

## A MAJOR EOCENE SPONGE FAUNA (CASTLE HAYNE FORMATION, NORTH CAROLINA)

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**Abstract:** The Castle Hayne Formation (Middle and Upper Eocene, North Carolina) contains a rich, diverse and well-preserved sponge fauna, equaled among known Tertiary faunas only by the Eocene fauna of Western Australia and the Miocene fauna of Algeria. It includes among Calcarea two genera of lithonines, (3 new species); among Demospongia one hadromerine, two genera of choristids (2 new species), one cephalorhaphiditid (new genus and species), and three genera and species of plinthosellid lithistids (2 new species); and among Hexactinellida four genera of hexactinosan hexactinellids (1 new genus, 1 new subgenus, 2 new species), two genera of lychniscosan hexactinellids (1 new genus, 2 new species), and a new genus and species of lyssacine hexactinellid. Noteworthy are whole fossil specimens of *Geodia* and *Stellella* (*Stolleya*), two new genera (one of which is extremely abundant) of cup-shaped hexactinellids with radial fins, and the first fossil species of the Recent genus *Verrucocoeloidea*. Two faunal facies are recognized: a near-shore one dominated by demosponges and an off-shore one dominated by hexactinellids (with lithonine Calcarea), a pattern known from other published Cretaceous and Tertiary faunas. The off-shore facies is dated from associated fossils as late Claibornian (Auversian); the near-shore facies is probably of approximately the same age because of some common species. The prominence of the extinct plinthosellid lithistids and the absence of rhizomorines and megamorines is noteworthy. All the genera have close relatives in the Cretaceous; all but the plinthosellids have living relatives as well, and five genera are still extant. It is noteworthy that this Eocene fauna is richer than any known North American Cretaceous sponge fauna, even though the Cretaceous was elsewhere very sponge-rich.

**Key Words:** Eocene; Porifera; North Carolina; Castle Hayne Formation; systematics; paleoecology; evolution; faunal facies.

### INTRODUCTION

This study is based on a large collection of sponges made by Druid Wilson, of the United States Geologic Survey, from the Castle Hayne Formation of North Carolina, who placed them in the hands of the senior author in 1962 for description and publication. They were supplemented by collections made by two of the present authors (Finks and Thies) in 1975 from the Ideal Cement Company Quarry at Castle Hayne (the type locality), and from other localities, under the guidance of Peter J. Harmatuk and Edgar A. Womble Jr. In 1981 Rigby published a study of Castle Hayne sponges from an outcrop near Mt. Olive, North Carolina, the only previous study of this fauna that has been published (Rigby 1981). Our study was preliminarily reported in Finks (1986).

The Castle Hayne Marl is a thin veneer, some 15 m (50 feet) thick (or less) that covers a wide area of the North Carolina coastal plain. It is exposed chiefly in quarries and pits, with natural outcrops confined mainly to the banks of larger streams. It is apparent from the

literature (e.g., Baum, Harris and Zullo 1978) that it contains lateral facies changes as well as internal diastems. The age has not been settled to the satisfaction of all, the formation having been assigned variously to the Middle Eocene (Claibornian or Lutetian-Auversian) or to the Upper Eocene (Jacksonian or Bartonian-Ludian) or to both (for summary reviews see Baum, Harris and Zullo 1978, pp. 8–9; Kier 1980, pp. 1–7; Ward, Lawrence and Blackwelder 1978; Harris and Zullo 1980; Jones 1982; Harris and Zullo 1982; and Murray 1961, p. 383, 391). Baum, Harris and Zullo (1978) separated off the New Bern Formation in the northeastern part of the main outcrop belt, referring it to the Jacksonian, and the restricted Castle Hayne to the Claibornian, but they cite conflicting faunal evidence (Claibornian vs. Jacksonian) for the age of the New Bern (ibid., pp. 11–12) and also suggest that the restricted Castle Hayne may range into the Jacksonian (ibid., p. 9). In the restricted Castle Hayne they recognize a lower bryozoan biosparrudite (with phosphate pebble conglomerate locally at the base) and an upper bryozoan biomicrudite. The entire upper biomicrudite is sponge-bearing in the vicinity of Castle Hayne,

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(ibid., p. 8, fig. 3; also Upchurch and Textoris 1973; a detailed stratigraphic section of the Ideal Cement Company quarry is given in Upchurch 1973, p. 9, fig. 2) including the sponge-bearing beds we collected in the Ideal Cement Company Quarry, and may represent the source of all the sponge collections described in the present paper except those from locality 21849 near Dudley. They are the source of the “southern sponge fauna” of the present paper (see below).

Ward, Lawrence and Blackwelder (1978) established three members of the Castle Hayne Limestone: the New Hanover Member, equivalent to the basal phosphate pebble beds; the Comfort Member, equivalent to the bryozoan biosparrudite and bryozoan biomicrudite facies of Baum, Harris and Zullo (1978); and the Spring Garden Member, equivalent to the overlying New Bern Formation of Baum, Harris and Zullo. Ward, Lawrence and Blackwelder considered both the New Hanover and Comfort Members to be Middle Eocene (Claiborrian) with the latter member (from which our “southern Sponge fauna” comes) equivalent to the late Claiborrian Gosport Sand of Alabama. They selected the Ideal Cement Company Quarry as the type locality for the Castle Hayne Limestone. Kier (1980) recognized three biostratigraphic zones in the echinoid faunas of the Castle Hayne Limestone: the lower two in the bryozoan biosparrudite facies and the upper in the bryozoan biomicrudite facies (Kier 1980, p. 5, table 3), all three, therefore, in the Comfort Member. He found that the New Hanover Member at its type locality contained a “middle zone” echinoid fauna and therefore considered it a lateral equivalent of the Comfort Member (ibid., p. 6). Kier (1980, pp. 7–8) considers the Ideal Cement Company Quarry and the Lanier Pit at Maple Hill (from both of which we have sponges) to be from his “late” echinoid zone. In addition, the richest locality of our “southern sponge fauna,” USGS 22389, has a “late zone” echinoid fauna (Kier 1980, p. 10). The following localities, also bearing the “southern sponge fauna,” have an echinoid fauna that could be either “middle zone” or “late zone,” but are probably “late zone” because of the presence of *Echinolampas appendiculata* which is more common in that zone (Kier 1980, p. 7, 10, 12): USGS 7794 (Kier lists it as “779” but the locality data are the same), USGS 19020, and USGS 22329. Thus nearly all of our “southern sponge fauna” localities are probably from Kier’s “late” echinoid zone. Only two (USGS 19019, and 8-13-7) were not included in Kier’s study, but both are close to USGS 22389 (see Text-Fig. 1). Kier (1980, p. ii) considers his “late zone” to be “probably late middle Eocene” which would thus be also the probable age of our “southern sponge fauna,” approximately Auversian of the type-section.

Our collections from the Ideal Cement Company quarry were chiefly made from large loose slabs which

the quarry manager, Mr. Cristelli, said were from approximately the upper 9 m (30 feet) of the Castle Hayne, there overlain unconformably by Pleistocene. This would be roughly equivalent to the 8.8 m thick biomicrudite facies measured by Baum, Harris and Zullo (1978, p. 8, fig. 3) at the nearby Martin Marietta quarry. The specimens were mostly of *Druidia wilsoni* but also included *Laocoetis* sp. cf. *L. crassipes* and *Bactronella womblei*. We observed similar sponges in place in the uppermost foot (30 cm) of the formation in the quarry wall but did not collect them owing to difficulty of access. The Ideal Cement Company test pit locality between Burgaw and Maple Hill was collected by us from spoil heaps adjacent to the water-filled pit. The specimens are mainly of *Bactronella womblei* along with fragments of *Druidia wilsoni*. This is near the faunally richest sponge locality, USGS 22389, which had been collected by Druid Wilson but was no longer exposed at the time of our visit. That fauna includes abundant *Druidia wilsoni* and *Bactronella womblei*. All three collections appear to be of the same sponge facies.

The inlandmost locality of Druid Wilson near Dudley (USGS 21849) contains a different fauna from the rest of the Castle Hayne localities, and is in an outlying patch of Castle Hayne surrounded by Cretaceous. The specimens were weathered-out from a surface outcrop or shallow pit (Druid Wilson, pers. comm.). This locality may represent a different facies or a different stratigraphic level. A more extended discussion is given below.

The reader who is unfamiliar with technical terms for sponge morphology, especially the numerous names for particular forms of spicules, is referred to the Glossary in the Treatise on Invertebrate Paleontology, Part E (Revised), v. 1, pp. 177–190 (Kaesler, 2003).

## GEOGRAPHIC DISTRIBUTION OF THE CASTLE HAYNE SPONGE FAUNA

Sponges are not equally abundant, nor the fanules equally rich in species, at all Castle Hayne collecting localities. Greatest abundance and diversity is concentrated in two areas, the one in the main outcrop belt from Castle Hayne itself, to the vicinity of Maple Hill, the other some 72 km (45 miles) to the north, near Dudley, south of Goldsboro, in a patch of Castle Hayne Formation surrounded by Cretaceous sediments of the Black Creek Formation. The sponge faunas from these two areas are distinctly different, though they share a few species in common. In terms of paleogeography, the second locality is nearer the paleoshore. It is also possible that there is an age difference, for in terms of regional dip, the second locality could be from an older horizon.

The first, or southern, fauna is present throughout the main outcrop area of the Castle Hayne Formation. The

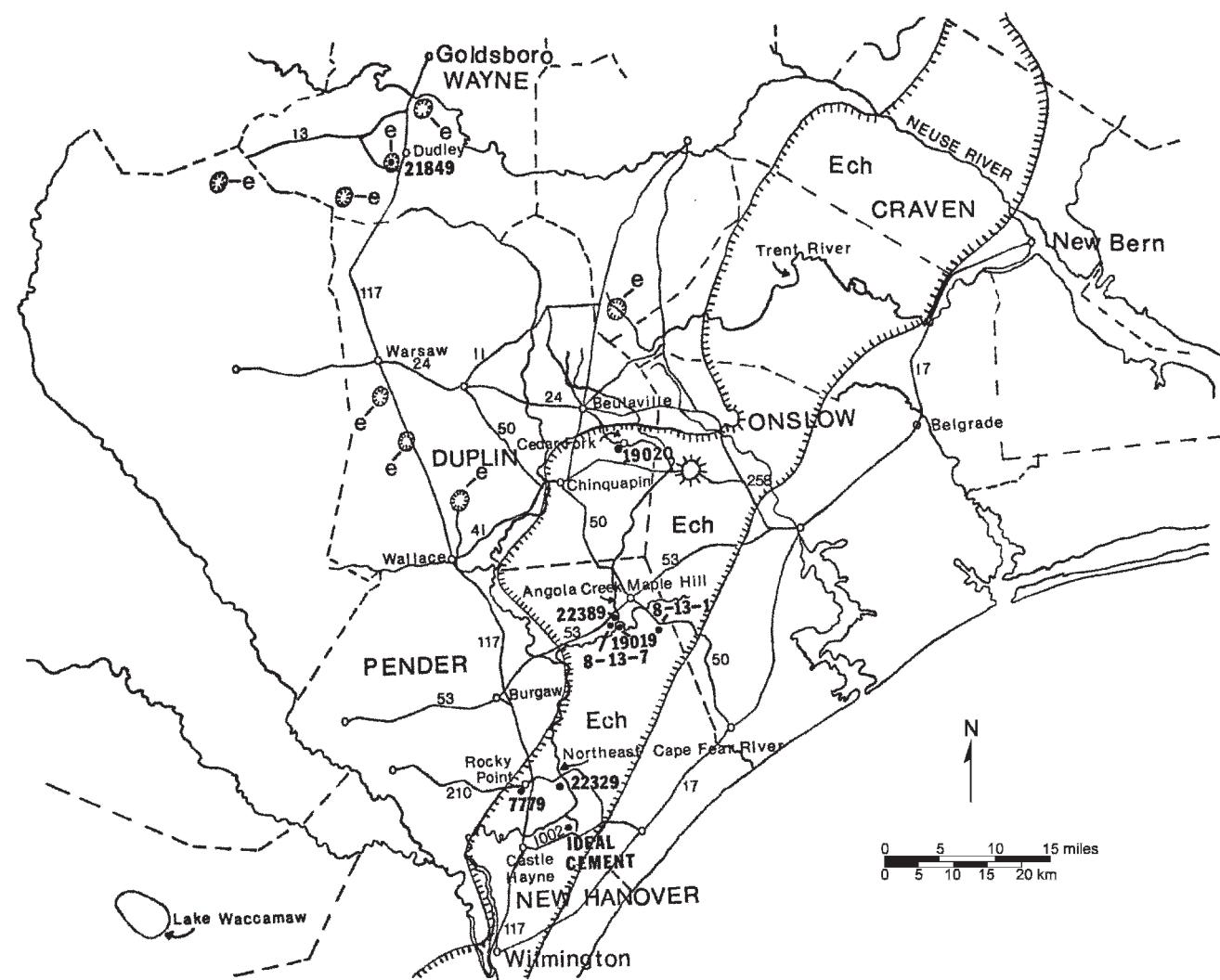


FIG. 1. Map depicting collecting localities and limits of the Castle Hayne (Ech, e) including New Bern Formation of Baum et al. (1978). After Saunders and Stuckey (1958).

hexactinellid *Druidia wilsoni* is dominant in biomass. It is the most conspicuous species in the Ideal Cement Company quarry at Castle Hayne. It is similarly dominant in the collections of Druid Wilson from locality 22389 (between Burgaw and Maple Hill) which is the richest in species of all the localities. It has also been found at less productive localities scattered through the main outcrop belt: near Rocky Point (locality 22329), in the Ideal Cement Company test pit near locality 22389 east of Burgaw, in the Lanier Pit near Maple Hill, and in the Cedar Fork Swamp south of Beulaville (locality 19020). The most abundant species in terms of individuals, and equally widespread, are the small lithonine calcisponges belonging to the two species of *Bactronella*. We will call this southern fauna the *Druidia-Bactronella* fauna. These two genera are not only the most abundant in the southern fauna but also they are completely absent from the northern fauna.

The *Druidia-Bactronella* fauna consists mainly of dictyonine hexactinellids and lithonine calcisponges (Table 1). The most abundant hexactinellids after *Druidia* are *Exanthesis ovatus* and *Laocoetis cf. crassipes*. *Verrucocoeloidea* (*Euretella*) *corallina* and the camerospongiid *Robinia striatopunctata* are less common hexactinellids. Calcisponges are, in order of abundance, *Bactronella womblei*, *B. incrassata*, and *Plectroninia pertusa*. Demosponges consist only of rare fragments and loose spicules. They are of interest however in establishing a clear relationship to the northern fauna, thereby supporting the idea of contemporaneity. The plinthosellid lithistid *Claytonia rayi* is common to the two faunas. Indeed it is the only species that is so with certainty. Closely related plinthosellids are present in both faunas, *Hazelina* in the south, *Acrochordielia* in the north. Loose ophirhabds are present in the matrix of the southern fauna. They closely

Table 1. *Druidia wilsoni*, n. gen., n. sp.: dimensions of the most complete specimens. These data were used in constructing Text-Figures 5 and 6. Data omitted could not be measured because of incomplete preservation.

Specimen USNM no.	Height (mm)	Width (mm)	Top of Cone Diameter (mm)	Apical Angle	Locality
127672	50+	125	0 × 75 (mean 62.5)	-	22,389
127701	75	130	70 × 75 (mean 72.5)	-	Ideal Cement
127674	50	95	-	30°	22,389
127699	75+	165	55 × 100 (mean 77.5)	25°–42°	Ideal Cement
127700	130	244	80 × 120 (mean 100)	25°–45°	Ideal Cement
127697	95+	220	75 × 110 (mean 92.5)	40°–70°	Ideal Cement
127696	150+	150	-	-	Ideal Cement
127698	-	-	105 × 130	35°–45°	Ideal Cement
127673	-	-	42 × 71) (mid-height)	40°–55°	22,389

resemble those of the northern *Cerberorhaphidites auriformis*, and may belong to that species, but in the absence of the diagnostic triactins an identification cannot be made with certainty. Loose dichotriaenes and a *Cliona* complete the roster of preserved demosponges in the *Druidia-Bactronella* fauna.

