TULANE STUDIES IN GEOLOGY AND PALEONTOLOGY

Volume 16, Number 4 October 28, 1981

THE SPONGE FAUNA OF THE EOCENE CASTLE HAYNE LIMESTONE FROM EAST-CENTRAL NORTH CAROLINA

J. KEITH RIGBY
DEPARTMENT OF GEOLOGY, BRIGHAM YOUNG UNIVERSITY

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I. ABSTRACT

The Eocene Castle Hayne Limestone has yielded one of the most varied and best preserved sponge faunas known from Tertiary rocks of North America, from outcrops near the community of Mt. Olive in east-central North Carolina. Demosponges include: *Ophiraphidites infundibuliformis* Schrammen, 1899; the new species *Ophiraphidites hadros;* and the new genus and species *Acrochordiella vokesi*. Hexactinellid sponges include the new lyssacinosid euplectelloid species, *Regadrella trabecula*, and the new dictyid *Haynespongia vokesae*. Fragments of root tufts and lychniscosid sponges also occur. This is the first report of lychniscosid sponges in North American Tertiary rocks.

II. INTRODUCTION

Fossil sponges are relatively rare in the Tertiary and Cretaceous rocks of North America. Although many units within the Gulf Coastal Plain and the Atlantic Coastal Plain contain dissociated spicules in some profusion, discrete identifiable fossil sponges are relatively unusual.

The sponge fauna described here is based upon collections from the Castle Hayne Limestone in south-central Wayne County, North Carolina. The Castle Hayne Limestone was named by B. L. Miller (1910, p. 674-675) for exposures near Castle Hayne in northern New Hanover County, near Wilmington, in the coastal section of southern North Carolina. The type section is approximately 60 miles south of the fossil locality.

Age of this formation has been somewhat controversial. T. W. Vaughan (*in* Miller, 1910) stated that fossils from the Castle Hayne Limestone were peculiar but recognizable as Jacksonian forms. Bryozoans of the fauna were monographed by Canu and Bassler (1920), and the larger invertebrate fossils were described by Kellum (1926). Canu and Bassler and Kellum agree in assigning the Castle Hayne Limestone a Jacksonian age, but Cooke and MacNeil (1952) concluded that it is of Claibornian age. Cheetham (1961) reworked some of the byozoan fauna and determined that the formation is unquestionably of Jacksonian age, as

EDITORIAL COMMITTEE FOR THIS PAPER:
MATTHEW H. NITECKI, Field Museum of Natural History, Chicago, Illinois
BOB F. PERKINS, Graduate School, University of Texas, Arlington, Texas

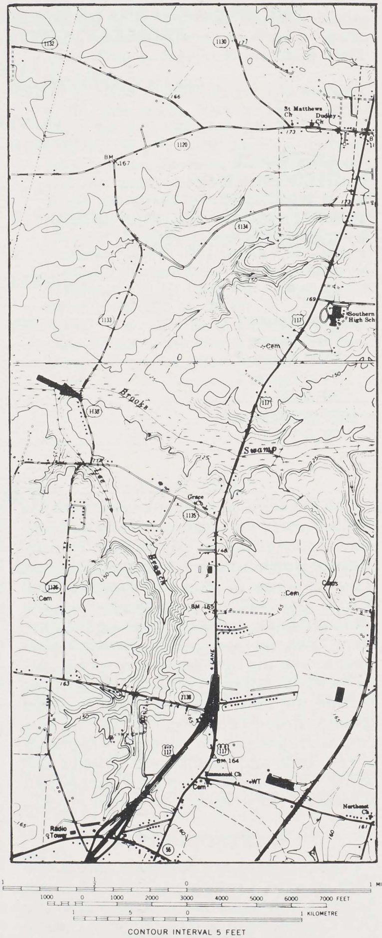
exposed in the classic localities of North Carolina.

In down-dip subsurface rocks, where the formation has been given a Claibornian age (Brown, 1958), the rocks appear to be definitely older, with the relationship most easily explained as an updip onlap, as suggested by LeGrand and Brown (1955). Stuckey and Conrad (1958, p. 44-45) show the unit as middle and upper Eocene. They apparently included within the Castle Hayne Limestone rocks that initially had been mapped as Castle Hayne Limestone as well as the Trent Formation of older maps. These two units now appear to be of roughly equal age, but of differing facies.

All the fossils described in the present paper came from a single locality in the upper Eocene (Jacksonian) Castle Hayne Limestone, Tulane University locality TU 869, collected by Harold and Emily Vokes. This locality is on the south side of Brooks Swamp (see Index map) in roadcut south of the bridge, 2.1 miles (3.4 km) southwest of Dudley and 3.6 miles (5.8 km) due north of the center of the community of Mount Olive; at 35°14′40″ N and 78°04′13″ W (3904300 N — 766650 E, Zone 17, Universal Transverse Mercator) on the Mount Olive, North Carolina 1:24,000 7.5 minute topographic quadrangle. The locality is reached by travelling northward on U.S. Highway 117 for 3.0 miles (4.8 km) from the center of Mount Olive, then west-northwestward 0.8 miles (1.3 km) along State Route 1135 and then north-northwestward 0.4 miles (1.0 km) along State Road 1133 to the south bridge cuts.

The locality has since been destroyed by road construction and the isolated outcrops covered by fill. When the initial collections were made, the sponges occurred in a weathered red clay. The stratigraphic position of these outcrops within the Castle Hayne Limestone is not known because of the isolated position of the outcrop. The sponges occurred largely free of matrix as a weathered lag.

The sponges were washed to remove the clay matrix and were further cleaned in the laboratory by short treatment in an ultrasonic vibrator cleaner with warm soapy water. Some isolated specimens were also treated with dilute hydrochloric acid but with little effect. For photographs, specimens were painted with black fountain-pen ink and then coated with sublimated ammonium chloride.



Map showing location of TU locality 869, Wayne Co., North Carolina.

III. ACKNOWLEDGMENTS

Appreciation is given to Harold E. and Emily H. Vokes for loan of the collection and for review of various drafts of the manuscript. Study of the collection was done while on a research leave from the Department of Geology, Brigham Young University.

IV. SYSTEMATIC PALEONTOLOGY

Class DEMOSPONGEA Sollas, 1875
Order CHORISTIDA Sollas, 1888
Family CEPHALORAPHIDITIDAE Reid, 1968

Reid (1968, p. 1252) proposed the Cephaloraphiditidae to include the triaene-bearing sponges included by Schrammen (1903) in the Ophiraphiditidae, thus presumably including the several fossil species of *Ophiraphidites* per Schrammen, *Cephaloraphidites*, *Polytretra*, and *Megaloraphium*, but excluding *O. tortuosus* Carter (1876, p. 458) and *Heteroraphidites* Schrammen 1901 (=*Allioraphium* Schrammen, 1910). When Schrammen (1903, p. 17; 1910, p. 119) proposed and expanded the Family Ophiraphiditidae, he placed it in the then recognized Order Tetraxonia, but was uncertain as to which suborder it belonged because microscleres of the sponges were not known. De Laubenfels (1955, p. E-43) placed the family in the Order Choristida, presumably based upon the occurrence of long shafted triaenes in the skeletal net and of smaller triaenes as dermal spicules in the several genera included. Reid (1963) constructed a classification of Demospongea that updated Schrammen's work (1910, 1924) but still left those sponges whose spicules are ophirhabds, among others, in uncertain ordinal position.

The family Ophiraphiditidae was based by Schrammen (1903, p. 17; 1910, p. 119) on the recent genus *Ophiraphidites* Carter, 1876. The type species of the genus, *O. tortuosus* Carter (1876), was based on macerated fragments containing only ophirhabds. Schrammen (1910, p. 119) emended the generic description to include variously shaped sponges in which the main skeleton consists of matted ophirhabds but also includes straight or slightly bent oxeas, and which have triaene dermalia that have unfolded rays. Reid (1968, p. 1252) pointed out that ophirhabds occur in several modern sponges and erected the Family Cephaloraphiditidae to include these sponges with triaenes.

Cephaloraphidites Schrammen (1899, p. 6; 1910, p. 124) is separated from several fossil species of *Ophiraphidites* by possessing common club-shaped styles, in addition to the matted ophirhabds, oxeas, and dermal triaenes.

OPHIRAPHIDITES INFUNDIBULIFORMIS
Schrammen, 1899
Plate 1, figs. 1, 3, 5, 6; Text-fig. 1

Ophiraphidites infundibuliformis SCHRAMMEN, 1899, p. 5, pl. 1, fig. 4, pl. 2, fig. 6; SCHRAMMEN, 1910, p. 121-123, pl. 14, fig. 7, text-fig. 7, fig. 5; DE LAUBENFELS, 1955, p. E43, fig. 22.

Diagnosis: Wavy, ear-shaped to palmate or irregularly conical to conico-bylindrical sponges composed of matted irregularly curving ophirhabds, coarsest in gastral part of wall. Gastral and dermal layers a felt of small smooth-rayed triaenes. Canals labyrinthic with cross-connecting radial, concentric-horizontal and vertical to inclined series.

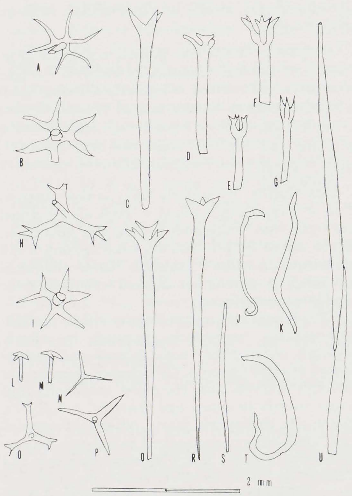
Description: Irregularly wavy, ear-shaped, to flat or irregularly conical to conical-cylindrical sponges and fragments are in the collection. Walls range up to 12 mm thick but are only 5 to 6 mm thick in most fragments. Numerous canal openings are somewhat aligned, on both exterior and interior surfaces.

