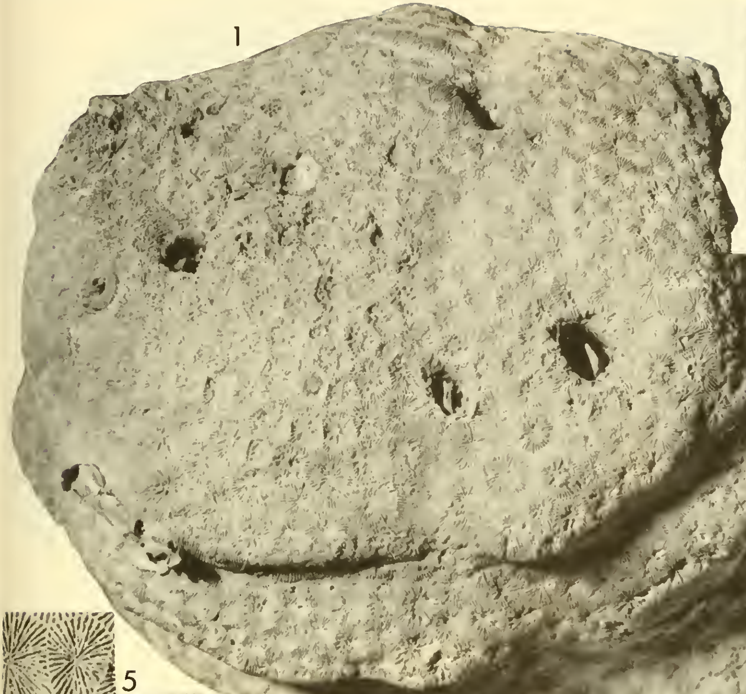

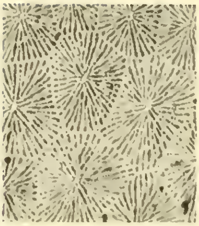

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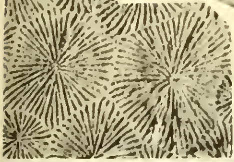

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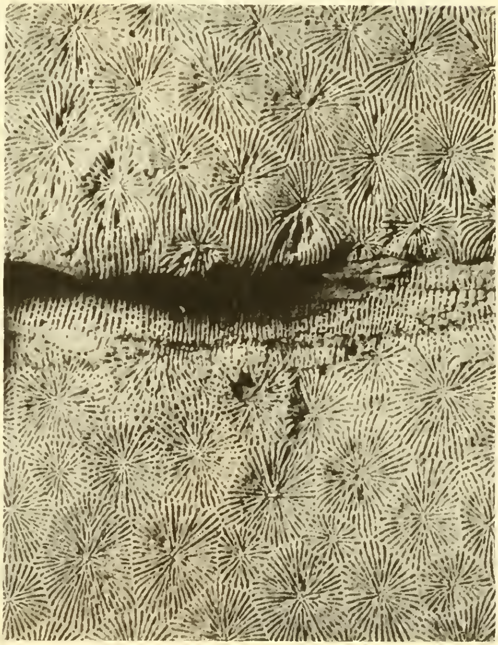

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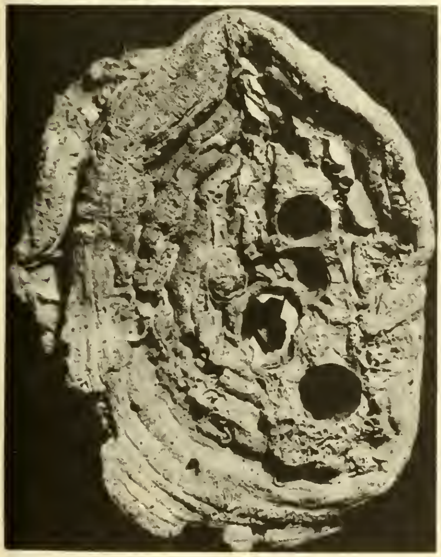

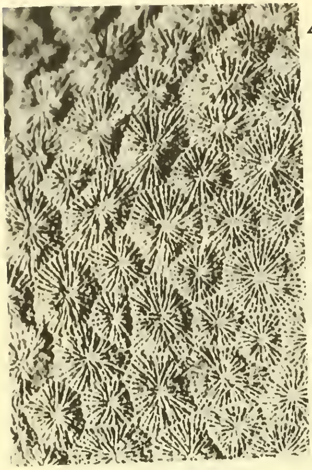
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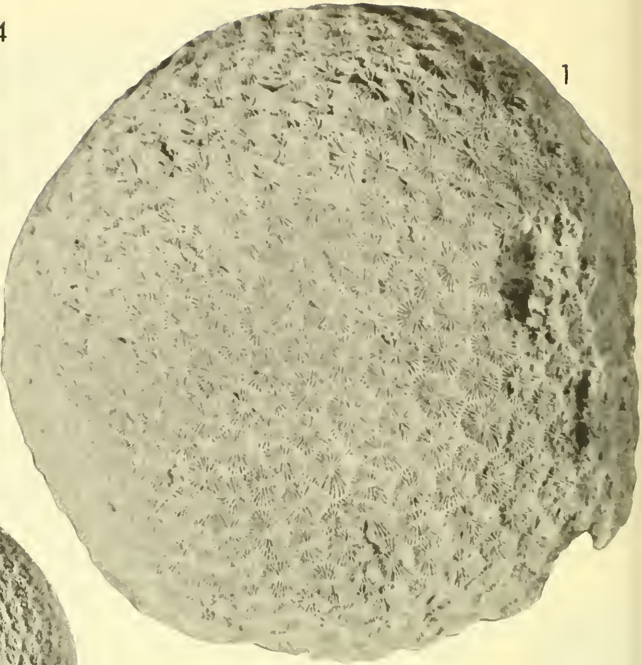
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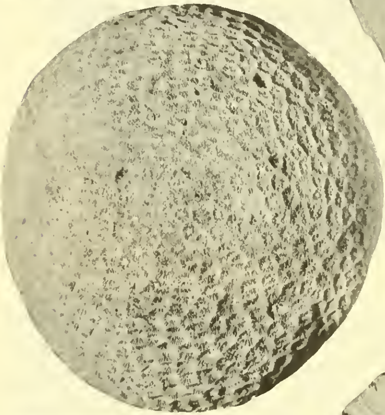
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EXPLANATION OF PLATE 28

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1-5. **Siderastrea pliocenica** Vaughan 308

Figs. 1, 2. Specimen USNM-7893. Caloosahatchee Marl or Fort Thompson Formation. Diameters of calicinal surface 65 mm × 61.5 mm. 1. Calicinal surface × 1.5. 2. Section below calicinal surface × 1.5. 3, 4. Specimen Ort-1a. Caloosahatchee Marl or Fort Thompson Formation at Ortona Locks. Corallum diameters 77 mm × 69 mm × 69 mm. 3. General view × 0.75. 4. Calices × 2. 5. Specimen FLX-12, showing type of the embedded barnacle *Ceratoconcha neogenica* (Weisbord). Length of barnacle 9 mm. Illustration × 5.5.

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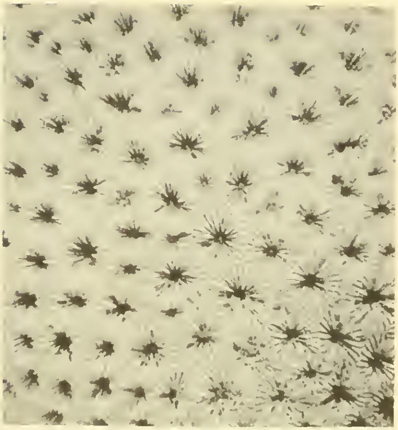

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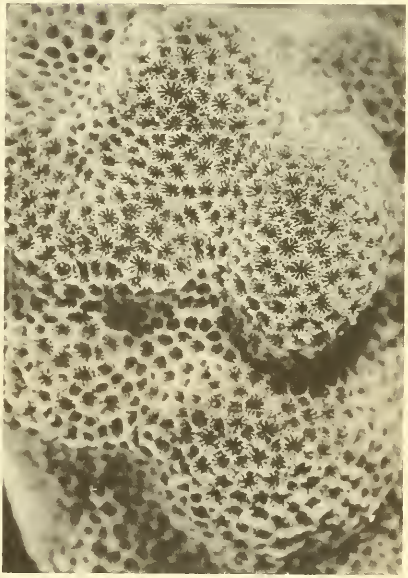

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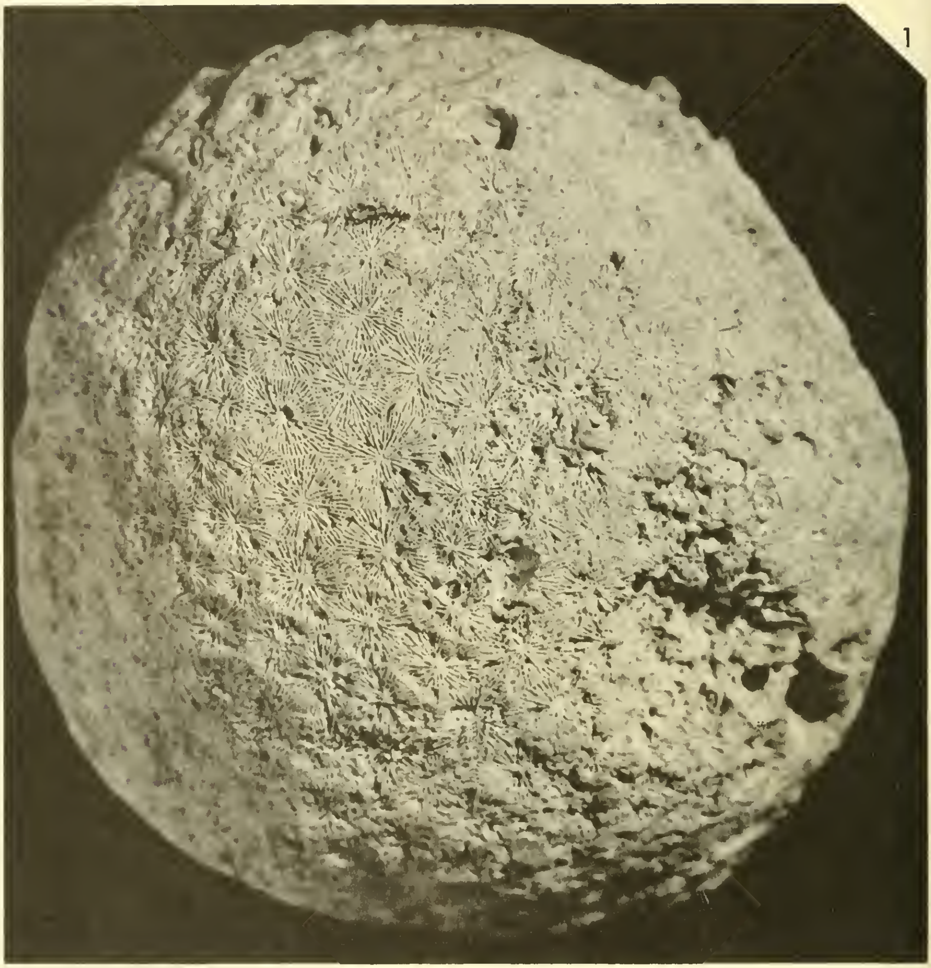
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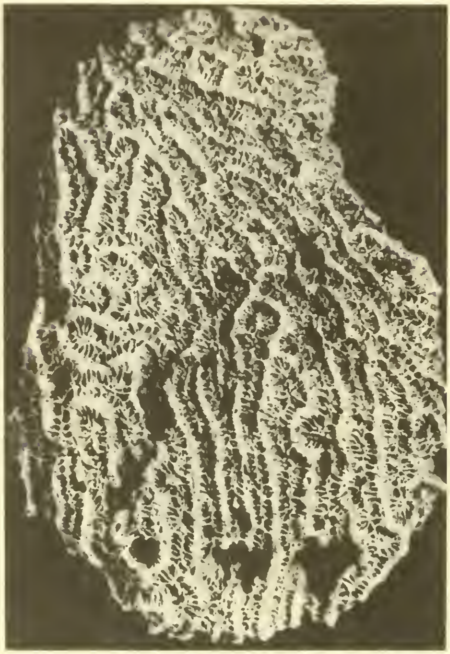

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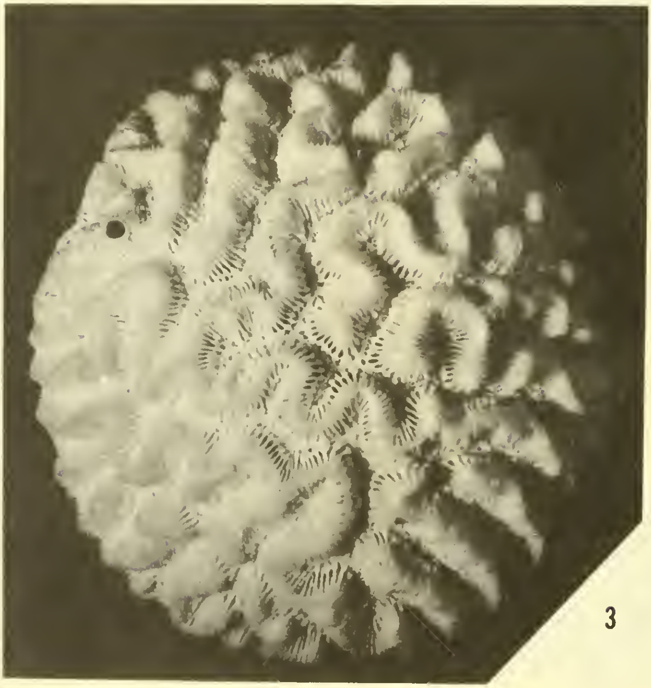

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1.	**Diploria clivosa** (Ellis and Solander)	340
	Specimen USNM-3695. St. Marks, Wakulla County, Florida. This was found loose and may have been ballast. Length 77 mm. Illustration × 1.1.	
2.	**Diploria labyrinthiformis** (Linnaeus)	345
	Illustration from Matthai (1928, p. 63, pl. LXIX, fig. 2) as *Maeandrina labyrinthiformis*. Length about 80 mm, natural size.	
3.	**Diploria strigosa** (Dana)	353
	Cabinet specimen, Dept. of Geology, Florida State University. Recent, Freeport, Grand Bahama Island. Length 81 mm. Illustration about natural size.	

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	Specimen I-1013 (2696), Florida Bureau of Geology: Caloosahatchee Marl in Caloosahatchee River, west of LaBelle, Hendry County. Length of calicinal surface 136 mm. Illustration × 0.8.	
2, 3.	**Diploria strigosa** (Dana)	353
	Specimen FWK-1a. Pleistocene, in quarry on Windley Key, Monroe County (Key Largo Limestone). Length 100 mm. Illustrations × 0.75. 2. Calicinal surface. 3. View of side.	
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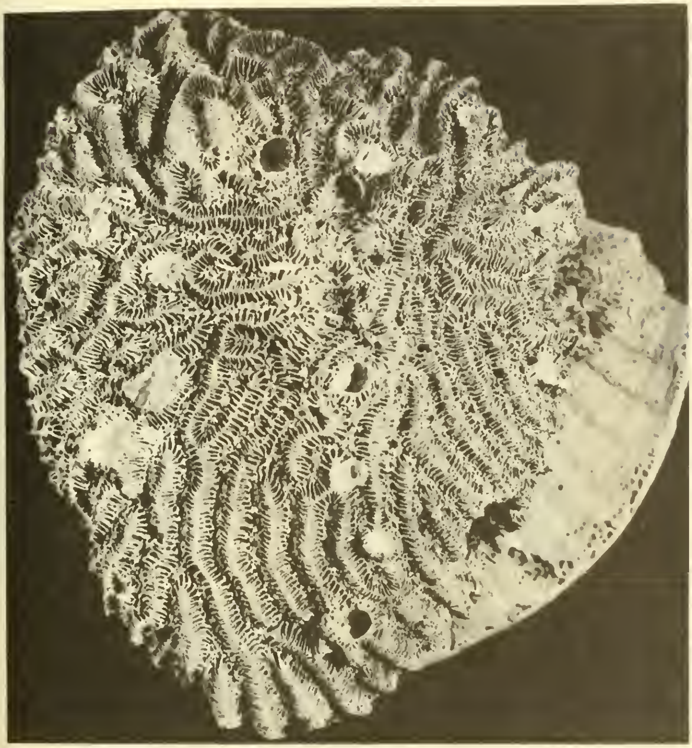
	Specimen USNM-2094. Caloosahatchee Marl in Caloosahatchee River. Length 75 mm. Illustrations × 1.1. 4. View of calicular surface. 5. View of base.	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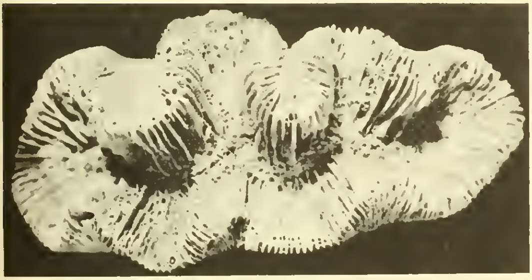
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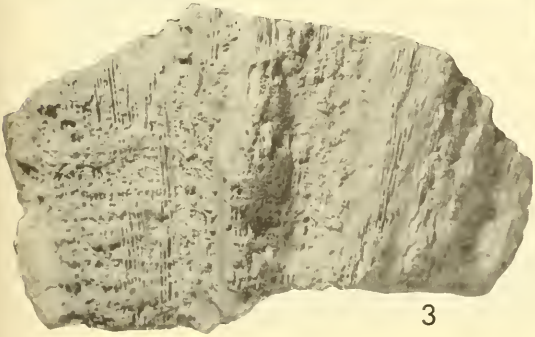
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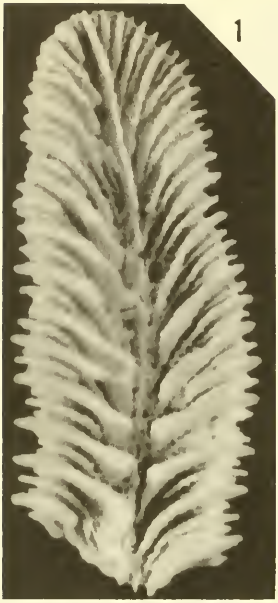

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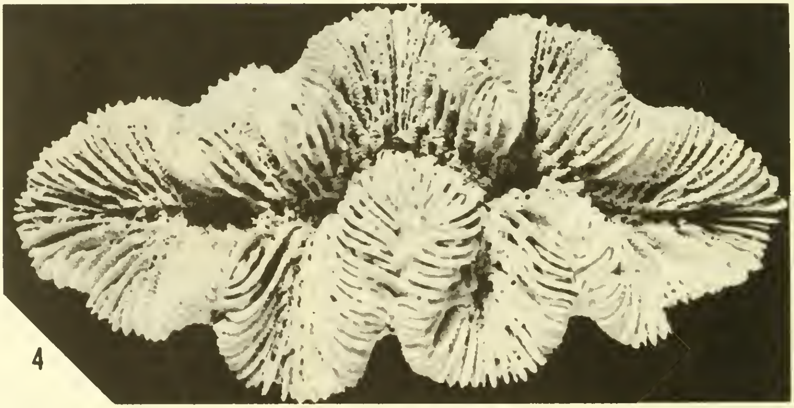

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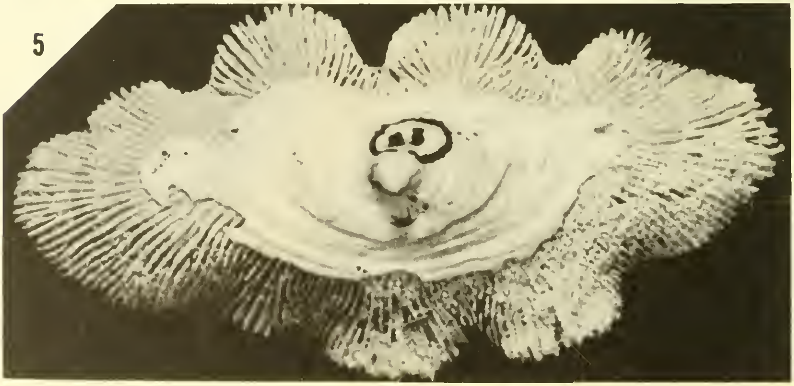

Explanation of Plate 34

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1-3.	**Thysanus floridanus** Weisbord, n. sp.	356
	Holotype, USNM-3300. Caloosahatchee Marl, Shell Creek, Charlotte County. Length 22.5 mm. Illustrations × 3.5. 1. View of calice. 2. View of base. 3. View of side.	
4, 5.	**Manicina areolata** (Linnaeus)	358
	Specimen USNM-24322, No. 11. Labeled *Manicina pliocenica* Gane. Glades Formation. Length 67 mm. Illustrations × 1.5. 4. View of calicular surface. 5. View of base.	

EXPLANATION OF PLATE 35

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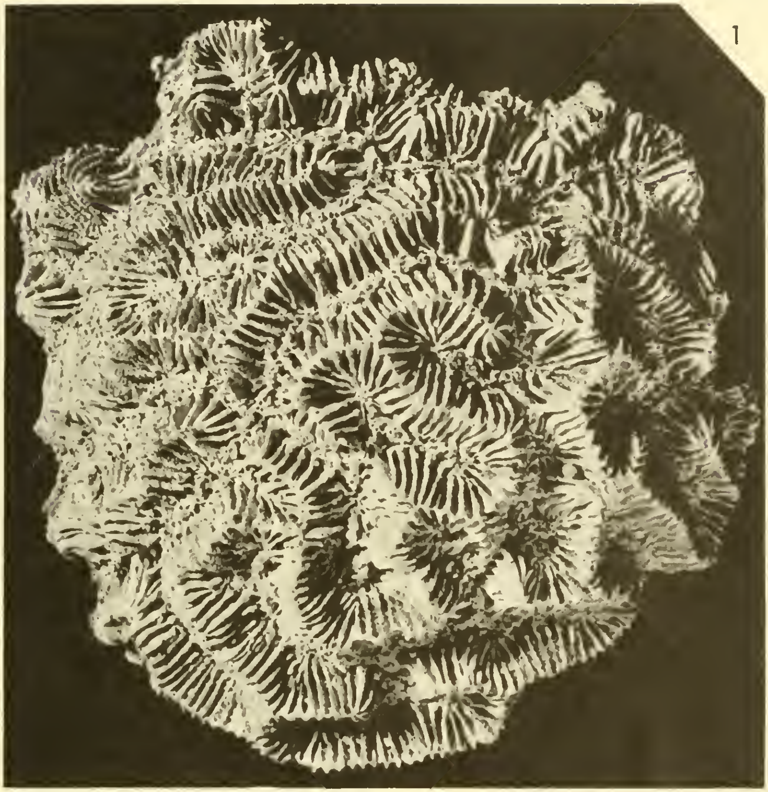
1, 2.	**Diploria sarasotana** Weisbord, n. sp.	351

Holotype, SP-4a. Pinecrest Sand, Sarasota, Sarasota County. Length 79 mm. Illustrations × 1.5.
1. Calicinal surface. 2. View of side.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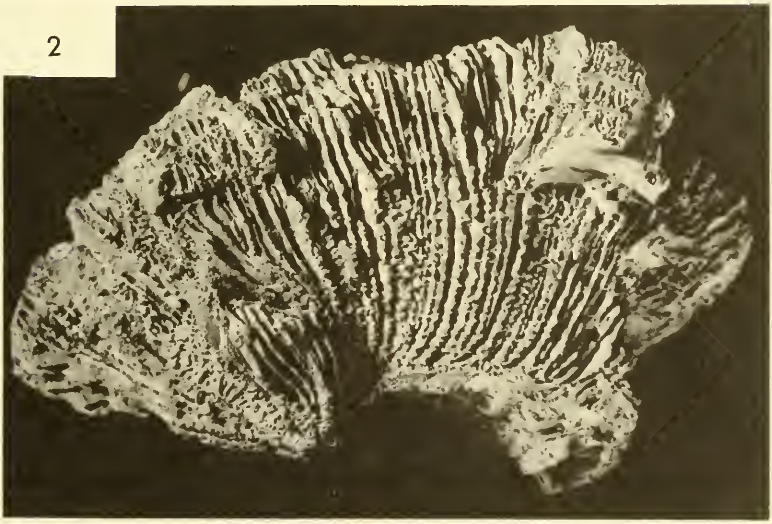
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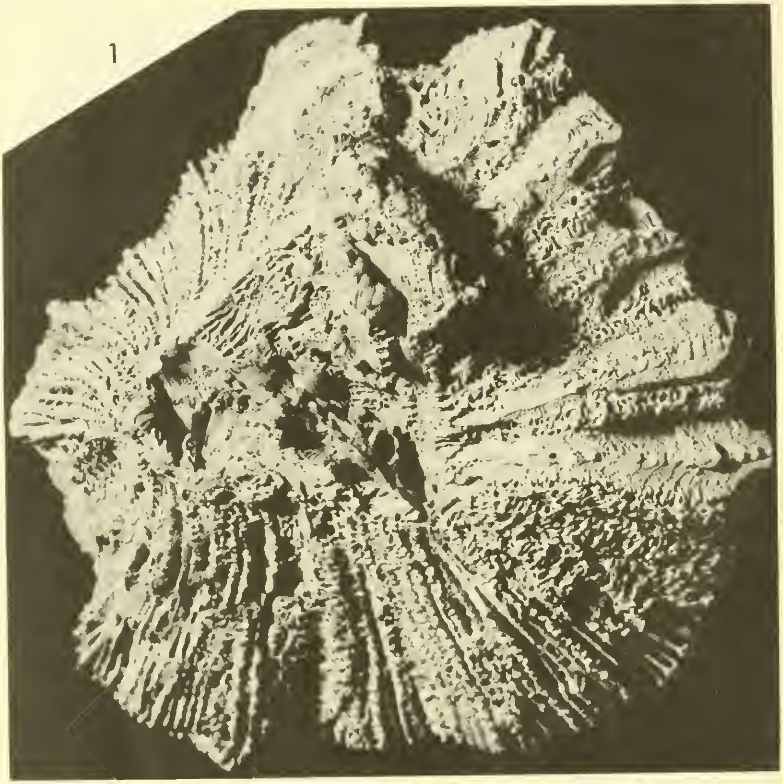

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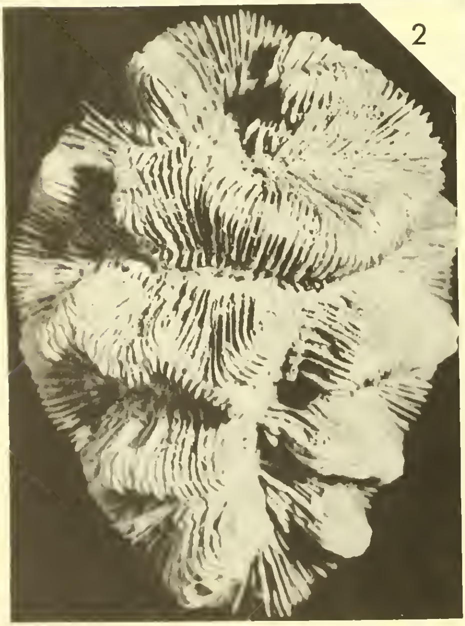

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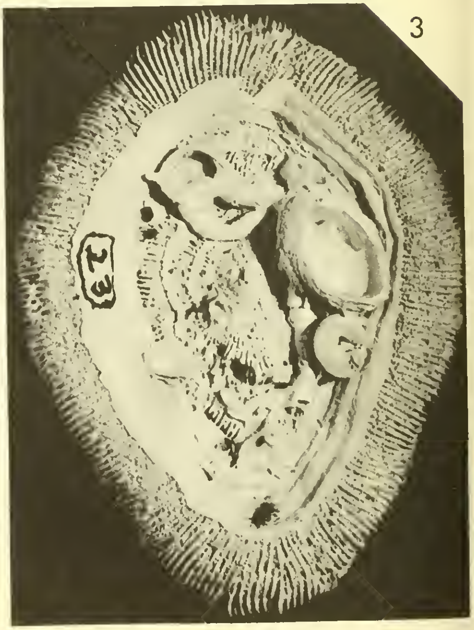

EXPLANATION OF PLATE 36

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1.	**Diploria sarasotana** Weisbord, n. sp.	351
	Holotype, SP-4a. Pinecrest Sand, Sarasota, Sarasota County. Length 79 mm. Illustration × 1.5. View of base.	
2, 3.	**Manicina areolata** (Linnaeus)	358
	Specimen USNM-24322, No. 23. Labeled *Manicina pliocenica* Gane. Glades Formation. Length 92 mm. Illustrations about natural size. 2. View of calicular surface. 3. View of base.	

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Figure		Page
1.	**Diploria labyrinthiformis** (Linnaeus)	345
	Illustration from Matthai (1928, p. 63, pl. LXX, fig. 1) as *Maeandrina labyrinthiformis,* "cited by Linnaeus under *Madrepora labyrinthiformis,* with inscription below in his handwriting." Natural size about 115 mm in length and 82 mm in width.	
2, 3.	**Manicina areolata** (Linnaeus)	358
	Specimen BG-3b. Glades Formation, south edge of Belle Glade, Palm Beach County. Length 109 mm. 2. View of calicular surface. Illustration × 0.75. 3. View of base. Illustration × 0.8.	

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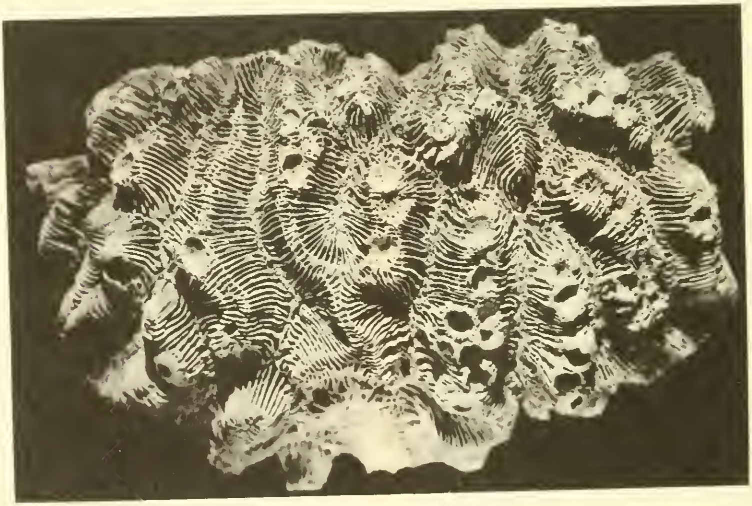

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Explanation of Plate 38

Figure Page

1. **Manicina areolata** (Linnaeus) 358

   Specimen BG-3c. Glades Formation. Length 240 mm, width 143 mm, height 95 mm. Illustration × 0.5, calicinal surface.

2. **Manicina cf. M. gyrosa** (Ellis and Solander) 363

   Specimen CAL-7a. Caloosahatchee Marl, in Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. Length 184 mm, width 120 mm, height 75 mm. Illustration × 0.5, calicinal surface. The embedded barnacles are referable to *Ceratoconcha prefloridana* (Brooks and Ross).

EXPLANATION OF PLATE 39

Figure Page

1. **Manicina areolata** (Linnaeus) 358

   Specimen BG-3c. Glades Formation. Length 240 mm, width 143 mm, height 95 mm. Illustration × 0.5, view of base.

2. **Manicina** cf. **M. gyrosa** (Ellis and Solander) 363

   Specimen CAL-7a. Caloosahatchee Marl, in Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. Length 184 mm, width 120 mm, height 75 mm. Illustration × 0.5, view of base.

3, 4. **Colpophyllia natans** (Müller) 368

   From Matthai (1928, p. 101, pl. LXVII, figs. 1, 2). Length and width 125 mm, height 65 mm.
   3. (Fig. 1 of Matthai), calicinal surface. Illustration × 0.5.
   4. (Fig. 2 of Matthai), side view of head. Illustration × 0.5.

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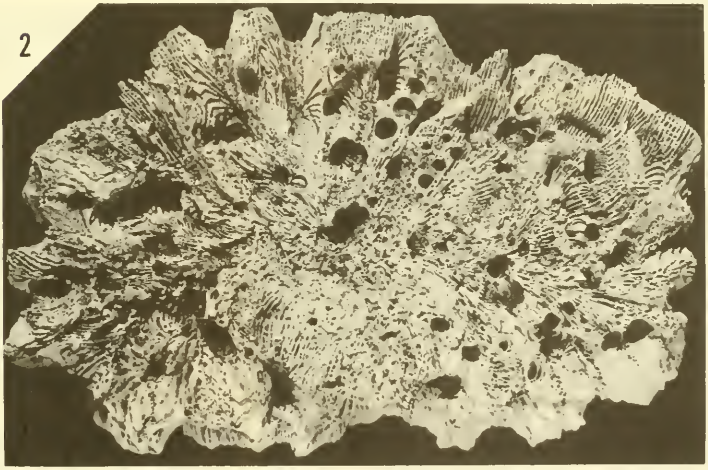

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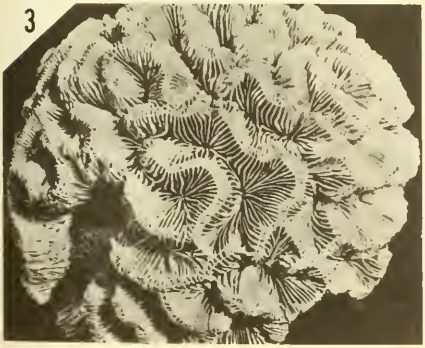

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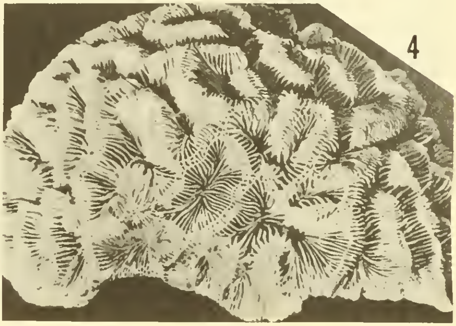

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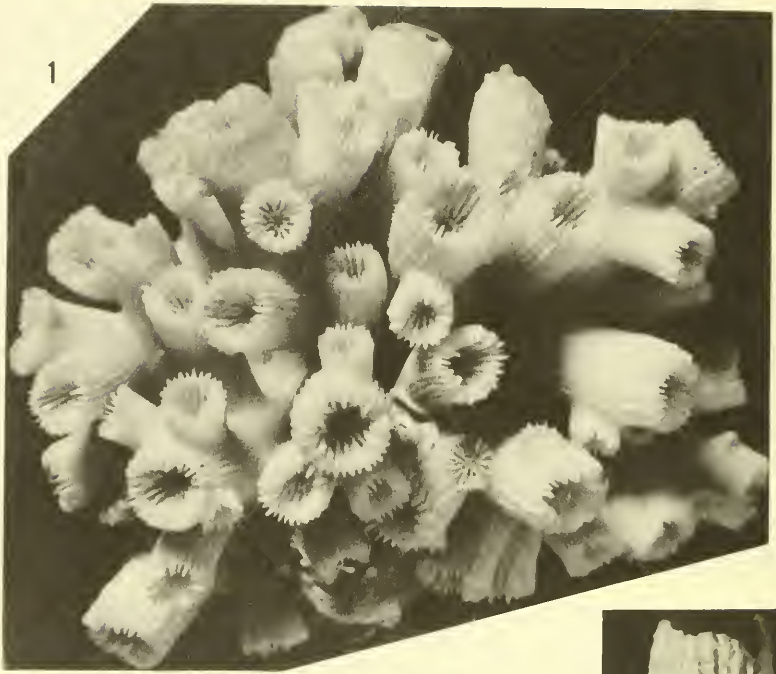

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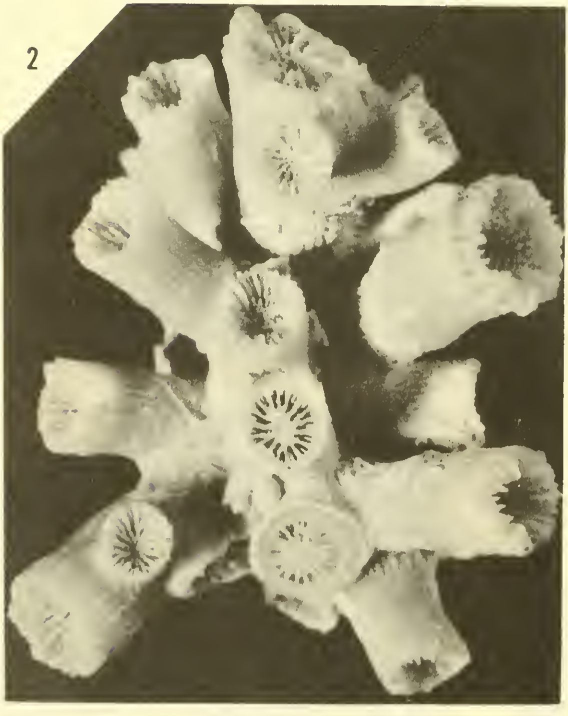

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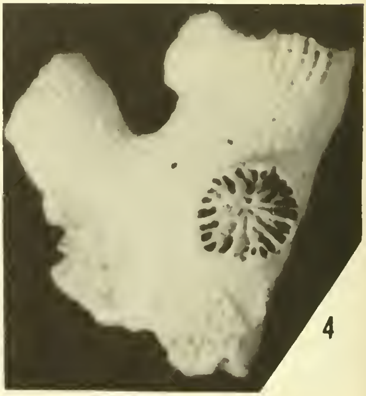

EXPLANATION OF PLATE 40

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1, 2. **Cladocora arbuscula** (Lesueur) 372

1. Specimen CPT-1a. Recent, Gulf of Mexico, 20 miles south of St. Marks, Florida, in 48 ft. of water. Corallum length 33.5 mm, width 28.5 mm, height 25 mm. Illustration × 3. 2. Specimen SB-3a. Glades Formation. Corallum length 24.5 mm, width 17.2 mm, height 22 mm. Illustration × 3.7.