The northern fauna is known only from one locality, a small outlier southwest of Dudley. It is dominated by demosponges. There are but two hexactinellid genera, neither of them occurring in the southern fauna. One, *Haynespongia vokesae* is morphologically similar to *Druidia*, and like it a hexactinosan. The other, *Sheldonia syndocus* is a euptectellid and the only known lyssacine from the Castle Hayne Formation. Calcareous sponges are completely absent. With reference to biomass the fauna is dominated by the lithistid demosponge *Achrochordiella vokesi* (a plinthosellid) followed by the choristid demosponges *Cerberorhaphidites auriformis* and *Geodia harmatuki*. Next in abundance is the choristid *Stelletta (Stolleya) silvigera*. All these are preserved as entire sponges. In addition their loose spicules (especially the ophirhabds of *Cerberorhaphidites* and the sterrasters of *Geodia*) are very abundant in the associated matrix and the choristids were probably more common than the whole specimens would indicate relative to the more cohesive lithistids such as *Achrochordiella vokesi*. All the demosponges just mentioned, with the probable exception of *Cerberorhaphidites*, are confined to the northern fauna. The remaining demo-sponge of the northern fauna, the relatively rare lithistid *Claytonia rayi*, also occurs in the south. We call this northern fauna the *Geodia-Haynespongia* fauna, because both genera are diagnostic and abundant. The easily recognized large sterrasters of *Geodia*, which, in addition to their occurrence on whole specimens of *Geodia harmatuki*, are very abundant as loose spicules in the matrix of the northern fauna, are completely absent from the matrix of the southern fauna. Ophirhabds, as large and siliceous as sterrasters, are abundant in the matrix of both faunas, so the absence of sterrasters in the south cannot be ascribed to chemical or hydrodynamic factors and must reflect a genuine absence of

*Geodia* sponges. *Haynespongia* is likewise diagnostic because both it and *Druidia wilsoni* are not only mutually exclusive but also resemble one another in gross morphology and probably played similar ecologic roles. It is possible that the absence of calcareous sponges like *Bactronella* is because of weathering. The material from this locality was collected from weathered material in which much of the calcareous matter may have been leached out. Weathering, however, cannot account for the considerable difference in the silic.sponge faunas.

What is the cause of the difference between the two faunas? The northern locality, being more inland, was presumably closer to the paleoshore. Such a position is supported by the unusually heavy skeletons, compared with their nearest relatives, of many of the species, especially *Geodia harmatuki*, *Stelletta (Stolleya) silvigera*, and *Sheldonia syndocus*. The fractured condition, (in some cases during life, as evidenced by healing) of the more lightly built *Haynespongia vokesae* offers additional evidence of rough water. The marly matrix, insofar as it has been preserved, has a higher iron content, evidenced by rusty weathering, and a higher silicate to carbonate ratio, evidenced by low solubility in acid of even an unweathered fragment, than the matrix of the southern localities. This would be compatible with a nearer-to-source position. The southern *Druidia-Bactronella* fauna occurs in a more calcareous matrix, widely quarried for cement. It is characterized by rather large and relatively delicate hexactinellids. Their complex bodies have been preserved whole and unbroken, despite the solution at some localities of the original silica skeleton leaving only external and internal molds. This certainly suggests rather quiet water, compatible with a more offshore position.

Inasmuch as Calcarea today are almost entirely confined to depths shallower than 60 m (200 feet) it is quite possible that the offshore *Druidia-Bactronella* fauna occurred in depths no greater than this. Although *Geodia* and *Stelletta* have a much greater depth range, they frequently occur today in extremely shallow nearshore localities (e.g., Hechtel 1965; Bergquist

1968), so their present distribution is compatible with a much shallower environment for the *Geodia-Haynespongia* fauna relative to the *Druidia-Bactronella* fauna. Assuming the present depth limit (ignoring a few exceptions) for calcareous sponges, and an offshore position for the calcareous sponge-containing fauna, the entire range of Castle Hayne water depths would be no greater than 60 m (200 feet). This is compatible with the rich molluscan-echinoid-bryozoan fauna of the offshore facies (Kellum 1926; Canu and Bassler 1920; and pers. obs.). It is likely that the bottom was soft in both areas, judging from the laterally expanded form of both *Druidia* and *Haynespongia* with their radial fins and tubes adapted for spreading their weight over the substrate. Kier (1980, p. 11) concludes that the Castle Hayne sediments were well-aerated and the sea tropical.

The possibility of an age difference for the *Geodia-Haynespongia* fauna was raised earlier. Its position as an outlier well into the Cretaceous terrane, being separated from the main outcrop belt by part of the Black Creek and all of the PeeDee Formations, as well as the sponge-faunal difference, naturally raises such a question. Unfortunately the sponges can do little to resolve this question in the present state of restricted knowledge of Tertiary sponge faunas. As discussed elsewhere in this paper, the entire Castle Hayne sponge fauna of both facies has a "Cretaceous" aspect. Nevertheless, there are significant differences from Cretaceous sponge faunas. The abundant *Druidia* of the main outcrop belt has a close relative of similar shape, *Badinskia* from the Miocene of Algeria (Pomel 1872). Furthermore, a species of *Laocoetis* closely resembling the abundant Algerian Miocene species, *Laocoetis crassipes* (Pomel 1872), occurs in the Castle Hayne with *Druidia*. These "forward-looking" species being absent from the *Geodia-Haynespongia* fauna of the outlier, makes an older age for the outlier plausible if not particularly likely. We believe that an overriding piece of evidence favors contemporaneity, namely the occurrence in both faunas of *Claytonia rayi*, and the occurrence of ophirhabds in the main outcrop belt identical to the ophirhabds of *Cerberorhaphidites auriformis* in the outlier. It is not possible to resolve this question at present, as the sponge-bearing outcrop of the outlier has apparently disappeared. Druid Wilson collected the sponges from a roadside outcrop. When we returned to the site in 1975 the outcrop was completely covered by housing and golf-course development. There were no other outcrops in the vicinity and one must await future substantial artificial excavations to recollect.

Additional evidence that the *Geodia-Haynespongia* fauna is from shallower water is the fact that Cretaceous faunas in which lithistids dominate over hexactinellids have been interpreted on geologic grounds as being from

shallower water than those in which hexactinellids dominate (Reid 1962, 1968). The same might be said also of the Miocene fauna of Algeria, particularly that from Beni bou Mileuk described by Moret (1924), and also that from Italy described by Manzoni (1882). The spiculitic Eocene Plantagenet Beds of Western Australia also exhibit evidence of near-shore conditions, such as fossil leaves (Chapman and Crespin 1934, p. 105), and their sponge fauna is similar to that of the *Geodia-Haynespongia* fauna, in the dominance of choristids and lithistids, the near-absence of hexactinellids, and the total absence of Calcarea (see below). By contrast, hexactinellids were the only recognizable sponges in the probably offshore *Globigerina*-limestones of the Eocene of Israel reported by Avnimelech (1943, and see below). The accompaniment of the hexactinellid fauna of the Castle Hayne by lithonine calcisponges is not inconsistent with Cretaceous patterns, for the lithonine *Porosphaera* occurs typically in the chalk facies with hexactinellids (Reid 1968, p. 17) even though most pharetrotrinids are associated with lithistids in the nearer shore facies (loc. cit.).

## SIGNIFICANCE FOR THE HISTORY OF SPONGES

As one of the three richest known Tertiary sponge faunas, the Castle Hayne assemblage provides a view of a little known part of sponge history. Its 16 genera, including representatives of the three major living classes of sponges, may be compared to that of the Miocene of Algeria (Pomel 1872; Zeise 1906, 1907; Moret 1924) with its 17 genera. It may also be compared to the Eocene (described originally as Miocene) fauna of Western Australia (Hinde 1910; Chapman and Crespin 1934; De Laubenfels 1953; Pickett 1982, 1983) with 17 or 18 genera (10 according to Pickett 1983) based on whole sponges.

One is struck at first by the "Cretaceous" aspect of this fauna. *Stolleya*, plinthosellids (*Claytonia*, *Hazelina*, *Achrochordiella*) cephalorhaphiditids (*Cerberorhaphidites*), craticulariids (*Laocoetis*), cribrospongids (*Haynespongia*), aphrocallistids (*Druidia*), camerospongidiids (*Robinia*), and *Exanthesis*, are all common Cretaceous forms that are rare or extinct today. In addition, all the other genera, or their close relatives, have Cretaceous representatives, even though they are still common today: *Geodia*, *Cliona*, euretids (*Verrucococoeloides*), euplectellids (*Sheldonia*), and lithonina (*Plectroninia*, *Bactronella*). This is surely not unrelated to the marly, almost chalky, lithofacies of the Castle Hayne Formation and its echinoid-rich associated fauna, which is characteristic of the most sponge-rich Cretaceous deposits of Europe. However, other factors must be involved, for the Cretaceous deposits of the United States are quite poor in sponges, even in the chalky facies.

To some extent the “Cretaceous” aspect is the product of our poor knowledge of Tertiary sponge faunas. In many major groups of organisms (viz., pelecypods, gastropods, angiosperms) a substantial proportion of living genera were already present in the Cretaceous. However, there is also no doubt that the Cretaceous was a high for sponge diversity and that sponges have undergone a decline through the Tertiary to the present day. This is demonstrable with easily fossilizable groups such as the dictyonine hexactinellids, lithistid demosponges, and the pharetronid calcisponges, all of which have more genera in the Cretaceous than at the present day: dictyonine hexactinellids, about 170 Cretaceous genera and 120 Recent; lithistids, 150 Cretaceous and 50 Recent; pharetronids, 70 Cretaceous and 10 Recent (Finks 1967, p. 336).

The Castle Hayne sponge fauna enables us to document to some extent the pattern of this Tertiary decline. The plinthosellids sensu lato, that is, the taxon including the new Castle Hayne genera *Claytonia*, *Hazelina*, and *Achrochordiella* were hitherto thought to have become extinct at the end of the Cretaceous, with the exception of *Thamnospongia* and *Phymaplectia* from the Eocene of Australia. Thus this family persisted in some diversity through the Eocene at least. Of interest is the similarity of *Thamnospongia* to the most abundant of the Castle Hayne plinthosellids, namely *Achrochordiella*. This may be the longest lived branch of the family. The species *Phymaplectia sterea* De Laubenfels 1953, from the Eocene of Australia may actually be an *Achrochordiella*. The dictyonine hexactinellids are the other major element in the Castle Hayne fauna that exhibits little decline from the Cretaceous, *Exanthesis*, *Haynespongia* (close to *Guettardiscyphia*), and *Robinia* (close to *Tremabolites*) directly extend lineages previously thought to have died out at the end of the Cretaceous. It is of interest that the most abundant Castle Hayne dictyonine, *Druidia*, has a close relative (*Badinskia*) in the Miocene of Algeria and another close relative, *Aphrocallistes*, exists today. *Laocoetis* likewise is abundant in the Algerian Miocene, and moderately so in the Castle Hayne. Both *Laocoetis* and *Aphrocallistes* date from the Cretaceous, and it would seem that their respective lineages (craticulariids and aphrocallistids) are among the longest lived of the dictyonine hexactinellids. The euretidids (*Verrucocoeloidae*) are a similarly long-lived branch. Among the dictyonines, therefore, there is less of a decline during the Tertiary, but the Castle Hayne fauna is on the whole more like that of the Cretaceous than that of the Recent. Inasmuch as Castle Hayne time is almost at the half-way mark between the end of the Cretaceous and the present day, the decline in sponge diversity during the Tertiary was not linear. One can speculate that the worldwide drop in temperatures at the end of the Eocene which affected so many other

animal groups (Gingerich 1980, p. 409) may have been the time and cause for the first restriction of the old Cretaceous sponge fauna. On the other hand, Moret (1924, p. 24) noted that even the Miocene sponge fauna of Algeria has a Cretaceous appearance, due in that case not only to the dictyonines mentioned above but also to its rhizomarine lithistids, a group not represented in the Castle Hayne. Perhaps the final blow was delivered by the Plio-Pleistocene cooling. It is certain that we need to know much more about Tertiary sponge faunas.

The lack of diverse Cretaceous sponge faunas in North America is puzzling. The same lithofacies that are so sponge-rich in Europe, namely, greensands and chalks, also exist in the North American Cretaceous. The intervening Atlantic was narrower than it is today. Yet the paucity of Cretaceous sponges seems genuine, as indicated by stunting of some genera that do occur; the only known specimen of *Coelptychium* from the New Jersey Cretaceous (in greensand) is only 25 mm or so in diameter, while average specimens from Europe are more than 100 mm in diameter. The lithonine calcisponge *Porosphaera* is fairly common in the chalky facies of the Cretaceous of Texas (personal observations of museum collections), but few other sponges are reported to be present (Howell 1957, p. 4). The Castle Hayne fauna appears to be more diverse than any that have been described from the North American Cretaceous. Presumably the submarine climate of the North Carolina Eocene was closer to that of the European Cretaceous than was that of the North American Cretaceous. Since all the lithologies discussed have low levels of terrigenous detritus, that factor must not be involved in the difference, nor is there evidence of strong differences in temperature or salinity (except perhaps the Cretaceous of the Western Interior). The answer may lie in differences of dissolved nutrients and/or phytoplankton productivity, perhaps related to patterns of upwelling.

The Miocene fauna of Algeria (Pomel 1872; Zeise 1906, 1907; Moret 1924), one of the other two large samples of Tertiary sponges, exhibits some interesting differences from that of the Castle Hayne which must be because of facies rather than to historical change. More than half the genera reported from it are rhizomarine lithistids known from the Cretaceous (Moret 1924, p. 25). These are totally absent from the Castle Hayne fauna. Lack of preservation cannot be the reason, for they are as cohesive as the other Castle Hayne sponges. The Algerian lithofacies is described as a brownish, quartz-sandy, glauconitic marl (Moret 1924, p. 9); possibly this is correlated with environmental differences significant for sponges. Moret (*loc. cit.*) considered it to represent shallow, sublittoral, agitated waters (“*peu profondes, sublittorales...en mouvement*”). This would place it close to the environment inferred here for the

*Geodia-Haynespongia* facies of the Castle Hayne. Like that facies, lithistids are dominant, but the Castle Hayne lithistids are plinthosellids whereas the Algerian ones are mostly rhizomorines. However, Zeise (1906, pp. 951–952) describes four species of the Algerian fauna from Djebel-Djambeida, without naming them formally, or illustrating them, that would appear to be plinthosellids and probably constitute four genera. Two are said to have desmas like those illustrated by Zittel (1878, pl. 10, fig. 6) for *Spongodiscus radiatus*, one being an auriform sponge without oscules, the other a pyriform one with surface furrows and a central bundle of apochetes. A third one is said to be conical without cloaca, oscules, or ostia, and to have desmas like those of *Plinthosella squamosa* as illustrated by Zittel (1878, pl. 10, fig. 5a). A fourth is said to be thickwalled, laterally-compressed platter-shaped, with a lumpy to lobate outer surface, and a shallow, elongate cloacal depression, and to have desmas larger than the preceding three but resembling those of *Spongodiscus radiatus*. Moret (1924) did not recognize any plinthosellids in his material from Benibou-Mileuk, unless the sponges described with doubt as *Discodermia* sp. (*ibid.*, p. 19) are plinthosellids, although the lithofacies is said to be the same (*ibid.*, p. 9). There may be subtle environmental differences not reflected in the sediment, or we may be dealing merely with sampling accidents relative to a very patchy local distribution of species. In addition to the differences mentioned, the Algerian Miocene fauna seemingly lacks Castle Hayne forms which still exist: *Geodia*, *Stelletta*, and ophirhabd-bearing sponges, which might be expected to be preserved if present, if only as isolated spicules. Moret (*loc. cit.*) states that isolated sponge spicules are almost completely absent from the sediment, those that occur are rare rhizoclones, oxeas and hexactinellid debris, but no triaenes or microscleres. He attributes this to winnowing or mechanical destruction (*loc. cit.*). The presence of rhizoclones at least tends to confirm their dominance in the fauna.