The sponge wall is composed mainly of matted, intertwined, irregularly curving to nearly straight ophirhabds, with dermal and gastral layers of small triaenes. Ophirhabds are gently to strongly curved and recurved monaxons that taper evenly to sharp tips (Text-fig. 1-J, K, T). Some are irregularly wavy, others are serpentine, and others are hooked to almost circular. These spicules are up to 0.08 mm in diameter and 2 mm long, with most ophirhabds in the interior of the wall 0.04 to 0.06 mm in diameter at midlength and 1.0 to 1.5 mm long. Strongly curved spicules are particularly common near the gastral and dermal surfaces or in the vicinity of the canals; nearly straight spicules are concentrated in the linear tracts between aligned series of canals. This relationship is best seen on outer parts of the wall where, on some specimens, there is an upward and outward fanning of bundles of generally less strongly curved spicules.

Gastral surfaces are layered with a dominance of coarse ophirhabds. Finer spicules dominate in the main part of the wall and on the dermal surface. Gastral ophirhabds are up to 0.08 mm in diameter and nearby main wall and dermal ophirhabds are generally 0.04 to 0.06 mm or less in diameter.

One triaene (orthotriaene) seen in the gastral surface of a large conical irregularly wavy fragment has smooth, unbranched, small rays approximately 0.2 mm long, with basal diameters of 0.06 mm. These are bent forward about 10 to 15 degrees and taper evenly and smoothly to pointed tips. The longer shaft is buried within the sponge wall and is of unknown total length.

The gastral layer is a felt of varying thickness that grades from the almost exclusively ophirhabd interior of the wall, out through interlayered rare to common small triaenes, to a gastral-most layer of almost exclusively small triaenes. This gradation takes place through 1 to 2 mm of wall thickness. These small triaenes (Text-fig. 1-N, P) are arranged with one proximal and three paratangential rays. Paratangential rays are most evident on weathered surfaces. They are oriented 120° apart from their junction and are bent foreward only slightly to as much as approximately 20 degrees. Rays on the spicules are smooth, unbranched, and gently taper to a sharp point. They range up to 0.14 to 0.16 mm long and have basal diameters of 0.02 to 0.03 mm. The most common triaenes are smaller, with tangential rays approximately 0.10 mm long and basal diameters of approximately 0.01 mm. Many triaenes are much smaller, however, and some with ray lengths of only 0.02 to 0.03 mm are common and well preserved.



Text-figure 1. Spicules of *Ophiraphidites infundibuliformis* Schrammen, 1899. A, B, I, O. Dichotriaenes, in large part from the gastral or dermal layers. C-G, Q, R. Protriaenes, some with simple rays and others with modified secondary rays. H. Modified dermal triaene with three secondary rays on each of the paratangential rays. J, K, S, T. Ophirhabds of the main skeletal net showing variations in curvature and size. L-N, P. Simple small orthotriaenes from the gastral or dermal net. U. Large oxeas from a main spicular bundle in the main wall.

There is a general pattern within the dermal layer for one tangential ray of the triaenes to be subparallel to the long axis of the adjacent canal series or the major skeletal bundles. Such a pattern is most evident for the larger triaenes, and obscure for smallest spicules. There is no layering nor size gradient visible in the distribution of gastral triaenes but all fit into an irregular, matted, felt-like layer.

The dermal triaene felt is composed of spicules of similar size and distribution. The layer is thickest on crests of main ophirhabd bundles, between canals, and there the triaenes obscure the large spicule pattern.

A few long, smooth, sharply pointed oxeas occur throughout the sponge. They are most common in association with the nearly straight ophirhabds in the main upward fan-like bundles. but occur elsewhere and at other orientations, as well. They are up to 4 or 5 mm long and 0.10 to 0.12 mm in maximum diameter. Most are of the same general dimensions as the associated ophirhabds and possibly grade into them, through increased curvature and irregularity.

Largest canal openings on the coarsely spiculed side of the walls, are spaced from 1 to 4 mm apart, but most are spaced 1.5 to 2.0 mm from center to center. Five to seven such ostia occur per 5 mm square. Small canal openings are separated by approximately 0.5 mm of skeletal net and are relatively uniformly spaced. There are 30 to 40 of the small openings per 5 mm square.

Internally canals are labyrinthic with radially-oriented outer segments that open onto the dermal or gastral surfaces. These labyrinthic canals are connected by horizontal canals, which meander somewhat, but maintain a concentric pattern in the wall of conical forms. In addition, vertical to steeply inclined, meandering to straight slit-like canals occur in the wall interior. These are somewhat aligned in areas where the spicules are bundled prominently. In areas where the sponge is sharply bent the canals form more linear and elliptically opened series. In one area, considered to be typical, slit-like, elongate, elliptical openings occur in a series between bundled nearly straight spicules. These bundles occur eight in 5 mm, measured horizontally. The intervening canals range from only 0.2 to 0.5 mm wide, with most being 0.2 to 0.3 mm across. Canals are spaced four to six per 5 mm in the beam-bound series. They also emerge at an acute angle to the surface, producing an apparent lenticularity.

Elsewhere on the same specimen, opposite the canal pattern measured on the larger spiculed side, the canals are circular and range from 0.3 to 0.6 mm in diameter, with most approximately 0.4 mm across. They are uniformly spaced and separated by 0.3 to 0.6 mm of skeletal material. None of these radial canals extends through the wall, but most extend to near midwall where radial horizontal concentric and steep rising canals interconnect.

Concentric horizontal canals are circular to strongly elliptical, parallel to the skeletal bundles. Canals are 0.3 to 0.5 mm across, up to 0.8 mm high, and are concentrated in the middle third of the wall. They cross-connect the radial canals and the steeply rising series in a somewhat labyrinthic fashion. It is far from a uniformly spaced subrectangular pattern in most areas, but approaches such an arrangement in the sharply folded regions where the skeletal tracts are most linear.

In cross sections of the sponge wall, the horizontal concentric canals and the rising fanning canals are spaced approximately 1.0 mm apart, measured horizontally parallel to the radial series. The concentric canals are spaced approximately the same distance apart, vertically, although they are quite irregular.

A series of upward and outward fanning canals is seen in some of the sponge fragments, and is particularly well developed in the thicker walled specimens. These canals are slit-like to circular, approximately 0.3 mm across, and are parallel to the tracts of nearly straight spicules. They are most prominent in the two-thirds of the wall closest to the finer spiculed and more linear spiculed surface, whether gastral or dermal is at present a question. They cross-connect with the radial and concentric series and are less labyrinthic than either because of their position between the ascending and fanning spicule tracts. They are not uniformly developed, however, and they are loci of crushing in those specimens that have been flattened during fossilization.

One specimen of the thin, blade or ear-like form shows the surface sculpture and canal pattern well. The coarse-spiculed side is marked by obscure rings where the large canal openings are common. These canals slope inward (or down) and distally to the radiating patterns of the spicule tracts on the other side. The bands or areas of concentration are 10 to 15 mm apart, radially, and are normal to the radiating tracts. Intervening areas are perforated by the smaller canal openings.

The reverse side is the part of the wall with finer ophirhabds and is the part that best shows pinnation of the spicule tracts. Tracts expand distally and new tracts are inserted as the net expands.

A few rare club-ended spicules are present near the gastral (?) surface on some fragments. One such spicule is broken but has a diameter of 0.11 mm along the short staff fragment, expanding abruptly to a spherical knob-like termination 0.14 mm in diameter; both spicule parts are smooth. These very rare spicules are like the amphistyles in *Allioraphium spongiosum* Schrammen (1910, p. 122, fig. 7-40), or more club-shaped tips of styles of *Cephaloraphidites milliporatus* Schrammen (1910, p. 124-125).

Discussion: In all respects the many fragments of the species in the North Carolina collection agree with the type material described by Schrammen (1899, p. 5; 1910, p. 121-123) from the Upper Cretaceous of Northern Germany. Even the siliceous preservation appears strikingly similar. The North Carolina specimens commonly encrust dictyid sponges and are themselves rarely encrusted. This suggests a relatively loose dermal layer for the species or else the fragments were buried early in the ontogeny of the sponge so that epizoic or epiphytic organisms could not become attached. The associated dictyid sponge fragments are intensely overgrown. In a few instances fragments of *Ophiraphidites* are encrusted by cheilostome bryozoans, but rarely are sponges or other organisms, other than possible worm tubes, attached to these irregularly spiculed forms.

Ophiraphidites infundibuliformis has characteristically overgrown the associated dictyid sponges indicating that the latter were the primary colonizers. In addition, worm tubes and lychniscosid sponges have encrusted *Ophiraphidites* and *Acrochordiella*.

Figured specimens: U. S. National Museum 252484 to 252487.

OPHIRAPHIDITES HADROS n. sp.
Plate 1, figs. 7, 8; Text-fig. 2

Diagnosis: Massive cavernous sponges composed of crudely bundled, curved to serpentine ophirhabds and rare oxeas, with dermal layer of matted, smooth-rayed small triaenes. Surface with round ostia or slits or upward-radiating or cross-connecting horizontal canals.

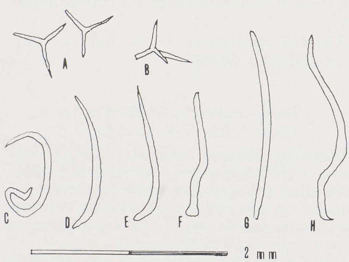
Description: One large sponge and two small fragments are in the collection. The large specimen, the holotype, is a coarse textured, cavernous sponge, now approximately 80 mm high and 55 mm across, with a broken base but almost complete upper part. it has a rough, almost clinker-like, exterior that is marked by several vertically elongate openings, over 10 mm across, and by numerous, more or less equally spaced, openings 2 to 5 mm across, which are distributed over the entire sponge surface. The large openings probably functioned as major excurrent openings. One, 5 × 12 mm in cross section, penetrates deep into the sponge, but is open above. Elsewhere, moderately uniformly spaced openings, 2 to 5 mm across, occur in slits 5 to 8 mm high. They are spaced 5 to 10 mm apart and probably functioned as large excurrent openings.

Numerous canals, approximately 1.0 mm in diameter, meander through the massive, somewhat pillared sponge body. They mark open or loosely spiculed areas between the skeletal tracts, which appear to fan upward and outward. Openings of these canals widen near the surface and produce the rounded to elongate depressions that are scattered over the sponge surface. These canals are irregularly developed as horizontal cross connections, as well, even near or at the exterior of the sponge.

