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Cenozoic and recent lunulitiform bryozoans of the Gulf and Atlantic coasts

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CENOZOIC AND RECENT LUNULITIFORM BRYOZOANS

OF THE GULF AND ATLANTIC COASTS

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ABSTRACT

Free, cup-shaped colonies of cheilostomatous bryozoans, equipped with vibracula, are termed lunulitiform bryozoans. This group is found in sandy and calcareous Cenozoic deposits of the Gulf and Atlantic Coastal Plains. Cupuliform bryozoans are taxonomically distinct from, but in many ways similar to, lunulitiform bryozoans; the two groups are frequently found together.

Known lunulitiform genera of the Gulf and Atlantic Coastal Plains are diagnosed and their species described: *Lunulites* Lamarck, fifteen species, one new; *Oligotresium* Gabb and Horn, six species, two new; *Discoporella d'Orbigny*, two species; *Cupuladria* Canu and Bassler, two species; *Selenaria* Busk, one species; *Otionella* Canu and Bassler, four species, one new; and New Genus A, one new species. One cupuliform genus is diagnosed: *Schizorthosecos* Canu and Bassler, four species.

Morphological terms applied to lunulitiform bryozoans are clarified. So-called "hollow" zoaria are proved to result from mode of preservation. The "*Trochopora*" type, or solid, zoarium is shown to be a structural variation that is not considered to be of taxonomic significance.

Various hypotheses of modes of life and orientation are reviewed and compared with results obtained by observation of living material collected from the Gulf of Mexico.

All hypotheses involving a natatory mode of life during the adult stage are discarded. Lunulitiform zoaria can exist in both apex-up and apex-down positions.

Lunulitiform bryozoans have numerous associated commensals and predators, as observed with live material. Commensal organisms include coelenterates, polychaetes, foraminifera, planarians, and other bryozoans. The major predators observed were the common blue crab and the hermit crab.

Regenerated zoaria are considered to result from breakage by predators rather than from breakage by current action.

Lunulitiform bryozoans and some cupuliform bryozoans are associated with calcareous sands deposited in shallow shelf areas with moderate current action and tropical to semitropical temperatures.

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I. INTRODUCTION

The Bryozoa of the Gulf and Atlantic Coastal Plain have been included in many studies. However, most of these studies were made in the nineteenth century without the benefit of modern concepts of evolution and stratigraphic relationships. As a result, although a great many bryozoans were named, very little was contributed to the taxonomic or ecologic relationships of Bryozoa.

Because many of the clastic Tertiary beds of this region are highly fossiliferous and the state of preservation very good, numerous paleontologic studies have been made. Although, in general, bryozoans are found in limy deposits which are frequently indurated, one group occurs most frequently in sandy or calcareous sandy facies with mollusks. As a result, the group was usually included in early paleontologic studies. This group, the lunulitiform bryozoans, is the subject of this report.

Lunulitiform bryozoans were defined by Lagaaij (1953, p. 13) as free, conical colonies equipped with seta-like appendages. Lunulitiform genera range from Cretaceous (in Europe) to Recent. In North America they range from Paleocene to Recent. Lunulitiform specimens are common in the shallow coastal waters of the tropical and semi-tropical oceans today. Although encountered frequently both as fossils and in coastal waters, the group has not been studied in detail.

The purpose of this investigation of the lunulitiform bryozoans of the Cenozoic of the Gulf and Atlantic Coastal Plains is twofold. First, the identification and classification of specimens from the area; second, to determine the ecologic and morphologic relationships of the group. Because species of the group exist today, data concerning the distribution and functional relationships of live lunulitiform bryozoans can be applied to fossil forms and are included as a part of the study.

Acknowledgements

A great many people have given freely of time, aid, and material during the course of this investigation; I wish to thank them and acknowledge this assistance. In addition to the several hundred bryozoan specimens representing many pounds of washed and screened material from the study area, Professor D. L. Frizzell, thesis advisor, is gratefully thanked for the countless counselling sessions concerning the numerous problems which arose during the investigation. Professor Frizzell, after making suggested corrections in this report, departed on sabbatical leave and Professor A. C. Spreng assumed responsibilities as thesis advisor; Dr. Spreng's suggestions and help are appreciated. Other persons contributing specimens are F. F. Mellon, former State Geologist, Mississippi; the staff of the Mississippi Geological, Economic and Topographical

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Classification

As is often the case with faunal groups which are poorly understood and little studied, a number of classifications of Bryozoa have been proposed. No single classification is acceptable to everyone. As zoologists have recognized for some time, the group includes two quite distinct phyla: Ectoprocta and Entoprocta. The ectoprocts have a well developed coelom and lack nephridia as opposed to the entoprocts which are pseudocoelomic and possess a pair of protonephridia. The name Bryozoa should be restricted to the ectoprocts and in this report is so used.

The restricted Phylum Bryozoa is subdivided into two distinct classes: Phylactolaemata and Gymnolaemata. The former are fresh water bryozoans which lack mineralized skeletons and in which the tentacles are arranged in a horseshoe-shaped pattern. Thus, fossil forms are extremely rare. The gymnolaemates are nearly exclusively marine and include the majority of fossil and Recent bryozoans.

The Class Gymnolaemata is divided into five orders on the basis of zooecial form, type of processes around the mouth, and form of aperture. In abundance and diversity of species, the Order Cheilostomata is most important in Cenozoic deposits. The cheilostomes are distinguished by an operculum which closes the zooecial orifice.

The Order Cheilostomata is divided into two suborders: Anasca and Ascophora. The basis of subdivision is presence or absence of a zooecial hydrostatic system. The ascophorans have a special sack-like organism, called the compensatrix, within the zooecial chamber, which can fill with fluids. When so filled, the volume displaced causes the polypide to be extruded. The anascans are without this mechanism.

Lunulitiform genera are placed in three anascan families: Cupuladriidae Lagaaij, 1952; Selenariidae Harmer, 1926; and Lunulitidae Lagaaij, 1952.

The Family Cupuladriidae includes genera which are lunulitiform anascans with the vibraculoecia alternating with zooecia along the same longitudinal row; with cryptocyst; and without ovicells. The family contains three genera: Cupuladria, Discoporella, and new genus A.

The Family Selenariidae is characterized by asymmetric vibraculoecia positioned irregularly over the zoarium and a complicated frontal wall. As recognized in this report, the family is restricted to genera with auriform or reniform vibraculoecia and basal sides composed of radial tubes. *Otionella* and *Selenaria* are placed in this family.

The Family Lunulitidae includes genera in which the vibraculoecia are regularly placed in distinct rows between the zooecial rows and are symmetrical. The cryptocyst of the zooecia is usually well developed and ovicells, if present, are endozooecial. The family includes *Lunulites* and *Oligotresium*.

Cupuliform bryozoans are outwardly similar to lunulitiform bryozoans in zoarial form and habitat, but are taxonomically distinct. Cupuliform genera are placed in families of Suborder Ascophora because of the zooecial hydrostatic system. Cupuliform bryozoans included in this report are discussed more fully in a separate chapter.

General account of cheilostomatous and lunulitiform bryozoans

The name Bryozoa (from the Greek *bryon*, meaning moss and the Latinized Greek *zoa*, meaning animals) is applied to a phylum (restricted to Ectoprocta) of invertebrate animals. Most are colonial and, although individuals (zooids) seldom exceed 1 mm in size, the colony (zoarium) may reach 25 to 30 cm in length. Fossil zoaria have been found with greater dimensions.

Bryozoans are characterized by: 1) U-shaped alimentary canal; 2) retractile, tentaculated lophophore; 3) coelomic cavity; 4) lack of definite excretory organs; and 5) sexual and asexual reproduction. Fossil bryozoans are distinguished by the colonial habit and size of the zooecia.

Cheilostomatous bryozoans are the most complex of the five orders of gymnolaematous bryozoans (Class Gymnolaemata, mostly marine); they are the most abundant, both in number of individuals and number of species, found in Tertiary and younger rocks and in the oceans today. The cheilostomes are distinguished (Brown, 1952) by: 1) zooecia which vary considerably in form and are seldom a simple tube as in the other orders; 2) position of orifice is parallel or oblique to the axis of the zooecium, rather than simply terminal; and 3) possession of an operculum, in most species, for closure of the orifice when the polypide (internal living movable parts of the zooid) is retracted. Cheilostomatous bryozoans have a known range from Jurassic to Recent.

Lunulitiform is a term first clearly defined by Lagaaij (1953, p. 13, footnote) to describe a zoarial type as "... free, conical zoaria, equipped with vibracula, in...Lunulites, Cupuladria, Discoporella, Selenaria, etc.", in which vibracula (vibraculoecia) are zooecia with the operculum modified to a seta-like structure. Lunulitiform genera have been found in Cretaceous sediments in Europe; however, the earliest known representatives in the United States are of Paleocene age.

Life histories of various species of cheilostomes are well known and can, in general, be applied to lunulitiform species: Sexual reproduction is initiated by formation and fertilization of the egg. Many species are hermaphroditic and formation and fertilization occurs in the same zooid. The egg is passed to a brood chamber (ovicell), in species possessing ovicells, where the egg develops to a larva (unnamed). These larvae lack digestive tracts and are unable to feed, allowing a maximum free mode of life of one day (Hyman, 1959, p. 350). Further development is as with the cyphonautes larva.

Fertilized eggs produced from species without ovicells are released in sea water where a trochophore type larva forms the cyphonautes.

Varying in appearance with the species, all cyphonautes have complete digestive tracts, apical organs, and are ciliated and bivalved. Feeding and locomotion are by ciliary currents, and the cyphonautes may live as long as two months.

Larvae produced from both ovicelled and non-ovicelled species eventually seek a suitable substratum. A vibratile plume, consisting of a tuft of elongated cilia, acts as a sensory organ to select the preferred substratum. When the required material is located, the larva inverts and spreads an adhesive sac over it and by a secretion completes attachment. Through a complex series of changes, the larva metamorphoses to the first individual of the colony, the ancestrula. Larva of some, including lunulitiform, species complete metamorphosis by secreting a calcareous box-like structure, the zooecium.

Most lunulitiform species are without ovicells and the larva is assumed to be a cyphonautes with a fairly long free mode of life. The substratum selected is usually a small grain of sand or material of sand size; however, fixation to foraminiferal tests and shell fragments also occurs. Asexual budding from the ancestrula incorporates the sand grain and produces the characteristic bowl, umbrella, cup, or dome-shaped zoarium.

Asexual budding is accomplished by formation of a body wall cutting off a portion of the parent cystid (living part of zooid wall). Invagination and differentiation of an ectodermal thickening produces the polypide and cystid of the new zooid. Cuticle is secreted, and in calcareous species deposition of minute crystals beneath the cuticle completes formation of the new zooecium.

Although in most groups of bryozoans zooecia are polymorphic, the greatest variety is in the cheilostomes. Normal zooids with fully developed feeding polypides are termed autozooids. Heterozooids are characterized by a reduction of the polypide and loss of nutritive and reproductive functions and include avicularia, vibracula, and kenozooids.

Avicularia are zooids in which the operculum is modified to a mandibular structure hinged to a cross-bar or pair of appendages (Hastings, 1963). The mandible opens and snaps shut. It varies in shape from spatulate to triangular and elongate-pointed. The name is derived from its fancied resemblance to a bird's head.

Vibracula are highly specialized avicularia with the mandible modified to a seta. It may be ten times the length of the autozooecium and is free to move in all directions. Avicularia and vibracula develop by budding in a manner similar to autozooecia. However, the distal epidermis proliferates to form a degenerated polypide and secretes a thick cuticle. The cuticle subdivides to form the mandible and processes of hingement.

Kenozooids lack zooidal differentiation and are simply body walls enclosing strands of tissue. Rhizoids, holdfasts, stalks, and pore chambers are types of kenozooids. Detailed information on heterozooids is found in Busk,(1854, 1881, 1884), Harmer (1900), Hastings (1963), Hincks (1882), and Waters (1885).

Rate of budding varies with the species and conditions; however, under laboratory conditions the following has been reported (Hyman, 1959, p. 363): Electra pilosa, 900 zooids in 10 weeks (Marcus, 1926); Watersipora cucullata, 4-6 zooids in 3 days, 20 in one week, 200 in a month (Mawatari, 1952); Membranipora crustulenta, 10,000 zooids in 21 days in Chesapeake Bay (Osburn, 1944). The ancestrula lacks gonads, and zoarial growth by asexual budding continues for some time before sexual reproduction completes the cycle.

Type of substratum selected and direction of asexual budding produces a variety of zoarial forms in cheilostomatous bryozoans. Stach (1936) described zoaria as belonging to nine groups based on zoarial form, one of which is lunulitiform. He postulated that zoarial form is dependent upon environment and cited Caleschara denticulata (Macgillivray) as occurring in two zoarial forms, each being an adaptation to the environment encountered. In near shore waters it is found with free, bilaminar (eschariform) zoarium, in deeper waters it is of the vinculariform (attached, erect, rigid, sub-cylindrical branches) type zoarium. The proposal was that the colony changed in form, not the individual. Brown (1952) added two forms and Lagaaij and Gautier (1965) added one form to Stach's original nine forms.

"Creeping" and encrusting bryozoans have a variety of individual forms. Such configuration might be influenced by type of bottom, current strength, biologic community, etc. However, Hyman (1959, p. 357) states that the budding pattern is characteristic for each species; hence, zoarial form should be of value taxonomically to some degree. Correlation of zoarial form with habitat, as proposed by Stach (1936), has been the result of several studies, notably Lagaaij and Gautier (1965).

Degeneration and regeneration of the polypide, in the same zooecium, is characteristic of some groups. Natural senescence, exposure to unfavorable conditions and sexual reproduction are given by Hyman (1959, p. 365) as reasons for degeneration. Marcus (1926, as cited by Hyman, 1959, pp. 365-366) suggested that accumulation of excretory substances in the ephithelium of the stomach is the main cause of degeneration, but Hyman subordinates this cause to the three given above.

In degeneration the polypide contracts violently, ruptures, and partially disintegrates, a portion of the digestive tract forms a brown mass (the brown body) and is suspended from the cystid wall. Depending upon the species, the brown body either remains in the zooecium, or is eventually voided through the anus. Apparently initiated by the absence of a polypide, a new polypide is regenerated from the cystid wall.

Degeneration and regeneration may occur several times and accumulation of two or three brown bodies in one zooecium is common. Degeneration has been shown to occur under laboratory conditions (Rey, 1927, according to Hyman, 1959, p. 365) every 1 to 2 weeks or at most 3 to 4 weeks under ideal conditions. However, polypides apparently cannot be regenerated by the same cystid more than three or four times (Hyman, 1959, p. 367).

Interchangability of autozooids (normal zooids) and heterozooids (e.g., vibracula, avicularia) has been noted by many workers (Levinsen, 1907; Buchner, 1918). Avicularia may occupy a degenerated autozooecium and vice versa. Entire zooids may be replaced in old zoaria.

II. HISTORICAL RESUME

Early history of bryozoan studies

The present state of knowledge of bryozoans has resulted from several centuries of study. As with many phyla, most of the early concepts and beliefs of bryozoans were rather bizarre. Hyman (1959, pp. 275-278) provides a historical review of bryozoans and much of the following summary is from her review.

Rondelet (1558, fig. 98) is credited as first to illustrate a recognizable bryozoan, probably a reteporid. During the Sixteenth Century the frondose organisms growing on rocks, pieces of wood, or washed on the beach were regarded as zoophytes or giroflade de mer. Although Imperato (1599) first mentioned the animal nature of zoophytes, he believed that these forms had "degenerated" to animals or were stony plants.

Peyssonel (1729, 1753 cited in Hyman, 1959) should receive credit for first recognizing that zoophytes are animals. In placing pieces of living red coral in sea water he noted the emergence of polyps which he considered insects. Encrusting the coral were numerous madrepores (ectoprocts) which he thought to be the works of animals. Although first met with skepticism, Peyssonel's ideas were confirmed by de Jussieu (1742 cited in Hyman, 1959) who observed zoophytes along the Normandy coast. Jussieu proposed the name polyp for the group. Trembley, in 1744, and later Ellis, in 1754 and 1755, published on the animal nature of the polyps. Ellis provided the term celliferous corallines for the various hydroids and ectoprocts.

Unfortunately, the systematists of the Eighteenth Century such as Linnaeus, 1758, Pallas, 1766, and Cuvier, 1798, continued to classify sessile animals as Zoophyta and Lithophyta.

Early history of lunulitiform bryozoan studies

Lamarck in 1815 (1815-1822), in his *Histoire Naturelle des Animaux Sans Vertèbres*, classified the polyps as the Second Class of the primary division *Animaux Apathiques*. In volume two of this same work, he established the genus *Lunulites* as follows: Division of Polypes, Third Order, First Division: *Polypiers ou fourreaux d'une seule substance*, #4. *Polypiers foramines; genus Lunulites*. Thus, the lunulitiform bryozoans were clearly established in the Animal Kingdom. Two fossil species, *L. radiata* and *L. urceolata* were introduced with the genus.

Lamouroux (1821) later described and figured these species, although he indicated that *L. urceolata* probably should be placed in a separate genus "*Cupulaire*." The nomenclatural histories of *Lunulites* and other lunulitiform genera are given in the generic descriptions under Systematics.

Following Lamarck and Lamouroux were a number of naturalists who described and illustrated species of lunulitiform Bryozoa of Europe and North America.

Isaac Lea (1833) was probably the first to describe Tertiary fossil Bryozoa of the Coastal Plain in his treatment of the geology (Eocene) of Claiborne Bluff, Alabama. Lea received in 1829 a quantity of fossil specimens from a friend of his, Judge Tait, a citizen of the town of Claiborne, Alabama, from which he described two species of Lunulites and two of Orbitolites (=Schizorthosecos).

The first monographic treatment of the Bryozoa of the Coastal Plain was by Lonsdale (1845), in which two species of Lunulites were described. Conrad (1847) described one species of Lunulites from the Oligocene near Vicksburg, Mississippi.

Although Gabb and Horn (1862), in their Monograph of the Fossil Polyzoa of the Secondary and Tertiary Formations of North America did not describe any new lunulitiform species, they did propose the genus Oligotresium, separating this group of species from Lunulites.

De Gregorio (1890) described a number of new species and subspecies after working on material from Claiborne Bluff, Alabama.

Canu and Bassler (1920, 1923), in their two monumental works on the Cenozoic Bryozoa of North America, redescribed and proposed a number of lunulitiform species and genera. Since their work, no comprehensive study has been made of the lunulitiform bryozoans of the Coastal Plain.

III. MORPHOLOGY

Morphological terminology of the Bryozoa has evolved to a complex and often confusing state. Many authors have attempted to establish a single set of terms, but no one set has been entirely accepted. However, Bassler (1953, pp. 7-16) provides an extensive glossary. In this glossary, Bassler has indicated the terms which he believes to be: (1) acceptable and useful, (2) of secondary importance or commonly used synonyms, and (3) of little use and should be discarded. Some terms in the latter category, however, are essential for congruent terminology and are utilized here.

Soft parts of bryozoans are not fossilized and cannot be employed by paleontologists for identification. However, the relationships of hard parts to soft parts is significant and should be thoroughly understood for identification.

Terms applied to the orientation of structures of the Bryozoa are fairly well accepted by bryozoologists. The <u>frontal</u> surface, termed the "celluliferous side" by early workers, is characterized by the openings or "cells" of the individuals of the colony and is the convex side of the lunulitiform bryozoan. The <u>basal</u> surface or side ("non-celluliferous") is the concave side. <u>Proximal</u> structures lie closest to the ancestrula and <u>distal</u> structures lie away from the ancestrula.

Morphology of the soft parts

The following discussion refers to figures 1 and 2 and is based on Recent specimens of Discoporella umbellata.

A characteristic of the Bryozoa is the ability of a part of the individual to extrude from the calcareous chamber. Figure 1, left side, shows an individual extruded and in a position of feeding. The individual on the right has retracted within the calcareous part of the zoarium. Figure 2 similarly shows the individual in a retracted position. A single unit, or individual, of the colony is termed a zooid, which consists of both soft, living parts and secreted, lifeless parts. Two zooids are shown in figure 1.

The living parts of the zooid may be classed in two groups: the movable or extrudable parts termed the polypide and the fixed box-like body wall termed the cystid.

The polypide. - The polypide consists of the tentaculated lophophore (l); the digestive (e), nervous (g), and muscular (re, au, ac) systems; and the rectum (ar). In the retracted position, the tentacles (en) are housed in the tentacular sheath (ts). For extrusion of the polypide, a frontal membrane (m) covering the hypostege (h) depresses and forces fluids from hypostege to the area below and displaces the polypide. At the same time, the operculum opens and the polypide is extruded through the vestibulum (v). In the extruded position, the alimentary tract assumes the U-shape characteristic for Bryozoa. Retractor muscles (re)

Figure 1. Cross section of Discoporella umbellata illustrating two zooids and two vibracula; zooid on left is in position of feeding with polypide extruded; zooid on right is retracted. X 120 (modified from Marcus and Marcus, 1962).

Figure 2. Soft-part morphology. X 150.

ac	adductor	k	chamber of connecting tube
ar	rectum	m	frontal membrane
au	abductor	me	connecting tube
ca	calcareous wall	n	basal membrane
dm	depressor muscles	nc	amebocytes
e	stomach	o	operculum
en	tentacles	re	retractor of polypide
ez	endocyst	s	seta (vibraculum)
g	ganglion	t	pore to basal side
i	cryptocyst	ts	tentacular sheath
j	gyrators	v	vestibulum

(modified from Marcus and Marcus, 1962)

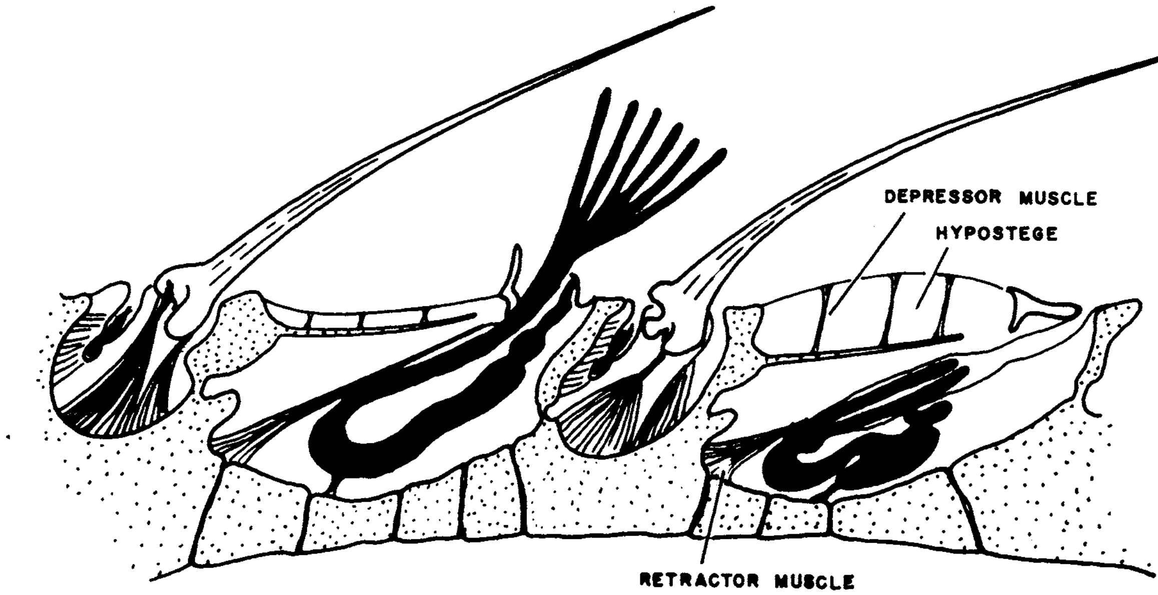


FIGURE 1

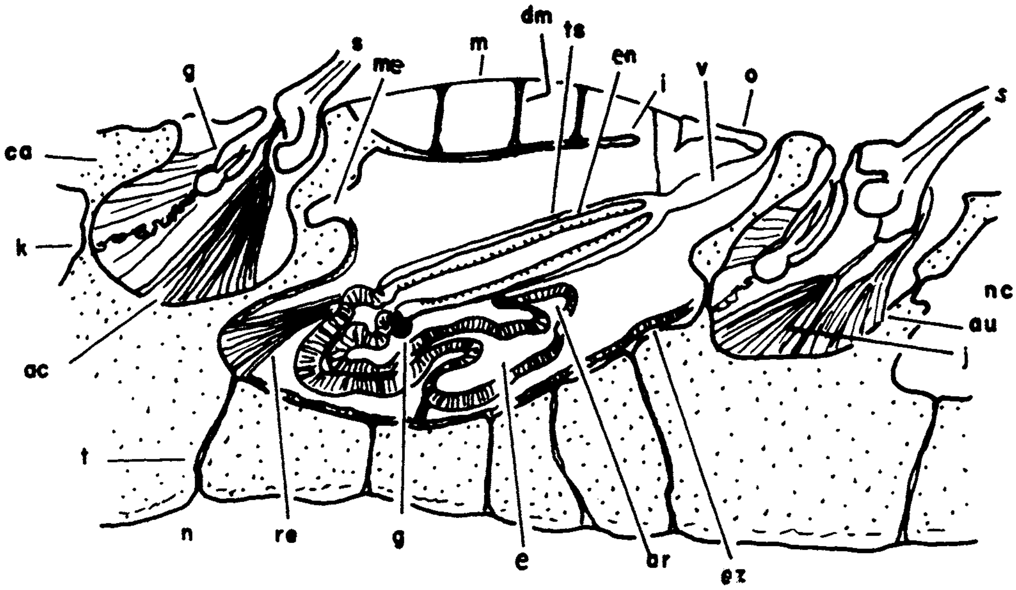


FIGURE 2

extending from the fixed body wall (cystid) to the lophophore base retract the polypide, displacing the fluids to the hypostege as the frontal membrane relaxes.

The cystid. - The cystid, or fixed living part, includes the chitinous frontal membrane (m); the endocyst (ez), the fixed body wall; and the basal chitinous membrane (n). Interzoidal pores (me), through the calcareous walls, provide communication between zooids. In living specimens of the Gymnolaemata the pores are never open holes, but are plugged with a rosette of epidermal cells. Communication may be by a slow percolation of fluids through these cells (Hyman, 1959, p. 306).

The vibraculozooid. - The soft parts of the vibraculozooid are essentially the same as those of the autozooid. However, the polypide (p) is much reduced and the operculum is modified to a seta-like structure, the vibraculum (s). The term vibraculum has been used indiscriminately by many authors to apply to the calcareous part, the soft body parts, the seta or true vibraculum, or the cavity remaining after removal of the vibraculum. Adductor (ac), abductor (au), and gyrator (j) muscles pivot the vibraculum through 360°. The term vibraculoecium is applied to the secreted part of the vibraculozooid.

Morphology of the hard parts

The morphology of the hard parts is especially important in the classification of lunulitiform bryozoans because most species occur only as fossils. A bryozoan colony made up of a group of individuals is termed the zoarium. The zooecium comprises all the hard parts of the zooid and is the basic unit of a fossil zoarium. Lunulitiform bryozoans include two types of zooecia; autozooecia, or normal zooecia; and heterozooecia, which are modified zooecia. The vibraculoecium, discussed above, is a heterozooecium in which the operculum has been modified to a seta-like structure.

Morphology of the zoarium. - Characters of the zoarium include diameter, height, growth pattern of the zooecia, arrangement of vibraculoecia in relation to the zooecia, and thickness of zoarium measured from frontal surface to basal surface. Dimensions and their significance are discussed later under Measurements.

In all lunulitiform bryozoans, growth of the zoarium is by radial budding of the zooecia from the ancestrula. As the zoarium expands, new rows are formed in two ways. In most cases, the new zooecial row is inserted between two existing zooecial rows and distal to a vibraculoecium. The first zooecium of the interpolated row is often of slightly different shape. In the other way, which is rather rare, a normal zooecial row bifurcates to form two new zooecial rows.

On the frontal surface, the zooecia may be arranged in quincunx, in which the zooecia of one row are staggered with the zooecia of adjacent rows (figure 3), or the zooecia may be arranged in regular radial and concentric rows as shown in figure 4.

Zooecial growth assumes two patterns. Each pattern is diagnostic generically. Shown in cross-section, in one form the zooecia are erect, or nearly erect, with the tubes perpendicular to the frontal surface (figure 5). In the other form, the zooecia in cross-section are horn-shaped (figure 6), originating from a point. The point or line of origin for each set moves outward as zoarial growth continues. The lines of origin are concentric, as illustrated in figure 7. No regularity in the number of zooecia per set is apparent, nor any regular spacing for the shift of each line of origin.

The arrangement and number of vibraculoecia in relation to the zooecia is very important in generic diagnoses. The vibraculoecia of Cupuladria and Discoporella are situated distally to each zooecium. In this way, there are no vibraculoecial rows; rather, the vibraculoecia alternate with the zooecia radially from the ancestrula along a zooecial row. In Lunulites, Otionella, and Oligotresium the vibraculoecia and zooecia are in distinct rows, both radiate from the ancestrula. Lunulites is characterized by a vibraculoecial-zooecial ratio of 1:1. Oligotresium is distinguished by a vibraculoecial-zooecial ratio of 1:2. Often, especially in the area around interpolated or bifurcating zooecial rows, the ratio of vibraculoecia to zooecia may be irregular. This

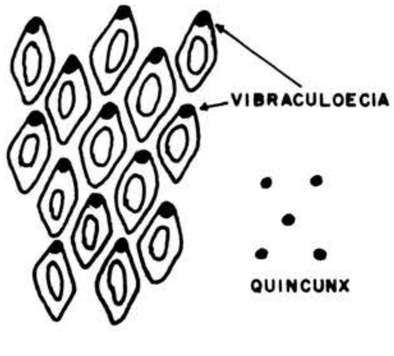


FIG. 3. Zooecia arranged in quincunx.

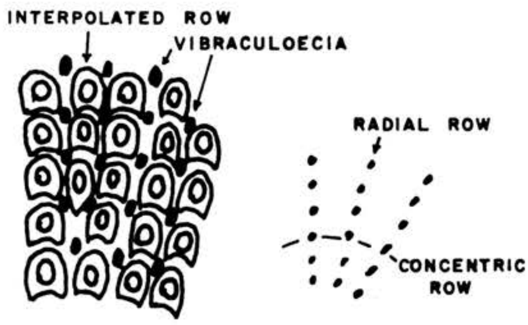


FIG. 4. Zooecia arranged in radial and concentric rows.

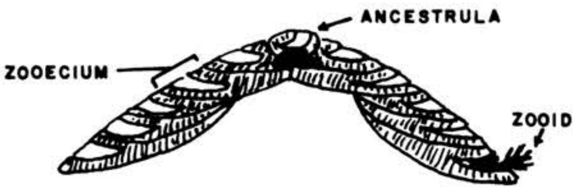


FIG. 6. Cross section of zoarium with radial zoecia.

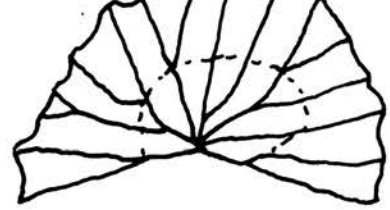


FIG. 7. Basal side of zoarium with radial zooecia.

FIG. 5. Cross section of zoarium with erect, vertical zoecia.

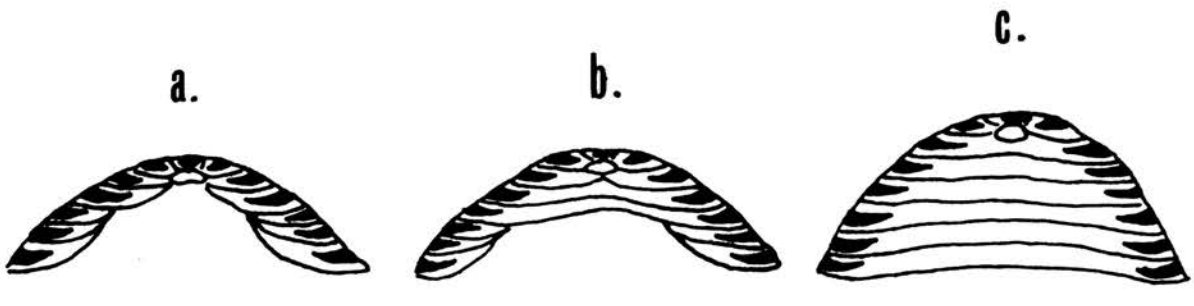


FIG. 8. Modes of growth (*Lunulites bouei,* Little Stave Creek, Clarke County, Alabama) a. normal, concaval base; b. intermediate form; c. completely filled, solid zoarium.

character must be determined on a normal part of the zoarium.

A feature of both Recent and fossil lunulitiform zoaria is the "solid" zoarium, in which the concave side of the zoarium is filled with varying amounts of calcareous deposits. This feature has puzzled bryozoologists since its discovery and a reasonable explanation is wanting. Originally, it was thought to be genetically controlled, and at least one genus, Trochopora d'Orbigny, was founded on the basis of the solid zoarium. However, specimens of the same species were found to occur both with solid and normal zoaria. Figure 8 shows Lunulites bouei in cross-section occurring as a solid form, a hollow form, and a stage intermediate between solid and hollow. Similar occurrences are seen on Recent specimens of Discoporella doma.

Frontal surface morphology-zooecia. - The differences of the features on the frontal surface provide an important basis for species differentiation. The zooecial outline is characteristic for species; various zooecial shapes are illustrated in figure 9. The structures described and illustrated in figure 10 may not be present on all species. The mural rim surrounds the zooecium and has a texture ranging from very fine to papillate or verrucose. The width of the mural rim varies greatly and seems to be genetically controlled. Filling the area between the mural rims is the cryptocyst, so named because in live specimens it is often

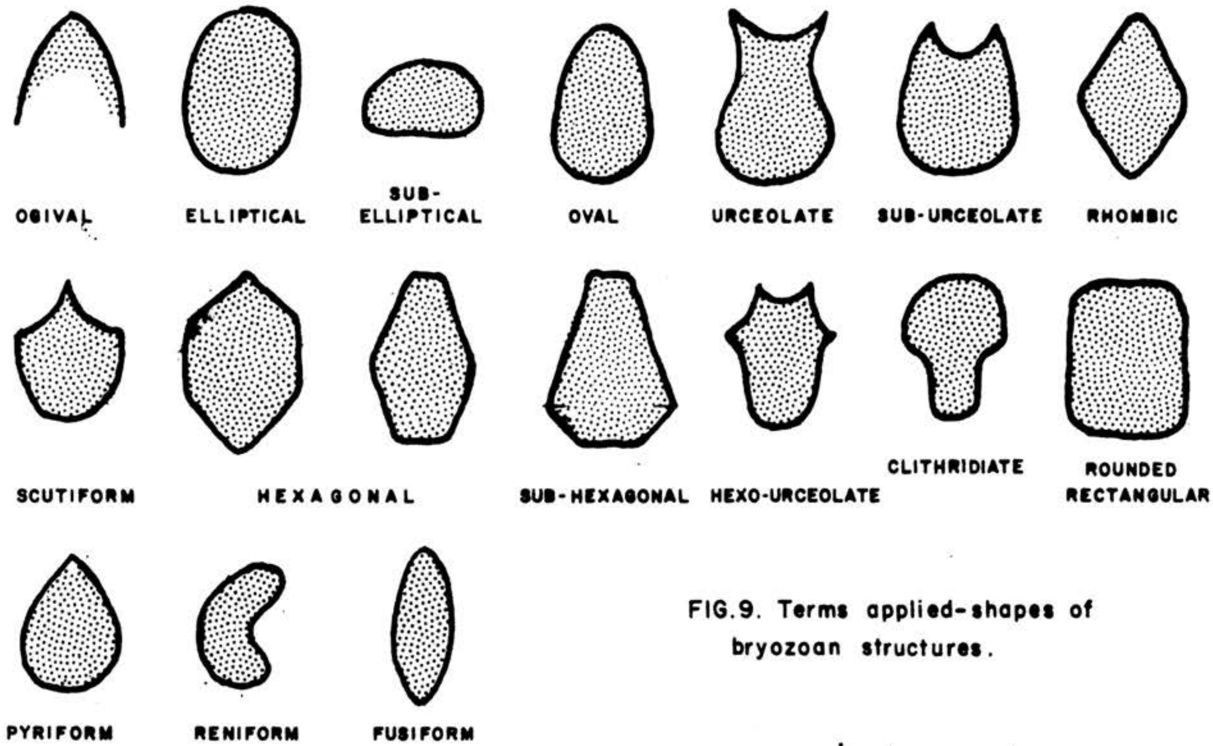


FIG. 9. Terms applied-shapes of bryozoan structures.