3, 4. **Cladocora johnsoni** Gane 375

3. Specimen USNM-3300a. Caloosahatchee Marl, Shell Creek, Charlotte County. Branch length 8.5 mm. Illustration × 5. 4. Specimen USNM-3300b. Caloosahatchee Marl, Shell Creek, Charlotte County. Corallum height 9 mm, maximum width 8.5 mm. Illustration × 5.6.

Explanation of Plate 41

Figure Page

1. **Montastrea annularis** (Ellis and Solander) 377

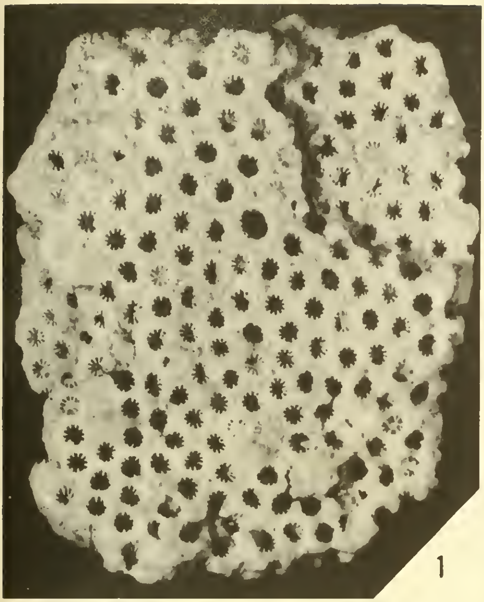
Specimen I-641b. Pleistocene, Matecumbe Key, Monroe County. Corallum length 68.5 mm, width 57 mm, thickness 26 mm; × 1.1.

2, 3. **Montastrea cavernosa** (Linnaeus) 381

Specimen I-641a. Pleistocene, Matecumbe Key, Monroe County. Corallum length 62 mm, width 52.5 mm, height 50 mm.
2. View of calicinal surface; × 1.1. 3. View of side; × 1.1.

4-6. **Astrangia floridana** Gane 395

Specimen CAL-1a. Caloosahatchee Marl in Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. Corallum length 20 mm, width 17 mm, height 15 mm.
4. View looking down on calices; × 3.2. 5, 6. Views of corallites; × 2.15.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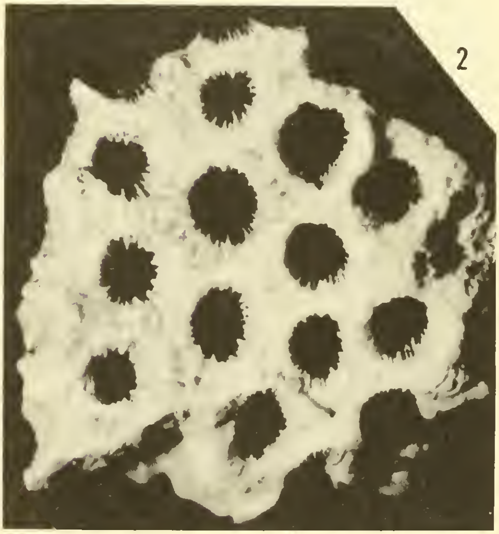
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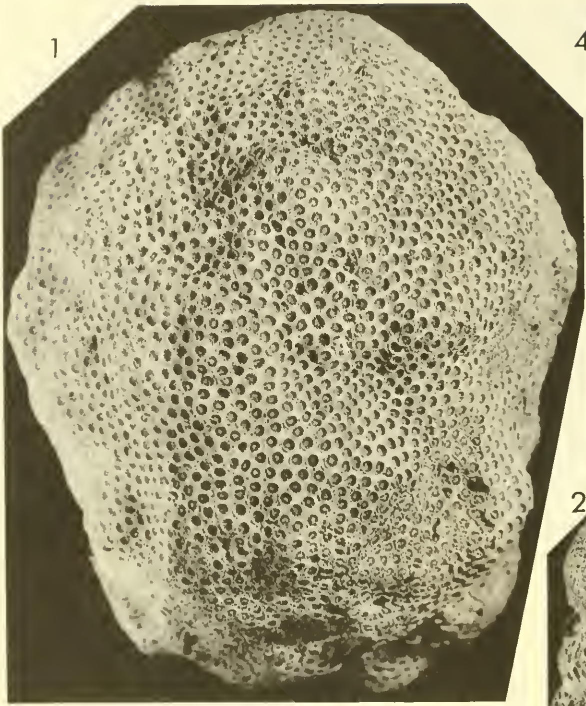

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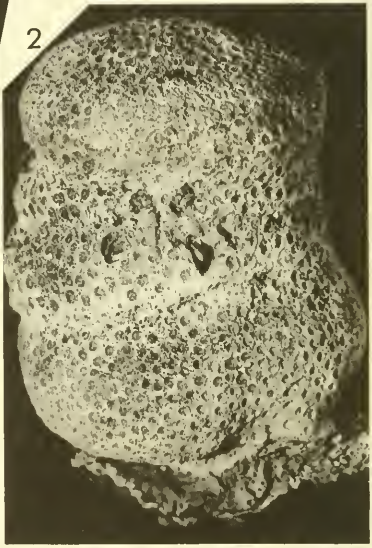

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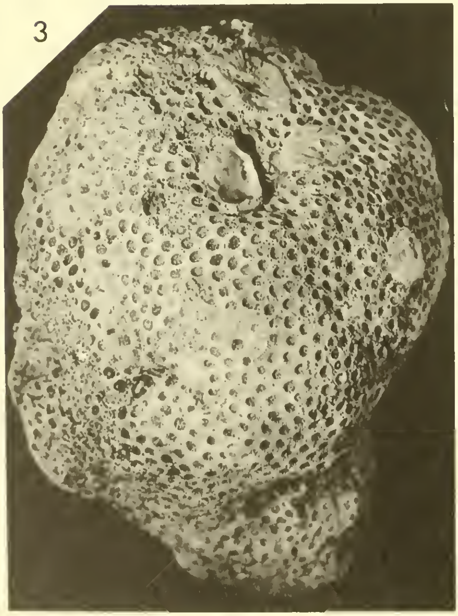

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EXPLANATION OF PLATE 42

Figure		Page
1-5.	**Solenastrea bournoni** Edwards and Haime	387

Pinecrest Formation, Warren Brothers Pits, Sarasota.

1. Specimen SP-7a. length 129 mm, width 101 mm, height 98 mm. Illustration × 0.8. 2. Specimen SP-7b. height 80 mm, diameters of calicinal surface 62 mm × 39 mm. Illustration × 1.1. 3. Specimen SP-7c. height 115 mm, maximum width 78 mm. Illustration × 0.75.

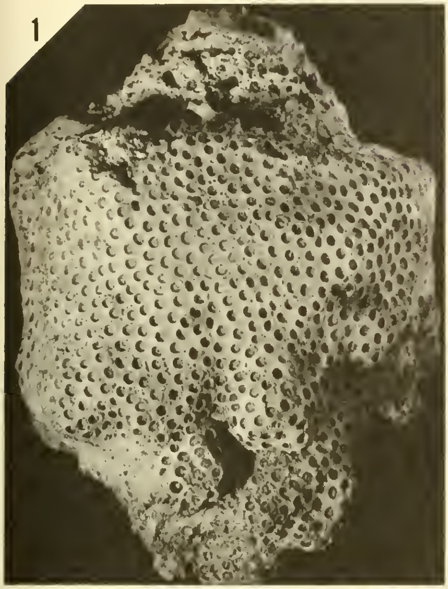
4, 5. Specimen SP-7d. height of broken corallum 110 mm, diameters of calicinal surface 85 mm × 53 mm.

4. Partial view of side. Illustration × 2. 5. Partial view of calicinal surface. Illustration × 2.

EXPLANATION OF PLATE 43

Figure		Page
1-6.	**Solenastrea hyades** (Dana)	391

Figs. 1, 2. Specimen SP-8a. Pinecrest Formation, Warren Brothers Pits, Sarasota. Height 148 mm.
1. General view. Illustration × 0.5. 2. Calices. Illustration × 2.
3. Specimen USNM-2795. Caloosahatchee Marl. Corallum height 74 mm, diameters of calicinal surface 130 mm × 124 mm. Illustration × 0.5.
4-6. Specimen CAL-6c. Caloosahatchee Marl in Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. Corallum length 111 mm, width 93.5 mm, height 91 mm.
4. View of calicinal surface. Illustration × 0.5. 5. View of section. Illustration × 0.5. 6. Calices. Illustration × 1.5.



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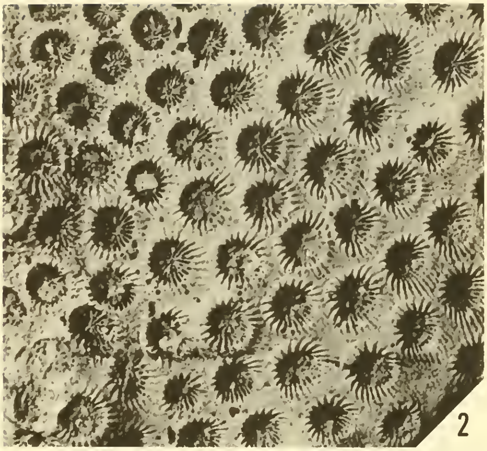

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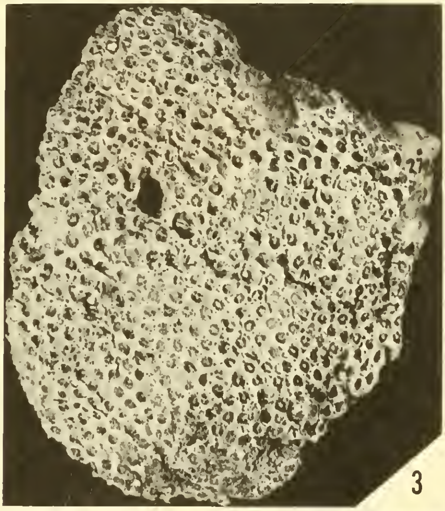

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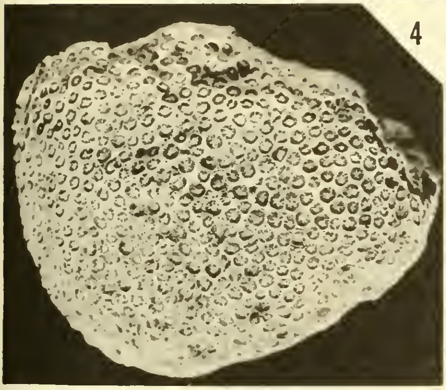

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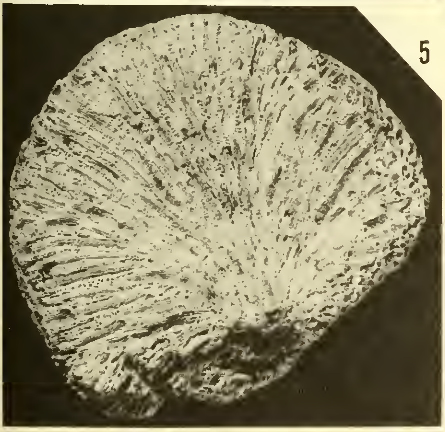

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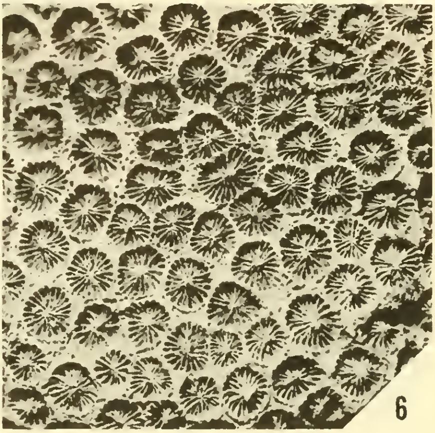

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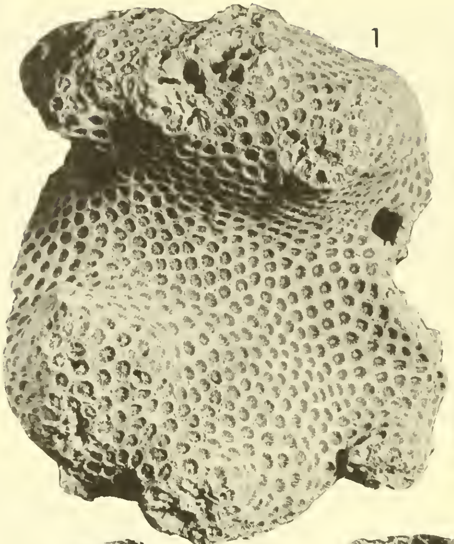

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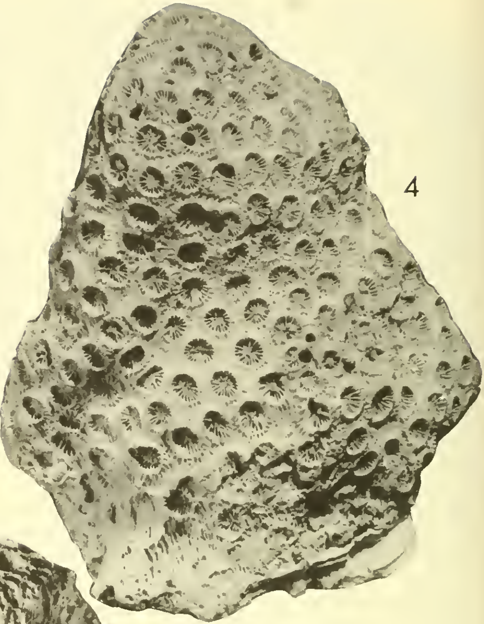

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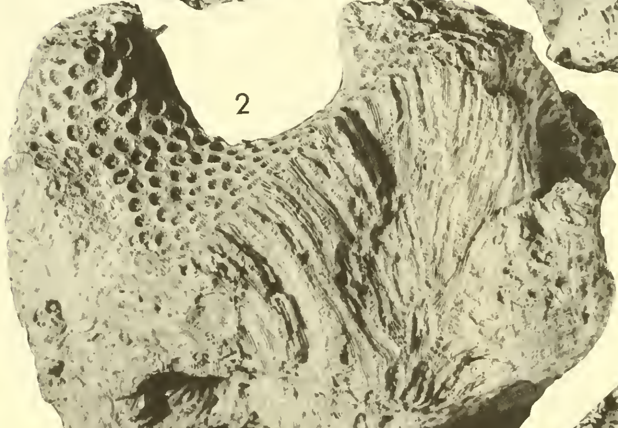

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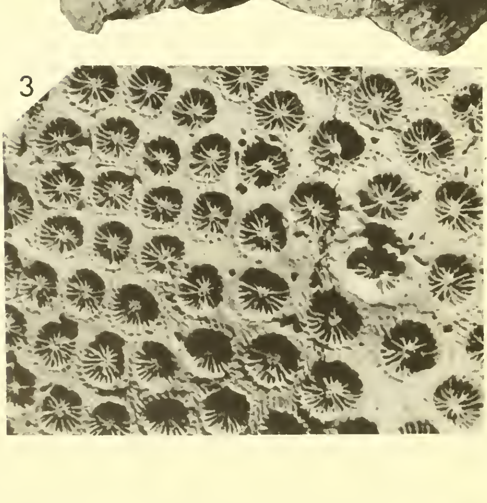

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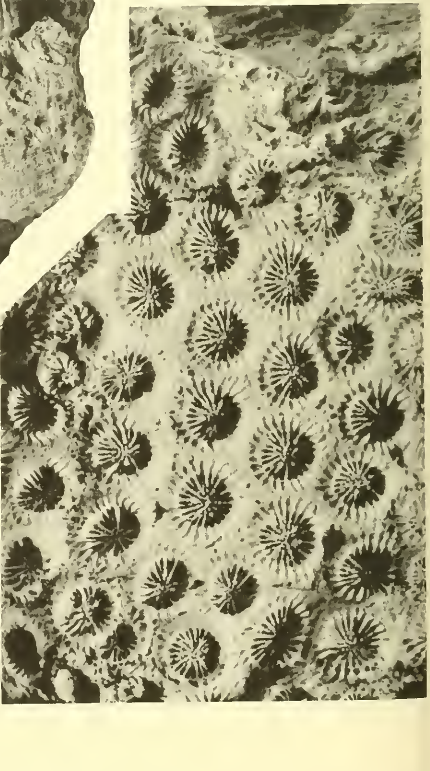

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EXPLANATION OF PLATE 44

Figure		Page
1-3.	**Solenastrea** cf. **S. hyades** (Dana)	391
	Specimen PG-4a. Caloosahatchee Marl 3.5 miles southeast of Punta Gorda, Charlotte County. Corallum length 98.5 mm, width 95 mm. 1. View of calicinal surface. Illustration × 0.8. 2. View of side. Illustration × 0.8. 3. Calices. Illustration × 2.5.	
4, 5.	**Solenastrea** cf. **S. bournoni** Edwards and Haime	387
	Specimen PG-3a. Caloosahatchee Marl 3.5 miles southeast of Punta Gorda, Charlotte County. Corallum height 67 mm. 4. View of calicinal surface. Illustration × 0.9. 5. Calices. Illustration × 3.	

EXPLANATION OF PLATE 45

Figure		Page
1-5.	**Astrangia floridana** (Gane)	**395**

1. Specimen I-1932a. Caloosahatchee Marl in Caloosahatchee River, 1 mile below Hugget's Landing. Corallum length 26 mm, height 16.2 mm, width of base 11.2 mm. Illustration × 4. 2. Specimen USNM-3300a. Caloosahatchee Marl, Shell Creek, Charlotte County. Corallum length 14.5 mm, width 10.5 mm, height 12.5 mm; largest corallite height 5.7 mm, maximum diameter of calice 6.6 mm. Illustration × 4. 3. Specimen USNM-3300b. Caloosahatchee Marl, Shell Creek, Charlotte County. Corallum height 8 mm, length of base 12 mm. Illustration × 4. 4, 5. Specimen USNM-3300c. Labeled *Phyllangia floridana* Gane. Caloosahatchee Marl, Shell Creek, Charlotte County. Length of base 10 mm, height of corallite 4 mm, maximum diameter of calice 5.1 mm. 4. Side of corallite. Illustration × 4. 5. View of calice. Illustration × 6.


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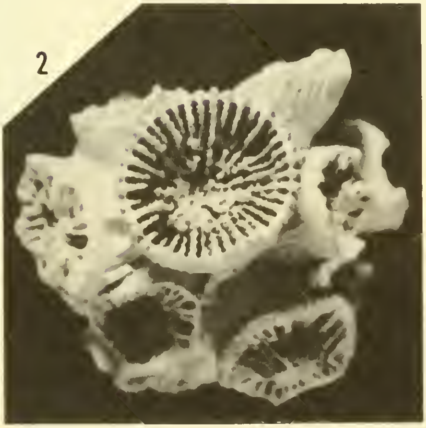
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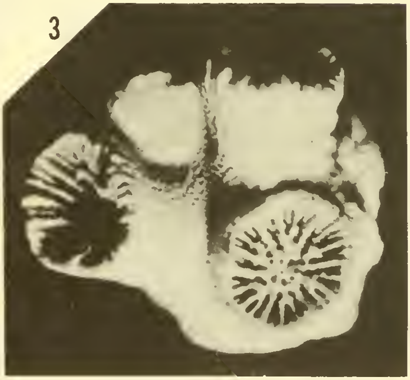
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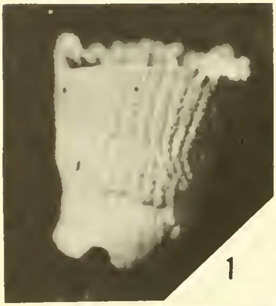
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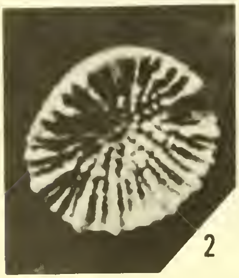
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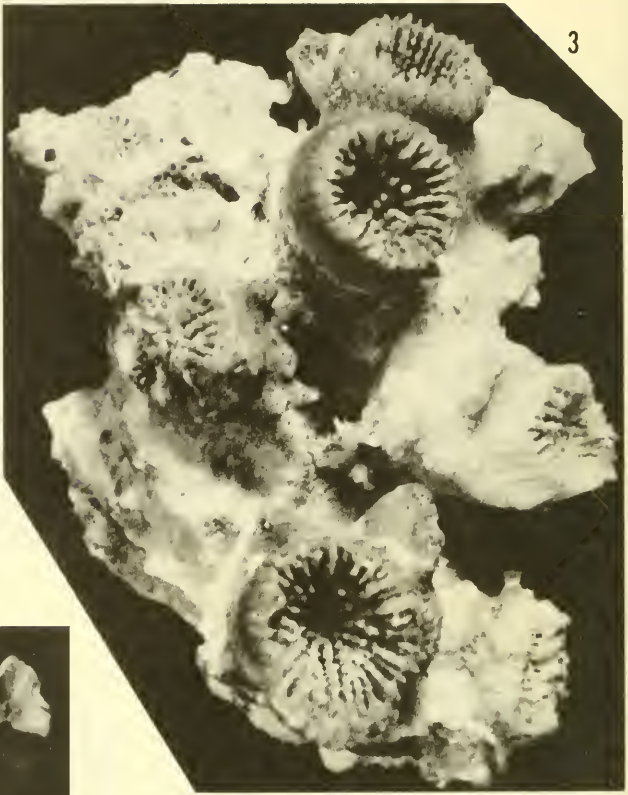
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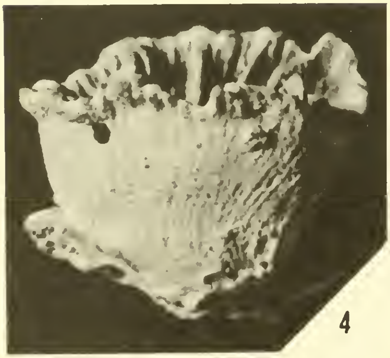
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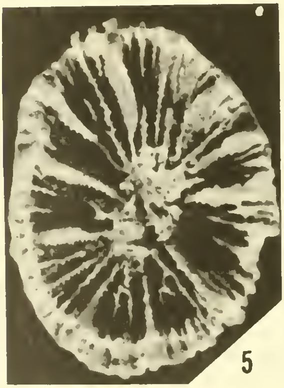
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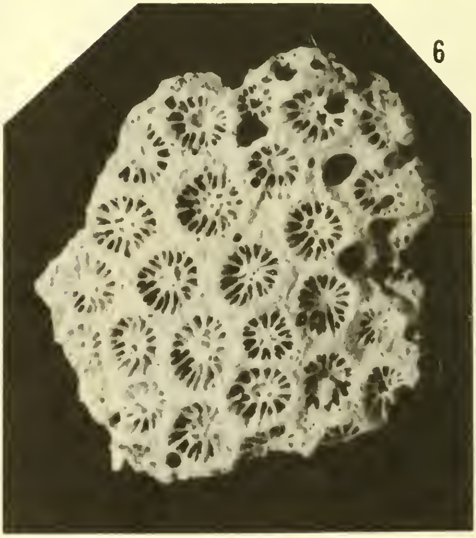
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EXPLANATION OF PLATE 46

Figure Page

1, 2. **Astrangia leonensis** Weisbord 398

Specimen SP-4a. Pinecrest Formation, Warren Brothers Pits, Sarasota. Corallite height 6.1 mm, diameter at base 3.4 mm, diameters of calice 5.1 mm × 4.4 mm.

1. View of side. Illustration × 5. 2. Calice. Illustration × 5.

3. **Astrangia solitaria** (Lesueur) 399

Specimen Hond-1a. Recent, Honduras. Corallum length 20 mm, width 4.7 mm, height 10 mm. Illustration × 5.

4, 5. **Phyllangia americana** Edwards and Haime 403

Specimen CAL-4a. Caloosahatchee Marl in Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. Height of corallite 10.5 mm, diameter at base 10 mm, diameters of calice 13.5 mm × 10.5 mm.

4. General view of side and upper part of calice. Illustration ×4. 5. Calice. Illustration × 5.

6. **Septastrea crassa** (Holmes) 405

Specimen USNM-DeLeon Spring (b), Volusia County. Corallum length 21 mm, width 18 mm. Illustration × 3.

EXPLANATION OF PLATE 47

Figure Page

1, 2. **Septastrea crassa** (Holmes) 405

1. Specimen IW-1a. Pleistocene ?, Intracoastal Waterway, South Carolina. Corallum length 127.5 mm, maximum width 85 mm, maximum thickness 24 mm. Illustration × 0.8. 2. Specimen DSD-1b. Duplin Marl (Mio-Pliocene) at Dismal Sink, Leon County. Corallum length 107 mm, maximum width 75 mm. Illustration × 0.9.

3. **Septastrea marylandica** (Conrad) 408

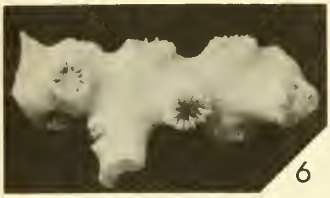
Specimen SP-2d. Pinecrest Formation (Warren Brothers Pits, Sarasota. Corallum length 45 mm, width 31.5 mm. Illustration × 1.9.

4, 5. **Oculina diffusa** Lamarck 410

4. Specimen CAL-8a. Caloosahatchee Marl in Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. Corallum length 41 mm, maximum width 27.5 mm. Illustration × 2.25. 5. Specimen SB-2d. Glades Formation, South Bay, Palm Beach County. Corallum length 21 mm, maximum width 8.5 mm. Illustration × 3.2.

6, 7. **Archohelia limonensis** Vaughan 414

6. Specimen SB-1a. Glades Formation, South Bay, Palm Beach County. Corallum length 15.3 mm, maximum width 8 mm. Illustration × 3. 7. Specimen USNM-135643. Pliocene-Pleistocene, Costa Rica. Corallum length 29.5 mm, maximum width 8 mm. Illustration × 2.4.



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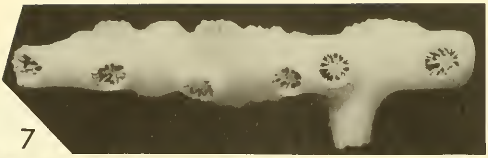

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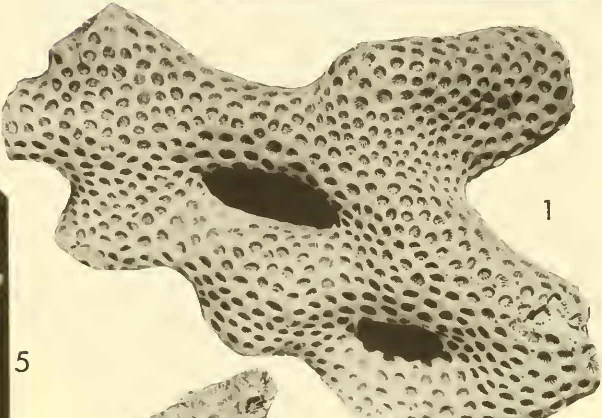

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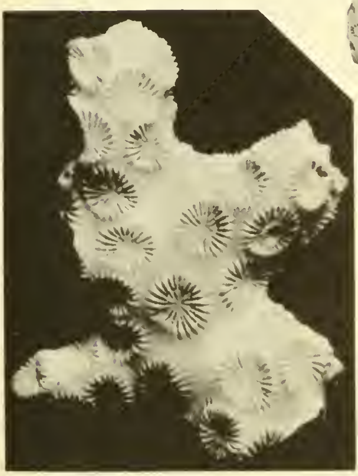

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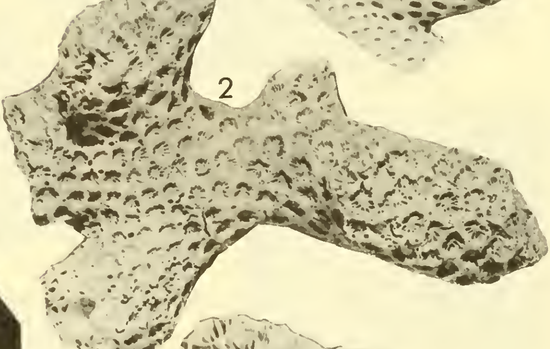

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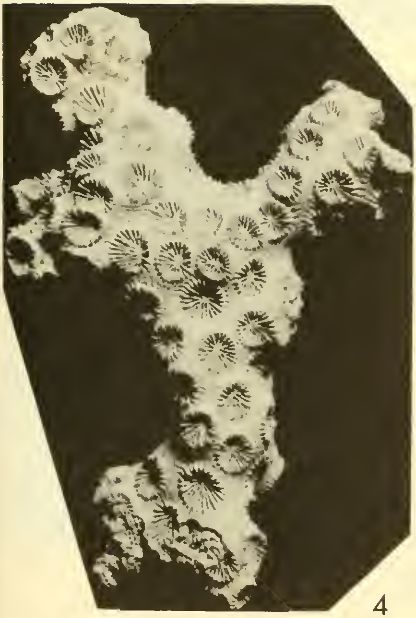

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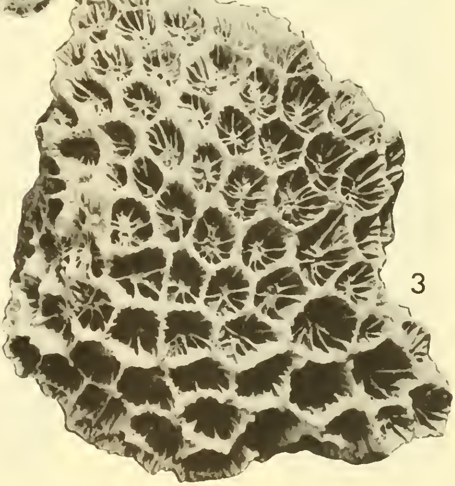

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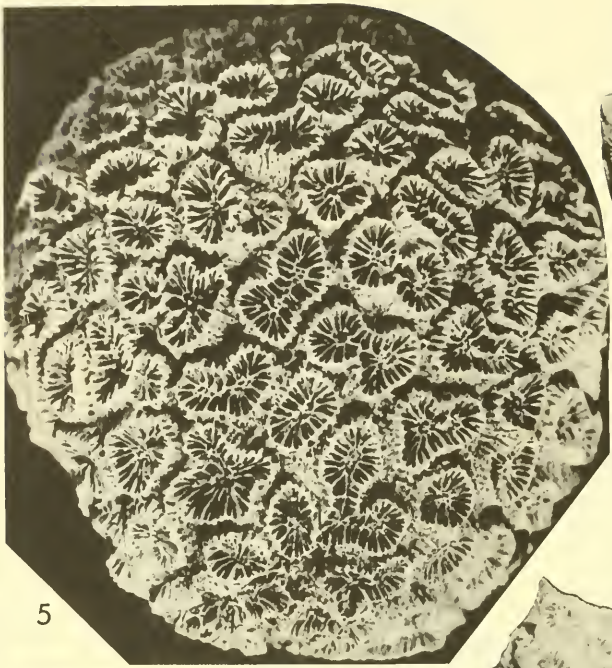

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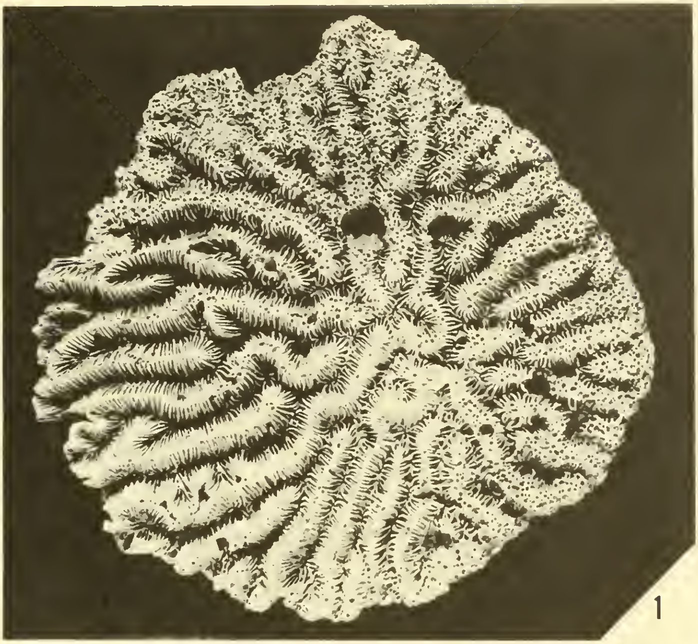
EXPLANATION OF PLATE 48

Figure		Page
1-4.	**Oculina sarasotana** Weisbord	412
	1-3. Specimen PG-5a. Caloosahatchee Marl, 3.5 miles southeast of Punta Gorda, Charlotte County. Length of main branch 132 mm. 1. Main branch. Illustration × 0.75. 2. Portion of main branch near crotch. Illustration × 1.8. 3. End view of smaller branch. Illustration × 3. 4. Specimen TEL-2a. Caloosahatchee Marl, 18 miles east of Punta Gorda, Charlotte County. Length 90 mm. Illustration × 1.2.	
5.	**Dichocoenia caloosahatcheensis** Weisbord, n. sp.	423
	Paratype, USNM-325299a. Caloosahatchee Marl in Caloosahatchee River. Diameters of head 60 mm × 55 mm. Illustration × 1.6.	

EXPLANATION OF PLATE 49

Figure		Page
1, 2.	**Meandrina meandrites** (Linnaeus)	416

Specimen USNM-325303. Caloosahatchee Marl, Shell Creek, Charlotte County. Diameters of calicinal surface 160 mm × 150 mm, height 85 mm. Illustrations × 0.5.
1. Calicinal surface. 2. Under surface.