Smaller openings, 0.4 to 0.5 mm in diameter, are also common on the exterior and interconnect with the intermediate-size canals and the larger excurrent openings. These smaller canals generally open into the meandering, impressed, surficial depressions, as do the larger canals, but a few of the smaller ones also open on the crests and flanks of the intergroove ridges.

The surficial grooves are rounded and 1 to 2 mm across and 2 to 3 mm deep. They meander and anastomose irregularly, but generally with a vertically elongate trend. Ridges between the grooves are also rounded and mark the emergence of spicule bundles.

Spicules are ophirhabds, triaenes, and oxeas (Text-fig. 2). Ophirhabds are wavy to strongly curved or irregularly serpentine spicules that may blend in a variety of planes. They are smooth and taper to sharp points or rounded tips at both ends, are smoothly to irregularly curved around canal openings and over rounded surfaces, and are most regular in the central parts of closely packed spicule bundles. Ophirhabds are most irregular in surficial areas where adjacent spicules have least interferred with them. They are mostly 0.08 mm in maximum diameter and up to 5.0 mm long. Smaller spicules, up to 0.06 mm in diameter, are locally common particularly on the tips of the bristled spicule bundles on the upper part of the sponge. These may be immature ophirhabds.



Text-figure 2. Spicules of *Ophiraphidites hadros*, n. sp. A. Simple orthotriaenes from the dermal layer. B. Simple protriaene from the dermal net. C-H. Ophirhabds from the main skeletal net showing size and variation in curvature.

Oxeas are not common but are scattered throughout the sponge as slightly larger spicules, with maximum diameters of 0.14 to 0.22 mm. They are smooth, gently doubly tapering, and have pointed tips, and are inserted at various angles within the net. Some may be overgrown foreign spicules since, in two cases, foreign oxeas are inserted into large canal openings on the surface.

Triaenes are not common within the main matted skeletal net, but are moderately common in tips of the spicule bundles and on crests of irregular ridges and appear to be principally dermal. Their preservation, mainly on the elevated regions, may be related to a possible cortex. Triaenes are most common where tightly matted to one another or infilling open spaces between outer ophirhabds. They thus produce dense areas of the skeletal structure. These small dermal spicules have three equally spaced, paratangential rays, have diameters up to 0.04 mm, and are up to 0.75 mm long. Most of these spicules are less than half that size, however, with ray lengths of less than 0.3 mm and diameters of less than 0.03 mm.

A few larger triaenes occur in the main skeleton and are of the same general dimensions as the ophirhabds. For example, one well preserved spicule has three tangential rays 0.12 to 0.14 mm in diameter and 1.4 to 1.5 mm long. These rays are bent slightly distally, are pointed and unbranched, and taper uniformly from their junction with the proximal ray, which is embedded in the skeletal net.

Acid-etched residues from the sponge include two anatriaenes, two loose hexactines, and one dichotriaene, in addition to wavy smooth oxeas and equirayed triaenes. The dichotriaene, hexactine, and anatriaenes are common in associated hexactinellids and are probably foreign to the present species.

Vertical spicule bundles are generally 0.7 to 1.2 mm in diameter, are irregular vertically, and are cross-connected at irregular intervals, generally less than 1 mm, by sub-horizontal bundles, by bifurcation, or by merging with lateral bundles.

Discussion: Schrammen (1899, 1910) defined various genera now included in the family Ophiraphididae on the basis of spicule structure. He included within the genus *Ophiraphidites* (Schrammen 1910, p. 120) those forms that have skeletons of ophirhabds and straight or slightly bent oxeas, with dermal layers of triaenes with unbranched rays. *Cephaloraphidites* (Schrammen, 1910, p. 124), in addition, contains club-shaped styles. *Heteroraphidites (=Allioraphium)* (Schrammen, 1910, p. 125-126) is composed of ophirhabds but includes large tylostyles, amphistrongyles, tylotes, and oxeas.

Polytretia (Schrammen, 1910, p. 126) and *Megaloraphium* (Schrammen, 1910, p. 127) are flattened, ear-shaped sponges with large canals and skeletons of matted ophirhabds, triaenes, and oxeas. These genera differ from *Ophiraphidites* mainly in their canal structure, size of their small main spicules, and in lacking coarse triaenes.

Schrammen added *Ophiodesia* (1936, p. 183) and *Euleraphe* (1936, p. 184) to the family. *Ophiodesia* has matted sinuous ophirhabds and lumpy styles while *Euleraphe* has thin short, eulerhabd spicules, as in *Megaloraphium*.

Based upon spicule patterns, the North Carolina specimen belongs in the genus *Ophiraphidites* but differs from other described species in its massive growth habit. *O. infundibuliformis* Schrammen (1899, p. 5; 1910, p. 121, 123) is funnel, club, or irregularly shaped and differs in being much less massive, even in areas that are somewhat folded.

Ophiraphidites tuberosus Schrammen (1899, p. 5; 1910, p. 124; pl. 18, fig. 8) is perhaps the most closely related species in its irregular growth but has triaene dermalia with tangential rays that are bent backward rather than forward like in the present species. In addition, *O. tuberosus* is much less massive, and lacks the sculpture, the clustered tracts, and the large openings that are typical of the North Carolina species.

Ophiraphidites cylindricus Schrammen (1910, p. 121), *O. annulatus* Schrammen (1910, p. 120-121), and *O. ramosum* Schrammen (1910, p. 123-124) are all simple or forked ramose, tubular sponges and much different in general growth form from the North Carolina species.

Type material: Holotype USNM 252488, paratypes BYU 1540 and 1541.

Etymology: Hadros, Latin, bulky, stout, thick, referring to the relatively massive form of the species.

Order LITHISTIDA Schmidt, 1870
Suborder TETRACLADINA Zittel, 1878; emended Sollas, 1887
Family ACHROCHORDONIIDAE Schrammen, 1910

Achrochordonia Schrammen (1901, p. 96) was the only genus included in the Achrochordoninae when it was first proposed by Schrammen (1910, p. 96) as a subfamily in the then Family Tetracladina. Tetracladina in this sense of Schrammen are those sponges whose skeleton is composed of spicules with four rays, which are bound together by zygosis. Dermalia in the group are triaene-based, or rare anaxial siliceous fragments or plates. De Laubenfels (1955, p. E52) considered the Tetracladina as a suborder of the Lithistida and included in that suborder sponges with tetracrepid desmas that unite with adjacent spicules at elaborately sculptured ray extremities.

Schrammen differentiated the Achrochordoniidae from other tetracladinid sponges on the basis of the family having modified dermalia and on the warty nature of the tetraclone spicules. The Achrochordoniidae contain only dichotriaene dermalia and, as such, differ from most of the other tetraclad sponges with heavily nodose or warted tetraclones. In general, other forms have phyllotriaenes, discotriaenes, or other modifications of triaenes as dermalia. Until now only a single genus, *Achrochordonia* Schrammen, 1912, has been included in the family. Two species of that genus were both described from the Quadraten Kreide near Oburg, where both were indicated to be relatively rare.

ACHROCHORDIELLA, n. gen.

Diagnosis: Massive, lobate to digitate, anastomosing to branched, finger-like sponges. Principle skeleton of small to medium sized, warty, tetraclones. Dermalia of characteristic dichotriaenes or modifications of dichotriaenes that may have lost one or two primary or secondary branches. Phyllotriaenes rare. Surfaces marked by moderately indented strong, somewhat anastomosing, generally nearly vertically oriented canals. Individual branches without spongocoel and relatively dense.

Discussion: Achrochordonia Schrammen, 1901, is a closely related genus but differs from *Achrochordiella* principally in the character of the triaene-based dermal spicules. *Achrochordonia* Schrammen (1910, text-fig. 6-7, 10) is shown with dermalia that are clearly simple, radial, dichotriaenes in which the secondary rays of the main rays branch at uniform angles and appear to be moderately consistant and uniformly developed. In addition, the main skeletal tetraclones are somewhat more irregular and have warts or tubercules that consistantly have larger diameters, relative to the main axis, than in *Achrochordiella*. Both genera, however, are of the same gross shape with relatively massive bases, from which extend rounded, pointed, or club-shaped branches, or with bulbous to rounded lobate masses that project from the general surface. In general, the North Carolina genus is distinctly more branched and certainly has a more sculptured appearance produced by the indented short, tangential canals.

Plinthosella Zittel (1878, p. 153), *Pycnodesma* Schrammen (1910, p. 115), and related forms, have similar, warty, tetraclad spicules, but differ significantly in possessing an array of decidedly different dermal triaenes.

Type species: Achrochordiella vokesi, new species.

ACHROCHORDIELLA VOKESI, n. sp.
Plate 3, figs. 1-3, 5; Text-fig. 3

Diagnosis: Digitate to arborescent sponges, with earlier parts fused and enlarged by lateral growth of individual branches and increase in diameter. Major excurrent canals developed between fused branches are largest canal openings. Relatively massive and dense skeleton of fused, knobby or warty tetraclones. Sculpture particularly prominent on distal surface of spicules, but evident on practically all surfaces. Dermalia dichotriaenes or dichotriaene-based spicules in which a secondary ray aborted to produce a secondary pentactine commonly with irregular wavy or bent rays. Other tetraxonic-based spicules, such as smooth-rayed tetraxons may occur. Surface marked by more-or-less continuous to anastomosing vertical canals impressed into the sponge surface. These are bridged in interior of digitations and function as major excurrent canals without producing porous zones in branches.

PLATE 1

Ophiraphidites and *Regadrella* from Eocene Castle Hayne Limestone

FIGS. 1, 2, 5, 6 — *Ophiraphidites infundibuliformus* Schrammen, 1910. *1*, Photomicrograph of the gastral surface of a plesiotype, USNM 252484, showing the relatively coarse nature of the skeletal net, the somewhat bundled occurrence of the spicules, slit-like canals that penetrate the sponge wall, and dense areas where the fine dichotriaene-based dermal spicules are preserved. ×5. *2*, Photomicrograph of a plesiotype surface showing characteristic curved ophirhabds and irregularly spaced and arranged circular canals that feed more or less radially through the sponge wall. Dense areas are composed, in large part, of tiny dichotriaenes of the dermal and gastral layers. ×5. USNM 252485. *5*, Ear-shaped fragment of a plesiotype showing irregular folding and thickness of one of the walls, as well as the distinctly aligned canals that parallel the bundledspicules of the wall. Cross section of the sponge wall in the lower left shows the generalized upward radiating canal pattern. USNM 252486. Natural size. *6*, Somewhat tubular fragment of the sponge showing the irregular growth form, wall thickness, and irregular arrangement of various canals on both the interior and exterior. Natural size. USNM 252487.