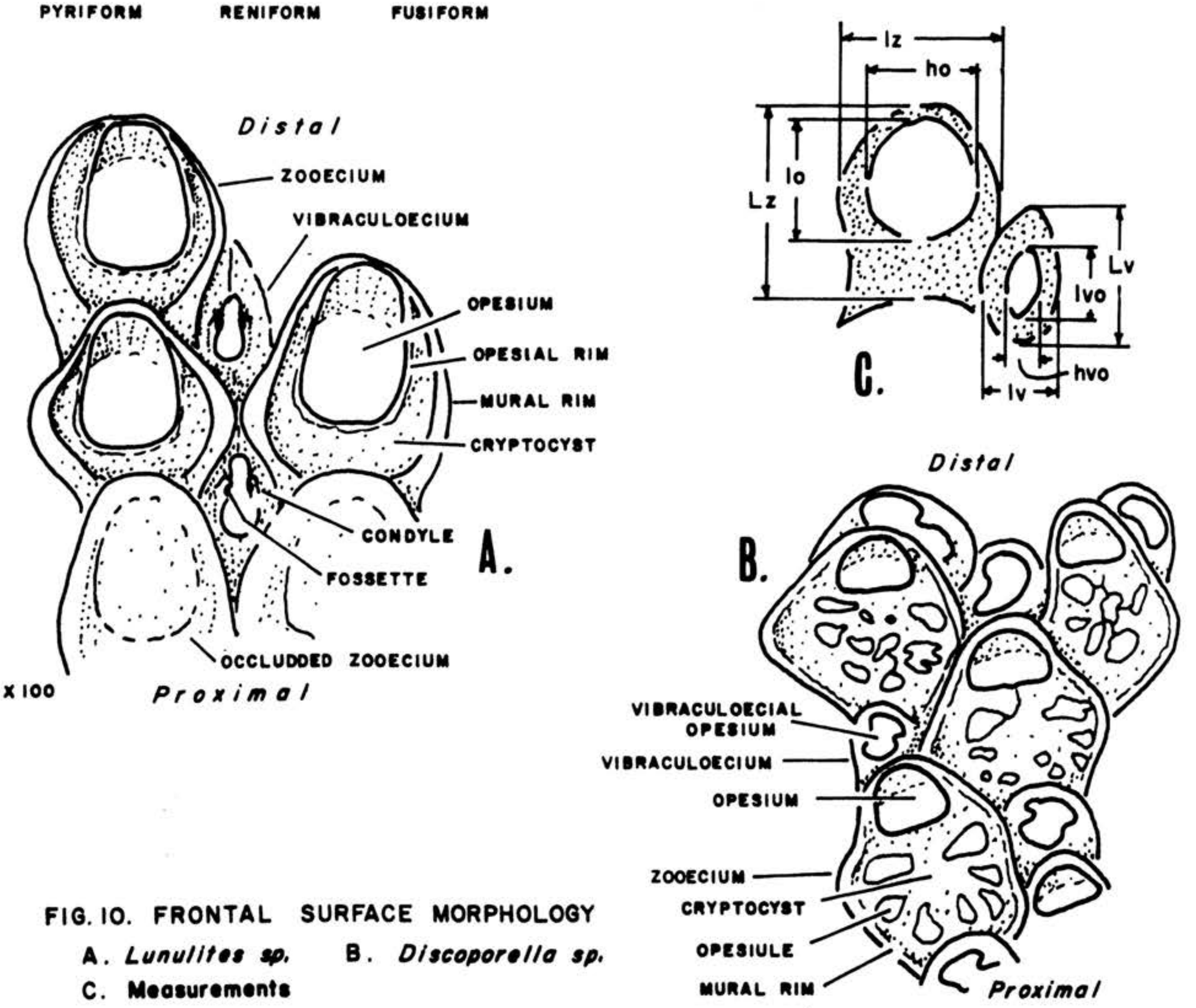


FIG. 10. FRONTAL SURFACE MORPHOLOGY

A. *Lunulites sp.* B. *Discoporella sp.*

C. Measurements

hidden by the chitinous frontal membrane. The cryptocyst also has characteristic textures, but is usually finer in texture than the mural rim. The cryptocyst may be perforated by irregular pores, termed opesiules. These are openings for muscles connecting the frontal membrane with the base of the zooecium. The opesium is the open area surrounded by the cryptocyst. It serves as a passageway for the polypide. Some species are characterized by the presence of an opesial rim, a slight rim made of the cryptocyst which surrounds the opesium. It, too, has varying textures. The zooecia may overlap distally (see the cross-section shown in figure 8). The degree of overlap, or imbrication, is significant in identification.

Occluded zooecia are zooecia which have been covered by a secondary calcareous deposit. In the simplest form of occlusion, the entire frontal surface of the zooecium is covered with a lamina of fairly even texture. In others, the lamina is perforated by a single pore, the shape and size of which may be diagnostic. In some species, the occlusion is only partial: A calcareous bar extends from the proximal edge of the mural rim, distally across the opesium, and may or may not touch the distal mural rim. The occlusion may be fairly complete on some species, but on others, the lamina reflects the form of the underlying opesium. The lamina may be pierced by four small pores. The texture of the occluding material and the form of occlusion is diagnostic.

Frontal surface morphology-vibraculoecia. - Vibraculoecial outlines are illustrated in figure 9. The terms describing the mural rim, opesium, and cryptocyst of the vibraculoecia are the same as those applied to the zooecia. The opesium may be surrounded by a prominent collar. Frequently, the collar is terminated distally by two knobs, the lateral condyles, which served as pivot points for the vibraculum. Some condyles possess small pits or depressions, the fossettes. Vibraculoecia may be occluded.

Basal surface morphology. - There are two types of basal surfaces in lunulitiform bryozoans, depending upon the growth pattern of the zooecia, as discussed previously under Morphology of the Zoarium. Zooecia that are nearly perpendicular to the frontal surface produce a basal surface of small sectors, termed kenozooecia by many authors. Zooecia that radiate from the ancestrula produce zooecial rows (figure 7). The various aspects of the kenozooecia include number, arrangement, and size of pores, degree of separation, and texture. Diagnostic structures of the zooecial rows are texture, size, number, and arrangement of pores, convexity of the rows, and width of the sulcus separating the rows. Some rows are hollowed at the distal end. Growth patterns of the zoarium are best seen by the arrangement of the zooecial tubes on the basal side. Zoarial regeneration and interpolation of zooecial rows are evident on this side.

Measurements. - Some measurements of the structures discussed are diagnostic. Figure 10c indicates the position of the measurements and the standard abbreviations used.

Length of zooecium.....................Lz
Width of zooecium......................lz
Length of zooecial opesium.............ho
Width of zooecial opesium..............lo
Length of vibraculoecium...............Lv
Width of vibraculoecium................lv
Length of vibraculoecial opesium.......hvo
Width of vibraculoecial opesium........lvo

The ratio of width to length, expressed in per cent, is often characteristic of a species. Other measurements which may be useful are diameter and height of the zoarium, diameter of various pores on the basal surface, and width of the zooecial rows of the basal surface. All measurements are expressed in millimeters.

Glossary of terms applied to lunulitiform bryozoans

basal wall. Calcareous side of zooecium opposite the orificial side.

brown body. Dark mass of organic material resulting from the degeneration of the polypide.

compensatrix. A membranous sac which, when filled, extrudes the polypide; characteristic of ascophoran bryozoans.

condyles. Small knobs, usually modified from the mural rim, serving as pivots for the vibracula.

cryptocyst. Calcareous lamina beneath the frontal membrane.

cystid. Non-movable soft parts of the zooid.

fossettes. Small pits or depressions in the condyles.

frontal membrane. Uncalcified part of the body wall usually covering the calcareous component.

frontal wall. Calcareous side of zooecium on same side as orifice.

heterozooid. Any modified individual other than the autozooid.

hypostege. Area between the frontal membrane and cryptocyst which, when frontal membrane is depressed, displaces hydrostatically the polypide; in anascan bryozoans.

interzoidal pores. Passages in the lateral walls of the zooecia which serve as interzoidal communication pores.

kenozooid. Modified individual without a polypide or operculum.

lophophore. Circular or horseshoe-shaped ridge around polypide mouth bearing ciliated tentacles.

mural rim. Calcareous rim surrounding or partly enclosing the frontal surface of the zooecium.

occluded zooecium. Individual in which the opesium has been closed by secondary calcareous deposits.

operculum. A chitinous or calcareous structure covering the zooecial orifice.

opesiular indentations. Reentrants in the cryptocyst, serving same function as opesiules.

opesiules. Openings in the cryptocyst serving as passage for depressor muscles of the frontal membrane.

opesium. Large opening on the frontal wall surrounded by the cryptocyst.

orifice. Primary opening of the zooecium for extrusion of the polypide.

ovicell. Any structure, usually a swelling of the zooecium, serving as a brood chamber for the bryozoan larvae.

polypide. The soft, movable parts of the zooid.

vibraculoecium. Calcareous structure housing the vibraculum.

vibraculum. Seta-like chitinous structure housed by the vibraculoecium.

zoarium. Bryozoan colony.

<u>zooecium</u>. Chitinous or calcareous structure housing the soft parts of the zooid.

<u>zooid</u>. Single bryozoan consisting of the hard and soft parts.

IV. ECOLOGY AND LIFE HABITS

Throughout the long history of study of the lunulitiform bryozoans, very little constructive work on ecology or paleoecology has been done until recently. What little effort has been done in this field prior to 1960 was more speculative than observational; postulations were based on very little evidence and in view of current data often seem ludicrous. The work of Cook (1963) and Lagaaij (1963) laid the groundwork for valid ecologic and paleoecologic interpretations.

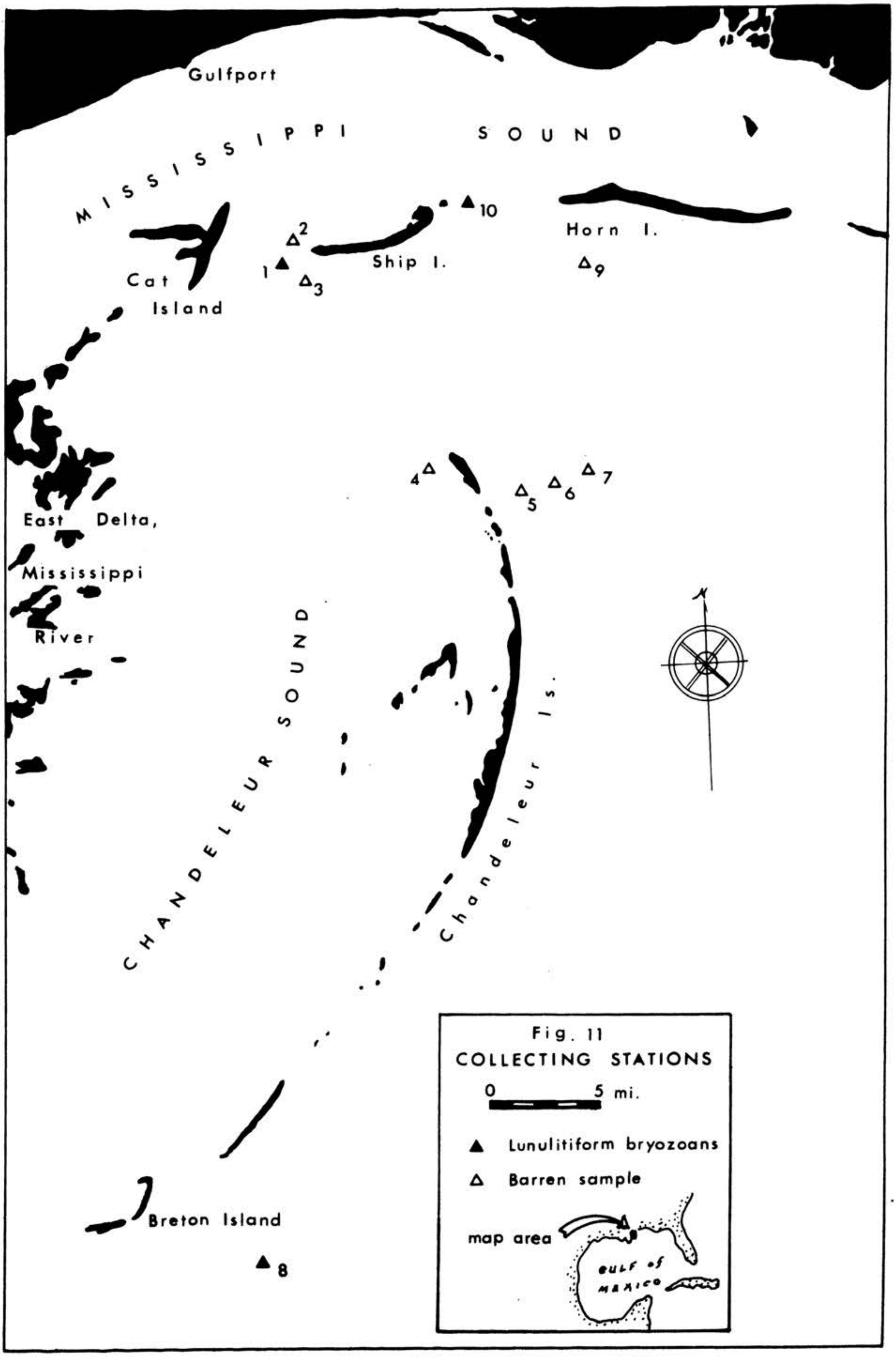
Observations of live bryozoans

Two lunulitiform genera, *Cupuladria* and *Discoporella*, range from at least Miocene to Recent. Lagaaij (1963) presented an extensive account of the distribution and general ecology of *C. canariensis* and provided valuable information which can be applied to the paleoecology of *Cupuladria* and lunulitiform bryozoans. His information is based on sample occurrence and not direct observation of living specimens. Cook (1963) presented the results of her studies of live lunulitiform bryozoans, *Discoporella umbellata* and *D. doma*, collected in the Bay of Funchal, Madeira, and transported to the British Museum (Natural History) for study in sea water aquaria. Miss Cook presented many interesting observations on orientation and life activity of these two species. She did not, however, maintain any of the assemblage associated with the bryozoans. The relationships between the bryozoans and the associated fauna is of paramount importance to the natural orientation and life activities of the lunulitiform bryozoans.

During the spring and summer of 1965, collections of live lunulitiform bryozoans were made in the shallow coastal waters of the East Mississippi River Delta region and North Central Gulf of Mexico (figure 11). With modifications of a design suggested by Professor Frizzell, a dredge was constructed of steel bars and one-fourth inch hardware cloth (figure 12). The dredge can be towed easily behind a boat to capture benthonic specimens, including fast moving species such as crabs and flounders. The specimens are taken without apparent harm. The dredge also will take a substantial sample of substratum and specimens living in the upper part of the substratum.

The dredge is towed for five minutes or less, then pulled aboard; the contents are emptied into a large tub and sorted. The specimens are identified and counted as they are transferred to a 40 gallon plastic container half filled with sea water aerated by a battery operated pump. The specimens can be transported in this container. Additional sea water is collected and can be stored in one gallon, thoroughly cleaned, plastic utility bottles. Several cubic feet of substratum is also kept.

A pilot collecting trip was made on April 23, 1965, to


Gulfport
MISSISSIPPI SOUND
Cat Island
Ship I.
Horn I.
1
2
3
10
9
East Delta, Mississippi River
CHANDELEUR SOUND
Chandeleur Is.
4
5
6
7
Breton Island
8
N
Fig. 11
COLLECTING STATIONS
0
5 mi.
Lunulitiform bryozoans
Barren sample
map area
GULF of MEXICO

test the dredge and to locate possible collecting stations. Seventy-five specimens of Discoporella umbellata and ten of Cupuladria canariensis were collected at Station 1. As noted by other authors (Cook, 1963, p. 409; Shier, 1964, pp. 610, 621), live specimens of C. canariensis are brownish, and D. umbellata is reddish-pink to dark red, as contrasted with dead specimens which are grayish to white. Live specimens were taken to Rolla, Missouri, and maintained until July 2, 1965, a period of 10 weeks. A limited number of specimens representing the assemblage was maintained with the Bryozoa, as shown in the list below.

PROTOZOA
Foraminifera*

COELENTERATA
Hydractinia*

PLATYHELMINTHES
Planaria*

ANNELIDA
Serpula sp.*

BRYOZOA
Bugula sp.

ARTHROPODA
Pagulas sp. (hermit crab)

ECHINODERMATA
Clypeaster subdentata (echinoid)

During the period July 8, 1965, to July 13, 1965, more extensive sampling and collecting was done in the same general area as the pilot collecting trip (figure 11). Specimens of lunulitiform Bryozoa (C. canariensis and D. umbellata) were taken at Stations 1, 8, and 10. At this time, specimens representing the assemblage taken in the dredge were retained.

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* Species commensal with lunulitiform bryozoans.

Shown in Table 1 are the species and relative abundance for each of the three stations where collections were made. These specimens were transported to New Orleans, Louisiana, and maintained under somewhat controlled conditions until September 6, 1965, a period of eight and one-half weeks.

In New Orleans, sea water aquaria were arranged as shown in figure 13. Table 2 lists ten major ecologic factors in a marine environment (from Weller, 1960). Of these ten, the following were selected for ecological experiments: salinity, temperature, light, substratum, and organic associations. These could be controlled under laboratory conditions and I had hoped to establish tolerance ranges for each of these factors. A 20 gallon tank was maintained under a constant temperature of 78°F. It contained specimens representing the assemblage collected. Four two gallon tanks were established; one for each of the remaining four ecologic factors. The effect on the Bryozoa was not apparent. The polypides were no longer seen in an extended position on any of the specimens after the first week. For the ranges shown, the vibracula remained active until the experiment was ended.

The results of varying light, salinity, temperature, and substratum are not significant.

The polypides seem to have degenerated after the first week as a result of adverse conditions in collecting, transporting, etc., while the vibracula remained active. The

TABLE I

FAUNA COLLECTED IN DREDGE

	Station 1	8	10
PROTOZOA			
Foraminifera	a	a	a
PORIFERA			
Cliona sp.	n		n
Microciona prolifera, red sponge	n		c
COELENTERATA			
Astrangia astreiformis, coral	vr		
Calliatus tricolor, sea anemone	r		r
Renilla mulleri, sea pansey	a	c	c
Hydractinia sp.	a	a	a
BRYOZOA			
Cupuladria canariensis	a	a	a
Discoporella umbellata	a	a	a
Membranipora sp.	a	a	a
Bugula neritina	n		
PLATYHELMINTHES			
Planaria	n		
ANNELIDA			
Arenicola cristata	c	r	r
Cistenides gouldi, sand worm	r	r	r
MOLLUSCA			
Various gastrapods	a	a	a
ARTHROPODA			
Callinectes sapidus, blue crab	c	r	c
Callinectes ornatus		vr	
Paguras spp., hermit crabs	a		a
ECHINODERMATA			
Luidia clathrata, star fish	a		a
Amphiodia sp., brittle star	vr		
Clypeaster subdentata, echinoid	vr		
Mellita quinquiesperforata, sand dollar	r		
CHORDATA			
Hippocampus hudsonius, sea horse	vr		
Paralichthys albigattus, flounder	vr		
Lactophrys triconis	vr		

a abundant; c common; n normal; r rare; vr very rare

Table 2

Major Ecologic Factors in the Marine Environment (from Weller, 1960)

1. Salinity
2. Dissolved gases
3. Temperature
4. Depth
5. Light
6. Turbidity
7. Currents, wave action
8. Substratum
9. Food supply
10. Organic associations

length of time may not have permitted regeneration of the polypides, or the conditions may have been too adverse. Apparently, the vibracula are very hardy, for they remained active throughout the experiment. Perhaps, if a longer time were involved and the range of variation were increased, the vibracula would have ceased to function. While results might have been obtained in the laboratory through more closely controlled conditions and longer lengths of time, more significant results could be obtained by field methods, i.e.: collecting lunulitiform Bryozoa from numerous localities and recording the ecologic factors involved for each station.

The results obtained from observations of the Bryozoa and associated fauna have important implications concerning the life habits of lunulitiform Bryozoa. The vibracula may serve in a minor capacity of defense against microorganisms as noted below; however, lunulitiform zoaria apparently have no mechanism for defense against the megafauna.

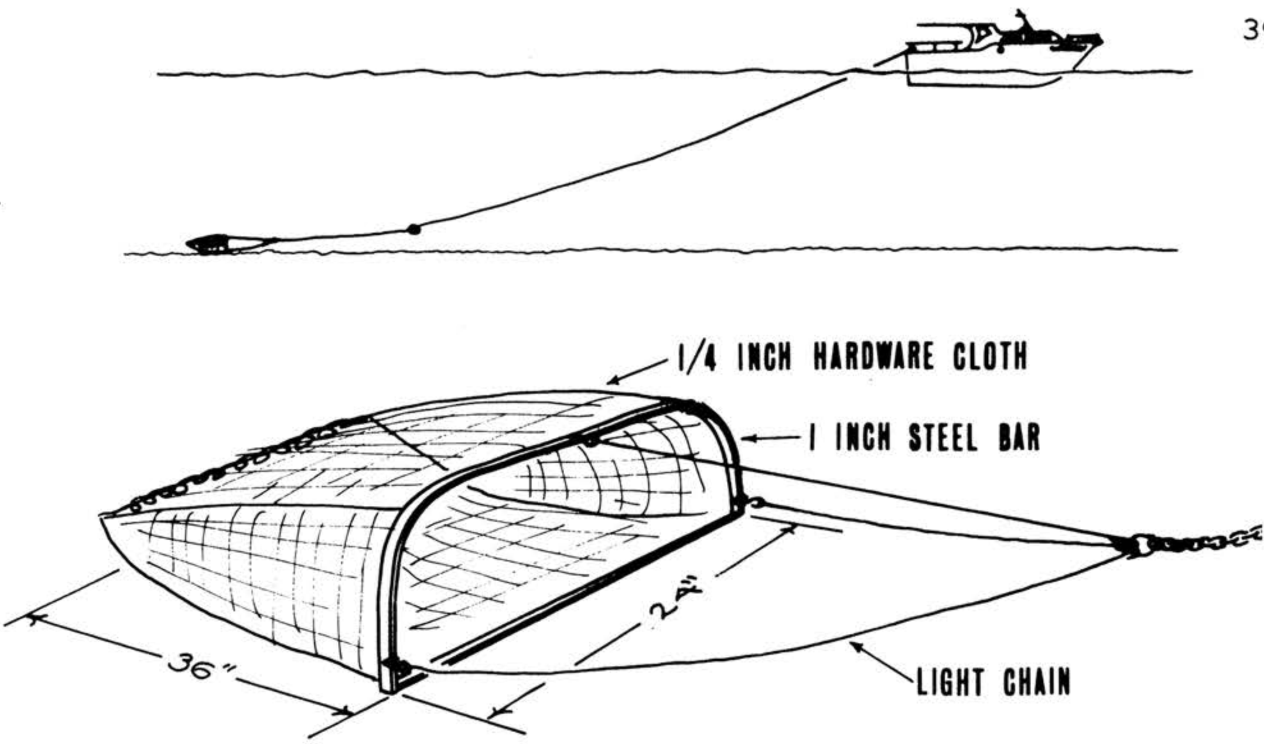


FIG. 12. SHALLOW WATER DREDGE

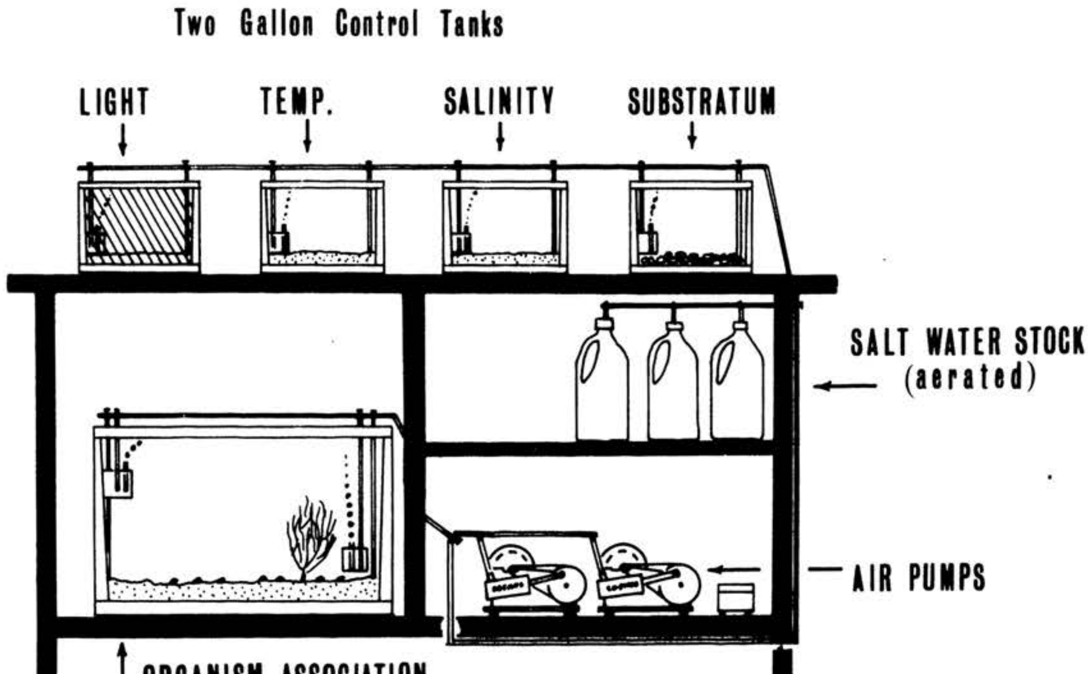


FIG. 13. APPARATUS FOR ECOLOGIC STUDY

Specimens of Calliatus tricolor, a sea anemone, were observed to attach to the frontal surface and rim of D. umbellata (figures 14-15). As the coelenterate swung to and fro in the process of feeding, the zoarium was rocked from side to side across the apex. After three days, the sea anemone detached with no apparent ill effects to the bryozoan.

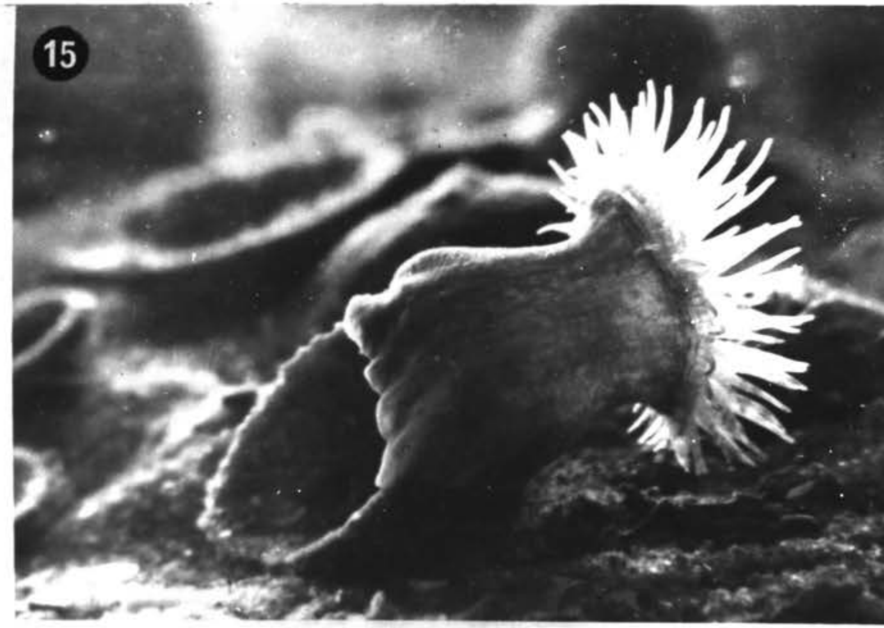
Growing on both the frontal and basal surfaces of many zoaria of C. canariensis and D. umbellata were specimens of Serpula sp., a polycheate which secretes a calcareous tube (figure 16). Usually, the tube originated on the basal surface, presumably the vibracula prevented the polycheate larvae from initiating growth on the frontal surface. However, some specimens did show growth which was initiated on the frontal surface. Often the tube winds haphazardly over the face of the zoarium and crosses from the basal to the frontal side. The zooecia in the vicinity of the tube were not altered physically, but it is assumed that the zooecia and vibracula under the tube were either killed or degenerated. The erosion of the surface of the zoarium shown in figure 16 was caused by crabs and not the polychaete. It is apparent that the zoaria with attached Serpula are unbalanced as compared to a normal zoarium.

One specimen of D. umbellata had a coral, Astrangia astreiformis, growing on the basal side. Again, the vibracula may have presented the larvae from settling on the frontal surface. Although no physical ill effects to the

Figures 14-15. Sea anenome (*Bunodactis capitata*) attached to the frontal surface of a lunulitiform zoarium (*Discoporella umbellata*). X3

Figure 16. Calcareous worm tube (*Serpula* sp.) encrusted initially on basal side of lunulitiform zoarium (*Discoporella umbellata*); tube winds over zoarial edge to frontal surface. X6.

Figure 17. View of substratum. A sand dollar (*Mellita quinquiesperforata*) has pushed through the sand and shell debris and overturned several zoaria of *Discoporella umbellata* and *Cupuladria canariensis*. The starfish (*Luidia clathrata*) in the upper left part of the photograph also overturned zoaria. X 3/4


14

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bryozoans were apparent, the added weight of the calcareous corallite may have affected the life functions of the bryozoan.

The microfauna observed in association with live zoaria includes foraminifera, *Hydractinia* sp. (Coelenterata), and *Planaria* sp. (Platyhelminthes). No doubt many more species live on or around lunulitiform zoaria. Cook (1963, p. 411) reported small colonies of *Barentsia* sp. (Bryozoa, Entoprocta) growing between the zooecia of *D. umbellata*. *Hydractinia* sp. is frequently found in great abundance on the basal side of both *C. canariensis* and *D. umbellata*. With the exception of *Barentsia* and an occasional polychaete, it would seem that species which attach are restricted to the basal side of the zoarium, at least during initial growth. One foraminifer (not identified) and several specimens of *Planaria* were seen moving about the frontal surface of the zoarium. Only occasionally were the vibracula seen to make any movement against them. This was a jerking motion and did not bring adjacent vibracula to action. The process seemed to be one of slight irritation rather than defense and the planarian resumed activity over the surface of the zoarium.

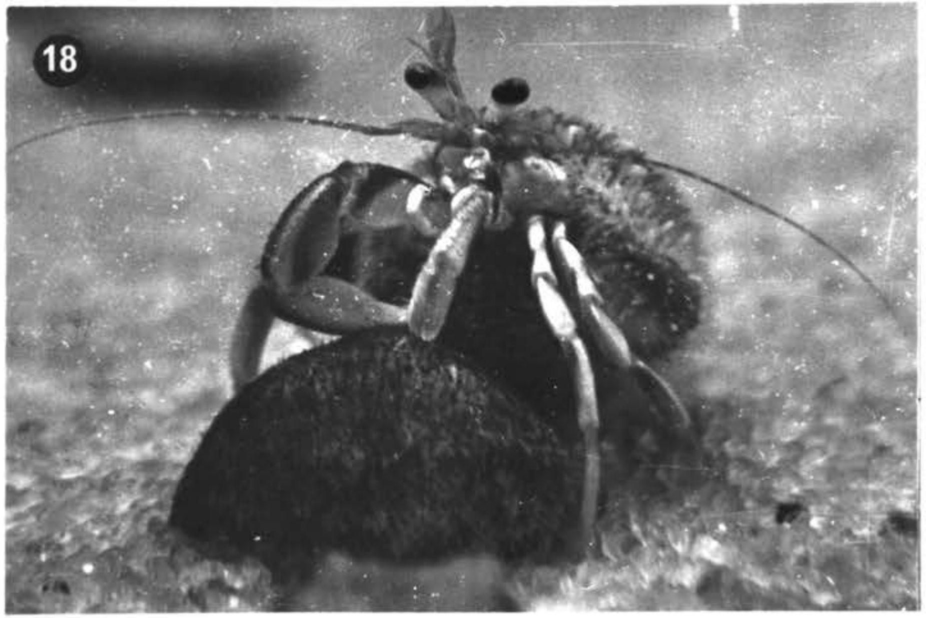
The relationships described above all seem to be commensal, in which the bryozoans are not harmed and the attached organisms are provided a place for attachment. As mentioned, the vibracula seem to prevent the organisms from attaching to the frontal surface where they might interfere with the feeding processes of the polypides. There does not seem, however, to be any defense against the megafauna associated with the Bryozoa on the sea bottom.

The echinoderms and arthropods seem to have the greatest effect on the lunulitiform bryozoa. Luidia clathrata, a starfish, Clypeaster subdentata, an echinoid, and Mellita quinquiesperforata, a sand dollar, were seen to plow through specimens of lunulitiform bryozoa, turning the zoaria over several times and leaving them disoriented (figure 17). Various species of gastropods produced similar results in their movement from place to place. Although the echinoderms were not observed eating or mutilating the zoaria, Lagaaij (1963, p. 187) cites numerous examples of zoarial fragments and even whole colonies of C. canariensis found in the stomachs of holothurians (sea cucumbers).

Various species of Paguras, hermit crabs, were seen scraping Hydractinia from the basal side of the zoaria for food (figure 18). Often, the hermit crabs picked at the frontal surface of the zoaria (figure 19) either in an attempt to get at the zooids or the microfauna on the frontal surface. In the process, the crabs would often tear the chitinous membrane from both the frontal and basal surfaces, leaving the zoarium a bright pink. Although the vibracula on these mutilated zoaria remained active, new chitin was not seen to be formed on either surface. The hermit crabs maintained with the Bryozoa were all rather small (none

Figures 18-20. Hermit crabs (_Paqurus_ sp.) were observed overturning lunulitiform zoaria and scrapping attached organisms from the zoaria. Numerous coelenterate polyps (_Hydractinia_ sp. ?) frequently grow on the basal side of the zoaria, on which the hermit crabs feed by peeling the basal chitinous membrane from the zoaria. The large zoarium in Figure 20 has the basal membrane removed, leaving the light colored calcareous part of the zoarium exposed. The crabs frequently picked at the frontal surface (Figure 18) in an apparent attempt to remove the zooid. X3

Figure 21. Blue crabs (_Callinectes sapidus_) were also observed overturning zoaria and in two cases broke fragments from zoaria. X 3/4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19


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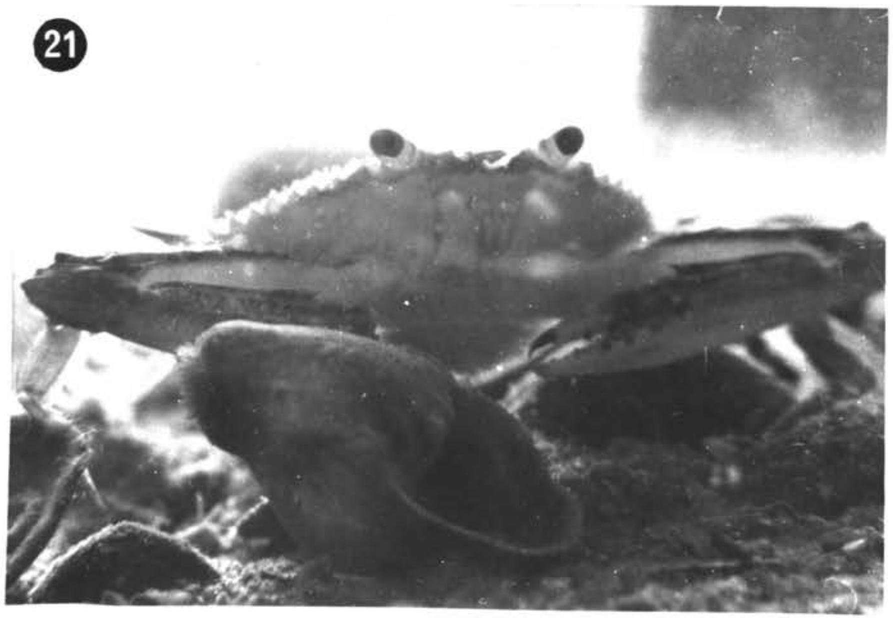
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longer than 3 cm) and apparently were too small to break the zoaria.

Callinectes sapidus, the common blue crab, and C. ornatus, a deeper water form, were maintained with the Bryozoa. The largest specimen was about 10 cm wide. These larger and more powerful crabs were observed breaking the zoaria into fragments, apparently in an attempt to feed on either the Bryozoa or the attached organisms (figure 20).

The common sand worm, Cistenides gouldi (Annelida) builds a tube of cemented bottom detritus. In one case, a whole zoarium of D. umbellata was incorporated into the tube. Because the cementation was rather loose, the colony seemed otherwise to function normally.

From the observations cited above, it is apparent that the greatest harm comes to the bryozoans from the crabs. The results are breakage of the zoarium or destruction of the chitinous membrane of the frontal or basal surfaces.

Throughout the total period of observation (18 weeks) the zoaria were not seen to assume a floating or swimming mode of life. By far the most active features of the zoaria were the vibracula. These were seen to sweep over the surface of the colony, often in unison. Although the substratum was often quite turbid from the action of the starfish, crabs, etc., the frontal surface was kept fairly clean by the sweeping action of the vibracula. Under a microscope, the vibracula were observed to remove by pushing action a grain of sand placed on the surface. Cook (1963, p. 410) reports observing D. umbellata cleaning the zoarium by action of the peripheral, supporting vibracula. These vibracula would irregularly, and infrequently, make a small movement together, producing a slight jerk. This would cause the sand grains to roll off the surface without any action being taken by the vibracula of the central part of the zoarium. The instances cited apply to colonies in the apex-up position. Colonies which were in an apex-down position had detritus filling the cup from above. This position was not maintained very long; they were often overturned by the other fauna.

Although not observed during this experiment, Cook (1963, p. 409) reports zoaria being capable of reversing their position through action of the vibracula. Zoaria placed apex-down on sand and gravel were able to assume an apex-up position within a 24 hour period. Miss Cook did state that the zoaria could feed successfully in an apex-down position; the results here are similar.