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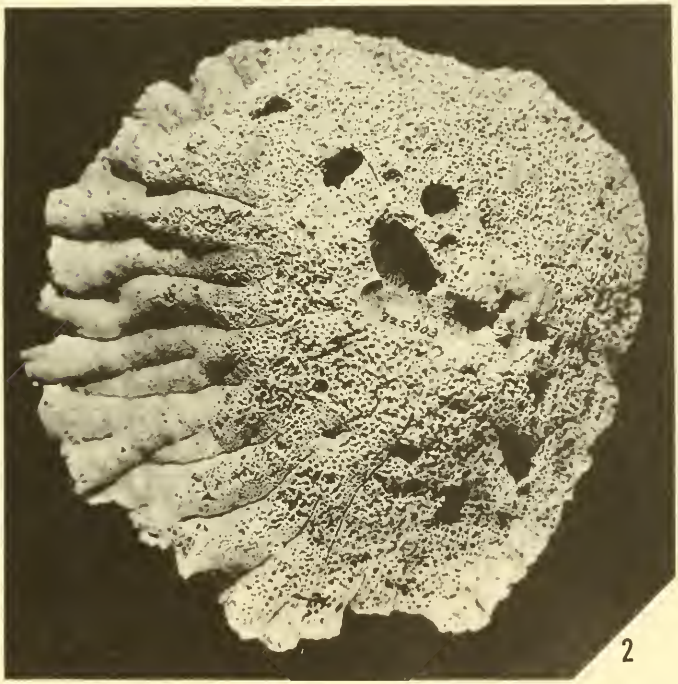

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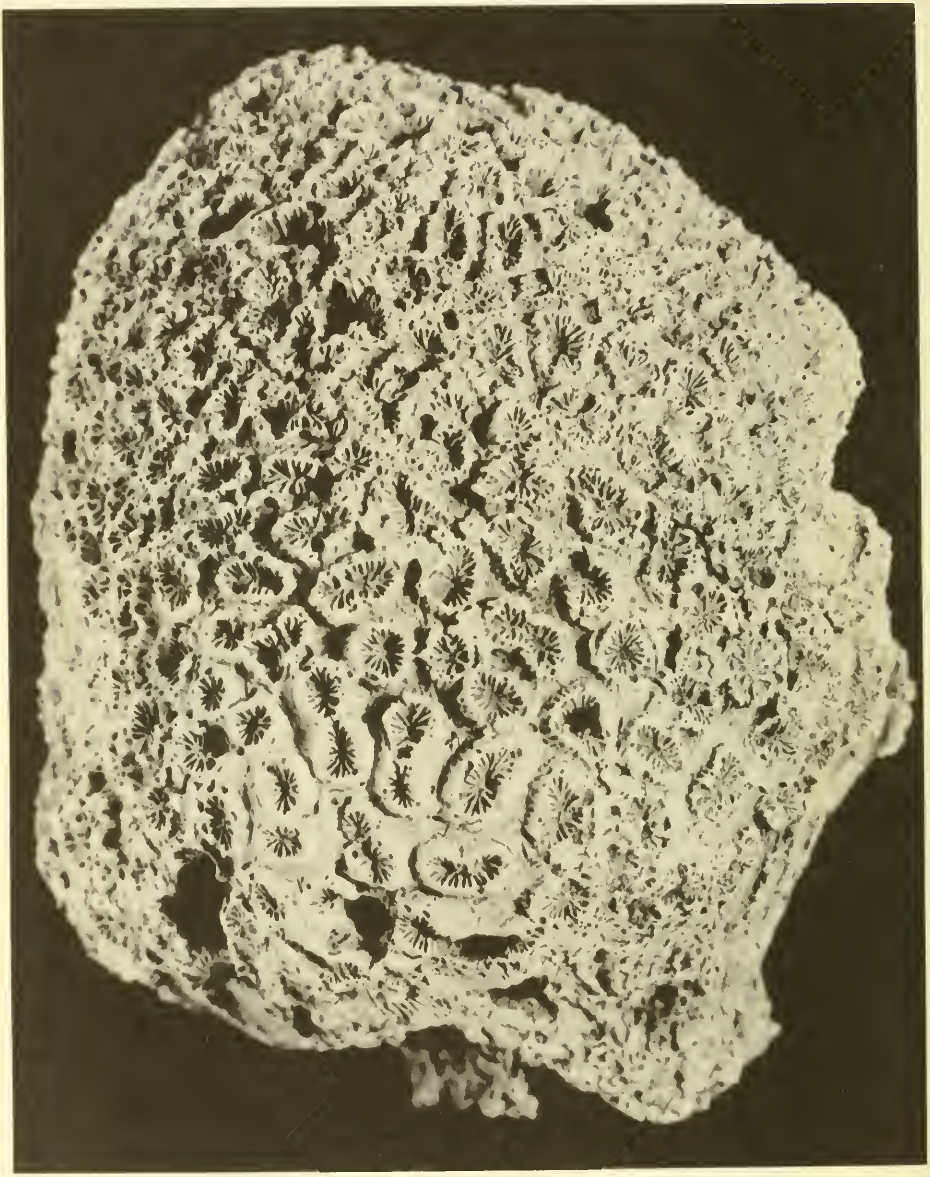

EXPLANATION OF PLATE 50

Figure		Page
1.	**Dichocoenia caloosahatcheensis** Weisbord, n. sp.	423
	Holotype, USNM-325299a. Caloosahatchee Marl in Caloosahatchee River. Corallum height 140 mm, width below middle 107 mm × 91 mm. Illustration about natural size. General view of surface.	

EXPLANATION OF PLATE 51

Figure Page

1. **Dichocoenia caloosahatcheensis** Weisbord, n. sp. 423

Holotype, USNM-325299a. Caloosahatchee Marl in Caloosahatchee River. Corallum height 140 mm, width below middle 107 mm × 91 mm. Illustration about natural size. View of interior.

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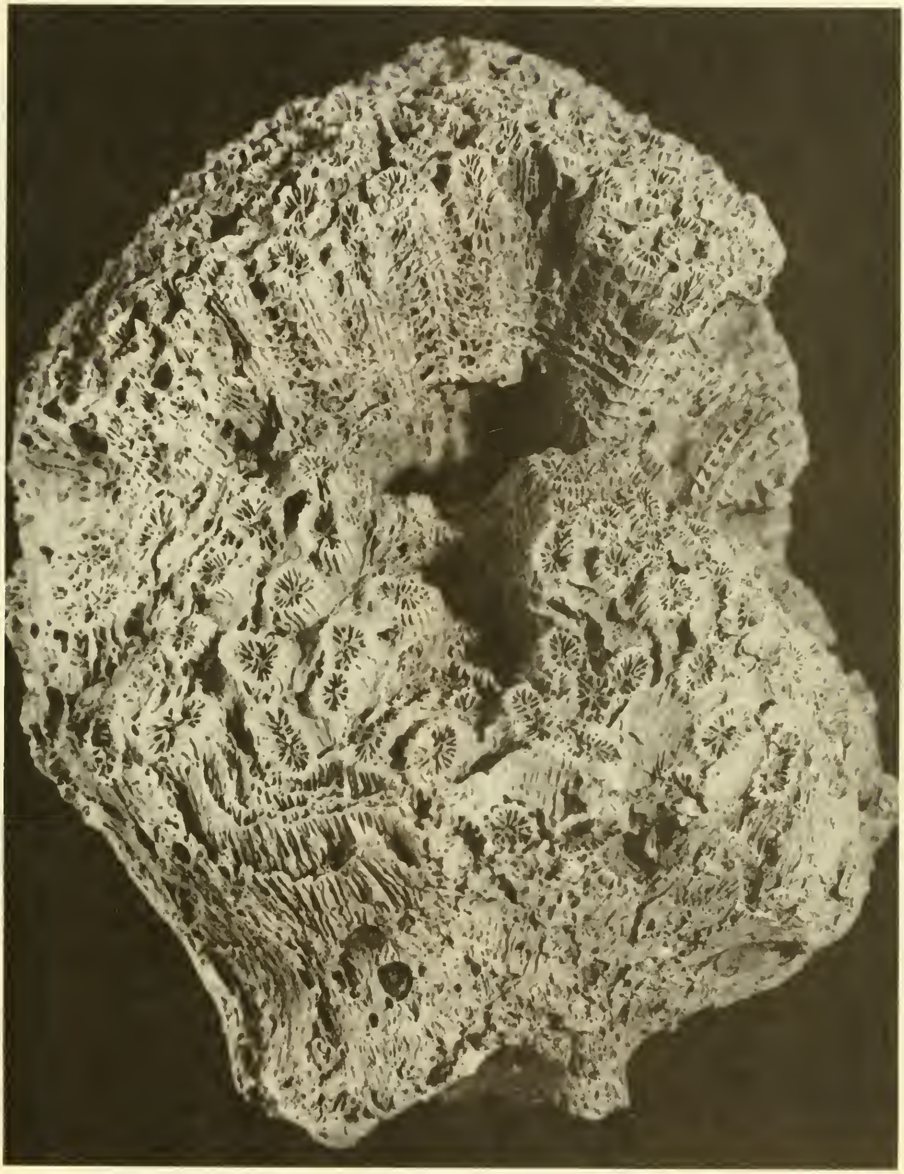

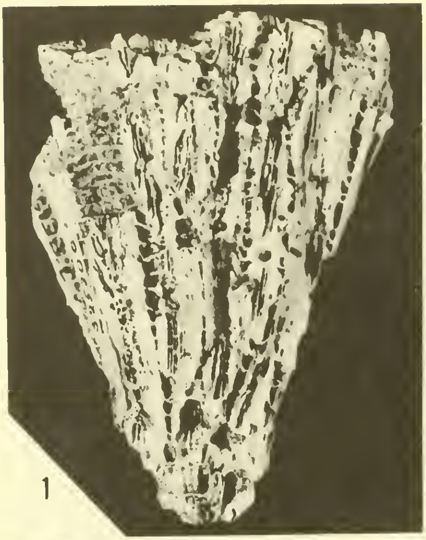
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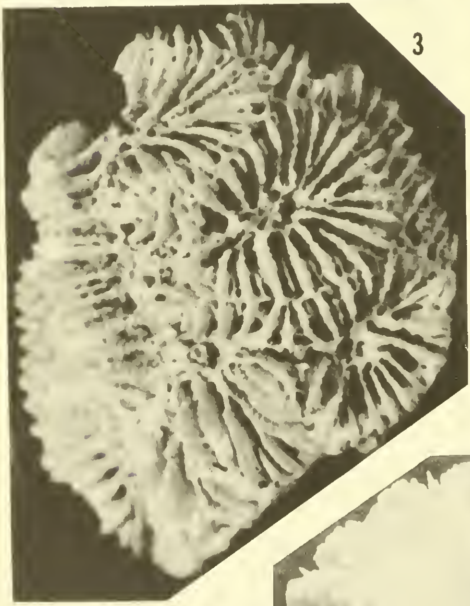
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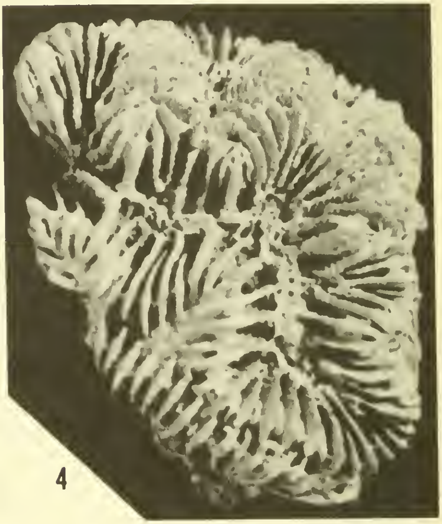
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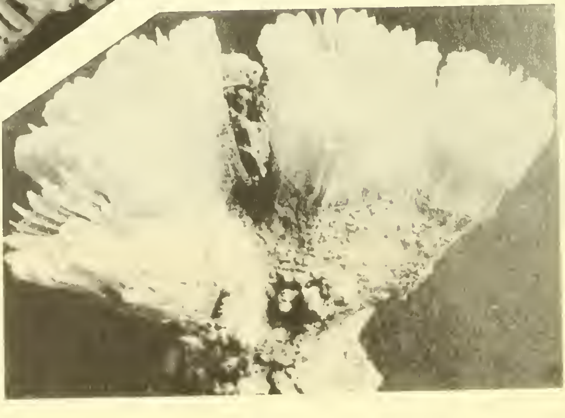
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EXPLANATION OF PLATE 52

Figure		Page
1, 2.	**Dichocoenia caloosahatcheensis** Weisbord, n. sp.	423
	Specimen USNM-325300 (3300). Caloosahatchee Marl, Shell Creek, Charlotte County. Corallum height 65 mm, diameters of calicinal surface 45 mm × 35 mm. Illustrations about natural size. 1. Side view. 2. View of calicinal surface.	
3, 4.	**Isophyllia ? desotoensis** Weisbord, n. sp.	439
	Holotype, SP-3a. Pinecrest Formation, Warren Brothers Pits, Sarasota. Corallum length 26.5 mm, width 21 mm, height 11.5 mm. Illustrations × 3. 3. Canted view of head. 4. View of calicular surface.	
5.	**Eusmilia fastigiata** (Pallas)	446
	Illustration from Vaughan and Wells (1943, p. 220, pl. 47, fig. 1). Recent, Tortugas, Florida. Natural size about 53 mm in width. Reproduction herein × 1.4.	

EXPLANATION OF PLATE 53

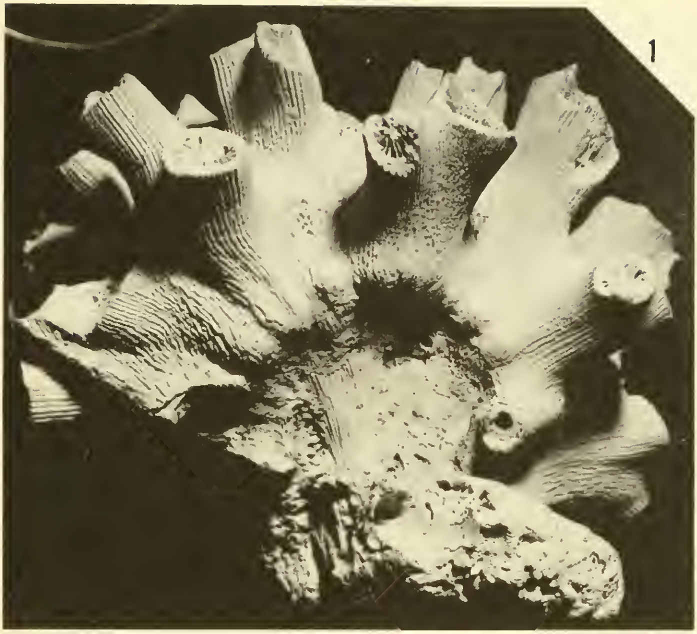
Figure Page

1-3. **Dichocoenia eminens** Weisbord, n. sp. 426

Holotype, PG-2a. Caloosahatchee Marl, 3.5 miles southeast of Punta Gorda, Charlotte County.
1. Corallum width 96 mm, height 80 mm. View of side. Illustration × 0.8. 2. Corallum width 96 mm, height 80 mm. View of head. Illustration × 0.8. 3. Young corallum nestled into depression shown on figure 1 above. Corallum length 31 mm, width 21 mm, height 15 mm. Illustration × 1.5.

4, 5. **Mycetophyllia lamarckiana** Edwards and Haime 443

Reproduced from Matthai (1928, p. 250, pl. LIV, figs. 4, 5). Recent, Coconut Point, Andros Island, Bahamas.
4. Specimen BM 28.3.1.110. (= pl. LIV, fig. 4 of Matthai). Diameters of calicinal surface 86 mm × 70 mm. Illustration × 0.5. 5. Specimen BM 28.3.1.109 (= pl. LIV, fig. 5 of Matthai). Diameters of calicinal surface 80 mm × 65 mm. Illustration × 0.5.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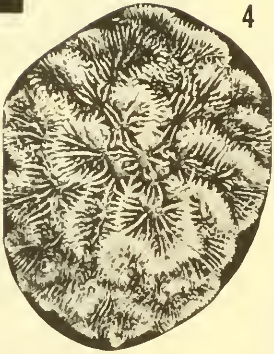
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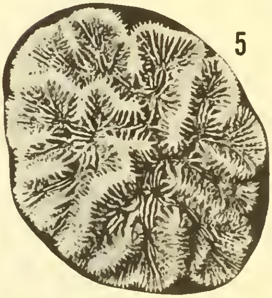
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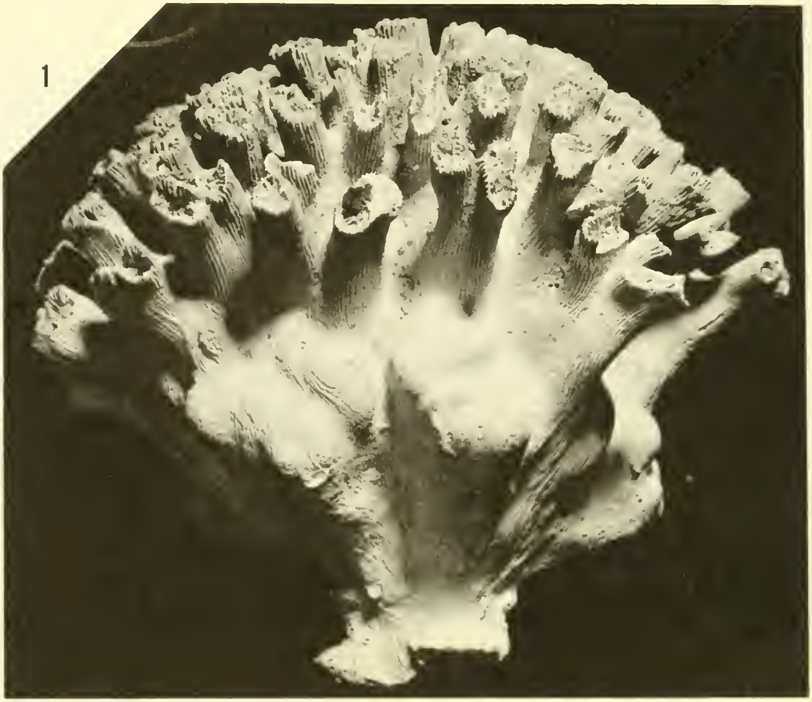

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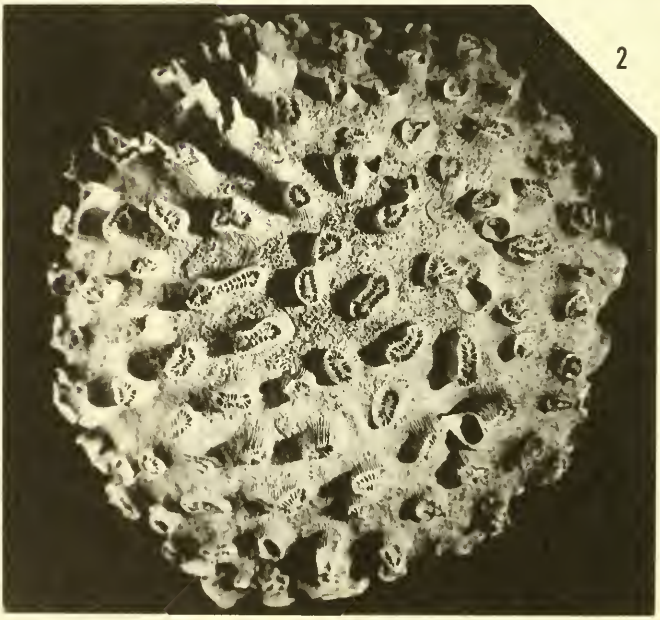


Explanation of Plate 54

Figure		Page
1, 2.	**Dichocoenia eminens** Weisbord, n. sp.	426

Paratype, FLX-14a. Caloosahatchee Marl, Florida, locality not known. Corallum height 115 mm, diameters of head, including projecting corallites 144 mm × 127 mm. Illustrations × 0.73. 1. View of side. 2. View of head.

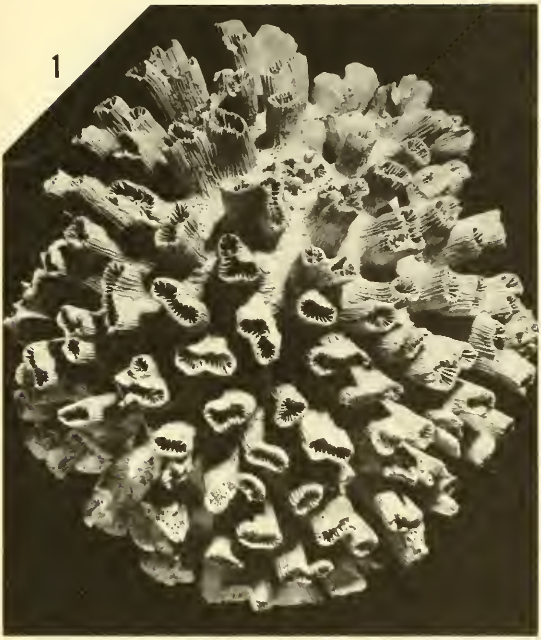
EXPLANATION OF PLATE 55

Figure Page

1-3. **Dichocoenia eminens** Weisbord, n. sp. 426

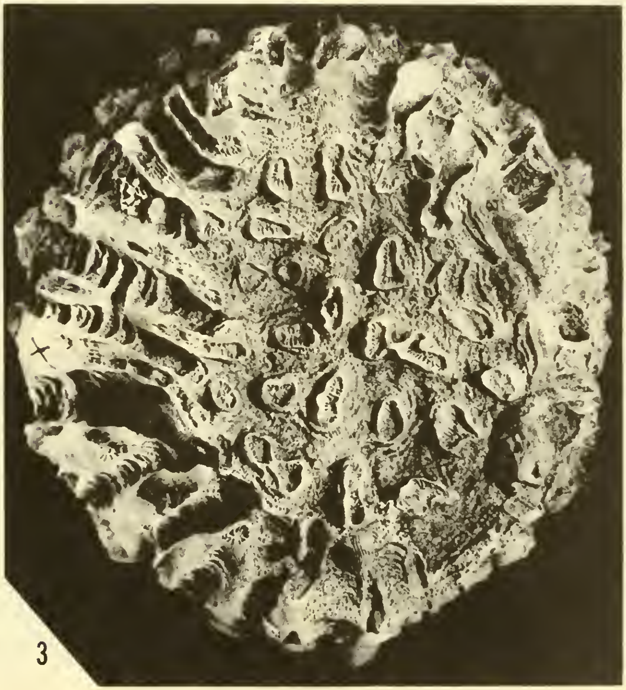
1, 2. Paratype, FLX-14a. Caloosahatchee Marl, Florida, locality not known. Corallum height 115 mm, diameters of head, including projecting corallites 144 mm × 127 mm.
1. View of head. Illustration × 0.5. 2. Calices, Illustration about natural size. 3. "Cotype," USNM-325293. Caloosahatchee Marl in Caloosahatchee River. Corallum length 162 mm, width 155 mm, height 104 mm. View showing corallites and calices. Illustration × 0.55.

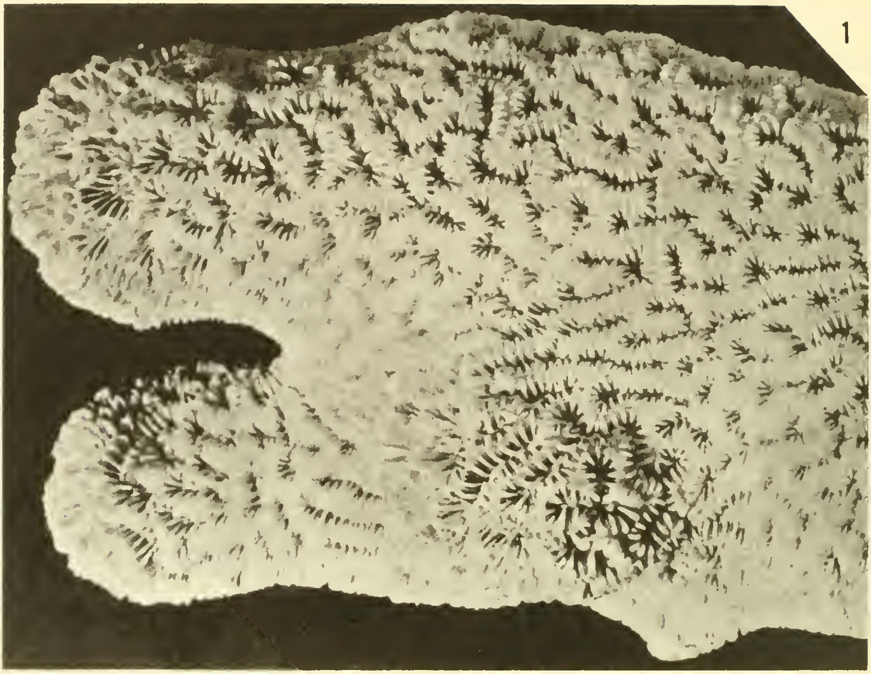
1



2

3





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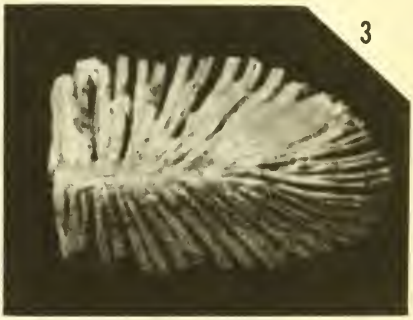

3

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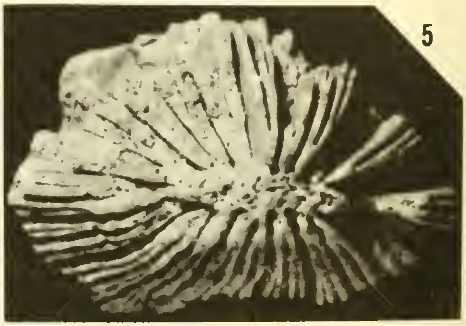

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Figure		Page
1.	**Dendrogyra cylindrus** Ehrenberg Distal part of Ehrenberg's type, from Matthai (1928, p. 170, pl. LXVI, fig. 1). Length of distal end shown by Matthai 115 mm, width 82 mm. Illustration herein about the same as Matthai's, which is natural size.	433
2, 3.	Incertae sedis "A" Specimen CAL-9a. Caloosahatchee Marl in Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. Internal mold, length 23 mm, height 14.5 mm, maximum width 14.5 mm. 2. View of side. Illustration × 2. 3. View of base and columella. Illustration × 2.	451
4, 5.	Incertae sedis "B" Specimen CAL-10a. Caloosahatchee Marl in Caloosahatchee River, 2-5 miles west of LaBelle, Hendry County. Internal mold, length 27 mm, height 19 mm, maximum width 18.5 mm. 4. View of side. Illustration × 2.2. 5. View of base and columella. Illustration × 2.2.	451

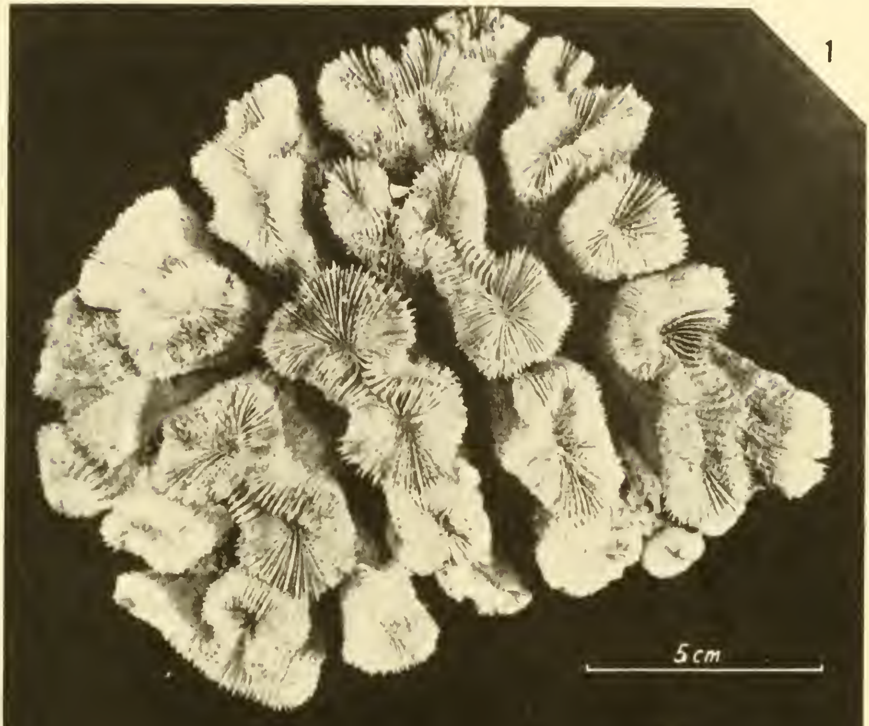
EXPLANATION OF PLATE 57

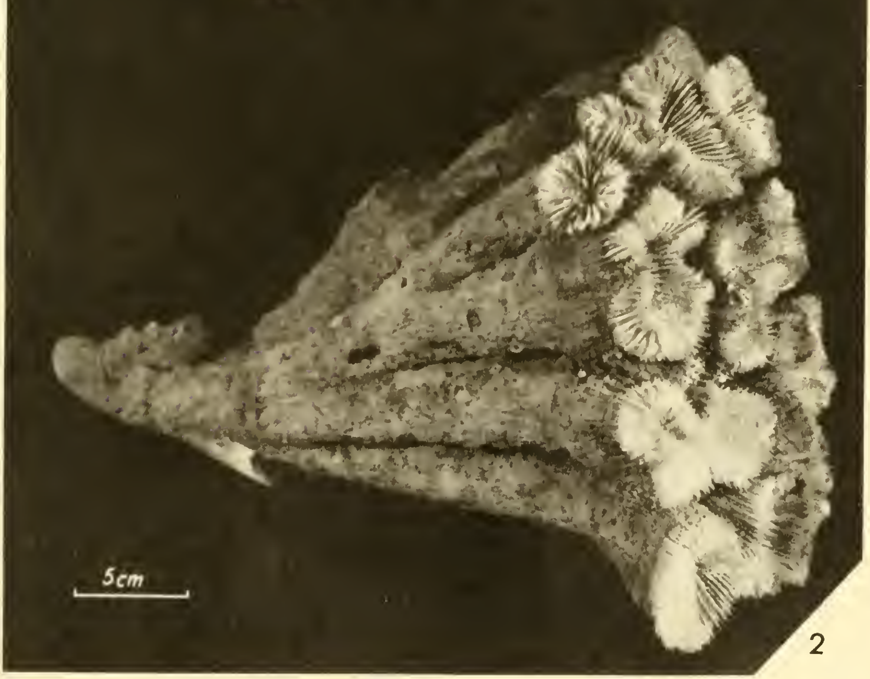
Figure		Page
1, 2.	**Mussa angulosa** (Pallas)	435

Specimen PJR-111. Recent, Piscaderabaai, Curaçao. Reproduced from Roos (1964, pl. VIII). Actual measurements, height 330 mm, diameters of head 167 mm × 158 mm.

1. View of calicinal surface. Illustration reduced to scale as shown. 2. View of side and part of calicular surface. Illustration reduced to scale as shown.

1





2

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by

W. A. van den Bold

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W. A. VAN DEN BOLD

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NEOGENE BIOSTRATIGRAPHY (OSTRACODA) OF SOUTHERN HISPANOLA

W. A. van den Bold

ABSTRACT

On the basis of material under the jurisdiction of the Seaboard Oil Corporation of Delaware, Atlantic Refining Company of Cuba, and the Standard Oil Company of New Jersey, in and around the Hoya de Enriquillo in the Dominican Republic and the Plaine du Cul-de-Sac in Haiti, an attempt is made to use brackish-water ostracodes for the correlation of Neogene strata in the Larger Antilles. The Jimaní Formation of the Dominican Republic is correlated with the brackish-water beds and fresh-water beds overlying the Morne Delmas Formation in Haiti and with the Harbour View beds in Jamaica, and tentatively an upper Pliocene age is suggested. The Las Salinas Formation of the Dominican Republic is correlated with the Morne Delmas Formation in Haiti and with parts of the Gurabo Formation and Bowden Formation, also with the Ponce Formation and "Lajas" beds of Puerto Rico and the La Cruz Formation (Cuba). The Upper Las Salinas is placed in the Pliocene, the Lower Las Salinas Formation and Angostura Formation in the Upper Miocene. Underlying these beds are the Rivière Grise and Arroyo Blanco and Trinchera Formations, in part of considerably deeper marine environment and of ages of upper and upper middle Miocene.

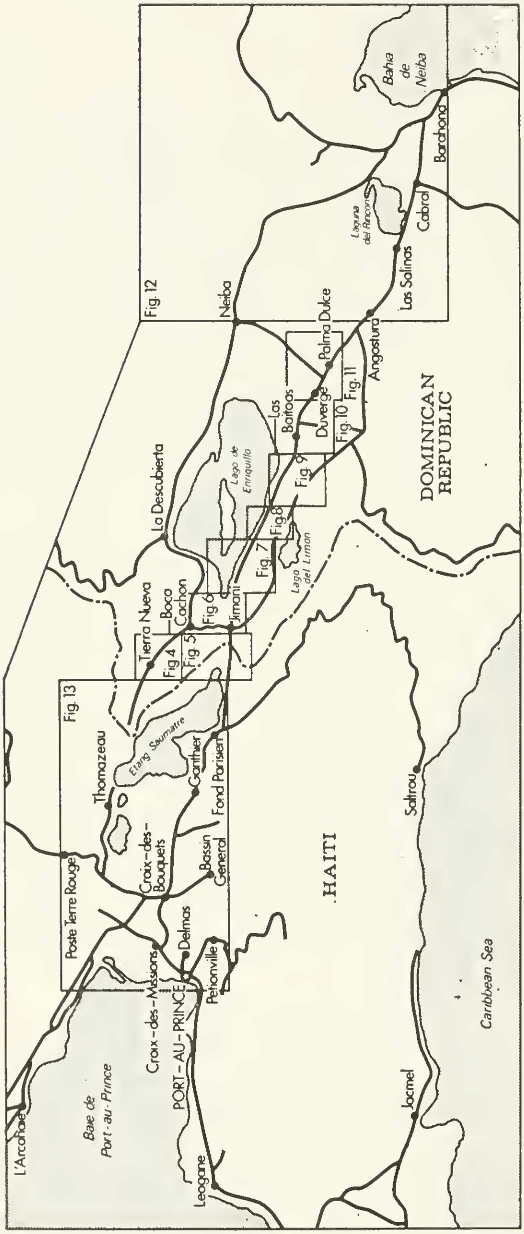
INTRODUCTION

LOCATION OF THE AREA (TEXT-FIG. 1)

The area with which we are concerned here lies in the southern part of the island of Hispañola. It trends from the Golfe de la Gonave on the west side of the Republic of Haiti in a general 115° E. direction towards the Bahi de Neiba on the south shore of the Dominican Republic. The area is bordered on the north and south by faults, forming a graben-structure, and should be treated as a single unit in discussing the Neogene geological history. However, historically the graben has been divided by an international boundary and as a result a different terminology has been developed in the western French-speaking region and the eastern Spanish-speaking region, the western Plaine du Cul-de-Sac and the eastern Hoya de Enriquillo.

PREVIOUS WORK

As the result of this political subdivision, two largely unconnected sets of literature have sprung up, only slightly united in cases where the same investigators worked in both areas. On the Haitian side, the earliest work that has stood the test of time is by L. G. Tippenhauer (1901), followed by that of Woodring, Brown, and Burbank (1924). Between this and the various publications by Butterlin and his students (1950-1960), there was only one description of a fauna by Coryell and Rivero (1940). Independent of those



Text-figure 1.—Map of Southern Hispañola, showing the individual location maps of Text-figures 4-13.

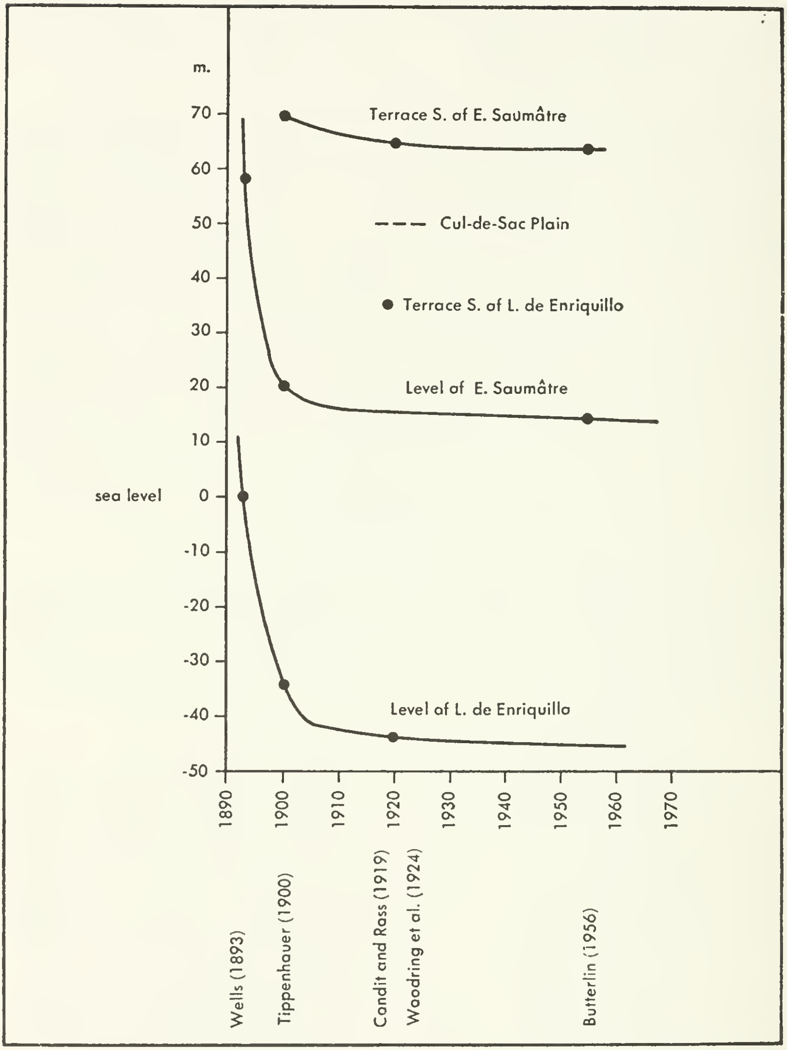
studies was the survey of Haiti by geologists of the Atlantic Refining Company; the Haitian part of this report is based on their collections.

In the area of the Dominican Republic there was hardly any work until the reconnaissance by Vaughan, *et al* (1921). It was W. P. Woodring who provided the only link with Haiti. In later years, important geological work has been done by R. Weyl and by students of Princeton University under the leadership of H. H. Hess. However, these resulted in publications, dealing almost exclusively with structure, petrology, and stratigraphy of the Pre-Tertiary and are, therefore, of little direct interest to the present study. A survey by geologists of the Seaboard Oil Company of Delaware was reported on by Bermúdez (1949); their collections form the basis of the present report in the Hoya de Enriquillo. A short survey into this territory was made by Kirk and Moore of the Atlantic Refining Company: they sampled some type areas and their material has also been used.