FIGS. 3, 4 — *Regadrella trabecula*, n. sp. Holotype, USNM 252492. *3*, Photomicrograph of the skeletal net showing the compound beam-like architecture of the sponge, where subparallel hexactine-based spicules are laterally fused into beams by a synapticular web or by cross-bracing synapticulae, with somewhat bundled spicules separating the moderately large canals. ×5. *4*, View of the holotype fragment showing the relatively coarsely canaled architecture and the bundled, beam-like, skeletal net characteristic of the species. Weak ribs show as densely spiculed areas in the lower part of the sponge and appear to represent former oscular margins. These dense layers are composed of short-rayed spicules and synapticulae, with limited development of the compound beams. Natural size.

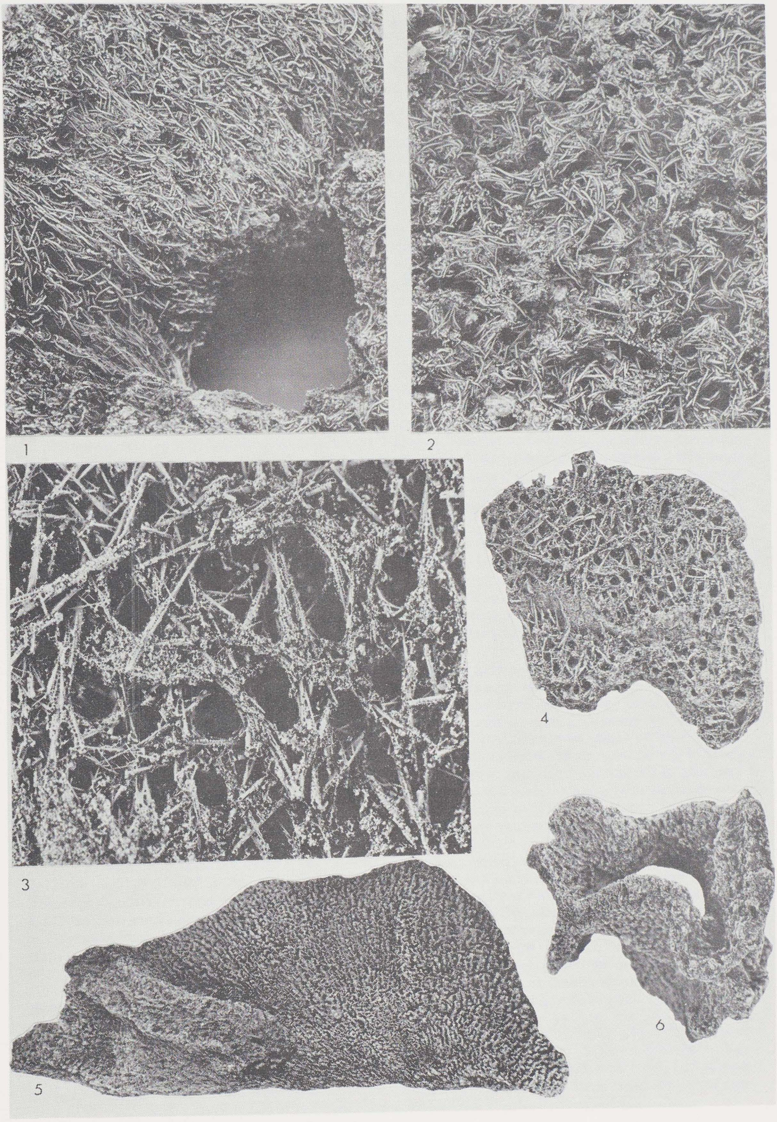


PLATE 1

Description: Fragments of individual sponges are up to 105 mm tall and form masses up to 90 mm wide. These are upward arborescent or branched sponges with the massive, basal part of the sponge having individual lobes or branched growths several millimeters across. Each individual lobe terminates in a series of branches that diverge at 60° to 70° from the main axis of the lobe. The lateral branches may merge with adjacent major stalks in the lower part of the sponge. Secondary branches, from 10 to 20 mm across, tend to be circular in section, but those that are larger than this tend to be flattened elliptical or flattened irregular in section. The entire growth produces an interlocking, interbraced, anastomosing colony in the lower part and a sharply branched and digitate to arborescent appearance in the upper part of the sponge. The form lacks a spongocoel or a pronounced zone of excurrent canal development along the central axis of the sponge. Excurrent and incurrent canals are moderately uniformly distributed throughout the massive skeleton.

Surfaces are marked by a series of pronounced, uniformly indented, tangential canals that rise approximately vertically, although somewhat anastomosing to arborescent. Individual canals range from 1.0 to 1.4 mm in diameter, with most 1.0 to 1.2 mm across. Where most pronounced, individual canals are separated by 1 mm or less. Commonly only 0.3 to 0.5 mm of skeletal material intervenes where the system is best developed. Individual canals are traceable, vertically, for from only a few mm to 30 or 40 mm, where they lose their identity and are replaced in *en echelon* fashion by other somewhat meandering surficial canals.

Canals of the interior are somewhat irregularly placed. Main excurrent canals appear to be only former surficial canals that have been bridged over during growth. These formerly surficial canals become major excurrent features of later parts of the interior, or are filled in, because the interiors of the sponge branches, where broken across, show only a few moderately large, 1 mm and above, canals. The interior of the sponge is perforated primarily by irregular anastomosing skeletal openings and minor canals, 0.5 mm across or finer. These have no predictable pattern, or orientation, but merely appear to form a very complex interconnected system that, with the irregularity of the skeletal net, tends to form a massive, uniform, yet unpatterned sponge.

The somewhat pointed tips of individual branches are marked only by the impressed semi-circular canals converging toward the tip. There are no clusters of major excurrent canals visible at the tip nor in any of the broken branches. There is a weak tendency toward radial arrangement of skeletal openings and canals but there is no clearly defined transverse nor longitudinal system on the branches, other than the surficial, impressed, U-shaped openings.

The principal skeletal net is composed of small to medium-sized, warty, tetraclones (Text-fig. 3-H, I, M) that are generally arcuate or convex toward the distal surface of the sponge. Individual tetraclones may unite tip to tip, but commonly have complex arborescent ray tips fused to the sculptured back or distal surface of the curved spicules. Generally speaking, the distal ray is aborted to a knob, or wart, of the same general proportions as those that mark the distal surfaces of the various clads. The skeletal net is firmly fused by zygosis of these complex arborescent ray tips to adjacent spicules.

Clads of the main tetraclones are 0.2 to 0.3 mm long. They have a relatively small diameter from near the clad junction to the beginning of the arborescent expansion of the ray tips. The inner, moderately smooth, subcylindrical to elliptical part of the ray is approximately 0.2 mm long in the largest main body spicules. The ray extends beyond this an additional 0.10 to 0.15 mm, to where the arborescent tip flares markedly to articulate with the adjacent spicule surfaces.

In their thinnest part the main large-bodied spicules are 0.08 to 0.10 mm across. Diameter increases to approximately 0.12 to 0.14 mm at the ray junctions, and up to 0.15 mm across the many arborescent branches at the articulation.

Surfaces of the main body spicules are covered by rounded, hemispherical, warts, or nodes, that are somewhat irregularly placed, although of remarkably uniform size. These warts range from 0.025 to 0.030 mm across in the large body spicules. They are almost perfectly hemispherical, and are packed side-by-side over much of the lateral and distal surfaces of the spicules. They tend to be more widely and irregularly spaced on proximal parts of the spicules.

Considerably smaller warty tetraclones occur in the outer and dermal parts of the branches. These are particularly evident on one of the paratypes, where these well-defined spicules have rays 0.15 to 0.20 mm long and only 0.06 to 0.08 mm across. These more delicate spicules have well-defined arborescent ray tips, some with a significant expansion. After narrowing to 0.04 to 0.05 mm across, rays subdivide into small branches, 0.02 to 0.04 mm across, that articulate with the distal surfaces of the adjacent delicate spicules. In general, these fine spicules have nodes 0.010 to 0.025 mm across, which are locally arranged in almost ringlike patterns although on most spicules they are irregularly spaced, as in the larger spicules.

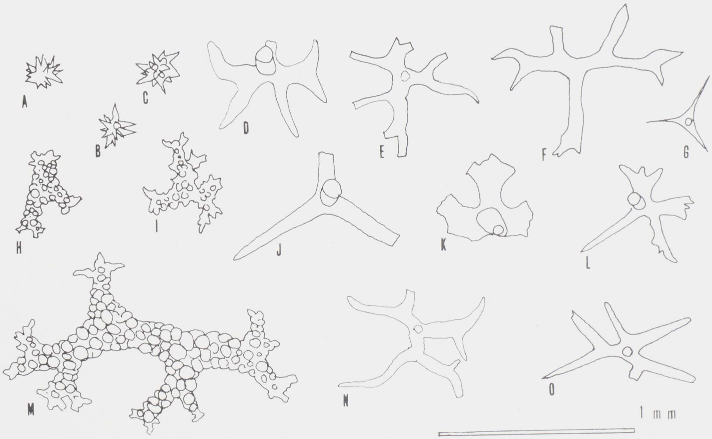
There is apparent gradation from relatively small spicules in the outer part of the branches, to large spicules in the inner part of the branches and the main mass of the skeleton. Some of this apparent gradation may be related to enlargement of individual spicules during growth, so that individual spicules become round and more robust. The obvious fine arborescent ray tips of the tetraclones become confused and thoroughly fused to the adjacent, more interior, spicules of the skeletal net. There is a general increase in size of individual nodes on the spicule surface, as well. In the smallest, presumably most recently formed, spicules these individual nodes or irregularities are separated by a short distance of moderately smooth main ray axis surface. Individual irregularities increase in size, however, so that on most robust spicules the hemispherical warts are side by side, or in some instances, actually impinge to produce almost a polygonal packing of the irregularities on the spicule surface.