The Miocene fauna from northern Italy described by Manzoni (1882) is also dominated by lithistids, with four genera as opposed to one hexactinellid. Only one of the lithistids is a rhizomarine, the other three are phymatellid tetracladines; there are no plinthosellids. This fauna occurs in sandstone, and like other demosponge-dominated Cretaceous-Tertiary faunas may be nearshore.

It is difficult to compare the Castle Hayne fauna with contemporary Eocene faunas because the others that have been published are limited in diversity (except one), or consist only of isolated spicules which cannot be identified as to genus (or even as to higher categories). The only other large Eocene fauna in the literature that contains whole sponges is the fauna from the Plantagenet Beds of Western Australia (Chapman and Crespin

1934; De Laubenfels 1953). These beds were originally dated as Miocene, but more recent study assigns them to the Eocene (Brown et al. 1968, p. 300). An earlier paper by Hinde (1910) on isolated spicules from these beds, near Norseman, made generic identifications which cannot be sustained because the spicules are not diagnostic (De Laubenfels 1953). Chapman and Crespin included these identifications in their paper (1934) and added 11 other genera based on whole sponges from the Albany area. Unfortunately even these are incompletely described as to spiculation and their generic identity is in doubt (except for two: *Ecionema* and *Verruculina* according to De Laubenfels 1953). However it is possible to assign them with reasonable certainty to orders, and is likely that they are distinct genera. Ten are demosponges (3 choristids and 7 lithistids); one is a hexactinosan hexactinellid. De Laubenfels (1953) added 6 or 7 additional lithistid genera, from south of Ravensthorpe, plus reclassifying one (*Thamnospongia* to *Stachyspongia*) and possibly another (*Thecosiphonia* to *Pleroma*) of Chapman and Crespin's genera. This totals 17 or 18 genera, including 3 choristids, 13 or 14 lithistids, and one hexactinellid. Of the lithistids, one and possibly three are plinthosellids (*Phymaplectia*, “*Tragalimus* Pomel 1872” (?), and *Nedlandsia* De Laubenfels 1953 (?)) one a discoderiid (*Dactylocalycites* Carter 1871), two are rhizomorines (*Stachyspongia* Zittel 1878, and *Zosterospongia* De Laubenfels 1953), and one is a megamarine (*Pleroma* Sollas 1888). It is possible that the species referred to *Phymaplectia* (*P. sterea* De Laubenfels 1953) belongs to the genus *Achrochordiella*, and that the species referred to *Tragalimus* (*T. amechanus* De Laubenfels 1953) belongs to *Pseudojerea* Moret 1926, or even to the genus *Claytonia* established herein. Pickett (1983) has published a brief review in which he reduces the number of *lithistid* species to 10 but does not attempt a generic reallocation of species.

It is obvious that demosponges, and especially lithistids, dominate the Western Australian Eocene fauna. It is apparently more diverse in choristids and lithistids than the Castle Hayne fauna, and includes rhizomorines and a megamarine, two orders not represented in the Castle Hayne. On the other hand, there is only one certain hexactinellid, and no Calcarea. It is possible that calcareous sponges were lost through diagenesis, for the sediment is described (Chapman and Crespin 1934, p. 105) as having an “almost total absence of calcium or magnesium carbonates.” Pickett (1983) has not described a silicified sphinctozoan from these beds. In facies, it resembles the peculiar fauna of Locality 21849 of the Castle Hayne in being dominated by demosponges. In this respect it also resembles the Miocene fauna of Algeria. The Plantagenet Beds form a thin veneer of sediment (mainly spiculites) lying directly

on the Precambrian (Brown, Campbell and Crook 1968, p. 300), and locally contain fossil leaves occurring together with the sponges and other marine fossils (Chapman and Crespin 1934, p. 105), and thus are almost certainly near shore deposits, as are probably also the Algerian beds and Locality 21849 of the Castle Hayne. The Plantagenet Beds are to some extent more like the Algerian beds in that they contain the rhizomorines absent from the Castle Hayne. The presence of at least one and possibly three plinthosellids, of which the most certain is close to the Castle Hayne *Achrochordiella*, confirms the importance of plinthosellids among Eocene sponges, particularly in shallow environments.

Hinde (1900) described three genera and four species of supposedly Eocene calcisponges from three localities in the Bass Basin of southern Victoria, Australia. They include the lithonines *Plectroninia* (one species—the type) and *Bactronella*, (two species), very similar, though not identical, to the species of the Castle Hayne, plus another pharetronid, *Tretocalia pezica*. Pickett (1983, p. 106) identifies these outcrops as Miocene.

Sponges have been reported from Eocene limestones in the Shephela region of Israel (Avnimelech 1943). They occur as molds, which in many cases preserve the form of a dictyonine hexactinellid skeleton ("The fine retiform print is similar to the skeleton of the genus *Coscinopora*," *ibid.*, p. 480). Although, as Avnimelech points out (*ibid.*, p. 481), hexactinellids need not have dominated the living fauna but may merely be more recognizable under the conditions of preservation, the fact that they can be recognized at numerous localities suggests that they were more abundant than in the Western Australian fauna. In this connection, the limy facies of the sediment, a *Globigerina*-limestone (*loc. cit.*), suggests a comparison with the hexactinellid-dominated *Druidia-Bactronella* facies of the Castle Hayne, and strengthens the interpretation of hexactinellid-dominated Eocene sponge faunas as being more offshore than demosponge-dominated ones.

A fauna of three hexactinellids, one of them (*Ceriosymplegma*), a probable close relative of *Druidia* (q.v.), was described by Rauff (1924) from Eocene chalk near Aleppo in Syria. They were described as Cretaceous, but according to Avnimelech (1943, p. 484) the beds were remapped by Dubertret (1941) as Eocene. Again this is an association of hexactinellids with a probable offshore environment.

A relative of *Guettardiscyphia* is apparently common in the Eocene deposits near Biarritz, France (D'Archiac 1846, 1848). It was assigned to a new genus *Pseudoguettardia* by Moret (1925) based in part on additional Eocene material from Catalonia. Both genera resemble *Haynespongia* but appear to differ from it in much the same way (see Systematic Paleontology).

The supposed whole sponges reported by Rutot (1874) from the Eocene sands of the Brussels area in Belgium appear to be burrows containing sponge spicules, similar to *Ophiomorpha*, to judge by description and illustrations of these objects given by Carter (1877), who named them *Broeckia* (*ibid.*, p. 390).

Other records of Eocene sponges known to us, such as those of Hinde and Holmes (1892) from New Zealand, describe isolated spicules only and will not be reviewed here.

## EVOLUTIONARY TRENDS

The Castle Hayne fauna can help us see evolutionary trends in some lineages and evolutionary stasis in others. The aphrocallistids perhaps are best documented. The ancestral genus *Aphrocallistes*, which first appeared in the Cretaceous and continued to the present day, has a tubular to irregularly folded body wall. None of the Cretaceous or Recent species, so far as they are preserved, has the radially symmetrical foldings of the body wall around a deep central cone, lined with the homologue of a terminal diaphragm, that is characteristic of *Druidia*. However, one late Cretaceous species, *Aphrocallistes cylindrodactylus* Schrammen 1912, has a partial development in this direction, and may very well be ancestral to *Druidia*. *A. cylindrodactylus* has a funnel-like depression at the top of the sponge which appears to be lined with a mesh similar to that of the *Druidia* cone, with alternate radial bands of small and large openings. Outpocketings similar to the tubes of *Druidia* radiate from the axial area but they are not arranged with any kind of regularity and there is no development of the wings or fins seen in *Druidia*. *A. cylindrodactylus* first appears in the Senonian (Reid 1968, p. 19 ff.). *Ceriosymplegma* Rauff 1924, is an Eocene aphrocallistid that may have the form of *A. cylindrodactylus* with an even deeper central sieve, or it may have developed the radial fins, and possibly the central cup, of *Druidia*; unfortunately the described material is incomplete and does not enable us to choose between these alternatives. Both *A. cylindrodactylus* and *Druidia* have a well-developed exterior cortex with small round pores, that is lacking in *Ceriosymplegma*, and for that matter, in all other known aphrocallistids except the Cretaceous species *Aphrocallistes lobatus* Schrammen 1912, which is close (so far as incomplete preservation permits us to say) to *A. cylindrodactylus* in form. The Miocene *Badinskia* Pomel 1872, is another aphrocallistid similar to *Druidia*. It has the same type of radial fins and also tubes, but the number of fins is smaller (4 to 6 according to Pomel 1872, p. 85) and the central funnel is apparently lacking, the fins joining directly at the central axis. The Castle Hayne *Druidia* would appear to represent the highest development of this radially

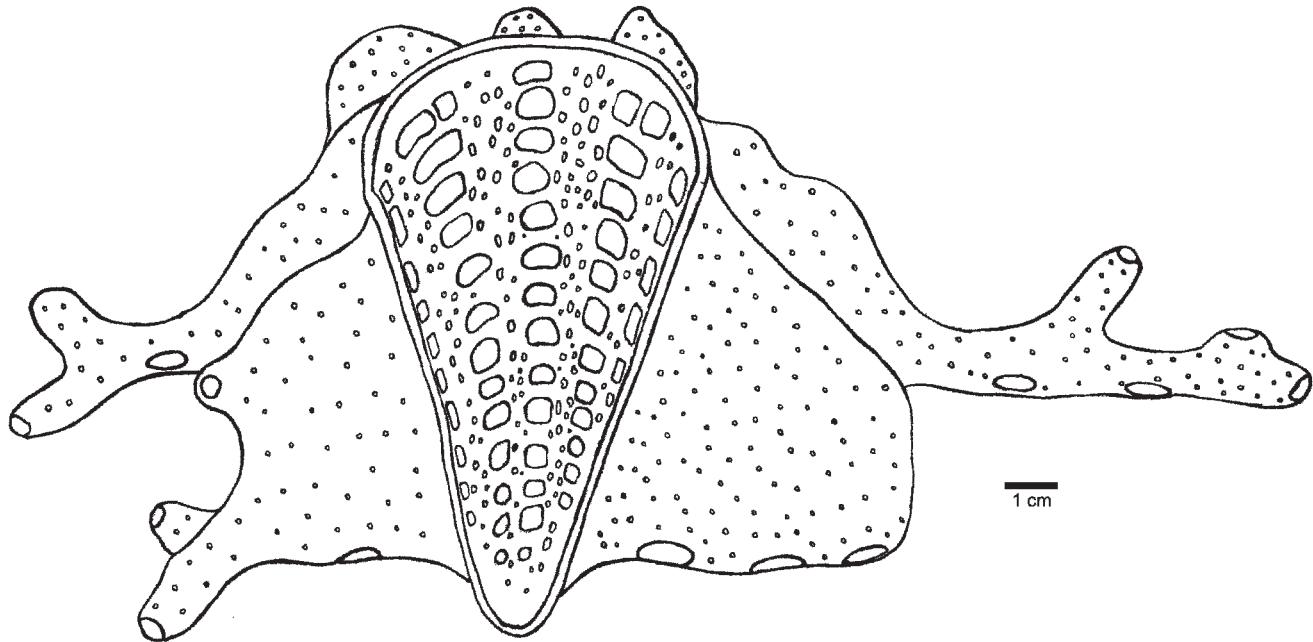


FIG. 2. Reconstruction in life-position of *Haynespongia vokesae*, n. gen., n. sp., showing cutaway view of central cone. Drawn by R.M. Finks.

symmetrical and broadly cup-shaped type of aphrocallistid. So far as we now know, the Miocene *Badinskia* is the last of the aphrocallistids with radial vertical fins. The living *Aphrocallistes vastus* Schulze 1887 (p. 317) has fin-like foldings of the body wall but there is no trace of the inner-cone and lining seen in *Druidia*; although the specimen is incomplete, enough is present so that if such a cone and lining had existed at least traces of it would be preserved; the sponge was described (*loc. cit.*) as “parts of the lateral wall of a large cup,” but the illustration of it (*ibid.*, pl. LXXXV, fig. 1) shows very little of the form of a cup, and it is unlikely that it was organized like a *Druidia*. Schrammen (1912, p. 222) considered that his Cretaceous species *Aphrocallistes lobatus*, together with *A. cylindrodactylus* and the living *A. vastus*, formed a lineage characterized by an open cup-shape and the lack of a terminal sieve-plate (*loc. cit.*). The material of *A. lobatus* consists only of two fragmentary specimens: the one (*ibid.*, Text-Fig. 2) consisting of three attached lobes like those of *Druidia*, the other (*ibid.*, pl. XXVI, fig. 1) a similar single lobe. No central cone is preserved. If such existed, and was lined by a sieveplate-like mesh, this would be closer to *Druidia* than *A. cylindrodactylus*, but in the absence of such material we must suspend judgment. We have discussed this lineage in more detail under *Druidia wilsoni* and under the Aphrocallistidae. Basically, we believe that *Druidia* arose from the *A. cylindrodactylus*-*A. lobatus* species group (which share with it a dermal cortex), that *Badinskia* is from a separate but parallel lineage, as is *Ceriosymplegma*, and that the living species of *Aphrocallistes* descended from the Cretaceous *A. alveolites*.

The lineage involving *Haynespongia* can be traced with some question. If *Guettardiscyphia* is indeed related, then the development of tubes on the lobes and the development of an open central cup proceeded in parallel with, or through, the genus *Hillendia*, in which tubes are present but not the central cup. These are both Cretaceous forms. A less regular arrangement of epirhyses and aporhyses would also have to take place, as well as the development of branching canals. It is possible that *Haynespongia* arose from a cribrospongiid that already had a branching canal system, such as *Cribrospongia* itself, and developed a *Guettardiscyphia*-like form as a parallel evolution.

Among the demosponges, *Cerberorhaphidites* can be fitted best into an evolutionary sequence. Compared with the Cretaceous *Cephalorhaphidites*, its probable ancestor, it exhibits a reduction of dermal triaenes to simple triradiates, as well as a diminution in size of the ophirhabds. The last is open to some question, and may be an environmental effect, for Moret (1926, p. 133) notes that *Ophirhaphidites infundibuliformis* from France has smaller ophirhabds (of the same size as those of *Cerberorhaphidites*) than those described by Schrammen (1910) from Germany though both are of the same age (Santonian). The living ophirhabd-bearing *Jaspis serpentina* has neither triaenes nor triradiates and may represent the end term of the lineage. Like *Cerberorhaphidites* it possesses euasters; microscleres which are not preserved from the Cretaceous species but which were very likely present.

An essential lack of evolution since the Eocene is demonstrated by *Geodia harmatuki*. Although the

sterrasters of this species are unusually large and the sterraster-bearing cortex usually thick, there are living species, such as *G. rex*, *G. macandrewii*, and *G. hirsutus*, that have sterrasters as large or larger, and cortices nearly, or quite, as thick. Furthermore, in its remaining spiculation, including megascleres, microscleres, and their arrangement in the skeleton, *G. harmatuki* is identical to living species. The Castle Hayne specimens are a unique document of the existence of modern *Geodia* at least as early as the Eocene, for they are the only complete *Geodia* skeletons in the fossil record, other than the Polish Cretaceous species described by Hurcewicz (1966, p. 25). That species (unnamed) differs in having dermal orthodichotriaenes with stubby cladome rays in place of the simple orthotriaenes of the Eocene and many Recent species. Also prodichotriaenes with stubby rays occur in the interior. Whether this indicates that Cretaceous *Geodia* was closer to a *Stelletta*-like ancestor, cannot be confirmed without a wider sampling of Cretaceous *Geodia*.