Syntheses by Butterlin (1954) and Weyl (1966) are hampered by this lack of unified nomenclature and lack of correlation between the Republic of Haiti and the Dominican Republic. This, and the fact that at the time there was no well-established basis for Neogene stratigraphy, has resulted in some erroneous correlations.

MOVEMENT OF LAKE LEVELS (TEXT-FIG. 2)

It has been pointed out by various authors (Woodring, Butterlin, Weyl, Peña) that the bottom of the Cul-de-Sac and Enriquillo plains represents an ancient seabottom. The present position of the levels of the two lakes: Étang Saumâtre at 14 m above sealevel, Lago de Enriquillo about 45 m below sealevel, indicates a tilting movement of the Cul-de-Sac - Enriquillo Graben towards the east. If a plot is made of the known positions of the lake levels as observed by Wells (1893), Tippenhauer (1901), Condit and Ross (*in* Vaughan, *et al,* 1921) and Butterlin (1956), we see that the lowering of the lake levels between 1893 and the present is of the same order, about 45 m, whereby since the beginning of the century it is not more than 6 m for the Etang Saumâtre and less than 10 m for the Lago de Enriquillo. During the same time, the lowering of the cliffs on the south side of Etang Saumâtre was of the same order, indicating that the downward movement of the graben is persisting.



Carto. Sect. GeoSci. L.S.U.

Text-figure 2. — Lake levels of Étang Saumâtre and Lago de Enriquillo from 1893 to the present.

ACKNOWLEDGMENTS

The previous works have been utilized throughout this study. Very useful geologic observations are recorded by Tippenhauer; Butterlin, and students; Condit and Ross; and Woodring. Of even more importance are the observations of paleontological nature, published by Bermúdez (1949) on the Dominican Republic, and those contained in unpublished company reports by R. C. Harris and Dorothy K. Palmer. Essential, of course, for the present study are the maps and reports by Kirk, Moore (Atlantic Refining Co.), and Hunter and Beall ([Dominican] Seaboard Company of Delaware). However, I must express in the first place my gratitude towards those, who supplied the material on which this study is based. P. J. Bermúdez (Ministerio de Minas e Hidrocarburos, Caracas, Venezuela) retained much of the material collected by Seaboard Oil Company of Delaware geologists, and thereby saved it for future use. He also provided sample maps. K. V. W. Palmer, Director, Paleontological Research Institution, Ithaca, New York made the Atlantic Refining Company's material available for research. Through these efforts, I have been able to study this wealth of material, maps, and paleontological reports. Some of the material used for comparison was donated by Bermúdez: *e.g.* Tuy and Cumaca Formations, material from Lago de Valencia; H. M. Bolli (Zürich) donated Recent and Subrecent material of the same lake and Ch. Ducloz (Geneva) contributed young Neogene material from southwest Puerto Rico.

Through the efforts of H. M. Kirk, manager in Cuba of the Atlantic Refining Company in Cuba, that company with the Standard Oil Company of New Jersey, and the Seaboard Company of Delaware, donated to the Paleontological Research Institution in 1947 the extensive suites of well samples and core samples, slides, and reports of their drillings in Haiti and the Dominican Republic. The material resulted from the cooperative work of the three companies and consists of the reports of the geologists and paleontologists of those companies.

The collection was donated to the Paleontological Research Institution by the Atlantic Refining Company of Cuba as a memorial to the late Dorothy K. Palmer in appreciation of her long, industrious service to that company. The material is preserved at the

Paleontological Research Institution and is available to persons for study of the region involved. The present paper is a study of a part of those suites.

P. A. Sandberg used some of the species of *Perissocytheridea* in his micropaleontology class at the University of Illinois. The SEM photographs reproduced in Plate 63 were made there. Two new species of this genus are described by Richard Forester in the Appendix.

D. Delorme (Calgary) kindly identified the three species of *Limnocythere,* H. V. Howe loaned some picked slides of ostracodes from Port-au-Prince harbour and from the Laguna de Leche, Camagüey (Cuba) from his private collections. Comparative material of the La Cruz Formation, Oriente (Cuba), was collected by the writer in August, 1972.

Lately a very interesting correspondence has developed with Richard Dempsey in Pointe-à-Pierre, Trinidad, who has been working along similar lines for Texaco Trinidad, Inc., and who has kindly permitted me to quote some of his observations.

Planktonic Foraminifera of the Central Plateau area of Haiti were studied by Aybars Hunerman for his MS thesis (LSU, 1972). Some of his results are used in the comparison of various areas. Financial support for this study came from the National Science Foundation through grant GA 16522.

MATERIAL

When the Atlantic Refining Company of Cuba closed its operations in Cuba in 1959, they wished to dispose of their collections of samples from their campaign in Haiti. Fortunately, most of the samples and the reports were saved by the cooperation of H. M. Kirk, Manager in Cuba, at the suggestion of Mrs. K. V. W. Palmer and eventually all material was stored in the collections of the Paleontological Research Institution in Ithaca. It was only when I submitted a manuscript on the ostracodes of the northern Dominican Republic (van den Bold, 1968), that Dr. K. Palmer informed me about the existence of this material. Practically the whole collection of slides worked by the late Dorothy Palmer for the Atlantic Refining Company of Cuba, with additional samples from her private collection and many paleontological reports are available; however, a number of reports are missing and some location maps. Therefore, I have a number of samples of which the location is only very imperfectly known and they had to be omitted from the present report.

The material from the Dominican Republic was donated almost entirely by P. J. Bermúdez who also provided samplemaps. Unfortunately lithological description is only available for part of the material. These samples were all collected by geologists for the Dominican Seaboard Oil Company, namely R. Beall and J. W. Hunter. H. M. Kirk and B. N. Moore of the Atlantic Refining Company made short collecting trips to important areas in the Dominican Republic, and their samples are preserved in the collections of the Paleontological Research Institution, Ithaca, New York.

Dominican Republic, Hoya de Enriquillo.

1. Quaternary

6818 (R. Beall), Lake Enriquillo mud, W. of Baitoa (Text-fig. 9) Ostr.: *Haplocytheridea karlana* (Stephenson), *Cyprideis portusprospectuensis* van den Bold, *Perissocytheridea bicelliforma* Swain?, *Loxoconcha purisubrhomboidea* Edwards, *Campylocythere*? sp. A. Most, if not all, of these forms are derived from the Jimaní Formation.

10287 (J. W. Hunter), Isla Cabritos, Recent, shallow brackish-water limestone. Ostr.: *Limnocythere* cf. *L. friabilis* Benson and MacDonald, *Cytheridella ilosvayi* Daday?, *Cyprideis salebrosa* van den Bold, (noded), *Cyclocpyris* sp. 1.

10319 (J. W. Hunter): 1 km E of Duvergé on Hwy. to Barahona, fig. 11. With *Tagelus plebeius* (Solander) (*T. gibbus* Splendler), corals and oysters. Ostr.: *Cypridopsis vidua* (Müller), *Cyclocypris* sp.

10359 (J. W. Hunter): W of the road from La Furnia to Boca Cachón, at gas-seep (Bermúdez, 1949, p. 46: Miocene). Ostr.: *Cyprideis salebrosa* van den Bold. (Text-fig. 6).

2. Jimaní Formation

6795 (R. Beall): Hills E. of Palma Dulce (Text-fig. 11), fossiliferous limestone and clay.

6800 (R. Beall): E. of Palma Dulce, chalky limestone and calcareous clay (Text-fig. 11).

6801 (R. Beall): E. of Palma Dulce (Text-fig. 11), fossiliferous limestone, pebbles.

6816 (R. Beall): W. of Baitoa (Text-fig. 9), fossiliferous limestone, reef rubble.

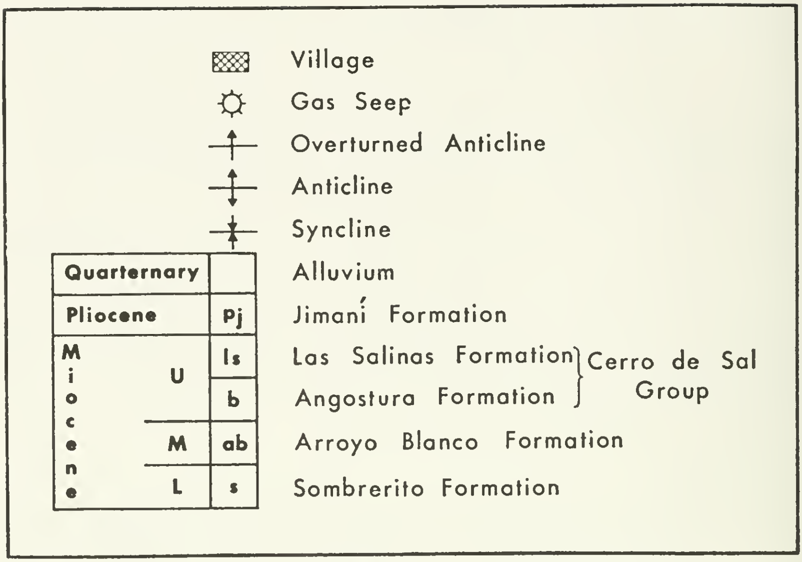
6817 (R. Beall): W. of Baitoa (Text-fig. 9), fossiliferous limestone.

6825 (R. Beall): Hills W. of Baitoa (Text-fig. 9), fossiliferous limestone, limestone conglomerate.

6846 (R. Beall): S. of Arroyo Blanco, 1 km E. of La Furnia (Text-fig. 6): fossiliferous limestone and buff calcareous clay.

10279 (J. W. Hunter): location not on map, chalky clay and thin-bedded fossiliferous limestone.

10340 (J. W. Hunter): Cañada del Muerto, SW of Baitoa (Text-fig. 9), gray nodular, fossiliferous clay.

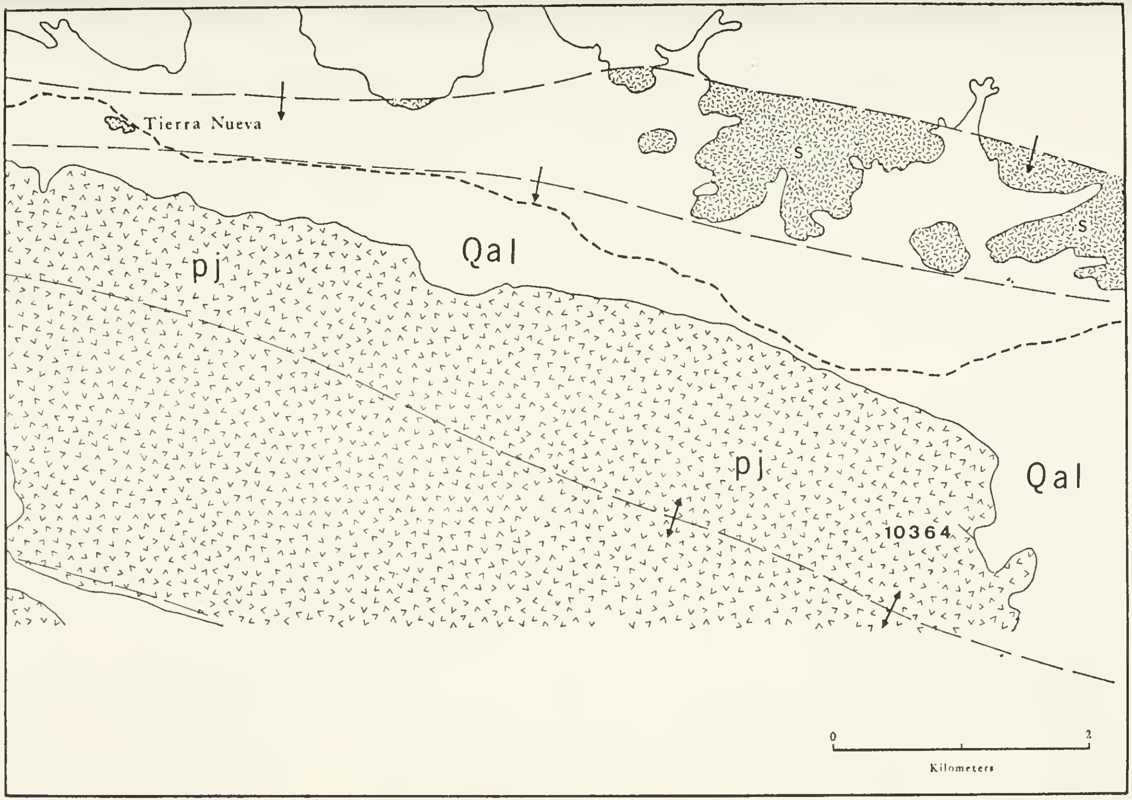


Text-figure 3. — Legend to maps 4-11; geology on these maps is by Hunter and Beall, geologists with Dominican Seaboard Oil Co.

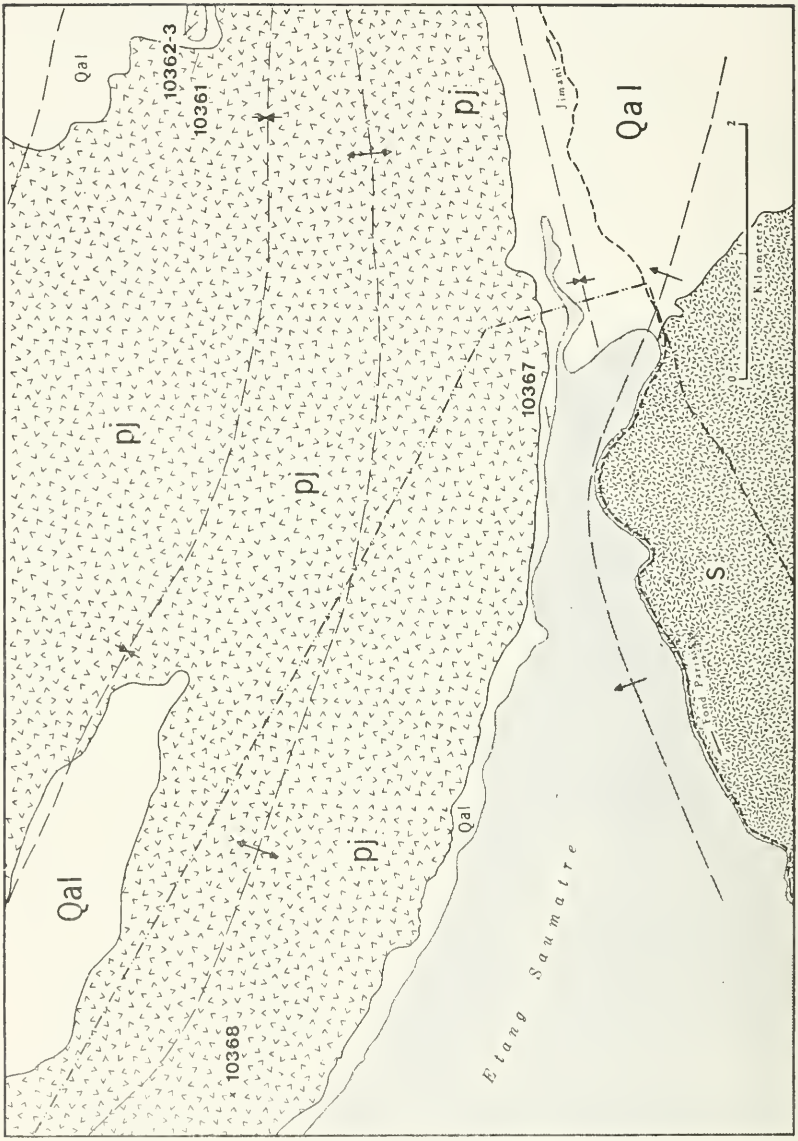
10343 (J. W. Hunter): Loma de Baitoita (Text-fig. 9), gray coralline limestone and calcareous clay.
10352 (J. W. Hunter): NE of El Limón (Text-fig. 8), white to gray fossiliferous clayey limestone (Bermúdez, 1949, p. 46: Miocene).
10353-4 (J. W. Hunter): Cañada Mocal (Text-fig. 8), chalky limestone and clay.
10361 (J. W. Hunter): (Text-fig. 5): thin marly fossiliferous limestone.
10362 (J. W. Hunter): Tierra Prieta, N. of Jimaní (Text-fig. 5): silty clay, thin limestone.
10363 (J. W. Hunter): same location as 10362 (Bermúdez, 1949, p. 46: Jimaní Formation).
10364 (J. W. Hunter): along scarp of Boca Cachón road, Tierra Prieta (Text-fig. 4): oysterbed, granular clay (Bermúdez, 1949, p. 46: Jimaní Formation).
10367 (J. W. Hunter): North of Etang Saumâtre (Text-fig. 5), calcareous clay.
10368 (J. W. Hunter): (Text-fig. 5): calcareous clay.
10394 (J. W. Hunter): Cañada Mocal, gray fossiliferous clay. (Not on map).

3. Las Salinas Formation.

6821 (R. Beall): sump along trail from Baitoa to Limón. Cañada Guayabo, W. of Baitoa (Text-fig. 9): thin-bedded conglomeratic limestone, clay-shale.
6822 (R. Beall): Arroyo Guayabo (Text-fig. 9): limestone, sandstone, clay-shale (Bermúdez, 1949, p. 46: Jimaní Formation).
6823 (R. Beall): Arroyo Guayabo (Text-fig. 9): sandstone, clayey limestone.

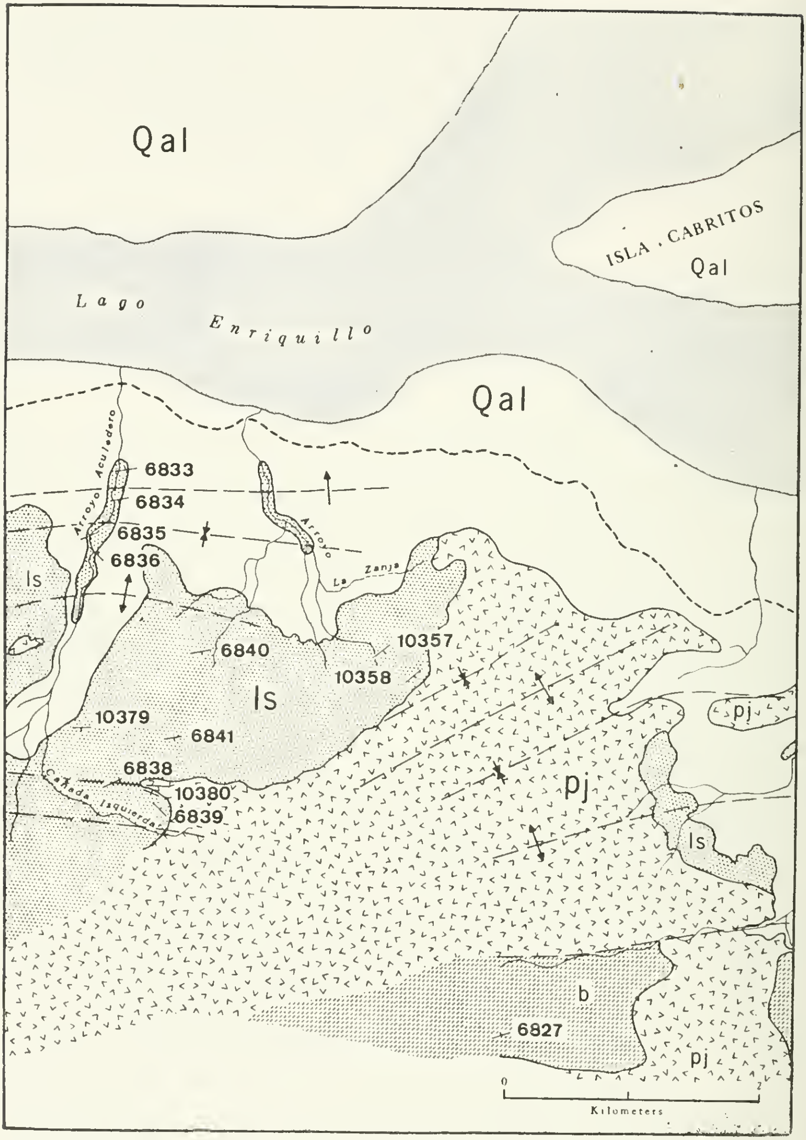


Text-figure 4. — Geological and sample map of the area southeast of Tierra Nueva and north of the eastern end of Étang Saumâtre.



Text-figure 5.—Geological and sample map of the area of the east end of Étang Saumâtre.

Text-figure 6. — Geological and sample map of the area east of Jimaní.



Text-figure 7.— Geological and sample map of the area south of the west end of Lago de Enriquillo.

6833 (R. Beall): Arroyo Aculadero (Text-fig. 7): thin-bedded shale and limestone.

6834 (R. Beall): Arroyo Aculadero (Text-fig. 7): paper shale.

6835 (R. Beall): Arroyo Aculadero (Text-fig. 7): calcareous clay.

6836 (R. Beall): Arroyo Aculadero (Text-fig. 7): thin-bedded shale, limestone.

6838 (R. Beall): E. of Arroyo Blanco (Cañada Isquierda (Text-fig. 7): chalky limestone, coquina.

6839 (R. Beall): Aculadero structure, Cañada Isquierda (Text-fig. 7): thin-bedded shale, limestone, and sandstone.

6840 (R. Beall): E. of Arroyo Blanco (Text-fig. 7): thin-bedded shale.

6841 (R. Beall): E. of Arroyo Blanco (Text-fig. 7): thin-bedded shale, limestone (Bermúdez, 1949, p. 46).

6843 (R. Beall): SE of Arroyo Blanco (Text-fig. 6), ½ km E of Hato Nuevo: thin limestone coquina and conglomerate.

6844 (R. Beall): SE of Arroyo Blanco (Text-fig. 6): ½ km E. of Hato Nuevo: thin limestone, shale, coquina, and limestone conglomerate.

6845 (R. Beall): E. of Arroyo Blanco (Text-fig. 6): paper shale.

5847 (R. Beall): S. of Arroyo Blanco, Cañada Grande (Text-fig. 6): limestone conglomerate, shale, and limestone.

6867 (R. Beall): Arroyo Blanco area (Text-fig. 6): white limestone, calcareous clay.

10267 (J. W. Hunter): Barahona Province (location not on map): gray, nodular to thin-bedded clayshale below main gypsum-horizon.

10268 (J. W. Hunter): (Bermúdez, 1949, p. 46) not on map: gray nodular to thin-bedded clayshale, below main gypsum-horizon.

10282 (J. W. Hunter): (Text-fig. 6) (Bermúdez, 1949, p. 46): silty fossiliferous sand.

10286 (J. W. Hunter): N. of Jimaní (Text-fig. 6): thin-bedded clay.

10337 (J. W. Hunter): Cañada del Muerto SW of Baitoa (Text-fig. 9): conglomeratic limestone and sandy clay.

10339 (J. W. Hunter): Cañada del Muerto (Text-fig. 9: fossiliferous shelly limestone.

10341 (J. W. Hunter): Cañada del Muerto (Text-fig. 9): gray nodular clay.

10346 (J. W. Hunter): Loma de Baitoita (Text-fig. 9): calcareous clay and chalky limestone.

10347 (J. W. Hunter): (near 10346): limestone conglomerate.

10348 (J. W. Hunter): trail to El Limón (Text-fig. 8): Gray clay.

10351 (J. W. Hunter): S. of El Limón trail (Text-fig. 9): thin-bedded clay, limestone coquina.

10357 (J. W. Hunter): E. of Arroyo Aculadero at foot of bluff (Text-fig. 7): sandy clayshale (Bermúdez, 1949, p. 46).

10358 (J. W. Hunter): Cañada Mocal (Text-fig. 7): marly clay.

10369 (J. W. Hunter): Jimaní area (Text-fig. 6): fossiliferous clay.

10379 (J. W. Hunter): Arroyo Aculadero (Text-fig. 7): thin clay.

10380 (J. W. Hunter) Cañada Izquierda of Arroyo Aculadero (Text-fig. 7): thin clay.

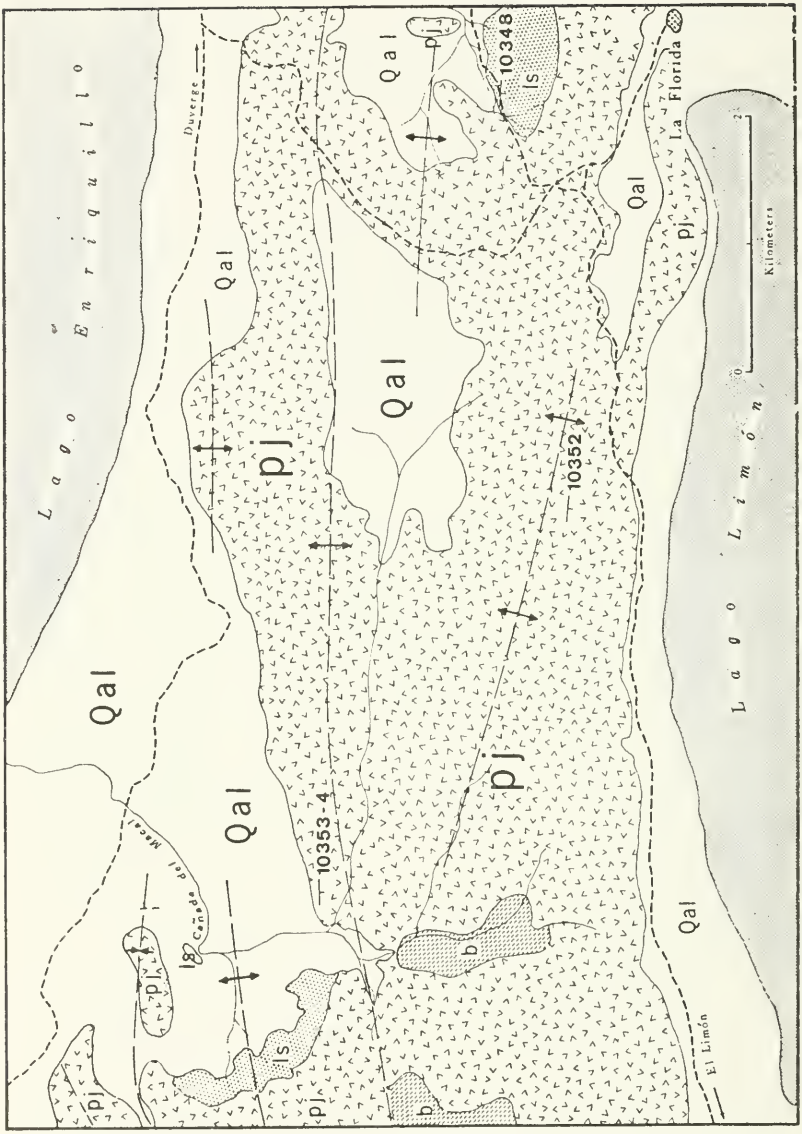
10393 (J. W. Hunter): (Text-fig. 6): thin-bedded limestone and shale.

10396 (J. W. Hunter): Cañada Grande (Text-fig. 6): thin-bedded limestone, shale and limestone conglomerate.

4. Angostura Formation. Both samples probably belong to younger formations.

6794 (R. Beall): E. of Palma Dulce (Text-fig. 11), limestone, clay, limestone.

6827 (R. Beall): N. of Limón, samp area, clayshale with oilsmell (Text-fig. 7): (Bermúdez, 1949, p. 46, Miocene). See Table 4.



Text-figure 8. — Geological and sample map of the area between Lago de Enriquillo and Lago de Limón.

5. Arroyo Blanco Formation.

6809 (R. Beall): S. of Venganaver (Text-fig. 10), sandy clay, limestone conglomerate.

10272 (J. W. Hunter): (Text-fig. 10) white fossiliferous chalky limestone.

10330 (J. W. Hunter): Just SE of Vanganaver (Text-fig. 10), fossiliferous limestone. (Bermúdez, 1949, p. 167), also containing *Elphidium cercadense* Bermúdez, marker for the Cercado Formation).

6. Samples from Atlantic Refining Company (Text-fig. 12).

H 109 (5754): near Angostura, grayish-tan, slightly sandy calcareous shale.

H 112 (5757): near Angostura, greenish gray calcareous fine sandstone.

H 114 (5759): near Angostura, greenish gray calcareous shale.

H 1212 (7792): Arroyo Sombrerito, Azua Prov., interbedded light-gray calcareous clayshale and marly limestone: Upper Sombrerito. Ostr.: *Cytherella* sp. aff. *C. vulgata* Ruggieri, *Macrocypris* sp., *Abyssocypris pykna* (van den Bold), *Krithe morkhoveni* van den Bold, *Agrenocythere hazelae* (van den Bold).

H 5054 (7098): Arroyo Molinillo, Azua Prov., gray calcareous sandstone. Ostr.; *Cytheromorpha curta* Edwards.

H 5062 (7106): Arroyo Molinillo, Azua Prov., grayish-tan fine sandy calcareous shale. Ostr.: *Radimella* ex gr. *confragosa* (Edwards), *Quadracythere* aff. *compacta* (Brady), *Caudites nipeensis* van den Bold, Bairdia cf. *antillea* van den Bold, *Cytheromorpha curta* Edwards, *Perissocytherida* sp., *Paracypris* sp.

H 5072 (7116): Arroyo Molinillo, Azua Prov., tan, fine-grained calcareous sandstone and gray calcareous shale. Ostr.: *Cytheromorpha curta* Edwards.

H 5073 (7117): Arroyo Molinillo, Azua Prov., grayish tan calcareous sandstone and shale. Ostr.: *Bairdia* sp.

H 5074 (7118): Arroyo Molinillo, Azua Prov., grayish tan fine-grained calcareous sandstone and shale. Ostr.: *Bairdia* sp.

H 5084 (7128): Arroyo Molinillo, Azua Prov., gray calcareous fine-grained sandstone and shale. Ostr.: *Radimella* ex gr. *confragosa* (Edwards), *Cativella navis* Coryell and Fields, *Cytheromorpha curta* Edwards, *Orionina similis* van den Bold, *Cyprideis* sp., *Haplocytheridea* sp.

K 10 (5909): Trinchera Bluff.

K 10A (5901), K 123 (6233): Trinchera Bluff.

K 155 (6417): Rio Yague del Sur, below Bao. Ostr.: *Radimella* ex gr. *confragosa* (Edwards), *Caudites nipeensis* van den Bold, *Quadracythere producta* (Brady), *Neocaudites triplistriatus* (Edwards), *Loxoconcha fischeri* (Brady), *Xestoleberis* sp., *Bairdia antillea* van den Bold.

K 156 (8418): Rio Yague del Sur, below Bao. Ostr.: *Cytheromorpha curta* Edwards.

K 206 (6591): Arroyo Blanco. Ostr.: *Cyprideis* sp.

K 221 (6604): on trail to Limón, 4 km from Jimaní (just off Text-fig. 6).

K 227 (6610): 400 m NW of Salt Mine loading shed, Angostura.

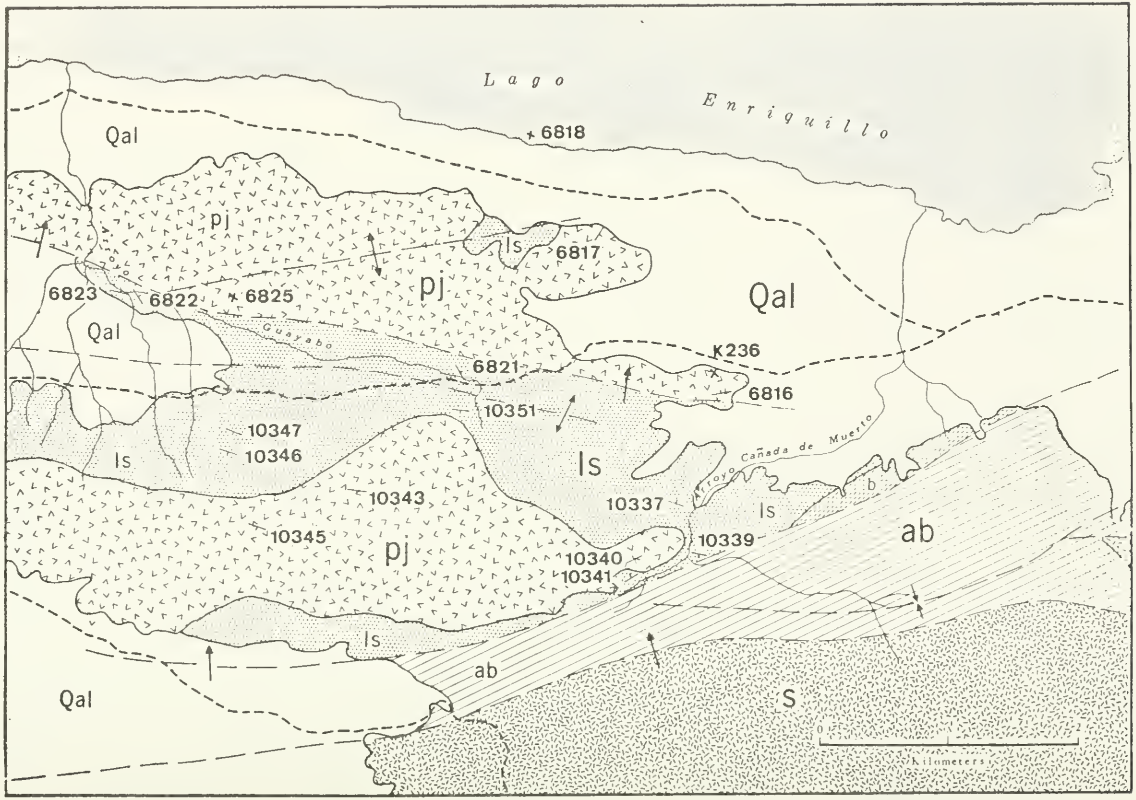
K 236 (6619): 13 km W. of Duvergé.

K 250 (6724): Mouth of Arroyo Moyalito, between Arroyo Batida and Arroyo Blanco. Ostr.: *Agrenocythere hazelae* (van den Bold), *Abyssocythere trinidadensis* (van den Bold).

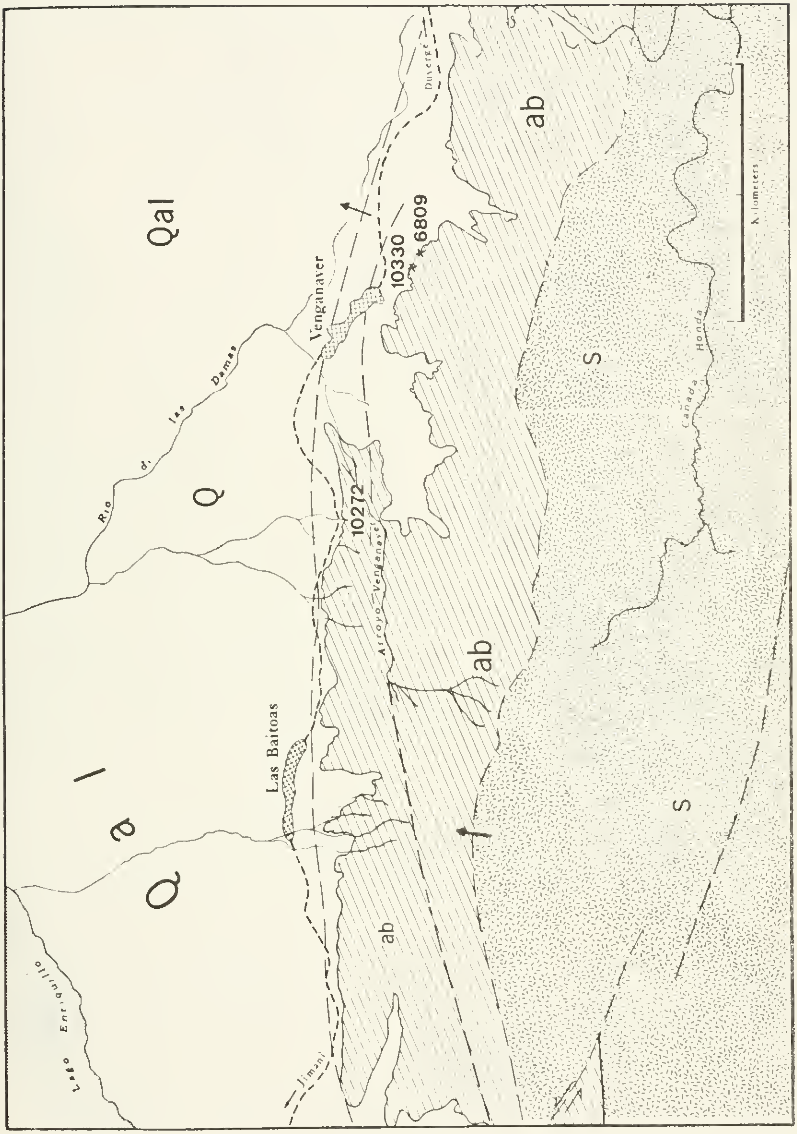
K 254 (6728): Arroyo Sombrerito. Ostr.: *Bairdia oarion* van den Bold, *Bradleya* ex gr. *dictyon* (Brady), *Agrenocythere hazelae* (van den Bold), *Costa maquayensis* van den Bold.