Individual spicules articulate such that in the outer and dermal parts of the wall there are skeletal openings 0.18 to 0.25 mm across. These rounded openings are produced by gentle arching of individual spicule clads as they articulate with distal surfaces of more interior spicules. The larger canals interrupt the spicule pattern and are cross-connected with the openings between rays in the main body spicules.

The dermal layer is only intermittently preserved apparently because these spicules were not thoroughly fused to the main skeletal mass. As a consequence, the layer is moderately intact only in isolated areas on the crest of ridges between the surficial canals. More often these small spicules are preserved in canals or on flanks of canals. The dermal layer is dominated by dichotriaene-based spicules (Text-fig. 3-D-G, J-L, N, O) that have one long proximal ray and three main rays, the latter tangential to the surface of the sponge. The three primary tangential rays are subdivided on some to produce uniform symmetrical dichotriaenes. In other spicules, which are almost as numerous, one of the primary rays is not subdivided and has a somewhat irregular or wavy trend. This produces a pectactine-appearing spicule, but with the three tangential principal rays diverging at approximately 120 degrees. The secondary rays, generally, have a sweeping, almost fork-like appearance. They diverge initially at 50° to 60° to the primary axis but then commonly swing distally to within a few degrees of the primary axis.

Where the dermal layer is still moderately intact, there seems to be no regular orientation of individual spicules to the branch or to the canals.

Some medium to small-sized smooth, normal, tetraxons appear on the surface of the sponge. These range from small spicules, with rays 0.18 mm long and basal diameters of 0.02 to 0.025, up to moderately large spicules that have rays 0.45 to 0.50 mm long and basal diameters of 0.08 to 0.10 mm. In general, these spicules have straight,



Text-figure 3. Spicules of *Achrochordiella vokesi*, n. sp. A-C. Small polyaxons, possible foreign, from the surface of the holotype. D-F, N, O. Dichotriaenes of the dermal net, with paratangential rays having elliptical to circular cross-sections and with cylindrical fragments of proximal rays. G, J. Simple orthotriaenes showing variation in size. H, I, M. Knobby tetraclones of the main sponge body. Larger spicules are from the interior of the sponge wall. K, L. Examples of rare phyllotriaenes with bladed paratangential rays.

smoothly tapering rays that diverge from one another at approximately 120 degrees, three dimensionally. Some spicules are weakly sculptured with irregular low rounded nodes but most are smooth. In general, they are oriented with one ray proximally and the other three paratangentially. In some of these spicules, the three primary paratangential rays bifurcate to produce smooth, pointed secondary tips, that are one-third to one-half the total ray lengths.

In residues cleaned from the surface of one of the paratypes, a few rare phyllotriaenes (Text-fig. 3-K) were also recovered. The three paratangential rays on these spicules are markedly flattened, almost bladed and subdivided. These phyllotriaenes include small forms with basal ray diameters of 0.06 mm and a length of approximately 0.02 mm. The rays broaden into a flat blade and then subdivide into flattened, stubby, secondary rays 0.05 to 0.06 mm long and 0.05 to 0.08 mm wide. Larger, but still rare phyllotriaenes have ray lengths of 0.25 to 0.30 mm and basal ray widths of 0.10 mm. Their rays flare to 0.18 to 0.20 mm wide, then subdivide into two very broad, plate-like, short secondary rays which are 0.08 to 0.10 mm across. These secondary rays have blunt, almost rectangular to slightly rounded terminations.

Proximal rays of these phyllotriaenes have basal diameters of approximately 0.05 mm and are of undetermined length because they were broken as they were removed from the sponge surface. Phyllotriaenes are exceedingly rare spicules as compared to other elements in the dermal layer. Because of this they could be considered as foreign spicules, associated with the matrix, for normal tetraxons, ophirhabds, fragments of dictyid skeletal nets, fragments of lychnisks, and smooth, normal hexactines also occur as rare spicules adhering to the surface or in associated matrix cleaned from the sponges.

Discussion: Because only a single species of the genus is known, differentiation between generic and specific characters is somewhat problematical. Nonetheless spicule size, size of branches, and details of shape variation of the dominant dichotriaene dermal spicules are considered to be of specific rank. The general form, the general skeleton composed of warty tetraclones, with somewhat wavy dichotriaenes are assumed to be the main elements of generic differentiation, when coupled with the growth form.

PLATE 2

Ophiraphidites, Haynespongia and Hexactinellid Root Tufts

FIGS. 1, 3, 4, 6 — *Haynespongia vokesae*, n. sp. *1*, Photomicrograph showing dictyonine skeletal net surrounding moderately well-defined large epirhyses. The skeletal net is locally perforated by small circular ostia of apodiarhysal canals. Large opening in the upper left is a lateral osculum to the spongocoel. The skeletal pattern is generalized cribrospongiid, although with considerable irregularity. Holotype USNM 252494. ×10. *3*, Somewhat conical paratype showing the canal pattern of the gastral surface inside the funnel, the dermal surface, and the relatively thin walls characteristic of the species. Bryozoans have encrusted the exterior and produced the regularly spaced openings on the lower left. Paratype, USNM 252495. Natural size. *4*, Photomicrograph of the skeletal net showing expanded nodes at the ray junctions and the net perforated by relatively large epirhyses. Smaller circular openings in the main skeletal net are apodiarhysal canals, which connect to the aporhyses of the gastral margin. Holotype, USNM 252494, ×20. *6*, General view of the subcylindrical finger-like holotype showing prominent lateral osculi to the tubular spongocoel, which extends virtually the entire length of the fragment, and the net perforated by relatively large epirhysal ostia. USNM 252494, Natural size.

FIGS. 2, 5 — Root Tuft. USNM 252493. *2*, Photomicrograph of part of the same specimen shown in figure 5. Characteristic doubly tapering oxeas of varying size make up most of the root fragment. ×20.5, Root tuft fragment showing the distinct parallelism of the dominantly monaxial spicules. Natural size.

FIGS. 7, 8 — *Ophiraphidites hadros*, n. sp. Holotype, USNM 252488. *7*, The relatively massive cavernous sponge is typical of the species, with irregular tracts of the skeletal net surrounded by moderately small canals that interconnect to the large openings throughout the sponge. Broken base shows the densely silicified interior of the specimen. Natural size. *8*, Photomicrograph of the skeletal net showing curved ophirhabds united to form irregular tracts that are separated by variously sized canals. Dense areas are composed, in large part, of fine dichotriaene-based dermal spicules that are much smaller than the principal ophirhabds. ×5.

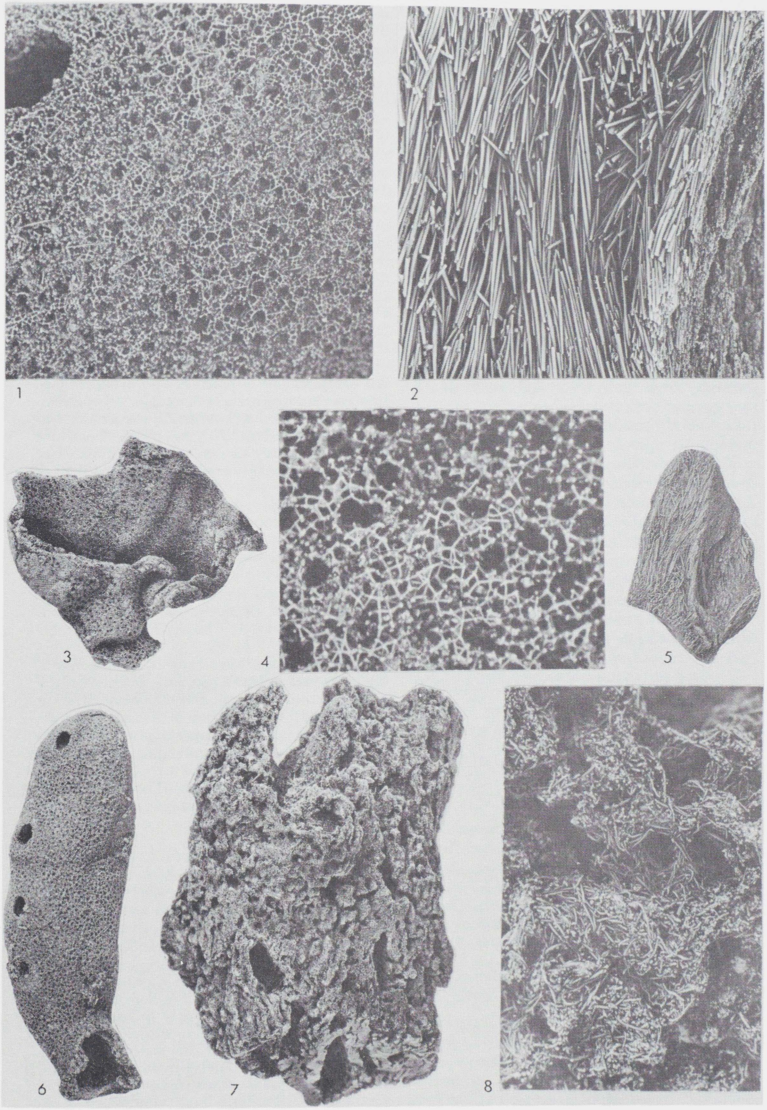


PLATE 2

Two small fragments of a lychniskid sponge apparently overgrew or attached to a paratype, as did a variety of laminar cheilostome bryozoans, spirorbid worms, and other benthonic forms. Bryozoans apparently encrusted the sponge when it was partially alive, because bryozoan colonies are incorporated within the sponge.

In one of the paratypes there are several arcuate, rounded, depressions in the basal part, as if the sponges had overgrown moderately smooth bivalves, snail fragments, or pebbles. This is the only indication of the method of attachment of these rigid sponges to the substrate.

Type material: Holotype USNM 252489, and paratypes USNM 252490-252491 and BYU 1542 are in the collection. In addition, slides of individual spicules were prepared from residues gathered from each of the sponge surfaces representing, in part, dermal or body spicules and in part, extraneous foreign spicules and debris.

The North Carolina occurrence represents an extension of the family into the Tertiary, from the single described Cretaceous locality of northern Germany. These sponges also represent the first occurrence of the family in North America.