If the frontal surface is stimulated by a needle or a fine camel hair brush, the vibracula in the stimulated area simultaneously close over the object. The power of these appendages is demonstrated by the fact that the entire zoarium may be lifted at this time. Similar results were shown by Cook (1963, p. 411).

Of the several hundred zooecia comprising a single zoarium, very few were observed with the polypide extruded in a feeding position at any one time. Brown bodies were seen in numerous zooecia. A check for regeneration from such zooecia was not made.

Natural orientation

The problem of the natural orientation of lunulitiform zoaria with respect to the substratum has been a matter of controversy among bryozoologists. A number of hypotheses have been proposed suggesting the natural orientation; these hypotheses are reviewed and discussed (figure 22).

The earlier postulations on orientation of lunulitiform zoaria were indirectly derived from ideas applied to conical, non-lunulitiform zoaria, the conescharellinids (Ascaphora). Whitelegge (1888, p. 347, cited in Harmer, 1931, p. 151) gave an account in which he observed live specimens of Bipora philippinensis attached by a pair of tubular filaments to other objects. There is no indication, however, as to whether the zoaria were in an apex-up or apex-down position. A possible reason for this is given later.

Maplestone (1910, p. 2) noted that numerous specimens of Bipora dredged by H. M. C. S. Miner in South Australia had the coral Dunocyathus parasiticus growing on the basal, concave side. From this Maplestone concluded that the zoaria must have been oriented with the base-up, for if the zoaria were base-down, then "...the delicate tentacles of the coral would be crushed, and the coral could not live under such circumstances." Evidence of a concurrent existence of the coral and bryozoan is given by the calcareous intergrowth of the coral and zooecia.

Canu and Bassler (1920, pp. 238-239) wrote of Lunularia (=Lunulites)..."The larva ordinarily attaches itself firmly on a grain of sand. The ancestrula which is derived from it immediately gives rise to some closed hydrostatic zooecia which by their lightness permit the zoarium to commence its growth by ascending away from the sand dangerous to its development. (Aborted zooecia of d'Orbigny.) When in the vicinity of algae, the zoarium remains fixed under their fronds. When they do not offer sufficient shelter, the closed zooecia transform themselves into perforated, calcified zooecia which are radicular; the radicles then attach the zoarium to shells, stones, or small algae. The zoarium continues to develop in a more or less widened cone and always with the apex below." This passage was written by Canu earlier (1915, p. 21), by M. Faura and Canu (1916, p. 125), and later by Canu and Lecointre (1927, p. 35).

Waters (1921, p. 400), in writing of Cupuladria canariensis, assumed the zoarium to be in an apex-up position, at least in earlier stages. He also suggested that in the mature form, the zoarium may be reversed.

Canu and Bassler finally wrote, first for Conescharellina (1929, p. 482, cited in Lagaaij, 1963, p. 186), then for Lunulites (1931, p. 9, 31, cited in Lagaaij, 1963, p. 186) that the zoaria would rise above the substratum, rotate, and disengage the sand from the basal surface, an idea in which planktonic mode of life persists.

Dartevelle (1933, p. 69; 1943, p. 108) also proposed a planktonic mode of life for Lunulites and Cupuladria.

Silen (1942, cited in Cook, 1963, p. 408) reports that in 1881 nine lunulitiform zoaria (Cupuladria) were taken at the surface of the Atlantic. This is the only recorded instance of lunulitiform zoaria having been observed in a planktonic mode of life. This singular occurrence and the observations of live specimens by Cook (1963) and myself would not substantiate a planktonic mode of life as normal for lunulitiform zoaria. The postulations proposed by Canu and others that involve any natatory or planktonic mode of life are rejected.

The functions of the vibracula are not clearly known. However, on specimens of Cupuladria canariensis and Discoporella umbellata, the vibracula are longer toward the periphery of the zoarium. In an apex-down position, this may be explained by the longer reach required from frontal surface to substratum. In this position, Cook (1963, p. 412) reports that the polypides were capable of feeding. However, in this position, detritus could readily collect in the cup.

The longer vibracula at the zoarial periphery also may be explained in the apex-up position. On many specimens, both Recent and fossil, the vibraculoecia extend beyond the outer edge of zooecia. This, together with the longer vibracula would provide a very stable arrangement for the zoarium in the apex-up position.

From the evidence presented by observations of the associated megafauna, it is clear that lunulitiform zoaria could not maintain any one position, apex-up or apex-down. It must have been apparent to Whitelegge (1888) that the orientation was irrelevant; the fact that he did not mention the orientation might mean that he found zoaria in both positions, even though attached by filaments. The results of this investigation and those of Cook (1963) lead to the conclusion that lunulitiform bryozoans can live successfully in either position.

Distribution

Of the several lunulitiform genera, two, or possibly three, are extant in the seas today. Species of *Cupuladria* and *Discoporella* are common in shallow coastal waters of the world within certain limits, as discussed below. Recent species of *Lunulites* occur only in Australian waters. Specimens of Recent *Lunulites* from the National Museum of Victoria were examined and identifications confirmed. However, observations on living specimens have not been made.

Lagaaij (1963) compiled from numerous sources data on

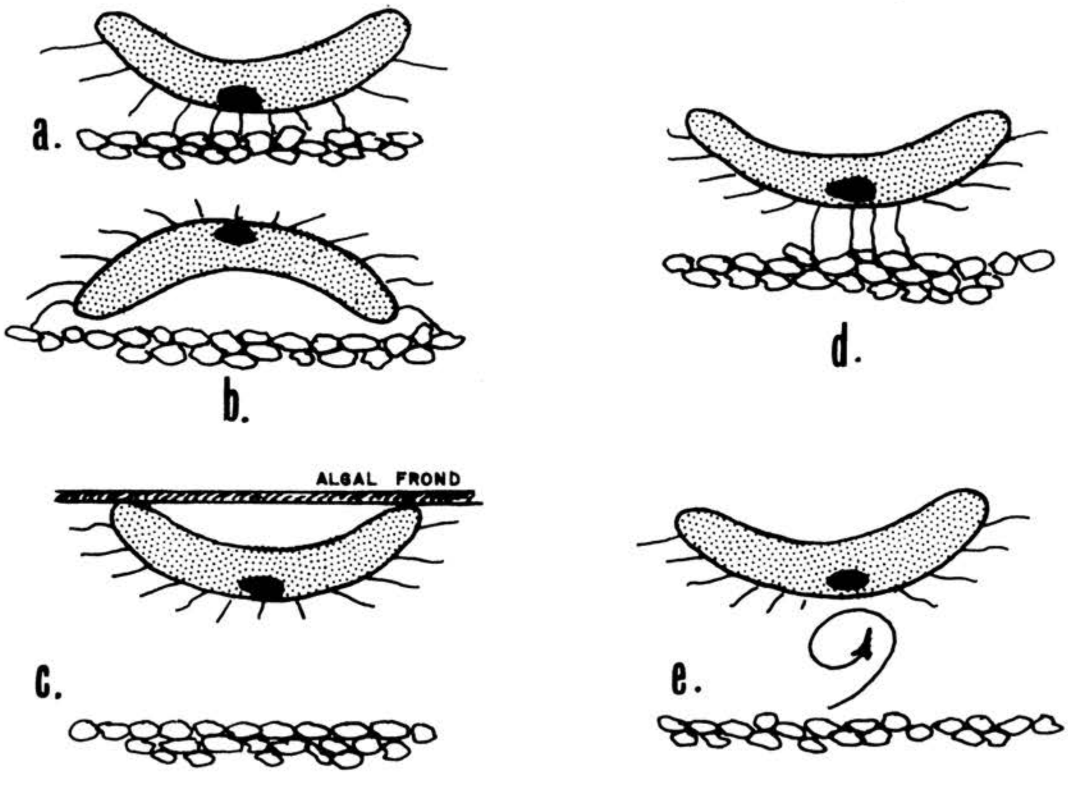


FIG. 22. POSTULATED NATURAL ORIENTATION. a - Apex down; b - Apex up; c - Attached to algal frond; d - Attached by radicles; e - Ascension and rotation. SAND GRAIN IN ZOARIUM SUBSTRATUM

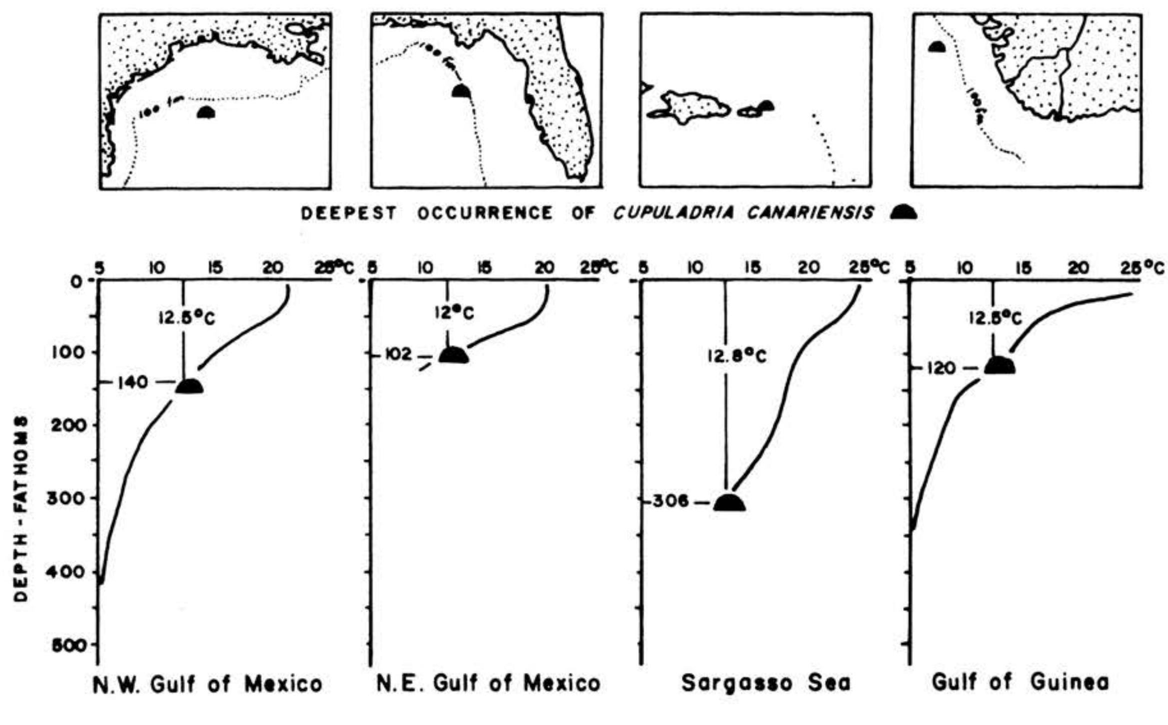


FIG. 23. Temperature - Maximum depth relation of *Cupularia canariensis* (from Lagaaij, 1963)

the ecology and zoogeography of Cupuladria canariensis, an abundant and widespread species. Aside from this excellent treatment, little has been done to establish data for lunulitiform species. Discoporella umbellata is nearly, if not equally, as abundant and widespread as C. canariensis and is often reported in Recent collections.

On the basis of the conclusions of Lagaaij (1963) and the limited collecting made in connection with this work, the following habitat relationships are discussed.

Substratum. - As previously pointed out, non-ovicelled bryozoans are thought to have a relatively long-living, free-swimming type larval stage. During this stage, the larva makes a careful selection of substratum particle size on which to metamorphose to the ancestrula. Although this phenomenon has not been observed in lunulitiform species, it is reported by Hyman (1958, p. 347) to be the general case for non-ovicelled species.

Because the particle selected will eventually be incorporated within the zoarium, it must be of appropriate size. Coarse quartz grains, glauconite pellets, small shell fragments, or foraminiferal tests are frequently used as the nucleus of the zoarium. The substratum best suited to lunulitiform bryozoans is one of medium particle size. As a result, specimens are seldom found in areas consisting of silt or clay bottoms.

Temperature-Depth. - Lagaaij (1963, pp. 189-191) reports a significant correlation between depth and temperature in the distribution of Recent specimens of *C. canariensis*. In world-wide distribution, this species is restricted to the 14° isocrymes, which occur approximately at 35° - 40° latitude north and south. Maximum depth at which this species is found depends directly upon the minimum temperature of the bottom water. Figure 23 from Lagaaij (1963) shows this relationship for four different areas.

Current. - Lagaaij (1963, pp. 187-189) attributes minimum depth at which *C. canariensis* is found to the intensity of water turbulence over the bottom, his belief being that above a certain intensity the larvae would be unable to settle and develop the colony.

The occurrence of *C. canariensis* and *Discoporella umbellata* noted above in collecting during spring and summer, 1965, shows localities to be near the passes between offshore islands and absent in areas of the same depth, temperature, and bottom type away from these passes. Although not located directly in the passes, Stations 1 and 10 are on sandy shelves slightly shallower than the passes (figure 11). Nevertheless, they are near the fairly strong currents as the tides move in and out of the passes between the islands to the Mississippi Sound. Minimum depth, therefore, should be governed by very strong turbulence such as wave scour and, as Lagaaij states (1963, p. 187), would vary from place to place depending upon wave intensity.

Salinity. - Maximum salinity tolerance for *C. canariensis* is indicated by its occurrence in the Mediterranean Sea where the surface salinity exceeds $37^{o}/oo$. The salinity increases at depths where the zoaria occur. Minimum salinity tolerance is indicated by the occurrence of *C. canariensis* in Chandeleur Sound near Breton Island, East Mississippi River Delta region. Here, a bottom salinity of $28.5^{o}/oo$ was recorded in the autumn of 1951 during flood tide.

Although the foregoing conclusions are based mostly on *C. canariensis* and *D. umbellata*, the general relationships of substratum, current strength, temperature-depth and salinity can be applied to some degree to lunulitiform species in general. As such, these data should play an important part in the paleoecology of the lunulitiform Bryozoa.

V. PALEOECOLOGY

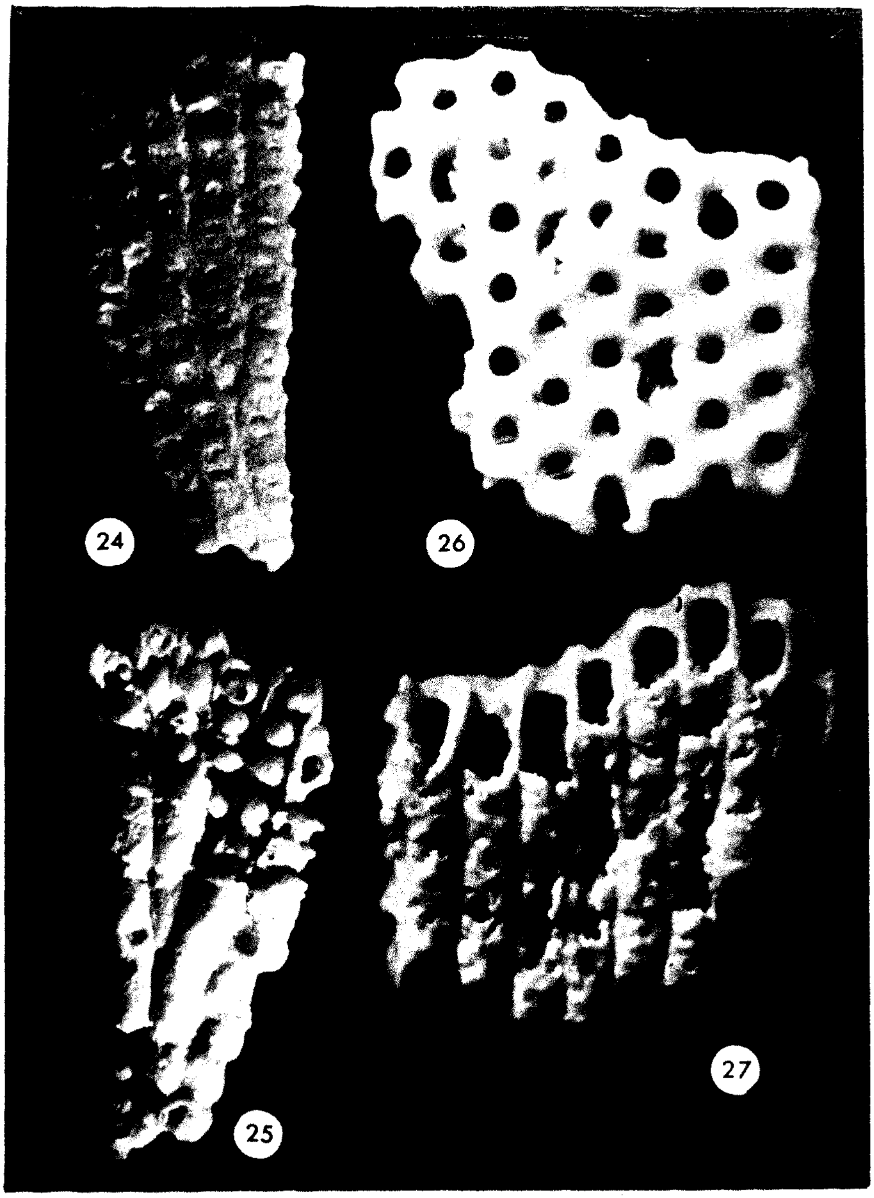
Information regarding the ecology of Recent lunulitiform species can be applied to fossil lunulitiform species. The environment has selected the zoarial form best suited for each ecological niche. Stach (1936) correlated nine zoarial forms with the habitat. Later workers, including Lagaaij and Gautier (1965) have distinguished about twenty zoarial types. Each habitat is characterized by one or more zoarial forms.

Recent lunulitiform bryozoans usually are found only on sandy or slightly rocky substrata in areas of moderate currents and within certain limits of temperature and salinity. In applying this information to fossil forms a number of problems arise as to.....

"Hollow" zoaria

Fossil zoaria consisting only of a frontal calcareous layer with the basal zoarial wall absent were termed as "hollow" by Canu and Bassler (1920). Examples are _Lunulites contigua_ (=_Oligotresium contiguum_), _L. distans_, and _L. tubifera_ (=_Oligotresium tubiferum_). Canu and Bassler (1920, p. 108) noted a similar phenomenon in _Otionella cava_. Cheetham (1962, p. 325) named _Oligotresium howi_ and noted that it, too, was without a basal zoarial wall.

Figure 24 illustrates a "hollow" specimen from the Eocene, type Moodys Branch Marl, Jackson, Mississippi, which



Figures 24-25. Frontal and basal sides of Lunulites ligulatus Canu and Bassler; Eocene, Jackson Group, Moodys Branch Marl; Jackson, Hinds County, Mississippi; specimen showing basal side in process of leaching away, forming a "hollow" zoarium.

Figures 26-27. Frontal and basal sides of Otionella tuberosa Canu and Bassler; same locality as specimen illustrated in Figures 24-25; specimen showing basal side in process of leaching away, forming a "hollow" zoarium.

closely resembles Lunulites ligulatus. Figure 25 shows the basal side with much of the calcareous wall removed. The result is the typical appearance of "hollow" zoaria. A similar situation is shown for Otionella perforata from the same locality in figures 26 and 27. Nearly all the specimens from this locality have the basal calcareous wall partly or wholly removed.

"Hollow" forms never seem to occur with "normal" lunulitiform specimens. Localities in the Ocala Formation at Claiborne Bluff, Alabama, and in the Moodys Branch Marl, Choctaw County, Alabama, yield only hollow lunulitiform bryozoans.

The fact that "hollow" zoaria occur in three distinct genera (Lunulites, Oligotresium, and Otionella) and that "hollow" forms occur separately from normal zoaria leads to the belief that the feature is due to factors which are not genetic. Possibly there is a compositional difference in the basal and frontal walls. Depending on the site of deposition or the composition of the preserving material, the basal side may be leached away during preservation.

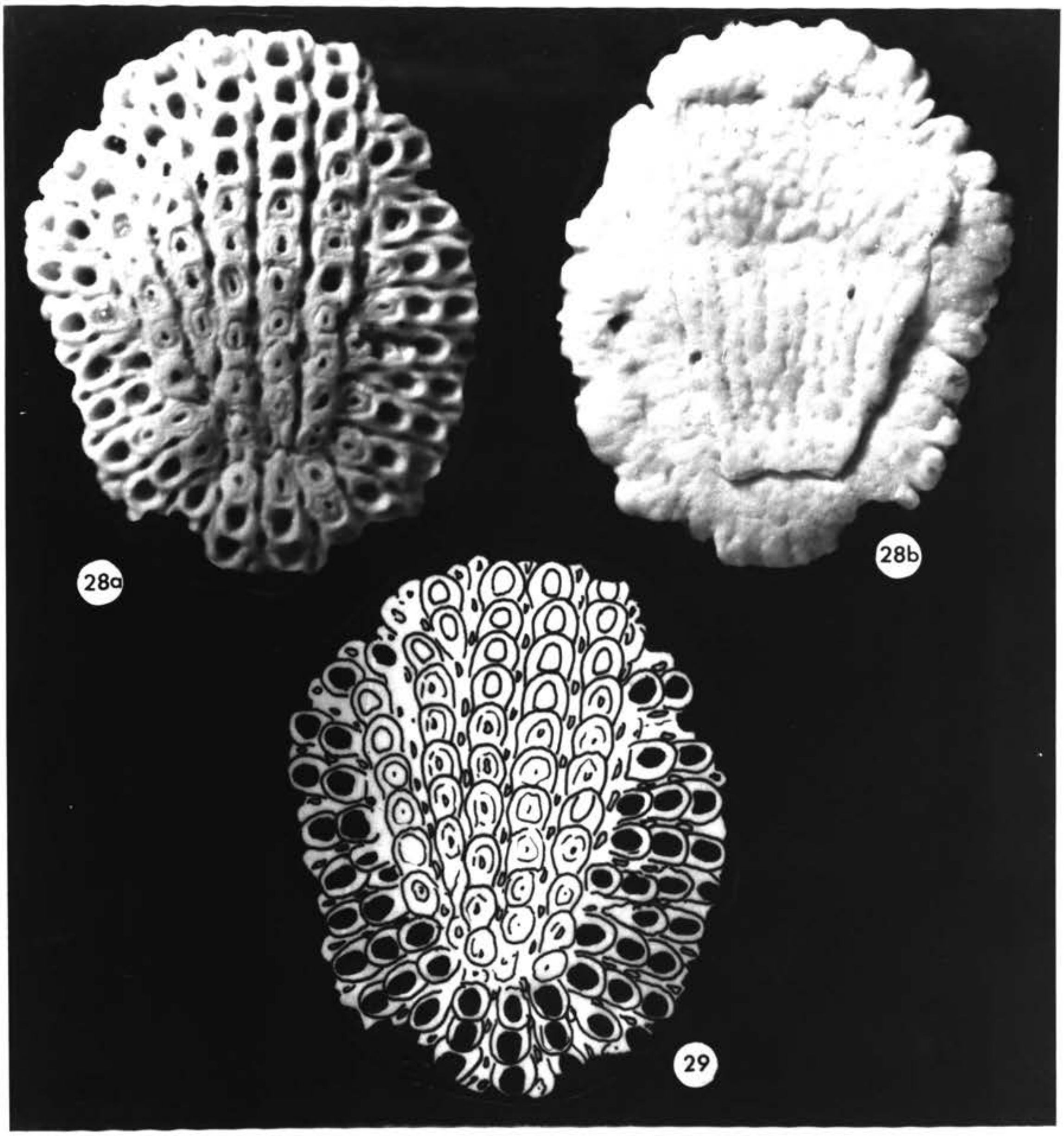
Although the "hollow" zoaria of Oligotresium contiguum, O. howei, Otionella cava, and Lunulites distans are not considered genetically significant, these species seem to be valid when based on other characters. The fact that they are found only with "hollow" zoaria, and always with other "hollow" species indicates placement in an ecological niche unique among the lunulitiform bryozoans. The preserving material is assummed to contain a substance capable of leaching the basal wall, but not the frontal.

The localities yielding "hollow" zoaria are generally rather limy and lack abundant sands. This assemblage suggests a highly calcareous environment as contrasted to the quartz sands normally characteristic for lunulitiform bryozoans.

Zoarial regeneration

Lunulitiform zoaria that are broken reestablish the characteristic disk or cup shape by zooecial budding along oriented directions. Figures 28 and 29 illustrate an example of zoarial regeneration. Figure 28 is a photograph of Lunulites bouei from the Eocene Lisbon Formation. The same specimen is shown in figure 29; the wedge-shaped central part is the original fragment and the radially budded zooecia are shown with black opesia. This wedge-shaped fragment is shown in figure 29 and represents the zoarial fragment before regeneration of the zoarium.

Specimens showing zoarial regeneration are rather common in Recent and fossil collections. Early workers regarded regenerated zoaria as taxonomically distinct and named several genera, such as Pavolunulites d'Orbigny, based on the shape resulting from regeneration. Although subsequent workers placed these forms in synonomy with the correct



Figures 28-29. Zoarial Regeneration; Lunulites bouei Lea; Eocene, Claiborne Group, Lisbon Formation; Little Stave Creek Clarke County, Alabama; 28a frontal surface; 28b basal side; 29 diagram of frontal side of specimen shown in figure 28 illustrating zooecia budded from original zoarial fragment. Black opesia indicate the zooecia newly budded. X 25.

genera, it was not until 1933 that there was an attempt to offer an explanation for the phenomenon.

Dartevelle (1933, p. 71), in studying material from the Eocene Ledian of the Belgian Basin, attributed regeneration to breakage of the original zoarium. This fragmentation was interpreted by Dartevelle (1933) and Stach (1936) to be indicative of contemporaneous strong current action.

From observations of Recent, living lunulitiform specimens, Dartevelle's interpretation seems to be in error, at least in part. In directing a strong jet of water into a large beaker containing live specimens of *Discoporella umbellata* and medium-grained sand, it was found that the zoaria were very tough and, of the several dozen specimens in the beaker, none was broken. However, as demonstrated in the previous chapter, lunulitiform bryozoans were fragmented by the action of the associated fauna, particularly by the crabs.

Although areas may exist where the combination of strong current and very coarse substratum could break the zoaria, zoarial breakage by organisms rather than current action is more likely. In this respect, regenerated zoaria indicate the presence of predators rather than strong contemporaneous currents.

Occluded zooecia

Occluded zooecia, as discussed above under Morphology, are normal individuals in which the frontal surface has been wholly or partly covered by a calcareous deposit. Although the junction of these zooecia is not fully understood, several hypotheses have been offered in explanation.

Early hypotheses and observations. - Canu (1915, p. 21) first, then Faura and Canu (1916, p. 125), Canu and Bassler (1920, p. 238) and Canu and Lecointre (1927, p. 35) postulated that the ancestrula budded off closed zooecia. These closed individuals were termed "hydrostatic" zooecia. The function of these was to provide buoyancy chambers whereby the zoarium could arise from the sand, which was supposed to be dangerous to its development, and attach to the underside of an algal frond. If the algae did not offer sufficient shelter, then the closed individuals "...transform themselves into perforated, calcified zooecia which are radicular..." (Canu and Bassler, 1920, p. 238).

The radicular zooecia were characterized as having radicles, or hair-like structures, which were used to anchor the zoarium to the substratum when the algae did not offer sufficient shelter.

Harmer (1926, p. 266) noted that in Recent specimens of Cupuladria guineensis the zooecia of the central part of the colony become closed by thin, horizontal laminae over the opesia, and that some had a few, irregularly arranged pores. He further noted that the occluded individuals become progressively closed from the center of the colony outward. Harmer concluded that the nutrition of the colony was left to the zooecia of the marginal, non-occluded zone.

Harmer (1900), in studying Recent species of Steganoporella, found that in colonies which had been encrusted by other bryozoans, the zooecia of the affected part had become occluded. This indicates that, at least in the case of Steganoporella, the zooecia are occluded as a protective measure.

Whitelegge (1888, p. 357, cited in Harmer, 1931, p. 151) observed specimens of Bipora philippinensis to anchor themselves by tubular filaments. These filaments may have been similar to those hypothetically described by Canu and co-authors, as "radicles."

Discussion and conclusions. - Some of the conclusions of Canu and co-authors are questionable and not based on observations of living material. The hypothesis that the function of the occluded zooecia was to lift the immature colony from the substratum is unfounded. The very small volume of the closed individuals would not be sufficient to allow the entire zoarium to rise. Further, the authors indicate that the colony is composed entirely of occluded zooecia in the immature colony. However, it is questionable that the zoarium could gain sufficient nourishment for development if all the zooecia were closed and there were no exits for the polypides. As cited above, Harmer (1926) noted that the zooecia become occluded from the center of the zoarium outward and occur secondarily to the development of the colony.

The postulation that the closed zooecia are radicular may be justified in some cases. As pointed out, Whitelegge (1888) has observed zoarial anchoring by tubular filaments. Perforations in the occluded individuals may indicate the former presence of such strucutres.

The pore of the occluded zooecia with a single perforation bears a close resemblance in size and shape to a vibracular cavity. In these cases, a vibraculozooid may have moved into a zooecium formerly occupied by a normal zooid. Interchangeability of types of zooids is well documented to occur among bryozoa (Hyman, 1959, p. 368). Such an interchange may be prompted by a number of conditions.

Increased sedimentation, when the zoarium is in an apex-up position, may necessitate more than the normal number of vibracula to keep the surface free of foreign material. Increased "invasion" by larvae or microorganisms might also require additional vibracula.

In an apex-down position, conditions of the substratum could require additional vibracula for zoarial stability. The fact that the occluded zooecia are in the central part of the zoarium suggests this condition in which the apex or central part would be in contact with the substratum.

As demonstrated by Harmer (1900) for species of <u>Steganoporella</u>, it is possible that closure is a protective measure.

Cited under Ecology, a number of organisms attach to and detach from lunulitiform zoaria. However, of the examples observed, none was seen in which the zooecia of the area covered by the organism were occluded.

The fact has been overlooked that each type of occluded zooecia, such as complete closure, single perforation, or double perforation, is characteristic for different species and must be genetically controlled. The occlusion seems to occur after maturity of the zoarium and is not present on all specimens of a species exhibiting occluded zooecia. Therefore, although genetically controlled as to the form of occlusion, some mechanism causes closure in some specimens but not others.

It is probable that no single hypothesis may apply for all forms of occlusion; rather, species capable of closure, each in its distinctive manner, may be reacting to different influences.

Fossil distribution

Fossil lunulitiform bryozoans are found most frequently in medium-grained quartz sands and marls, often in shell debris. Very rarely do they occur in clays, other fine-grained deposits, or glauconitic sands. Cheetham (1963, p. 32) described the environment of fossil lunulitiform species as marine, tropical to temperate, with a salinity range of 32°/oo to 37°/oo and a temperature range of 20°C to 22°C, in waters of moderate agitation, and depths of 100 to 200 feet. His conclusions agree fairly well with data obtained by observation of Recent specimens. However, the range for salinity, temperature, and especially depth for modern lunulitiform bryozoans is greater.

During adult stages, although not attached, lunulitiform zoaria are restricted to movement through current action or resulting from the associated fauna. The number of zoaria on the substratum can be enormous. Cook (1963, p. 408) reports more than 250 zoaria occurring in about two to three gallons of sand dredged from the bottom near the Madeira Islands. Marcus and Marcus (1962, p. 283) estimated from dredgings from the Atlantic off the Brazilian coast that the zoaria must number from 2000 to 3000 per square meter. Studer (1887, cited in Marcus and Marcus, 1962, p. 283) indicated that so many lunulitiform zoaria were dredged from waters off the coast of Liberia that the zoaria constituted a noticeable component of the substratum. Marcus and Marcus (1962, p. 283) state that from two of their localities only dead lunulitiform zoaria were obtained, and they conclude that the accumulation resulted from current concentration. They did not indicate the state of preservation for these zoaria.

Fossil localities that contain a great number of lunulitiform zoaria, especially if some zoaria show signs of abrasion, might indicate some transportation. These occurrences could have resulted from conditions similar to those reported by Marcus and Marcus (1962) of current concentrations. For example, the Eocene Gosport Sand deposit at Little Stave Creek, Alabama, contains a middle unit composed of a shell bed with medium- to coarse-grained sand filling the intertices. Lunulitiform bryozoans are very abundant. On some zoaria the frontal surface has been abraded, indicating possible transport. The bed is generally considered to contain the best preserved and most abundant fauna of Eocene age in the Coastal Plain (Toulmin, 1962, p. 20). Garner (1957, p. 583, cited in Toulmin, 1962, p. 20) compares the shell bed to that now accumulating on the beach on the west shore of Sanibel Island, Florida.

The distance of transportation was probably not very great. The occurrence of _Dentalium_, _Corbula_, _Venericardia_, and other similar molluscan genera is suggestive of a very near shore environment. The absence of solution pitting of most of the fauna indicates that the material probably was not carried very far from its biotope. It is doubtful that the frontal surface of the zoaria would remain intact very long during transportation with sands and shell debris. Therefore, the fauna collected with the bryozoans and the lithology of the preserving material probably can be used to interpret the paleoecology of the lunulitiform bryozoa.

The assemblage of mollusks, corals, and echinoids normally occurring with the lunulitiform bryozoans, indicates a near shelf environment. Some species are noted to occur in sandy facies; others, particularly those found with the basal side removed, occur in more calcareous facies.

VI. STRATIGRAPHY

The stratigraphy of the Gulf and Atlantic Coastal Plain is very complex and has been the subject of numerous studies. An understanding of the general geology, and specifically the stratigraphy, is essential to the understanding of the stratigraphic relations of the lunulitiform bryozoans.

It is not the intent in this study to cover the myriad stratigraphic aspects of this province; rather, the following is a summary of the general geology and stratigraphy. Detailed studies and comprehensive bibliographies may be found in Murray (1961).

The Gulf and Atlantic Coastal Plain is structurally, physiographically and stratigraphically a distinct province. It extends without interruption from Newfoundland to Central America. The province generally is bounded by discordant Paleozoic and Precambrian strata and the sediments of the present time plane.

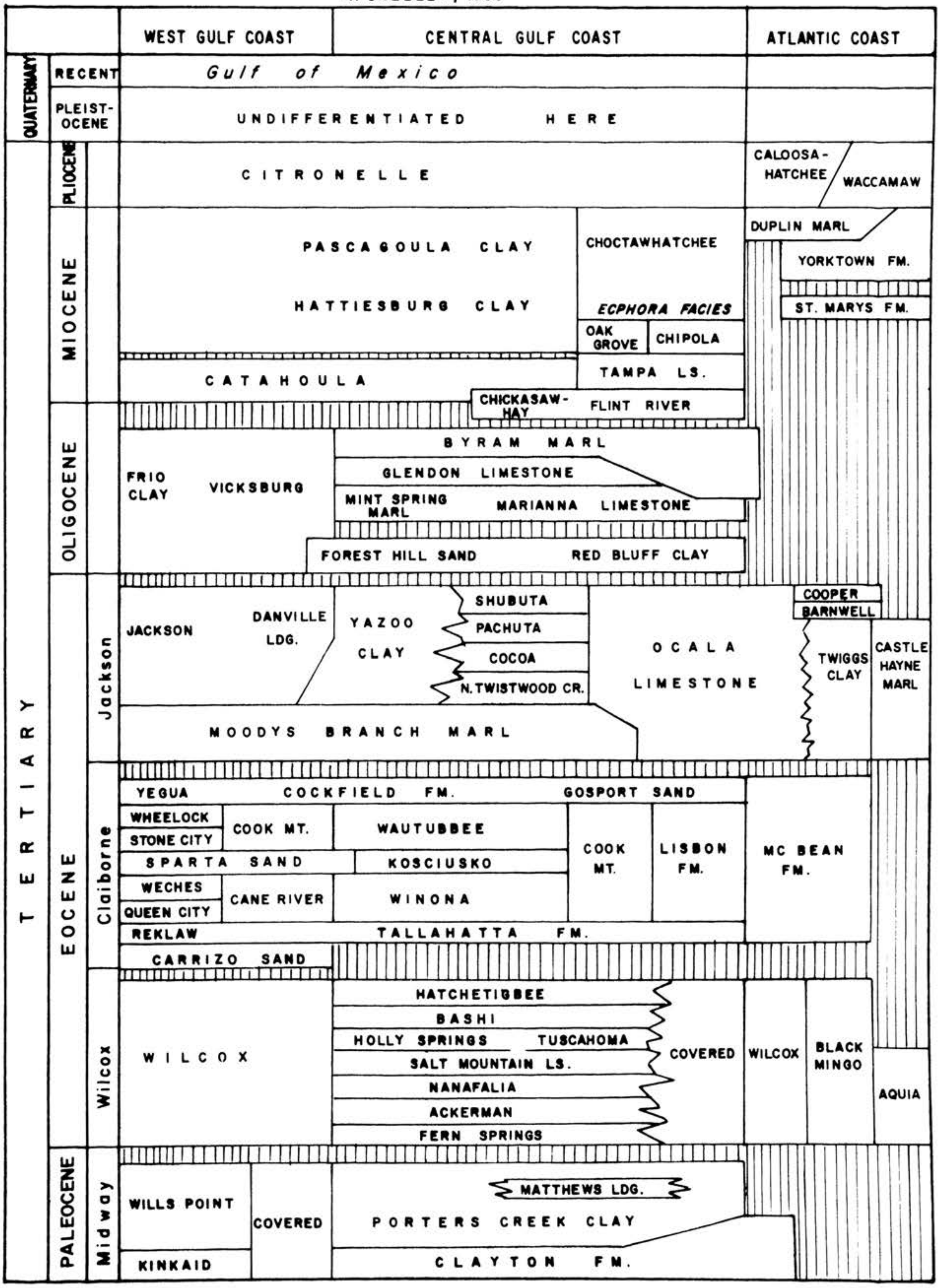
The province has been built from aggrading belts of shelf and geosynclinal deposits. The outcrop pattern of these belts reflects the shoreward shift of the center of deposition of the structurally negative areas. With the exception of several embayments, notably the Mississippi Embayment, the dips of the strata are toward the present shoreline. Age of the units present on the outcrop ranges from Cretaceous to Recent.