M 30 (6377): Gully E. of fork in Cabeza de Toro-Enriquillo and Banica road. Ostr.: *Cyprideis salebrosa* van den Bold, *Perissocytheridea bicelliforma* Swain?, *Orionina serrulata* (Brady), *Xestoleberis* sp.

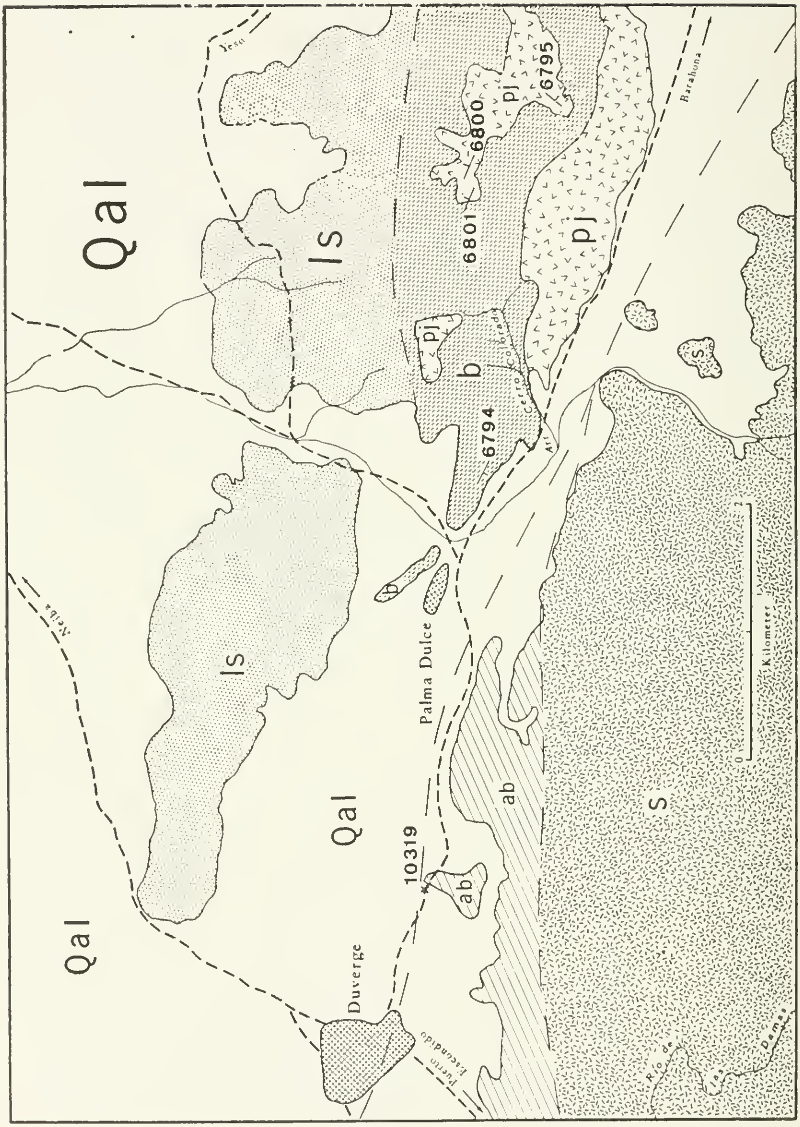
M 33 (6380): Enriquillo basin-Cabeza de Toro road. Ostr.: *Cyprideis salebrosa* van den Bold, *Campylocythere?* sp., *Xestoleberis* sp.



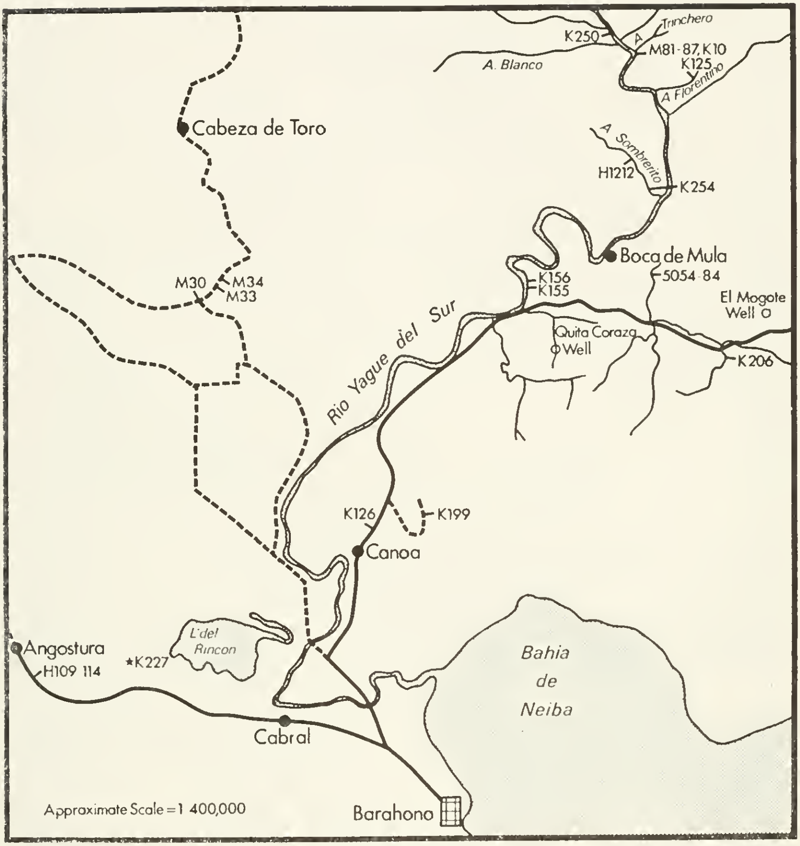
Text-figure 9.—Geological and sample map of the area south of Lago de Enriquillo, between Limón and Venganaver.



Text-figure 10.—Geological and sample map of the area south of Venganaver and Las Baitoas.



Text-figure 11.—Geological and sample map of the area east of Duvergé.



Text-figure 12. — Location of samples in Barahona Province, Dominican Republic.

M 34 (6381): Enriquillo basin-Cabeza de Toro road. Ostr.: *Haplocytheridea* aff. *stephensoni* (van den Bold).

M 81 (6381): Trinchera Bluff, collected from a bed of dark-blue shale, 15 cm thick, at the water's edge (flood level), about 300 m due S. of culvert of Hwy. or close to where the A. Trinchera flows into the Río Yague del Sur.

M 82 (6624): Trinchera Bluff, 300 m S. and 125 m above M 81. Gray to greenish-gray calcareous shale.

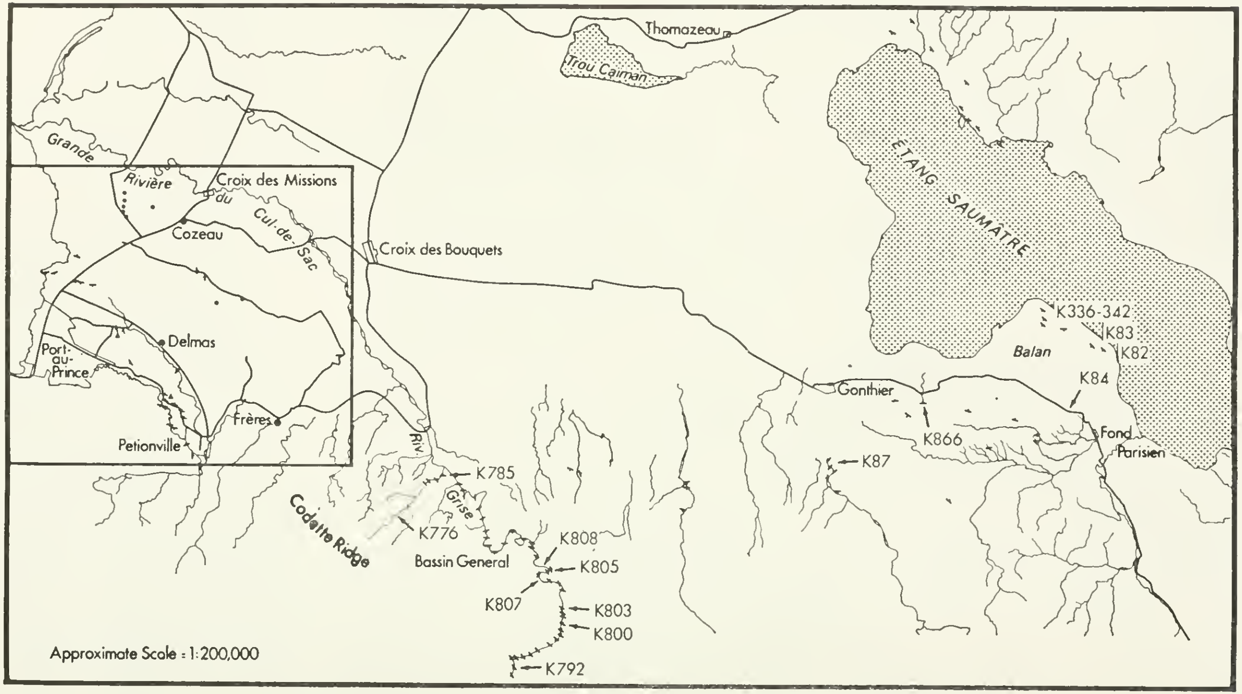
M 83 (6625): Trinchera Bluff, N end of Trinchera Bluff, 2.5 m straight above M 81, same lithology.

M 85 (6627): Trinchera Bluff, 5.25 m above M 81.

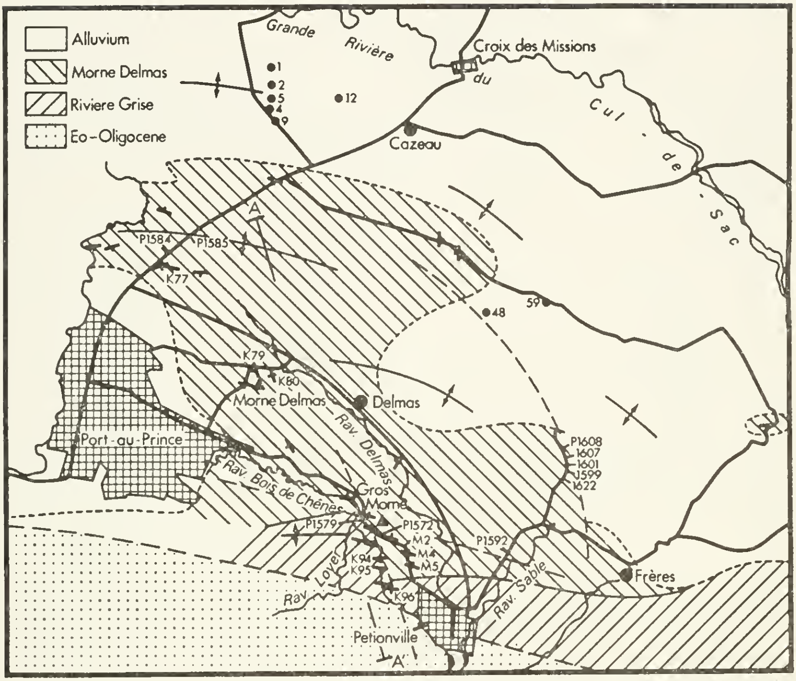
M 86 (6628): Trinchera Bluff, 7.75 m above M 81.

M 87 (6629): Trinchera Bluff, 10.25 m above M 81.

Plummer 7c: Trinchera Bluff, 30 feet above M 81.



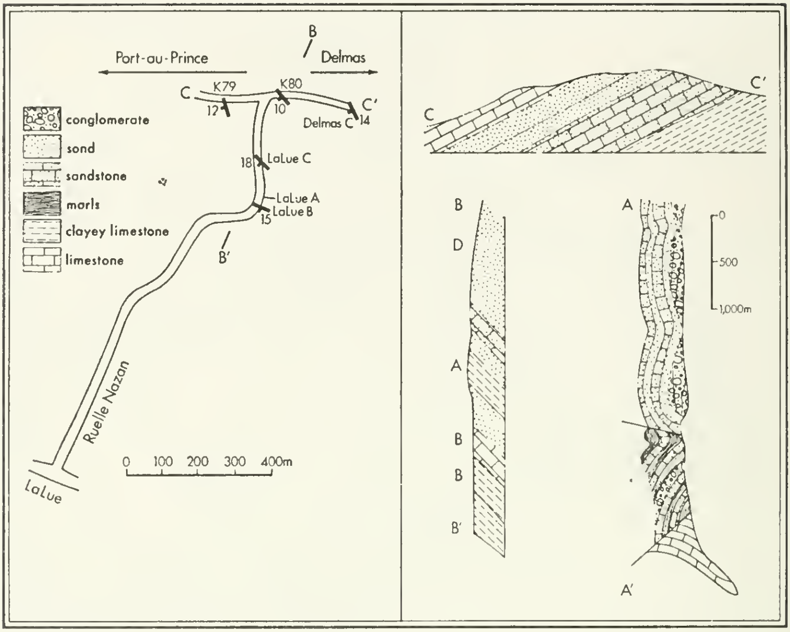
Text-figure 13. — Location of samples in the Cul-de-Sac Plain, indicating the position of the geological and sample map of the area between Port-au-Prince and Petionville (Text-fig. 14), Haiti.



Text-figure 14. — Geological and sample map of the area between Port-au-Prince and Petionville. Geology partly after Butterlin (1960), partly after reports of the Atlantic Refining Co. For cross section A-A′, see (Text-fig. 15).

HAITI, Plaine du Cul-de-Sac. Text-fig. 13.

K 77: Hasco Residence Hill, roadcut, 100 m from main road: Clayshale.
K 79: Delmas road, 2 km from old marine radio towers of Port-au-Prince, fossiliferous sandy marl. This is about 300 m NW of Morne Delmas and possible level Lalue of Pressoir (1951). See Text-fig. 15.
K 80: Same road, N. of Morne Delmas. See Text-fig. 15.
K 82: Cliff on S. shore of Étang Saumâtre: light gray, soft, clayey marl.
K 83: Cliff on S. shore of Étang Saumâtre: N. of Fond Parisien: light, cream soft limestone and coquina.
K 84: 1.5 km NW of Fond Parisien: chalk and leached coquina.
K 86: Río Parisi, upstream from where it fans out: cream limestone.
K 87: 250 m from spillway dam in Rivière Blanche: light cream marly limestone.
K 94: Source Plaissance, 500 m below headspring: light tan marl (Text-fig. 14).
K 95: Source Plaissance, 200 m below headspring: light tan marl (Text-fig. 14).
K 96: Source Plaissance, 1st outcrop below headspring: light, cream chalky marl (Text-fig. 14).



Text-figure 15. — Sections and location of sections in the Petionville-Delmas area, Haiti. Lower right: A-A′ section from Petionville to the NNW (Text-fig. 14) after Woodring and Brown (Woodring, *et al.*, 1924, fig. 15). Upper right: C-C′ section along Port-au-Prince-Delmas road, location in upper left (after A. Pressoir, 1951). Middle: section B-B′ along Ruelle Nazan, location in upper left (after A. Pressoir, 1951). Lithological units and legend for sections B-B′ and C-C′ after Pressoir and Butterlin. Location of Pressoir's fossil horizons Lalue A, B and D, and Delmas C is indicated in location map and sections.

K 336: S. side of Étang Saumâtre, top of escarpment: light cream chalk.
K 337: S. side of Étang Saumâtre, 20 feet below top: light cream chalk with small oysters.
K 338: S. side of Étang Saumâtre, 30 feet below top: cream chalk and coquina of gastropods.
K 339: S. side of Étang Saumâtre, 60 feet below top: light tan, very fine, calcareous sandstone.
K 340: S. side of Étang Saumâtre, 90 feet below top: coquina with light cream marly matrix.
K 341: S. side of Étang Saumâtre, 100 feet below top: light cream fossiliferous marl.
K 342: S. side of Étang Saumâtre, halfway down escarpment: light tan, highly calcareous, fossiliferous, fine-grained quartz and chert sandstone.
K 792: Rivière Grise: calcareous gray shale.
K 800: Rivière Grise: gray marly limestone.
K 803: Rivière Grise: gray calcareous shale and fine-grained calcareous sandstone.

K 805: Rivière Grise: dark gray compact, calcareous shale.
K 807, 808: Rivière Grise: same lithology.
K 866: Gauthier Hills, light tan, fine-grained calcareous sandstone.
M 2: Petionville road, 1.15 km E. of entrance to American Club: grayish tan marl (Text-fig. 14).
M 4: Petionville road, 1.6 km of entrance to American Club: (Text-fig. 14).
M 5: same locality, but E. end of roadcut.
P1572: 0.6 miles E. of club (Text-fig. 14).
P1579: 255 miles N. 40 W. of 1572 (Text-fig. 14).
P1584: Port-au-Prince - Croix des Missions road, about 200 m N. of side-road to Hasco Residence Hill.
P1585: 800 m NE. of 1584.
P1595, 1599, 1601, 1622: road cuts in new Petionville road (Text-fig. 14).

Samples not located on maps.

K 373: Cadette ridge between Rivière Grise and Kerscoff: cream chalk.
K 374: Cadette trail, 200 m beyond top of divide: light cream chalk.
K 375: On trail from Bassin Général to Cadette ridge, E. of Rivière Mayette: light cream chalk.
K 376: Cadette trail, near top of divide: light cream chalk.
K 766: Gauthier Hills: light tan, fine-grained calcareous sandstone.
K 848: E. fork of Rivière Blanche: light greenish-gray marly limestone.
K 850: E. fork of Rivière Blanche: Gray marl.
K 851: Rivière Blanche, 300 m below junction of E. and W. forks: gray marl.
K 852; K 855: Rivière Blanche: Gray marl.
K 866: Río Parisi: light cream limestone.
Material from Cul-de-Sac coreholes Noes. 1, 2, 4, 5, 9, 12.
Two samples of Recent mud dredged from Port-au-Prince harbour by C. R. Dunbar and sent to T. V. Howe were available for comparison.

STRATIGRAPHY

DOMINICAN REPUBLIC

A. General

In the Dominican Republic, the stratigraphy as set up by geologists of the Dominican Seaboard Oil Company, and published by Bermúdez (1949), has been used in this paper (see Table 1). The following formations are distinguished from top to bottom:

1. Jimaní Formation, Arick, 1941 (Bermúdez, 1949, pp. 18, 36)

Type locality: 1 km from the hamlet of Jimaní. (This should probably be 1 km N. of Jimaní, which would make it close to localities 10362 and 10363, Text-fig. 6).

Lithology: Hard to soft, fossiliferous limestone, granular limestones, coquinas, thin conglomerates, some clays.

Thickness not given. Age: Pliocene.

Geologic relations: unconformably on Las Salinas Formation.

Haiti							
Woodring, Brown, Burbank (1923)	Atlantic Refining (1941)	Butterlin (1960)	Present Report		Stages		
Alluvium (Qal)	Alluvium (Qal)	Alluvium (Qal)			23	Holocene	
Coral 1st., coquina congl. (Qc)	Gravel, congl. (Qpg) marine sed. (Qpm)	Old Alluvium (Qc) reef 1st, coquina	▨ ?	▨ ?	22	Pleistocene	
▨	▨	▨	Jimani	Jimani	21	Pliocene	
			▨ ? ?	▨	20		
			Marne Delmas	Las Salinas	19		
					18		
Congl., sst., sh., marl coral 1st = Part au Prince Formation	Weakly consolidated marine mud, 1st, sh., marl, sst., congl. (Tm)	Marne Delmas (Tm) detrital rocks + madreporal 1st 300-400 m.	Riviere Grise	Angostura	17	Miocene	U
				Arroyo Blanca	16		
				Lemba / Trinchera	15		
			▨	▨			M
					9		
		Riviere Grise (Tmi) detrital rocks more than 1000 m.	Madame Jaie?	Sambrerito	8		L
					4		
▨	1st, chalk, marl shale (Ta)	Massive 1st (Tam) Madame Joie?				Oligomiocene	
		▨				Oligocene	

Carto. Sect. GeoSci. L.S.U.

Dominican Republic				
Butterlin (1956)	Bermudez, (1949) pp. 33-37	(1949) table	Dominican Seaboard (1940)	Condit and Ross (1921)
Alluvium	clay, congl. 1st	estuarine + lacustrine deposits	Alluvium	Coast Limestone
Alluvium Reef 1st				
Jimani	Jimani 2-300m.	Jimani	Jimani	▨
Las Salinas	Las Salinas 2000m.	Las Salinas	Las Salinas	Cerros de Sal
Angostura		Angostura	Bermesi	
	?	Arroyo Seco	Arroya Blanca	
	Angostura / Arroyo Blanca 500 m.	Arroyo Blanca		Yague Group
Lemba	Lemba / Trinchera	Lemba	Sombrerita	Oligocene

Carto. Sect. GeoSci. L.S.U.

Table 1. Stratigraphic position of formations and units of southern **Hispañola.**

2. Las Salinas Formation, Cooke, 1920 in Vaughan, *et al.,* p. 218. Emended by Bermúdez, 1949, p. 39.
   Type locality: Las Salinas Village, Cerros de Sal, on road from Cabral to Duvergé (Text-fig. 12).
   Lithology: Brown to buff, calcareous clays, sandy shales and paper shales, interbedded with limestone conglomerates and thin coquinas.
   Thickness: 2000 m. Age: Upper Miocene to Pliocene.
3. Angostura Formation, Dohm, 1942, in Bermúdez, 1949, p. 34.
   Type locality: Upper part of Arroyo Salada, 300 m W. of government saltmine (close to locality K 227, Text-fig. 12).
   Lithology: Gypsum, rocksalt, black shales and black and red sandstones. The base is marked by the first downward occurrence of chalk, the top by the first occurrence of black platy shales.
   Thickness not given. Age: Upper Miocene.
   Geologic relations: Dominican Seaboard geologists considered it as more or less the equivalent of the Arroyo Blanco Formation. It rests unconformably on Lemba limestone.
4. Arroyo Blanco Formation, Dohm, 1942, in Bermúdez, 1949, p. 33.
   Type locality: Arroyo Blanco near Quita Coraza (E. bank of the Río Yague del Sur, 40 km W. of Azua) (Text-fig. 12).
   Lithology: sands, sandy clays and reefal limestones and conglomerates.
   Thickness: 500 m. Age: Miocene.
   In the Hoya de Enriquillo it consists of soft chalky limestone, sandy clays, and conglomerates.
   Geologic relations: Unconformably on Trinchera Formation. According to Bermúdez it is the equivalent of the Cercado Formation in the northern Dominican Republic.

B. Comments.

Jimaní and part of the Las Salinas Formation appear to have been combined by Condit and Ross on their map of the area S. of Lago de Enriquillo (Vaughan, *et al.,* 1921, pl. 15) in their Coast limestone (compare Table 1) and possibly part of their Matas Formation (coral limestone and associated rocks, gravels and marls). Only at about 3 km E. of Palma Dulce (see Text-fig. 11) they indicate Cerros de Sal Formation (which in the present usage includes both the Las Salinas and Angostura Formations). The samples from which the fossils have been described in Vaughan, *et al.*, p. 167, may have been collected in what was mapped by the geologists of Dominican Seaboard Oil Company as Quaternary Alluvium: USGS 8630 just W. of Duvergé should lie close to location 10330 and 6809 (Text-fig. 8), USGS 8525 between Duvergé and Palma Dulce should lie close to 10319 (Text-fig. 11), and USGS 8629, coral limestone near San José (=? Venganaver), should be close to 10272 (Text-fig. 10). The USGS samples were taken along the road, which, at least in 1940, lay to the north of the outcrops of bedrock.

From the Geological maps (Text-figs. 4-11) it appears that the Las Salinas Formation and Angostura Formation behave structurally as one unit and should as such be grouped together. However, the only sample in the area of Angostura outcrop in Text-figure 7 (6827) shows such a strong faunal relationship to the Jimaní Formation, that it is doubtful if this particular outcrop belongs to the Angostura Formation. The same is true for sample 6794 (Text-fig. 11). The only four samples definitely belonging to the Angostura Formation (Table 4) show an ostracode fauna which is almost identical to that of the (lower part of the) Las Salinas Formation (compare Table 12). The Arroyo Blanco Formation is structurally a different unit, which suggests that there is an unconformable contact between this and the younger formations. Only three samples have yielded ostracodes, which are quite distinct from those of the other formations (Table 5).

The deposits from Oligocene to Pliocene in the Enriquillo basin have a total thickness of 4900 m (H. A. Meyerhoff *in* Khudoley and Meyerhoff, 1971, pp. 144, 150). Well Mella No. 2 (just east of Lago de Enriquillo) penetrated 3325 m of Miocene sandstone, shale, limestone, and salt, and Cabritos well No. 1 (just west of Lago de Enriquillo) bottomed at 1644 m in Upper Eocene (Khudoley and Meyerhoff, 1971, p. 150). Calculated thicknesses of formations (Text-fig. 18) give at the east end of Lago de Enriquillo a maximum of 750 m for deposits of upper Miocene to Pleistocene, with an unknown thickness of middle Miocene and older deposits underlying it. For the area at the western end of Lago de Enriquillo there is a maximum of 1200 m thickness of upper Miocene to Pleistocene deposits, and it is suggested that no middle and possibly no lower Miocene occurs below it in this particular area.

HAITI

A. General

In the Republic of Haiti two formations have been established in the Plaine du Cul-de-Sac (Table 1).

1. Morne Delmas Formation, Butterlin, 1950, p. 56.

Type locality: on the Lalue-Delmas road (Ruelle Nazan), 300-500 m south of its junction with the Port-au-Prince - Delmas road (Text-fig. 14).

Lithology: Conglomerates, sands, sandstones, clays, some limestone horizons with *Ostrea haitensis* G. B. Sowerby I, other molluscs and madropores. Bullerlin called it a Molasse-facies.

Thickness: 300 - 400 m. Age, according to Butterlin: middle-late Miocene.

Geologic relations: Unconformably on Rivière Grise Formation. A detailed description of the type section was made by A. Pressoir (1951), see Text-fig. 15.

2. Rivière Grise Formation, Butterlin, 1950, p. 56.

Type locality: on path from Bassin Général - Morne Jacquot-hamlet of Cadet - Goujon; on the S. slope S. of Cadet at an elevation of 500 m. The Formation further crops out in the courses of the Rivière Grise and Rivière Blanche and their tributaries (Text-fig. 13).

Lithology: Folded, detrital rocks: conglomerates, brown sandstones, paper shales, clays, marls, clayey limestone.

Thickness: at least 100 m. Age: early Miocene, according to Butterlin. According to Butterlin, it represents a Flysch facies.

The localities K 373-376 along the Cadet trail should lie close to the type locality (see Table 14).

B. Comments

Butterlin correlated the Rivière Grise Formation with the Thomonde Formation of the Central Plateau of Haiti. Planktonic Foraminifera, however, indicate that it is, at least in part, considerably younger. The Thomonde Formation ranges from planktonic zone N 9 (Blow, 1969) to N 14-15 and is entirely of middle Miocene age (Hunerman, unpublished MS thesis, LSU, van de Bold, 1974a). The Rivière Grise Formation, in those samples examined from near the type locality, along the course of the Rivière Grise and in the Petionville area, ranges from N 14 - N 17, and, therefore, includes both upper middle and upper Miocene. It is partly equivalent both in age and environment to the Trinchera Formation of the Dominican Republic. The Morne Delmas Formation includes N 18 and may include younger zones. Consequently, there is not much of a hiatus between Rivière Grise and Morne Delmas Formation, but the Morne Delmas Formation was deposited in an environment considerably shallower than that of the Rivière Grise Formation.

If one accepts Butterlin's idea of considering the Trinchera, Rivière Grande, and Thomonde Formations as a Flysch-facies, then the Cerro de Sal Group, Las Cahobas, and Morne Delmas Formations could be considered as Molasse. The transition of Flysch to Molasse is rather abrupt, but takes place in different episodes of the Neogene and even varies from section to section from the upper part of the lower Miocene (N. flank of Plateau Central) to high middle Miocene (S. flank of Plateau Central) to basal Pliocene (St. Marc and Cul-de-Sac areas). This is comparable to what Richter (1970) described for different parts of the Alpine system.

OSTRACODE BIOSTRATIGRAPHY

A. Dominican Republic (Table 11)

The ostracode-fauna of the younger Neogene of the Enriquillo Basin can be subdivided into four stratigraphically distinct groups, which include:

1. Recent fauna of Lago de Enriquillo
2. Jimaní Formation
3. Upper part of Las Salinas Formation.
4. Lower part of Las Salinas Formation and Angostura Formation.
5. Arroyo Blanco Formation.

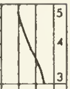
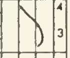
		Cytherella sp. aff C. pulchra Brady	Cytherella polita Brady	Cytherella sp.	Cyclocypris sp.	Darwinula sp.	Ostracode A	Ostracoda B	Ostracode C	Ostracode D	Ostracode E	Propontocypris sp.	Bairdia sp. aff B. laevicula (Edwards)	Cytheridella ilosvayi Daday?	Parakrithella sp.	Limnocythere staplini Gutentag and Benson	Haplocytheridea sp.	Haplocytheridea karlana (Stephenson)	Cyprideis salebrosa van den Bold	Cyprideis similis (Brady)	Cyprideis n. sp.	Cyprideis pastusprospectuensis van den Bold	Perissocytheridea bicelliforma Swain?	Perissocytheridea subrugosa (Brady)	Perissocytheridea sp. A	Perissocytheridea sp. B	Radimella ex gr. confragosa (Edwards)	Aurila laevicula (Ewards)	Orionina serrulata (Brady)	Quadracythere producta (Brady)	Jugosocythereis pannosa (Brady)	Caligella navis Coryell & Fields	Campylocythere ? sp A	Campylocythere ? perieri (Brady)	Basslerites minutus van den Bold	Loxoconcha dorsotuberculata (Brady)	Loxoconcha levis Brady?	Loxoconcha purisubrhomboides Edwards	Cytherura ex gr. johnsoni Mincher	Xestoleberis sp. A	freshwater	brackishwater	marine	
North of Etang Saumâtre	10368				/		X									O			X	O				●	O	O																		5
	10367										/					O			●				X	X	X													/						
	10362									O							X		●						O																			4
	10363																		X				X		O																			
	10364										/								X				X												●	/								
	10361											/						/			/															●								3
Jimani	K 221															/			X						X																			4
	6831																																											
	6846	O	O	X											X								X								X	●							/					3
	10380		X															X	/				X															X						
Limon	10279						/															X		/																				
	10394																		/				O								/	/												3
	10353											/				?			X			X																						2
	10352				X		/												●						X																			
S Hoya de Enriquillo (N flank)	K 236												/																							X								3
	6816												/					X	X		X				/		/	/																
	6817																						X										/											
	6825							/															X																					1
S Hoya de Enriquillo (S. flank)	10345																		/	X			/						X															3
	10343												O					X	X	/	X					O	/			X														2
	10340				O					X				/								X												/										
Duverge	6795		O														●						X	●			X										X			/				3
	6800		O																X	/				●			/																	
	6801					/		/						O									X																					1

Table 2. Distribution of ostracodes in the Jimaní Formation, Enriquillo Basin, Dominican Republic.

1. The Recent fauna consists almost exclusively of fresh- and brackish-water species (see Material and Table 6). In addition there are a few marine ostracodes, which, because of different preservation, are considered to be derived from the outcropping Neogene rocks. In Table 6, they are therefore not represented. Also the brackish- and fresh-water species occur in the exposed Neogene, with the exception of *Cypridopsis vidua*.
2. The ostracode fauna of the Jimaní Formation includes fresh-, brackish-water, and shallow marine species. It is difficult to arrange the samples in a stratigraphic succession, and although this has been attempted in Table 2, I do not feel confident that I have succeeded, except in a general way. Possibly correlatable levels have received numbers from 1 - 5 from bottom to top of the Jimaní Formation (Table 2), whereby level 3 has the strongest marine influence and 1 and 5 the strongest freshwater influence. One gets the impression that both the

basal and top layers, as far as the latter have not been removed by erosion, carry a fresh- brackish-water fauna, whereas the middle part is brackish - shallow marine, thus possibly forming a single sedimentary cycle. If this holds true for the whole formation, this becomes progessively older (lower in the cycle) towards the East. As species of possible stratigraphic importance the following species should be mentioned: *Cytheridella ilosvayi* Daday?, confined to the Jimaní Formation and Recent deposits: *Cyprideis portusprospectuensis* van den Bold; *Loxoconcha levis* Brady?, *Campylocythere? perieri* (Brady), and *Uroleberis torquata* van den Bold. The latter species has been found in one sample determined as Angostura Formation by the field geologists (6837) (see Table 4), but it is suggested here that it belongs instead to the Jimaní Formation.

		Cytherella polita Brady	*Cytherella* sp.	*Cyclocypris* sp.	*Potamocypris* sp.	Ostracode A	Ostracode B	Ostracode C	Ostracode E	*Pontocypris* sp.	*Bairdia* sp.	*Parakrithella* sp. B	*Limnocythere staplini* Gutentag and Benson	*Cyprideis salebrosa* van den Bold	*Cyprideis similis* (Brady)	*Cyprideis pascagoulaensis* (Mincher)	*Cyprideis curta* (Edwards)	*Cyprideis* sp. (reversed)	*Cyprideis* sp.	*Cyprideis subquadraregularis* (Brady)	*Haplocytheridea karlana* (Stephenson)	*Perissocytheridea bicelliforma* Swain?	*Perissocytheridea subrugosa* (Brady)	*Perissocytheridea cytheridellaformis*	*Perissocytheridea plauta*	*Perissocytheridea* sp. A	*Perissocytheridea* sp. B	*Orionina serrulata* (Brady)	*Radimella* ex gr. *confragosa* (Edwards)	*Caquimbo congestocosta* (van den Bold)	*Caivella navis* Coryell & Fields	*Basslerites minutus* van den Bold	*Loxoconcha purisubrhomboidea* Edwards	*Loxoconcha dorsotuberculata* (Brady)	*Paracytheroma* sp.	*Xestoleberis* sp. A	*Xestoleberis* sp. B	*Uroleberis* sp.	freshwater	Brackishwater	Marine •	
Jimaní	K 262													X											X				/			/			/						U
	K 261			X										X																											
	10369					X	X		/					●									X																		
	10282			/			/						X	●									●				X				/		O	X							
	10286													●	O							X																			M
	6844													O	X							O				X						X									
	6845																		X			X				X															
	6843													X								O																			
Cobritos	10396																	X					O	O		O															U
	10393													X							X			●		X							/								
	6835			O			/							●								●		O		●							/								
	6834																					X																			
	6833			X																X	X																				
	6838																			/		●											X	/							
	6867			/			X							X												X															
	6841	X												/								/																			M
	6839		/					X							/							O																			
	6847							X						/												X	●														
	10379																	X					O	/		●															
	10358	X	/						/			X		X								/	/													/		/			
	6840									/			CF									X						/									/				
	10357																					X				X															
S. of Hoyo de Enriquillo	10341	/	X											X					O																/						M
	10339	X												/								X							/		●										
	10337													X						X							/														
	10348													●			●									/															
	6821													●												O															
	10351													●			●																								
	10346				/											O		/		X		X						X													L
	10347															X	X									/															
	6822	/														X	X								●																
	6823							X		/												X				X															

Table 3. Distribution of ostracodes in the Las Salinas Formation, Enriquillo Basin, Dominican Republic.

2a. A number of species are characteristic of the Jimaní Formation and the upper part of the Las Salinas Formation: *Cyclocypris* sp. 1, Ostracode A, *Limnocythere staplini* Gutentag and Benson, *Cyprideis salebrosa* van den Bold, *Cyprideis similis* (Brady), *Haplocytheridea karlana* (Stephenson), *Perissocytheridea subrugosa* (Brady), *Parakrithella?* sp.

3. Upper Las Salinas Formation. (Table 3; upper and middle). Again it is difficult to arrange samples in stratigraphic succession and in general it is only possible to indicate in a particular part of the map which samples are high or low in the formation. It is not certain, that the boundary between upper and lower Las Salinas Formation always lies at exactly the same stratigraphic level. In Table 3 an attempt has been made to divide the upper part of the Las Salinas on the basis of general faunal similarity. In addition to the forms mentioned under 2a, the following species appear to be restricted to the upper part of the formation: *Cyprideis* sp., *Perissocytheridea cytheridellaformis* Forester, *Uroleberis* sp. The fauna is dominantly brackish water throughout the formation with small additions of either fresh-water or marine species. These small fluctuations are probably of local significance only; no regularity can be discerned in the succession.