Etymology: The specific name *vokesi* is proposed for Harold Vokes, collector of the fauna and long time student of Tertiary fossils of the Atlantic and Gulf Coastal Plain.

Class HEXACTINELLIDA Schmidt, 1870
Subclass LYSSACINA Zittel, 1877
Order LYSSACINOSA Zittel, 1877
Suborder AUTODERMARIA Reid, 1958
Superfamily EUPLECTELLOIDEA Gray 1867 (*nomen translatum* Finks, 1960)
Family EUPLECTELLIDAE Gray, 1867

REGADRELLA TRABECULA, n. sp.
Plate 1, figs. 3, 4

Diagnosis: Flabellate to low-conical sponges composed of confused, relatively dense matte of hexactines and hexactine-derived spicules, fused where rays cross and by synapticulae and synapticular webs. Ladder-like beams in skeleton formed of subparallel spicules united with synapticulae. Parietal gaps well defined, cross-connected with smaller radial to diagonal canal series.

Description: A fragment, approximately 50 × 60 mm square, of a broad, cylindrical or conical sponge is in the collection. It was probably part of an example approximately 16 cm in diameter, judging from curvature of specimen. The fragment of the wall is 9 to 10 mm thick but tapers in the upper 20 mm, so it may represent part of the upper wall.

The wall is perforated by large parietal gaps, which extend completely through the net, and by smaller canals, some of which pass through the net whereas others penetrate only part way into the wall, normal to the surface, or angle diagonally within the wall. Several canals expand inward to nearly double their exterior diameter. This is particularly evident in intermediate size canals. Most common exterior canal openings are 0.6 to 0.8 mm in diameter and are nearly circular. Next most common canals are less circular to distinctly elliptical and range from 0.9 to 1.2 mm wide and up to 2.0 mm high. Least common openings are the largest, strongly elliptical parietal gaps, which are 1.4 to 2.5 mm across and up to 3.5 mm high. All of these large gaps go through the wall. Smaller triangular to polygonal skeletal openings are highly irregular because of the matted arrangement of spicules and synapticulae. Interior openings are more circular, although the largest canals are still vertically elongate (1.4 to 0.2 mm wide and up to 3.0 mm high). Those that are approximately 1.0 mm across are mainly circular, although a few range up to 2.0 mm high at the entrance.

The skeletal structure is composed of a confused matte of small hexactines and larger diactines, all fused into a solid structure where spicule rays lie across one another, and by fused, regularly spaced, synapticulae and synapticular nets. Major tracts are composed of fused subparallel spicules, principally vertically oriented, although diagonal and nearly horizontal tracts also occur.

Largest spicules have rays up to 0.34 mm in diameter and at least 5 mm long, but most of the net is composed of spicules that have rays approximately 0.06 to 0.08 mm in diameter and less than 2 mm long. Exact proportions are difficult to determine because of the irregularly fused and synapticulate nature of the net. Spicules with rays as small as 0.01 to 0.02 mm in basal diameter and 0.1 mm long are present, although they are generally lost or obscure in the synapticulate structure.

Synapticulae are generally 0.02 to 0.04 mm in diameter at their thinnest between expansions where they are fused to adjacent spicules. Bar-like synapticulae usually extend for less than 0.2 mm between spicules. Where spicules are more widely spaced, there is a perforate net that unites adjacent spicules.

The overall appearance is of a series of inter-runged ladders uniting to develop larger open beams, which are irregularly interleaved and matted. Openings between synapticulae vary from "ladder" to "ladder" but are commonly approximately 0.1 mm in diameter or less. They are smaller when the main spicules are separated by less than that distance. Intersynapticular openings are rounded and vary from circular to strongly elliptical.

Secondary overgrowth of silica may have welded several "ladders" into a solid rod or beam with infilling of synapticular openings. These compound beams may be as large as the largest spicules, up to 0.3 mm in diameter. Overgrowths and the matted nature of the skeleton have obscured the original skeletal elements so that only rarely are ray junctions of hexacts seen, and these are mainly in smallest spicules, which apparently have been coated least. In general, the hexactine origin of the skeletal net is obscure.

Viewed from the side, in the vertical section, most spicules have rays subparallel to the elongate trend of the sponge wall, so that most other rays are oriented at high angles to the sponge exterior or interior. Most compound beams are also oriented parallel to the exterior surface, although they are at various angles to one another in the general plane of the sponge wall.

There is a series of irregular, densely and finely spiculed, subhorizontal bands that may mark former positions of the oscular margin. These show as weak ribs on the exterior and are traceable through the sponge wall. They have an upward arcuate profile, as seen in vertical sections through the wall. These skeletal bands are 2 to 3 mm thick and are present as dense discontinuous layers, which are spaced 5 or 6 mm apart, where most clearly defined in the skeletal net. Compound "beams" are ill-defined in the dense bands but do extend upward and downward within the sponge. These dense layers are composed almost entirely of short rayed spicules and synapticulae, with diameters of 0.02 to 0.03 mm or less. As such, the bands appear less matted and much less irregularly spiculed than most of the remainder of the sponge.

A small patch of fan-like radiating spicules is present on the exterior, near one of the dense layers. It has a radius of approximately 2 mm and appears to be a ropy tuft of spicules with diameters of 0.02 mm and less. it may represent part of a root tuft or it may be unrelated.

Discussion: The North Carolina species is somewhat similar to *Regadrella petrijacob* Schrammen (1912, p. 208; pl. 27, figs. 9-11), but is a larger form and is more densely spiculed. It also has thicker, more closely spaced wall elements, which result in smaller canal and parietal gap openings.

Proeuplectella fragilis Moret (1926, p. 204, pl. 9, fig. 1) is related in terms of a synapticulate and otherwise fused skeletal net but clearly is more open textured than the present specimen and lacks the well defined ladder-like compound beams that are distinctive of the North Carolina species.

Type specimen: Holotype USNM 252492.

Etymology: Trabecula, Latin, little beam, referring to the small compound beams formed by spicules united by synapticulae.

Genus and Species Undetermined
Root Tufts
Plate 2, figs. 2, 5

Two root tuft fragments occur in the collection. The largest is elongate, approximately 45 mm long and 30 mm across, and is composed of a rope-like, somewhat twisted matte of subparallel spicules, which range up to 5 mm long. Most appear to be diactines and are smooth doubly tapering oxeas. Rarely are both tips of the large spicules preserved, however. In the shorter spicules, where both ends are preserved, the tips are sharply pointed. Spicules are mainly approximately 0.15 mm in diameter, at midlength, and taper uniformly in both directions to sharp tips. Oxeas are the most common spicules throughout the tuft body.

Protriaenes and dichotriaenes are also preserved, in a small area, presumably from the outer part of the tuft. They are uniformly oriented. Primary rays in both protriaenes and dichotriaenes and the secondary rays in dichotriaenes are approximately 0.10 mm long. Primary rays are robust, have diameters of 0.08 to 0.10 mm, and taper slightly. Secondary rays have basal diameters of 0.06 to 0.08 and taper sharply to somewhat rounded conical tips.

Primary rays diverge at approximately 120° from center and swing to diverge from 50° to 90° from the trend of the main spicule axis. In some spicules the rays swing again to lie nearly parallel to the axis, but in others they remain nearly at right angles, particularly in the protriaenes.

Spicules of the smaller fragment are all sharply pointed, smooth, oxeas where spicule shape can be determined, but most are broken. Spicules are in a twisted tuft, are curved, and range up to 0.10 mm in diameter, though most are smaller. They are up to 5 mm long and are subparallel to parallel, commonly with mutually adjusted tapering boundaries.

Much of the root tuft is composed of spicules with maximum diameters of 0.04 to 0.05 mm. These small spicules appear to fill in areas between "ropes" of larger spicules within the tuft, or locally they appear to occur at the periphery of the tuft.

Figured specimen: USNM 252493.

Subclass HEXASTEROPHORA
F. E. Schulze, 1887
(emended F. E. Schulze, 1899)
Order HEXACTINOSA Schrammen, 1903
(emended Schrammen, 1912)
Suborder SCOPULARIA
F. E. Schulze, 1885
Family CRIBROSPONGIIDAE
F. A. Romer, 1864

HAYNESPONGIA, n. gen.

Diagnosis: Irregular leaf-like or anastomosing to thin-walled tubular cribrospongids lacking pronounced sculpture. Dictyonal net euretoid with primary framework at gastral margin and strands emerging at high angles on the dermal surface. Primary canals show diplorhysis with general alternation of epirhyses and aporhyses, although not in well defined linear series. Apodiarhysal canals connect to dermal surface and occur in net between epirhysal ostia.

Discussion: The new genus *Haynespongia* appears in general growth forms much like several species of *Eurete*, as for example *Eurete formosum* Reid (1958, p. 21-22, Pl. 2, figs. 7, 8) or *Eurete mantelli* Reid (1958, p. 23-25, Pl. 4, figs. 1, 2). The South Carolina genus differs from *Eurete* in having a cribrospongid rather than a simple canal pattern. *Pachyascus* Schrammen (1936, p. 35-36) appears somewhat similar, as well, but has a craticularid canal pattern.

Polyopesia Schrammen (1902, p. 25-26) was included within the emended Cribrospondiidae by Reid (1964, p. cxlvii), along with others, and differs from the South Carolina genus in being much coarser textured and in having a cylindrical form. Other genera also included in the family by Reid include *Andreaea* Schrammen (1902, p. 25), *Guettardiscyphia* Fromentel (1860, p. 39), *Cribrospongia* d'Orbigny (1849, p. 547), *Walcottella* de Laubenfels (1955, p. E-82), and *Tremadictyon* Zittel (1877, p. 46). These genera all show much more regular conical to cylindrical forms and have much greater regularity in their canal patterns.

Stichmaptyx Schrammen (1912, p. 255), also included in the family by Reid (1964, p. cxlvii), is an irregularly shaped sponge, but has a much more regular canal pattern and canals that penetrate nearly through the walls, much more deeply than in *Haynespongia*.

Stereochlamis Schrammen (1912, p. 231) was also included in the emended family and has an irregular cribrospongid canal pattern reminiscent of *Haynespongia*, but species included in the German genus are small conical forms.