On the surface, most of the sediments consist of unconsolidated sands, gravels, clays, and marls, or indurated marls and limestones. Facies changes in both time and space greatly complicate correlation from area to area. No one correlation chart for the Cenozoic Coastal Plain would be acceptable to everyone; however, figure 30 is a compilation from a number of sources (Murray, 1961; Lamber, 1961; Cooke, et al, 1953) and is followed in this study. This chart does not show all the subdivisions of the Tertiary units, however, all units referred to in this report are included with their stratigraphic equivalents in other parts of the province.

Sample localities

Lunulitiform bryozoans, as previously discussed, commonly are found in Tertiary sands and marls. Localities sampled by the author were restricted to Mississippi and Alabama; samples from other sources came from Texas, Louisiana, and Florida. In addition, bryozoan specimens from Georgia, South Carolina, North Carolina, Virginia, and Maryland were examined. Thus, although the bulk of the specimens are from the Central Gulf Coast, representatives from most of the rest of the province in the United States were examined. The localities are described as follows:

Fig30. Correlation Diagram, Gulf and Atlantic Coastal Plains - Cenozoic
R. GREELEY, 1966



Collecting Localities

MIDWAY GROUP (PALEOCENE)

Matthews Landing Marl Member (Porters Creek Clay)

1. Near intersection of Alabama Highway 33 and U. S. Highway 43 about five miles south of Linden, Marengo County, Alabama; on dirt road west of eastern entrance of Highway 33; about 75 yards down road from store and gas station; very thin beds in south ditch of road; three to five inch thick layer of concentrated shells below a two-foot glauconitic bed. Collectors: D. L. and H. E. Frizzell, June 20, 1964 (Station F-64-1).
2. Road cut, south bank of unnamed creek, on Alabama Highway 10, about 4.3 miles south of Junction of Alabama highways 28 and 10, Wilcox County, Alabama; fossiliferous sands within formation, above a conspicuous indurated sandstone ledge. Collectors: R. Greeley and R. L. Moody, Jr., December 29, 1964 (Station G-64-19).

WILCOX GROUP (EOCENE)

Aquia Formation

3. Upper Marlboro, Prince Georges County, Maryland; Bryozoan bed at base of formation. Collectors: unknown (from Canu and Bassler, 1920).

Bashi Formation

4. Woods Bluff (probably Woodbluff, Clarke County),

Alabama. Collectors: unknown (from Canu and Bassler, 1920).

CLAIBORNE GROUP (EOCENE)

Tallahatta Claystone

5. Road cut, south side of Souwilpa Creek, on Alabama Highway 17 (formerly Alabama Highway 29), about 4 miles south of Gilbertown, Choctaw County, Alabama; very glauconitic, fossiliferous, coarse sands, within two feet of overlying Lisbon Formation. Collectors: R. Greeley and R. L. Moody, Jr., December 28, 1964 (Station G-64-18B).

Winona Greensand

6. South wall of Souwilpa Creek, center ½ of E½, Sec. 19, T. 10 N., R. 3 E., Choctaw County, Alabama. Collector: F. F. Mellon, September, 1943 (Station M-43-1).

Weches Greensand

7. Smithville, Bastrop County, Texas. Collectors: unknown (from material from Humble Oil and Refining Company, August, 1965).

McBean

8. Ditch along Georgia State Highway 80 east of McBean, 0.4 miles east of bridge over McBean Creek, Richmond County, Georgia. Collector: R. W. Stephens, Jr., and Shell Bluff on Savannah River, Burke County, Georgia; below Ostrea gigantissima bed. Collector: H. V. Howe (Cheetham, 1962).

Lisbon Formation

9. Wautubbee Hills, four miles south of Enterprise, Clarke County, Mississippi; U.S.G.S. Station no. 2616, Collectors: unknown (Canu and Bassler, 1920).

10. Claiborne Landing, near town of Claiborne, Monroe County, Alabama; about 30 yards downstream from east end of bridge across Alabama River; best samples collected from zone of abundant Venericardia at water level, but other samples obtained from sandy beds and glauconitic strata above. Collectors: D. L. Frizzell and A. R. Troell, Jr., August 6, 1960 (Stations F-60-12, 13).

11. Little Stave Creek, Clarke County, Alabama; 3.5 miles north of town of Jackson, west of U. S. Highway 43; where trail enters creek and about 1250 feet downstream; samples from several layers of shell detritus within sands of foramation. Collectors: R. Greeley and R. L. Moody, Jr., December, 1964 (Station G-64-21).

Cook Mountain Formation (Undifferentiated)

12. Section on southeast side of Saline Bayou on Louisiana State Highway 101 (147?) two and three-fourths miles southeast of Arcadia, Bienville Parish, Louisiana; NW¼, NW¼, Sec. 28, T. 18 N., R. 5 W.; samples taken from shell layers within greenish-brown, fine calcareous sands about midway in the section;

identified as Milams Member (?). Collectors: unknown (McGuirt, 1941).

13. St. Maurice, Winn Parish, Louisiana; at railroad crossing over Saline Bayou; identified as the Saline Bayou Member of the Cook Mountain Formation. Collector: H. V. Howe (McGuirt, 1941).

14. Moseleys Ferry, Caldwell County (Burleson County?), Texas; U.S.G.S. Station no. 5473. Collectors: unknown (Canu and Bassler, 1920).

Stone City Beds

15. Burleson County, Texas, at boundary with Brazos County; bank of Brazos River at bridge on Texas Highway 21, about 10 miles west of town of Bryan; dark, very abundantly glauconitic, extremely fossiliferous silty shale below a marked depositional hiatus. Collector: Charles C. Smith, 1963 (Station F-CCS-6).

Wheelock Formation

16. Burleson County, Texas, at boundary with Brazos County; bank of Brazos River at bridge on Texas Highway 21, about 10 miles west of town of Bryan; dark, very abundantly glauconitic, extremely fossiliferous silty shale. Collectors: D. L. and H. E. Frizzell, October 19, 1951 (Station F-51-1).

Wautubbee Formation

17. Road cut on east side of Mississippi Highway 15, north at intersection with Interstate 20, SE¼, SE¼,

Sec. 23, T. 6 N., R. 11 E., Newton County, Mississippi. Collector: F. F. Mellon, 1964 (Station M-64-1).

Gosport Sand

18. Claiborne Bluff, near town of Claiborne, Monroe County, Alabama. Collectors: unknown (Canu and Bassler, 1920).

19. One mile southwest of Rockville, Clarke County, Alabama; U.S.G.S. Station no. 6158. Collectors: unknown (Canu and Bassler, 1920).

20. Gopher Hill, Tombigbee River, county not known, Alabama. Collectors: unknown (Canu and Bassler, 1920).

21. Little Stave Creek, Clarke County, Alabama; 3.5 miles north of town of Jackson, west of U. S. Highway 43; where trail enters creek and some yards downstream; lowest major shell bed of Gosport. Collectors: D. L. and H. E. Frizzell, July 4-5, 1964 (Station F-64-7).

JACKSON GROUP (EOCENE)

Moodys Branch Marl

22. Road cut on Louisiana State Highway 474, .7 mile northwest of Tullos, LaSalle Parish (?), Louisiana; NE¼, SE¼, Sec. 23, T. 10 N., R. 1 E. Collector: H. N. Fisk (McGuirt, 1941).

23. Creole Bluff at Montgomery, La Salle Parish,

Louisiana; center Sec. 20, T. 8 N., R. 5 W.; composite sample taken six feet above contact with the Cockfield Formation. Collectors: unknown (McGuirt, 1941). Basal part directly in contact with underlying Cockfield. Collectors: D. L. Frizzell, W. C. Horton, and C. K. Lamber, November 23, 1960 (Station F-60-A1).

24. Sabine Parish, Louisiana; SE¼, NW¼, Sec. 13, T. 5 N., R. 11 W. Collector: R. B. Grigsby (McGuirt, 1941).

25. Danville Landing, Catahouhla Parish, Louisiana; samples from fossiliferous, calcareous sticky clay from elevations 50 to 70 feet (upper Danville of Howe and Wallace, 1932). Collectors: H. V. Howe and H. N. Fisk (McGuirt, 1941).

26. Grandview Bluff, Caldwell Parish, Louisiana; shell marl and calcareous concretions near base of formation, between elevations 55 to 61 feet. Collector: H. V. Howe (McGuirt, 1941).

27. Heison Bluff, Caldwell Parish, Louisiana; SW¼, SW¼, Sec. 12, T. 12 N., R. 4 E.; samples taken at elevation 112 feet. Collector: H. V. Howe (McGuirt, 1941).

28. Gibson Landing on the Ouachita River, Caldwell Parish, Louisiana. Collector: R. W. Harris (McGuirt, 1941).

29. Stock Landing on the Ouachita River, Caldwell Parish, Louisiana; samples taken eight feet below top of bluff at elevation 177 feet. Collectors: H. V. Howe and W. D. Chawner (McGuirt, 1941).

30. Riverside Park, Jackson, Hinds County, Mississippi (considered the reference section for the Moodys Branch Marl); very fossiliferous greensand, about 10 feet above the underlying shales and clays of the Cockfield Formation. Collector: R. Greeley, July 28, 1964 (Station G-64-8).

31. Bluff on Moodys Branch, about 100 yards southeast of junction of Poplar Boulevard and Hazel Street, town of Jackson, Hinds County, Mississippi (Murray, _et al._, 1948, p. 23). Original type locality, now inaccessible. Collector: W. C. Morse, November, 1939 (Station Ms-39-1).

32. Type locality ?' Jackson, Hinds County, Mississippi; from different horizon than Ms-39-1. Collectors: unknown (from material from the University of Missouri at Rolla).

33. Claiborne Bluff, near town of Claiborne, Monroe County, Alabama; exposed in road cut, east end of bridge, about ten feet above road level at bridge; shell detritus in marl of formation. Collectors: R. Greeley and R. L. Moody, Jr., December, 1964 (Station G-64-20B).

34. Tcheva Creek, one mile north of town of Midway, Yazoo County, Mississippi (NW¼, SW¼, Sec. 10, T. 12 N., R. 16 E.) sample taken 8-16 feet below the contact with the Yazoo Clay. Collectors: F. F. Mellon, December, 1942 (Station M-42-1) and D. L. Frizzell, 1960 (Station F-60-4).

35. J. W. Tinnin locality, NW¼, NE¼, Sec. 20, T. 13 N., R. 1 W., Yazoo County, Mississippi. Obtained from F. F. Mellon, December, 1964. Collectors: unknown (Station M-64-2).

36. Road cut on Choctaw County road 14, about 10 miles west of Gilbertown, Choctaw County, Alabama; very fossiliferous sandy marls, with abundant Periarchus lyelli, a few inches below the overlying North Twistwood Creek Member of the Yazoo Clay; from cut on north side of road. Collector: R. Greeley, July 30, 1964 (Station G-64-15).

37. Road cut on Choctaw County road 14, about 10 miles west of Gilbertown, Choctaw County, Alabama; very fossiliferous sandy marls at base of section, about 15 feet below contact with overlying North Twistwood Creek Clay Member, Yazoo Clay; from cut on north side of road. Collector: R. Greeley, July 30, 1964 (Station G-64-15).

38. Bunker Hill, Caldwell Parish, Louisiana. Collectors: H. V. Howe, H. N. Fisk, and W. D. Chawner (McGuirt, 1941).

Ocala Limestone

39. Claiborne Bluff, near town of Claiborne, Monroe County, Alabama; exposed in road cut, east end of bridge, about 25 feet above road level at bridge; shell detritus within marl of formation. Collectors: R. Greeley and R. L. Moody, Jr., December, 1964 (Station G-64-20A).

40. Rich Hill, five and one-half miles southeast of Knoxville, Crawford County, Georgia; U.S.G.S. Station no. 3604; from Tivola tongue of lower part of formation. Collectors: unknown (Canu and Bassler, 1920).

41. Three and one-half miles north of Grovania, Houston County, Georgia; from Tivola Tongue of lower part of formation. Collectors: unknown (Canu and Bassler, 1920).

42. Wing Jaw Bluff on Oconee River, 18 miles west of town of Wrightsville, Johnson County, Georgia; U.S.G.S. Station no. 5539; from Tivola Tongue of lower part of formation. Collectors: unknown (Canu and Bassler, 1920).

43. Brooks farm, 12 miles southeast of Marshallville, Macon County, Georgia; U.S.G.S. Station no. 3996; from Tivola Tongue of lower part of formation. Collectors: unknown (Canu and Bassler, 1920).

44. Three and one-fourth miles south of Perry, Houston County, Georgia; from Tivola Tongue of lower part of

formation. Collectors: unknown (Canu and Bassler, 1920).

45. One-half mile southeast of Georgia Kaolin Company Mine, Twiggs County, Georgia; from Tivola Tongue of lower part of formation. Collectors: unknown (Canu and Bassler, 1920).

46. Steamboat Point on west bank of Sepulga River, Escambia County, Alabama; U.S.G.S. Station no. 6747; near top of formation. Collectors: unknown (Canu and Bassler, 1920).

47. Near Plant System Railroad Wharf, Bainbridge, Decatur County, Georgia; U.S.G.S. Station no. 3390; near top of formation. Collectors: unknown (Canu and Bassler, 1920).

48. West bank of Chipola River, east of Marianna, Jackson County, Florida; U.S.G.S. Station no. 6768; upper part of formation. Collectors: unknown (Canu and Bassler, 1920).

Castle Hayne Marl

49. Wilmington, New Hanover County, North Carolina. Collector: unknown (from material from the University of Missouri at Rolla, Station X-65-2).

Yazoo Clay

50. Bluff on south side of Suck Creek, half mile above its mouth, Clarke County, Mississippi; U.S.G.S. Station no. 7377; *Zeuglodon* zone of formation.

Collectors: unknown (Canu and Bassler, 1920).

51. Cocoa Post Office, two and one-half miles east of Melville, Choctaw County, Alabama; U.S.G.S. Station no. 7219; _Zeuglodon_ zone of formation. Collectors; unknown (Canu and Bassler, 1920).

52. Shubuta, Clarke County, Mississippi; U.S.G.S. Station no. 7376b; _Zeuglodon_ zone of formation. Collectors: unknown (Canu and Bassler, 1920).

53. From drill hole #23, SE¼, SE¼, SE¼, Sec. 17, T. 12 N., R. 1 E., Yazoo County, Mississippi; taken from depth 39.5' to 41.5' of total depth 49.2'; equivalent to North Twistwood Creek Member. Collector: F. F. Mellon, December 3, 1942 (Station M-52-2).

54. Mississippi Light Aggregate Plant, near town of Cynthia, Hinds County, Mississippi; samples taken from very fossiliferous weathered material in spoil area opposite small pond across from picnic area. Collector: R. Greeley, July 29, 1964 (Station G-64-9).

Barnwell Formation

55. Will Scott spring, three and one-half miles southeast of Shell Bluff Post Office, Burk County, Georgia; base of formation. Collectors: unknown (Canu and Bassler, 1920).

56. Town of Baldock, Allendale County, South Carolina; _Ostrea georgiana_ bed at base of formation. Collectors: unknown (Canu and Bassler, 1920).

Copper Marl

57. Eutaw Spring, county unknown, South Carolina. Collectors: unknown.

58. Santee River, three miles above Lenuds Ferry, Georgetown County, South Carolina. Collectors: unknown (Canu and Bassler, 1920).

VICKSBURG GROUP (OLIGOCENE)

Undifferentiated

59. Rosefield, Catahoula Parish, Louisiana; samples taken between elevations 262-264 from friable, fossiliferous sandy marl near base of section, below a one and one-half to two feet thick coquina layer. Collectors: W. D. Chawner and H. V. Howe (McGuirt, 1941).

Red Bluff Clay

60. Bank of Chickasawhay River at Red Bluff Landing (Hiwannee, Wayne County), Mississippi; shell pockets within clay of formation. Collectors: D. L. Frizzell and A. R. Troell, Jr., August 4, 1960 (Station F-60-11).

Mint Spring Marl

61. National Cemetery, Vicksburg, Warren County, Mississippi, (type locality); falls of Mint Spring Bayou at southern boundary of cemetery; fossiliferous shell detritus within marl of formation. Collectors: D. L. Frizzell and A. R. Troell, Jr., August 1, 1960 (Station F-60-6, 7); R. Greeley, June 4, 1964 (Station G-64-3).

Marianna Limestone

62. Vicksburg, Warren County, Mississippi. Collectors: unknown (Canu and Bassler, 1920).

63. One mile north of Monroeville, Monroe County, Alabama; U.S.G.S. Station no. 6717; Chimney rock Member. Collectors: unknown (Canu and Bassler, 1920).

64. Mississippi Valley Portland Cement Plant, near town of Redwood, Warren County, Mississippi, about 2.5 miles NE of junction of U. S. Highway 61 and Mississippi Highway 3, on Mississippi Highway 3; along section that begins in drainage ditch opposite cement plant office, across Highway; fossiliferous beds between first waterfall and limestone ledges. Collector: R. Greeley, June 4, 1964 (Station G-64-1B).

Glendon Limestone

65. McGowen's Bridge, Conecuh River, Alabama Highway 29, NW¼, Sec. 6, T. 2 N., R. 13 E., Escambia County, Alabama; samples from west bank, below bridge, #1 from upper marl bed, #2 from lower, exposed marl units. Collector: Martin Mumma (Station Mu-39-1, 2).

66. Smith County Agricultural Lime Plant, on Mississippi Highway 18, about four miles east of town of Sylvarena, Smith County, Mississippi; samples from shell layer within marl unit about 36 feet above quarry floor, below prominent indurated marl ledge. Collector: R. Greeley, July 30, 1964 (Station G-64-17).

Byram Marl

67. One-fourth mile west of Woodwards, Wayne County, Mississippi; U.S.G.S. Station no. 6648. Collectors: unknown (Canu and Bassler, 1920).

68. Old Byram, Hinds County, Mississippi (type locality); bank of Pearl River below suspension bridge; irregular beds of shell drift within sandy shell marl of formation. Collectors: D. L. Frizzell and A. R. Troell, Jr., July 29, 1960 (Station F-60-1); R. Greeley, June 5, 1964 (Station G-64-6).

69. Old Quarry, Marquette Cement Plant, about one mile southwest of Brandon, Rankin County, Mississippi; sandy, fossiliferous beds within marl, about 5 feet underlying Glendon Limestone, from exposures north of old parking area. Collector: R. Greeley, July 29, 1964 (Station G-64-11).

70. Haynes Bluff, Yazoo River, Warren County, Mississippi (NE¼, NW¼, Sec. 26, T. 18 N., R. 4 E.). Collectors: F. F. Mellon, W. S. Parks, September 5, 1964 (Station M-64-4).

71. Wansley Bend, Pearl River, Rankin County, Mississippi, (SW¼, SW¼, Sec. 30, T. 4 N., R. 1 E.). Collector: M. Kern (Mississippi Geological Survey), 1964 (Station M-64-3).

72. Rosefield, Catahoula Parish, Louisiana. Samples taken between elevations 262'to 254' from marls near

base of section. Collectors: W. D. Chawner and H. V. Howe (McGuirt, 1941).

MIOCENE

Chickasawhay Marl

73. Railroad cut, Washington County, Alabama, about two miles north of town of Millry on Alabama Highway 17; about 200 feet west of highway; marl beds in unindurated part of formation. Collectors: R. Greeley and R. L. Moody, Jr., December, 1964 (Station G-64-25 A, B, C).

Lower Miocene

74. Superior Oil Producing Company, P. O. Hernandez No. 1 well, Sec. 34, T. 8 S., R. 3.E., Acadia Parish, Louisiana; samples taken between top of Heterostegina zone (7948) and top of Marginulina zone (8363). Collectors: Unknown (McGuirt, 1941).

75. Superior Oil Producing Company, Duplantier Community No. 1 well, Sec. 65, T. 7 S., R. 1 W., East Baton Rouge Parish, Louisiana; samples taken 7671-8101 feet. Collectors: unknown (McGuirt, 1941).

Oak Grove Sand

76. Below bridge over Yellow River, southwest of Laurel Hill, Okalooska County, Florida. Collectors: unknown (from Humble Oil and Refining Company, August, 1965).

Chipola Formation

77. Ten mile Creek, about four miles south of Willis, Calhoun County, Florida. Collectors: unknown (from material from Humble Oil and Refining Company, July, 1965).

78. Chipola River, Calhoun County, Florida. Collectors: unknown (Canu and Bassler, 1923).

Choctawhatchee Formation

79. Borrow pit south of dam for Lake Talquin, Gadsden County, Florida; 27 miles south of Tallahassee, Florida, on State Highway 20; samples from light buff to brown sandy marl about 11 feet from bottom of section. Collectors: D. L. and H. E. Frizzell, July 1, 1964 (Station F-64-6A).

Choctawhatchee Stage, Ecphora biofacies

80. Jackson Bluff, Ochlockonee River, Leon County, Florida (Sec. 21, T. 1 S., R. 8 W.). Collectors: H. K. Brooks, R. Scolaro, and C. Dimmick, November 10, 1963 (Station Sc-63-1).

St. Marys Formation

81. St. Mary's River, St. Mary's County, Maryland. Collectors: unknown (Canu and Bassler, 1923).

Yorktown Formation

82. Williamsburg, James City County, Virginia. Collectors: unknown (Canu and Bassler, 1923).

83. York River, (unknown county), Virginia. Collectors: unknown (Canu and Bassler, 1923).

Duplin Marl

84. Wilmington, New Hanover County, North Carolina. Collectors: unknown (Canu and Bassler, 1923).

85. Natural well, two miles southwest of Magnolia, Duplin County, North Carolina. Collectors: unknown (Canu and Bassler, 1923).

MIOCENE-PLIOCENE ?

86. Terrebonne Gas Company, Fee no. 1 well, Sec. 50, T. 19 S., R. 19 E., Terrebonne Parish, Louisiana; collected when well blew out at approximately 2300 feet. Collectors: unknown (McGuirt, 1941).

PLIOCENE

Waccamaw Marl

87. Waccamaw River, Horry County, South Carolina. Collectors: unknown (Canu and Bassler, 1923).

Caloosahatchee Marl

88. Monroe County, Florida. Collectors: unknown (Canu and Bassler, 1923).

RECENT

89. Mississippi Mud Lump SP 94, Mississippi River Delta Complex, South Pass Area, Louisiana; situated about 100 yards west of Mud Lump SP 5. Collector: unknown (Station Mu-65-1).

Range and distribution

The range and distribution for each species is presented in Table 3. The numbers for the localities correspond to the numbers presented under Sample Localities. Three methods of indicating the occurrence are shown on the table: numerals indicate the number of specimens taken from samples for the particular locality; the designations vr (very rare), r (rare), c (common), and vc (very common) are from Canu and Bassler (1920, 1923); X indicates occurrence as given by McGuirt (1941) with no indication of abundance. Sizes of the samples ranged from individual specimens collected from the outcrop to samples of over 500 pounds. Thus, the values given cannot be readily compared quantitatively.

The stratigraphic ranges for genus and species is summarized as follows:

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Lunulites #1											1			vc	12						34		
L. almina																					19		
L. bassleri																							31
L. montgomeryensis																					31		
L. bouei					4	2			vr	7	200		x	vc	4	12		vc	vr	c	400	x	29
L. distans																							
L. fenestratus																9						x	
L. grandipora												x	x										
L. jacksonensis																					4	x	2
L. ligulatus																						x	16
L. ovatus				r												2							
L. reversus			r																				
L. tintinabulus																							
L. truncatus														vc				c	r	c			x
L. verrucosus																							
Otionella #1																	3						
O. cava																							
O. perforata									r				x					c	c	c		x	8
O. tuberosa														r	2						78		1
Selenaria auricularia													x					r					

Table III. Range and distribution, lunulitiform species.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
Oligotresium #1																					31		
O. #2																							3
O. claibornicum																		r	c	c	86		
O. contiguum																							
O. tubiferum																							
O. vicksburgense																							
New Genus A n.sp.´1	25	1																					
Cupuladria biporosa																							
C. canariensis																							
Discoporella doma																							
D. umbellata																							
Schizorthosecos danvillensis											72					3					25	x	7
S. grandiporosum													x					c				x	x
S. interstitium						1			c			x	x	vr			6	c	c	r	68	x	140
S. radiatum							2		vr									r					

Table III. (continued) Range and distribution, lunulitiform species

	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Lunulites #1																							
L. almina											2												
L. bassleri							75	3			3												
L. montgomeryensis																							
L. bouei			x	x	x	x	242	10		80	6			47									
L. distans									9				5			11		c					r
L. fenestratus					x																		
L. grandipora																							
L. jacksonensis				x	x	x	175	18	105	4	10				x	120							
L. ligulatus	x			x	x	x	95	3	53		9												
L. ovatus																							
L. reversus																							
L. tintinabulus																							
L. truncatus																							
L. verrucosus																	c		r	r	r		
Otionella #1																							
O. cava													1								c		
O. perforata			x	x	x	x	94			6	1	5		74	x								
O. tuberosa	x	x	x	x	x	x	270	8	41		1		3		x	28							
Selenaria auricularia																							

Table III. (continued) Range and distribution, lunulitiform species.

	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46
Oligotresium #1							2							2									
O. #2							124	1			6		1			5							
O. claibornicum																							
O. contiguum																							
O. tubiferum																						r	
O. vicksburgense										4				1									
New Genus A n.sp. 1																							
Cupuladria biporosa																							
C. canariensis																							
Discoporella doma																							
D. umbellata																							
Schizorthosecos danvillensis		x		x			35	3		3				3									
S. grandiporosum				x																			
S. interstitium		x	x	x	x	x	300	2		10	1			31	x								
S. radiatum																							

Table III. (continued) Range and distribution, lunulitiform species.

	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
Lunulites #1			2				62								55			26				16	
L. almina																							
L. bassleri																		3					
L. montgomeryensis																							
L. bouei									r					r									
L. distans	r		43	r	r						c	c					r						
L. fenestratus																							
L. grandipora																							
L. jacksonensis																							
L. ligulatus				vr					r				x	40									
L. ovatus																							
L. reversus																							
L. tintinabulus													x	68	40	vr		37	17	9	vr	300	8
L. truncatus									r														
L. verrucosus	r	r								r							r						
Otionella #1																							
O. cava				r		r				c													
O. perforata																							
O. tuberosa							5																
Selenaria auricularia																							

Table III. (continued) Range and distribution, lunulitiform species.

	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69
Oligotresium #1																							
O. #2															5								
O. claibornicum																							
O. contiguum			4																				
O. tubiferum																							
O. vicksburgense														260	4	c		28			c	300	
New Genus A n.sp. 1																							
Cupuladria biporosa																							
C. canariensis																							
Discoporella doma																							
D. umbellata																							
Schizorthosecos danvillensis								1															
S. grandiporosum																							
S. interstitium								2	r														
S. radiatum																							

Table III. (continued) Range and distribution, lunulitiform species.

	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
Lunulites #1																				
L. almina																				
L. bassleri																				
L. montgomeryensis																				
L. bouei																				
L. distans																				
L. fenestratus																				
L. grandipora																				
L. jacksonensis																				
L. ligulatus		1	x																	
L. ovatus																				
L. reversus																				
L. tintinabulus	35		x																	
L. truncatus																				
L. verrucosus																				
Otionella #1																				
O. cava																				
O. perforata																				
O. tuberosa																				
Selenaria auricularia																				

Table III. (continued) Range and distribution, lunulitiform species.

	70	71	72	73	74	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89
Oligotresium #1																				
O. #2																				
O. claibornicum																				
O. tubiferum																				
O. vicksburgense	50	2	x																	
New Genus A n.sp. 1																				
Cupuladria biporosa				59																1
C. canariensis					x	x	2	1		34	8						x		r	19
Discoporella doma										130	61	r	r	r	vc	r		vc	vc	55
D. umbellata					x	x			c	12	5				c	x	x			35
Schizorthosecos danvillensis																				
S. grandiporosum																				
S. interstitium																				
S. radiatum																				

Table III. (continued) Range and distribution, lunulitiform species.

VII. CUPULIFORM BRYOZOANS

Although placed in a different suborder (Suborder Ascophora) than the lunulitiform (Suborder Anascan), cupuliform bryozoans are similar to them in many respects. Of the several genera, Schizorthosecos (Family Orbituliporidae) is most commonly found associated with Tertiary lunulitiform zoaria. In Recent material, Mamillopora and Anteropora (Family Mamilloporidae) are encountered, often with Cupuladria and Discoporella.

Classification

Cupuliform genera are placed in two closely related families: Mamilloporidae and Orbituliporidae. The Family Mamilloporidae ranges from Eocene to Recent; however, most genera of the family are restricted to the Quaternary; it is distinguished from the Orbituliporidae by the deeply embedded ovicell within a special interzooecial cavity; the ovicells of theorbituliporids are recumbent.

Schizorthosecos and the species of this genus are diagnosed and discussed under Systematics. Although Mamillopora ranges from the Eocene and Anteropora from the Pliocene, specimens of these genera were not encountered in the samples studied and are not included in the section on Systematics, but discussed below.

Mamillopora was described by Smitt in 1873 from samples from the Gulf of Mexico. The type species is _M. cupula_. The genus is characterized by its cup-shaped to conical zoarium with both frontal and basal sides bearing mamilloid protuberances; the aperture is subelliptical with two submedian cardelles; the ovicelled zooecia are larger, deeply embedded and have elongate apertures.

Anteropora was described by Canu and Bassler in 1929 from material from the Jolo Islands, Philippines. The type species is _A. magnicapitata_. The genus is similar to _Mamillopora_ but is distinguished by having a porous basal side and large distal, transverse, triangular avicularia.

Morphology

Many of the terms defined under Morphology of the lunulitiform bryozoans are applied to cupuliform bryozoa. However, there are some differences and structures which are not found on lunulitiform specimens.

The zoarial form of the cupuliform bryozoans is the same as in the lunulitiform; the distinction between the two is the presence of vibracula on the lunulitiform zoarium and their absence on that of the cupuliform. Zoaria in which the concave side is filled, or solid zoaria, are not known to occur in cupuliform species. The substratum selected by the larva evidently is not incorporated within the colony as with the lunulitiform bryozoans (Siler, 1947, p. 29). Marcus and Marcus (1962, p. 306) suggest that the ancestrula is only loosely attached to the substratum and then detaches from it as the colony expands. Like those of Cupuladria, the zooecia of cupuliform bryozoans are erect prisms, perpendicular to the frontal surface. The arrangement may be in distinct rows, quinqunx, or irregular.

The following terminology (figure 31) is applied to Schizorthosecos, but may apply in some cases to other cupuliform genera: the aperture is the main opening of the zooecium; there may be a small cleft or fissure in the proximal edge of the aperture, termed the rimule, the function of which is to serve as an opening for the compensatrix. A lyrule, or small tooth, may be placed in the rimule. Proximal to the lyrula may be a number of small, radial slits termed radial costules. The function of these structures is not known. The aperture is surrounded by a calcareous tube, the peristome. It may have two small lateral projections termed cardelles that serve as pivots for the chitinous operculum. The ovicell is a swollen protuberance on the distal part of the zooecium.

Between adjoining zooecia there may be small pores of irregular shape termed zooeciules. These are thought (Canu and Bassler, 1920, p. 626) to be capable of transforming into radicular zooecia or avicularia. Aviculoecia are positioned irregularly over both the frontal and basal surfaces. An avicularian bar may be present; this structure serves as a pivot for the mandibles of the avicularium.

On the basal side, the basal part of the zooecia may be perforated by pores which connect the interior of the zooecium with the basal side. Irregularly positioned on the basal side may be a number of rather large round tubules which deeply penetrate the zoarium.

Conclusions

Very few studies of cupuliform Bryozoa have been conducted. As a result, ecologic and paleoecologic information is not available. Observation on living material has not been made. Although some analogies can be drawn from the lunulitiform bryozoans, clearly, more investigations of cupuliform bryozoans are needed.

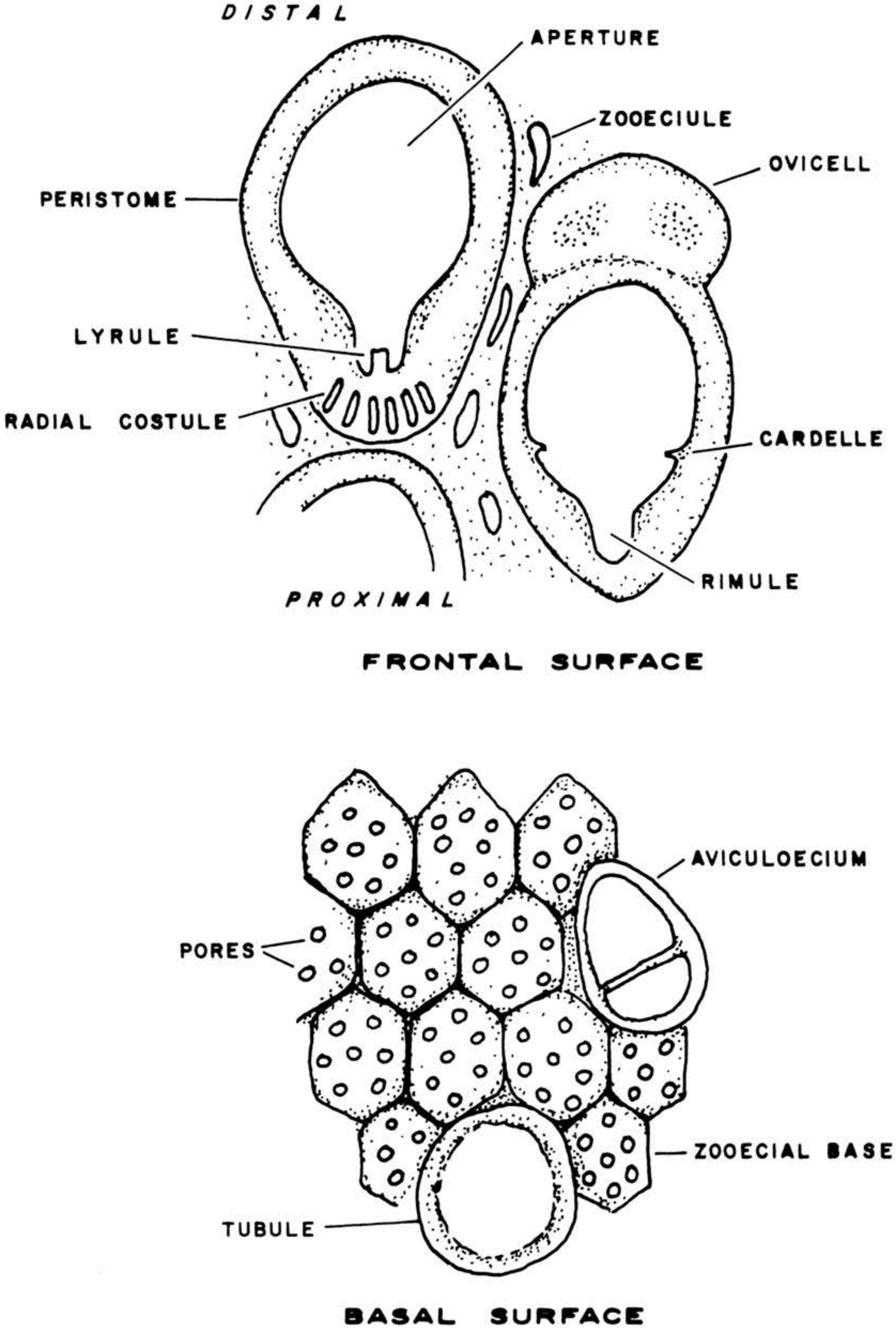

DISTAL
APERTURE
ZOOECIULE
OVICELL
PERISTOME
LYRULE
RADIAL COSTULE
CARDELLE
RIMULE
PROXIMAL
FRONTAL SURFACE
AVICULOECIUM
PORES
ZOOECIAL BASE
TUBULE
BASAL SURFACE

FIGURE 30

VIII. SUMMARY AND CONCLUSIONS

The following paragraphs summarize the topics discussed and the conclusions determined during this investigation. Each paragraph refers to the chapter covering the particular topic. Details of the subject matter are given in the particular chapter.

The history of the classification of bryozoans and lunulitiform bryozoans is reviewed. The life history of a typical non-ovicelled bryozoan is summarized and contrasted with the life history of a typical ovicelled bryozoan.

The morphology of lunulitiform bryozoans is given in detail and terminology clarified. "Hollow" zoaria are shown to result from mode of preservation. The "*Trochopora*" type zoarium is shown to be a structural variation not of taxonomic significance.

The life habits of the lunulitiform bryozoans are reviewed; hypotheses of Canu, Bassler, and others are discarded. Living material was collected and observed. Commensal relationships between lunulitiform bryozoans and the associated organisms are discussed. Crabs, star fish, and echinoids are shown to overturn lunulitiform zoaria.