*Stelletta (Stolleya) silvigera* also documents a lack of major evolutionary change within the genus *Stelletta*, at least since the Eocene and probably since the Cretaceous. It is true that the unusually thick dichotriaenes with horizontal secondary rays, characteristic of the subgenus *Stolleya*, are not found in most living species of *Stelletta*, but they are found in some, especially *S. lithodes*, which also has the unusually dense inner skeleton of very large radial oxeas that is found in the Eocene species. It is apparent that at least some species of *Stelletta* have had a dense dermal armor and/or a dense inner skeleton since Cretaceous times.

The remaining species in the Castle Hayne fauna do not demonstrate any clear-cut trends, nor do they clearly prove the lack of them. A possible exception is *Verrucocoeloidea (Euretella) corallina*. The living *Verrucocoeloidea burtoni* could be derived from the Cretaceous *Verrucocoelia* by the addition of plexiform tubes to the inner lining of the central funnel. However, the Eocene species is not funnel-shaped, but cylindrical and branching and the plexiform tubes fill the entire axial area; also the lateral tubes are flaring as in *Eurete* rather than terminally contracted as is typical of both *Verrucocoelia* and *Verrucocoeloidea burtoni*. It is possible to derive both the Eocene and the living species by separate divergent paths from the Cretaceous *Verrucocoelia*. It is also possible that the Eocene species came directly from a plexiform, branching, Cretaceous species of *Eurete*. On the whole, the Castle Hayne fauna suggests that the sponges did not evolve very rapidly between the Cretaceous and the present day, and that the differences between the Cretaceous sponge faunas and those of the present may be due more to extinction than evolution, and that, rather more late in the Tertiary than early.

With reference to extinction, note that the plinthosellids, which form the entire complement of lithistids (three genera) in the Castle Hayne fauna, are no longer extant. This is a Cretaceous family (with some 10 genera, essentially the families Plinthosellidae and Phymaraphiniidae of De Laubenfels 1955) that still remained diverse in the Eocene. Besides the Castle Hayne fauna they form a significant element (at least one and perhaps three genera) in the Eocene fauna of Western Australia (De Laubenfels 1953, and see discussion above). They are also a significant element in the Miocene of Algeria, for Zeise (1906, p. 951–2) described, without naming, four species (perhaps four genera) of probable plinthosellids (see discussion above). Their extinction thus took place rather rapidly in post-Miocene time.

#### A NOTE ON PREPARATION

Specimens described in this paper required considerable effort in preparation. The sponges from the rich locality 22389 (also 19019 and 19020) are preserved as original silica, locally permineralized with additional chalcedony, in a matrix of indurated white marl. This matrix, presumably because of its clay content, is very little affected by acid. Thus the sponges cannot be prepared out with acid. Dental drills and carborundum disks in a dental handpiece were found to be the most effective means of removing the major proportion of matrix, especially for the large silicified specimens of *Druidia*. The finest details were prepared out with an S.S. White Co. Airbrasive machine using dolomite powder. Great care had to be exercised in this last stage because the spicule networks were easily destroyed by the blast of dolomite powder. The latter work was done under a binocular microscope. A final ultrasonic cleaning was given to the sturdier specimens without ill effect (after testing on fragments.)

The specimens from the Ideal Cement Company quarry are preserved only as molds in the matrix, the siliceous spicules having been completely dissolved away. The white marl matrix is relatively friable, particularly in local pockets that can be almost as loose as sand, and the sponge, except for the external impression of the outermost spicules, can be freed with small chisels driven by a small hammer, or with a dissecting needle. Occasionally the sponge fractured and the pieces were glued immediately with Duco Cement. The initial part of this work was in the field, for it was the only way of extracting the large, complexly ramifying *Druidia* specimens from the rock. Individual dictyonalia are moderately well preserved as holes in the rock in these desilicified specimens; the form of the canals, pores, and external outline of the whole sponge is completely preserved. The calcisponge *Bactronella*

from this and nearby localities preserves the original calcareous spicules, in part recrystallized.

Siliceous specimens from the outlier, locality 21849, were mostly weathered free of the matrix when collected by Druid Wilson. However the internal canals and mesh spaces were still filled with residual clay and loose, foreign siliceous spicules, and parts of the external surfaces were still covered. The grosser portions of this tenacious material were removed with a dissecting needle, and the finer details revealed by repeated alternations of immersion in an ultrasonic cleaner (with a detergent solution), teasing with very fine needles, and application of the Airbrasive machine with dolomite powder. The ultrasonic cleaner was very effective for a final cleaning and did not seem to harm the skeletal net in any way (small fragments were tested for each species before proceeding), but it only removed a thin surface layer of matrix with each application, necessitating the use of the needles for clearing out pores and canals.

In general, photography was done after coating the specimen with a sublimate of ammonium chloride, which was absolutely necessary for bringing out detail, but the highest-power closeups of the skeletal net were done on the natural spicules, for at this scale the powdery ammonium chloride would alter appearances.

Some specimens were not completely prepared, partly for lack of time, partly so that future studies, using newer techniques, might not be vitiated.

## MEASUREMENTS

Statistical analysis of each of the dozens of measurable, and measured, characters on each of the species would involve a labor incommensurate with the known usefulness of the results. Based on visual inspection, the range of values given for each character can be assumed to represent the approximate extremes of a "normal" distribution with the mean (and mode) approximately halfway between. Where visual inspection indicated a polymodal distribution, separate ranges are given for each presumed mode (*viz.*, "large pores," "intermediate pores," and "small pores"). Every last pore and spicule was not measured, however, and the cited ranges may possibly exclude some extreme values.

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## LOCALITY REGISTER AND FAUNAL LISTS

Locality numbers prefixed by "USGS" are those of the United States Geological Survey Tertiary locality series. Other numbers are field locality numbers of the present authors. All are from the Castle Hayne Formation.

USGS 7794. Rocky Point, North Carolina (Pender County). W.B. Clarke, collector. (See also USGS 22329.)

*Bactronella incrustans* n. sp.

USGS 19019. Old pit about 4.8 km (3 miles) south of Maple Hill, Pender County, North Carolina, near Angola Creek. Druid Wilson, collector. (See also Locality 8-13-7, and USGS 22390.)

*Exanthesis ovatus* n. sp.

USGS 19020. Cedar Fork Swamp, 8 km (5 miles) SE of Beulaville, Duplin County, North Carolina. Druid Wilson, collector.

*Druidia wilsoni* n. g., n. sp.

USGS 21849. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117, approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. Druid Wilson, collector.

*Achrochordiella vokesi* Rigby

*Claytonia rayi* n. g., n. sp.

*Cerberorhaphidites auriformis* n. g., n. sp.

*Stolleya silvigera* n. sp.

*Geodia harmatuki* n. sp.

*Haynespongia vokesae* Rigby

*Sheldonia syndocus* n. g., n. sp.

USGS 22329. South of North Carolina Route 210 on dirt road about 0.16 km (0.1 mile) south of Route

210. (First dirt road west of bridge over Northeast Cape Fear River.) Pender County, North Carolina. Druid Wilson, collector. (This is near Rocky Point, see also USGS 7794.)
- Bactronella womblei* n. sp.
- Bactronella incrustans* n. sp.
- Druidia wilsoni* n. g., n. sp.
- USGS 22389. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. Druid Wilson, collector. (See also Locality 8-13-7, and USGS 19019.)
- Plectroninia pertusa* n. sp.
- Bactronella womblei* n. sp.
- B. incrustans* n. sp.
- Hazelina bisbifurcata* n. g., n. sp.
- Claytonia rayi* n. g., n. sp.
- Euretella corallina* n. subgen., n. sp.
- Druidia wilsoni* n. g., n. sp.
- Exanthesis ovatus* n. sp.
- Robinia striatopunctata* n. g., n. sp.
- 8-13-1. About 5.6 km (3.5 miles) southeast of Maple Hill, Pender County, North Carolina, on south side of North Carolina Route 50, 5.6 km (3.5 miles) southeast of its intersection with Route 53, K.I. Lanier marl pit. R.M. Finks, K.J. Thies, and E.A. Womble, Jr., collectors.
- Druidia wilsoni* n. sp.
- 8-13-7. Ideal Cement Company test pit, south of North Carolina Route 53 on dirt road, about 13 km (8 miles) east of bridge over Northeast Cape Fear River, Pender County, North Carolina. R.M. Finks and K.J. Thies, collectors. (This is near USGS 22389 and USGS 19019.) Collected from spoil heaps.
- Bactronella womblei* n. sp.
- B. incrustans* n. sp.
- Druidia wilsoni* n. g., n. sp.
- Ideal Cement Company Quarry. 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina, on north side of County Road 1002, opposite the end of County Road 2023. R.M. Finks, K.J. Thies, P.J. Harmatuk, and E.A. Womble, Jr., collectors. Collections were made from large indurated blocks in the quarry, removed from the upper 9 m (30 feet) or so (according to the quarry manager, Mr. Cristelli) of the Castle Hayne Formation during quarrying operations. (This has been designated the type locality of the Castle Hayne Formation by Ward, Lawrence and Blackwelder 1978).
- Bactronella womblei* n. sp.
- "*Cliona*" sp.
- Laocoetis* sp. cf. *L. crassipes* Pomel
- Druidia wilsoni* n. g., n. sp.
- ### SYSTEMATIC LIST OF THE CASTLE HAYNE SPONGES
- Phylum Porifera Grant 1836
- Subphylum Gelatinosa Bidder 1929
- Class Calcarea Bowerbank 1864
- Subclass Calcaronea Bidder 1898
- Order Lithonida Döderlein 1892
- Family Minchinellidae Dendy and Row 1913
- Plectroninia* Hinde 1900
- P. pertusa* n. sp.
- Bactronella* Hinde 1884
- B. womblei* n. sp.
- B. incrustans* n. sp.
- Class Demospongea Sollas 1875
- Order Hadromerida Topsent 1898
- Family Clionidae Gray 1867
- Cliona* Grant 1826
- "*Cliona*" sp.
- Order Tetracladida Zittel 1878
- Family Plinthosellidae Schrammen 1910, emend.
- Achrochordiella* Rigby 1981
- A. vokesi* Rigby 1981
- Hazelina* n. gen.
- H. bisbifurcata* n. sp.
- Claytonia* n. gen.
- C. rayi* n. sp.
- Order Choristida Sollas 1880
- Family Cephalorhaphiditidae Reid 1968, emend.
- Cerberorhaphidites* n. gen.
- C. auriformis* n. sp.
- Family Ancorinidae Gray 1867
- Stellella* Schmidt 1862
- Subgenus *Stolleya*
- Schrammen 1899, emend.
- Stolleya silvigera* n. sp.
- Family Geodiidae Gray 1867
- Geodia* Lamarck 1815
- G. harmatuki* n. sp.
- Subphylum Nuda Bidder 1929
- Class Hexactinellida Schmidt 1870
- Subclass Hexasterophora Schulze 1887
- Order Hexactinosida Schrammen 1903
- Family Euretidae Zittel 1877, emend., Reid 1964
- Verrucococeloidea* Reid 1969, emend.

- Subgenus *Euretella* n.  
subgen.
- Euretella corallina* n.  
sp.
- Family Craticulariidae Rauff  
1893, emend., Reid 1964
  - Laocoetis* Pomel 1872
  - Laocoetis* sp. cf. *L. crassipes* Pomel 1872
- Family Cribrospongiidae Roe-  
mer 1864, emend., Reid 1964
  - Haynespongia* Rigby 1981
  - H. vokesae* Rigby 1981
- Family Aphrocallistidae Gray  
1867, emend., Reid 1964
  - Druidia* n. gen.
  - D. wilsoni* n. sp.
- Order Lychniscosida Schram-  
men 1903
  - Family Dactylocalyctidae Gray  
1867, emend., Reid 1957
  - Exanthesis* Regnard in  
Moret 1926
  - E. ovatus* n. sp.
- Family Camerospongiidae  
Schrammen 1912
  - Robinia* n. gen.
  - R. striatopunctata* n. sp.
- Order Lyssacinosida Zittel 1877
  - Family Euplectellidae Gray 1867
    - Sheldonia* n. gen.
    - S. trabecula* (Rigby 1981)

## SYSTEMATIC PALEONTOLOGY

The diagnoses, unless otherwise indicated, are summaries of what is generally accepted in the literature. They generally conform to the definitions given in the Treatise on Invertebrate Paleontology, Part E (Revised), v. 2 (Finks, Reid, and Rigby 2004).

### SUBPHYLUM GELATINOSA Bidder 1929

**DIAGNOSIS:** Mesoglea present; choanocytes not syncytial; spongin fibers present.

### CLASS CALCAREA Bowerbank 1864

**DAGNOSIS:** Skeletal elements of magnesian-calcite.

### SUBCLASS CALCARONEA Bidder 1898

**DIAGNOSIS:** Choanocyte nucleus apical; larva an amphblastula; triradiates predominantly sagittal.

### ORDER LITHONIDA Döderlein 1892 (as Lithones)

**DIAGNOSIS:** Skeleton composed of interlocked or fused, anapodal tetraradiates with three short, bowed

proximal rays, often with clasping terminations, and one usually longer distal ray, generally pointed and often spinose; skeleton simple or fibrous; spicules variably invested with calcareous cement; a dermal layer of free monaxons, triradiates, tetraradiates, and tuning-forks, may be present.

### FAMILY MINCHINELLIDAE Dendy and Row 1913

**DIAGNOSIS:** With characters of the order.

**DISCUSSION:** See under *Plectroninia*.

### GENUS PLECTRONINIA Hinde 1900

**DIAGNOSIS:** Minchinellids with tetraradiates *not* strongly organized into concentric layers, nor distal rays into continuous radial series; prominent vertical exhalant canals present, also forming external grooves; dermal layer present or absent; shape usually more equidimensional than elongate, and not branching.

**DISCUSSION:** The various lithonine genera are highly overlapping in structure and difficult to separate. The reticulate nature of the main skeleton in *Plectroninia*, without strong concentric and radial organization, was cited by Hinde (1900, p. 57, 59, 60) as a distinguishing feature relative to *Bactronella* Hinde 1884, and *Petrostroma* Döderlein 1898. Likewise, the prominent vertical exhalant canals, and rounded shape of the sponge, were also cited in the same context. Hinde indicated that both *Plectroninia* and *Bactronella* differed from *Petrostroma* in that the termini of the proximal rays of their principal spicules were expanded rather than tapering, and that zygosis was largely effected thereby, rather than by lateral fusion as in *Petrostroma*. The Cretaceous *Porosphaera* Steinmann 1878, in addition to its usually globular shape, has a more consistent fibrous structure with more than one spicule ray fused side by side to form the structural elements of the principal skeleton. A number of genera belong to this family, some of which may be synonyms. A revision of the family is beyond the scope of this paper, but we should cite here the genera involved. In order of establishment and with the geologic age of their type species, they are: *Porosphaera* Steinmann 1878 (Cretaceous); *Bactronella* Hinde 1884 (Jurassic); *Petrostroma* Döderlein 1892 (Recent); *Plectroninia* Hinde 1900 (Miocene); *Minchinella* Kirkpatrick 1908 (Recent); *Sagittularia* Welter 1910 (Cretaceous); *Porosphaerella* Welter 1910 (Cretaceous); *Retespinopora* Brydone 1912 (Cretaceous); (?) *Petrobiona* Vacelet and Levi 1958 (Recent); *Monoplectroninia* Vacelet 1967 (Recent).

Note here that the supposed Eocene deposits in Victoria, Australia, from which Hinde (1900) described the type species of *Plectroninia* and two species of *Bactronella*, are now considered Miocene (see Pickett 1983). They are all in the Bass Basin. The type of *Plectroninia* is from "clays exposed in the banks of the

Moorabool River at Griffin's Farm northwest of Geelong" (*ibid.* p. 59). This species, along with *Bactronella australis* Hinde 1900, was found in "Polyzoal Limestone" above the "Older Volcanics" at Flinders (Victoria) (*ibid.*, p. 59, 62). *B. parvula* Hinde 1900, was from beds with bryozoa at Mt. Martha or Mornington (*ibid.*, p. 61).