PLATE 3

Achrochordiella, *Ophiraphidites*, and "Worm Tubes" from Eocene Castle Hayne Limestone from North Carolina

FIGS. 1-3, 5 — *Achrochordiella vokesi*, n. gen., n. sp. *1*, Paratype shows the characteristic broad, indented, surficial canals and the somewhat fused, but arborescent, growth habit of the sponge. Internal canals apparently are bridged former surficial canals. During growth many of the numerous surficial canals were filled with spicules to produce the massive interior of the sponge. Paratype, USNM 252490, Natural size. *2*, Holotype showing the branched arborescent nature of the sponge, with a relatively massive base but with finger-like digitations in the upper part, all marked by anastomosing to vertical surficial grooves. USNM 252489, Natural size. *3*, Tetraclones of the principal skeletal net are sculptured with rounded nodes. Spicules tips are fused to the distal margin of more interior spicules. Arcuate spicules produce the open skeletal net characteristic of the sponge. Holotype, USNM 252489, ×10. *5*, A cluster of dichotriaenes of the dermal net on the holotype, preserved as a low ridge across the principal skeletal net along the flank of one of the exterior canals. Irregular branching of the somewhat elliptically-sectioned rays is characteristic of the species. Holotype, USNM 252489, ×20.

FIG. 4 — "Worm" tube composed of sponge spicules, principally oxeas, although the specimens are attached to a dictyid sponge and *Ophiraphidites*. USNM 252497, ×2.

FIG. 6 — *Ophiraphidites infundibuliformus* Schrammen, 1910. Photomicrograph of a somewhat tubular form, showing the difference in the general skeletal makeup of the irregular exterior versus the somewhat bundled interior. Irregularities of the skeletal net are paralleled by the canal system. USNM 252487, ×2.

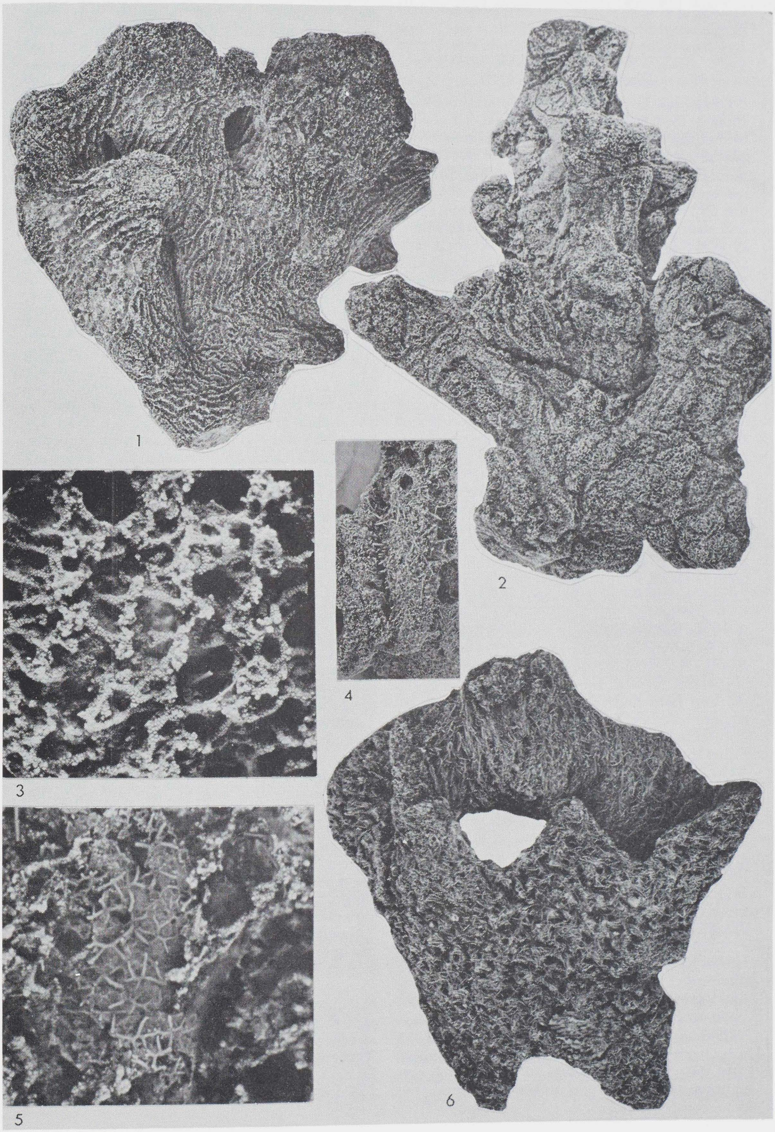


PLATE 3

Type species: Haynespongia vokesae, n. sp.

HAYNESPONGIA VOKESAE, n. sp.
Plate 2, figs. 1, 3, 4, 6

Diagnosis: Irregular leaf-like or anastomosing sponge from which extend hollow, simple or branching tubes up to 25 mm in diameter with lateral osculae. Surface smooth or with weak mounds or annulations around osculae. Skeletal net euretoid with primary framework at gastral margin, with spicular nodes 0.25 to 0.30 mm apart and strongly swollen in outer part of wall where synapticulae also most common. Primary canals show diplorhysis in cribrospongid arrangement although distinct alignment is ill defined. Aporhysal chambers 0.40 to 0.55 mm in diameter and separated by 0.4 to 0.7 mm of net, connected to exterior by apodiarhysae 0.15 to 0.20 mm in diameter. Latter canals occur between epirhysal chambers that are 0.20 to 0.35 mm in diameter and separated by 0.4 to 0.5 mm of skeletal net.

Description: The sponge, as reconstructed from numerous available fragments, consists of an irregular anastomosing, tubular, leaf-like mass, from which extend numerous cylindrical, simple or branching tubes, commonly the most nearly intact part of the sponge preserved. The tubes apparently arise from the irregular, uneven, leaf-like base at low irregular mounds extending from minor lateral oscular openings. The preserved tube fragments range from 11 to 12 mm in diameter, up to relatively large tubes, 20 to 22 mm in diameter. Many are slightly elliptical with a long axis half again that of a short axis. Some of this undoubtedly is related to modification following burial for many of the tube fragments are perfectly cylindrical.

Exterior of the tubes is relatively smooth, marked here and there with weak, round, irregular annulations arranged approximately normal to the long axis of the tube. Many of the tubes show virtually no modification, other than weak, wavy annulation in their general profile. Except for low mounds that surround the lateral osculae, there is no evidence of major surficial or dermal canals nor significant ribbing. The only modification of the surface is produced by mounds of the lateral osculae. The surface is hispid, however, as a result of the unattached rays at the end of the skeletal strands or of lateral beams, where the strands or beams emerge from the sponge surface at a high angle.

All the tubes are perforated throughout their length by a smooth subcylindrical spongocoel or opening. This opening mirrors the variation in diameter of the exterior for the walls of the tubes have remarkably uniform thickness.

The tube wall thickness ranges from 1.5 to 3.3 mm in the fragments that are available. This is also the general thickness of the leaf- or ear-shaped, somewhat open conical fragments of the basal area as well. Most of the tubes, however, show variation in wall thickness only from approximately 1.5 to 2.0 mm although, locally, walls of individual tubes may be up to 2.5 mm for much of their length. In general, wall thickness decreases sharply around the lateral osculae and towards the terminus of the rounded branch, in those rare instances where tips of the tubes are preserved. As a consequence the spongocoel varies from 6 or 7 mm in diameter up to approximately 9 mm in diameter in the largest branches. In those branch tips where the oscular margin is at the terminus of the branch, the wall thins in a somewhat rounded way, to produce a wall that has a bullet-shaped profile in cross-section.

The lateral osculae generally perforate only one side of the wall of the branches. These circular openings range from 2 mm up to 5 mm across, although most are 3 to 4 mm in diameter. There are some elliptical openings for lateral osculae, with the long axis of the ellipse parallel to the tube axis. These are up to 11 or 12 mm long, but are only 3 to 5 mm wide. Most of the openings however, are perfectly circular. All are situated on low humps or mounds that extend a short distance above the general tubular surface, somewhat like a flaring lip. In other instances they are on merely rounded, subhemispherical, irregularities. In these, the lateral osculae are almost always nearly perfectly circular.

The skeletal net is euretoid with a dictyonal framework of the walls composed of the principal or primary framework, which is situated near the gastral margin, and an upward and outward diverging series of dictyonal strands of the main framework. They sweep from nearly tangential at the gastral surface to meet the dermal surface almost at right angles or at a very high angle, with additional strands being formed near or at the gastral surface sweeping upward and outward in the general direction of growth.

Individual dictyonal strands range from 0.04 to 0.08 mm in diameter, but most are 0.05 to 0.06 mm across at their thinnest dimension in between the expanded nodes at the ray junctions. Beams in the structure that are at high angles to the threads, generally, are somewhat smaller, ranging from 0.01 to 0.06 mm in diameter. Some of the smallest beams may be extraneous secondary elements in the main skeletal net, for many of them seem to cross through the roughly quadrangularly arranged skeletal mesh almost like synapticulae.

Swollen nodes range from inconspicuous minor swellings up to spherical enlargements 0.14 to 0.16 mm in diameter. Most nodes, however, in the main part of the skeletal net are 0.08 to 0.12 mm across. Along any individual dictyonal strand, spicular nodes are spaced 0.25 to 0.30 mm apart, with most approximately 0.25 mm apart. This results in 8 or 9 spicule units in thin walls, and up to 12 to 15 spicule units in thick walls, forming along any one individual dictyonal strand from where the strand starts to diverge from asymptotic to the gastral surface to the dermal surface.

Most of the mesh openings, as seen in longitudinal sections, are roughly quadrangular, with modified rounded margins related to swelling of the nodes and fusion of the rays in the skeletal nets. In radial sections the openings in the skeletal net are approximately of the same dimensions as seen in the longitudinal section. In the interior and subdermal part of the wall, the dictyonal strands are separated by approximately 0.20 mm, although with some irregularity so that there are many more triangular or trapezoidal type openings, as viewed tangentially, than as viewed in vertical sections in the wall. This is a result of more irregularity in beam orientation as they connect variously placed dictyonal strands. These somewhat irregularly oriented, often extraneous, rays must occur at moderately uniform levels within the strands so that in cross-section the regularity of spacing of the nodes and beams is not interrupted but is varied when seen in tangential view. There is some variation of thickness of beams within the dictyonal strand, as well as of the lateral beams that cross connect the strands.