Paleoecologically, lunulitiform bryozoans are associated with calcareous sands and near shore fauna. Regenerated zoaria are attributed to predators. Rapid sedimentation, increased predator activity and invasion of commensal organism is suggested as possible causes of occluded zooecia.

Taxonomically, the known Gulf area lunulitiform species are described from type material, when available. One new genus, a pre-*Cupuladria* form, with one new species, one new species of *Otionella*; one new species of *Lunulites*; and two new species of *Oligotresium* are described.

IX. SYSTEMATICS

Class Gymnolaemata

Order Cheilostomata

Suborder Anasca

Family Cupuladriidae Lagaaij, 1952

NEW GENUS A

Type species. - Genus A, new species 1.

Diagnosis. - Unilaminar zoarium encrusting small mollusk fragments or other debris, growth may extend off fragment, or nearly incorporate fragment; zooecia in irregular radial rows, arranged in quincunx, alternate with vibraculoecium; vibraculoecia distal to each zooecium; zooecia rhombic; ancestrula without vibraculoecia; basal side of smooth rhombic sectors, indicating zooecial outline; ovicells absent.

Comparisons. - New genus A is very similar to *Cupuladria*, but is distinguished by its encrusting zoarium and lack of basal kenozooecia. *Vibracellina* (Suborder Anasca, Division Malacostega, Family Hincksinidae) is also encrusting and outwardly resembles New genus A; however, the vibraculoecia of *Vibracellina* are irregularly situated among the zooecia.

Content of genus. - New genus A currently contains only the type species.

Range and distribution. - The genus is known currently only from the Paleocene, Midway Group of the Gulf Coastal Plain.

Remarks. - The close resemblance of Cupuladria and New genus A suggests a phylogenetic relationship. Lunulitiform bryozoans probably originated from encrusting forms. The early forms settled on smaller fragments and eventually incorporated the substratum within the zoarium. Thus, New genus A is considered a "Pre-Cupuladria" form.

GENUS A NEW SPECIES 1

Plate IV, figures 1-3

Description of zoarium. - Zoarium unilaminar, encrusts mollusk fragments or other small detritus, growth may extend slightly beyond fragment; zooecia in irregular radial rows from ancestrula, arranged approximately in quincunx, alternate with vibraculoecia along zooecial row; vibraculoecium distal to each zooecium. Basal side of smooth rhombic sectors separated by faint, fine sutures; sectors are zooecial bases.

Description of zooecia. - Zooecia rounded rhombic; mural rim well developed, rounded, thick, with crenulations lateral and proximal, slightly granular; cryptocyst very thin, usually absent; opesium oval, broad end proximal, narrow end distal, to rounded rhombic; distal end marks former position of operculum; lateral septulae numerous, large. Ancestrula slightly smaller than autozooecia, without vibraculoecium.

Vibraculoecia very slightly asymmetrical, reniform, with rounded, smooth mural rim; opesia irregular, oval to reniform.

Measurements
(average of 10 measurements per parameter)

Lz	0.46 mm	Lv	0.17 mm
lz	0.32 mm	lv	0.15 mm
ho	0.32 mm	hvo	0.11 mm
lo	0.16 mm	lvo	0.074mm

zooecia width/length ratio	70%
zooecial opesia width/length ratio	50%
vibraculoecia width/length ratio	88%
vibraculoecial opesia width/length ratio	68%

Comparisons. - The encrusting form of the zoarium separates this species from lunulitiform species. Genus A n. sp. 1 is resembled by some species of Vibracellina, but is distinguished by the regular placement of the vibraculoecia distal to the zooecia.

Type material. - Holotype and 24 paratypes, Greeley Collection.

Range and distribution. - Paleocene, Midway Group, Matthews Landing Marl Member (Porters Creek Clay): near Linden, Marengo County, Alabama; Alabama Highway 10, Wilcox County, Alabama.

Type locality. - Near intersection of Alabama Highway 33 and U. S. Highway 43, about five miles south of Linden, Marengo County, Alabama.

Material examined. - Holotype and 24 paratypes; one specimen from Wilcox County, Alabama.

Genus CUPULADRIA Canu and Bassler 1919

?Cupularia Lamouroux, 1821. D'Orbigny, 1850, Prod. Paleo., vol. 2, p. 264. - D'Orbigny, 1852, Paleo. Fr. Cret., tome 5, pp. 510-511. - Busk, 1859, Micros. Sci., Quart. Jour., vol. 7, p. 66. - Levinsen, 1909, Morph. syst. Cheil. Bry., p. 154. - Canu and Bassler, 1923, U. S. Nat. Mus., Bull. 125, p. 75. - Hastings, 1930, Proc. Zool. Soc., London (1929), pp. 717-718 (Nomen dubium).

Cupuladria Canu and Bassler, 1919, Carnegie Inst., Wash., pub. no. 291, pp. 77-78. - Canu and Bassler, 1920, U. S. Nat. Mus., Bull., 106, p. 103 (Synonomous homonym) Lagaaij, 1952, Meded. Geol. Stich., ser. c, vol. 5, no. 5, p. 32.

Type species. - Cupularia canariensis Busk (1859, p. 66, pl. 23, figs. 6-9) (original designation).

Diagnosis. - Lunulitiform zoarium; zooecia in regular radial rows arranged in quincunx, alternating with vibraculoecia; vibraculoecium distal to each zooecium; zooecia rhombic with thin mural rim; cryptocyst very thin or absent; zooecia may be occluded; basal side of perforate irregular rectangular sectors; vibraculoecia reniform, with condyle at reentrant; ovicells absent.

Comparisons. - *Cupuladria* is closely resembled by *Discoporella* but is distinguished by the lack of extensive cryptocyst and basal side of rectangular sectors.

Range and distribution. - (Restricted to Gulf and Atlantic Coastal Plains) Miocene (Upper Chickasaway) to Recent.

Remarks. - As stated by Lagaaij (1952, p. 32), this genus has been a taxonomic problem for more than a century. Lamouroux, in 1821, examined specimens of *Lunulites urceolata* Lamarck and noted differences from *L. radiata* Lamarck. Lamouroux's illustrations of *L. urceolata* show quincunx arrangement of the zooecia and leave little doubt that the specimens are not *Lunulites*, but could be *Cupuladria* or *Discoporella*. Lamouroux stated (1821, p. 44) that if there were not already too many divisions, he would establish the group *Cupulaire*. It was not Lamouroux's intention to establish a new genus and he did not use a Latinized name.

Canu, 1907, described specimens as *L. urceolata* which he felt were Lamarck's species. Canu's figures are of a species of *Lunulites*.

However, Canu and Bassler (1923, p. 75) employed *Cupularia* Lamouroux, 1821, with type species as *C. umbellata* Defrance 1823, for specimens with extensive cryptocyst (microporine forms).

Earlier, Canu and Bassler (1919, pp. 77-78), had established for forms with no cryptocyst the name *Cupuladria* with the type species *Cupularia canariensis* Busk, 1859.

Harmer (1926) accepted *Cupuladria* Canu and Bassler for Recent species and *Cupularia* Lamouroux for fossil species. This, however, is biologically invalid, and as Lagaaij (1952, p. 32) suggested, one name must be rejected. *Cupuladria* Canu and Bassler is in current usage and it seems best to reject *Cupularia* Lamouroux as a *nomen dubium*.

CUPULADRIA CANARIENSIS (Busk), 1859

Plate III, Figures 13-14

Cupularia canariensis Busk, 1859, Quart. Jour. Micr. Sci., vol. 7, p. 66, pl. 23, figs. 6-9.

Membranipora canariensis (Busk). Smitt, 1873, Kungl. Svenska Vetensk. - Akad. Handl., vol. 11, p. 10, pl. 2, figs. 69-71.

Lunulites conica Defrance var. *depressa* Conrad. Lorie, 1885, Arch. Mus. Teyler, ser. 2, p. 133, pl. 3, figs. 15a, b.

Cupuladria canariensis (Busk). Canu and Bassler, 1919, Publ. Carnegie Instn., vol. 291, p. 78, pl. 1, figs. 8-10.

Description of zoarium. - Zoarium a broad shallow cup, often encrusting small shells, or debris in early stages; zooecia in radial and irregular transverse rows; zooecia arranged in quincunx; vibraculoecium distal to each zooecium, alternating with zooecia in radial row. Basal side of rectangular sectors, each sector corresponding to a zooecium or vibraculoecium; sectors perforated by inconstant number of irregular pores.

Description of zooecia. - Zooecia rhombic to elongate, scutiform, some elongate pyriform; mural rim thin, rising sharply laterally, slightly imbricate distally, coarsely granular; cryptocyst very thin, papillate, most prominent laterally, absent or nearly absent distally; opesium irregular, rounded rectangular to oval.

Vibraculoecia irregular, urceolate; mural rim very slight; opesia reniform, alternating in orientation to right, then left, along radial row; slight condyle with fossette at reentrant.

Measurements
(average of 10 measurements per parameter)

Lz	0.46 mm	Lv	0.20 mm
lz	0.31 mm	lv	0.18 mm
ho	0.21 mm	hvo	0.14 mm
lo	0.19 mm	lvo	0.08 mm

zooecia width/length ratio	68%
zooecial opesia width/length ratio	90%
vibraculoecia width/length ratio	90%
vibraculoecial opesia width/length ratio	60%

Comparisons. - Cupuladria canariensis is closely resembled by C. biporosa, from which it may be separated by its having more than two pores on each basal sector.

Type material. - Figured syntypes, British Museum 99.7.1.4697, Busk Collection.

Range and distribution. - The following range and distribution are restricted to surface and subsurface localities of the Gulf and Atlantic Coastal Plain: Miocene -

undifferentiated (subsurface): Superior Oil Producing Company, Acadia Parish, Louisiana; Superior Oil Producing Company, East Baton Rouge Parish, Louisiana; - Oak Grove Sand: southwest of Laurel Hill, Okalooska County, Florida; - Chipola Formation: Ten mile Creek, four miles south of Willis, Calhoun County, Florida; - Choctawhatchee Formation, undifferentiated: near Lake Talquin, Gadsden County, Florida; Choctawhatchee Formation, Ecphora Biofacies: Jackson Bluff, Leon County, Florida; Miocene - Pliocene (?) (subsurface), Terrebonne Gas Company, Terrebone Parish, Louisiana. Pliocene: Caloosahatchee Marl: Monroe County, Florida. Recent: Mississippi Mud Lump SP94, South Pass Area, Louisiana.

Type locality. - Recent: Canary Islands.

Material examined. - Miocene: Two specimens from Oak Grove Sand, Okalooska County, Florida; one specimen from Chipola Formation, Calhoun County, Florida; 35 specimens from Choctawatchee Formation, Gadsden County, Florida, eight specimens from Choctawhatchee Formation, Ecphora Biofacies, Jackson Bluff, Leon County, Florida. Recent: 19 specimens from Mississippi Mud Lump SP94, South Pass Area, Louisiana.

Remarks. - Busk's syntypes from the Canary Islands contain two species (Cheetham, 1964, p. 1021). Dr. P. L. Cook (personal communication) of the British Museum (Natural History) is studying Cupuladria canariensis with the possibility of determining subspecies.

CUPULADRIA BIPOROSA Canu and Bassler, 1923
Plate III figures 15-16

Cupuladria biporosa Canu and Bassler, 1923, U. S. Nat. Mus., Bull. 125, pp. 29-30, pl. 47, figs. 1-2.

Description of zoarium. - Zoarium a broad, shallow cup; zooecia in radial and irregular transverse rows; new rows formed by bifurcation of zooecial rows; vibraculoecia at distal end of zooecia, alternating with zooecia in each row. Basal side (description based on figure by Canu and Bassler, 1923, pl. 47, fig. 2) of regular radial rows separated by pronounced sutures; rows transected by less pronounced sutures, forming basal rectangular sectors; each rectangle perforated by two large pores.

Description of zooecia. - Zooecia symmetrical, elongate octagonal to elongate hexagonal, some rhombic; mural rim well developed, coarsely granular, rounded, slightly salient distally, separated from mural rim of adjoining zooecia by deep furrow; cryptocyst very thin, coarsely granular, most prominent proximally, absent or nearly absent distally; opesia irregular, may be oval, rounded rectangular, or distally ogival-proximally straight, becoming larger distally.

Vibraculoecia asymmetrical, reniform to irregular; mural rim rounded to indistinct; opesia reniform; single condyle at reentrant; direction of curvature (clockwise or counterclockwise) generally alternate along each radiate row.

Measurements
(average of 10 measurements per parameter)

Lz	0.48 mm	Lv	0.25 mm
lz	0.36 mm	lv	0.20 mm
ho	0.31 mm	hvo	0.18 mm
lo	0.20 mm	lvo	0.11 mm

zooecia width/length ratio	75%
zooecial opesia width/length ratio	65%
vibraculoecia width/length ratio	80%
vibraculoecial opesia width/length ratio	61%

Comparisons. - This species is distinguished by the two pores in each rectangular sector on the basal side and the high zooecial opesia width/length ratio.

Type material. - Figured holotype (USNM 68425).

Range and distribution. - Miocene, Bowden Marl: Santo Domingo; Chickasawhay Formation, two miles north of Millry, Washington County, Alabama.

Type locality. - Santo Domingo.

Material examined. Holotype (USNM 68425), 55 specimens from near Millry, Washington County, Alabama.

Genus DISCOPORELLA d'Orbigny, 1852

Discoporella d'Orbigny, 1852, Paleo. Fr. t. Cret., pp. 472-473.

Type species. - Lunulites umbellata Defrance, (1823, p. 361, pl. 47, figs. 1, 1a, b). (Original designation).

Diagnosis. - Lunulitiform zoarium; zooecia in radial rows, arranged in quincunx, alternating with vibraculoecia; vibraculoecium distal to each zooecium; zooecia irregular, rhombic, with mural rim and extensive cryptocyst with opesiules or opesiular indentations; zooecia may be occluded; basal side or irregular radial rows separated by fine sutures; vibraculoecia reniform with condyle at reentrant; ovicells absent.

Comparisons. - Discoporella is closely resembled by Cupuladria but is distinguished by the more extensive cryptocyst, presence of opesiules or opesiular indentations, and radial rows of the basal side.

Range and distribution. - Gulf and Atlantic Coastal Plains. - Miocene to Recent.

DISCOPORELLA DOMA (d'Orbigny), 1851

Plate IV, figures 6-7

Discoflustrella doma d'Orbigny, 1851, Paleo. Fr. t. Cret., t. 5, p. 561.

Cupularia doma (d'Orbigny). Smitt, 1873, K. Svenska Vetensk. - Akad. Handl., Bd. 11, p. 14, pl. 3, figs. 81-84. - Canu and Bassler, 1923, U. S. Nat. Mus., Bull. 125, pp. 77-78; pl. 1, fig. 18, pl. 15, figs. 1-5. - Canu and Bassler, 1928, U. S. Nat. Mus., Proc., vol. 72, art. 14, p. 64, pl. 6, figs. 2-5.

Cupuladria doma (d'Orbigny). Annoscia, 1963, Geol. Romana, vol. II, p. 227, tav. IX, fig. 3, tav. X, fig. 3, tav. XIII, fig. 2, tav. XIV, figs. 2a, b, e.

Discoporella doma (d'Orbigny). Shier, 1964, Bull. Mar. Sci. Gulf and Carib., vol. 14, no. 4, pp. 621-622. - Cheetham, 1964, Jour. Paleo., vol. 38, no. 6, p. 1022, text fig. 15.

Description of zoarium. - Zoarium a very high, filled or thick dome, height may exceed diameter; zooecia arranged in quincunx and radial rows and concentric rings from ancestrula; zooecia of ancestrular area often occluded; ring of kenozooecia at zoarial periphery; vibraculoecia distal to zooecia, alternate with zooecial along row. Basal side of irregular radial rows or fine radial lines of papillae; papillae large, prominent, hollow.

Description of zooecia. - Zooecia rhombic, many asymmetric; mural rim thin, merging with mural rim of adjacent zooecia; cryptocyst very coarse, forms spinous projects into opesium, irregular; opesia very irregular, distally rounded, marking position of operculum. Occluded zooecia covered with a continuous coarse to papillate lamina; occluded zooecia are most frequently in ancestrular area of mature zoaria, but may also occur on lateral margins of zoarium; occlusion not covering vibraculoecia.

Vibraculoecia irregular, asymmetric, pyriform to reniform; opesia reniform, direction of curvature alternates right and left along row.

Measurements
(average of 10 measurements per parameter)

Lz	0.27 mm	Lv	0.18 mm
lz	0.28 mm	lv	0.16 mm
ho	0.16 mm	hvo	0.09 mm
lo	0.12 mm	lvo	0.07 mm

zooecia width/length ratio	103%
zooecial opesia width/length ratio	75%
vibraculoecia width/length ratio	89%
vibraculoecial opesia width/length ratio	78%

Comparisons. - Discoporella doma is separated from D. umbellata by its high, thick zoarium.

Type material. - The location of d'Orbigny's type material is not known.

Range and distribution. - (Gulf and Atlantic Coastal Plain) Miocene - Duplin Marl: Wilmington, New Hanover County, North Carolina.

Recent: Mississippi Mudlump SP 94, Mississippi River Delta Complex, South Pass Area, Louisiana.

Type locality. - Algerian Coast.

Material examined. - Thirty-five specimens from Recent material, Mississippi Mud Lump SP 94, South Pass Area, Louisiana.

DISCOPORELLA UMBELLATA (Defrance), 1823

Plate IV, figures 4-5

Lunulites umbellata Defrance, 1823, Dict. Sci. Nat., Paris, t. 27, p. 361. - Michelin, H., 1840-47, Icon. 200, p. 76, pl. 15, figs. 8a-8b.

Discoporella umbellata (Defrance). d'Orbigny, 1852, Paleo. Fr. T. Cret., t. 5, Bry., pp. 473-474, pl. 717, figs. 1-5. - Emmons, 1858, North Carolina Geol. Sur., Report Ag. east counties..., pp. 312-313, figs. 254-255.

Cupularia umbellata (Defrance). Canu and Bassler, 1923, U. S. Nat. Mus., Bull. 125, pp. 80-82, pl. 2, figs. 15-19. - Canu and Bassler, 1928. U. S. Nat. Mus., Proc., vol. 72, art. 14, p. 64, pl. 7, figs. 1-3.

Discoporella umbellata (Defrance). Hastings, 1930, Zool. Soc. London, Proc. (1929), pp. 718-719, pl. 11, fig. 54. - Osburn, 1950, Allan Hancock Pacific Exped., vol. 14, no. 1, pp. 113-114, pl. 11, figs. 7-10. - Lagaaij, 1953, Meded. Geol. Stichting (n.s.) no. 7, pp. 16-17, pl. 1, fig. 3. - Cheetham, 1964, Journ. Paleo., vol. 38, no. 6, p. 1022, text fig. 14. - Shier, 1964, Mar. Sci. Gulf and Carribbean, vol. 14, no. 4, p. 621.

Description of zoarium. - Zoaria range from nearly flat disks to deep cups; large (15 mm diameter); young zoaria often found encrusted on large shell fragments, stones, or foraminifers; zooecia in radial rows and irregular concentric rings from ancestrula; zooecia arranged in quincunx, new rows formed by bifurcation of zooecial rows; vibraculoecia distal to each zooecium, alternating with zooecia in each row; zooecia of central zoarium may be occluded. Basal side of radial, papillate, rows, becoming more papillate distally, rows moderately rounded separated by faint to well defined sutures.

Description of zooecia. - Autozooecia symmetric and unsymmetric rhombic, often rounded rhombic, proximal end indented by placement of vibraculoecium of preceeding zooecium; mural rim thin, sharp, fused with mural rim of adjoining zooecia, coarsely granular; cryptocyst well developed, formed of coalescing spinose projections from mural rim; cryptocyst coarsely granular to papillate, perforated by laterally positioned, irregular opesiules; opesium subelliptical, with surrounding rim, rim higher distally than proximally. Occluded zooecia covered with thickened cryptocyst; cryptocyst fills opesiules, opesium, bringing frontal surface to level of mural rim.

Vibraculoecia placed distally to opesium, depressed slightly, surrounded by faint mural rim; irregularly reniform; opesium reniform, alternating right-facing and left-facing along zooecial row.

Measurements
(average of 10 measurements per parameter)

Lz	0.40 mm	Lv	0.13 mm
lz	0.28 mm	lv	0.14 mm
ho	0.10 mm	hvo	0.09 mm
lo	0.13 mm	lvo	0.08 mm

zooecia width/length ratio	70%
zooecial opesia width/length ratio	130%
vibraculoecia width/length ratio	108%
vibraculoecial opesia width/length ratio	89%

Comparisons. - *Discoporella umbellata* is easily distinguished from *D. doma* and *D. denticulata* by the more widely developed cryptocyst.

Type material. - The present location of Defrance's material is not known.

Range and distribution. - Miocene, undifferentiated (subsurface): Superior Oil Producing Company, Arcadia Parish, Louisiana; Superior Oil Producing Company, East Baton Rouge Parish, Louisiana. - Chipola Formation: Chipola River, Calhoun County, Florida; Choctawhatchee Stage, Ecphora Biofacies: Jackson Bluff, Ochlockanee River, Leon County, Florida; Lake Talquin, Gadsden County, Florida; - Duplin Marl: Wilmington, New Hanover County, North Carolina; Natural Well, near Magnolia, Duplin County, North Carolina.

Miocene - Pliocene (?) (subsurface): Terrebone Gas Company, Terrebone Parish, Louisiana.

Recent: Mississippi Mud Lump SP 94, South Pass Area, Louisiana; tropical and subtropical waters of the Mediterranean, East and West Atlantic, East Pacific.

Type locality. - Italy.

Material examined. - Miocene, Choctawhatchee: five specimens from the Ecphora biofacies at Jackson Bluff, Leon County, Florida; 12 specimens from Lake Talquin, Gadsden County, Florida. Recent: 35 specimens from Mississippi Mud Lump SP 94, South Pass Area, Louisiana; approximately 350 specimens from Mississippi Sound Area, Gulf of Mexico.

Remarks. - Dr. P. L. Cook (personal communication) of the

British Museum (Natural History) has in manuscript a paper describing the subspecies of Discoporella umbellata, in which the Western Atlantic group will be separated.

Family Selenariidae Harmer, 1926

Genus SELENARIA Busk, 1854

Selenaria Busk, 1854, Cat. Mar. Poly. Brit. Mus., pt. II, London, p. 101. - Levinsen, 1909, Mor. syst. studies cheil. Bry., Copenhagen, p. 155. - Harmer, 1926, Poly. Siboga Exped., vol. 28b, pp. 312-313.

Type species. - Selenaria maculata Busk (1854, p. 101, pl. LXVII) (Original designation).

Diagnosis. - Lunulitiform zoarium; zooecia arranged in irregular rows, basal side of perforate, radial rows; opesia irregular, may be partly or entirely closed by cryptocyst; with opesiules or opesiular indentations; vibraculoecia asymmetric, may be covered with an arched, perforated lamina. Ovicells (reported by Levinsen, 1909, p. 155) endozooecial, positioned as low, rounded, pent-roof-shaped swellings.

Comparisons. - Selenaria is closely resembled by Otionella in the shape of vibraculoecia and the arrangement of zooecia, but Selenaria is distinguished by the more extensive cryptocyst forming opesiules or opesiular indentations, or the arched lamina over the vibraculoecia.

Range and distribution. - Eocene, Claiborne Group in Gulf Coast of the United States; Recent, southwest Pacific.

Remarks. - This genus is represented in the Gulf Coast by one rare species, Selenaria auricularia (Canu and Bassler, 1923). The many morphologic similarities of Otionella and Selenaria would indicate placement in the same family.

SELENARIA AURICULARIA Canu and Bassler, 1923

Plate III, figures 15-16

Selenaria auricularia Canu and Bassler, 1923, U. S. Nat. Mus. Bull. 125, pp. 59-60, fig. 5 a-c. - McGuirt, 1941, La. Geol. Sur., Bull. 21, p. 63, pl. 31, figs. 4, 7.

Description of zoarium. - Zoarium a broad, shallow cup (diameter/height ratio, 25%); zooecia in rows radial from ancestrula, interpolated rows initiated frequently but not always from vibraculoecia; vibraculoecia irregularly disposed among zooecia; zooecia grouped around each vibraculoecia. Basal side (description based on paralectotype) of radiating, finely textured, slightly convex rows separated by very narrow, shallow sutures; rows perforated by large pores distinctly arranged in two parallel lines. A secondary, irregularly perforated, calcareous layer exists on one specimen (Canu and Bassler, 1923, fig. 5b).

Description of zooecia. - Autozooecia symmetrically hexourceolate becoming hexagonal to elongate hexagonal when weathered; mural rim well developed, salient to imbricating distally, coarsely granular to papillate; cryptocyst very deep, narrow, with two very large opesiular indentations; opesia distal, indistinct from opesiular indentations. Occluded zooecia partly closed with expansion of cryptocyst; cryptocyst deep, of finer texture than mural rim, perforated with two lateral, rounded to irregular opesiules; opesia distal, subelliptical, some with slight rim. First zooecia of interpolated row-like autozooecia but elongate, pentagonal, pointed end proximal.

Vibraculoecia large, asymmetrical, broadly pyriform wide end proximal, small end distal and curved in clockwise direction; mural rim thin, high, standing above the zooecial mural rims; mural rim modified to condyle at reentrant.

Measurements
(average of 10 measurements per parameter)*

Lz	0.25 mm	Lv	0.34 mm
lz	0.28 mm	lv	0.26 mm
ho	0.09 mm		
lo	0.14 mm		

zooecia width/length ratio	110%
zooecial opesia width/length ratio	156%
vibraculoecia width/length ratio	76%

* average of 5 measurements on vibraculoecia

<u>Comparisons</u>. - Many species of <u>Selenaria</u> display auriculate or curved vibraculoecia. <u>S. auricularia</u> is characterized by the large vibraculoecia, clockwise curvature of the vibraculoecia, extensive cryptocyst, and the parallel line of

pores on the basal rows.

Type material. - Lectotype, here designated: specimen (USNM 68481) represented by Canu and Bassler's (1923) figure 5c; seven figured paralectotypes (USNM 68481).

Range and distribution. - Eocene, Claiborne Group, Cook Mountain Formation: St. Maurice, Winn Parish, Louisiana. - Gosport Sand: Claiborne Bluff, near Claiborne, Alabama.

Type locality. - Claiborne Bluff, near Claiborne, Alabama.

Material examined. - Lectotype and seven paralectotypes from Claiborne Bluff, near Claiborne, Alabama.

Genus OTIONELLA Canu and Bassler, 1917

Otionella Canu and Bassler, 1917, U. S. Nat. Mus., Bull. 96, p. 13. - Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, pp. 105-106.

Type species. - Otionella perforata Canu and Bassler (1917, pp. 13-14, pl. 1, figs. 3-4). (Original designation).

Diagnosis. - Lunulitiform zoarium of varying height; zooecia arranged in radial rows and irregular concentric rings from ancestrula, interpolated rows at distal end of vibraculoecial row; ratio of vibraculoecia to zooecia, 1:2, usually arranged with six zooecia clustered around each vibraculoecium; vibraculoecia asymmetric, "ear-shaped" or reniform, oriented with concave side pointing in the counterclockwise direction. Basal side of radial rows separated by sutures.

Comparisons. - Otionella closely resembles Selenaria, but is without the extensive development of the cryptocyst, opesiules or opesiular indentations which characterize Selenaria.

Range and distribution. - Eocene: Claiborne Group; Jackson Group (Gulf Coast).

Remarks. - Species of Otionella are commonly associated with other lunulitiform bryozoans in sandy deposits. O. cava seems restricted to a more limy facies.

OTIONELLA CAVA Canu and Bassler, 1920

Plate IV, figures 12-13

Otionella cava Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, p. 108, pl. 21, figs. 8-14.

Description of zoarium. - Zoarium a large (at least 10 mm in diameter) cup; frontal surface abraded, zooecia in radial and more or less tranverse rows; vibraculoecia irregularly distributed among zooecia; zooecia grouped six to eight around each vibraculoecia. Basal side not preserved, showing internal structure of zoarium; zooecial rows separated by straight, calcareous, papillate walls; interpolated rows of zooecia shown as bifurcation of calcareous wall.

Description of zooecia. - Detail of zooecia somewhat eroded; zooecia elongate; urceolate becoming elongate hexagonal when weathered; mural rim slightly salient distally, becoming indistinct with mural rim of adjoining zooecium laterally, nearly indistinct on badly worn specimens; cryptocyst finely granular, very thin proximally to absent or nearly absent distally; opesia irregular, elliptical to oval, narrow end usually proximal but may be reversed.

Vibraculoecia very large, unsymmetrical, elongate oval, wide end proximal, small distal and curved in clockwise direction; mural rim thin; single condyle at reentrant.

Measurements
(average of 10 measurements per parameter)*

Lz	0.38 mm	Lv	0.73 mm
lz	0.31 mm	lv	0.28 mm
ho	0.28 mm		
lo	0.19 mm		

zooecia width/length ratio	82%
zooecial opesia width/length ratio	68%
vibraculoecia width/length ratio	38%

* average of 4 measurements for vibraculoecia

Comparisons. - O. cava is readily distinguishable by the very large vibraculoecia.

Type material. - Lectotype, here designated: specimen (USNM 63876) represented by Canu and Bassler's (1920, pl. 21), fig. 10; three figured paralectotypes (USNM 63876).

Range and distribution. - Eocene, Jackson Group, Yazoo Clay: Suck Creek, Clarke County, Mississippi; Shubuta, Mississippi. - Ocala Limestone: 3 and one-fourth miles south of Perry, Georgia. - Barnwell Formation: Baldock, Barnwell County, South Carolina.

Material examined. - Lectotype and three paralectotypes, from Baldock, Barnwell County, South Carolina.

Type locality. - Baldock, Barnwell County, South Carolina.

Remarks. - Although the very large vibraculoecia of the lectotype would distinguish *O. cava* from other species of *Otionella*, the vibraculoecia of the specimen illustrated in Canu and Bassler's (1920) plate 21, fig. 9 are somewhat smaller. This specimen may be *O. tuberosa* Canu and Bassler, 1920. The non-calcareous basal side is not considered to be a taxonomic character but a result of preservation.

OTIONELLA PERFORATA Canu and Bassler, 1917

Plate IV, figures 8-9

Otionella perforata Canu and Bassler, 1917, U. S. Nat. Mus., Bull. 96, pp. 13-14, pl. 1, figs. 3-4; 1920, U. S. Nat. Mus., Bull. 125, pp. 106-107, pl. 11, figs. 7-19. - McGuirt, 1941, La. Geol. Sur., Bull. 21, p. 47, pl. 15, figs. 2, 7, 10. - Cheetham, Geol. Soc. Am., Mem. 91, p. 45 (in part).

Description of zoarium. - Zoarium a broad shallow cup, very slightly concave-convex; zooecia in irregular radial and concentric rows, interpolated rows at distal end of vibraculoecial rows; ancestrula like autozooecia; breaks along vibraculoecial rows; six zooecia grouped around each vibraculoecium. Basal side of radial, slightly rounded rows separated by sutures, interpolated rows marked by bifurcation of suture; rows perforated with medium to large, numerous pores, rows usually smooth, but may be somewhat papillate.

Description of zooecia. - Zooecia asymmetric, broadly sub-urceolate to scutiform, or urceolate; mural rim well defined, rounded, papillate, slightly salient; cryptocyst wide, granular; opesia rounded, rectangular, completely surrounded by a finely granular, rounded collar. First zooecium of interpolated row like autozooecia but symmetrically scutiform.

Vibraculoecia asymmetrical, elongate, oval, wide end proximal, narrow end distal and curving in clockwise direction; mural rim papillate, most prominent proximally; opesia unsymmetrical, elongate oval, like vibraculoecia; single, pointed condyle present at reentrant.

Measurements
(average of 10 measurements per parameter)

Lz	0.26 mm	Lv	0.31 mm
lz	0.29 mm	lv	0.13 mm
ho	0.11 mm	hvo	0.21 mm
lo	0.11 mm	lvo	0.07 mm

zooecia width/length ratio	110%
zooecial opesia width/length ratio	100%
vibraculoecia width/length ratio	42%
vibraculoecial opesia width/length ratio	33%

Comparisons. - *O. perforata* with papillate basal rows and larger vibraculoecia may be confused with *O. tuberosa*. However, it is distinguished by its more narrow vibraculoecia with pointed condyles, more prominently developed and granular cryptocyst and mural rim, and opesial collar.

Type material. - Lectotype, here designated: specimen (USNM 62571) represented by Canu and Bassler's (1920, pl. 11) fig. 11; eight paralectotypes (USNM 62571) figured by Canu and Bassler (1920, pl. 11) figs. 7-10, 12-19.

Range and distribution. - Eocene, Claiborne Group, Cook Mountain Formation: St. Maurice, Winn Parish, Louisiana; Saline Bayou, near Arcadia, Bienville Parish, Louisiana. - Lisbon Formation: Wautubbee Hills, 4 miles south of Enterprise, Mississippi. - Gosport Sand: Claiborne Bluff, near Claiborne, Alabama; Gopher Hill, Tombigbee River, Alabama; 1 mile southeast of Rockville, Clarke County, Alabama; Little Stave Creek, Clarke County, Alabama.

Eocene, Jackson Group, Moodys Branch Marl: Jackson, Mississippi; Montgomery, La Salle Parish, Louisiana; Gibson Landing, Caldwell Parish, Louisiana; Heison Bluff, Caldwell Parish, Louisiana; Bunker Hill, Caldwell Parish, Louisiana; Tullos, La Salle Parish, Louisiana; near Water Valley, Choctaw County, Alabama; Claiborne Bluff, near Claiborne, Alabama.

Type locality. - Jackson, Mississippi.

Material examined. - Lectotype and 8 paralectotypes (USNM 62571); Eocene, Jackson Group, Moodys Branch Marl: approximately 78 specimens from reference section, Jackson, Mississippi; approximately 63 specimens from near Water Valley, Choctaw County, Alabama; from Claiborne Bluff, near Claiborne, Alabama; 9 specimens from Montgomery, La Salle Parish, Louisiana.

Eocene, Claiborne Group, Gosport Sand: 60 specimens from Little Stave Creek, Clarke County, Alabama.

OTIONELLA TUBEROSA Canu and Bassler, 1920

Plate IV, figures 10-11

Otionella tuberosa Canu and Bassler, 1920. U. S. Nat. Mus., Bull. 106, p. 107, pl. 12, figs. 5-15. - McGuirt, 1941. La. Geol. Sur., Bull. 21, pp. 48-49, pl. 15, figs. 1, 5-6.

Otionella perforata Canu and Bassler, 1920. Cheetham, 1963. Geol. Soc. Am., Mem. 91, p. 45 (in part).

Description of zoarium. - Zoarium a broad, shallow cup; zooecia in irregular radial and concentric rows; new radiate rows irregularly interpolated; ancestrula like autozooecia; breaks along vibracular rows or between zooecia; six zooecia grouped about each vibraculoecium. Basal side of radial, gently rounded rows separated by sutures; rows finely to coarsely papillate, some parts of zoarium smooth; may be finely perforate; end of some rows slightly hollowed; interpolation of new zooecial rows easily seen on basal side as bifurcation of suture.

Description of zooecia. Zooecia irregular, most symmetrically hexagonal to hexo-urceolate, some irregularly scutiform or elongate to sub-hexagonal, mural rim small, rising sharply to mural rim of adjacent zooecium, indistinct from cryptocyst; cryptocyst finely granular, widest proximally, narrow laterally, and absent or nearly absent distally; opesia irregular; most symmetrically oval, widest end proximal; some rounded hexagonal and sub-hexagonal; slight peristome present around some opesia.

Vibraculoecium large, unsymmetrical, oval, wide end proximal, narrow end distal and carved in clockwise direction; mural rim rounded, cryptocyst absent, opesium shaped like vibraculoecium; single condyle at reentrant.

Measurements
(average of 10 measurements per parameter)

Lz	0.32 mm	Lv	0.48 mm
lz	0.32 mm	lv	0.30 mm
ho	0.18 mm	hvo	0.38 mm
lo	0.16 mm	lvo	0.22 mm

zooecia width/length ratio	100%
zooecial opesia width/length ratio	89%
vibraculoecia width/length ratio	63%
vibraculoecial opesia width/length ratio	58%

Comparisons. O. tuberosa was separated from O. perforata by Canu and Bassler on differences in the texture of the basal side and the size of vibraculoecia. However, the character of the basal side is highly variable in both species. Some specimens of O. tuberosa are quite smooth, others grade into coarsely papillate forms; many are finely perforate. Specimens of O. perforata may be smooth or somewhat papillate. Some specimens exhibit both smooth and papillate areas on a single zoarium. In this respect, the character of the basal surface is of poor diagnostic value. The size and shape of the vibraculoecia are reliable, distinguishing features. The vibraculoecia of O. tuberosa are 1½ times as long as the zooecia and have a more pronounced curvature of the narrow end than does O. perforata. The vibraculoecia of O. perforata are about the same length as the zooecia, more slit-like, and less prominently curved.

The specimens from the Ocala Limestone, Claiborne Bluff, Alabama, are without the basal calcareous deposit, and identification is based on characters of the vibraculoecia.

Type material. - Lectotype, here designated: specimen (USNM 63841) represented by Canu and Bassler's (1920, pl. 12) fig. 11; 10 paralectotypes (USNM 63841) figured by Canu and Bassler (1920, pl. 12, figs. 5-10, 12-15).