A number of living species of lithonines have been referred to *Plectroninia* (e.g., Kirkpatrick 1900; Vacelet 1967; Pouliquen and Vacelet 1970) but they do not especially resemble the fossil type species. Most have the encrusting habit and general organization of *Bactronella incrassata* of this paper, with a well-developed dermal spiculation of free spicules. There is often a concentric and radial arrangement of these dermal triradiates, tetraradiates and monaxons about the oscules, sometimes supporting a quite tall oscular chimney. Similar patterns have been recognized in *Bactronella womblei* and *B. incrassata* of the present paper (see below). Separation of the living species has depended in part on details of the dermal spiculation. Vacelet (1967, p. 49) notes that the regular superposed arrangement of the principal spicules, of the four living species he assigned to *Plectroninia* in that paper, accords better with *Bactronella*. It is probable that these species, and others, should be transferred to *Bactronella*.

**PLECTRONINIA PERTUSA** Finks, Hollocher and Thies, new species  
pl. 1, Fig. 1-5

**DESCRIPTION:** Sponge cake-shaped; circular in outline with concave encrusting base and convex upper surface parallel to base; vertical sides more or less well-defined; diameter of sponge 10–25 mm, height 6–13 mm. Well developed exhalant surface canals run vertically, with converging tributaries, up the sides of the sponge and a few mm across the top, terminating in an oscule; top surface covered with oscules, 0.2–0.5 (mostly 0.3) mm in diameter and 3–16 mm apart, serving as termini of similar vertical canals in sponge interior. Smaller openings, 0.1–0.2 mm in diameter, interspersed among them, may represent inhalant ostia, or may be merely smaller exhalant postica. The regular interspicular spaces are 0.05–0.10 mm in diameter. They are sometimes elongate or meandriform and in general less regular in shape and more variable in size than those of *Bactronella*. No dermal spicules are preserved. The underside is generally molded to a bryozoan or other shell, but on one specimen there is a pattern of concentric growth lines; these are seemingly developed in the underside of the principal skeleton and exhibit no special spiculation. The main skeleton is of the typical lithonine type with layers of fused tetraradiates that have three downwardly curving proximal rays and a conical vertical distal ray. The distal ray is laterally

spined and the distal surfaces of the proximal rays appear to be bluntly spined or granular. The distal ray is slightly longer than the proximal rays, relatively shorter than in *Bactronella*. (Distal ray length: 175 µm; proximal ray chord length: 88 µm). Because the distal rays are not strongly elongate they do not form continuous vertical columns as in *Bactronella*. Likewise the organization into horizontal layers is not as apparent. In the linings of some of the larger exhalant canals the distal rays of the lining spicules may protrude into the lumen in a radial orientation. The spicules are always single in the net and do not parallel one another to form a fibrous structure.

**DISCUSSION:** This differs from the type, *Plectroninia halli* Hinde 1900, from the Miocene of Victoria, Australia, in its cake-like shape (rather than depressed-globular pedunculate) in the absence of a dermal layer on the side of the sponge, in the absence of a basal layer, in the absence of tuning-fork spicules or tylostyle-like spicules, in the smaller size of the principal spicules, and in the fact that the spicule rays do not occasionally lie side by side to form locally fibrous skeletal elements.

**MATERIAL:** Ten specimens, all calcareous.

**LOCALITIES:** USGS 22389 (9 specimens); 8-13-7 (1 specimen).

**TYPES:** Holotype USNM 133081; paratypes USNM 133082-133087.

**Genus BACTRONELLA Hinde 1884**

**DIAGNOSIS:** Minchinellid with tetraradiates strongly organized into concentric layers, and their respective distal rays lined up to form radial series which may be fused to form continuous rods; no large canals developed, only regular mesh spaces, though clusters of exhalant pores may be present; dermal layer present or absent; sponge generally club-shaped to ramose, may also be discoidal and encrusting.

**DISCUSSION:** The strong radial and concentric structure of the skeletal net, because of its more regular organization and longer distal rays as well as the denser nature of the net, without large canals, distinguishes this genus from *Plectroninia* Hinde 1900. The tendency to club-like, branching or encrusting shapes is also characteristic. The Jurassic type species *Bactronella pusilla* Hinde 1884, is poorly-preserved as to spicular features and Hinde (1900, p. 59) amplified the generic diagnosis from the better-preserved Australian, Miocene species *B. australis* and *B. parvula*. The specimens of the type species are tiny, club-shaped forms with a partial dermal layer composed of triradiates and tetraradiates, and with the typically spinose interior tetraradiates. It is not clear from the original description and illustrations (Hinde 1884, p. 205–206, pl. 38, figs. 3, 3a–g) whether the type species has the strong radial and concentric structure cited in the above diagnosis. For further discussion see under *Plectroninia*.

**BACTRONELLA WOMBLEI** Finks, Hollocher and Thies new species  
pl. 2, Figs. 1–5; pl. 3, Figs. 1–11

**DESCRIPTION:** Ramose, pedunculate; arising from an encrusting base which is expanded, circular, concave beneath, bearing an external mold of the bryozoan, shell or other object to which the sponge was attached; contracts above this basal plaque to form a short cylindrical peduncle which then expands to form a club-shaped upper part. Continued growth enlarges the club-shaped part laterally, ultimately producing two to five flattened, palmate, or blade-like branches given off peripherally at the same level. A thin, concentric, somewhat discontinuous dermal layer may be developed on the base, stalk and lower sides of the sponge. It consists of a feltwork of very fine tangential monaxons, seemingly oxeas, over which is an outer coat of larger triactins and larger monaxons (oxeas and strongyles). Some of the triactins are equiangular but most are sagittal with the paired rays uppermost, straight, and separated by a wider angle. They tend to overlap closely at the outer edge of the dermal layer. The dermal layer is sometimes developed in a series of subhorizontal bands on the side of the sponge. These may represent the edges of a basal layer formed following an interruption in growth. On some specimens tangential equiangular triradiates occur on the surface apart from the dermal layer of monaxons and lie directly on the inner skeleton. They may be isolated or they may occur in dense patches in which their rays have random orientations. Sometimes they are concentrated about circular depressions, a half millimeter or so in diameter, which may represent the sites of oscules. On many such spicules one can see that no fourth, or proximal, ray is present; on others this part of the spicule is not visible and one cannot assert that there are *no* dermal tetraradiates; nevertheless, none has been found. The interior skeleton consists of characteristic tetraradiates in which three equiangular proximal rays form an upwardly convex triple arch surmounted centrally by an elongate, straight, upwardly directed distal ray, about three times as long, that bears short lateral spines. The distal ray terminates in a sharp point. The proximal rays have expanded terminations which rest upon and interlock or fuse with the distal surface of an underlying proximal ray near its junction with the distal ray. The spicules are oriented such that each proximal ray is part of a superposed series. The skeleton is built of concentric layers of these spicules. They are parallel and quincuncially arranged within each layer and alternate in position between successive layers. Thus the spicules of every other layer coincide in position and the long distal rays form a continuous rod-like structure by fusion or contact with the base of the overlying spicule two layers above. The interlocked or

fused inner skeleton thus has a conspicuously concentric and longitudinal structure. Other than the continuous interspicular spaces thus formed, there are essentially no canals, and the skeletal net is noticeably dense. On one specimen shallow surface grooves are present; they avoid the oscular depression. Occasionally two rays may lie side by side in the interior net, but there is not the regularly multiple or fibrous structure seen in *Porosphaera* Steinmann 1878.

**DISCUSSION:** This differs from *Bactronella australis* Hinde 1900 and *B. parvula* Hinde 1900, both from Miocene beds in Victoria, Australia, in its ramose growth form and larger size. It resembles *B. australis* in spicule size but differs in the absence of a continuous dermal layer. It resembles *B. parvula* in the absence of a dermal skeleton over much of the surface but differs in having a partial dermal skeleton composed of triactins and monaxons, rather than a basal layer only composed of loose spicules like those of the interior plus triradiates and tetraradiates. It also has larger spicules. Differences from *B. incrassans* are discussed below under that species. We name this species in honor of Mr. Edgar A. Womble, Jr., who guided us to several field localities.

**MEASUREMENTS:** (Additional to those in the description; all in millimeters.)

Height of sponge: 9–33 mm.

Interior tetraradiates: ray length 1.0–1.5 mm.

Diameter of basal disc: 3–12 mm.

Length of distal ray: 325 µm.

Diameter of peduncle: 3–7 mm.

(Chord) length of proximal ray: 125 µm.

Diameter of club-shaped upper part: 3–15 mm.

Dermal triactins ray length: 3 mm.

Diameter of branches: 4–12 mm.

Dermal monaxons, length: 0.3–0.5 mm.

**MATERIALS:** One hundred twenty five specimens, all calcareous.

**LOCALITIES:** USGS 22389 (60 specimens); 8-13-7 (63 specimens); USGS 22329 (1 specimen); Ideal Cement Co. Quarry (1 specimen).

**TYPES:** Holotype USNM 133089; paratypes USNM 133090–133106

**BACTRONELLA INCRUSTANS** Finks, Hollocher and Thies, new species  
pl. 3, Figs. 12–17.

**DESCRIPTION:** Sponge subcircular, 8 to 38 mm in diameter, and in the form of a flat, crenulate, or upwardly convex sheet, as thin as 0.5 mm, or developed into a domical mass as much as 9 mm thick. Sometimes encrusting on other sponges or shells, but characteristically free, with a concentrically ridged basal surface, the ridges representing successive positions of the

sponge margin. The basal surface is covered with a dermal layer of monaxons. The monaxons may be irregularly felted but characteristically they are oriented radially, perpendicular to the growth lines and margin. The dermal layer is more noticeable near the periphery and many of the radial monaxons are as much as 0.5 mm long. Triradiates have not been seen on this basal surface. It is possible that the radial monaxons are part of a slightly deeper layer of the dermal skeleton with smaller, more random monaxons above. The upper surface of the sponge is wholly or partly covered with a similar dermal layer. This seems distinctly divided into an outer zone of smaller, irregularly felted monaxons, and an inner zone of somewhat coarser, larger spicules which include not only monaxons (oxeas) but also equiangular and sagittal triradiates. The upper dermal skeleton is as much as 0.6 mm thick. Its absence in some places may be because of subsequent removal, but there are small, circular areas, 0.15–1.5 mm in diameter, that appear to have been the sites of oscules, where the dermal layer is absent, revealing a cluster of a few circular pores 0.05–0.20 mm in diameter, separated by only 0.05–0.10 mm interspaces, in the underlying inner skeleton. The oxeas and triradiates of the inner dermal layer have a roughly concentric arrangement around this area, and partly lie upon the inner skeleton as though they may have collapsed upon it from an original position about an oscular chimney. The finer monaxons of the outer dermal layer have a more obscure concentric pattern about these areas. In some cases a distinct protuberance of the entire dermal layer surrounds these oscules. One specimen has isolated larger pores and obscure traces of surface grooves. The interior skeleton is composed of the usual tetractins with a very long distal ray, up to 350 µm long surmounting three shorter upwardly convex proximal rays about one-third as long (chord length 100 µm).

**DISCUSSION:** This species differs from *B. womblei*, new species, in its discoidal to subhemispherical shape, its greater basal diameter, the radial arrangement of oxeas on the basal dermal layer, the complete, or nearly complete dermal layer on the upper surface, and the fact that the finer monaxons of this layer cover the larger triactins instead of the triactins lying outside the finer dermal oxeas. The greater diameter of the base in these forms as compared with the basal surface of a branching *B. womblei* implies that these are not merely early stages of the branching form (there is a slight overlap in the two ranges and some doubt inheres in some of the intermediates). Nevertheless it is possible that these are variant growth forms of a single species. They occur at the same localities. The bases of the branching forms are generally molded to a bryozoan or other shell which may have interfered with the expression of the radial arrangement of monaxons. Some individuals lack the

upper dermal layer entirely and, except for their larger diameter, would in theory be difficult to distinguish from a juvenile *B. womblei*. However, it is possible to identify almost every individual as either *B. incrassata* or *B. womblei*, and we prefer to call attention to the distinction by recognizing the two species.

This species differs from *B. australis* Hinde 1900, and *B. parvula* Hinde 1900, in its unique shape. It resembles *B. australis* more closely in spicule size and in having a complete dermal layer. However, the spiculation of the dermal layers cannot be compared, as that of *B. australis* is unknown. *B. parvula* has a basal layer quite different from that of *B. incrassata* (see above under *B. womblei*). This species resembles several living species assigned to *Plectroninia* (see Vacelet 1967) that are probably better called *Bactronella*, differing in the absence of tuning-fork spicules and of spinose dermalia.

**MATERIAL:** 38 free specimens, all calcareous, plus several encrusting other sponges (including *Druidia*, *Exanthesis*, and *Robinia*, all at USGS 22389).

**LOCALITIES:** USGS 22389 (26 specimens); USGS 22329 (1 specimen); USGS 7794 (8 specimens); 8-13-7 (3 specimens).

**TYPES:** Holotype USNM 133109; paratypes USNM 133110-133119.

#### CLASS DEMOSPOONGIAE Sollas 1886

**DAGNOSIS:** Spicules siliceous; principal rays follow the axes of a tetrahedron.

#### ORDER HADROMERIDA Topsent 1898

**DIAGNOSIS:** Exclusively monaxonid demosponges whose chief megascleres are tylostyles and whose microscleres (if present) include spinispines or their derivatives.

#### FAMILY CLIONIDAE Gray 1867

**DIAGNOSIS:** Hadromerida of boring habit, whose megascleres are almost exclusively tylostyles, in some genera centrotylete or polytylete (oxeas, styles or strongyles may also be present) and whose microscleres are spinispines or their derivatives (microxeas may also be present).

**DISCUSSION:** Although De Laubenfels (1936, p. 154) in his revision of the sponges, defined the family compatibly with the above diagnosis, he included genera whose megascleres are largely or exclusively oxeas, (*Aka*, *Clionopsis*, *Donotella*, *Scantilella*, *Amphius*, *Anandalia*, *Dotona*, and *Nisella*) as well as one with strongyles (*Dyscliona*). There is substantial reason for this, inasmuch as some individuals of certain species of *Cliona*, such as *C. vastifica*, may have more oxeas than tylostyles (see Hartman 1958, p. 21). Given this variability, the diagnosis reduces to "Hadromerida of boring habit" and it would be difficult to exclude any of

the other known boring sponges, including the spirastrellid hadromerines *Anthosigmella* and *Spheciospongia*, as well as the supposed adociid poecilosclerine *Siphonodictyon*, which has only oxeas and no microscleres.

#### GENUS CLIONA Grant 1826

**DIAGNOSIS:** Clionid with only simple spinispikes (microxeas may be present); megascleres tylostyles, but oxeas also present in some species.

“CLIONA” (sensu lato) sp.

pl. 4, Figs. 1–4; pl. 5, Figs. 1, 2; pl. 6, Figs. 1, 2

**DESCRIPTION:** A fragment of a large, thick pelecypod shell is preserved in the form of an internal mold of the galleries of a clionid together with an external mold of the outer surface of the shell in the surrounding matrix, mostly, if not entirely, on the base of an encrusting cheilostome. The openings for the “*Cliona*” papillae penetrate the bryozoan, indicating either that the bivalve was already encrusted by the cheilostome when it was infested by the clionid or that the bryozoan grew faster than the sponge. There is suggestive evidence that the latter is true. A small area that preserves the external surface of the cheilostome (see pl. 4, Fig. 4 right) seems to indicate that the bryozoan grew around the papillar openings (the surface is depressed next to them and they are not clearly cross-cutting) and in other cases grew over the openings (see pl. 4, Fig. 4 left), indicating that bryozoan and sponge were alive simultaneously.

Most of the volume of the shell, which is 12 mm thick and was well in excess of the 60 mm preserved length of the fragment, is occupied by the clionid galleries, indicating that the shell was essentially destroyed by the sponge. The external surface of the pelecypod is smooth with prominent growth lines, the only large, thick-shelled pelecypod with such an exterior, that has been reported as common in the Castle Hayne Formation, is *Crassatellites alta* (Conrad; see Kellum 1926, p. 22), and this may be the host for the “*Cliona*.”