4. Lower Las Salinas Formation and Angostura Formation (Tables 3,4). A few samples reported from the Angostura Formation (Table 4) contain a fauna which is typical of the Jimaní Formation and they are not included here. The overall fauna of the few Angostura samples left is identical to that of the lower part of the Las Salinas Formation, although somewhat impoverished: *Cyprideis pascagoulaensis* (Mincher), *Cyprideis curta* (Edwards), *Perissocytheridea plauta* Forester, n. sp. The latter species has also been found in a sample in the Cibao Valley (northern Dominican Republic), near Monte Cristo, in the lower (?) Gurabo Formation. A number of species occur throughout the Las Salinas and Jimaní Formations, *e.g. Bairdia* sp., *Perissocytheridea* sp. A and B, *Cativella navis* Coryell and Fields, *Basslerites minutus* van den Bold, *Campylocythere?* sp., *Aurila* sp. aff. *A.*

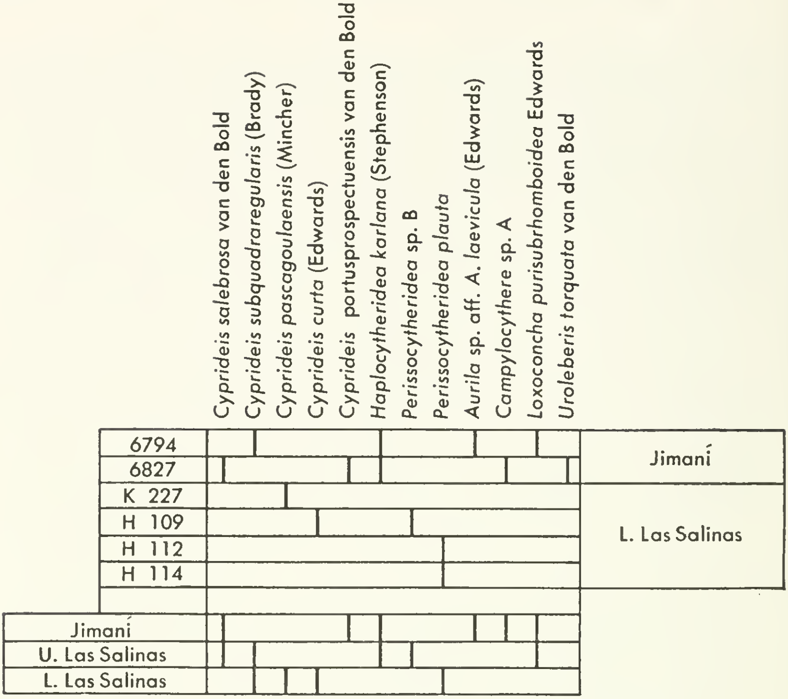


Table 4. Distribution of ostracodes in the Angostura Formation.

	Cytherella ap. aff. *C. pulchra* Brady	*Cytherella* sp.	*Cytherelloidea* sp.	*Paracypris* sp.	*Cyprideis pascagoulaensis* (Mincher)	*Cyprideis curta* (Edwards)	*Perissocytheridea bicelliforma* Swain?	*Cushmanidea* sp.	*Xestoleberis* sp. A	*Xestoleberis* sp.
6809	?	?	/	X	O		/	X	/	
10272				X			/	/	/	/
10330						/				

Table 5. Distribution of ostracodes in the Arroyo Blanco Formation.

laevicula, Loxoconcha dorsotuberculata (Brady), *Loxoconcha purisubrhomboidea* Edwards. *Cyprideis subquadraregularis* (Brady) occurs in the whole of the Las Salinas Formation and in the Angostura Formation.

5. Arroyo Blanco Formation (Table 5)
Whereas brackish-water ostracodes predominate in the Las Salinas Formation and Angostura Formation, their number is strongly reduced in the Arroyo Blanco Formation and the few samples examined have a much stronger marine character, except for a few occurrences of *Perissocytheridea bicelliforma* Swain, *Cyprideis curta* (Edwards), and *Cyprideis pascagoulaensis* (Mincher); the first of which is long ranging, the latter two of which are also present in the lower Las Salinas Formation and Angostura Formation.

Stratigraphically important species.

A. Species which can possibly be used for dating the Jimaní Formation, resp. correlating it with deposits outside the Enriquillo Basin are: *Cytheridella ilosvayi* Daday?, *Campylocythere? perieri* (Brady), *Cyprideis portusprospectuensis* van den Bold, and *Uroleberis torquata* van den Bold.

1. *Cytheridella ilosvayi?* To my knowledge this species has not been reported previously from fossil deposits. In the present material it occurs in the Jimaní Formation, the top part of the boreholes in the Cul-de-Sac plain and in a sample (D 14) from the Lajas Valley (Barrio Paris) of Puerto Rico, donated by Ducloz, who indicates a Pleistocene age.
In Trinidad specimens of a slightly smaller, but morphologically similar (possibly specifically identical) form have been found in the upper Pliocene Talparo Formation (R. Dempsey, material received on loan).
2. *Campylocythere? perieri* was found in only one sample of the Jimaní Formation. It has been reported from the Cabo Blanco Formation and Cumaná Formation of Venezuela

(Pleistocene) and from Recent deposits off the coast of Venezuela (van den Bold, 1966, p. 24, pl. 2, fig. 4 a-b, pl. 5, fig. 2 a-b) and Recent deposits off Puerto Rico. In this last case it was reported as *Campolycythere (sic) striata* van den Bold, *Campylocythere striata,* and *Campylocythere stricta (sic)* (Baker and Hulings, 1966, resp. p. 166, fig. 3, pl. 2, fig. 5).

3. *Cyprideis portusprospectuensis* van den Bold, has been reported from the Harbour View beds of Jamaica. It occurs in two samples of the Jimaní Formation and in the upper part of the boreholes of the Cul-de-Sac plain.
4. *Uroleberis torquata* was originally described from the Mayo Formation of the northern Dominican Republic (van den Bold, 1968, p. 81, pl. 6, fig. 4; pl. 10, fig. 2).

On this evidence, a Pleistocene age seems probable and was in fact suggested for the Harbour View beds (van den Bold, 1971). However, a late Pliocene age cannot be excluded, and has tentatively been adopted in Text-fig. 15.

B. A possibly datable horizon may separate upper and lower part of the Las Salinas Formation. *Cyprideis salebrosa, Haplocytheridea karlana* both with an apparent range of Pliocene to Recent occur in the uper part, *Cyprideis curta* (Edwards), *Cyprideis pascagoulaensis* (Mincher), and *Perissocytheridea plauta* Forester, n.sp. in the lower part.

1. *Cyprideis salebrosa* was found in Pliocene and younger deposits, starting well above the earliest occurrence of *Radimella* ex gr. *confragosa,* which appears to coincide almost exactly with the Mio-Pliocene boundary.
2. *Cyprideis curta* (Edwards) was originally described from the Duplin marl of South Carolina, which for a long time has been dated as late Miocene but it may be Pliocene (see Hazel, 1971, p. 8). This is in accordance with the presence of *Radimella confragosa.*
3. *Cyprideis pascagoulaensis* (Mincher) was found in the northern Dominican Republic just above the earliest appearance of the *Radimella confragosa* group. The same is true for *Perissocytheridea plauta.* The near absence of *Radimella* in

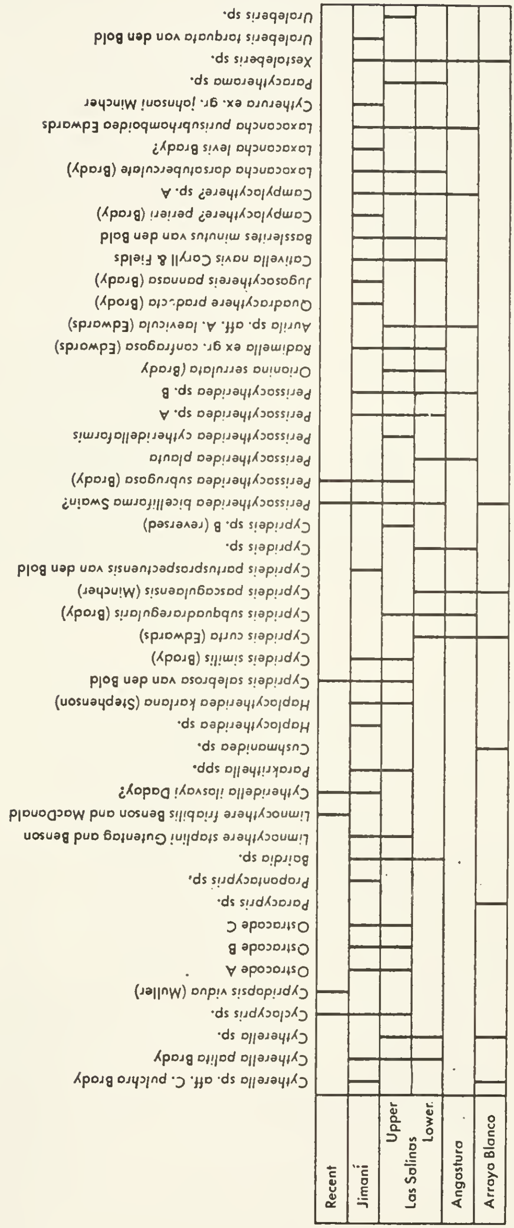


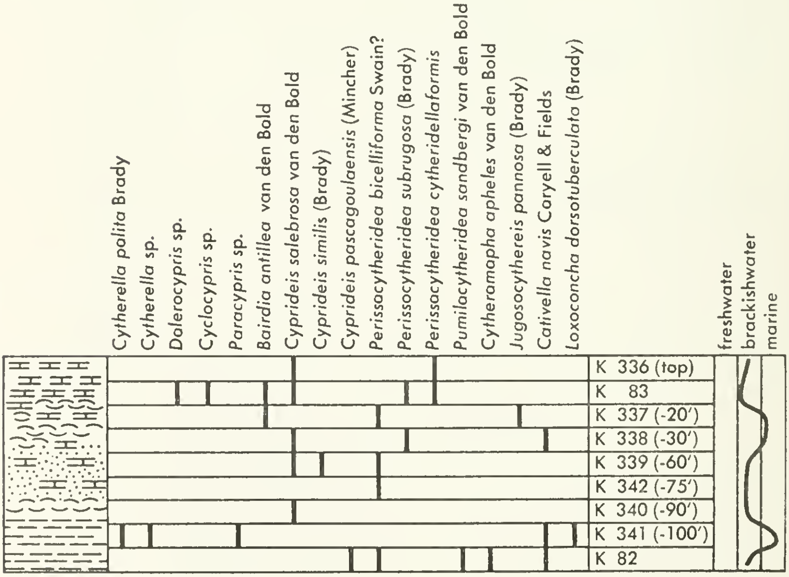
Table 6. Composite range chart of ostracodes in the Enriquillo Basin, Dominican Republic.

the largely brackish-water deposits of the Last Salinas Formation makes this group practically unusable here.

It, therefore, appears probable, that the highest occurrence of *Cyprideis pascagoulaensis* is just within the lower Pliocene, which would make the upper Las Salinas Formation definitely Pliocene and the lower part of the Las Salinas Formation and the Angostura Formation, upper Miocene, possibly extending in the lowermost Pliocene. Compare Text-figure 18 and explanation.

C. Haiti.

1. Moving westward from the Enriquillo Basin into the Republic of Haiti, the association is typical for the upper Las Salinas Formation *(e.g. Perissocytheridea cytheridellaformis)* in the cliffs at Balán (Text-fig. 13, Table 7) south of the Etang Saumâtre. This suggests a Pliocene age for these beds, which have been placed by previous workers in the Quaternary (Butterlin, 1954, Atlantic Refining map). Only the bottom sample may be lower Las Salinas.



Cytherella polita Brady	*Cytherella* sp.	*Dolerocypris* sp.	*Cyclocypris* sp.	*Paracypris* sp.	*Bairdia antillea* van den Bold	*Cyprideis salebrosa* van den Bold	*Cyprideis similis* (Brady)	*Cyprideis pascagoulaensis* (Mincher)	*Perissocytheridea bicelliforma* Swain?	*Perissocytheridea subrugosa* (Brady)	*Perissocytheridea cytheridellaformis*	*Pumilacytheridea sandbergi* van den Bold	*Cytheramorpha apheles* van den Bold	*Jugosocythereis pannosa* (Brady)	*Cativella navis* Coryell & Fields	*Loxoconcha dorsotuberculata* (Brady)	
						●					●						K 336 (top)
		●	●		●	●				●	●						K 83
					●				●					●			K 337 (-20′)
						●				●					●		K 338 (-30′)
						●	●		●								K 339 (-60′)
									●								K 342 (-75′)
						●											K 340 (-90′)
●	●			●											●	●	K 341 (-100′)
								●	●			●	●		●		K 82

Table 7: Distibution of ostracodes in samples from Balán, Haiti.

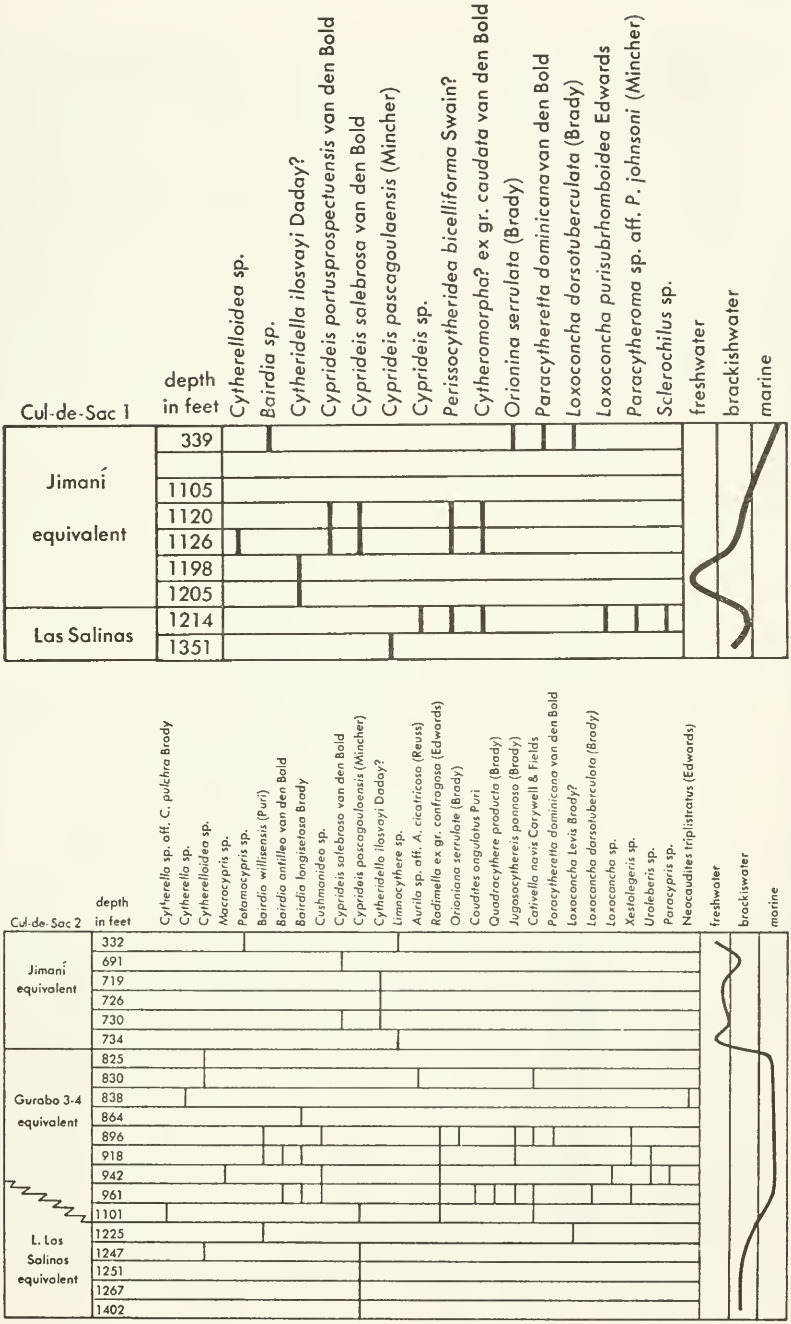


Table 8-9. Distribution of ostracodes in the Cul-de-Sac coreholes 1, and 2 Haiti.

2. In the area NE of Port-au-Prince, in the Cul-de-Sac coreholes (Text-fig. 16, 14), the upper part of the section penetrated shows alternations between fresh-water and brackish-water deposits, where the presence of such species as *Cytheridella ilosvayi* ? and *Cyprideis portusprospectuensis* suggests correlation with the Jimaní Formation. In corehole 2 (Table 9) there is a marine interval between the lowest occurrence of *Cyprideis salebrosa* and the highest of *Cyprideis pascagoulaensis*. The presence of *Radimella* ex gr. *confragosa* in the marine interval indicates its Pliocene age, and its range over-

Cul-de-Sac 5	depth in feet	*Cytherelloidea* sp.	*Paracypris* sp.	*Bairdia longisetosa* Brady	*Bairdia willisensis* (Puri)	*Bairdia antillea* van den Bold	*Bairdia* sp.	*Limnocythere staplini* Gutentag and Benson	*Cyprideis portusprospectuensis* van den Bold	*Perissocytheridea* sp.	*Cativella navis* Coryell & Fields
Jimaní	385										
	747								▮		
	796							▮			
	832									▮	
	836									▮	
Morne Delmas	849	▮									
	852		▮								▮
	943			▮	▮	▮	▮				

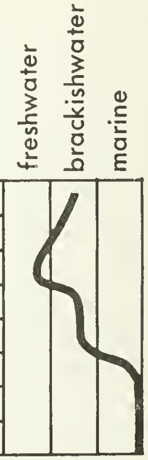
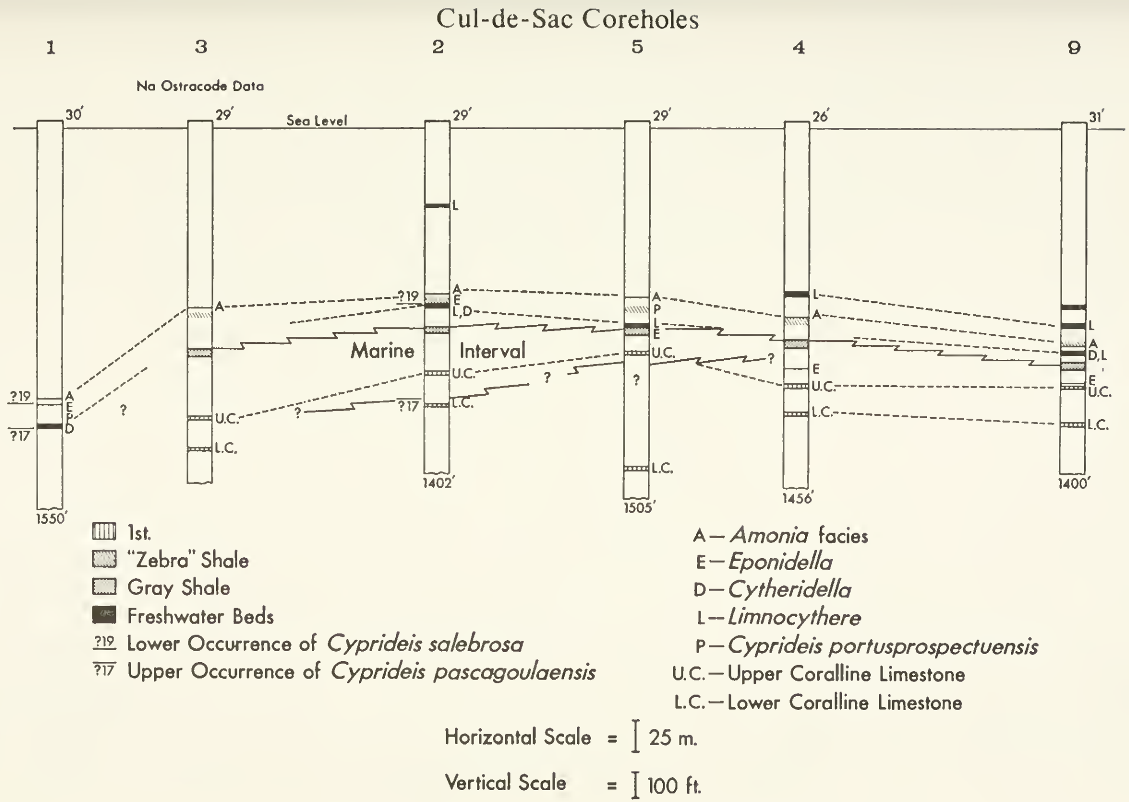


Table 10: Distribution of ostracodes in Cul-de-Sac corehole 5, Haiti.



Text-figure 16. — Section through Cul-de-Sac coreholes 1-9, Haiti. The position of lithological units is taken from a section by the Atlantic Refining Co., as is the presence of the *Amonia* and *Eponidella* facies. Top of *Eponidella* was used for contouring by the Atlantic Refining Co.

laps slightly with that of *Cyprideis pascagoulaensis,* as it does in the Cibao Valley of the northern Dominican Republic (van den Bold, 1968, bottom of association 4). The change upwards of marine into brackish-freshwater environment is usually abrupt which may be an indication of a slight unconformity between the Morne Delmas and the overlying Jimaní equivalents. Text figure 16 shows the marine interval restricted to the slightly updomed central part of the structure, where it may occupy the remnants of a former structural low. It wedges out in both directions below this postulated unconformity.

3. Samples along the Petionville-Port-au-Prince road (Table 11) and other scattered samples in the Morne Delmas Formation (Table 12), including some near the type locality (Text-fig. 14) yield a fauna which is close to the above mentioned marine interval in the coreholes. It is, therefore, rather definite, that this marine interval should be regarded as Morne Delmas Formation. It seems fairly certain also, that the "Port au Prince" beds of Coryell and Rivero (1940) represent the same marine interval, but as the locality from which this fauna was described is not indicated, the name will not be used here. This fauna is similar to the one found in outcrops near Hasco Residence Hill and along the Petionville road near the American club. This fauna can be correlated with associations 3 and 4 of the Gurabo Formation (van den Bold, 1968) of the northern Dominican Republic. As pointed out before, the brackish-freshwater fauna above the marine beds is similar in fauna and, therefore, probably equivalent to the Jimaní Formation. The brackish-water deposits below the marine interval in the coreholes carry a fauna which is similar to that of the lower part of the Las Salinas Formation in the Enriquillo Basin.

Whereas there appears to be a distinct unconformity between the Las Salinas Formation and Jimaní Formation in the Hoya de Enriquillo, there is only vague evidence for an unconformity between the marine interval (Morne Delmas Formation) and the overlying brackish-water interval (Jimaní Formation) in the Cul-de-Sac coreholes.

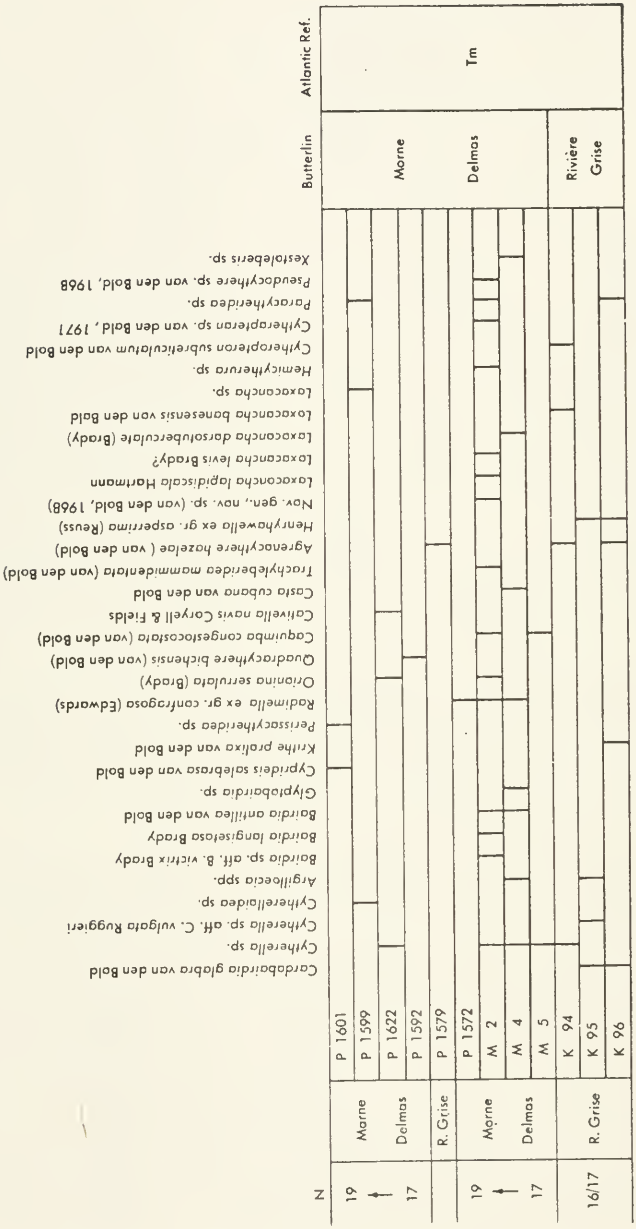


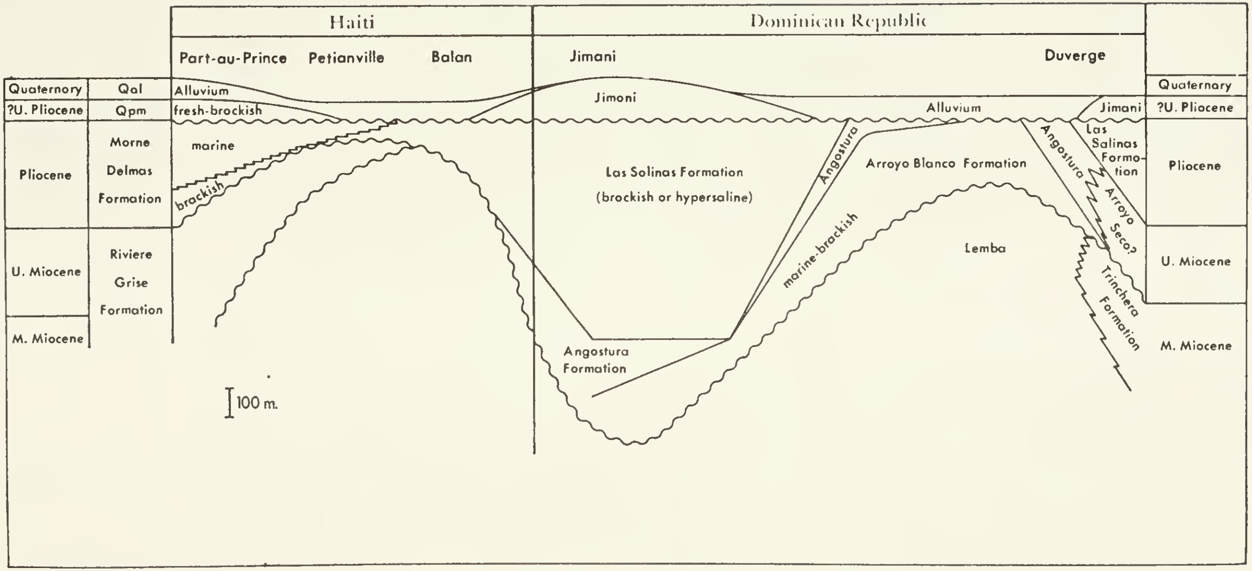
Table 11. Distribution of ostracodes in the Petionville area, Haiti.

	Cytherella sp.	*Bairdia* sp.	*Cyprideis* sp.	*Cyprideis pascagoulaensis* (Mincher)	*Perissocytheridea* sp.	*Pumilocytheridea sandbergi* van de Bold	*Gangamocytheridea? plicata* van den Bold	*Radimella* ex gr. *confragosa* (Edwards)	*Aurila* sp. aff. *A. laevicula* (Edwards)	*Orionina serrulata* (Brady)	*Quadracythere bichensis* (van den Bold)	*Puriana* sp.	*Loxoconcha fischeri* (Brady)	*Loxoconcha purisubrhomboidea* Edwards	*Loxoconcha levis* Brady?	*Cytherura* sp.	*Hemicytherura cranekeyensis* Puri	*Paracytheridea* sp.	*Pellucistoma magniventra* Edwards	*Xestoleberis* sp.
K 77	/	X				X	/		O		X	X	X	/		X	O	/		/
P 1584			/					/	/	/	/				/					
P 1585													/							
K 79				/	/			/	/										/	
K 80	/																			

Table 12: Distribution of ostracodes in the Morne Delmas Formation, Haiti.

Tentative thicknesses of the formations have been plotted in Text-figure 17, where the base of the Jimaní Formation in the Hoya de Enriquillo and the base of the "Jimaní" fauna in the Plaine du Cul-de-Sac has been plotted as a horizontal line.

4. The Recent fauna off Port-au-Prince harbour consists of the following species: *Cytherella polita* Brady (originally described from here, Brady, 1869, p. 161, pl. 19, fig. 5-7), *Cytherella* sp. aff. *C. sordida* Müller, *Cytherelloidea* sp., *Paracypris* sp., *Propontocypris* sp., *Bairdia bradyi* van den Bold, *Bairdia* cf. *amygdaloides* Brady, *Bairdia victrix* Brady, *Bairdia longisetosa* Brady, *Cyprideis similis* (Brady), *Perissocytheridea bicelliforma* Swain, *Perissocytheridea subrugosa* (Brady), *Cytheretta* sp. aff. *C. pumicosa* (Brady), *Radimella* ex gr. *confragosa* (Edwards), *Orionina serrulata* (Brady), *Quadracythere producta* (Brady), *Jugosocythereis pannosa* (Brady), *Hermanites*? *hornibrooki* (Puri), "*Leptocythere*" *yoni* Puri,



Text-figure 17.—Facies relationship and thicknesses of late Neogene formations in southern Hispañola. Thicknesses are computed from sections based on the geological maps of the Dominican Seaboard Oil Co. and the Atlantic Refining Co.

Cativella navis Coryell and Fields, *Pterygocythereis* sp. aff. *P. americana* (Ulrich and Bassler), *Loxoconcha fischeri* (Brady), *Loxoconcha dorsotuberculata* (Brady), *Loxoconcha ochlockoneensis* Puri, *Cytherura* ex gr. *johnsoni* (Mincher), *Cytherura* ex gr. *forulata* (Edwards), *Paracytheridea* sp., *Pellucistoma* sp., *Xestoleberis* sp. This fauna is similar to that of the Morne Delmas Formation.

D. General remarks on the biostratigraphy of the older Neogene

In the area northwest of Petionville (Text-fig. 14) the Morne Delmas Formation with strictly shallow-water facies, lies immediately upon deep-water deposits of the Rivière Grise Formation. Noting the occurrence of such genera as *Krithe, Agrenocythere* (Benson, 1972, p. 58), *Henryhowella* and *Bradleya,* they must be (outer) slope deposits (Table 11). On the basis of the distribution of planktonic Foraminifera the upper part of the Rivière Grise Formation in the Petionville area can be placed as N 16-17 (Blow, 1969), therefore upper Miocene. Scattered samples from the type area of the formation and the course of the Rivière Grise (Table 13) are indicative of zones N 15-N 17, and deposition must have taken place at considerable depth. The presence of reversals of valve size in the genus *Krithe* may indicate deposition below 1000 m water-depth (van den Bold, 1971 b, van Morkhoven, 1972). A few samples in the upper part of the formation contain some shallow-water forms, including a few specimens of *Radimella* ex gr. *confragosa,* which may indicate, that there is some sort of a transition between the Rivière Grise Formation and the Morne Delmas Formation. There is, however, a strong general difference in depth of deposition, suggesting an uplift in earliest Pliocene times.

The distribution of facies in samples along the Petionville road and the Ravine Bois de Chène also suggests the presence of a NW striking fault between the road and the river (Text-fig. 14, see also Table 11).

In facies and general age the Rivière Grise Formation appears to be well comparable with the Trinchera Formation of the Dominican Republic, although the ostracode fauna of the latter has only been studied at the type locality at Trinchera Bluff, which, according to Bermúdez (1949, p. 41) is in the basal part of the formation. A study of the planktonic Foraminifera of the type section

		Abyssocypris tipica van den Bold	*Cytherella* sp. aff. *C. vulgata* Ruggieri	*Cytherella* sp.	*Argilloecia* sp.	*Macrocyprina* sp.	*Bairdia antillea* van den Bold	*Bairdia cassida* van den Bold	*Bairdia* sp. aff. *B. longisetosa* Brady	*Paranesidea* sp.	*Krithe trinidadensis* van den Bold	*Krithe prolixa* van den Bold	*Krithe markhoveni* van den Bold	*Krithe dolichodeira* van den Bold	*Radimella* ex. gr. *confragosa* (Edwards)	*Coquimba congestocostata* (van den Bold)	*Bradleya* ex gr. *dictyon* (Brady)	*Agrenocythere hazelae* (van den Bold)	*Henryhowella* ex gr. *asperrima* (Reuss)	*Ambocythere exilis* van den Bold	*Costa cubana* van den Bold	*Loxoconcha* sp.	*Xestoleberis* sp.	Blow 1969 N
Cadet trail	373																	│						
	o) 374		│								│		│						│	│				17
	o) 375						│				│					│								17
	376																│							
Ravine Maillet	x) 776A			│	│														│					14-15
	x) 785																				│			14-15
Rivière Grise	x) 792												│		│									18
	x) 800										│			│										
	x) 803										│													
	x) 805	│										│	│											
	x) 807				│			│												│				
	x) 808	│																					│	15
Rivière Blanche	849														│									18
	850										│	│	│											
	851								│		│												│	
	852							│																
	855				│																	│		
	x) 87			│	│	│					│										│			15
Rio Parisi	86									│	│									│				15-16

o) Close to type locality of Rivière Grise Formation

x) on map

Table 13. Distribution of ostracodes in the Rivière Grise Formation, Haiti.

indicates zone N 15 of Blow, 1969. The environment in which these beds were deposited is similar to that of the Rivière Grise Formation: presence of *Agrenocythere, Bradleya, Abyssocypris* van den Bold, 1974c, and reversed *Krithe*. See Table 14.

This fauna is also comparable to that of the Madame Joie-Thomonde Formation sequence on the Central Plateau, which is, however, slightly older (lower and middle Miocene, with the greatest depth of deposition in the lower Miocene). Uplift in the Central Plateau area appears to have taken place towards the end of the middle Miocene, therefore, earlier than in the Cul-de-Sac Plain (basal Pliocene) (van den Bold, 1974a).

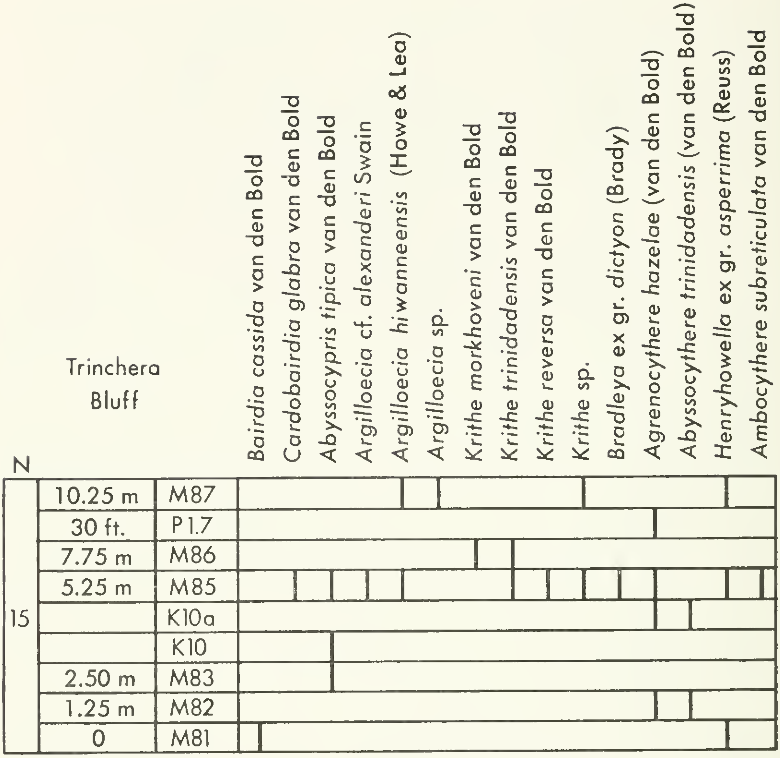
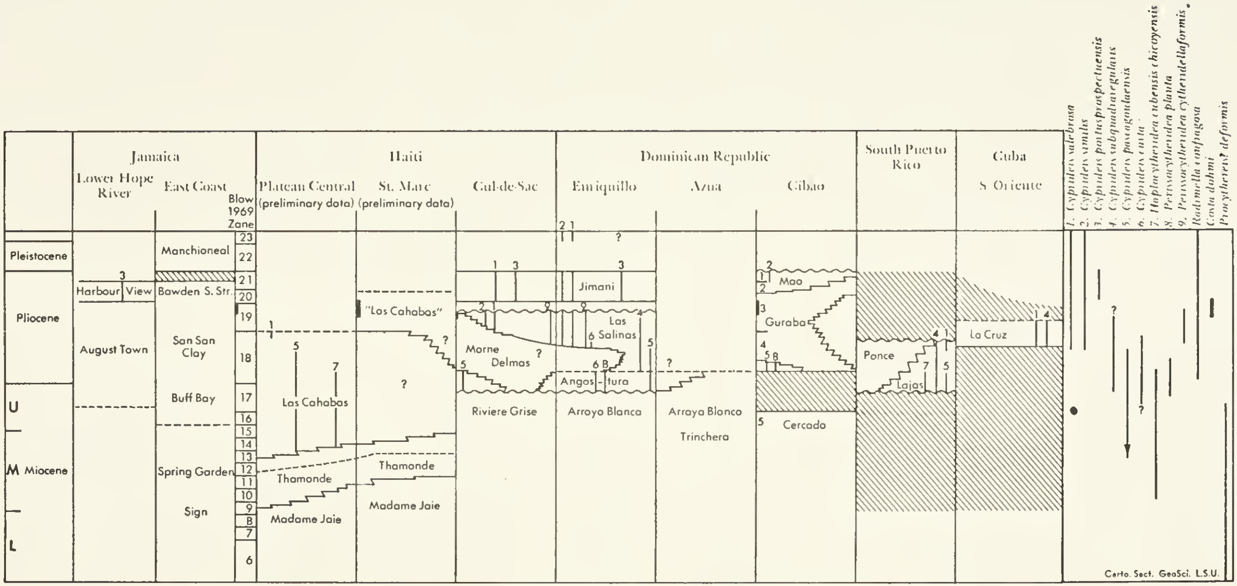


Table 14. Distribution of ostracodes at Trinchera Bluff, Dominican Republic.