Range and distribution. - Eocene, Claiborne Group, Cook Mountain Formation: Moseleys Ferry, Caldwell County, Texas.

Eocene, Jackson Group, Moodys Branch Marl: Jackson, Mississippi; near Water Valley, Choctaw County, Alabama; Montgomery, Louisiana; Bunker Hill, Louisiana; Gibson Landing, Caldwell Parish, Louisiana; Grandview Bluff, Caldwell Parish, Louisiana; Heison Bluff, Caldwell Parish, Louisiana; Stock Landing, Caldwell Parish, Louisiana. - Upper Marl Member, Danville Landing Shale: Danville Landing, Catahoula Parish, Louisiana. - Ocala Limestone: Claiborne Bluff, Alabama. Yazoo Clay: south side of Suck Creek, Clarke County, Mississippi.

Type locality. - Moodys Branch Marl, Jackson, Mississippi.

Material examined. - Lectotype (USNM 63841) and ten paralectotypes (USNM 63841), approximately 125 topotypes; 23 specimens from the Eocene Jackson Group, Ocala Limestone, Claiborne Bluff, Alabama; 3 specimens from the Eocene, Jackson Group, Moodys Branch Marl, Choctaw County, Alabama.

OTIONELLA NEW SPECIES #1

Plate V, figures 1-2

Description of zoarium. - Zoarium a large (maximum diameter, 8.0 mm, from reconstruction), broad cup, zooecia in irregular radial and concentric rows, interpolated rows at distal end of vibraculoecial rows; breaks along vibraculoecial rows; six zooecia grouped around each vibraculoecium.

Basal side of radial, slightly rounded rows, separated by sutures, rows perforated with numerous, large pores.

Description of zooecia. - Zooecia asymmetric, broadly sub-urceolate to urceolate; mural rim well defined, absent distally, moderately papillate, well set off from cryptocyst; cryptocyst wide, absent distally, granular; opesia rounded rectangular to elliptical, distally bordered by a smooth, rounded bar extending from right-lateral mural rim to left-lateral mural rim; outer concentric zooecial rows without distal bar structure.

Vibraculoecia only slightly asymmetrical, large, with indistinct mural rim; vibraculoecia more like a cavity among zooecia than a distinct calcareous structure.

Measurements
(average of 10 measurements per parameter)

Lz	0.25 mm	Lv	0.27 mm
lz	0.27 mm	lv	0.13 mm
*ho	0.12 mm		
*lo	0.11 mm		

zooecia width/length ratio	108%
zooecial opesia width/length ratio	92%
vibraculoecia width/length ratio	48%

* measurements of zooecia with distal bar structure.

Comparisons. - Otionella new species #1 is closely resembled by Otionella perforata but is distinguished by the bar structure bordering the zooecial opesium distally.

Type material. - Holotype and two paratypes, Greeley Collection.

Range and distribution. - Eocene, Claiborne Group: Wautubbee Formation, intersection of Interstate 20 and Mississippi Highway 15, Newton County, Mississippi.

Type locality. - Road cut on east side of Mississippi Highway 15, north at intersection with Interstate 20, SE¼, SE¼, Sec. 23, T. 6 N., R. 11 E., Newton County, Mississippi.

Material examined. - Holotype and two paratypes.

Family Lunulitidae Lagaaij, 1952

Genus LUNULITES Lamarck, 1816

Lunulites Lamarck, 1816, Hist. Nat. Anim. sans Vert., 1st. ed., vol. 2, pp. 194-195.

Reptplunulites d'Orbigny, 1852, Paleo. Fr. t. Cret., p. 356. - Bassler, 1935, Fossilium Cat., pars 67, p. 185.

Pavolunulites d'Orbigny, 1852, Paleo. Fr. t. Cret.

Trochopora d'Orbigny, 1853, Paleo. Fr. t. Cret., p. 506.

Lunularia Busk, 1884, Rept. Vog. H. M. S. Challenger, Zoo. - Poly., p. 208.

Type species. - *Lunulites radiata* Lamarck, 1816, p. 195 (subsequent designation, Gregory, 1893, p. 233).

Diagnosis. - Lunulitiform zoarium; zooecia in regular radial rows and concentric rings, alternating with radial and concentric rows of vibraculoecia; zooecia and vibraculoecia equal in number; zooecia usually symmetrical, with cryptocyst symmetrical opesia, and mural rim; zooecia may be occluded; basal side usually of radial rows separated by sutures, may be without rows, smooth; zoarium may be built of successive disks, resulting in a "solid" zoarium.

Comparisons. - Lunulites is closely resembled by Oligotresium; however, the vibraculoecial:zooecial ratio of 1:1 for Lunulites distinguishes it from Oligotresium with a ratio of 1:2.

Range and distribution. - Gulf and Atlantic Coastal Plains: Paleocene, Midway Group to Oligocene, Vicksburg Group.

Recent species were identified from waters near Eden, New South Wales, Australia.

Remarks. - Several references (Dartevelle, 1952; Canu, 1900; Gabb and Horn, 1862; d'Orbigny, 1852) have been made to Lunulites Lamarck, 1801; however, Dr. Bernhard Kummel, of the Museum of Comparative Zoology, Harvard University (personal communication), checked the entire volume of Lamarck (1801) and did not encounter Lunulites.

LUNULITES ALMINA De Gregorio, 1890

Lunulites (Discoflustrellaria) bouei almina De Gregorio, 1890, Ann. Geol. Pal., Liv. 7-8, p. 246, pl 42, figs. 7-10.

Trochopora bouei (Lea). Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, p. 103, pl. 10, figs. 1-17 (in part).

Description of zoarium. - Zoarium a shallow cup; height/diameter ratio, 40%; many zoaria showing regeneration, zooecia disposed in radiating rows and concentric rings; interpolation of rows beginning with bifurcation of vibracular row with two pairs of parallel vibracular opesia preceeding first zooecium of new zooecial row; some occluded zooecia of ancestrula region perforated by small pore; vibraculoecial: zooecial ratio 1:1; zoaria break along zooecial rows. Basal face of coarsely papillate rows; rows divided by longitudinal, parallel lines of papillae; ends of some rows hollowed.

Description of zooecia. - Zooecia rounded rectangular to distally ogival, some urceolate; mural rim very thick, slightly granular, moderately salient distally; cryptocyst thin, more coarsely granular than mural rim, may be absent on abraded specimens; opesia rectangular, slightly rounded, proximal end of many sharpely squared. Occluded zooecia like autozooecia but partly closed by fine calcareous material, central part of occlusion with pore similar to vibracular opesia.

Vibraculoecia fusiform, connected by a broad canal; opesia fusiform to rounded rectangular, some constricted centrally by slight protuberances which may be condyles.

Measurements
(average of 10 measurements per parameter)

Lz	0.34 mm	Lv	0.30 mm
lz	0.30 mm	lv	0.15 mm
ho	0.20 mm	hvo	0.13 mm
lo	0.12 mm	lvo	0.16 mm

zooecia width/length ratio	88%
zooecial opesia width/length ratio	60%
vibraculoecia width/length ratio	50%
vibraculoecial opesia width/length ratio	46%

Comparisons. - *Lunulites almina* closely resembles *L. bouei* in the imbrication of the zooecia, vibraculoecial similarities, and breakage along zooecial rows. However, it is distinguished by the rectangular zooecia and opesia.

Type material. - The present location of De Gregorio's type material is not known.

Range and distribution. - Eocene, Claiborne Group: undifferentiated Claiborne, Claiborne Bluff, near Claiborne, Alabama; Gosport Sand, Little Stave Creek, Clarke County, Alabama.

Type locality. - Claiborne Bluff, near Claiborne, Alabama.

Material examined. - Seventeen specimens from the Gosport Sand, Little Stave Creek, Clarke County, Alabama.

LUNULITES BASSLERI (McGuirt) 1941

Plate I, figures 15-16

Reptolunulites bassleri McGuirt, 1941, La. Geol. Sur., Bull. 21, p. 60, pl. 17, figs. 1-2, 9.

Description of zoarium. - Zoarium a broad disk, slightly concave-convex, large (diameter, 16 mm or greater), breaks irregularly along vibracular rows; zooecia in radial rows from ancestrula, interpolation of rows not initiated by modified zooecium at distal end of vibraculoecial row; vibraculoecial:zooecial ratio 1:1 as typical for genus. Basal side of papillate, radial rows, separated by pronounced furrow; rows distinctly perforated with numerous large pores; pores on some specimens becoming distally fewer, and smaller.

Description of zooecia. - Autozooecia large, oval to urceolate or suburceolate; mural rim moderate, slightly salient to somewhat moderately imbricating distally; opesia oval to broadly urceolate, some constricted laterally, cryptocyst slight to absent, finely granular.

Vibraculoecia pyriform, not connected by furrow or canal; opesia broadly clithrididate, much rounded proximally, constricted distally by two slight lateral condyles, condyles without fossettes; smooth cryptocyst slightly developed between condyles.

Measurements
(average of 10 measurements per parameter)

Lz	0.51 mm	Lv	0.22 mm
lz	0.44 mm	lv	0.15 mm
ho	0.39 mm	hvo	0.15 mm
lo	0.25 mm	lvo	0.11 mm

zooecia width/length ratio	86%
zooecial opesia width/length ratio	64%
vibraculoecia width/length ratio	68%
vibraculoecial opesia width/length ratio	73%

Comparisons. - *Lunulites bassleri* is distinguished from *L. montgomeryensis* by the larger dimensions, lack of cryptocyst, and more papillate basal surface.

Type material. - Holotype, McGuirt Collection #1306, deposited with Louisiana State University, School of Geology Museum, Baton Rouge, Louisiana.

Range and distribution. - Eocene, Jackson Group, Moodys Branch Marl: Jackson, Hinds County, Mississippi; Riverside Park, Jackson, Hinds County, Mississippi; Tcheva Creek, Yazoo County, Mississippi; Montgomery Landing, La Salle Parish, Louisiana.

Type locality. - Montgomery Landing, La Salle Parish, Louisiana.

Material examined. - Six specimens from Moodys Branch Marl, Jackson, Hinds County, Mississippi; 75 specimens from Riverside Park, Jackson, Hinds County, Mississippi; three specimens from Tcheva Creek, Yazoo County, Mississippi; 31

specimens from Montgomery Landing, La Salle Parish, Louisiana.

LUNULITES BOUEI Lea 1833

Plate I, figures 7-8

Lunulites bouei Lea, 1833. Cont. Geol., pp. 189-190, pl. 6, fig. 202.

L. duclosii Lea, 1833. Cont. Geol., pp. 190-191, pl. 6, fig. 203.

L. (Discoflustrellaria) bouei (Lea). DeGregorio, 1890. Ann. Geol. et. Paleo. Liv. 7-8, pp. 243-244, pl. 41, figs. 1-9, pl. 42, figs. 1-6.

L. (D.) bouei var. _duclosii_ (Lea). DeGregorio. Ann. Geol. et Paleo. Liv. 7-8, p. 245, pl. 41, figs. 26-33.

L. (D.) bouei var. _concava_ DeGregorio, 1890. Ann. Geol. et Paleo. Liv. 7-8, p. 244, pl. 41, figs. 10-14.

L. (D.) bouei var. _depressa_ DeGregorio (not Conrad, 1941), 1890. Ann. Geol. et Paleo. Liv. 7-8, p. 244, pl. 41, figs. 15-19

L. (D.) bouei var. _tiza_ DeGregorio, 1890. Ann. Geol. et Paleo. Liv. 7-8, p. 246, pl. 42, figs. 11-12.

Discoflustrellaria bouei (Lea). Gabb and Horn, 1862. Phil. Acad. Nat. Sci., Jour., ser. 2, vol. 5, pt. 2, pp. 154-155.

Heteractis duclosii (Lea). Gabb and Horn, 1862. Phil. Acad. Nat. Sci., Jour., ser. 2, vol. 5, pt. 2, pp. 156-157, pl. 20, fig. 39.

Trochopora bouei (Lea). Canu and Bassler, 1920. U. S. Nat. Mus., Bull. 106, p. 103, pl. 10, figs. 1-17.

Description of zoarium. - Zoarium varies from a shallow, nearly flat cup to a high, solid dome; zooecia in concentric and radial rows from ancestrula; interpolated rows originating from split vibracular rows, often preceeded by two parallel vibraculooecia; zooecia of ancestrular area often occluded by calcareous layer perforated by single pore; vibraculoecial:zooecial ratio, 1:1. Basal side of radial rows separated by indistinct sutures; rows strongly papillate, imperforate. Zoaria with filled concavity without radial rows; basal surface evenly papillate.

Description of zooecia. - Autozooecia suburceolate, symmetrical, some ogival distally; mural rim very prominent, strongly imbricate distally, coarsely granular to papillate; cryptocyst very thin to absent; opesia oval, wide end proximal, narrow end distal. First zooecium of interpolated row like autozooecia but elongate pyriform. Occluded zooecia may occupy entire zoarium; like autozooecia but opesia covered with smooth calcareous layer; mural rims prominent; occlusion with single, irregular, large pore.

Vibraculoecia fusiform, connected by broad, deep canal; opesia elongate elliptical, constricted laterally by two slight condyles; some with indistinct mural rim.

Measurements
(average of 10 measurements per parameter)

Lz	0.34 mm	Lv	0.31 mm
lz	0.33 mm	lv	0.15 mm
ho	0.27 mm	hvo	0.16 mm
lo	0.19 mm	lvo	0.07 mm

zooecia width/length ratio	97%
zooecial opesia width/length ratio	70%
vibraculoecia width/length ratio	48%
vibraculoecial opesia width/length ratio	44%

Comparisons. - The strongly imbricating zooecia and papillate, imperforate basal side distinguish *Lunulites bouei* from other species of *Lunulites*.

Type material. - The present location of Lea's type material is not known.

Range and distribution. - Eocene, Claiborne Group - Claiborne undifferentiated: Claiborne Bluff, near Claiborne, Alabama. Tallahatta Formation: Souwilpa Creek, four miles south of Gilbertown, Choctaw County, Alabama; Winona Formation: Souwilpa Creek, Choctaw County, Alabama. Lisbon Formation: Wautubbee Hills, four miles south of Enterprise, Clarke County, Mississippi; Little Stave Creek, near Jackson, Clarke County, Alabama; Claiborne Bluff, near Claiborne, Monroe County, Alabama. Cook Mountain Formation: Moseleys Ferry, Caldwell County, Texas; Sabine Parish, Louisiana; St. Maurice, Winn Parish, Louisiana; Wheelock Member, Burleson County, Texas; Stone City Beds: 10 miles west of Bryan, in Burleson County, Texas. Gosport Sand: Claiborne Bluff; Gopher Hill, Tombigbee River, Alabama; one mile southwest of Rockville, Clarke County, Alabama; Little Stave Creek, near Jackson, Clarke County, Alabama.

Eocene, Jackson Group - Moodys Branch Marl: - Jackson, Hinds County, Mississippi; three and one-half miles southwest of Shell Bluff Post Office, Georgia; Gibson Landing, Caldwell Parish, Louisiana; Bunker Hill, Caldwell Parish, Louisiana; Grandview and Heison Landing, Caldwell Parish, Louisiana; Tullos, La Salle Parish, Louisiana; Montgomery Landing, La Salle Parish, Louisiana; Tcheva Creek, Yazoo County, Mississippi; Claiborne Bluff, near Claiborne, Monroe County, Alabama; near Water Valley, Choctaw County, Alabama.

Oligocene, Vicksburg Group - Red Bluff Marl: Hiwannee, Wayne County, Mississippi.

Type locality. - Claiborne Bluff, near Claiborne, Monroe County, Alabama.

Material examined. - Four specimens from the Tallahatta Formation, Souwilpa Creek, four miles south of Gilbertown, Alabama; two specimens from Winona Formation, Souwilpa Creek, Choctaw County, Alabama; four specimens from Stone City Beds, 10 miles west of Bryan, in Burleson County, Texas; 12 specimens from Wheelock Member, Burleson County, Texas; seven specimens from Lisbon Formation, Claiborne Bluff, Monroe County, Alabama; approximately 200 specimens from Lisbon Formation, Little Stave Creek, Clarke County, Alabama; approximately 400 specimens from Gosport Sand, Little Stave Creek, Clarke County, Alabama; approximately 254 specimens from Moodys Branch Marl, Jackson, Hinds County, Mississippi; six specimens from Moodys Branch Marl, Tcheva Creek, Yazoo County, Mississippi; 29 specimens from Moodys Branch Marl, Montgomery Landing, La Salle Parish, Louisiana; approximately

80 specimens from Moodys Branch Marl, Claiborne Bluff, Monroe County, Alabama; 47 specimens from Moodys Branch Marl, Choctaw County, Alabama.

LUNULITES DISTANS Lonsdale, 1845

Plate I, figures 3-4

Lunulites distans Lonsdale, 1845, Geol. Soc. of London, Quart. Jour., vol. I, p. 531, 3 text figs. - Gabb and Horn, 1862, Phil. Acad. Nat. Sci., Jour., ser. 2, vol. 5, pt. 2, pp. 119-120, pl. 19, fig. 4. - De Gregorio, 1890, Ann. Geol. Paleont., Liv. 7-8, p. 250, pl. 42, fig. 29. - Cheetham, 1963, Geol. Soc. Am., Mem. 91, p. 49, pl. 1, figs. 15-17.

Lunularia distans (Lonsdale). Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, pp. 245-247, pl. 38, figs. 1-20.

Description of zoarium. - Zoarium varies from a shallow cup to a high cone, some casts of the concave side very large (diameter, 5 cm); zooecia in radial and concentric rows from ancestrula; interpolated rows at distal end of vibracular row; zooecia increase slightly in size distally; zooecia in ancestrula region occluded on some zoaria; breaks very irregularly, usually along vibracular rows; vibraculoecial:zooecial ratio, 1:1 as typical for genus. Basal side leached away; however, fossil molds of concave side indicate basal side composed of radial, slightly rounded rows, separated by deep sutures, perforated by scattered pores.

Description of zooecia. - Autozooecia suburceolate; mural rim thin laterally, broad and slightly salient distally;

cryptocyst fine, prominently developed proximally, absent or nearly absent distally; opesia rounded rectangular to ogival distally, rounded rectangular proximally, may be serrate. First zooecia of interpolated row like autozooecia but pyriform. Occluded zooecia covered with coarsely papillate calcareous deposit. Ancestrula large, oval, cryptocyst well developed, opesium like autozooecia.

Vibraculoecia very small, fusiform, surrounded by slight collar ending distally in two lateral condyles, opesium clithridiate.

Measurements
(average of 10 measurements per parameter)

Lz	0.39 mm	Lv	0.28 mm
lz	0.42 mm	lv	0.15 mm
ho	0.20 mm	hvo	0.13 mm
lo	0.17 mm	lvo	0.06 mm

zooecial width/length ratio	101%
zooecia opesial width/length ratio	85%
vibraculoecial width/length ratio	53%
vibraculoecia opesial width/length ratio	46%

Comparisons. - This species is distinguished by the rounded rectangular opesium and small vibraculoecia.

Type material. - The present location of Lonsdale's type material is not known. Twenty-one figured topotypes, USNM 63997, 63998 (Canu and Bassler, 1920, pl. 38, figs. 1-20).

Range and distribution. - Eocene, Jackson Group, - Moodys Branch Marl: 10 miles west of Gilbertown, Choctaw County, Alabama; Bluff south side of Suck Creek, Clarke

County, Mississippi; - Ocala Limestone: Claiborne Bluff, near Claiborne, Monroe County, Alabama; west bank of Sepulga River, Escambia County, Alabama; - Castle Hayne Limestone: Wilmington, New Hanover County, North Carolina.

Oligocene, Vicksburg Group, Marianna Limestone: one mile north of Monroeville, Monroe County, Alabama; west bank of Conecuh River, Escambia County, Alabama.

Type locality. - Near Wilmington, New Haven County, North Carolina.

Material examined. - Five specimens from the Moodys Branch Marl, Choctaw County, Alabama; 11 specimens from Ocala Limestone, Claiborne Bluff, Monroe County, Alabama; 43 topotypes (Greeley Collection) and 18 topotypes (USNM 63997) from Castle Hayne Limestone, near Wilmington, New Haven County, North Carolina; three specimens (USNM 63998) from Marianna Limestone, Monroe County, Alabama.

LUNULITES FENESTRATUS De Gregorio, 1890

Plate I, figures 1-2

Lunulites (Dimiclausa) fenestrata De Gregorio, 1890, Ann. Geol. Pal., Liv. 7-8, p. 249, pl. 42, figs. 23-27.

L. fenestrata (De Gregorio). Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, pp. 244-245, pl. 37, figs. 10-13 (in part).

Description of zoarium. - Zoarium varies from a broad shallow cup to a high (height/diameter, 50%) solid dome; zooecia in concentric rings and radial rows from ancestrula; interpolated rows originate from symmetrical zooecium at distal end of vibracular row; zooecia of ancestrular area partly occluded by calcareous layer perforated by four holes; vibraculoecial:zooecial ratio, 1:1. Basal side of irregular, mildly rounded, smooth to slightly granular rows separated by deep sutures; rows perforated by scattered pores; ends of some rows scooped out.

Description of zooecia. - Autozooecia mostly semilunar, some broadly urceolate; mural rim moderately thick, papillate laterally, less developed distally; cryptocyst coarsely granular, most prominent proximally; opesia subelliptical, slightly squared proximally, surrounded by well defined rim. First zooecia of interpolated row-like autozooecia but broadly pyriform; mural rim not prominent. Occluded zooecia occupying first 2 to 4 tiers of zooecia from ancestrula, like autozooecia but opesia partly closed by calcareous layer perforated by four holes, mural rim not well defined.

Vibraculoecia fusiform, some connected by broad canal; opesia broadly clithridiate, much rounded proximally, constricted distally by two lateral condyles.

Measurements
(average of 10 measurements per parameter)

Lz	0.23 mm	Lv	0.20 mm
lz	0.25 mm	lv	0.10 mm
ho	0.13 mm	hvo	0.10 mm
lo	0.11 mm	lvo	0.053 mm

zooecia width/length ratio	109%
zooecial opesia width/length ratio	85%
vibraculoecial width/length ratio	50%
vibraculoecia opesial width/length ratio	53%

Comparisons. - Lunulites fenestratus is easily recognized by the occluded zooecia of the ancestrular region perforated with four holes. From Oligotresium #2 it may be distinguished by the vibraculoecial:zooecial ratio of 1:1. It resembles closest some specimens of Lunulites ligulatus Canu and Bassler in which the "tongue" or radial bar is joined by two transverse calcareous projections, giving the appearance of an occluded zooecium with four perforations. However, the larger dimensions of L. fenestratus and the more complete calcification of the occluded zooecia will separate it from L. ligulatus.

Type material. - The present location of De Gregorio's type material is not known.

Range and distribution. - Eocene, Claiborne Group: Claiborne undifferentiated, Claiborne Bluff, near Claiborne, Alabama; Cook Mountain Formation, Wheelock Member, Burleson County, Texas.

Type locality. - Claiborne Bluff, near Claiborne, Alabama.

Material examined. - Five specimens from the Wheelock Member of the Eocene, Cook Mountain Formation, from Burleson County, Texas.

LUNULITES GRANDIPORA (Canu and Bassler), 1920

Plate II, figures 7-8

Lunularia grandipora Canu and Bassler, 1920. U. S. Nat. Mus. Bull. 106, p. 242, pl. 12, figs. 3, 4.

Description of zoarium. - Zoarium probably a shallow cup (description based on two broken specimens), breaking along vibracular rows, zooecia in radial rows; interpolated rows from either modified individual at distal end of vibracular row or by bifurcation of zooecial row; vibraculoecial: zooecial ratio, 1:1 as typical for genus. Basal side of irregular radiating rows, separated by narrow, shallow sutures; rows non-perforate, strongly papillate to knobby; average width of rows, 0.34 mm.

Description of zooecia. - Zooecia irregularly elliptical to elongate urceolate, unsymmetrical; cryptocyst absent; mural rim with sharp summit, slightly salient distally; opesium oval, unsymmetrical, crenulated proximally. Endozooecial ovicell a distal concavity of mural rim.

Vibraculoecia broadly pyriform to broadly fusiform; opesia broadly oval, constricted distally by two slight lateral condyles, surrounded by very thick, papillate collar.

Measurements
(average of 10 measurements per parameter)

Lz	0.48 mm	Lv	0.27 mm
lz	0.36 mm	lv	0.18 mm
ho	0.31 mm	hvo	0.12 mm
lo	0.19 mm	lvo	0.079 mm

zooecial width/height ratio	75%
zooecial opesia width/height ratio	61%
vibraculoecia width/height ratio	67%
vibraculoecial opesia width/height ratio	66%

Comparisons. - Lunulites grandipora resembles L. bassleri in that the zooecia are very large and the cryptocyst narrow. However, Lunulites grandipora is distinguished by the much larger zooecial dimensions and the strongly papillate, non-perforate inner face, and the thick collar around the vibraculoecia.

Type material. - Lectotype, here designated: specimen represented by Canu and Bassler's (1920, pl. 12) figure 3. Although the caption for figure 3 and figure 4 states that both photographs are of the holotype, these are two different specimens. The two specimens carried on the label are designated as cotypes (=syntypes), USNM #63840. Under these circumstances, it is mandatory that a lectotype be selected.

Range and distribution. - Eocene, Claiborne Group: Lisbon Formation, Wautubbee Hill, four miles south of Enterprise, Clarke County, Mississippi; Winona Formation, Souwilpa Creek, Choctaw County, Alabama.

Type locality. - Lisbon Formation, Wautubbee Hill, four miles south of Enterprise, Clarke County, Mississippi.

Material examined. - Type material and two specimens from the Winona Formation, Souwilpa Creek, Choctaw County, Alabama.

Remarks. - Canu and Bassler questionably placed this species in Lunularia (=Lunulites). They stated that the large opesium and endozooecial ovicell bear strong affinities with the membranipores. However, the zoarial form, disposition and symmetry of the vibraculoecia, and the familiar inner face clearly place L. grandipora in the genus Lunulites. Possession of ovicells, lack of cryptocyst, and stratigraphic position might indicate a primitive species.

LUNULITES JACKSONENSIS (Canu and Bassler), 1920

Plate II, figures 13-14

Lunularia jacksonensis Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, pp. 250-251; pl. 37, figs. 19-22.

Reptolunulites jacksonensis (Canu and Bassler). McGuirt, 1941, La. Geol. Sur., Bull. 21, p. 56, pl. 17, figs. 3, 11.

Description of zoarium. - Zoarium a shallow cup with frontal slightly convex, outline varies from circular to elliptical; growth initiated by radial rows of zooecia from ancestrula, interpolation of subsequent rows from modified individual; zooecia in approximate concentric annular rows; rows of vibracula alternate with the zooecia' vibraculoecial:zooecial ratio 1:2 as typical for genus.

Inner, concave, face composed of radial rows (corresponding to rows of zooecia on the frontal surface); rows moderately rounded and separated by deep sutures, coarsely papillate, perforated by large, scattered pores, ends of some of the rows slightly hollowed. Interpolation of the radial rows of zooecia clearly seen by the ramose sutures on the inner face.

Description of zooecium. - Autozooecia broadly oval, distal end of mural rim slightly salient, tending to cover proximal part of mural rim of succeeding zooecium; mural rim coarsely granular, not prominent; cryptocyst moderately developed, texture finer than mural rim, not deep, evanescent with mural rim distally; opesia ogival distally, rounded-rectangular proximally, rim very slightly developed in some. Vibraculoecia fusiform not connected by canal, cryptocyst smooth, collar-shaped, open, distally ending in two lateral condyles; opesium pyriform, constricted distally by the condyles. Occluded zooecia in ancestrular region numerous (may comprise half the colony), with same characters as autozooecia but covered by calcareous layer described by Canu and Bassler as olocyst.

Measurements
(average of 10 measurements per parameter)

Lz	0.37 mm	Lv	0.26 mm
lz	0.34 mm	lv	0.16 mm
ho	0.25 mm	hvo	0.14 mm
lo	0.18 mm	lvo	0.075 mm

zooecia width/length ratio	92%
zooecial opesia width/length ratio	72%
vibraculoecia width/height ratio	62%
vibraculoecial opesia width/height ratio	54%

Comparisons. - *Lunulites jacksonensis* closely resembles *L. tintinabula*, but differs from it by not having a prominent distal semi-lunar thread on the occluded zooecia and by having condyles which are more rounded.

Type material. - Lectotype, here designated: specimen (USNM 63996) represented by Canu and Bassler's (1920, pl. 37) figure 21; seven figured paralectotypes (USNM 63996).

Range and distribution. - Eocene, Jackson Group, Moodys Branch Marl: Jackson, Mississippi; Montgomery, La Salle Parish, Louisiana; Tullos, La Salle Parish, Louisiana; Stock Landing, Caldwell Parish, Louisiana; Gibson Landing, Caldwell Parish, Louisiana; Heison Bluff, Caldwell Parish, Louisiana; Grandview Bluff, Caldwell Parish, Louisiana.

Type locality. - Jackson, Mississippi.

Material examined. - Lectotype and seven paralectotypes; 18 topotypes; 150 specimens from Riverside Park, Jackson, Mississippi; four specimens from Montgomery, La Salle Parish, Louisiana.

Remarks. - Although Canu and Bassler (1920, p. 250) state that *Lunulites jacksonensis* has a non-perforate base, the type specimens do have small, scattered pores.

LUNULITES LIGULATUS (Canu and Bassler), 1920

Plate II, figures 3-4

Lunularia ligulata Canu and Bassler, 1920. U. S. Nat. Mus., Bull. 106, pp. 243-244, pl. 13, figs. 10-12.

Reptolunulites ligulata (Canu and Bassler). McGuirt, 1941, La. Geol. Sur., Bull. 21, p. 58, pl. 7, figs. 1, 4, 6, 10, pl. 18, fig. 1.

Description of zoarium. - Zoarium a shallow (height/diameter ratio, 33%) thick-walled cup; zooecia in radial rows and concentric rings about the ancestrula; interpolated rows from modified individual at distal end of vibracular row; breaks along vibracular rows; zooecia of central area partly occluded by longitudinal bar or "tongue" and secondary calcification over cryptocyst; occluded zooecia may constitute half of zoarium; vibraculoecial:zooecial ratio, 1:1. Basal side of moderately papillate rounded rows, irregularly radial from center, about 0.19 mm wide, separated by sutures, lightly perforated with scattered pores, of finely granular material; interpolation of zooecial rows seen as bifurcation of sutures; ends of some rows slightly hollowed.

Description of zooecia. - Autozooecia symmetrical, sub-urceolate to broadly urceolate or oval, narrow end distal; mural rim well developed, moderately granular, slightly salient; cryptocyst deep proximally, moderately granular, rising to mural rim laterally toward distal end, absent at distal end; opesium broadly oval, narrow end distal, to nearly round, surrounded by slight rim. First zooecium of interpolated row like autozooecia but broadly pyriform and cryptocyst more prominent proximally. Occluded zooecia with calcareous bar or "tongue" extending from proximal margin, bar may extend to and fuse with distal margin of zooecium; two elongate pores flank bar laterally (remaining part of opesium); lateral calcification from bar may produce four pores on some zooecia; secondary calcareous material fills rest of zooecium to level or nearly to level of mural rim.

Vibraculoecia deep-set, indistinctly fusiform, connected by broad, deep canal; opesium clithridiate, narrowed distally by two slight lateral condyles, without collar or rim, condyles without fossettes.

Measurements
(average of 10 measurements per parameter)

Lz	0.21 mm	Lv	0.17 mm
lz	0.22 mm	lv	0.07 mm
ho	0.11 mm	hvo	0.10 mm
lo	0.095 mm	lvo	0.05 mm

zooecia width/length ratio	105%
zooecial opesia width/length ratio	85%
vibraculoecia width/length ratio	41%
vibraculoecial opesia width/length ratio	50%

Comparisons. - Lunulites ligulatus is closely resembled by L. #1 and Oligotresium #2, all of which have a calcareous "tongue" on the central zooecia. It differs from O. #2 by having smaller vibraculoecia and a vibraculoecial:zooecial ratio of 1:1. From Lunulites #1 it is distinguished by its papillate and perforate basal side and slightly smaller zooecial and opesial dimensions.

Type material. - Lectotype, here designated: specimen (USNM 63846) represented by Canu and Bassler's (1920, pl. 13) figure 10; two figured and two unfigured paralectotypes (USNM 63846).

Range and distribution. - Eocene, Jackson Group, Moodys Branch Marl: original type locality, Jackson, Hinds County, Mississippi; Riverside Park, Jackson, Hinds County, Mississippi; 3½ miles southeast of Shell Bluff post office, Georgia; Montgomery, La Salle Parish, Louisiana; Gibson Landing, Caldwell Parish, Louisiana; Heison Bluff, Caldwell Parish, Louisiana; Stock Landing, Caldwell Parish, Louisiana. Yazoo Clay: bluff on south side of Suck Creek, Clarke County, Mississippi.

Oligocene, Vicksburg Group, Red Bluff Marl: Red Bluff Landing, Hiwannee, Wayne County, Mississippi; Vicksburg undifferentiated: Rosefield, Eutahoula Parish, Louisiana.

Type locality. - Jackson, Hinds County, Mississippi.

Material examined. - Lectotype, four paralectotypes, and two topotypes; 75 specimens from Riverside Park, Jackson, Hinds County, Mississippi; 13 specimens from Montgomery, La Salle Parish, Louisiana; 43 specimens from Red Bluff, Hiwannee, Wayne County, Mississippi.

Remarks. - Included with Canu and Bassler's type material was an unnumbered vial containing five specimens labeled as cotypes (=syntypes) from the Eocene, Claiborne Group, Cook Mountain Formation, from Moseley's Ferry, Caldwell (Burleson?) County, Texas. They are separated as _Lunulites_ #1. It is probable that the measurements given by Canu and Bassler (1920, p. 243) were made on one of these specimens.

LUNULITES MONTGOMERYENSIS (McGuirt) 1941

Plate I, figures 13-14

Reptolunulites _bassleri_ McGuirt var. _montgomeryensis_ McGuirt, 1941, La. Geol. Sur., Bull. 21, p. 61, pl. 17, figs. 4, 6-8.

Description of zoarium. - Zoarium a broad concave-convex disk, large; breaks along vibracular rows; zooecia in radial rows from ancestrula; vibraculoecial:zooecial ratio 1:1 as typical for genus. Basal side of radial smooth to distally papillate rows separated by distinct sutures; rows perforated with single row of large pores, pores more irregularly arranged distally.

Description of zooecia. - Autozooecia large, urceolate; mural rim coarsely papillate, distally salient; opesia oval, broad end distal, narrow end proximal, opesia constricted laterally by projections of cryptocyst, opesia denticulate proximally; cryptocyst slight, coarsely papillate. Vibraculoecia broadly fusiform, opesia broadly clithridiate, constricted distally by two slight condyles, condyles with very small fossettes.

Measurements
(average of 10 measurements per parameter)

Lz	0.37 mm	Lv	0.25 mm
lz	0.37 mm	lv	0.15 mm
ho	0.28 mm	hvo	0.14 mm
lo	0.19 mm	lvo	0.10 mm

zooecia width/length ratio	100%
zooecial opesia width/length ratio	68%
vibraculoecia width/length ratio	60%
vibraculoecial opesia width/length ratio	72%

Comparisons. - *Lunulites montgomeryensis* is resembled by *L. bassleri* from which it is separated by the smaller zooecial dimensions, smoother basal surface and more extensive cryptocyst.

Type material. - Holotype, McGuirt Collection #1307, deposited with Louisiana State University, School of Geology Museum, Baton Rouge, Louisiana.

Range and distribution. - Eocene Claiborne Group, Gosport Sand: Little Stave Creek, Clarke County, Alabama. Jackson Group, Moodys Branch Marl: Jackson, Hinds County, Mississippi; Montgomery Landing, La Salle Parish, Louisiana.

Type locality. - Montgomery Landing, La Salle Parish, Louisiana.

<u>Material examined</u>. - Thirty-two specimens from Eocene, Gosport Sand, Little Stave Creek, Clarke County, Alabama.

LUNULITES OVATUS (Canu and Bassler), 1920

Plate I, figures 9-10

<u>Lunularia</u> <u>ovata</u> Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, p. 241, pl. 9, figs. 11-12.

<u>Description of zoarium</u>. - Zoarium a slightly concave-convex disk (height/diameter, 17%); zooecia in radial rows; interpolated rows from modified individual at distal end of vibrabular row; central half of zoarium with occluded zooecia; vibraculoecial:zooecial ratio, 1:1, as typical for genus. Basal side of regular radial rows separated by deep sutures; rows of moderate width (0.25 mm), papillate, non-perforate, well-rounded; ends of some rows slightly hollowed.

<u>Description of zooecia</u>.—Autozooecia symmetrical or unsymmetrical, elliptical to elongate hexagonal; mural rim well developed, slightly granular, somewhat imbricating distally; cryptocyst very slightly developed proximally, thin finely granular; opesia slightly rounded proximally, ogival to oval distally. Modified zooecia like autozooecia but broadly pyriform. Central zooecia occluded with moderately

granular calcareous material. Each ovicell a distal concavity of mural rim.

Vibraculoecia broadly fusiform, opesia elongate, ogival proximally; constricted distally in some by two lateral condyles.