The papillary openings on the exterior surface of the shell are mostly 0.8–1.6 mm in diameter and rather uniformly spaced some 4–6 mm apart. Those on the interior surface are similar but in addition there are numerous smaller openings, 1–4 mm in diameter and a millimeter or less apart; a much smaller number of these may be found on the exterior as well. Each papillary opening is at the center of a round inner chamber, some 3–5 mm in diameter, to which it is connected by a papillary canal, 0.3–1.2 mm long, of the same diameter as the papillary opening. They are in close lateral contact with one another, being separated by a few tenths of a millimeter of unbored shell. It is apparent that they mutually interfered with one another; they are often mutually polygonal, implying a more or less

uniform growth rate from evenly spaced centers. In some cases they have coalesced, leaving traces of their original boundaries. The chambers are periodic enlargements along galleries that ramify parallel to the shell-surface, generally in two layers; they have expanded to such an extent that the gallery is a mere constriction between the chambers. However, smaller galleries branch off from them, often occupying the narrow space between two larger ones. These small galleries presumably record an earlier stage in the boring process; they lack enlargements and branch dichotomously, mostly at angles between 45° and 90°. A typical size is 0.2–0.3 mm in diameter with papillary openings every millimeter or so and dichotomous branching at 1.5–2.0 mm intervals. Extremely fine tubules, 0.025–0.125 mm in diameter, radiate out from both the large chambers and the smaller galleries at 0.3–0.5 mm intervals. They taper to a point in a length of 0.3–0.8 mm, and presumably represent the initial stages of boring. Both the fine tubules and the small galleries may connect adjacent large chambers and in this position are equivalent to the *foramina* between chambers of some authors (e.g., Rützler 1974, p. 5). The surfaces of the larger galleries and chambers, thanks to their fine-grained micrite filing, preserve the outlines of the individual flakes of shell removed by the sponge. These, are 50–100 µm in diameter and correspond to the size of the individual amoebocytes that perform the boring by surrounding a flake and lifting it off (see Cobb 1969; Rützler and Rieger 1973). These dimensions are comparable to the dimensions reported by Cobb (1969, p. 787, fig. 8) and Rützler and Rieger (1973, p. 159, table 2). Casts of extremely fine branching tubules coat the surfaces of some of the large galleries; they are only 25–37 µm in diameter. It is unclear whether these were produced by the same sponge or whether they were produced by some later occupant of the gallery, such as an endolithic alga or fungus.

No molds of spicules could be seen, and solution of fragments of the gallery molds in hydrochloric, nitric, and formic acids failed to release any spicules.

**DISCUSSION:** The tunnels and chambers, with rows of papillary openings penetrating to the surface, and multiple connections between chambers, are characteristic of clionid sponge borings (Rützler 1971, p. 1). Two genera of another hadromerid family, the spirastrellids *Anthosigmella* and *Spheciospongia*, have boring species, as does a more distantly related monaxonid, the adociid *Siphonodictyon* (Rützler and Rieger 1973, p. 159). These last three genera, however, form notably larger excavations, not arranged like beads on a string (see Rützler 1971, p. 3, 4, 6; 1974, pp. 29–30) although at least two clionids, *Cliona flavifodina* and *C. amplicavata* (Rützler 1974, p. 9, 26) approach them in size, and not all clionids consistently develop the bead-like arrangement of

chambers. The present specimen, in both size of excavation and its bead-like structure, matches that of typical clionids. Generic distinctions within the family (see De Laubenfels 1936, p. 156) rest on the presence of oxeas, strongyles or modified spinisires along with, or instead of, the more typical tylostyles and spinispines. Indeed, so far as spicules go, all the boring sponges mentioned could be accommodated within the family. The lack of preserved spicules obviously prevents a generic determination, but the lumping of all clionids into the genus "*Cliona*" sensu lato has the sanction of history if not of refined taxonomy.

There is no doubt that the borings were produced by a sponge. The clearly preserved molds of arcuate pits that everywhere cover the surface of the cast are only produced by the unique boring method of sponges, in which the pseudopods of a sponge amoebocyte surround and lift-off an arcuate chip of shell. The size and shape of the resulting chip are more or less uniform in all the boring sponges known (Rützler and Rieger 1973, p. 159). The fine, radiating, tapering tubules, also beautifully preserved in this material, were likewise observed by Rützler and Rieger (1973, p. 146; figs. 2:1–3, 3:2 as the initial stage of boring.

Bromley (1970) has argued, in an extended discussion, that fossil borings of clionid type should be called *Entobia* Portlock and be treated as an ichnofossil. In our opinion, precision is not served by this procedure, as no more biological information is provided by the designation *Entobia* than by "*Cliona*," and indeed considerably less if *Entobia* is not considered to be restricted to sponges. It is possible that other sponges than clionids can produce clionid-like borings, but the probability of error in lumping them all into a form-genus "*Cliona*" may be no greater than that inherent in the present taxonomic classification of demosponges, to say nothing of the Clionidae, and it has the added advantage of placing the organism approximately within the phylum. We are also of the opinion that sponge-borings are as much body-fossils as the impression of a brachiopod shell in a sedimentary rock. They faithfully record the shape of the endolithic part of the sponge body even down to the size and shape of the excavating cells.

SPECIMENS (2); USNM 133123, 133124.

LOCALITY: Ideal Cement Co. Quarry.

#### Order TETRACLADIDA Zittel 1878

**DIAGNOSIS:** Demosponges whose principal skeleton consists of desmas of tetraxial form, and whose dermal spicules, when present, are radial dichotriaenes or derivatives, and/or tangent monaxons, and/or siliceous plates. Microscleres of living forms include streptoscleres.

**DISCUSSION:** This large, somewhat intergrading, and probably natural group is divisible into three

subgroups, already recognized by Zittel (1878, pp. 36–7) without being named (Zittel also included a fourth group equivalent to *Orchocladina* Rauff 1894, which should be a separate order). One subgroup is characterized by largely smooth tetraclasses with terminal zygomes, and usually simple dichotriaenes; the family name *Phymatellidae* Schrammen 1910, is available for this group. Another subgroup is characterized by tuberculate tetraclasses and usually phyllotriaenes or discotriaenes for dermalia; the family name *Discodermiidae* Schrammen 1910, is available for this group. The third subgroup is characterized by tuberculate anapodal tripods, sometimes with a rudiment of the fourth ray, and usually with phyllotriaenes or plates for dermalia; the family name *Plinthosellidae* Schrammen 1910, is available for this group.

**Family PLINTHOSELLIDAE Schrammen 1910 (nom. transl. ex *Plinthosellinae* Schrammen 1910), emend.**

**DIAGNOSIS:** Tetracladida with tuberculate anapodal desmas that are basically tripods but whose clones may branch; a rudiment of the fourth ray may be present; dermalia typically phyllotriaenes or siliceous plates, but may include other dichotriaene-based forms.

**DISCUSSION:** We interpret this family broadly to include essentially all lithistids with tuberculate anapodal desmas that are tetraxon-based, and which have dermal triaenes or their derivatives (thus excluding *Dicranocladina*, *Eutaxicladina* and *Megamorina*). Besides the genera included by Schrammen (1910) in his *Plinthosellinae* we would add those he included in his *Achrochordoniinae* and *Phymaraphiniinae*. We also include *Thamnospongia* Hinde 1884, and *Phymaplectia* Hinde 1884, which Schrammen did not mention, as well as the new genera established here. It is possible that some genera included by various authors in the *Dicranocladina* belong here (or vice-versa); this depends on identifying the desmas as tetraxon-based rather than monaxon-based, which is not always possible to do with certainty. Further discussion may be found under the species *Achrochordiella vokesi*.

#### Genus ACHROCHORDIELLA Rigby 1981

**DIAGNOSIS:** Large plinthosellid with large anapodal spicules covered with quincuncially arranged capstan tubercles; mainly asymmetrical tripods that are once bifurcate, sometimes with short fourth (distal) ray with pointed end; accompanied by slenderer, less tuberculate, megarhizoclone-like spicules; skeletal net of superposed arches of either single desmas or of a few side by side; dermalia range from delicate dichotriaenes with slender, irregularly curving cladi, through stouter forms with similarly curving, smooth-outlined, strap-like cladi, essentially phyllotriaenes, to discotriaene-like forms with laterally coalesced cladi that make an

irregularly lobate plate; external form stoutly and densely digitate, arising, or expanding laterally, from a massive base; surface largely covered with deep, subparallel, exhalant grooves, bordered by sharp ridges and separated by ostia-bearing areas; interior net dense with few canals; cloacas either absent, or present at the tips of the branches; phyllotriaene-like dermalia mainly found in the bottom of grooves; closely-spaced monaxons (oxeas?) present in interior net, perpendicular to, and just below, outer surface.

**DISCUSSION:** The desmas most closely resemble in size and shape those of *Plinthosella* Zittel 1878, and *Phymaplectia* Hinde 1884. They are larger than those of *Thamnospongia* Hinde 1884. Those with a rudimentary fourth ray resemble the desmas of *Acrochordonia* Schrammen 1901. The delicate dichotriaenes resemble those of many tetracladines with smooth tetraclasses, such as *Phymatella* Zittel 1878, or *Siphonia* Parkinson 1822. The more phyllotriaene-like forms lie somewhere between those of *Phymaplectia* Hinde 1884, or *Thamnospongia* Hinde 1884, and the less elaborate varieties of *Ragadinia* Zittel 1878. The occasional lobate plates are rather like the scales of *Plinthosella* Zittel 1878, but appear to have a proximal ray. The external form is like that of *Thamnospongia* Hinde 1884, but more robust. The strong surface grooves are not found in *Thamnospongia*; they are more like those of *Aulaxinia* Zittel 1878.

**TYPE SPECIES:** *Achrochordiella vokesi* Rigby 1981.

**ACHROCHORDIELLA VOKESI** Rigby 1981  
pl. 6, Fig. 3; pl. 7, Figs. 1–4; pl. 8, Figs. 1–3; pl. 9, Figs. 1, 2; pl. 10, Figs. 1, 2; pl. 11, Figs. 1–4

*Achrochordiella vokesi* Rigby 1981, p. 130, pl. 3, figs 1–3, 5; Text-Fig. 3.

**DESCRIPTION:** A large, digitate sponge arising from a massive, encrusting base. Individual branches are cylindrical, subparallel, and very closely spaced, with either a narrow space between them or no space at all, in which case they are laterally fused along much of their length. Branches are 11–25 mm in diameter; the entire sponge ranges from 28 mm wide and 79 mm long to 66 mm wide and 170 mm long. The shape of at least one specimen (USNM 133127) suggests that the sponge may have been reptant and the branches subhorizontal. The frequency with which objects, including other sponge fragments, are encrusted on all sides of this sponge, tends to support this idea. The skeletal surface is covered with prominent, subparallel, closely-spaced hemicylindrical grooves, 1.0–2.0 mm wide, bordered by sharp-crested ridges. These grooves tend to converge toward branch tips, or toward smaller bumps on the sponge surface which may represent incipient branches or the location of oscules. The grooves usually die out short of the tip of the bump or branch. Away from these

foci the grooves may form an anastomosing pattern or be replaced by a rough, porous surface. Where the grooves have converged closely, a single sharp-crested ridge may be all that separates them. Elsewhere the intergroove strips may contain a linear series of circular pores, 0.5–1.0 mm in diameter, sometimes separated by less than their own diameter. Similar pores are more generally scattered over areas where the grooves are not well-developed. These pores tend to avoid the convergent grooves proper, though the pore-bearing intergroove strips sometimes resemble grooves because of the bounding ridges. Occasionally a true groove may bear a large pore or two the diameter of the groove; these seem to represent tributary canals from the sponge interior. The mesh spaces of the skeletal net are 0.1–0.5 mm in diameter. The skeletal interior is very dense but where branches are broken one can see several cross-sections of similar canals. In at least one case a surface groove plunges into the interior toward the branch tip, forming a canal that is not a tributary. It is probable that the surface grooves and associated canals are exhalant and the intervening circular pores are inhalant ostia. Cloacas are absent on the specimens with well developed branches, but seem to be present on the incipient branches of irregular specimens.

A dermal spiculation of overlapping orthodichotriaenes has a patchy distribution on the specimens. The patchiness may be original or it may be because of preservation. Where surface grooves are not well developed the dichotriaenes have delicate, slender cladi, and are distributed over the entire surface including such grooves as are present. The secondary cladi vary from straight and divergent at approximately 90° to curving and crescentic. The entire cladome is 0.35–0.75 mm in diameter (mostly 0.4–0.5 mm). Irregularities of shape and suppression of cladi are common. Simple triaenes also occur. Where surface grooves are well developed, and dichotriaenes are present, they tend to be concentrated in the bottoms of the grooves, *to which they may be molded* (implying that they did not roof them over in life). In these situations the cladi are laterally expanded and strap-like (the straps 50–75 µm wide), sometimes attaining the form of phyllotriaenes. Tertiary cladi may be developed on some branches. In a very few instances lateral fusion of the cladi produces an irregular plate, thus approaching a discotriaene. The flattest dichotriaenes were found on one specimen (USNM 133126) near its base where it was actively overgrowing one or two individuals of *Cerberorhaphidites*, perhaps while the latter was still alive. It may be that the development, or retention, of dichotriaenes is related to areas of actively growing sponge, for they seem to be present either near the upper parts of branches or near the overgrowing edges around foreign bodies. The dichotriaenes may have been lost during the lifetime of the sponge from

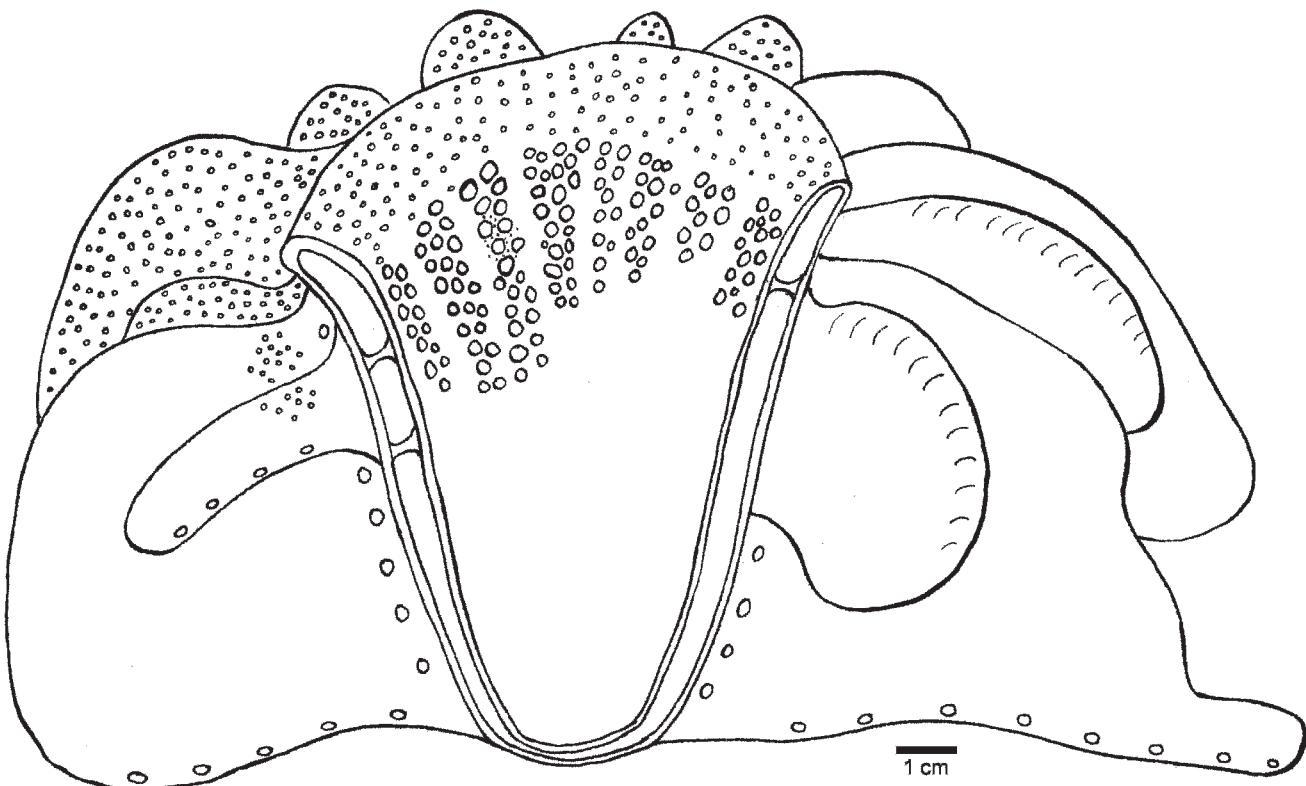


FIG. 3. Reconstruction in life-position of *Druidia wilsoni*, n. gen., n. sp., showing cutaway view of central cone. The pores have been drawn-in on only part of the surface. Drawn by R.M. Finks.

abandoned areas of the skeleton. On the holotype (USNM 133125) the dichotriaenes are preserved only near the tip of the central branch; they have more strap-like cladi on the side of this branch that faces other branches, and more delicate cladi on the more exposed side of the branch.