In Barahona Province (Dominican Republic) the sequence under discussion here (Arroyo Blanco-Las Salinas) is underlain by the Lemba Formation. No samples of this formation were available. They are thought to be the shallow-water equivalent of the Trinchera Formation (Bermúdez, 1949, p. 23), which crops out further east in the Azua Province.

The Trinchera Formation in turn is underlain by the Sombrerito Formation, which, in most of the outcrop area (*e.g.* Arroyo Sombrerito) has a deep-water character similar to the Trinchera Formation. Some shallow-water beds assigned to the Sombrerito Formation in Azua Province and Benefactor Province by geologists of the Atlantic Refining Company, have yielded an ostracode-fauna similar



Text-figure 18. — Correlation of some Neogene Formations in the Greater Antilles. Also indicated is the range in the different formations of some brackish-water ostracodes (numbered 1-9) and the range of the zonal (?) markers: *Radimella* ex gr. *confragosa* (Edwards), *Procythereis? deformis* (Reuss) and *Costa dohmi* van den Bold.

to that of the basal Paso Real Formation in Cuba with *Haplocytheridea subovata* (Ulrich and Bassler), *Haplocytheridea stephensoni* (van den Bold), and *Triebelina crumena* (Stephenson), about Blow's N 6 zone.

E. Summary

There is evidence in southern Hispañola of a deep-water sequence of middle Miocene age, with abrupt shallowing, suggesting orogenic movement, in the late Miocene; this is followed by brackish or hypersaline deposition of shallow nature in most of the area, except in the West (part of the Cul-de-Sac Plain and St. Marc area), where shallow marine deposition continues. In the late Pliocene another movement took place, followed by deposition of the Jimaní Formation or its equivalents.

STRATIGRAPHIC AND ECOLOGIC SIGNIFICANCE OF SOME BRACKISH- AND FRESH-WATER GENERA AND SPECIES (TEXT-FIG. 18).

A. General

In determining the age of formations such as the Jimaní, Las Salinas Formation and Angostura Formation or the beds above and below the marine wedge of the Morne Delmas Formation, it is imperative to have some knowledge of the stratigraphic range of the brackish-water ostracodes, that form the bulk of the fossil fauna. A preliminary attempt to determine such ranges was presented at the Colloquium on Paleoecology of Ostracoda in Pau (van den

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In Jamaica the Harbour View beds have been placed here in the upper Pliocene, but a Pleistocene age is possible. In Central Haiti the ranges of *Cyprideis pascagoulaensis* (Mincher) and *Haplocytheridea cubensis chicoyensis* van den Bold in the Las Cahobas Formation are based on unpublished studies of the Atlantic Refining Co.'s material from the Plateau Central. Note the presence of *Cyprideis salebrosa* van den Bold in the uppermost beds. The "Las Cahobas" in the St. Marc area is purely marine, comparable to the Morne Delmas Formation further south, but here considered slightly younger on the basis of the prescence of *Costa dohmi,* which suggests correlation with the middle part of the Gurabo Formation (northern Dominican Republic). In the Cul-de-Sac Basin and Enriquillo Basin this marine interval is under- and overlain by brackish-water deposits and it disappears towards the east. Similarly the lower part of the Gurabo Formation in the northern Dominican Republic has in the western part a basal brackish-water intercalation and is overlain by partially brackish-water deposits of the Mao Formation. In Puerto Rico the Lajas beds appear to correlate with part of the Las Salinas Formation (Enriquillo basin) on the basis of the distribution of brackish-water ostracodes. On the same basis, the similar fauna of the La Cuz Formation (Cuba) is slightly younger.

Bold, 1971b, fig. 4) and the opportunity is taken here to enlarge on this subject and to present new evidence, although the scope of this paper limits the discussion to distribution in Pliocene and later deposits. Outstanding among the genera of ostracodes that occur in the Hoya de Enriquillo Basin and the Cul-de-Sac Basin, are *Cyprideis* and *Perissocytheridea,* both of which are known to have great salinity tolerance and may occur from practically freshwater to hypersaline environment. In order to determine stratigraphic ranges of species of these genera, known brackish-water (or hypersaline) deposits in the Neogene of the Caribbean material from the following parts of the Greater Antilles have been studied:

1. Puerto Rico: "Lajas beds" and brackish-water intercalations in the Ponce Formation in the SW part of the island (van den Bold, 1969).
2. Dominican Republic: Jimaní, Las Salinas and Angostura Formations, intercalations in the lower Gurabo and in the Mao Formations (van den Bold, 1968).
3. Haiti: beds above and below the marine interval in the Cul-de-Sac coreholes, cliff at Balán, scattered samples in the Cul-de-Sac Plain, and the Las Cahobas Formation (Maissade Tongue) of the Central Plateau (van den Bold, 1974a).
4. Jamaica: Harbour View beds (van den Bold, 1971a).
5. Cuba: La Cruz Formation, East Oriente Province. Brackish-water intercalations in a largely marine formation.

In Venezuela brackish-water beds from the Tuy Formation and Cumaca Formation have been used for comparison (van den Bold, 1972a, p. 1012).

In Central America brackish-water deposits are known from the Caribe Formation of Guatemala (l? - m. Miocene) and in the young Neogene of the Puerto Limón area of Costa Rica (Moín Formation). Further there are brackish intercalations in the Miocene of Central Aguirre Province in Puerto Rico, in the Anguilla Formation (Anguilla) (van den Bold, 1970) and the La Boca Formation of Panama (van den Bold, 1972b). All these occurrences are much older than the ones we are concerned with here and will be included in a further study of the distribution of *Cyprideis* in brackish-water deposits of the Caribbean.

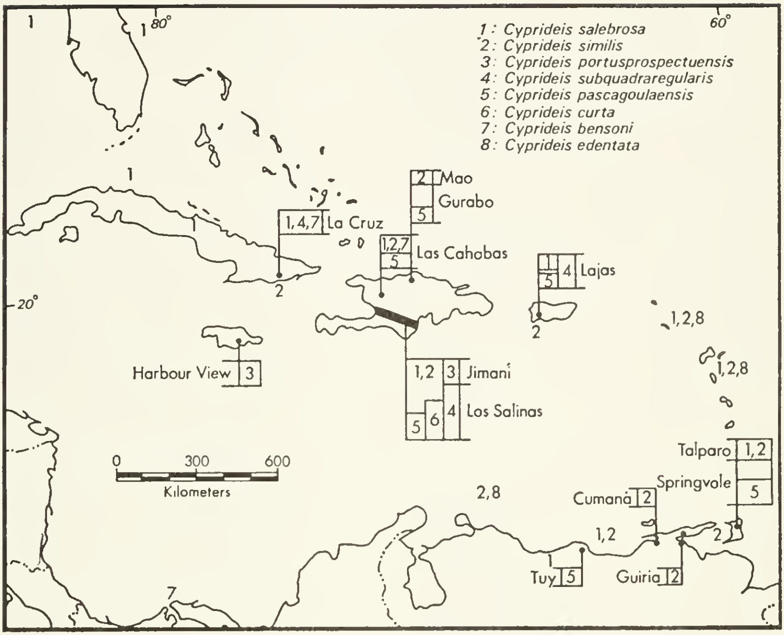
These young Neogene brackish-water beds do not always show the same distribution of species. This can be due to: 1) provincialism of the faunas, 2) slight ecologic variations, 3) slight differences in age between different deposits.

Recent brackish-water deposits to which reference is made for comparison are: Cuba (Laguna de Leche, Camagüey); Dominican Republic (Lago de Enriquillo); Puerto Rico (Laguna de Cartagena); St. Martin (salinas); Barbuda ("stinking" lagoon); Trinidad (Oropouche swamp); Venezuela (Lago de Valencia, Laguna de Boca chica, Margarita, mangrove swamp, Los Roques); Colombia (Bahia de Tucacas, Goajira); Panama, (Las Minas Bay, Isla Grande); Bonaire (Salinas); Nicaragua (Lago de Nicaragua); Guatemala (Lago Izabal); Mexico (Laguna de Tamiahua, Laguna Madre).

B. *Cyprideis*

In the preceding section it has been argued, that the distribution of *Cyprideis pascagoulaensis* and *Cyprideis salebrosa* is governed by age-differences: *Cyprideis salebrosa* is found in the Cul-de-Sac coreholes above the marine interval and in the upper part of the Las Salinas Formation, whereas *C. pascagoulaensis* occurs in the bottom of the corehole sections and in the lower part of the Las Salinas Formation. Only in a few cases have the two forms been found together, which might indicate a slight overlap in range. However, local reworking of the older form cannot be excluded and would not be surprising in the very shallow-water environment in which both occur.

The situation is different for some of the other forms. *Cyprideis portusprospectuensis* occurs in the Jimaní Formation, in the Cul-de-Sac coreholes, and in the Harbour View beds of Jamaica. In the Jimaní Formation it has been found in only two samples, both with stronger than normal marine influence, and in one case together with *C. salebrosa*. In the Cul-de-Sac coreholes it occurs with *C. salebrosa* in hole No. 1 (Table 6), without it in hole No. 5 (Table 8) and it is found without it in the Harbour View beds of Jamaica (van den Bold, 1971 b). It must be assumed, that the environment favourable to *C. portusprospectuensis* is not suitable to *C. salebrosa*. The latter species, which otherwise is one of the most common in



Text-figure 19. — Distribution of some species of *Cyprideis* in the late Neogene of the Caribbean. Plio-Pleistocene distribution boxed in, Recent distribution open. N.B. As *Cyprideis bensoni* Sandberg was not found in the southern Hispañola area, this species (7) is not discussed, nor has it been entered in Text-fig. 18.

these deposits, has been found from Argentina to Kansas in fresh- to brackish-water environments, rarely in normal marine milieu and only in one case in higher than normal salinity in Lago de Enriquillo (49 °/oo, Condit and Ross, in Vaughan, *et al.*, 1921, p. 191). However, it has not been found living there and may be reworked, just as a number of other species in this thanatocoenosis. In cases where *C. salebrosa* and *C. americana* (Sharpe) have been found in the same vicinity, *C. salebrosa* generally is more abundant in lower salinities, *C. americana* in higher ones. Therefore, it is also possible, that in the indicated association *C. portusprospectuensis,* which is one of the rare species of *Cyprideis* with a reversal of valve-size and hingement, and which might be a variant of *C. bensoni* Sandberg, could be indicative of higher salinities.

Cyprideis subquadraregularis occurs in the Dominican Repub-

Formations According to Dohm		*Cytherella dominicana* van den Bold	*Cytherella* sp. aff. *C. vulgata* Ruggieri	*Cytherella* sp.	*Cytherella* sp. B	*Cytherella caelata* van den Bold	*Paracypris* sp.	*Argilloecia* sp. 1	*Macrocyprina* sp. aff *M. decora* (Brady)	*Bairdia willisensis* (Puri)	*Paranesidea* sp. aff. *P. fortificata* (Brady)	*Disopontocypris? keiji* (van den Bold)	*Krithe dolichodeira* van den Bold	*Krithe markhoveni* van den Bold	*Cushmanidea andersoni* Puri?	*Gangamocytheridea? plicata* van den Bold	*Munseyella bermudezi* van den Bold	*Digmocythere* sp. aff. *D. russelli* (Howe & Lea)	*Bosquetina* sp. aff. *B. tarentina* (Baird)	*Orionina serrulata* (Brady)
Moo	15207	X								/			X	/						X
Moo Adentro	15208		/															/		
Gurabo	15209			/																
	15210		X		O			/		X									/	
	15211			/	X					X		/				X				
	15212			/	O	X	/	O	X	O	/		X		/	O	/			X
	15214																			
Cercado	15216																			/
	15219														/					

Formations According to Dohm		*Caudites medialis* Coryell & Fields	*Caudites nipeensis* van den Bold	*Caudites* n. sp.	*Radimella* ex gr. *confragosa* (Edwards)	*Procythereis? deformis* (Reuss)	*Jugosocythereis pannosa* (Brady)	*Quadracythere producta* (Brady)	*Costa dohmi* van den Bold	*Puriana scrupulosa* van den Bold	*Puriana pustulosa* van den Bold	*Hermanites hornibrooki* (Puri)	*Aurila* sp.	*Acuticythereis? elongata* van den Bold	*Pterygocythereis polita* van den Bold	*Pterygocythereis miocenica* van den Bold	*Cytheretta karlana* Howe & Taylor	*Cytheretta ponceana* van den Bold	*Loxoconcha farda* van den Bold	*Loxoconcha dorsotuberculata* (Brady)
Moo	15207																			
Moo Adentro	15208																			
Gurabo	15209																			
	15210				X															
	15211	/	/		O		X		X				/	X				/	X	
	15212	/	X		●		O	X		/	X	/		/		X			O	/
	15214				O									/						
Cercado	15216																			
	15219	/		/		/				/					/		X			

Formations According to Dohm		*Loxoconcha fischeri* (Brady)	*Loxoconcha rugosa* van den Bold	*Cytherura cresera* van den Bold	*Kangarina depressa* van den Bold	*Kangarina quellita* Coryell & Fields	*Hemicytherura cronekeyensis* Puri	*Paracytheridea* sp.	*Paracytheridea altila* Edwards	*Paracytheridea tschoppi* van den Bold	*Paracytheridea* sp. aff. *P. hispida* van den Bold	*Eucytherura* sp.	*Pseudocythere* sp.	*Pseudocerotina droogeri* van den Bold	*Bythoceratina* sp.	*Paradoxostoma* sp.	*Xestoleberis* sp. 1	*Xestoleberis* sp. 2	*Uroleberis triangula* van den Bold	*Nov. gen. vob. sp.* van den Bold 1968	Ostracoda Association	
Moo	15207																					2
Moo Adentro	15208																				2	
Gurabo	15209								X													
	15210									/											3	
	15211	X	/				/		X								X	X		/	3	
	15212																				4	
	15214			O	O	X	X	/		O	/	/	/	/	/	/	O	O	O	X		18
Cercado	15216																					16
	15219									X											5	

Table 15. Emended distribution of ostracodes in samples from the Río Mayo, northern Dominican Republic.

lic in the upper and lower Las Salinas Formation and in the Angostura Formation, and in Puerto Rico in the "Lajas beds." Almost in every case it is unaccompanied by other species of the same genus, except in one case with *C. pascagoulaensis* in the Las Salinas and on another occasion with *C. salebrosa* in the Lajas beds. *C. subquadraregularis* was originally described by Brady from Recent deposits at Santiago de Cuba. Sandberg (1964) in redescribing it, noticed its reworked appearance in the fauna and suggested its derived nature in the bay of Santiago. The youngest Neogene deposits outcropping in the area of Santiago de Cuba belong to the La Cruz Formation and this species has, indeed, been found in recently collected samples from Santiago. The fauna of the La Cruz Formation is closely similar to the combined fauna of the Ponce Formation and the "Lajas beds" of southern Puerto Rico and contains apart from a rich fauna of Bairdiidae and the genus *Jugosocythereis* the following, possibly diagnostic ostracode species: *Radimella* ex gr. *confragosa* (Edwards), *Acuticythereis* ? *elongata* van den Bold, *Cytheretta ponceana* van den Bold, *Neocaudites triplistriatus* (Edwards), *Coquimba congestocostata* (van den Bold), *Quadracythere producta* (Brady), *Quadracythere bichensis* (van den Bold), *Hermanites hornibrooki* (Puri), *Caudites angulatus* Puri, *Caudites nipeensis* van den Bold and, in brackish-water intercalations: *Cyprideis subquadraregularis* (Brady), *Cyprideis salebrosa* van den Bold, *Cyprideis bensoni* Sandberg, and at least three species of *Perissocytheridea*, which, however, are different from those mentioned in this report. The association suggests for the La Cruz Formation a similar age and facies as the upper part of the "Lajas beds" of Puerto Rico and equivalence to ostracode zones 3 and 4 of the Gurabo Formation of the northern Dominican Republic (Table 15) which should be placed in the Pliocene in accordance with our present knowledge of the ranges of marine ostracodes in the Caribbean. Compare also Seiglie and Cucurullo, 1971.

In one of Duclos' samples from the Lajas Valley (Puerto Rico) *Cyprideis subquadraregularis* was found to co-occur with *Haplocytheridea cubensis chicoyensis* van den Bold. This species has so far not been found in beds of an age certainly younger than middle Miocene, although specimens have been found in the Las Cahobas Formation of Haiti in samples of possibly late Miocene age. It is suggested, therefore, that *C. subquadraregularis* may have a range from upper Miocene to Pliocene, the top of the range overlapping with that of *C. salebrosa* (La Cruz Formation).

Whereas *C. subquadraregularis* occurs with only rare specimens of *Perissocytheridea* in the Las Salinas Formation, it is found with abundant specimens of this genus in the Lajas beds and the La Cruz Formation. The same goes for *C. portusprospectuensis,* which is found with only rare specimens of *Perissocytheridea* in the Jimaní Formation but with common occurrence of the latter genus in Cul-de-Sac corehole 1 (Table 6) and in the Harbour View beds (van den Bold, 1971). Speculation on the significance of these relative abundances is still premature.

The geographical distribution of *Cyprideis* is poorly known as it is governed by the availability of certain environments at certain times (Text-fig. 20). Of the extant species the distribution of *C. salebrosa* only is known comparatively well (Sandberg, 1964) from Argentina to Kansas and from eastern Mexico to the Lesser Antilles. Its recent distribution is, therefore, directly comparable to that of *C. beaconensis* (LeRoy) along the Pacific Coast from Chile to California, and inland to Utah, and to that of *C. torosa* (Jones) in the old world. *C. torosa* has been reported from freshwater up to salinities of 60 °/oo (Hartmann, 1964, p. 62). The fossil distribution of *C. salebrosa* appears more limited: it is so far unknown west of a line from Trinidad to the Florida panhandle. (van den Bold, 1971b). The Recent distribution is wider, but so far the species has not been reported from an area west of a line from Aruba to Yucatán. In this area its place appears to be taken by *C. bensoni,* which was originally described from the Gulf of Mexico and has recently been found in the La Cruz Formation and Canímar Formation of Cuba, and in the very top of the Las Cahobas Formation in Haiti, in both cases with *C. salebrosa,* and above the highest occurrence of *C. pascagoulaensis.* The latter species is another form that has been reported over a large area of the Caribbean, from Louisiana over the Greater Antilles to Trinidad and Venezuela. Possibly the same species occurs in Central America.

C. *Perissocytheridea*

Judging by their geographical distribution, species of *Perissocytheridea* appear to be even more provincial. Although forms similar to *P. matsoni* and *P. bicelliforma* occur over a wide area in the Caribbean, it is not certain that these reported occurrences are in fact conspecific. In individual samples a great variation in the development of nodes and ridges can be seen, whereby it may be questioned whether one should accept a wide latitude of variation within a species or if some of these should be granted a (sub) specific status. Some of the new species found in Hispañola have not yet been found outside this island, but in another case an unnamed species from the Cul-de-Sac Plain of Haiti cannot be separated morphologically from a form of the Pleistocene of Costa Rica (Pl. 62, figs. 4a, b), and it may be identical to *P. rugata* Swain of the marginal Gulf of Mexico (Swain, 1955; Morales, 1966).

In the species called here *Perissocytheridea* sp. B. which is probably related to *P. subrugosa* (Brady) and which is similar in shape, although larger, than *P. alata* (van den Bold) (l-m Miocene of Cuba, Puerto Rico, Anguilla, Panama, van den Bold, 1972b) there is a great deal of variability in the size of the ventral alate process. It appears that *P.* sp. B is present in samples with more than usual marine influence. *Perissocytheridea* sp. A shows some similarity in shape and size to *P. cytheridellaformis,* but differs by the presence of a ventral process in both male and female which varies from a mere spine to a regular ala. This form occurs together with *P. cytheridellaformis* in the top of the Las Salinas Formation but has a much larger range than this species. If these two species are really related their differences may be due to different reaction to environmental conditions.

D. *Limnocythere*

Another genus which should be able to give evidence of changing ecologic conditions by variation in nodosity is *Limnocythere.* This genus, as in the case of *Cyprideis* and *Perissocytheridea,* is supposed to come originally from marine milieu and to have become dominantly freshwater late in its development. Unfortunately only a few species occur in the present material and in insufficient numbers to yield much information. *Limnocythere staplini* Gutentag and Benson occurs in the Jimaní Formation and the top of the Las Salinas Formation (also in the upper part of the Cul-de-Sac coreholes). In the Las Salinas Formation a form resembling *L. ceriotuberosa* Delorme has been found. This same species occurs in the

Laguna de Leche (Camagüey) in Cuba, together with a fauna which includes some typical Jimaní-Las Salinas species: *Cyprideis salebrosa* (punctate and nodose forms), *Haplocytheridea? setipunctata* (Brady), *Darwinula stevensoni* (Brady and Robertson), *Paracytheroma* sp. aff. *P. johnsoni* (Mincher), *Perissocytheridea bicelliforma* Swain, *Cyclocypris* sp. 1, *Loxoconcha levis* Brady, *Uroleberis* sp., and *Xestoleberis* sp. (see also Table 6). Unfortunately I have no data of the chemistry of this body of water; according to Martashville and Luege (1968) it is fresh, but the fact that it is surrounded by Miocene limestones suggests a high carbonate concentration and the presence of uplifted older deposits in the neighbourhood indicates the presence of saltdomes. Most *Limnocythere* species occur in fresh to slightly brackish-waters, often with fairly high sulphur content which suggests lack of ventilation. It is even thought that high concentrations of *Limnocythere* may be indicative of hypersaline conditions (see discussion of Delorme, 1971). *Limnocythere* cf. *friabilis* Benson and MacDonald occurs in the present Enriquillo Lake, the waters of which are rich in Na, CO_2, and Ca, but low in C1 and Mg, while the SO_3 content is about equal to that of normal seawater (Condit and Ross *in* Vaughan, *et al.*, 1921). The same species has been found on the south side of New Providence (Bahamas) in a brackish-water assemblage which includes *Haplocytheridea setipunctata, Cyprideis americana* and rare *Cyprideis salebrosa,* together, with *Perissocytheridea. Limnocythere* is absent from Recent Lago de Valencia, the fauna of which is otherwise fairly similar: *Darwinula* sp., *Cytheridella ilosvayi?*, *Perissocytheridea bicelliforma* ?. In the Tuy Formation a species of *Limnocythere,* identical to one in the Cul-de-Sac coreholes occurs together with *Cyprideis pascagoulaensis.*

E. *Loxoconcha*

Another species which appears to be indicative of slightly brackish conditions is *Loxoconcha levis* Brady. Fossil representatives of this species were first recorded (van den Bold, 1963) from the Talparo Formation of Trinidad (with *Cyprideis salebrosa*), later in the Cumaná Formation (van den Bold, 1966) of Venezuela and in surface exposures of the Cubagua Formation on Cubagua. Further from the Mao Formation of the Dominican Republic (van den Bold, 1968), from possible Morne l'Enfer equivalents in wells of the Gulf of Paris (van den Bold, 1970b, table 1) from the Harbour View beds of Jamaica (van den Bold, 1971a) and now from the Jimaní Formation and Morne Delmas Formation of Hispañola. Its oldest occurrence so far is in the *Globorotalia crassaformis-altispira* zone of Bolli and its range appears to be from upper Pliocene to Recent, similar to that of *Cyprideis salebrosa.*

SYSTEMATIC DESCRIPTIONS

These have been kept to the barest minimum; however, in some cases it is necessary to add to synonymies or give some additional notes on species earlier described from the Caribbean. Some of the discussed species are not illustrated as the number of plates was kept low on purpose. In the synonymies only the latest, or pertinent, literature is quoted.

Subclass OSTRACODA

Order PODOCOPIDA

Superfamily **CYPRIDACEA**

Family **CYPRIDIDAE**

Subfamily **CYCLOCYPRIDINAE**

Genus **CYCLOCYPRIS** Brady and Norman, 1889

Cyclocypris sp. 1 Pl. 58, fig. 2 a-d

Description. — Carapace in side view almost circular, except for the flattened venter. Anterior end obliquely rounded; dorsal margin strongly arched with a slight angulation at the greatest height, just a little anterior to the middle; posterior end obliquely rounded, similar to anterior; ventral margin slightly sinuate just in front of the middle, almost straight in outline. Dorsal view rather similar to side view, but the anterior end is slightly pointed, posterior end broadly rounded and the greatest width lies just behind the middle. Surface finely and densely punctate; the center of the valves may be almost completely smooth.

Dimensions. — Left valve: L: 0.80; H: 0.62; W: 0.38
Right valve: L: 0.78; H: 0.59; W: 0.34

Remarks. — The species is close to *Cyclocypris serena* (Koch), but no positive identification can be made, especially as that species has, in the past, been confused with *C. ovum* and *C. laevis,* both of which are completely smooth. The present material is similar to the species illustrated by Jones (1857, pl. 4, fig. 4 a,b) as *Cypris ovum* from Quaternary deposits of Cambridgeshire.

Occurrence.—This species has been found in the Jimaní Formation and upper Las Salinas Formation of the Dominican Republic, where it also occurs in Recent deposits of Lago de Enriquillo. It is also present in Recent deposits of the Laguna de Leche, Camagüey, Cuba, and in the Pleistocene (?) of southwest Puerto Rico. Species of *Cyclocypris (e.g. C. laevis)* are known to penetrate brackish-water environment.

Cyclocypris sp. 2 Pl. 58, fig. 5 a-b

Description.—Carapace ovate, highest about the middle. Anterior end obliquely rounded; dorsal margin regularly arched; central margin convex; posterior end obliquely rounded, somewhat truncate in the upper slope, so that it forms a blunt posterior cardinal angle with the dorsal margin. Valves subequal, the left slightly overlapping dorsally and midventrally. Dorsal view egg-shaped, widest behind the middle, ends blunt.

Dimensions.—L: 0.58; H: 0.39; W: 0.30

Remarks.—This species is much smaller and more flattened dorsally than the preceding one. It is somewhat reminiscent of *Cyclocypris cinera* (Brady) = *Cypris globosa* Sars (non Dieff).

Occurrence.—The species was found at only one locality in the Jimaní Formation (10340), where it occurs together with *Cyclocypris* 1. For this reason the two have not been separated in table 2.

Superfamily **CYTHERACEA**

Family **CYTHERIDEIDAE**

Subfamily **CYTHERIDEINAE**

Genus **HAPLOCYTHERIDEA** Stephenson, 1936

Haplocytheridea? karlana (Stephenson) Pl. 60, fig. 2

Haplocytheridea karlana (Stephenson), Sandberg, 1964, p. 363, pl. 2, figs. 5-6.

Occurrence.—Originally described from the Caloosahatchee Formation of Florida, this species has been found in the upper Las Salinas Formation and Jimaní Formation.

Haplocytheridea sp. A Pl. 59, fig. 7 a-d

Description. — Carapace triangular. Anterior end broadly rounded; antero-dorsal margin very slightly convex until the greatest height, about 1/3 of the length from the anterior extremity, where the dorsal margin is obtusely angled; posterodorsal margin slightly convex; sloping down converging towards the venter, the convexity slightly but continuously increasing posteriorly; the dorsal margin merges without distinct cardinal angle with the posterior end, which is obliquely rounded, narrowly rounded below; ventral margin slightly sinuate, ventral outline convex in the left valve. Left valve overlapping the right almost along the entire periphery, hardly any overlap at upper and lower half of anterior margin; strongest overlap mid-ventrally and posterodorsally. Dorsal view elongate ovate, ends rather blunt; in the female the greatest width lies in the posterior third, in the male roughly in the middle; the middle half of the carapace has parallel sides. There is a slight medium sulcus, sloping obliquely forward from the greatest height; it is more pronounced in the male than in the female, where it is hardly visible.

Dimensions. — Female: L: 0.73; H: 0.41; W: 0.38
Male : L: 0.81; H: 0.43; W: 0.36

Remarks. — This form is identical to a species described by Teeter from the British Honduras shelf (Teeter, in press). As this has not been published open nomenclature will be used.

Occurrence. — In Hispañola restricted to the Jimaní Formation.

Genus **CYPRIDEIS** Jones, 1856

Cyprideis salebrosa van den Bold

Cyprideis salebrosa van den Bold, Sandberg, 1969, pp. 144-152, pl. 8, figs. 10-25; pl. 9, figs. 1-12; pl. 14, figs. 1-3; pl. 17, figs. 3 a-f; pl. 18, fig. 10; pl. 20, figs. 5-10; pl. 22, figs. 5, 8.
Cyprideis swaini Hall, 1965, pp. 42, 43, pl. 10, figs. 5-17.
Cyprideis hartmanni Ramirez, 1967, pp. 40-42, pl. 11, figs. 74-79; pl. 12, figs. 80-89.
?*Cyprideis* sp. Benson, 1969, p. 109, pl. 21, fig. 4; pl. 22, figs. 4,5,6.
Cyprideis salebrosa van den Bold, van den Bold, 1971b, figs. 2,4.

Occurrence. — In Hispañola in the Jimaní Formation and the upper part of the Las Salinas Formation.

Cyprideis similis (Brady)

Cyprideis similis (Brady), Sandberg, 1964, pp. 152-157, pl. 10, figs. 1-17; pl. 16, fig. 7; pl. 20, fig. 11; pl. 21, fig. 5.

Cyprideis sp. aff. *C. pascagoulaensis* (Mincher), van den Bold, 1968, pp. 29, 50 (part), not pl. 7, figs. 6 a,b; pl. 8, figs. 3 a,b.
Cyprideis similis (Brady), van den Bold, 1971b, figs. 2,4.

Occurrence. — Rare in Jimaní Formation and Las Salinas Formation in the present material, also in the Mao Formation (?) of the Cibao Valley (northern Dominican Rep.).

Cyprideis portusprospectuensis van den Bold Pl. 60, figs. 6 a-d

Cyprideis sp. No. 1, van den Bold, 1971b, figs. 2,4.
Cyprideis portusprospectuensis van den Bold, 1971a, p. 337, pl. 1, figs. 9 a-d; pl. 4, figs. 5 a,b.

Occurrence. — Jimaní Formation (southern Hispañola), Harbour View beds (Jamaica).

Cyprideis subquadraregularis (Brady)

Cyprideis subquadraregularis (Brady), Sandberg, 1964, pp. 162-164, pl. 6, figs. 9-13; van den Bold, 1969, p. 121, pl. 1, figs. 8 a-f, text fig. 3 a-c; van den Bold, 1971b, fig. 2,4.

Occurrence. — Angostura Formation and Las Salinas Formation, southern Hispañola, Ponce Formation (southern Puerto Rico), La Cruz Formation (E. Cuba).

Cyprideis pascagoulaensis (Mincher) Pl. 60, figs. 5 a, b

Cyprideis pascagoulaensis (Mincher), Sandberg, 1964, pp. 141-143, pl. 12, figs. 6-9; pl. 15, figs. 3-6; pl. 21, figs. 3 a,b.
Cyprideis sp. aff. *C. pascagoulaensis* (Mincher), van den Bold, 1968, p. 50 (part), pl. 7, figs. 6 a,b; pl. 8, figs. 3 a,b (not p. 29); van den Bold, 1971b, figs. 2,4.

Occurrence. — Arroyo Blanco, Angostura Formation and Las Salinas Formation; lower part of Morne Delmas Formation; base of Gurabo Formation.

Cyprideis curta (Edwards) Pl. 60, fig. 3

Cyprideis curta (Edwards), Sandberg, 1964, p. 111-113, pl. 12, figs. 10,11; van den Bold, 1971b, figs. 2,4.

Occurrence. — Arroyo Blanco, Angostura Formation and Las Salinas Formation.

Cyprideis sp. (reversed) Pl. 60, fig. 1

Description. — Female: Carapace subrhomboid in shape, highest about 2/5 of the length from the anterior extremity. Anterior end obliquely rounded, dorsal margin convex, sloping down behind the greatest height; posterior end steeply truncate, rounded below; ventral margin almost straight. Right valve larger than the left and overlapping along almost the entire periphery, least at the posteroventral corner, strongest overlap anterodorsally and ventrally. Dorsal view elongate eggshaped, widest in posterior third. Male: More elongate than the female and with the greatest height at about 1/3 from the front.

Dimensions. — Female: L: 1.05; H: 0.65; W: 0.53
Male : L: 1.20; H: 0.65

Remarks. — The female has a superficial resemblance to *Haplocytheridea karlana* but differs by its *Cyprideis* type hinge, and reversed valve overlap.

Occurrence. — Las Salinas Formation.

Cyprideis sp. Pl. 60, fig. 4 a,b

Description. — Female: Carapace elongate ovate, greatest height behind the middle. Anterior end slightly obliquely rounded; dorsal margin regularly convex; posterior end obliquely truncate above, rounded below; ventral margin slightly sinuate, concave in front of the middle. Left valve overlapping the right especially antero- and posterodorsally, less around the greatest height. Dorsal view bombshaped, widest at about 1/3 from behind, sides convex, anterior end less blunt than posterior. Male: Elongate ovate, with a strong resemblance to many species of *Cytherella*. Anterior end evenly rounded; dorsal margin slightly convex, flatter than in the female; posterior end obliquely rounded with almost straight upper slope; ventral margin slightly sinuate. Dorsal view wedge-shaped, widest near posterior end, sides almost straight and converging anteriorly.

Dimensions. — Female: L: 0.95; H: 0.58; W: 0.50
Male : L: 0.95; H: 0.53; W: 0.45

Remarks. — The species is different from other species of the same genus in its *Cytherella*-like shape. The female shows some similarity in form with *C. curta* but is much more elongate.

Occurrence. — Rare in both Las Salinas Formation and Jimaní Formation.

Family **CYTHERIDAE**

Subfamily **PERISSOCYTHERIDEINAE**

Genus **PERISSOCYTHERIDEA** Stephenson, 1938

Perissocytheridea bicelliforma Swain?

Perissocytheridea bicelliforma Swain ?, van den Bold, 1963b, p. 380, pl. 4, figs. 1 a-d; pl. 12, fig. 11; van den Bold, 1971a, pl. 1, figs. 8 a-d.

Perissocytheridea sp. cf. *P. matsoni* (Stephenson), van den Bold, 1969, p. 121, pl. 1, figs. 10 a-d.

Remarks. — This species is widespread in the brackish-water young Neogene deposits of the Caribbean, but exhibits some local variation which makes it difficult to assign it without restrictions to the Gulf of Mexico species, first described by Swain. Either this species is variable, or different geographical subspecies have developed in various parts.

Perissocytheridea subrugosa (Brady)

Perissocytheridea subrugosa (Brady), van den Bold, 1963b, p. 380, pl. 4, figs. 2 a-d; van den Bold, 1966b, pl. 1, figs. 7 a,b.

Remarks. — This species also exhibits a great amount of variation, especially in the development of the ventral ridge. Locally it may be possible to distinguish a more alate form (here described as *Perissocytheridea* sp. B) which may be a separate (sub)species or a mere local variant.

Perissocytheridea cytheridellaformis Forester, n. sp.
Pl. 60, figs. 8 a-c; Pl. 61, figs. 1 a-b; Pl. 62, figs. 1 a-b

Description. — See Appendix.