Measurements
(from Canu and Bassler)

Lz	0.25 mm	Lv	0.25-0.30 mm
lz	0.23 mm	lv	0.16 mm
ho	0.15 mm		
lo	0.12 mm		

zooecia width/length ratio	92%
zooecial opesia width/length ratio	80%
vibraculoecia width/length ratio	57%

Comparisons. - *Lunulites ovatus* is similar to *L. grandipora* and *L. bassleri*; however, it is distinguished by the smaller zooecial and opesial dimensions and hexagonal zooecia.

Type material. - Lectotype, here designated: specimen (USNM 63834) represented by Canu and Bassler's (1920, pl. 13) figure 11; one figured paralectotype (USNM 63834).

Range and distribution. - Eocene, Wilcox Group, Bashi Marl: Woods Bluff (probably Woodbluff, Clarke County, Alabama.

Type locality - Woods Bluff (probably Woodbluff, Clarke County), Alabama.

Material examined. - Lectotype and one paralectotype.

<u>Remarks</u>. - *Lunulites ovatus*, *L. grandipora*, and *L.* #1 all have ovicells, lack or nearly lack cryptocyst, and are similar in shape of zooecia and opesia. This would suggest a possible species group for these three taxa.

LUNULITES REVERSA Ulrich, 1901

Plate II, figures 9-10

Lunulites reversa Ulrich, 1901, Eocene-Paleontology (Bryozoa), Md. Geol. Sur., p. 217, pl. 40, figs. 19-20.

Lunularia reversa (Ulrich). Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, pp. 240-241, pl. 1, figs. 17-19.

<u>Description of zoarium</u>. - Description based on holotype and one broken specimen; zoarium probably originally a shallow cup, maximum diameter, 5.0 mm; zooecial rows radiate irregularly from apex, interpolated rows originate from modified zooecium at distal end of vibracular row; vibraculoecial: zooecial ratio, 1:1. Basal side of irregular radial rows separated by shallow sutures, rows slightly convex, coarsely papillate, imperforate.

<u>Description of zooecia</u>. - Zooecia broadly rounded distally, symmetrical, slightly constricted proximally by position of vibraculoecia; mural rim very thick and coarsely papillate raised and most prominent proximally; cryptocyst deep proximally, coarsely granular, widest proximally, narrow laterally and very narrow or absent distally; opesia rounded

rectangular, slightly wider proximally, surrounded by promi= nent, finely granular rim, distally very near the next zooecium. Modified zooecium of interpolated row like auto- zooecia but broadly pyriform.

Vibraculoecia fusiform to narrowly pyriform, increasing slightly in size, connected by broad, shallow canal, opesia oval, constricted distally by one or two lateral condyles.

Measurements
(average of 10 measurements per parameter)

Lz	0.31 mm	Lv	0.23 mm
lz	0.29 mm	lv	0.096 mm
ho	0.14 mm	hvo	0.13 mm
lo	0.13 mm	lvo	0.06 mm

zooecia width/length ratio	94%
zooecial opesia width/length ratio	93%
vibraculoecia width/length ratio	42%
vibraculoecial opesia width/length ratio	46%

Comparisons. - *Lunulites reversa* is distinguished by the marked papillosity of the mural rim, cryptocyst, and basal side and the prominence of the mural rim. In addition, it is apparently restricted to the basal bryozoan bed of the Aquia Formation in Maryland.

Type material. - Figured holotype (USNM unnumbered), one pleisiotype (USNM 63379).

Range and distribution. - Eocene, Wilcox Group, Aquia Formation: basal bryozoan bed two miles below Potomac Creek, Upper Marlboro, Prince Georges County, Maryland.

Type locality. - Two miles below Potomac Creek, Upper Marlboro, Prince Georges County, Maryland.

Material examined. - Holotype and one pleisiotype (USNM 63379).

Remarks. - The unnumbered holotype carries an original label stating..."Orig of figs. 19 and 20, Pl. 2, Lower Eocene, 2 m. below Potomac Creek, M.D." Ulrich's original description includes figures 19 and 20; however, these are on plate 40. There is little doubt, however, that Ulrich's figure and the unnumbered specimen match. In text, Canu and Bassler (1920, p.2241) refer to their pleisiotype (=hypotype) as USNM 63779. However, the label with the specimen bears USNM 63379. The numbers USNM 63799 and USNM 63779 are considered typographical errors and the true number for the hypotype, USNM 63379.

LUNULITES TINTINABULUS (Canu and Bassler), 1920

Plate II, figures 11-12

Lunularia tintinabula Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, pp. 251-252, pl. 83, figs. 12-16.

Reptolunulites tintinabula (Canu and Bassler). McGuirt, 1941, La. Geol. Sur., Bull. 21, p. 59, pl. 6, figs. 3, 5, 10.

Description of zoarium. - Zoarium a large (11.0 mm diameter) shallow disk; zooecia in radial rows and concentric rings; interpolation of rows initiated by modified zooecia at distal end of vibracular row or by rows increasing distally by bifurcation; central part with occluded zooecia; breaks along vibracular rows; vibraculoecial:zooecial ratio, 1:1. Basal side of smooth to slightly papillate, rounded, radial rows separated by deep sutures; perforated by scattered pores of moderate size; ends of some rows strongly hollowed.

Description of zooecia. - Autozooecia oval, narrow end distal, proximal end concave, some broadly urceolate; mural rim well developed, thin, sharp, imbricating distally, moderately granular; cryptocyst well developed, finely granular, most prominent proximally, absent distally; opesia rounded, quadrate to ogival distally, proximal end straight to rounded, surrounded by raised, prominent lip. First zooecia of row resulting from bifurcation like autozooecia but asymmetric and slightly elongate. Occluded zooecia with warty calcareous deposit filling opesium and partly covering cryptocyst, not covering distal part of opesial lip which remains as distal semi-lunar thread; some with prominent, smooth dome over opesium flanked by four or more small pores.

Vibraculoecia pyriform to broadly fusiform, somewhat symmetrical; some connected by shallow canal; some with slight mural rim; opesia broadly clithridiate, proximal end rounded, distal end constricted by two prominent, sharp lateral condyles; condyles with slight fossettes; most peripheral vibraculoecia without condyles, opesia large, broadly pyriform.

Measurements
(average of 10 measurements per parameter)

Lz	0.34 mm	Lv	0.25 mm
lz	0.31 mm	lv	0.16 mm
ho	0.19 mm	hvo	0.14 mm
lo	0.16 mm	lvo	0.08 mm
Wr	0.31 mm		

zooecia width/length ratio	91%
zooecial opesia width/length ratio	84%
vibraculoecia width/length ratio	64%
vibraculoecial opesia width/length ratio	57%

Comparisons. - *Lunulites tintinabulus* resembles *L. jacksonensis* in zooecial shape, dimensions, and presence of occluded zooecia. It is distinguished by the prominent distal semilunar thread of the occluded zooecia and the teeth-like lateral condyles of the vibraculoecia.

Type material. - Lectotype, here designated: specimen (USNM 64256) represented by Canu and Bassler's (1920, pl. 83) figure 13; four figured paralectotypes (USNM 64256).

Range and distribution. - Oligocene, Vicksburg Group, Red Bluff Marl: Red Bluff Landing, Hiwannee, Wayne County, Mississippi; - Marianna Limestone: Vicksburg, Warren County, Mississippi; - Byram Marl: ¼ mile west of Woodward, Wayne County, Mississippi; - Vicksburg, undifferentiated: Rose field, Catahoula Parish, Louisiana.

Type locality. - Red Bluff Landing, Hiwannee, Wayne County, Mississippi.

Material examined. - Lectotype and four paralectotypes; 64 topotypes.

LUNULITES TRUNCATUS De Gregorio, 1890

Plate I, figures 5-6

Lunulites (_Discoflustrellaria_) _bouei_ var. _truncata_ De Gregorio, 1890, Ann. Geol. Pal., Liv. 7-8, p. 245, pl. 41, figs. 34-46.

Trochopora _truncata_ (De Gregorio). Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, p. 104, pl. 11, figs. 1-6; - McGuirt, 1941, La. Geol. Sur., Bull. 21, p. 49, pl. 15, fig. 8.

Description of zoarium. - Zoarium a high, solid dome, composed of successively stacked disks; zooecia in regularly arranged radiating and concentric rows; interpolation of rows at distal end of vibraculoecial row; breaks along vibraculoecial rows; vibraculoecial:zooecial ratio 1:1 as typical for genus. Basal side of irregularly radiating, flat rows; rows may be perforate with pores of variable size, pores generally increase in number distally; ends of some rows slightly hollowed.

Description of zooecia. - Autozooecia sub-urceolate to hexagonal; mural rim thin, slightly salient distally; cryptocyst absent; opesia oval, wide end proximal, narrow end distal.

Vibraculoecia small, symmetrical, fusiform; mural rim not well defined; two lateral condyles present proximally.

Measurements
(from Canu and Bassler)

Lz	0.20 mm	Lv	0.15 mm
lz	0.15 mm	lv	0.07 mm

zooecial width/length ratio	75%
vibraculoecial width/length ratio	47%

Comparisons. - The solid or filled zoarium composed of stacked disks occurs in several species and is not considered to be of taxonomic significance. Worn specimens may be confused with Lunulites bouei as both occur with solid zoaria. However, the radiate basal side of L. truncatus serves to distinguish it from the papillate basal side of L. bouei.

Specimens of L. truncatus with the frontal surface abraded may be confused with similarly worn specimens of L. #1 occurring with thick zoaria. The zoarium of L. #1, however, does not occur as stacked disks and is without perforations on the basal side.

Type material. - The present location of De Gregorio's type material is not known.

Range and distribution. - Eocene Claiborne Group, Gosport Sand: Gopher Hill, Tombigbee River; one mile S.E. of Rockville, Alabama; Claiborne Bluff, near Claiborne, - Cook Mountain Formation: Moseley's Ferry, Caldwell County, Texas.

Eocene Jackson Group, Moodys Branch Marl: Jackson, Mississippi (presumed to be type locality of the Moodys Branch Marl), Creole Bluff at Montgomery, La Salle Parish, Louisiana. - Barnwell Formation: three and one-half miles southeast of Shell Bluff post office, Georgia.

Type locality. - Claiborne Bluff, near Claiborne, Alabama.

Material examined. - Nine specimens, USNM 63838, from Canu and Bassler's material were examined. The specimens had been damaged and the aspect of the frontal surface was not discernable. The description is based largely on the figures provided by Canu and Bassler. Specimens of *Lunulites truncatus* were not encountered in the other material available.

LUNULITES VERRUCOSUS (Canu and Bassler), 1920

Plate II, figures 5-6

Lunularia verrucosa Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, pp. 242-243, pl. 37, figs. 6-9.

Description of zoarium. - Zoarium a high cup (height/diameter ratio, 40%), with prominent apex, zooecia in radial rows and concentric rings, interpolated rows from modified individual at distal end of vibracular row, central two-thirds of zoarium with occluded zooecia, vibraculoecial:

zooecial ratio, 1:1 as typical for genus. Basal side of irregularly radial rows; rows granular, flat, and non-perforate.

Description of zooecia. - Autozooecia rounded rectangular, symmetrical, small; mural rim little developed, not distinct from cryptocyst, moderately granular; cryptocyst very wide, most prominent proximally, finely granular; opesia small, rounded rectangular to elliptical, transverse, some crenulated. Modified zooecium of interpolated row like autozooecia but broadly pyriform, symmetrical. Occluded zooecia with high dome-like structure of coarse calcareous materials giving a knobby aspect to central part of zoarium.

Vibraculoecia fusiform, opesia clithridiate constricted distally by two lateral condyles.

Measurements
(from Canu and Bassler)

Lz	0.24 mm	Lv	0.15 mm
lz	0.25 - 30.0 mm	lv	0.07 mm
ho	0.10 mm	hvo	0.062 mm
lo	0.07 mm	lvo	0.038 mm

zooecia width/length ratio	117%
zooecial opesia width/length ratio	70%
vibraculoecia width/length ratio	47%
vibraculoecial opesia width/length ratio	61%

Comparisons. - Lunulites verrucosus is distinguished by the domed, occluded zooecia and the small, transverse opesia. The high zoarium, presence of occluded zooecia, and zooecial dimensions are similar to L. ligulatus and L. #1. The specimen (USNM 63993) represented by Canu and Bassler's (1920, pl. 37) figure 9, may have had the basal side removed.

Type material. - Lectotype, here designated: specimen (USNM 63982) represented by Canu and Bassler's (1920, pl. 37) figures 7-8; two figured paralectotypes (USNM 63982, 63993).

Range and distribution. - Eocene, Jackson Group, Castle Hayne Limestone: Wilmington, New Hanover County, North Carolina. - Ocala Formation: Rich Hill, Crawford County, Georgia; 18 miles west of Wrightsville, Johnson County, Georgia; 12 miles southeast of Marshallville, Macon County, Georgia; three and one-fourth miles south of Perry, Houston County, Georgia; Chipola River, east of Marianna, Jackson County, Florida; Bainbridge, Decatur County, Georgia. - Barnwell Formation: Baldock, Barnwell County, Georgia.

Oligocene, Vicksburg Group, Marianna Limestone: one mile north of Monroeville, Monroe County, Alabama.

Type locality. - Wilmington, New Hanover County, North Carolina.

Material examined. - Lectotype and paralectotype from Wilmington, New Hanover County, North Carolina; one paralectotype, 18 miles west of Wrightsville, Johnson County, Georgia.

LUNULITES new species #1

Plate II, figures 1-2

Description of zoarium. - Zoarium a high, thickly calcified cup (height-diameter ratio 1:2), small; zooecia in rows and concentric rings from ancestrula, interpolated rows from aborted symmetrical individual at distal end of vibracular row; zooecia of central area partially occluded by longitudinal calcareous bar and secondary calcification over cryptocyst, may constitute over half of zoarium; vibraculoecial:zooecial ratio 1:1.

Inner face of smooth to slightly papillate, flattened rows of irregular width, separated by shallow sulci; interpolation of zooecial rows seen as bifurcation of sulci; ends of most rows hollowed.

Description of zooecia. - Autozooecia urceolate, most longer than broad; mural rim thin, somewhat papillate, little salient distally, cryptocyst well developed, slightly granular, prominent and depressed proximally, very thin distally may flow over mural rim laterally; opesia rounded rectangular without rim. Modified zooecia like autozooecia but pyriform. Occluded zooecia with smooth secondary calcification filling zooecial area to level of mural rim; opesia partially closed by single longitudinal bar originating proximally, bar may completely bridge opesia or terminate in slight bulb, transverse calcification from bar may resemble

Oligotresium fenestrata in appearance of occlusion with four perforations; ancestrula generally not occluded.

Vibracula pyriform, connected by broad, shallow canal; opesia clithridiate, entirely surrounded by thick, calcareous collar, medially constricted by two lateral condyles with slight depressions; vibracula in area of occluded zooecia often covered or plugged by calcareous deposits. Vibracula on periphery of zoaria without collar, cryptocyst, or condyles, opesia much wider: hvo = 0.11 mm, lvo 0.10 mm.

Measurements
(average of 10 measurements per parameter)

Lz	0.25 mm	Lv	0.22 mm
lz	0.26 mm	lv	0.11 mm
ho	0.12 mm	hvo	0.11 mm
lo	0.12 mm	lvo	0.054mm

zooecia width/height ratio	100%
zooecial opesia width/height ratio	100%
vibracula width/height ratio	50%
vibracular opesia width/height ratio	49%

Comparisons. - Lunulites #1 is distinguished by the smooth, non-perforate inner face.

Type material. - Holotype and 33 syntypes, Greeley Collection.

Range and distribution. - Eocene Claiborne Group, Lisbon Formation: Little Stave Creek, Clarke County, Alabama; - Wheelock Formation, Stone City Beds: ten miles west of Bryan, Burleson County, Texas; - Gosport Sand: Little Stave Creek, Clarke County, Alabama.

Type locality. - Gosport Sand, Little Stave Creek, near Jackson, Clarke County, Alabama.

Material examined. - Eocene, Claiborne Group: one specimen from the Lisbon Formation, Little Stave Creek, Alabama; twelve from the Stone City Beds, near Bryan, Texas; 34 specimens from the Gosport Sand, Little Stave Creek, Alabama.

Genus OLIGOTRESIUM Gabb and Horn

Lunulites of authors (in part; not Lamarck, 1816).

Oligotresium Gabb and Horn, 1862, Acad. Nat. Sci., Philadelphia, Jour., ser. 2, vol. 5, pt. 2, p. 139. - Cheetham, 1962, Micropaleontology, vol. 8, no. 3, p. 325.

Lunularia Busk (in part). Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, pp. 238-252.

Reptolunulites d'Orbigny (in part). McGuirt, 1941, La. Geol. Sur., Bull. 21, p.

Type species. - (by montotypy). _Lunulites vicksburgensis_ Conrad (1847, p. 296).

Diagnosis. - Lunulitiform zoarium, of varying convexity, zooecia in radial rows and concentric rings from ancestrula, interpolated rows usually initiated at distal end of vibraculoecial row, vibraculoecia in rows between zooecial rows, in a ratio of one vibraculoecium for two zooecia (or four zooecia grouped around each vibraculoecium). Basal side of radial rows separated by sutures.

Comparisons. - Oligotresium is closely allied with Lunulites. The ratio of vibraculoecia to zooecia will serve to separate these two genera; however, some parts of the zoarium may have vibraculoecia in a ratio to zooecia of 1:1. These are frequently found where new zooecial rows are initiated. Some species of Otionella also resemble Oligotresium, but may be distinguished by their asymmetric vibraculoecia.

Range and distribution. - Eocene: Claiborne Group, Jackson Group. Oligocene: Vicksburg Group. This range is given only for the Gulf Coast; it is probable that some species of Lunulites described from European localities belong to Oligotresium.

Remarks. - As pointed out by Cheetham (1962, p. 325), Oligotresium resembles Lunulites in many ways, particularly size and shape of zooecia, opesia, vibraculoecia, and aspects of the basal side; however, the arrangement and ratio of vibraculoecia and zooecia is sufficient to separate these genera.

OLIGOTRESIUM CLAIBORNICUM (Canu and Bassler) 1920

Plate III, figures 1-2

Lunularia (Oligotresium) claibornica Canu and Bassler, 1920. U. S. Nat. Mus. Bull. 106, pp. 248-249, pl. 13, figs. 13-15.

Description of zoarium. - Zoarium a large (diameter, +14.0 mm, based on fragments) cup, seldom complete; zooecia in radial rows and irregular concentric rings; interpolation of rows initiated by modified individual at distal end of vibracular row; breaks along vibracular rows; vibraculoecial:zooecial ratio 1:2, as typical for genus. Basal side of radial, rounded rows separated by sharp sutures; rows become slightly papillate toward sutures; perforated with large, deep pores arranged in two parallel rows; end of some rows slightly hollowed.

Description of zooecia. - Autozooecia unsymmetrically urceolate, some symmetrical, to distally rounded rectangular; mural rim well developed, papillate, most prominent proximally, absent or nearly absent distally; cryptocyst coarsely granular, absent distally; opesia rounded to ogival distally, rounded rectangular proximally, some not symmetrical, may be surrounded by a small rim. First zooecium of interpolated row like autozooecium but pyriform.

Vibraculoecia pyriform, large, connected irregularly by canal; mural rim coarsely granular, ending distally in two lateral condyles; condyles with fossettes; opesia broadly clithridiate, large.

Measurements
(average of 10 measurements per parameter)

Lz	0.33 mm	Lv	0.30 mm
lz	0.35 mm	lv	0.18 mm
ho	0.16 mm	hvo	0.16 mm
lo	0.16 mm	lvo	0.10 mm

zooecia width/length ratio	106%
zooecial opesia width/length ratio	100%
vibraculoecia width/length ratio	60%
vibraculoecial width/length ratio	63%

Comparisons. - Oligotresium claibornicum resembles O. #1 and O. #2. From O. #1 it is distinguished by the squared opesia and zooecia, more numerous and linear orientation of the pores and the zooecial width exceeding the zooecial length. From O. #2 it is distinguished by the non-papillate basal side, more numerous pores on basal side and better developed cryptocyst and small vibraculoecia.

Type material. - Lectotype, here designated: specimen (USNM 63847) represented by Canu and Bassler's (1920, pl. 13) figure 15; two figured paralectotypes (USNM 63847); six unfigured paralectotypes (USNM 63847).

Range and distribution. - Eocene, Claiborne Group - Gosport Sand: Claiborne Bluff, near town of Claiborne, Monroe County, Alabama; one mile southwest of Rockville, Clarke County, Alabama; Gopher Hill, Tombigbee River, Alabama; Little Stave Creek, near Jackson, Clarke County, Alabama.

Type locality. - Claiborne Bluff, near Claiborne, Monroe County, Alabama.

Material examined. - Lectotype and eight paralectotypes; 86 specimens from Little Stave Creek, near Jackson, Clarke

County, Alabama.

Remarks. - Canu and Bassler (1920, p. 248) state that the ovicell is a distal convexity often covered by external calcification. On many autozooecia, the mural rim is very thick and swollen proximally and may be the ovicell.

OLIGOTRESIUM CONTIGUUM (Lonsdale), 1845

Plate III, figures 3-4

Lunulites contiqua Lonsdale, 1845, Geol. Soc. of London, Quart. Jour., vol. 1, p. 533, 3 text figs. - Emmons, E., 1858, N. Car. Geol. Sur. Report, Ag. east. count.... desc. fossils marl beds, pp. 311-312, figs. 250-251.

Lunularia contiqua (Lonsdale). Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, pp. 247-248, pl. 39, figs. 1-5.

Description of zoarium. - Zoarium thin, varying from broad, shallow cup to high dome with sharp apex; zooecia in radial rows and irregular concentric rings from ancestrula; interpolated rows at distal end of vibracular row, initiated by modified zooecium; heterozooecia irregularly positioned among autozooecia; vibraculoecial:zooecial ratio, 1:2; breaks along vibracular rows. Basal side leached away, exposing basal side of frontal surface, fossil casts of basal side indicate radial papillate or perforate rounded rows.

Description of zooecia. - Autozooecia irregular, asymmetrically urceolate, size varies considerably, but usually small in size; mural rim poorly defined, gently rounded, thick and most prominent distally, slightly imbricating, moderately granular; cryptocyst well developed, of same texture as mural rim; opesia distally ogival, proximally rounded rectangular, transverse, may be irregularly denticulate. Modified zooecium of interpolated row like autozooecia but pyriform, with more extensive cryptocyst proximally. Heterozooecia large (Lz, 0.44 mm, lz, 0.50 mm) with small mural rim; without cryptocyst.

Vibraculoecia small, broadly fusiform, some connected irregularly by a broad, shallow canal; opesia clithridiate, surrounded by slight collar ending distally in two lateral condyles.

Measurements
(average of 10 measurements per parameter)u x

Lz	0.39 mm	Lv	0.33 mm
lz	0.38 mm	lv	0.20 mm
ho	0.13 mm	hvo	0.30 mm
lo	0.15 mm	lvo	0.90 mm

zooecia width/length ratio	97%
zooecial opesia width/length ratio	115%
vibraculoecia width/length ratio	61%
vibraculoecial opesia width/length ratio	30%

Comparisons. - *Oligotresium contiguum* has been found only with the basal side leached away and occurs with *Lunulites distans*. It is distinguished from *L. distans* by the vibraculoecial:zooecial ratio and its smaller zooecial measurements.

Type material. - The location of Lonsdale's type material is not known; four topotypes, Greeley Collection; 11 hypotypes, USNM 63999.

Range and distribution. - Eocene, Jackson Group - Castle Hayne Marl: Wilmington, New Hanover County, North Carolina.

Type locality. - Wilmington, New Hanover County, North Carolina.

Material examined. - Four topotypes, 11 hypotypes, USNM 63999, from Eocene, Jackson Group, Castle Hayne Marl, Wilmington, New Hanover County, North Carolina.

OLIGOTRESIUM TUBIFERUM (Canu and Bassler), 1920

Plate III, figures 7-8

Lunularia tubifera Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, p. 245, pl. 37, figs. 14-18.

Description of zoarium. - Zoarium probably (description based on four broken specimens) a shallow concave-convex disk (diameter at least 5.0 mm); zooecia in radial rows and concentric rings, interpolation of rows from modified individual at distal end of vibracular row, first one or two zooecia of interpolated row appear to be large vibraculoecia; ancestrular region with occluded zooecia perforated by large single pore; breaks along vibracular rows; vibraculoecial: zooecial ratio 1:2 as typical for genus. Basal side probably not calcified, zooecia and vibraculoecia show as sacks, many sacks broken.

Description of zooecia. - Zooecia asymmetrically urceolate becoming hexagonal in worn specimens; mural rim well defined in preserved specimens, much less distinct on worn zooecia, finely granular, high laterally, little salient; cryptocyst deep, little developed, most prominent proximally, evanescent distally; opesia oval, narrow end distal, proximal end nearly straight on some; some opesia crenulated to denticulated. Occluded zooecia like autozooecia but opesia partially closed by fine calcareous deposit, reducing opesia to size half that of autozooecia.

Vibraculoecia intermittently connected by broad, deep canal; irregularly fusiform, large, deeply set; opesia clithridiate, broadly rounded to moderately round proximally, distally constricted by two lateral condyles; in ancestrular area, opesia partly occluded as with autozooecia.

Measurements*

Lz	0.31 mm	Lv	0.26 mm
lz	0.28 mm	lv	0.12 mm
ho	0.14 mm	hvo	0.12 mm
lo	0.125mm	lvo	0.057mm

zooecia width/length ratio	90%
zooecial opesia width/length ratio	89%
vibraculoecia width/length ratio	46%
vibraculoecial opesia width/length ratio	47%

* based on average of 10 measurements per parameter for zooecial dimensions and average of 6 measurements per parameter for vibraculoecial dimensions.

Comparisons. - *Oligotresium tubiferum*, like *O. contiguum*, *O. howei*, and *Lunulites distans*, has been found only with the basal side absent. This is not considered a genetic character but due to mode of preservation. *O. tubiferum* may be distinguished from *O. contiguum* and *O. howei* by the zooecial dimensions and ratios and opesiular crenulations. Canu and Bassler (1920, p. 245) state that *O. tubiferum* is without vibracular condyles; however, these structures are quite distinct on the type specimens.

Type material. - Lectotype, here designated: specimen (USNM 63995) represented by Canu and Bassler's (1920, pl. 39) figure 15; three figured paralectotypes (USNM 63995).

Range and distribution. - Eocene, Jackson Group, Ocala Formation: One-half mile southeast of Georgia Kaolin Company mine, Twiggs County, Georgia.

Type locality. - One-half mile southeast of Georgia Kaolin Company mine, Twiggs County, Georgia.

Material examined. - Lectotype and three paralectotypes.

OLIGOTRESIUM VICKSBURGENSE (Conrad), 1847

Plate III, figures 5-6

Lunulites vicksburgensis Conrad, 1847. Acad. Nat. Sci., Phil., Jour., ser 2, vol. 1, p. 127.

<u>Oligotresium</u> <u>vicksburgensis</u> (Conrad). Gabb and Horn, 1862, Acad. Nat. Sci., Phil., Jour., ser. 2, vol. 5, pt. 2, p. 139, pl. 19, fig. 22.

<u>Lunularia</u> (<u>Oligotresium</u>) <u>vicksburgensis</u> (Conrad). Canu and Bassler, 1920, U. S. Nat. Mus., Bull. 106, pp. 249-250, pl. 83, figs. 1-11.

<u>Reptolunulites</u> (<u>Oligotresium</u>) <u>vicksburgensis</u> (Conrad). McGuirt, 1941, Louisiana Geol. Sur., Bull. 21, p. 96, pl. 6, figs. 6, 8-9, 11.

<u>Description of zoarium</u>. - Zoarium a broad, large (10.0 mm diameter) cup; zooecia in radial rows and concentric rings about ancestrula; interpolated rows originating from modified autozooecium at distal end of vibracular row; vibraculoecium preceeding interpolated row often larger than other vibraculoecia and with less cryptocyst; vibraculoecial: zooecial ratio 1:2 as typical for genus, breaks along vibracular rows. Basal side of irregular, well-rounded rows separated by sharp, deep sutures; rows vary from coarely granular to very papillate, perforate with fine to moderately large pores.

<u>Description of zooecia</u>. - Zooecial shape highly variable, unsymmetrical, usually variations of urceolate, clustered in groups of four around one vibraculoecium; mural rim well developed, thick, coarsely granular to finely papillate, usually distinct from mural rim of adjacent zooecium; becomes very thin distally; cryptocyst very thin proximally, absent distally, moderately granular; opesia variable, usually unsymmetrical, oval, elliptical, rounded rectangular or

combination. First zooecium of interpolated row like autozooecia but elongate pyriform, with more cryptocyst. Zooecia of ancestrular area elongate, often pyriform, with extensive cryptocyst and smaller opesia; ancestrula partly occluded.

Vibraculoecia symmetrical, pyriform; mural rim thick, rounded, surrounds opesium completely; condyles small with fossettes; opesium sharply ogival proximally, small, rounded distally.

Measurements
(average of 10 measurements per parameter)

Lz	0.35 mm	Lv	0.32 mm
lz	0.33 mm	lv	0.21 mm
ho	0.22 mm	hvo	0.18 mm
lo	0.17 mm	lvo	0.13 mm

zooecia width/length ratio	94%
zooecial opesia width/length ratio	77%
vibraculoecia width/length ratio	66%
vibraculoecial opesia width/length ratio	72%

Comparisons. - *Oligotresium vicksburgense* closely resembles *O.* #1, but is distinguished by its papillate and finely perforate basal side, and more irregular zooecial shape.

Type material. - Conrad's material is deposited with the Academy of Natural Science, Philadelphia.

Range and distribution. - Eocene, Jackson Group - Moodys Branch Marl: Claiborne Bluff, near Claiborne, Monroe County, Alabama; ? near Gilbertown, Choctaw County, Alabama.

Oligocene, Vicksburg Group - undifferentiated: Rosefield, Catahoula Parish, Louisiana; - Red Bluff Clay: Red Bluff

Landing, near Hiwannee, Wayne County, Mississippi; - Mint Spring Marl: National Cemetery, Vicksburg, Warren County, Mississippi; Marianna Limestone: Vicksburg, Warren County, Mississippi; - Glendon Limestone, near Redwood, Warren County, Mississippi; - Byram Marl: near Woodwards, Wayne County, Mississippi; old Byram, Hinds County, Mississippi; Haynes Bluff, Yazoo River, Warren County, Mississippi; Wansley Bend, Pearl River, Rankin County, Mississippi.

Type locality. - Vicksburg, Warren County, Mississippi.

Material examined. - Eocene, Jackson Group - Moodys Branch Marl: four specimens (?) from Claiborne Bluff, near Claiborne, Monroe County, Alabama; one specimen (?) from near Gilbertown, Choctaw County, Alabama.

Oligocene, Vicksburg Group, - Red Bluff Clay: 260 specimens from Red Bluff Landing near Hiawannee, Wayne County, Mississippi; - Mint Spring Marl: National Cemetery, Vicksburg, Warren County, Mississippi, - Glendon Limestone: 28 specimens from near Redwood, Warren County, Mississippi; - Byram Marl: 300 specimens from old Byram, Hinds County, Mississippi; 50 specimens from Haynes Bluff, Yazoo River, Warren County, Mississippi; two specimens from Wansley Bend, Pearl River, Rankin County, Mississippi.

OLIGOTRESIUM new species #1

Plate III, figures 11-12

Description of zoarium. - Zoarium a shallow cup or slightly concave-convex disk, rather large (diameter, 16 mm or greater), breaking along vibracular rows; zooecia in radial rows, interpolation initiated by modified individuals at distal end of vibraculoecial row; zooecia grouped in fours about each vibraculoecium, as typical for genus. Basal side finely granular, composed of mildly rounded, radial rows, separated by shallow sutures; rows perforated with numerous pores of moderate size. (On one specimen the suture ends abruptly and for a distance of about 0.7 mm two rows are fused and appear as a slightly swollen protuberance.)

Description of zooecia. - Zooecia asymmetrically urceolate; proximal border varying from rounded to ogival; mural rim moderately developed laterally, more prominently developed distally, with slight imbrication of proximal zooecia over distal zooecia; cryptocyst shallow, moderately granular, very narrow; opesia ovate to ogival, fairly large in relation to the zooecia, not enclosed by a collar with two lateral septulae on each side of zooecium in indistinct rosette plate.

Vibraculoecia pyriform, large, connected by distinct canal; opesia oval, constricted distally by two widely flaring lateral condyles bearing distinct fossettes, cryptocyst not well developed.

Measurements
(average of 10 measurements per parameter)

Lz	0.33 mm	Lv	0.31 mm
lz	0.29 mm	lv	0.19 mm
ho	0.22 mm	hvo	0.24 mm
lo	0.17 mm	lvo	0.11 mm

zooecia width/length ratio	85%
zooecial opesia width/length ratio	77%
vibraculoecia width/length ratio	61%
vibraculoecial opesia width/length ratio	46%

Comparisons. - *Oligotresium* n. sp. #1 is closely resembled by *O. claibornicum*; however, it is distinguished by (1) zooecia more rounded distally, (2) zooecial length greater than width, (3) cryptocyst less well developed, (4) larger, more elongate opesia, and (5) less numerous pores on basal side.

Type material. - Holotype and ten paratypes, Greeley Collection.

Range and distribution. - Eocene, Claiborne Group, Gosport Sand: Little Stave Creek, Clarke County, Alabama.

Eocene, Jackson Group, Moodys Branch Marl: Jackson, Hinds County, Mississippi; east of Gilbertown, Choctaw County, Alabama.

Type locality. - Little Stave Creek, near Jackson, Clarke County, Alabama.

Material examined. - Holotype and ten paratypes, twenty specimens from Eocene, Gosport Sand, Little Stave Creek, Alabama; Eocene, Moodys Branch Marl: two specimens from Jackson, Hinds County, Mississippi; two specimens from near Gilbertown, Choctaw County, Alabama.

OLIGOTRESIUM new species #2

Plate III, figures 11-12

Description of zoarium. - Zoarium a shallow disk, breaking along vibracular rows; zooecia disposed in radiating rows and concentric rings from ancestrula, interpolated rows initiated by individual of varying shape; vibraculoecial: zooecial ratio 1:2 as typical for genus. Inner face of moderately to coarsely papillate rounded rows separated by shallow sutures; rows perforated by large, sparse, irregularly disposed pores; end of some rows hollowed.

Description of zooecia. - Zooecia broadly urceolate to semi-lunar; mural rim well developed, most prominent proximally, strongly papillate laterally; cryptocyst coarsely granular, deep proximally, rising to mural rim distally; opesia ovate distally, rounded rectangular proximally, surrounded on same by a slight collar; two lateral septulae per zooecium.

Vibraculoecia pyriform, connected by deep canals; opesia clithridiate, enclosed proximally by papillate collar, collar terminated distally by two lateral condyles with slight depressions.

Measurements
(average of 10 measurements per parameter)

Lz	0.31 mm	Lv	0.27 mm
lz	0.33 mm	lv	0.14 mm
ho	0.15 mm	hvo	0.14 mm
lo	0.15 mm	lvo	0.075mm

zooecia width/length ratio	105%
zooecial opesia width/length ratio	100%
vibraculoecia width/length ratio	52%
vibraculoecial opesia width/length ratio	53%

Comparisons. - This species is distinguished by the papillate inner face. It is separated from Oligotresium #1 by the zooecial ratio of 105% as opposed to 85%, and in the non-imbricating zooecia. Oligotresium #2 is separated from O. claibornicum by its smaller opesial dimensions, the smaller zooecial ratio, and the fewer pores on the inner face.

Type material. - Holotype and two paratypes, Greeley Collection.

Range and distribution. - Eocene, Claiborne Group, Gosport Sand: Little Stave Creek, near Jackson, Clarke County, Alabama.

Type locality. - Little Stave Creek, Clarke County, Alabama.

Material examined. - Eocene, Claiborne Group, Gosport Sand: Little Stave Creek, near Jackson, Clarke County, Alabama.

Suborder Aschophora

Genus SCHIZORTHOSECOS Canu and Bassler, 1917

Schizorthosecos Canu and Bassler, 1917, U. S. Nat. Mus., Bull. 96, p. 74. - Canu and Bassler, 1923, U. S. Nat. Mus., Bull. 125, p. 190.

Type species. - Orbitolites interstitia Lea (1833, p. 191, pl. 6, fig. 204). (Original designation.)

Diagnosis. - Cupuliform zoarium; zooecia in radial rows, arranged in quincunx; avicularia, zooecials, and tubules irregularly situated among zooecia; zooecia tubular, erect, with rounded rim, symmetric; ovicells present on some species, swollen, distal protuberances on some zooecia.

Range and distribution. - Found only in Gulf Coastal Plain, Eocene: Claiborne to Jackson.

SCHIZORTHOSECOS DANVILLENSIS McGuirt

Plate V, figures 7-8

Orbitolites discoidea Lea, 1833. Contr. Geol., Phil., p. 192, pl. 6, fig. 205 (nomen oblitum).

Cupularia discoidea (Lea) Gabb and Horn, 1862, Phil. Acad. Nat. Sci., Jour., ser. 2, vol. 5, pt. 2, p. 155. - De Gregorio, 1890, Ann. Geol. - Paleo. Liv. 7-8, p. 249, pl. 42, fig. 28.

Schizorthosecos danvillensis McGuirt, 1941, La. Geol. Sur., Bull. 21, p. 100, pl. 28, figs. 2, 4, 5, 8.