The principal skeleton consists of interlocking desmas. They are anapodal tripods (clone length 0.10–0.35 mm; thickness 50–75  $\mu\text{m}$ ) covered with quincuncially arranged capstan tubercles (15–25  $\mu\text{m}$  in diameter). Usually one or more legs of the spicule may branch dichotomously. One of the primary cladi (legs) of the spicule may be greatly elongated relative to the others and form a broad arch. Spicule tips generally lie against a branch or against the centrum of an underlying or neighboring spicule. Owing to secondary silification, the zygomes are difficult to make out, but short, claw-like, terminal branches are present on some. These desmas fit the description of dicranocclones, provided one does not require that dicranocclones be monocrepid; these would seem to be based on a tetraxon with the distal ray suppressed. Rarely, a very short brachyome may be present. These desmas intergrade with much less common, slenderer, less tuberculate desmas, (clone length 75–200  $\mu\text{m}$ , thickness 35  $\mu\text{m}$ ), in which the dichotomous branching is more completely developed, in some branches to the point of tertiary cladi. Such

smaller spicules may bridge the elliptical interspaces outlined by the principal desmas, abutting against the latter all around. These smaller spicules might be termed megarhizoclones. It should be noted that both types of spicule are based externally on a trifid (i.e., tetraxial) pattern. Axial canals are not preserved to confirm this origin, however. The desmas tend to be greatly elongate parallel to the ridges whenever they form the sharp crests bordering the surface grooves. They also curve around pores.

Much of the skeleton is built up of single desmas forming a series of superposed arches. Often, however, two or more desmas will lie side by side, subparallel to one another, and either in contact or connected by their branches. To this extent the skeleton may be described as fibrous. These multiple-desma skeletal elements are especially noticeable where they form the walls of canals. On the floors of the large surface grooves several desmas may be packed together side by side to form a solid area as much as a 0.5 millimeter across.

Many loose demosponge spicules are found in the matrix filling the mesh spaces of this species. They are of the same sorts as those found with other demosponges at this locality and some demonstrably belong to these other species, for example, ophirhabds and sterrasters. In the case of generalized spicules, such as oxeas, strongyles and calthrops, one can only prove their

connection if they are actually molded to the surrounding desma skeleton, but none are. Those that occur with the present specimens, therefore, may or may not be related.

Note that Hurcewicz (1966, p. 23) has reported sterrasters from the skeletal net of all discodermiids she described from the Polish Cretaceous (species assigned to *Discodermia* Bocage 1869; *Phyllocladia* Schrammen 1924; *Eustrobilus* Schrammen 1910; and *Ragadinia* Zittel 1878) and has modified the diagnosis of the Discodermiidae to include the presence of sterrasters. The present species would not be a discodermiid as conceived here, in that its desmas are anapodal rather than with four equally developed rays. Hurcewicz notes for most of her species, however, that the distal ray of the tetraclasses is reduced or suppressed at the outer surface of the sponge. The anapodal form would appear to persist well into the interior of the present specimens but it must be admitted that secondary silicification makes it difficult to discern the limits of individual spicules in the interior net.

Closely spaced radial monaxons, probably oxeas, up to 2,000 µm long, or more, and about 20 µm thick, are visible on one cross-section of a branch, just below the outer surface. (USNM 133125). They are so numerous and uniformly distributed that they are probably in place and characteristic of the species, and/or genus.

**DISCUSSION:** There are two groups of lithistids that share the following cluster of characters: (1) a principal skeleton of tuberculate, anapodal desmas, mainly tripods, together with less tuberculate but more branched, variants; (2) a dermal spiculation of dichotriaenes, or variants such as phyllotriaenes or discotriaenes; and (3) a microspiculation of streptoscleres, when preserved. One group is the Dicranocladiina, centering around such forms as *Pachinon* Zittel 1877, in which the principal desmas would seem to be monocrepid. The other are several genera included in the Tetracladida, with tetracrepid desmas, differing from other tetracladines in the tuberculate and largely anapodal nature of their principal desmas, and centering around such genera as *Achrochordonia* Schrammen 1901, and *Ragadinia* Zittel 1878. A living genus in the first group would be *Corallistes* Schmidt 1870, and in the second group *Discodermia* Bocage 1869, both of which have streptosclere microscleres, not usually preserved in the fossils.

In the present specimens neither the axial canal nor the initial crepis of the spicule can be discerned. Thus we are left with comparing details of spicule form, and their combinations, as the only means of assignment to one group or the other, and with less certainty as the specimens do not seem to correspond exactly to any published genus. Despite the arch or bow-like form of some of the desmas, which is characteristic of many

dicranoclones, the prevailing tripodal form, and occasional rudimentary fourth ray, suggest a tetraclide origin (we leave aside here the possibility that even dicranoclones may have a tetraclide origin). This is reinforced by the similarity of the phyllotriaene-like dichotriaenes, with their strap-like cladi, to those of *Thamnospongia* Hinde 1884. The principal desmas, however, though generally similar to those of *Thamnospongia*, are much closer to the larger and more densely tuberculate desmas of *Plinthosella* Zittel 1878, or *Phymaplectia* Hinde 1884. The last is probably the closest of all published genera to the present specimens, for its dermalia are also flattened dichotriaenes. The dermalia of *Plinthosella*, on the other hand, are irregular siliceous plates. However, none of the genera mentioned seem to have also the very delicate dichotriaenes of the present specimens, nor do they have the strongly grooved external surface. These grooves are strikingly reminiscent of those of *Aulaxinia* Zittel 1878, a tetracladine with quite different, smooth desmas, reminiscent not only in their parallelism and depth, but also in their sharp bordering crests, and in the concentration of ostia in the intergroove strips. Because of these distinctions we concur in a new genus and species for the present specimens that was published independently by Rigby (1981, p. 129) from his own material.

The stoutly digitate form of the present species is closer to published species of *Thamnospongia* than it is to those of *Phymaplectia*, but the branches are stouter than in any of Hinde's (1884) species. In the presence of sparse, internal longitudinal canals, the present species is also closer to *Thamnospongia* than to *Phymaplectia*, but none of the published species has as strong external grooving. (As stated above, it is closer to *Phymaplectia* in spicular characters.)

It is possible that *Phymaplectia sterea* De Laubenfels 1953, from the Plantagenet Series (Eocene) of Western Australia, is an *Achrochordiella*. The description and figures (De Laubenfels 1953, p. 111, text-fig. 5) do not permit a detailed comparison, but the illustrated dichotriaene cladome has laterally expanded cladi like some of those on *Achrochordiella* and the "palmate slab" shape of the sponge is like the habit of *Achrochordiella* though no mention is made of surface grooves. De Laubenfels called these Miocene, but more recent dating (Brown et al. 1968, p. 300) is Eocene.

One of the specimens (USNM 133125), small but essentially complete, appears to have started its growth around a root (or root fragment) of *Haynespongia* and subsequently to have incorporated one or two individuals of *Cerberorhaphidites*. The *Cerberorhaphidites* protrudes in two places, each surrounded by a rolled lip of *Achrochordiella*, suggesting that the *Cerberorhaphidites* may have been still alive and

influencing the growth of the *Achrochordiella*. Indeed, this appears to be proved by the fact that ophirhabds in several places appear to be molded to the surrounding *Achrochordiella* skeleton. The phyllotriaene-like spicules of *Achrochordiella* are especially well developed in the vicinity of these lips and, in at least one place, a phyllotriaene appears to overlie the ophirhabds *directly*, with a thin layer of *Achrochordiella* desmas covering the ophirhabds immediately adjacent. This implies that the dermal layer of *Achrochordiella*, represented by the phyllotriaenes, encroached upon the *Cerberorhaphidites* first, followed by the choanosome with its desmas.

Another specimen (USNM 133127) is similarly overgrowing an obviously incomplete fragment of *Haynespongia*. In this case also the surface of the *Achrochordiella* in direct contact with the *Haynespongia* has an almost continuous covering of phyllotriaenes. There is no lip, perhaps related to the fact that the *Haynespongia* was possibly not alive at the time. (Sponges fragmented during their lifetime may still remain alive, and the margin of the *Haynespongia* fragment has an indentation which parallels an adjacent branch of *Achrochordiella*. Whether this was fortuitous or the result of growth by the *Haynespongia* fragment is not certain.)

There are circular to irregular openings a few millimeters in diameter on the last-mentioned specimen, some of which occur more or less centrally located in a branch. These are the only indications of possible cloacas. No such openings have been seen on cross-sections of broken branches (small canals of a millimeter or so are seen occasionally) nor have they been seen on complete branch tips on other specimens. It is possible that they represent shallow terminal cloacas, but one is lined with a solid silica coating and they may represent the tubes of epizoic worms or other organisms, or the site of a foreign body now lost.

A fifth specimen (USNM 133129) probably belongs to this species. It is bun-shaped, 89 mm in maximum dimension, and about 37 mm thick. It has a rather knobbly surface, appearing to represent incipient branches of the sort found on the more typical specimens, some of them bounded by sulcus-like grooves. Numerous deep cloaca-like pits, 2–7 mm in diameter, occur all over the surface, many in the centers of the incipient branches. Grooves 1–2 mm wide converge on several of these oscules. Parallel grooves of the sort found on the other specimens are not seen, save in one small area. The desmas, and their arrangement, are essentially the same as in the other specimens. A few phyllotriaenes were found, seemingly in place, and a few simple triaenes under like circumstances. Other than these, no dermalia are preserved. Some desmas have incipient annulations or cross-rows of tubercles. The oxyasters illustrated by Rigby (1981,

text-fig. 3A–C) are probably, as he says, foreign. On the basis of their size they may be from *Geodia harmatuki*.

**MATERIAL:** Four nearly complete large specimens plus a small specimen that may be a fragment or may be complete.

**LOCALITY:** USGS 21849.

**TYPES:** Hypotypes: USNM 133125, 133126, 133127.

Genus HAZELINA Finks, Hollocher and Thies,  
new genus

**DIAGNOSIS:** Plinthosellid whose external desmas are symmetrical, doubly dichotomously branching tripods covered on their distal surfaces by spheroidal tubercles that may be expanded to form annular swellings; the fourth ray is represented by a large tubercle; external skeletal net built of superposed single desmas; internal net more irregular, denser, and fibrous; dermalia unknown; sponge thin-walled with differentiated inhalant and exhalant surfaces (postica larger than ostia) and labyrinthine internal canals in an otherwise dense skeletal net.

**TYPE SPECIES:** *Hazelina bisbifurcata* Finks, Hollocher and Thies, new species.

**DISCUSSION:** The form of the principal desma is unique. It bears some resemblance to those of *Pseudoverruculina* Moret 1926, but is readily distinguished by the regular tetracladine form and doubly dichotomous branching. It also resembles those of *Pholidocladia* Hinde 1884, but the latter have more widely spaced annulations and presumably no dichotomous branching. For further comparison with *Pholidocladia* see below under the discussion of the species *Hazelina bisbifurcata*.

We are happy to name this genus after Dr. Joseph Hazel who facilitated our re-collection and study of the Castle Hayne sponge fauna.

HAZELINA BISBIFURCATA Finks, Hollocher and Thies, new species  
pl. 12, Figs. 1–4; pl. 13, Figs. 1–4

**DESCRIPTION:** The sponge is foliose, rather uniformly about 2.5 mm thick. The single fragment is an incomplete, laterally compressed cup, 49 mm in maximum dimension but it lacks an attachment; all edges are broken and one side is bent over such that the original shape could have been plicate. A small fragment of the same species is adherent to the convex side. The concave interior of the cup bears shallow, subparallel grooves, 0.3–0.5 mm wide and ranging from immediately adjacent to 2 mm apart, that run perpendicularly to the trough-like bottom of the cup and extend up the sides some 10 to 15 mm. They fade out at either end and are not obviously connected to any special pores or canals. The entire concave surface, which is probably exhalant, is covered with circular to elliptical skeletal

pores, 0.075–0.500 mm in diameter, which are the mesh spaces between the desmas. The convex surface, probably inhalant, bears much finer pores, 0.075–0.175 mm in diameter, and is quite smooth, lacking any trace of grooves.

The external skeletal net consists of tuberculate anapodal desmas in a non-fibrous arrangement. The desmas are tripods that branch dichotomously twice. The tertiary cladi may rest upon, or embrace, the centrum of the desma beneath, but it is not certain if this is a regular arrangement. Occasional quaternary cladi are formed. The primary cladi are 0.05–0.10 mm long and 0.08–0.10 mm thick; the secondary cladi are 0.08–0.18 mm long and 0.05–0.08 mm thick; the tertiary cladi 0.03–0.10 mm long and 0.02–0.05 mm thick. The entire desma is some 0.75 mm across. The tubercles are spheroidal (not capstan-like) and are 25–50  $\mu\text{m}$  in diameter. They are arranged quincuncially on the distal and lateral surfaces of the primary cladi. On the secondary and tertiary cladi there is usually room for only one row of tubercles along the distal surface; they are also scattered on the sides. Tubercles seem reduced or absent on the proximal surfaces of all cladi. A large tubercle, some 75  $\mu\text{m}$  in diameter, replaces the fourth (distal) ray of the desma. Over broad areas on both surfaces of the sponge the tubercles are so closely spaced as to be separated only by a narrow sulcus, so that the single rows of them on the secondary and tertiary cladi resemble a series of annular swellings. In some cases annular swellings may even replace the quincuncial tubercles on the primary cladi. There is a suggestion that the layer of desmas immediately below the surface layer has finer tubercles, making the development of annular swellings a surface or “dermal” feature. Unfortunately, it is difficult to see much of the deeper layer of desmas from the surface, and the interior spicules in cross-section are largely obscured by recrystallization. Where they are not completely submerged in cherty matrix they are covered with a densely and irregularly tuberculate coating that appears to be diagenetic. At one place, where the interior spicules appear to be free of matrix they exhibit annular swellings like that of many surface spicules, thereby casting some doubt on the hypothesis that the annulation is a surface feature.

Canals, 0.125–0.375 mm in diameter, have a rather labyrinthine arrangement on the sponge interior. Owing to coarse diagenetic silicification of the interior skeletal net they are difficult to trace. The largest are near and perpendicular to the exhalant surface where they form the larger pores on that surface. The interior desmas are more irregular than the surface spicules, similarly tuberculate, but commonly packed in fibers of several spicules side-by-side. The interior mesh is even denser than the exterior net; mesh spaces are rarely more than 0.125 mm, except for the major canals mentioned above.

No dermal triaenes of any kind have been seen. Neither are there any accessory desmas, although small cladi are occasionally seen that resemble tertiary cladi but are difficult to relate to the adjacent desmas; they may represent smaller accessory desmas or they may be tertiary cladi from underlying spicules. The net is so solidly silicified that the zygoes cannot be seen, but union would seem to be effected by the application of the ends of the tertiary or quaternary cladi to the distal surface of an underlying desma.