There is an ill-defined dermal layer, which is characterized by slightly thicker beam development, slight enlargment of the spicule nodes, and a significant increase in the number of small adventitious rays or synapticulae. The regular skeletal strands extend into and through the dermal layer, with the sharp pinnacled to steeply conical, unattached, rays extending through the dermal layer. Extraneous small skeletal elements in the dermal layer are generally less than 0.01 mm in diameter but may be long enough to extend from node to beam. They make the dermal surface of the sponge considerably more dense than the regular skeletal net of the interior.

Primary canals show fully developed diplorhysis, with well defined epirhyses and aporhyses. These radial canals are in characteristic cribrospongiid arrangement, in that within any linear series there is an alternation of epirhysid and aporhysid chambers. The distinct linear arrangement characteristic of many genera included within the family is ill-defined or wanting. In general, however, a single aporhyses is surrounded with quincuncially arranged epirhyses, so that the cribrospongid pattern is moderately well-defined.

The aporhyses, in addition to being open at the gastral margin, are connected with small canals to openings 0.15 to 0.20 mm in diameter on the dermal surface, and should be designated as apodiarhyses where that situation exists (Reid 1964, p. civ). Epidiorhyses are apparently not well developed, if present at all.

The epirhyses chambers are almost subcylindrical on the outer part of the wall, but have a rounded base where they are lost in the finer textured dictyonal net, in the middle to gastral half of the wall. In general, the epirhysal chambers are well-defined and uniformly scattered over the entire exterior of the sponge. They range from 0.20 to 0.35 mm in diameter with most 0.25 to 0.30 mm across. They are separated by 0.4 to 0.5 mm. They are not obviously stacked in horizontal nor vertical series, but are uniformly spaced and are so arranged that six to eight individual canals lie along a vertical line 5 mm long. They also have similar horizontal spacing.

Smaller ostia of the apodiarhysal canals are distinctly smaller than the main canals, are uniformly circular, and are placed in the central part of the space between the ostia of the epirhysal systems. These small tubular canals connect to the expanded aporhysal chamber that indent the gastral margin of the wall. They mark the tips of the rounded to V-shaped bases of the aporhysal chambers and, as such, enable clear definition of the cribrospongiid canal pattern.

Postica of the aporhysal systems are considerably larger. Most range from 0.40 to 0.55 mm in diameter. They are circular and the aporhysal chambers extend one third, or slightly less, of the wall-thickness into the sponge wall from the gastral margin, where they abruptly narrow and terminate, or continue through to the dermal surface as apodiarhysal canals. There are five or six aporhysal chambers in 5 mm, measured vertically, and six to eight in 5 mm, measured horizontally, along the gastral surface. In general, in any vertical series aporhysal chambers are separated by 0.4 to 0.7 mm of skeletal material but may be separated by considerably less horizontally, with some only 0.25 mm apart. They, like the epirhysal systems, do not fall into any clear vertical, horizontal, or diagonally ascending series of geometric patterns, but show considerable irregularity. Aporhysal chambers have sloping, rounded, upper lateral margins rather than the clear, sharply defined limits seen in the epirhysal systems.

In a few fragments that show the basal part of a sponge, the aporhysal chambers converge into large pits that may be 3 or 4 mm across and as much as 1 or 2 mm deep. The marked, irregular, large openings seem characteristic only of the lower part of the sponge in the zone of attachment, however, and are not characteristic of the gastral surface of the upper tubular or leaf-like parts of the sponge.

Surfaces of the beams and strands may be locally ornamented with small granules. Some of the sculpture may be a result of adhering foreign material, during silicification and fossilization, or may be related to original construction.

Discussion: Reid (1958-64, p. cxlv-cliv) proposed a new classification of the Order Hexactinosa, including two suborders, the Clavularia (F. E. Schulze, 1885) and the Scopularia (F. E. Schulze, 1885), based upon the occurrence of unique associations of microscleres in living forms. He has extended this classification to include fossils and included most of the dictyid hexactinellids in the Scopularia. He has arranged genera of Hexactinosa into eight families that are differentiated, in large part, upon the basis of the manner of formation of the skeletal net, as well as upon characteristics of canal development in the skeletal net. In the process he grouped together many of the numeroius families described by Schrammen (1912, 1924, 1926). Reid (1957; 1958-64, p. clic-liv) is highly critical of the classification of the hexactinosid sponges proposed by DeLaubenfels (1955, p. E78-E92), which was based, in large part, on habit and external appearance.

North Carolina specimens differ from those listed by Reid (1964, p. cxlvii) as examples of genera included in the Family Cribrospongiidae, in being consistantly finer textured, more consistantly tubular, and in having a less linearly arranged canal system, although the general cribrospongiid pattern, as defined by Reid (1958-64), is present. These dictyid sponges are a common base for attachment of encrusting unilaminar cheilostome bryozoans, as well as other sponges in the assemblage, particularly *Ophirhaphidites infundibuliformis*.

Type material: Holotype USNM 252494 and paratypes USNM 252495 and 252496. In addition, reference specimens are deposited in the Department of Geology, Brigham Young University (BYU 1543 and 1544). In total, approximately 80 moderately complete tubes or fragments of the sponge are in the collections from the Castle Hayne Limestone of North Carolina.

Etymology: The species is named for Emily Vokes, one of the collectors of the sponge fauna and a student of coastal plain geology.

Order LYCHNISCOSA Schrammen, 1902
Family UNCERTAIN
Genus UNCERTAIN

Description: Two small encrusting fragments occur in the collection. Both are attached to the same sponge and possibly were continuous at one time. The larger fragment is approximately 2.5 mm wide and 9 mm long, the smaller one is approximately 2 mm by 3 mm. Both are approximately 1 mm thick and show the same general development of canals and a skeletal net lacking a dermal layer.

Largest, presumably excurrent, canal openings, are 0.5 to 0.75 mm across. They are roughly round, but some are polygonal, defined by moderately straight segments of the skeletal net. Canals are spaced from one skeletal element up to 0.6 mm apart.

The intermediate-sized canals are 0.25 to 0.40 mm across and are similarly subpolygonal to subcircular. These may represent two distinct sizes because several are approximately 0.25 mm across. Smaller openings within the main skeletal net, between adjoining spicule rays, are 0.05 to 0.10 mm across. These are triangular to polygonal or subcircular, and occur in the middle of skeletal webs.

Individual beams of the spicules are 0.25 to 0.40 mm long and 0.025 to 0.040 mm across, except where they bifurcate to articulate with adjacent spicules in the web-like arrangement. At the articulation there is a slight nodal development, which is up to 0.06 mm across where most clearly defined. Subsidiary rays in the lattern-like lychnisks are small elements, 0.06 to 0.10 mm long and from 0.01 mm up to 0.025 mm across. The most delicate parts of the net are the tiny ray junctions in the centers of lychnisks.

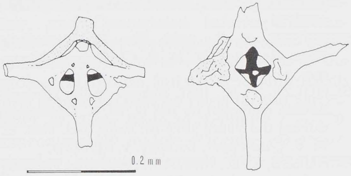
The skeletal net resembles a demosponge lithistid in its growth pattern with the lack of a noncubic arrangement and the ray tips that seem to articulate with tips of other rays except for the development of lychnisks. There is a distinct linearity to the skeleton, however, with individual canal series 0.50 to 0.75 mm apart.

Discussion: In general, spicule shape and size of the form resemble *Trembolites* Zittel (1877, p. 55-56), but the sponge has a more compound beam-like pattern, somewhat like that of *Coscinopora* Goldfuss, (1826, p. 30). Both of the above genera are from the Cretaceous of Europe. However, most of the Lychniscosa described, so far, have been moderately large sponges and an encrusting or attached form has not been defined. As a consequence, generic placement of these fragments is uncertain. This is the first lychniscosid sponge recorded from North America. It is unfortunate that the material is so fragmental and inconclusive.

Isolated Lychnisks
Text-fig. 4

Isolated lychnisks were recovered in acid residues from one of the paratypes of *Achrochordiella*. The small lantern-shaped lychnisks are 0.15 to 0.16 mm across in each of the three fragments. From this, lantern rays extend approximately 0.15 mm and have a diameter of 0.04 mm at the bifurcation where the cross-bracing buttresses diverge from the main ray. These cross-bracing buttresses are 0.08 to 0.10 mm long and 0.02 to 0.03 mm wide, in the central narrow part, and make triangular openings 0.06 mm across from the ray junction. These isolated lychnisks are considerably larger than equivalent units in the small sponge fragments. They clearly show, however, that the Order Lychniscosa is present in the North American Tertiary.

Figured specimens: BYU 1546 and 1547.



Text-figure 4. Isolated lychnisks from matrix associated with *Achrochordiella vokesi*, n. sp., Eocene Castle Hayne Limestone. BYU 1546, 1547.

Phylum Uncertain
"Worm Tubes"
Plate 3, fig. 4

Two small subcylindrical to pupaeform spicule-lined "worm tubes" occur in the collection. The larger is 17 mm long, 4 mm wide, and 2 mm thick and the smaller is broken but is now 8 mm long, 3 mm wide, and 1.5 mm thick. The smaller specimen was at least 13 mm long, judging from broken fragments cemented to the substrate.

Both tubes are long and sack-shaped, with smooth circular openings emptying through a circular aperture, which is 1.5 mm in diameter. The broken smaller specimen has an elliptically cross-sectioned tube, possibly because of flattening during fossilization, which is 2 mm wide and 0.8 mm high. In the large specimen the tubular central opening is sharply flexed, to open parallel to the wall, rather than terminally and normal to the wall trend.

The wall is composed of matted spicules, almost exclusively oxeas, even though the specimens are attached to *Ophiraphidites* and a dictyid sponge. The spicules range from small ones, 0.02 mm in diameter and approximately 0.5 mm long, up to those 0.20 mm in diameter and 4.0 mm long. The large spicules are inserted into the wall at various angles. A few triaenes, like those which occur as dermal elements in *Ophiraphidites*, occur on the fine textured upper wall.

Figured specimen: USNM 252497.

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