Description of zoarium. - Zoarium a broad, shallow cup; zooecia erect, arranged in quincunx and radial rows from zoarial center, avicularia irregularly disposed among zooecia. Basal side of radial, rounded, smooth rows, separated by sutures, sutures of some specimens zig-zag from center, rows perforate with numerous pores, several large tubules may pierce basal side.

Description of zooecia. - Autozooecia hexagonal prisms, erect, base fused with adjoining zooecia of same zooecial row; frontal surface of zooecia terminating in rounded rim, rim enclosing oval aperture completely. Avicularia raised above level of autozooecia; round, surrounded by rounded rim; diameter about 0.12 mm; some with two small lateral teeth, or thin bar distally situated; small zooecials irregularly positioned between autozooecial rims. Ovicell (?) observed on one specimen, positioned in distal half of autozooecial aperture, composed of thin calcareous material in form of rounded swelling.

Measurements
(average of 10 measurements per parameter)

Lz	0.24 mm
lz	0.24 mm
ha	0.15 mm
la	0.13 mm

zooecia width/length ratio	100%
zooecial aperture width/length ratio	87%

Comparisons. - Schizorthosecos danvillensis is easily distinguished by the radial rows on the basal side.

Type material. - Louisiana State University, School of Geology Museum Collection No. 1460; seven topotypes, Greeley Collection.

Range and distribution. - Eocene, Claiborne Group - Lisbon Formation: Little Stave Creek, near Jackson, Clarke County, Alabama; Wheelock Formation: Burleson County, Texas, 10 miles west of Bryan; Gosport Sand: Little Stave Creek, near Jackson, Clarke County, Alabama.

Eocene, Jackson Group - Moodys Branch Marl: Creek Bluff at Montgomery, La Salle Parish, Louisiana; .7 miles north of Tullos, La Salle Parish, Louisiana; Danville Landing, Catahoula Parish, Louisiana; Heison Bluff, Caldwell Parish, Louisiana; Jackson, Hinds County, Mississippi; Claiborne Bluff, near Claiborne, Monroe County, Alabama; 10 miles west of Gilbertown, Choctaw County, Alabama.

Type locality. - Creole Bluff, near Montgomery, La Salle Parish, Louisiana.

Material examined. - Eocene, Claiborne Group: 71 specimens from the Lisbon Formation at Little Stave Creek, Jackson, Clarke County, Alabama; 25 specimens from the Gosport Sand from same locality as above; Eocene, Jackson Group; Moodys Branch Marl - 40 specimens from Jackson, Hinds County, Mississippi; - seven topotypes from Montgomery Landing, La Salle Parish, Louisiana; three specimens from Claiborne Bluff, near

Claiborne, Monroe County, Alabama; three specimens from Choctaw County, Alabama.

Remarks. - On poorly preserved specimens, the bar across the avicularium is often gone, leaving two small projections, or teeth. The specimens from Claiborne Bluff exhibit both conditions. McGuirt's (1941) species, *Schizorthosecos danvillensis*, is illustrated in Plate 28, figure 4 as also having an avicularium bar, although no mention of the structure is made in his description.

Because the fifty-year rule of the International Code of Zoological Nomenclature suggests the exclusion of names not in use for an interval of fifty years, *Orbitolites discoidea* Lea is a *nomen oblitum* and *Schizorthosecos danvillensis* McGuirt is the valid name for this species.

SCHIZORTHOSECOS INTERSTITIA (Lea), 1833

Plate V, figures 7-8

Orbitolites interstitia Lea, 1833, Contr. Geol. Phila., p. 191, pl. 6, fig. 204.

Lunulites interstitia (Lea). Gabb and Horn, 1862, Acad. Nat. Sci., Phil., Jour., Ser. 2, vol. 5, pl. 2, pp. 120-121.

L. (*Cupularia*) *interstitia* (Lea). De Gregorio, 1890, Ann. Geol. Paleo., Liv. 7-8, p. 249, pl. 42, figs. 16, 21-22.

Schizorthosecos interstitia (Lea). Canu and Bassler, 1917, U. S. Nat. Mus., Bull. 96, p. 75, pl. 6, figs. 4-5; 1920, U. S. Nat. Mus., Bull. 106, p. 626, pl. 18, figs. 1-9; McGuirt, 1941, La. Geol. Sur., Bull. 21, p. 99, pl. 28, figs. 6-7, 9-10, pl. 29, figs. 1-2.

<u>Description of zoarium</u>. - Zoarium a broad, shallow (height/diameter ratio, 25%) cup; large (maximum diameter, 8.0 mm); zooecia erect, arranged in quincunx in somewhat radial rows from ancestrular region; ancestrular region of irregular, small zooecia; small zooeciules irregularly disposed among zooecia; some specimens with several large membraniporoid zooecia scattered over surface of zoarium. Basal side composed of lower part of zooecia as regular perforated hexagons separated by faint to distinct sutures; several large tubules may be present; avicularia-like structures present in ancestrular area of some specimens.

<u>Description of zooecia</u>. - Zooecia tubular, erect, vertical axis normal to zoarial surface; zooecia on frontal surface oval to pyriform, narrow end proximal, wide end distal; aperture rounded pyriform, small end proximal, constricted; aperture partly surrounded by a prominent, rounded rim, may be open distally and thickened proximally; rim absent on abraded specimens; basal sides of zooecia are perfect hexagons, perforated by 6 to 10 large pores; hexagons swollen or flat; some zooecia of ancestrular area small with thickened rim; membraniporoid zooecia on frontal surface, oval, irregularly placed, with prominent high rim; opesia oval, narrow end with two condyles; large tubules (0.4 mm diameter) on basal side, disposed at random, may penetrate zoarium deeply but not completely; on basal side in ancestrular area

heterozooecia may be present, these are slightly larger than basal hexagons, hooded, with aperture facing distally, these may be avicularia; ovicells hyperstomial, at distal end of zooecium; zooeciules small, irregularly placed between zooecial rims.

Comparisons. - *Schizorthosecos interstitia* is distinguished from *S. grandiporosum* by the basal hexagons not perforated with large single pores.

Type material. - Lea described the species from two specimens. The present location of these is not known.

Range and distribution. - Eocene, Claiborne Group: Lisbon Formation, Wautubbee Hills, four miles south of Enterprise, Clarke County, Mississippi; Cook Mountain Formation, Moseley's Ferry, Caldwell County, Texas; Gosport Sand - Claiborne Bluff, near Claiborne, Alabama; Gopher Hill, Tombigbee River, Alabama; one mile southwest of Rockville, Clarke County, Alabama; Little Stave Creek, Clarke County, Alabama.

Eocene, Jackson Group, Moodys Branch Marl: Claiborne Bluff, near Claiborne, Alabama; near Water Valley, Choctaw County, Alabama; Jackson, Mississippi; Montgomery, La Salle Parish, Louisiana.

Type locality. - Lea's specimens came from Claiborne Bluff, Alabama, his stratum No. 3. The base of this stratum is described as 122 feet above water level of the river and as being 17 feet thick. It was described as "...composed of loose quartzose, brownish sand, the grains of which are small and angular." This description and elevation from the water line, even with variations in water level, place the specimens in the Moodys Branch Marl.

Material examined. - Six specimens from the Gosport Sand of Claiborne Bluff, near Claiborne, Alabama; 61 from the Gosport Sand, Little Stave Creek, Clarke County, Alabama; 320 from the Moodys Branch Marl, Jackson, Mississippi; 31 from Moodys Branch Marl, near Water Valley, Choctaw County, Alabama; 11 from Moodys Branch Marl, Claiborne Bluff, near Claiborne, Alabama; 120 from Moodys Branch Marl, Montgomery, La Salle Parish, Louisiana.

SCHIZORTHOSECOS GRANDIPOROSUM Canu and Bassler, 1920

Plate V, figures 3-4

Schizorthosecos grandiporosum Canu and Bassler, 1920. U S. Nat. Mus., Bull. 106, pp. 627-628, pl. 18, figs. 10-15. - McGuirt, 1941, La. Geol. Sur., Bull. 21, p. 99, pl. 28, fig. 11, pl. 29, figs. 3-5.

Description of zoarium. - Zoarium a broad, shallow (height/diameter ratio, 25%) cup; zooecia erect, arranged in quincunx and radial rows from ancestrula; large zooeciules irregularly distributed between zooecia. Basal side of fused zooecial bases, each zooecial base perforated by one large pore (approximately 0.06 mm in diameter) and one or two small pores; large tubules (0.2 mm to 0.25 mm in diameter) penetrate, but do not reach frontal surface; tubules irregularly arranged, not present on all specimens.

Description of zooecia. Zooecia hexagonal prisms, base fused with adjoining zooecia, frontal surface terminating in elongate hexagonal to oval rim, small end proximal; rim very thick, encloses or nearly encloses round aperture, may be fused with rim of adjoining zooecia; secondary calcareous deposit borders aperture proximally. Zooeciules large (0.05 mm in diameter), round, bordered proximally by thick calcareous deposit; some zooeciules slit-like. Ancestrular zooecia irregular, with thicker rims, surrounded by numerous zooeciules.

Measurements
(average of 10 measurements per parameter)

Lz	0.23 mm
lz	0.20 mm
ha	0.12 mm
la	0.11 mm

zooecia width/length ratio	87%
zooecial apertura width/length ratio	92%

Comparisons. *Schizorthosecos grandiporosum* is distinguished by the single, large pore perforating the basal surface of each zooecium.

Type material. Lectotype, hereby designated: specimen (USNM 63863) represented by Canu and Bassler's (1920, pl. 18) figure 13; five figured paralectotypes (USNM 63863).

Range and distribution. - Eocene, Claiborne Group, Gosport Sand: Claiborne Bluff, near Claiborne, Alabama; Cook Mountain Formation: St. Maurice, Winn Parish, Louisiana.

Eocene, Jackson Group, Moodys Branch Marl: Jackson, Hinds County, Mississippi; Montgomery, La Salle Parish, Louisiana; Tullos, La Salle Parish, Louisiana; Heison Bluff, Caldwell Parish, Louisiana.

Type locality. - Claiborne Bluff, near Claiborne, Alabama.

Material examined. - Lectotype and five paralectotypes.

SCHIZORTHOSECOS RADIATUM Canu and Bassler, 1920

Plate VI, figures 1-2

Schizorthosecos radiatum Canu and Bassler, 1920. U. S. Nat. Mus., Bull. 106, p. 627, pl. 18, figs. 16-19.

Description of zoarium. Zoarium a small (diameter, 3 mm) shallow cup; zooecia nearly erect, slightly inclined outward from ancestrula; zooecia in quincunx and radial rows from ancestrula; two small zooeciules flank each zooecium distolaterally. Basal side of low to high, well-rounded, radiating, finely calcareous ridges, separated by broad furrows composed of hexagonal zooecial bases; some zooecial bases worn through exposing interior of zooecial tube.

Description of zooecia. - Zooecia nearly erect, hexagonal tubular prixms; zooecia frontal elongate hexagonal to oval, narrow end proximal (length, 0.14 mm; width, 0.13 mm); proximal to each aperture are 4 to 6 radial slits, on some broken zooecia the radial slits are connected and the aperture forms an elongate clithridiate opening; aperture and radiate slits surrounded by very thick rim; rim indistinctly fused with rim of adjoining zooecia. Ancestrula area of smaller zooecia with thickened calcareous deposits, ancestrular region of many specimens broken out of zoarium. Zooeciules with small round aperture (0.02 mm diameter) terminating a slight swelling of zooecial rimule, facing distally.

Comparisons. - The radiate ridges between the zooecial rows on the basal side and the radiate slits proximal to each aperture on this species make it unique among the species of Schizorthosecos and distinguish it from all others.

Type material. - Lectotype hereby designated: specimen USNM 63864 represented by Canu and Bassler's (1920, pl. 18) figure 16; 26 figured paralectotypes (USNM 63864).

Range and distribution. - Eocene, Claiborne Group, Gosport Sand: Claiborne Bluff, near Claiborne, Alabama; Lisbon Sand: Wantubee Hills, four miles south of Enterprise, Clarke County, Mississippi.

Type locality. - Claiborne Bluff, near Claiborne, Alabama.

Material examined. - Lectotype and 26 paralectotypes.

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PLATE I (left side)

Figures 1-2. Lunulites fenestratus (Canu and Bassler); Claiborne Group, Wheelock Formation; Burleson County, near Bryan, Texas; Frontal and basal sides; X 20.

Figures 3-4. L. distans Lonsdale; topotype; Eocene, Jackson Group, Castle Hayne Marl; Wilmington, New Hanover County, North Carolina. 3, interior of frontal side, illustrating four zooecial "sacks" characteristic of "hollow"zoaria; 4, frontal side,X20.

Figures 5-6. L. truncatus De Gregorio; Eocene, Claiborne Group, Gosport Sand; Claiborne Bluff, Monroe County, Alabama; reproduced from Canu and Bassler's (1920) Plate 11, figures 2-3; 5, illustrating basal side with ends of rows deeply hollowed; 6, frontal side; X 25.

Figures 7-8. L. bouei Lea; Eocene, Claiborne Group, Gosport Sand; Little Stave Creek, Clarke County, Alabama; 7, frontal side with central zooecia occluded, with single pores; 8, basal side; X 20.

Figures 9-10. L. ovatus (Canu and Bassler); Eocene, Wilcox Group, Bashi Marl; Woodbluff, Clarke County, Alabama; reproduced from Canu and Bassler's (1920) Plate 9, figures 11-12; 9-frontal side; 10 basal side; X 25.

Figures 11-12. L. almina De Gregorio; Eocene, Claiborne Group, Gosport Sand; Little Stave Creek, Clarke County, Alabama; 11, frontal side with rectangular opesia; 12, basal side; X 20.

Figures 13-14. L. montgomeryensis (McGuirt); Eocene, Jackson Group, Moodys Branch Marl; Jackson, Hinds County, Mississippi; 13, frontal side; 14, basal side; X 20.

Figures 15-16. L. bassleri (mcGuirt); topotype; Eocene, Jackson Group, Moodys Branch Marl; Montgomery Landing, La Salle Parish, Louisiana; 15, frontal side; 16, basal side; X 20.

PLATE II (right side)

Figures 1-2. Lunulites n. sp. 1; Eocene, Claiborne Group, Gosport Sand; Little Stave Creek, Clarke County, Alabama; 1, frontal side; 2, illustrating sand grain which served as nucleus for the zoarium (grain at top of photograph); X 20.

Figures 3-4. L. ligulatus (Canu and Bassler); Oligocene, Vicksburg Group, Red Bluff Clay; Hiwannee, Wayne County, Mississippi; 3, frontal side; 4 basal side; X 20.

Figures 5-6. L. verrucosus (Canu and Bassler); Eocene, Jackson Group, Castle Hayne Marl; Wilmington, New Hanover County, North Carolina; reproduced from Canu and Bassler's (1920) Plate 37, figures 7-8; 5, frontal side; 6, basal side; X 25.

Figures 7-8. L. grandipora (Canu and Bassler); Eocene, Claiborne Group, Lisbon Formation; near Enterprise, Clarke County, Mississippi; reproduced from Canu and Bassler's (1920) Plate 12, figures 3-4; 7, frontal side; 8, basal side; X 25.

Figures 9-10. L. reversa Ulrich; Eocene, Wilcox Group, Aquia Formation; Prince Georges County, Maryland; reproduced from Canu and Bassler's (1920) Plate 1, figures 17-18; 9, frontal side; 10, basal side; X 25.

Figures 11-12. L. tintinabulus (Canu and Bassler); Oligocene, Vicksburg Group, Red Bluff Clay; Hiwannee, Wayne County, Mississippi; 11, frontal side; 12, basal side; X 20.

Figures 13-14. L. jacksonensis (Canu and Bassler); Eocene, Jackson Group, Moodys Branch Marl; Jackson, Hinds County, Mississippi; 13, basal side; 14 frontal side; X 20.

Figures 15-16. Selenaria auricularia Canu and Bassler; lectotype; Eocene, Claiborne Group, Gosport Sand; Claiborne, Monroe County, Alabama; 15, frontal side; 16, basal side; X 35.

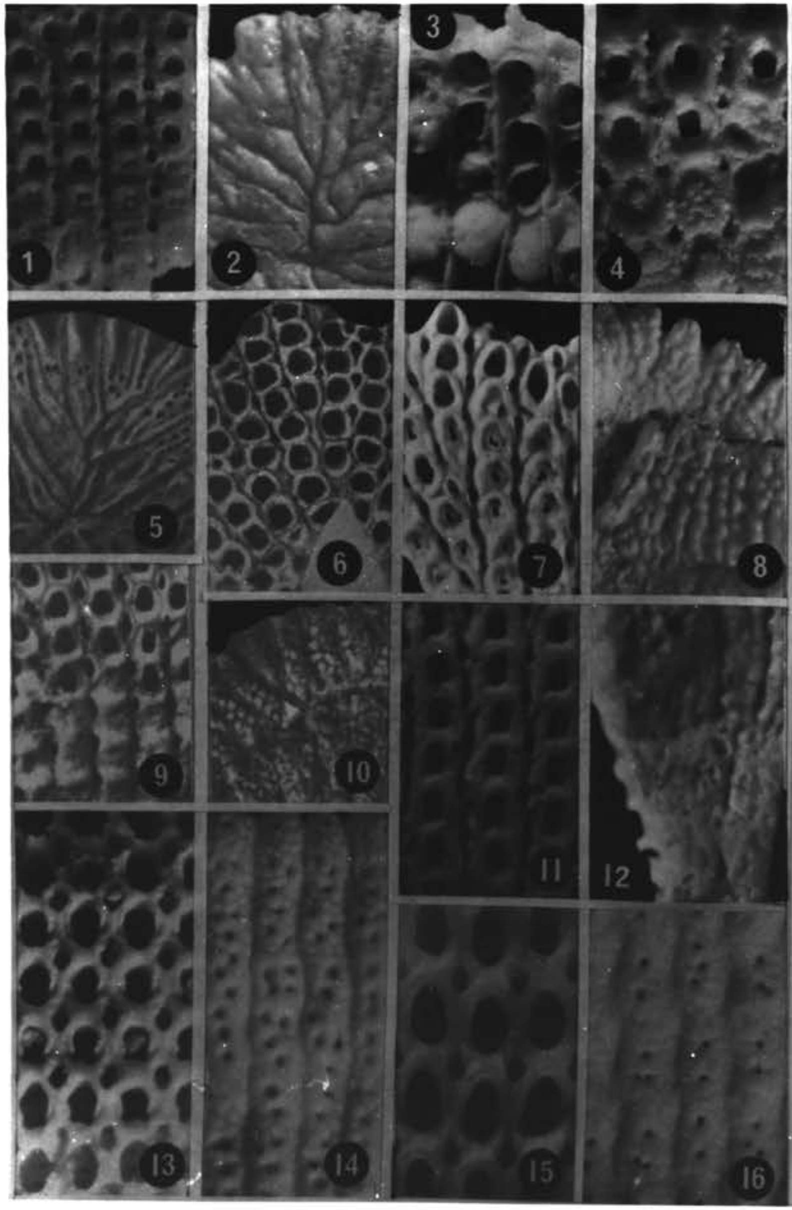

PLATE I

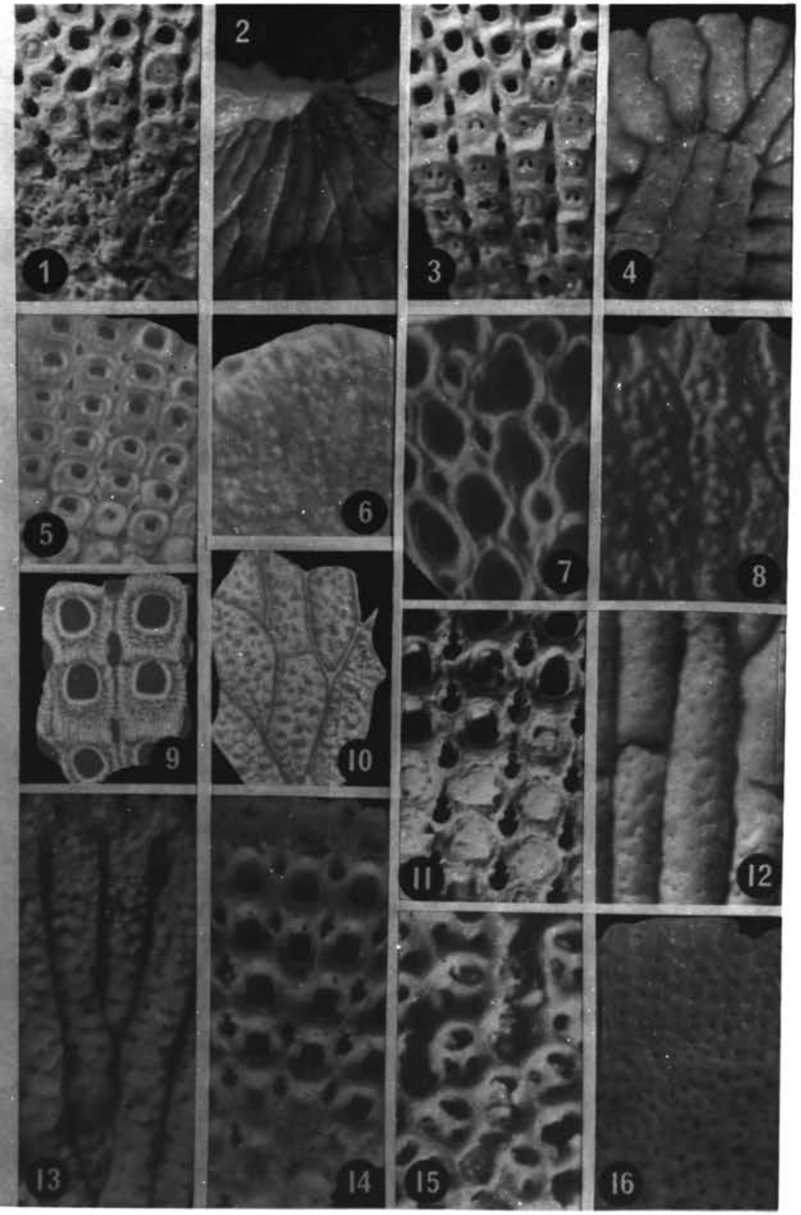

PLATE II

PLATE III (left side)

Figures 1-2. *Oligotresium claibornicum* (Canu and Bassler); Eocene, Claiborne Group, Gosport Sand; Little Stave Creek, Clarke County, Alabama; 1, frontal side; 2, basal side; X 20.

Figures 3-4. *O. contiguum* (Lonsdale); topotype; Eocene, Jackson Group, Castle Hayne Marl; Wilmington, New Hanover County, North Carolina; 3, frontal side; 4, interior of frontal side; X 20.

Figures 5-6. *O. vicksburgense* (Conrad); Oligocene, Vicksburg Group; Red Bluff Clay; Hiwannee, Wayne County, Mississippi; 5, frontal side; 6, basal side; X 20.

Figures 7-8. *O. tubiferum* (Canu and Bassler); Eocene, Jackson Group, Ocala Formation; near Georgia Kaolin Company Mine, Twiggs County, Georgia; reproduced from Canu and Bassler's (1920) Plate 37, figures 16, 18; 7, frontal side; 8, basal side; X 25.

Figures 9-10. *O.* n. sp. 1; Eocene, Claiborne Group, Gosport Sand; Little Stave Creek, Clarke County, Alabama; 9, frontal side; 10, basal side; X 20.

Figures 11-12. *O.* n. sp. 2; Eocene, Claiborne Group, Gosport Sand; Little Stave Creek, Clarke County, Alabama; 11, frontal side; 12, basal side; X 20.

Figures 13-14. *Cupuladria canariensis* (Busk); Miocene, Choctawhatchee Stage, *Ecphora* facies; Jackson Bluff, Ochlockonee River, Leon County, Florida; 13, frontal side; 14, basal side; X 20.

Figures 15-16. *C. biporosa* Canu and Bassler; 15, holotype, frontal side, Miocene, Bowden Marl: Santo Domingo, X 30; 16, basal side, Miocene (?), Upper Chicksawhay, near Millry, Washington County, Alabama; X 20.

PLATE IV (right side)

Figures 1-3. New Genus A n. sp. 1; Paleocene, Midway Group, Porters Creek Clay, Matthews Landing Marl Member; five miles south of Linden, Marengo County, Alabama; 1, zoarium encrusting worn mollusk fragment, X 20; 2, frontal side, X 28; 3, smooth basal side, X 28.

Figures 4-5. Discoporella umbellata (Defrance); Recent, Gulf of Mexico, Ship Island Pass; 4, basal side; 5, frontal side; X 20.

Figures 6-7. D. doma (D'Orbigny); Miocene, Choctawhatchee Stage, Ecphora facies; Jackson Bluff, Ochlockonee River, Leon County, Florida; 6 basal side; 7, frontal side; X 20.

Figures 8-9. Otionella perforata Canu and Bassler; Eocene, Jackson Group, Moodys Branch Marl; Jackson, Hinds County, Mississippi; 8, frontal side, X 28; 9, basal side, X 20.

Figures 10-11. O. tuberosa Canu and Bassler; Eocene, Jackson Group, Moodys Branch Marl; Jackson, Hinds County, Mississippi; 10, basal side; 11, frontal side; X 20.

Figures 12-13. O. cava Canu and Bassler; lectotype; Eocene, Jackson Group, Barnwell Formation; Baldock, Barnwell County, South Carolina; 12, frontal side; 13, basal side; X 20.

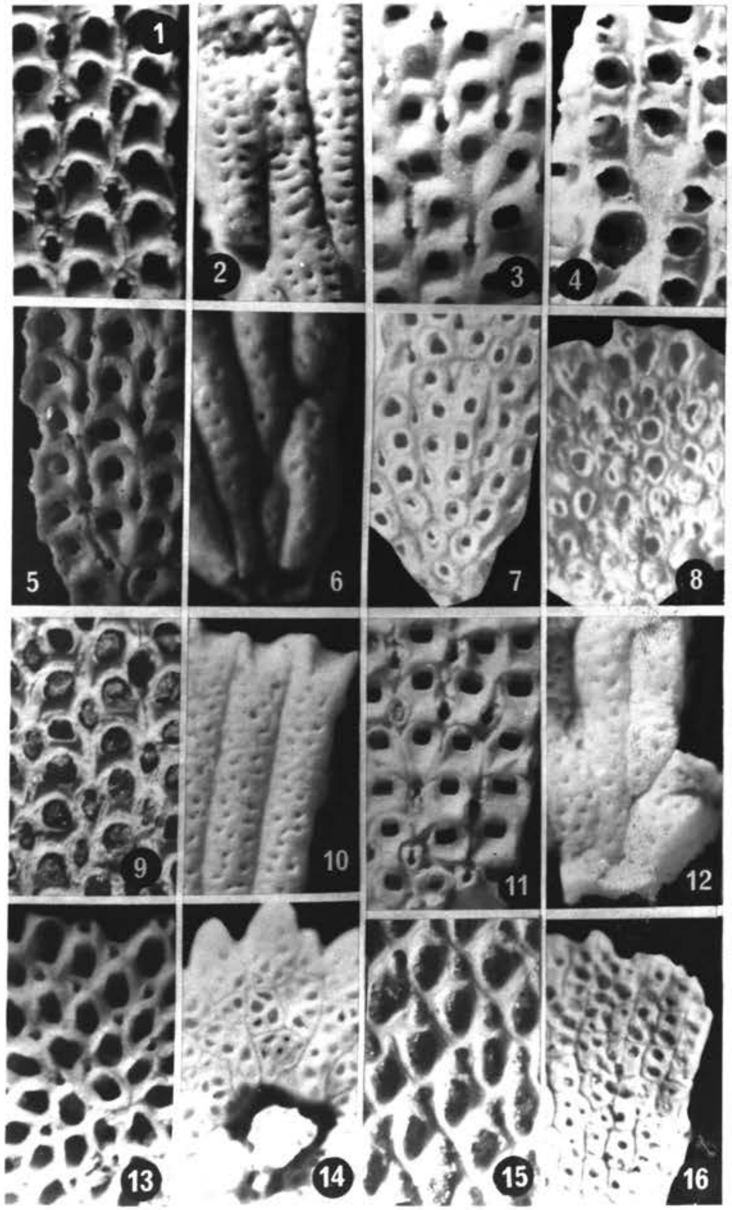

PLATE III

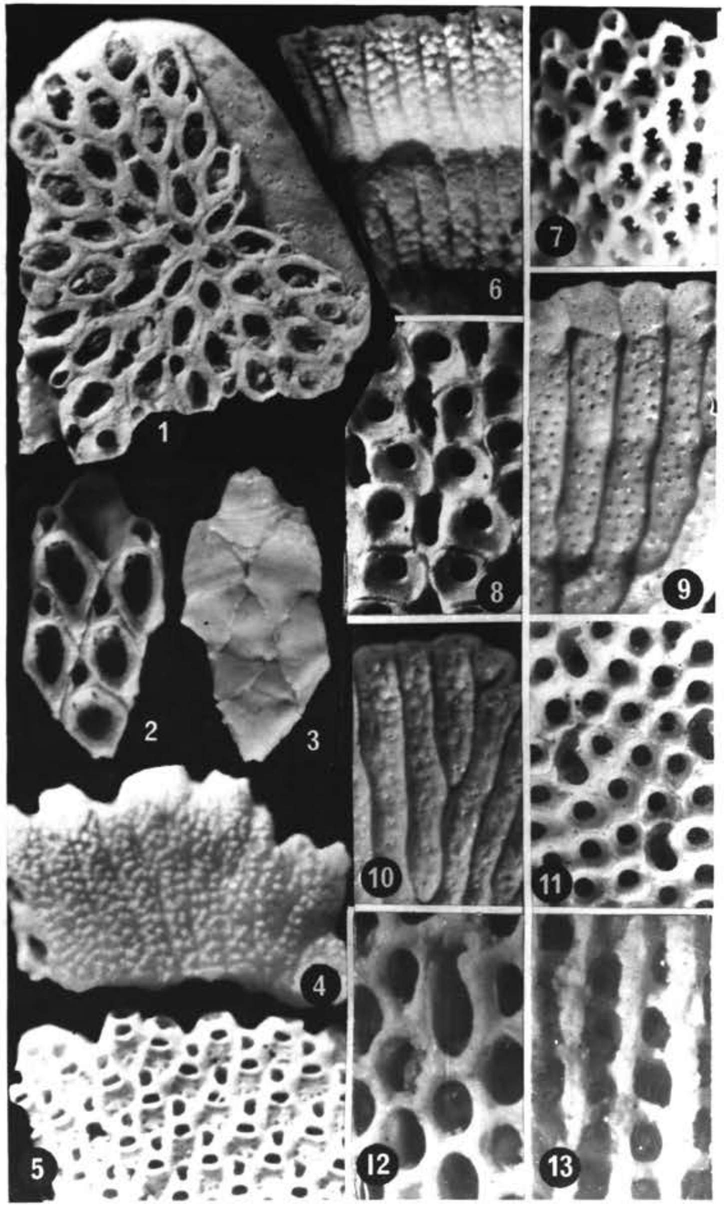

PLATE IV

PLATE V (left side)

Figures 1-2. Otionella n. sp. 1; Eocene, Claiborne Group, Wautubbee Formation; intersection of Interstate Highway 20 and Mississippi Highway 15, Newton County, Mississippi; 1, basal side; 2, frontal side; X 20.

Figures 3-4. Schizorthosecos grandiporosum Canu and Bassler; lectotype; Eocene, Claiborne Group, Gosport Sand; Claiborne, Monroe County, Alabama; 5, frontal side illustrating membraniporan zooecium in ancestrular area; 6, basal side, illustrating tubules and hexagonal sectors of the zooecial bases; X 20.

Figures 5-6. S. interstitia (Lea); Eocene, Jackson Group, Moodys Branch Marl; Jackson, Hinds County, Mississippi; 3, frontal side; 4, basal side; X 25.

Figures 7-8. S. danvillensis McGuirt; topotype; Eocene, Jackson Group, Moodys Branch Marl; Montgomery Landing, La Salle Parish, Louisiana; 7, frontal side; 8, basal side; X 20.

Figures 9-10. S. radiatum Canu and Bassler; lectotype; Eocene, Claiborne Group, Gosport Sand; Claiborne, Monroe County, Alabama; 1, frontal side; 2, basal side; X 25.

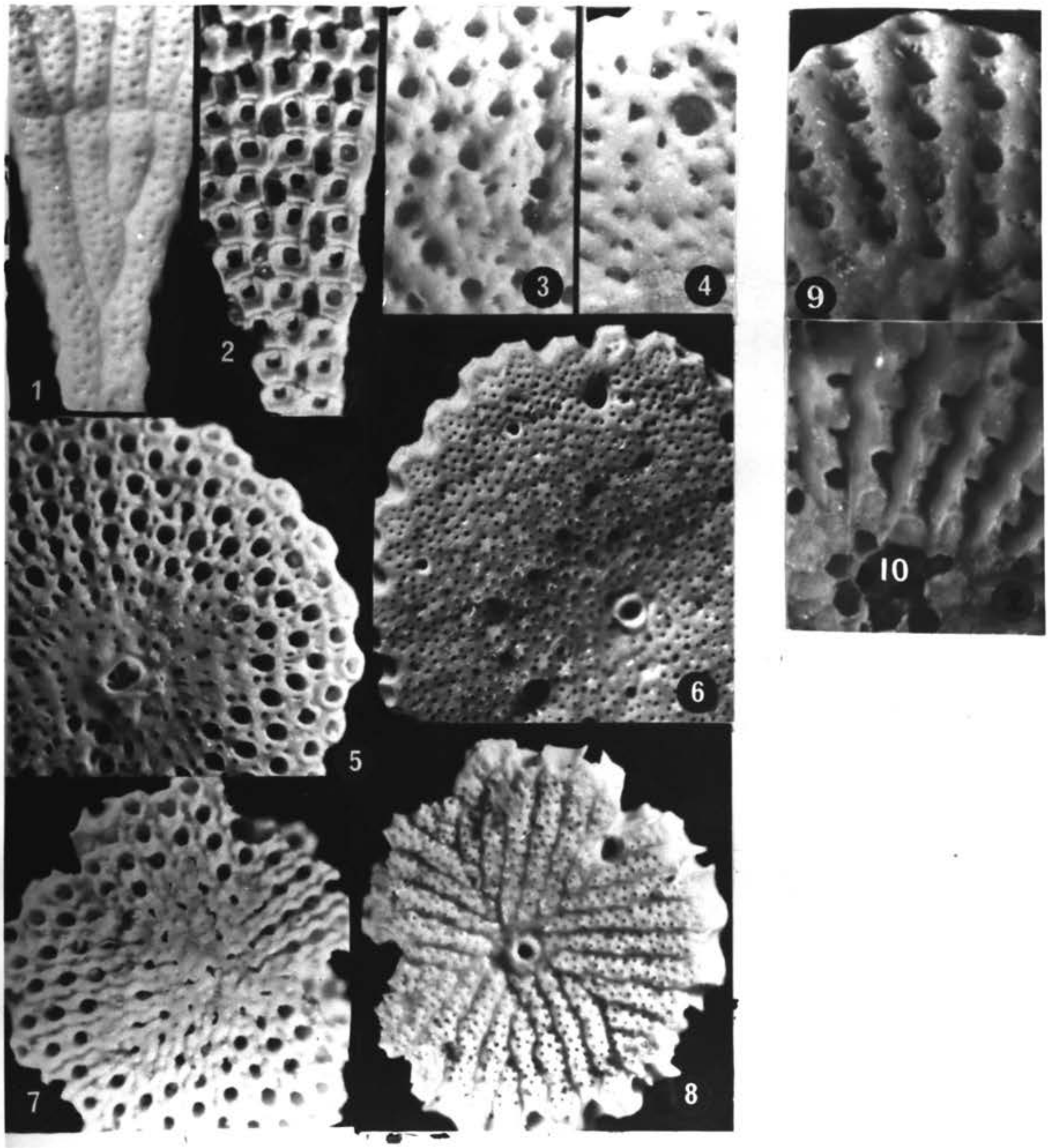

PLATE V

VITA

Ronald Greeley was born August 25, 1939, in Columbus, Ohio. As the son of a career Air Force Officer, he travelled extensively and attended several grade schools and high schools. In 1958, he received a diploma from Gulfport High School, Gulfport, Mississippi.

In the Fall of 1958, Mr. Greeley entered Mississippi State University and was graduated with a Bachelor of Science degree in 1962. During his senior year, financial aid was provided by a Texaco Scholarship and a Sigma Gamma Epsilon Scholarship. At the same university, he entered graduate school and received a Master of Science degree in 1963.

In August, 1960, Mr. Greeley married Cynthia Ray Moody of Gulfport, Mississippi.

He entered the former Missouri School of Mines and Metallurgy (University of Missouri at Rolla) in the fall of 1963. During the research of this thesis, financial aid was provided by teaching assistantships which were granted through the Department of Geology. During the summers of 1964 and 1965, research grants were provided by funds from the V. H. McNutt Foundation; during a part of the summer of 1965, financial aid was provided by a National Science Foundation Fellowship.

Mr. Greeley is a member of the national honor society for the earth science, Sigma Gamma Epsilon; American

Association of Petroleum Geologists; Geological Society of America; Society of Economic Paleontologists and Mineralogists, and International Bryozoology Association.