Remarks. — This species stands apart from others of the same genus by its small size, its typical shape in dorsal view, a slight modification of the median hinge element, which is slightly more coarsely crenulate in the anterior part and slightly wider there and the fact, that the longer specimens outnumber the shorter ones, which would suggest that the differences between sexes is the opposite from what is known in this genus! The species may be related to *Perissocytheridea* sp. A, from which it differs in being more strongly inflated and less strongly alate.

Occurrence. — Present in only a few samples, all from the upper part of the Las Salinas Formation. Also in the samples from the cliff at Balán, on the south side of Étang Saumâtre, Haiti.

Perissocytheridea plauta Forester, n. sp.
Pl. 60, figs. 7 a, b; Pl. 61, figs. 2 a, b; Pl. 62, fgigs. 2 a-f

Description. — See Appendix.

Remarks. — As in the preceding species there is some doubt about the assignment of sex by Forester, as the males (?) outnumber the females (?) by more than 2 to 1, which is very unusual in ostracodes.

Occurrence. — Lower Las Salinas Formation and Angostura Formation.

Perissocytheridea sp. A Pl. 62, figs. 3 a-d

Description. — Carapace subrhomboidal, highest at 1/4 of the length from the anterior extremity. Anterior end obliquely rounded; dorsal margin almost straight; ventral margin sinuate, converging posteriorly; posterior end obliquely rounded. Dorsal view bomb-shaped, side converging anteriorly to a point with anterior margin slightly projecting. Ventral side flattened, slightly alate, suddenly narrowed behind the posterior end of the ala at 1/4 of the length from behind. Surface finely punctate in some specimens almost smooth.

Male: More elongate than female with shorter anterior end, greatest height at 1/5 of the length from the front. Pronounced posterodorsal swelling, bordered in front by a narrow sulcus. In dorsal view it almost completely conceals the ala, which terminates at about 1/3 of the length from behind. Dorsal view elongate egg-shaped, sides convex, greatest width in posterior third, anterior end pointed.

Dimensions. — Female: L: 0.47; H: 0.27; W: 0.26
Male : L: 0.48; H: 0.25; W: 0.30

Remarks. — In dorsal view the male is similar to *P. cytheridellaformis* but differs by the alate venter. The female is in side view similar to *P. bicelliforma* but more strongly alate.

Occurrence. — In Jimaní Formation and Las Salinas Formation.

Perissocytheridea sp. B Pl. 59, figs. 13 a-c

Description. — Female: Carapace subrhomboid, highest at 2/7 of the length from the anterior extremity, alate, the alae terminating at about 2/7 of the length from behind. Dorsal view bomb-shaped with the alae projecting strongly, in some specimens abruptly constricted at ± 1/10 from behind. Male: Elongate pear-shaped with pronounced dorsal swelling, greatest height at 1/4 of the length from anterior extremity, but only slightly less than that at the posterodorsal swelling. Dorsal view bomb-shaped, with the posterodorsal swelling not obscuring the ala. Anterior end in both sexes blunt with the anterior margin projecting strongly forward. In the male the sides are flattened and converge forward, in the female the outline is more convex, with the ala projecting more strongly.

Dimensions. — Female: L: 0.53; H: 0.33; W: 0.33
Male : L: 0.55; H: 0.34; W: 0.34

Remarks. — Dorsal view in both sexes similar to that of *Perissocytheridea alata* van den Bold (1946, p. 84, pl. 14, fig. 4 a-c) but much larger.

Occurrence. — Common in Jimaní Formation, rarer in Las Salinas, very rare in the Angostura Formation.

Perissocytheridea sp. Pl. 62, figs. 4 a,b

A few specimens of a regularly ovate species of *Perissocytheridea* were found in the Cul-de-Sac coreholes. They are identical to specimens from the Pleistocene of the area of Puerto Limón, Costa Rica, and also similar in shape to *Perissocytheridea rugata* Swain (1955, p. 262, pl. 61, figs. 4 a,b; pl. 62, figs. 6, a,b, text-fig. 33c) but have a heavier shell with less prominent ridges. This difference may be due to the highly calcareous environment, compared to that of San Antonio Bay (Swain), in which these specimens lived.

Subfamily **LIMNOCYTHERINAE**

Genus **LIMNOCYTHERE** Brady, 1868

Limnocythere staplini Gutentag and Benson Pl. 59, figs. 8 a,b

Limnocythere staplini Gutentag and Benson, 1962, p. 51, pl. 1, figs. 1-3, text-fig. 15.
Not *Limnocythere staplini* Bhatia, 1968 = *Limnocythere frankei* Bhatia.

Occurrence. — This species was originally described from the Pleistocene of Kansas, the authors indicate one questionable occurrence in the upper Pliocene. In Hispañola the species has been identified in the upper Las Salinas and the Jimaní Formation. Possibly the same species occurs in the upper part of the Cul-de-Sac boreholes, but preservation is bad and for this reason the specimens are recorded as *Limnocythere* sp.

Limnocythere sp. cf. **L. friabilis** Benson and MacDonald Pl. 59, fig. 10

Limnocythere friabilis Benson and MacDonald, 1963, p. 24, pl. 3, figs. 1-4.

Occurrence. — This species was originally described from Post-Glacial (Holocene) deposits of Lake Erie. In Hispañola a similar form has been found in Recent or Subrecent deposits of the Lago de Enriquillo which also occurs in brackish water of the Bahamas.

Limnocythere sp. cf. **L. ceriotuberosa** Delorme Pl. 59, fig. 9

Limnocythere ceriotuberosa Delorme, 1967, p. 360, figs. 9-12.

Occurrence. — A species of *Limnocythere* which bears a close resemblance to *L. ceriotuberosa* Delorme was found in one sample (6840) of the Las Salinas Formation and is of common occurrence in the Laguna de Leche, Cuba. On Table 3 it has been indicated as *Limnocythere* cf. *staplini.*

Genus **CYTHERIDELLA** Daday, 1905

Cytheridella ilosvayi Daday? Pl. 58, figs. 1 a-g; Pl. 61, figs. 3 a,b

Cytheridella ilosvayi Daday, 1905, p. 262, pl. 17, figs. 15-18; pl. 18, figs. 1-11.
Cythereis ilosvayi (Daday), Müller, 1912, p. 336.
Cytheridella ilosvayi Daday, Klie, 1930, pp. 246-247.
Onychocythere alosa Tressler, 1939, pp. 337-339, figs. 1-11.
?*Metacypris?* sp. van den Bold, 1958, p. 74, figs. 3 a-f.
?*Cytheridella* sp. (van den Bold 1958), Pinto and Sanguinetti, 1962, p. 32.
Cytheridella alosa (Tressler), Pinto and Sanguinetti, 1962, p. 18.
Cytheridella ilosvayi Daday, Pinto and Sanguinetti, 1962, p. 14, pl. 1, figs. 4 a-d; pl. 2, figs. 4 a-e.
Metacypris ometepensis Swain and Gilby, 1964, p. 369, pl. 1, figs. 4 a-d; pl. 2, figs. 1-5; pl. 3, figs. 1-3; pl. 4, figs. 1-3; pl. 5, fig. 11.
Cytheridella ometepensis (Swain and Gilby), Y. Purper *in* Swain and Gilby, 1970, p. 1135.

Description. — Female: Carapace subrectangular to subrhomboidal in side view; Height about equal at the dorsal margin about 1/3 from anterior extremity and at the posterior swelling about 1/4 of the length from the posterior extremity. Anterior end only slightly obliquely rounded; dorsal margin sinuate, slightly concave behind the middle; ventral margin roughly parallel, sinuate, slightly concave about 1/3 from anterior, swinging broadly upward into the posterior end; greatest convexity of posterior margin just above the middle. Posterior end of carapace strongly swollen, bordered in front by a deep, subvertical sulcus, situated at about 3/7 of the length from the anterior extremity. Ventral surface strongly flattened. Valves subequal. Surface finely and densely punctate in the swollen portion of the carapace; the compressed anterior portion in front of the sulcus is only weakly punctate. Dorsal view pyriform, widest at about 1/3 of the length from the posterior. Posterior end wide, broadly rounded to almost truncate, and incised in the middle. Anterior end compressed with projecting margin, lateral outline in front of the sulcus slightly convex.

Male: Carapace in side view similar to the female. In dorsal view broadly lense-shaped, widest at 3/5 of the length from the anterior extremity, posterior end narrowly rounded, not incised. Interior deep, musclescars situated in deepest part of sulcus, forming a roughly vertical irregular row of four. Marginal area fairly wide except at the ventral concavity. Line of concrescence and inner margin widely separated, zone of concrescence narrow, radial pore-canals numerous, closely and evenly spaced.

Where this species has been found in Recent deposits, the adults are accompanied by many moult stages which resemble the male in shape.

Dimensions. — Female: L: 0.98; H: 0.53; W: 0.67
Male : L: 0.87; H: 0.47; W: 0.49

Remarks. — This species differs by its less obliquely rounded anterior end, less incised posterior end (female, dorsal view) and less deep median sulcus from *Metacypris*? sp. (van den Bold, 1958, p. 74, text-figs. 3 a-f) = *Cytheridella* sp. Pinto and Sanguinetti (1962, p. 32) which was described from Recent deposits of the Caroni Swamp (Trinidad) and subsequently found in the Caloosahatchee River (Florida). Difference with *Cytheridella ilosvayi* Daday is only slight and consists of a more strongly swollen posterior portion which in dorsal view is more truncate and less sharply incised. The male of the present form is almost identical to that of *C. ilosvayi*. Dimensions of *C. ilosvayi*: Female: L: 0.99; H: 0.57; W: 0.84; Male: L 0.88; H: 0.50; W: 0.60. According to Y. Purper (manuscript) the Trinidad material referred to above is identical to *C. ilosvayi*. The dimensions, however, are slightly larger: Female: L. 1.05; H: 0.57; W: 0.82; male: L: 0.93; H: 0.51; W: 0.43. R. Dempsey (Texaco Trinidad) kindly sent me some specimens of a possibly identical species from the subsurface of the Talparo Formation (u. Pliocene) of Trinidad. As the material consists only of pyritized internal molds a positive identification is not possible, but I consider it highly probable that it is conspecific with the present species. It is certainly different from the Recent species of Trinidad.

The present species is described as new by Y. Purper (MS. thesis, University of Rio Grande do Sul). As her paper, of which she was so kind to send me a preprint, has not yet been published, as far as I am aware, I prefer to assign the species questionably to *Cytheridella ilosvayi*, especially as I have some doubts about the validity of the new species. She assigns the Recent Trinidad material (van den Bold, 1958) to *C. ilosvayi.* Personally I consider the present material closer to *C. ilosvayi* than the Recent Trinidad species.

Distribution. — Recent occurrence of this species is in the Lago de Valencia (Venezuela) and the Lago de Enriquillo (Dominican Republic). Its fossil occurrence is in the Jimaní Formation of the Dominican Republic and in possibly equivalent deposits of Haiti (Cul-de-Sac boreholes). Possibly the same species occurs in the upper Pliocene Talparo Formation of Trinidad. The genus has so far been reported from Recent fresh-water bodies only. The highest chlorine content reported is in Trinidad (van den Bold, 1958) of 266 p.p.m.

Subfamily **CAMPYLOCYTHERINAE**

Subfamily **CAMPLOCYTHERINAE**

Campylocythere? sp. Pl. 59, figs. 5 a,b

Carapace subquadrate, highest at 0.3 of the length from the anterior extremity, dorsal and ventral margin slightly converging posteriorly. Anterior end obliquely rounded, short, dorsal margin convex, ventral margin sinuate, with a concavity at about 1/3 of the length from the anterior; posterior end almost regularly rounded, dorsal slope slightly flattened. Dorsal view elliptical, widest at 0.4 of the length from the posterior end. Sides generally regularly convex, interrupted only by a slight angularity at the location of greatest height. In front of the greatest height is a small but distinct eyespot. Surface almost smooth except for fairly deep irregularly spaced pits, which in the ventral part are more or less longitudinally arranged. No single valves were found, so that the hinge could not be studied. In the anterior margin, however, numerous porecanals could be seen, a small number of which are false and indent the line of concrescence.

Dimensions. — L: 0.63; H: 0.35; W: 0.32.

Remarks. — The arrangement of radial porecanals in the anterior end may indicate that this species belongs to *Proteoconcha.* The nearest species appears to be *Proteoconcha proteus* Plusquellec and Sandberg, (1969, p. 450-2, pl. 1, figs. 1-18; pl. 3, figs. 5-6; pl. 5, fig. 4; pl. 6, figs. 1-7, 17-19; pl. 8, figs. 1, 3-4, 6, 9, 11; pl. 10, figs.

1a-h, text-figs. 1, 21-m, 4, 7.), but it differs in the shape of the posterior end, especially in the right valve, and is also slightly smaller. In this respect it is perhaps closer to *Proteoconcha concinnoidea* (Swain), (Plusquellec and Sandberg, 1969, p. 452, pl. 2, figs. 12-16; pl. 5, fig. 7; pl. 6, figs. 14-15; pl. 7, fig. 6; pl. 10, figs. 4 a-e, text-figs. 2 d-e, 4, 8), but it is much larger.

Occurrence. — Jimaní Formation and Recent deposits of Lake Enriquillo.

Family **XESTOLEBERIDIDAE**

Genus **XESTOLEBERIS** Sars, 1865

Xestoleberis sp. A

An elongate, low species of *Xestoleberis* occurs as single or rare specimens scattered throughout the section. It could not be identified with any certainty with known species. Tables 2, 3.

Xestoleberis sp. B

Xestoleberis sp. van den Bold, 1963b, p. 402, pl. 10, figs. 14 a,b.
Xestoleberis sp. 1 van den Bold, 1968, p. 78, pl. 6, figs. 9 a-c; van den Bold, 1970, p. 123, pl. 2, figs. 1 a-b.

A species of *Xestoleberis,* that occurs as rare scattered specimens in the Las Salinas Formation is probably identical to the species described from the Gurabo Formation and Ponce Formation (Dominican Republic, Puerto Rico). Table 3. In Table 12 and in the Cul-de-Sac Plain both species have been plotted together in the tables as the occurrences were to rare to merit separate treatment.

INCERTAE SEDIS

Ostracode sp. A Pl. 58, figs. 3 a-b

Carapace, thin and fragile, cuneiform in dorsal and lateral view, highest and widest near anterior end. Anterior end slightly obliquely rounded, dorsal and ventral margin almost straight, converging posteriorly, posterior end narrowly rounded. Valves about equal in size, the left overlapping very slightly posterodorsally and mid-ventrally. Dorsal view more or less boat-shaped, widest in front of the middle, anterior end somewhat pointed, with convex sides, lateral outline behind the middle wedge-shaped, narrowly rounded posteriorly. Internal features not observed. Cyprid muscle scar.

Dimensions. — L: 0.62; H: 0.32; W: 0.30.

Remarks.—This is obviously a fresh-water species and has been found, though only on a few occasions, in both the Jimaní Formation and the Las Salinas Formation.

Ostracode sp. B Pl. 58, fig. 4

Carapace thin, fragile, elongate bean-shaped and narrow. Greatest height at about 2/3 of the length from the front. Anterior end obliquely rounded, dorsal margin arched, flattened in middle 1/3, curving obliquely down behind the greatest height into the posterior end which is narrowly rounded below median height. Ventral margin sinuate. Valves about equal in size. Dorsal view lanceolate, widest in the middle. Internal features unknown.

Dimensions.—L: 0.70; H: 0.34; W: 0.25 (HVH 8846).

Remarks.—Judging by the shape, this is a species of *Candona,* possibly immature. It has been found rarely in the Las Salinas Formation.

Ostracode sp. C Pl. 59, fig. 12

Carapace elongate ovate, highest in front of the middle. Anterior end obliquely rounded, dorsal margin regularly arched, sloping down towards the almost straight ventral margin behind the greatest height. Posterior end obliquely rounded, ventrally much more narrowly than the anterior. Dorsal view lanceolate, widest in the middle. Left valve appears to be overlapping the right along the posterodorsal margin and mid-ventrally. Apparently there is some sexual dimorphism, a few specimens are slightly longer and narrower than the majority. Interior unknown.

Dimensions.—Female: L: 0.60; H: 0.35; W: 0.26; male?: L: 0.61; H: 0.33; W: 0.22.

Remarks.—The nature of this species is completely unknown. It might be a cyprid, but on the other hand it might be a moult of one of the Cytherideinae. It occurs in both the Las Salinas Formation and Jimaní Formation but some of the identifications are uncertain due to poor preservation. Tables 3, 12.

Ostracode sp. D

Carapace elongate rhomboid, highest at 1/3 of the length from the anterior. Anterior end evenly rounded; dorsal margin angled at the greatest height with almost straight anterior and posterior slopes;

ventral margin sinuate, concave in the middle; posterior end obliquely rounded, almost obliquely truncate above, narrowly rounded below. Musclescars of candonid type. Zone of concrescence narrow, wide anteroventral vestibule.

Dimensions. — L: 0.66; H: 0.33.

Occurrence. — Jimaní Formation.

Ostracode E

Description. — Carapace elongate, highest in the middle. Both ends broadly rounded, anterior slightly higher; dorsal margin convex, ventral margin sinuate.

Dimensions. — L: 0.48; H: 0.23.

Remarks. — Muscle scars were not clearly discernible but appear similar to those of *Heterocypris,* with which genus the general shape also agrees.

Occurrence. — Las Salinas Formation and Jimaní Formation.

APPENDIX

The following species are described by R. Forester (Univ. of Illinois, Urbana). I have merely added the derivation of the name, holo- and paratype numbers and localities and distribution.

Perissocytheridea cytheridellaformis Forester, n. sp.
Pl. 60, figs. a-c; Pl. 61, figs. 1 a-b; Pl. 62, figs. 1 a-d

Name. — Shaped similar to species of *Cytheridella.*

Holotype. — A complete male carapace, HVH No. 9086.

Paratype. — HVH No. 9087.

Type locality. — 10393, Hoya de Enriquillo, Dominican Republic.

Stratigraphic horizon. — Las Salinas Formation.

Description. — Carapace of both male and female smaller in size than most species of the genus. Males subovate, females subpyriform in lateral view. Dorsal margin arched in the female, with greatest height just anterior to anterior hinge element, then straight and sloping towards posterior element. Dorsal margin in males slightly arched with greatest height at anterior terminal hinge element and straight between terminal hinge elements. Posterior margin rounded in the female, slightly pointed below median line in the male. Ventral margin straight, anterior margin rounded.

Carapace of male ovate; female elliptical in dorsal view; reticulate to punctate with area bordering hinge line from median point of hinge anteriorly predominantly smooth. Left valve slightly larger than right, overlapping anteriorly and, slightly, posteriorly.

Ornamentation consists of a reticulum constructed by predominantly rounded fossae (sola concave) which are typically smaller relative to valve size than in other species of the genus. Small postero-ventral alate expansions of valve posterior to medially located sulcus. Adductor muscle scars consist of a vertical row of four spots, the ventralmost scar largest and semicircular in outline. The next adductor scar approximates the figure 8 in shape, pointing towards the posterior. Third scar has the same shape but points towards the anterior, while the dorsal scar is rounded and touching the scar below it. The frontal scar, located just anteriorly of the fulcral point, is ovoid in outline, with a small circular scar attached to its antero-ventral margin. The fulcral point is located just anterior to the two dorsal most adductor scars and is ovoid in outline. Normal pores seive-type, numbering around forty; generally with setal opening. They are usually slightly smaller than the smaller fossae and all examined to date have been intramural. Inner lamellae well developed but not wide; a narrow, small vestibule visible in anterior; line of concrescence slightly undulatory in the anterior, but smooth along ventral and posterior margins. Prominent selvage medially located on the inner lamella, parallelling the outer margin. Radial porecanals straight to slightly sinuous, usually less than ten in the anterior. Hinge antimerodont. In the right valve, starting from the anterior, there is a prominent crenulate tooth, composed of six denticles, the four central ones larger and separated by narrow slits; a long crenulate median groove, composed of distinct, separated sockets, and a posterior crenulate tooth, consisting of six prominent denticles with little or no space between them. Sexual dimorphism strong, with males slightly higher, commonly longer and wider. Male carapace inflated posterior of medially located sulcus. Juveniles similar to adult females, except, that the valves are more triangular and the caudal process usually more prominently present.

Dimensions.—The values given below were computed for all non-broken, non-deformed specimens in my sample. All values are in millimeters. N = number of specimens measured, s = standard deviation, and O.R = observed range.

Females	N = 3	mean	s	OR
height		0.232	0.010	0.221-0.238
length		0.404	0.012	0.391-0.411
Males	N = 5	mean	s	OR
height		0.239	0.0014	0.238-0.241
length		0.469	0.0150	0.442-0.476

Perissocytheridea plauta Forester, n. sp.

Pl. 60, figs. 7, a-b; Pl. 61, figs. 2 a,b; Pl. 62, figs. 2 a-f

Name. — Plautus (L) — broad, flat.

Holotype. — A complete male carapace, HVH No. 9084.

Paratype. — HVH No. 9085.

Type locality. — 6822, Hoya de Enriquillo, Dominican Republic.

Stratigraphic horizon. — Las Salinas Formation.

Description. — Carapace small; male and female quadrate in lateral view. Dorsal margin straight, slightly arched at anterior portion of valve, just anterior of anterior hinge element. Ventral margin straight; anterior margin obliquely rounded; posterior margin rounded in female, round to slightly pointed below median line in male.

Carapace quadrate in dorsal view. Reticulate along posterodorsal margin, smooth from medial-dorsal area to posterodorsal.

Ornamentation consists of a reticulum, often more strongly developed in male. Longitudinal elements of the reticulum prominent, thickened plica, particularly wide in the anterior. Dorso-ventral elements of reticulum less prominent, sometimes absent in female, narrowing or absent between the longitudinal elements in the male. Fossae commonly rounded. Large thickened, smooth ridge in dorso-anterior area. Females have prominent alae in postero-ventral to medial-ventral area of valve.

Inner valve characters poorly preserved on available material (all whole carapaces filled or coated with calcite crystals). Inner lamella appears typical for genus, muscle scars and radial pores unknown. Normal pores not visible (probably calcite filled). Hinge antimerodont, but details unknown due to poor preservation. Sexual dimorphism strong, with males longer, wider than females, and lacking alae. Prominent expansion of valve in area posterior to medially located sulcus in males. Juveniles unknown.

Dimensions. — The values given below were computed for all non-broken, non-deformed specimens in my sample. All values in millimeters. N = number of specimens measured, s = standard deviation, OR = observed range.

Females	N = 9	mean	s	OR
height		0.301	0.013	0.272-0.323
length		0.476	0.009	0.459-0.493
Males	N = 30	mean	s	OR
height		0.294	0.019	0.238-0.309
length		0.561	0.024	0.510-0.612

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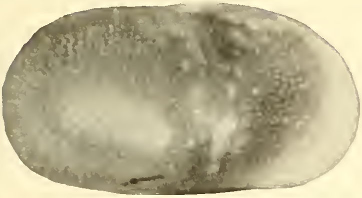
PLATES

EXPLANATION OF PLATE 58

Figure		Page
1.	**Cytheridella ilosvayi** Daday ?	613
	HVH No. 8830, Lago de Valencia, Venezuela, (Isla Tacarigua); × 100. a. Female, right valve view. b. Female, dorsal view. c. Male, right valve view. d. Male dorsal view. e-g. Molts, right valves.	
2.	**Cyclocypris** sp. 1	605
	HVH No. 8843, Dominican Republic No. 10287, Recent, × 100. a. Right valve. b. Left valve. c. Interior of left valve. d. Interior of right valve.	
3.	Ostracode sp. A	616
	HVH No. 8845, Dominican Republic No. 10369, Las Salinas Formation; × 100. a. Right valve view. b. Dorsal view.	
4.	Ostracode sp. B	616
	HVH No. 8846, Dominican Republic No. 10369, Las Salinas Formation; × 100. Left valve view.	
5.	**Cyclocypris** sp. 2	606
	HVH No. 8844, Dominican Republic No. 10340, Jimaní Formation; × 85. a. Left valve view. b. Dorsal view.	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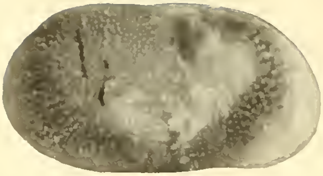
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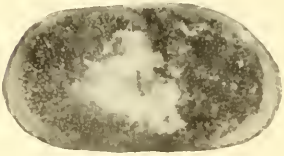
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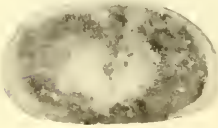
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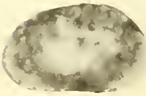
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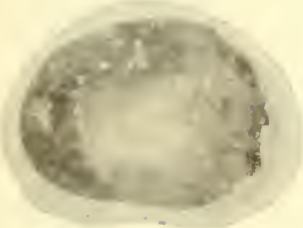
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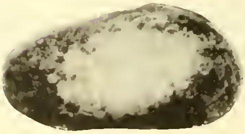
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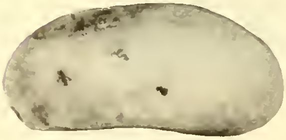
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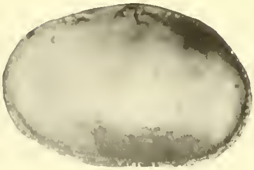
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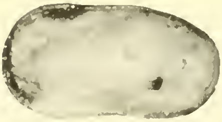
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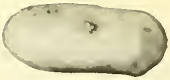
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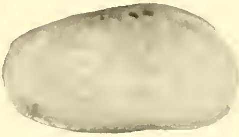
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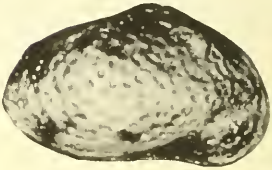
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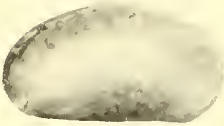
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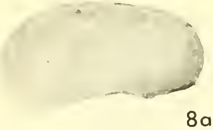
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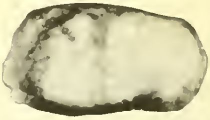
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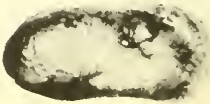
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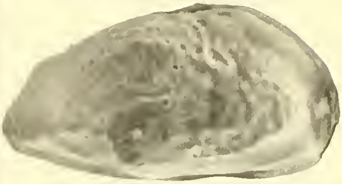
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Explanation of Plate 59

Figure Page

1. **Cytherella polita** Brady 595
   HVH No. 8827, Dominican Republic No. 6795, Jimaní Formation; × 100. a. Female, left valve view. b. Male, left valve view.

2. **Cytherella** sp. aff. **C. pulchra** Brady 580, 584
   HVH No. 8826, Dominican Republic No. 6846, Jimaní Formation; × 100. Left valve view.

3. **Cytherelloidea** ? sp. 595
   HVH No. 8828, Dominican Republic No. 10341, Las Salinas Formation; × 100. Left valve view.

4. **Parakrithella** ? sp. 589
   HVH No. 8842, Dominican Republic No. 10358, Las Salinas Formation. × 100. a. Right valve view. b. Dorsal view.

5. **Campylocythere** ? sp. A 615
   HVH No. 8832, Dominican Republic No. 6827, ? Angostura Formation (possibly Jimaní Formation); × 100. a. Right valve view. b. Dorsal view.

6. **Aurila laevicula** (Edwards) 579, 581, 587, 590
   HVH No. 8831, Dominican Republic 6816, Jimaní Formation; × 100. Right valve view.

7. **Haplocytheridea** sp. A 606
   HVH No. 8840, Dominican Republic No. 6795, Jimaní Formation; × 75. a. Right valve view, female. b. Dorsal view, female. c. Right valve view, male. d. Dorsal view, male.

8. **Limnocythere staplini** Gutentag and Benson 612
   HVH No. 8849, Dominican Republic No. 10367, Jimaní Formation; × 100. a. Left valve. b. Right valve.

9. **Limnocythere** sp. cf. **L. ceriotuberosa** Delorme 610
   HVH No. 8850, Dominican Republic No. 6840, Las Salinas Formation. Left valve.

10. **Limnocythere** sp. cf. **L. friabilis** Benson and MacDonald 610
    HVH No. 8851, Dominican Republic No. 10287, Recent; × 100. Left valve.

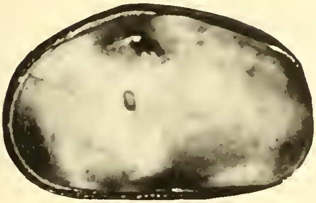
11. **Potamocypris** sp.
    Cul-de-Sac borehole 2, 232 ft.; × 100. Left valve view (specimen lost).

12. **Ostracode** sp. C 617
    HVH No. 8847, Dominican Republic No. 6847, Las Salinas Formation; × 100. Right valve view.

13. **Perissocytheridea** sp. B 611
    HVH No. 9089, Dominican Republic No. 10368, Las Salinas Formation; × 120. a. Male, right valve view. b. Female, dorsal view. c. Female, right valve view.

EXPLANATION OF PLATE 60

Figure		Page
1.	**Cyprideis** sp. (reversed) HVH No. 8838, Dominican Republic No. 10396, Las Salinas Formation; × 75. Left valve view.	608
2.	**Haplocytheridea ? karlana** (Stephenson) HVH No. 8839, Dominican Republic No. 6827, ? Angostura Formation (prob. Jimaní Formation); × 75. Right valve view.	606
3.	**Cyprideis curta** (Edwards) HVH No. 8837, Dominican Republic No. 10351, Las Salinas Formation; × 75. Right valve view.	608
4.	**Cyprideis** sp. HVH No. 8833, Dominican Republic No. 6816, Jimaní Formation; × 75. a. Left valve view, female. b. Right valve view, male.	609
5.	**Cyprideis pascagoulaensis** (Mincher) HVH No. 8834, Dominican Republic No. 6809, Arroyo Blanco Formation; × 75. a. Right valve view, female. b. Right valve view, male.	608
6.	**Cyprideis portusprospectuensis** van den Bold HVH No. 8835, Dominican Republic No. 6818, Recent; × 75. a. Female, left valve view. b. Female, dorsal view. c. Male, dorsal view. d. Male, left valve view.	608
7.	**Perissocytheridea plauta** Forester, n. sp. Dominican Republic No. 6822, Las Salinas Formation; × 120. a. male, right valve view, HVH No. 9085. b. Female, dorsal view, HVH No. 9085.	610, 620
8.	**Perissocytheridea cytheridellaformis** Forester, n. sp. HVH No. 9087, Dominican Republic No. 10393, Las Salinas Formation; × 120. a. Right valve view. b. Dorsal view. c. Ventral view.	610, 618
9.	**Bairdia** sp. aff. **B. laevicula** Edwards HVH No. 8829, Dominican Republic No. 10343, Jimaní Formation; × 75. Right valve view.	577
10.	**Paracypris** sp. HVH No. 8848, Dominican Republic No. 6809, Arroyo Blanco Formation; × 100. Right valve view.	581, 583, 585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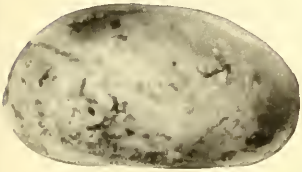
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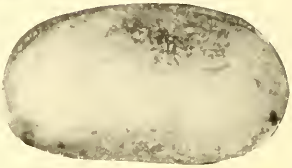
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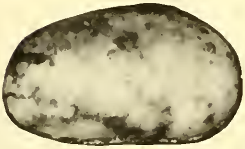
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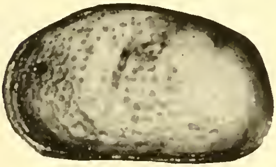
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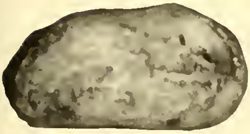
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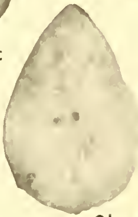
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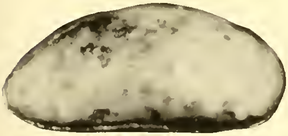
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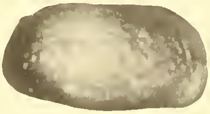
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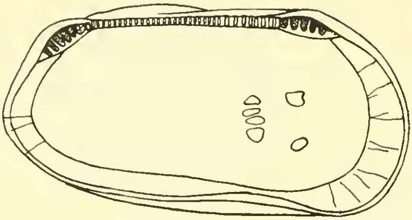
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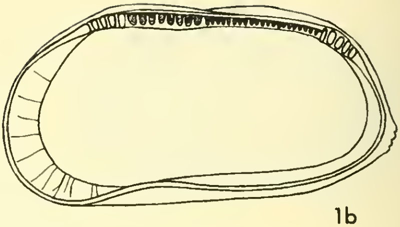
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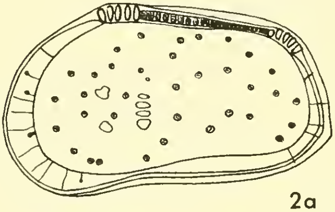
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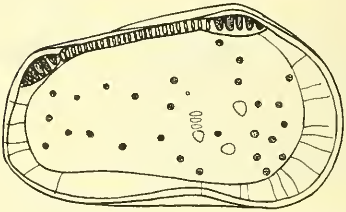
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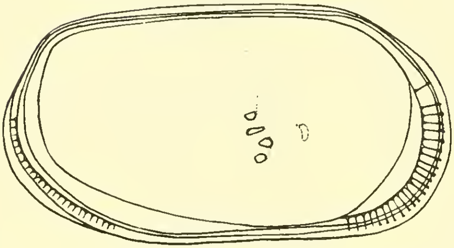
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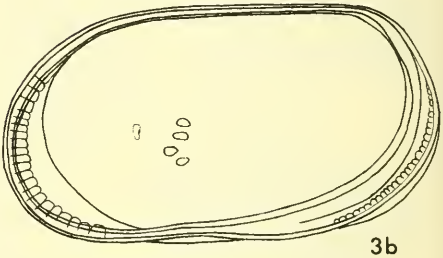
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Explanation of Plate 61

Figure Page

1. **Perissocytheridea cytheridellaformis** Forester, n. sp. 610, 618
HVH No. 9087, Dominican Republic No. 10393, Las Salinas Formation; × 200. a. Interior of left valve, female. b. Interior of right valve, male.

2. **Perissocytheridea plauta** Forester, n. sp. 610, 620
Dominican Republic No. 6822, Las Salinas Formation; × 200. a. Interior of right valve, female. b. Interior of left valve, female.

3. **Cytheridella ilosvayi** Daday ? 613
HVH No. 8830, Recent, Lago de Valencia, Isla Tararigua; × 100. a. Interior of left valve, female. b. Interior of right valve, female.

Explanation of Plate 62

Figure Page

1. **Perissocytheridea cytheridellaformis** Forester, n. sp. 610, 618

   Dominican Republic No. 10393, Las Salinas Formation; × 150. a. Female, left valve view (Univ. Illinois). b. Female, dorsal view, HVH No. 9087. c. Male, dorsal view, holotype, HVH No. 9086. d. Male, left valve view, paratype, HVH No. 9087.

2. **Perissocytheridea plauta** Forester, n. sp. 610, 620

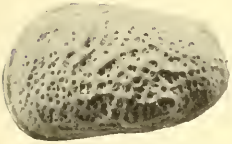
   Dominican Republic No. 6822, Las Salinas Formation. a. Female, right valve view, paratype, HVH No. 9085; × 135. b. Female, dorsal view (Univ. Illinois); × 150. c. Male, dorsal view, holotype, HVH No. 9084, × 125. d. Male, right valve view, paratype, HVH No. 9085, × 125. e. Male, left valve view (Univ. Illinois); × 125. f. Male, interior right valve.

3. **Perissocytheridea** sp. A 610

   Dominican Republic No. 10379, Las Salinas Formation; × 150 (Univ. Illinois). a. Female, right valve view. b. Male, left valve view. c. Female dorsal view. d. Male, dorsal view.

4. **Perissocytheridea** sp. 612

   Costa Rica, Loc. L4, Pleistocene; × 150. (Univ. Illinois). a. Female, left valve. b. Male, left valve.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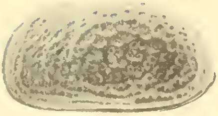
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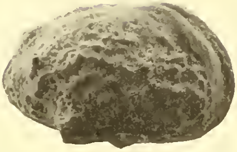
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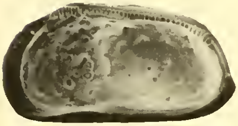
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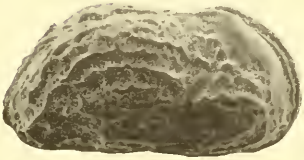
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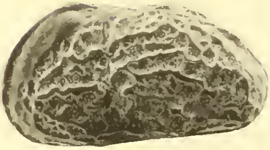
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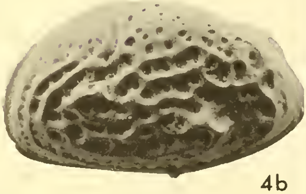
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