If a coating of dermal spicules was lost it must have occurred very early, because several encrusting cheilostomes are present, and the bryozoan is applied directly against the desmas, as are also some serpulid worm tubes.

**DISCUSSION:** The regularity of the external skeletal net of this species, with its doubly dichotomizing tripods, sets it apart from the other tuberculate tetractinellines of the fauna. The general appearance of the spicules, and the resulting skeletal net, is closest to that of *Pholidocladia* Hinde 1884, among published genera, especially in those parts of the net where the tubercles resemble annular swellings. However, the annulations of *Pholidocladia* are more collar-like and separated by a distinct space. Moreover, the desmas of *Pholidocladia* do not have the regular dichotomous branching found in the present species nor do they have the multiple tuberculation of the primary cladi. Finally, the thin-walled cup shape of the present species is not like that of the branching *Pholidocladia*. The external form is more like that of *Phymaplectia* Hinde 1884, but the desmas are not same. For these reasons it has been assigned to a new genus. The species name refers to the doubly dichotomous branching of the desmas.

**MATERIAL:** One specimen, incomplete, with a second fragment adherent.

**TYPE:** Holotype USNM 133130.

**LOCALITY:** USGS 22389.

**Genus CLAYTONIA** Finks, Hollocher and Thies,  
new genus

**DIAGNOSIS:** Foliose, cup-shaped; inhalant and exhalant surfaces differentiated with postica larger than ostia; internal canals well-developed perpendicular to surfaces with dendritic tributaries, exhalant especially prominent; outer desmas mainly irregular, branching, curved tripods (or tetractinellines with reduced distal ray) with capstan tubercles, and claw-like zygomata but some with reduced tuberculation near centrum; interior desmas include a larger proportion of tetractinellines with partly smooth clones; dermalia poorly known but may include simple triaenes; skeletal net non-fibrous.

**DISCUSSION:** It is with some hesitancy that we introduce a new generic name for two small fragments, but they are preserved in sufficient detail to provide as

full a diagnosis as most genera in the literature possess, and appear not to correspond to any previously described.

This genus differs from *Achrochordiella*, with which it is associated, at the type locality, and which its desmas resemble, in its foliose form, presence of smooth, or partly smooth, tetracrones, and largely non-fibrous skeletal net, as well as in the absence of dichotriaene-phylloctriaene dermalia. It differs from *Hazelina*, which its desmas also resemble, and which has a similar habit, and similarly non-fibrous skeletal net, on the exterior (but not internally), in the greater irregularity of the desmas and larger skeletal mesh spaces, as well as in the presence of smooth, or partly smooth tetracrones, and capstan-like, rather than spheroidal, tubercles. *Rhopalospongia* has a similar combination of partly smooth tetracrones and completely tuberculate irregular desmas, as well as a similar distribution of these types within the sponge, but its desmas are larger, and its habit is solid-cylindrical, although the species *R. obliqua* Hinde 1884, is incipiently cup-shaped. It is not clear from the published description (Hinde 1884, p. 89–90) to what extent the irregular desmas of that genus are branched; those shown in Hinde's illustration (*ibid.*, pl. 22, fig. 2c) are much less branched. *Pseudojerea* Moret 1927, which also has a combination of tuberculate and partly smooth tetracrones, has more regular spicules, a cylindrical habit and dermal phylloctriaenes.

We take pleasure in naming this genus after Dr. Clayton Ray, who greatly facilitated our collection of new material for this study.

TYPE SPECIES: *Claytonia rayi* Finks, Hollocher and Thies, new species.

CLAYTONIA RAYI Finks, Hollocher and Thies,  
new species  
pl. 14, Figs. 1–3; pl. 15, Figs. 1–4; pl. 16, Figs. 1, 2; pl.  
17, Figs. 1–3

**DESCRIPTION:** The holotype is a fragment of a cup, 4 mm thick and 29 mm in maximum dimension, from USGS 21849. The principal spicules are irregular, tuberculate, anapodal desmas. Most appear to have a tetraxial basis with the fourth (distal) ray absent, though a short fourth ray is present in a minority of spicules, especially on the concave (excurrent) side. The spicules are not symmetrical in direction and length of rays; the rays may be curved or bowed in either the radial or tangential direction, the angles between them may be unequal, and they may branch dichotomously, generally once. The clones or branches are 0.20–0.25 mm long and 0.05–0.10 mm thick. They are covered on their distal and lateral surfaces with closely spaced capstan tubercles, 25–50 µm in diameter, generally in a quincuncial arrangement, but occasionally in transverse rows along annular swellings. When the fourth ray is absent there is no

specially large tubercle in its place. At the end of the rays there are short, claw-like, terminal zygoes that interlock with the tubercles of adjacent spicules. In general the skeletal net is built of single desmas superposed; locally, however, two or three desmas may lie side by side. On the sponge interior, smooth, or partly smooth, tetracrones are present along with the more tuberculate desmas. Occasional partly smooth tetracrones are also present on the sponge surface. It is generally the central part of the spicule that is smooth or that has subdued tubercles, the terminal parts and branches of the clones being more strongly tuberculate. One smooth, stout, anapodal (or tripod: the proximal ray is not visible) may be a remnant of the dermal spiculation.

Circular to elliptical ostia, about 0.5 mm in diameter, are scattered over the convex surface, while similar but larger postica, 0.5–1.0 mm in diameter, occur on the concave surface. The remaining interspicular mesh spaces on both surfaces are mainly 0.1–0.3 mm in diameter. One obscure surface groove, 0.7 mm wide occurs on the convex surface. The ostia and postica lead into well defined canals of similar size, the principal of which run perpendicular to the inhalant and exhalant surfaces, joined by tributaries in a dendritic pattern. The exhalant are the more prominent; one exhalant trunk 0.8 mm in diameter extends about halfway through the sponge wall at the same diameter, then breaks up into smaller tributaries.

Another fragment is from USGS 22389. It is partly chertified. It agrees in all essential respects with the holotype. Partly smooth tetracrones are visible on a presumably broken edge across the 10 mm thick sheet. The larger pores, presumably postica, are found on the convex surface of the fragment, the reverse of the condition on the holotype. Well-developed distal rays on many of the outermost tetracrones are found on the concave side (as in the holotype) but not on the convex side. The tubercles on the concave side are distinctly capstan-like; those on the convex side somewhat more sessile and spheroidal, often lacking the basal neck. Dimensions of spicules and mesh spaces are the same as in the holotype, and smaller than in the associated *Hazelina bisbifurcata*.

**DISCUSSION:** The habit of these fragments, insofar as they are preserved, is somewhat like that of *Hazelina bisbifurcata*. Their desmas and skeletal net, however, are in some respects intermediate between those of *Hazelina* and those of *Achrochordiella vokesi*, and in other respects unlike either. The desmas are largely single as in *Hazelina* rather than grouped in fibers as is often the case in *Achrochordiella*; however, some are grouped in fibers. The length of the cladi is more like *Achrochordiella* than the shorter ones of *Hazelina*. Many of the desmas are rather symmetrical and even doubly bifurcate as in *Hazelina*, but most are less regular. Their

tuberculation is more like that of *Achrochordiella* in shape (but their greater size is like *Hazelina*); the desmas occasionally exhibit an incipient annulation reminiscent of *Hazelina* (it must be said that this occurs on rare occasions in *Achrochordiella* too). Unlike either *Hazelina* or *Achrochordiella*, however, numerous desmas are largely smooth or have reduced tuberculation. The mesh spaces of the skeletal net are larger than those of *Hazelina* and resemble those of *Achrochordiella*.

Because it occurs at the same locality as *Achrochordiella vokesi* one could interpret it as an individual variant of that species. This would involve accepting as individual differences characters commonly regarded as of generic significance. The same applies to its relation to *Hazelina bisbifurcata*, with which it also occurs.

The distinctive character of this species is the presence of partly smooth-armed spicules. They are mainly found in the interior, the outer desmas being almost entirely tuberculated. It is always the central part of the desma that is smooth, that is, the primary cladi, the tubercles remaining or being more strongly developed on the secondary branches. This is a general rule among tetractinines. A number of genera with normally smooth tetractolones, such as *Siphonia* Goldfuss 1833, may have tuberculations on the extremities of the clones. *Rhopalospongia* Hinde 1884, has, like the present species, a mixture of smooth but terminally tuberculate regular tetractolones and wholly tuberculate, less regular spicules. As in the present species also, the smoother, more regular spicules are more frequent in the interior of the sponge while the less regular, more tuberculate spicules predominate near the outer surface. *Rhopalospongia* has a club-shaped habit, unlike the present specimen, and its desmas are considerably larger. *Pseudojerea* Moret 1926, likewise has a mixture of smooth and tuberculate tetractolones, with a predominance of tripods near the surface. It is a cylindroid sponge with a cloaca.

De Laubenfels (1953 p. 112–113, text-fig. 7) described a sponge from the Eocene of Western Australia under the name *Tragalinus amechanus* which he said had spicules that “in some places ... are lumpy, as in *Phymaplectia*, but mostly ... are not” (*ibid.*, p. 113). Phyllotriaenes are also present, and the sponge is acorn-shaped. Possibly this is related to *Claytonia*, though *Pseudojerea* Moret 1927, would be closer.

**MATERIAL:** Two fragmental siliceous specimens.

**LOCALITY:** USGS 21849, USGS 22389.

**TYPES:** Holotype USNM 133131, paratype USNM 133132.

#### Order CHORISTIDA Sollas 1888

**DIAGNOSIS:** Demospongea with megascleres that include long-shafted triaenes or their derivatives and no desmas; and with microscleres that include euasters but

not streptoscleres; usually with a differentiated cortex and at least partly radial, architecture.

**DISCUSSION:** We use the order in a restricted sense to exclude forms with streptoscleres (Streptosclerina Reid 1963), forms without triaenes (Epipolasida, Sollas 1888; Homosclerophora Dendy 1905), and forms without euasters (Spirosclerina Reid 1963). It is equal to Euasterophora Reid 1963.

#### Family CEPHALORHAPHIDITIDAE Reid 1968, emend.

**DIAGNOSIS:** Sponges with choanosomal ophirhabds and dermal triaenes, or triaene derivatives, such as triactins.

**DISCUSSION:** We modify Reid's definition (Reid 1968, p. 1252) by adding “or triaene derivatives, such as triactins” in order to accommodate the new genus and species *Cerberorhaphidites auriformis*, which lacks (1) triaenes but has surface triactins with three equally-spaced, coplanar rays. Otherwise it generally resembles the Cretaceous genera placed by Schrammen (1910) in his family Ophirhaphiditidae, and for which Reid established the Cephalorhaphiditidae on the basis of the presence of triaenes, which are absent in the poorly-known, living *Ophirhaphidites* Carter 1876. In particular *Cerberorhaphidites* resembles *Cephalorhaphidites* Schrammen 1899, and *Polytretia* Schrammen 1910. Coplanar triactins (also called “trioids” and “triads”) occur in other demosponge genera and are regarded as reduced derivatives of calthrops or triaenes. Certainly they can be regarded as the cladome of an orthotriaene with the rhabdome suppressed.

Further discussion of the possible relationships of the Cretaceous cephalorhaphiditids, the Eocene *Cerberorhaphidites*, and the living *Ophirhaphidites*, is made below under the species *Cerberorhaphidites auriformis*.

#### Genus CERBERORHAPHIDITES Finks, Hollocher and Thies, new genus

**DIAGNOSIS:** Structural spicules subparallel, intertwined ophirhabds organized into laterally connected longitudinal columns or sheets that may be cored by straighter, more oxea-like spicules; entire sponge sheet-like to cup or ear-shaped, with spicule sheets perpendicular to broad surfaces of sponge, and separated by longitudinal and radial anastomosing canals (or cavae-dia) that open as circular pores on both surfaces; ophirhabd columns or sheets coated by small, spinose (?) triactins (coplanar, 120°) that are often, at least near outer surfaces of sponge, parallel to one another and with one ray longitudinal to sponge; no triaenes clearly belong to the sponge; large sphaerasters and oxyasters, as well as simple calthrops, are associated with the sponge and may or may not belong, as may a local surface coating of small, tangent, subparallel oxneas.

**DISCUSSION:** The possible relationships of this genus are discussed under the species *Cerberorhaphidites auriformis*.

We continue the zoomorphic tradition of *Ophirhaphidites* by invoking the name of the three-headed dog Cerberus to refer to the triactins that distinguish this genus from all other members of the Family Cephalorhaphiditidae. The organization of the skeleton into longitudinal, plate-like fibers cored by oxeas, seems also unique, though internal details are not available for some genera.

The absence of triaenes also distinguishes this genus from the other members of the family. This absence appears to be genuine. The only triaenes adherent to the specimen are either the specialized, stout dichotriaenes of the co-occurring *Stolleya silvigera* which are not in life-position, or they are broken-off cladomes of other dichotriaenes, mainly of a flattened, irregular variety approaching the form of a phyllotriaene, probably of *Achrochordiella yokesi*. Considering the delicacy of the small surface triactins, which are often preserved in their original parallel orientation, it seems unlikely that more robust triaenes would have been completely removed or broken away. The triactins could be considered the cladomes of orthotriaenes but there is no trace of a rhabdome visible on any of them. If the calthrops belong, they could be considered reduced triaenes also.

**TYPE SPECIES:** *Cerberorhaphidites auriformis* Finks, Hollocher and Thies, new species.

#### CERBERORHAPHIDITES AURIFORMIS Finks, Hollocher and Thies, new species

pl. 18, Figs. 1–6; pl. 19, Figs. 1–5; pl. 20, Figs. 1–4

*Ophirhaphidites infundibuliformis* Schrammen, Rigby 1981, p. 125, pl. 1, figs. 1, 2, 5, 6; text-fig. 1 (but not C-G, Q, R, and probably not A, B, H, I, O, P.)  
*?Ophirhaphidites hadros* Rigby 1981, p. 127, pl. 2, figs. 7, 8; text-fig. 2.

**DESCRIPTION:** Sponge auriform or irregularly cup-shaped. The largest and most nearly complete specimen is a half-funnel with a stalk that is at least partly hollow. It is 74 mm high, 52 mm at the widest point, and 3–14 mm thick. Thicknesses of the other fragmental specimens fall within the same range. The skeleton is organized into longitudinal columns or plates, perpendicular to the broad surfaces, that interconnect or anastomose, and are separated by longitudinal and horizontal tubular to slit-like spaces that are either skeletal canals (inhalant and exhalant) or are anastomosing cavaedia. They open on both surfaces of the ear or cup as circular pores 0.5–1.0 mm in diameter, and tend to be larger on the concave surface, which is presumably exhalant. On the concave exhalant surface the pores are mainly 1.0 mm in diameter and average 2.0 mm apart, spaced rather uniformly and subquincun-

cially. On the convex inhalant surface they are mainly 0.5 mm in diameter and average 1.0 mm apart. On the inhalant surface in particular, parallel longitudinal grooves may be developed, 0.5–1.5 mm wide, separated by 0.3–0.5 mm interspaces. The inhalant pores are then located on their floors in obscure vertical rows. These grooves appear to represent partly unroofed internal longitudinal canals. The intervening spaces are the structural columns. On the exhalant surface the grooves are less continuous and are separated by the conule-like ends of the columns, from which the coring oxeas protrude. On both surfaces the canals and columns intersect the surface obliquely, more nearly parallel on the inhalant surface. They tend to run inward and downward at a low angle on the inhalant side, inward and upward at a high angle on the exhalant side. In places, perhaps where less decorticated, the surface has a more meandriform pattern of somewhat finer grooves. This may occur where the principal canals are more nearly perpendicular to the broad surfaces. On one specimen with such an arrangement, one of these canals appears to penetrate the wall completely, supporting the idea that the canals are cavaedia. On the other hand, it has a constriction halfway through, suggesting an origin by the coalescence of separate inhalant and exhalant canals. This same specimen exhibits local variability from a dominantly radial to a dominantly oblique principal canal system, with irregularly anastomosing, meandriform or labyrinthine cross-connections.

The principal structural spicules are intertwined and subparallel ophirhabds, which run longitudinally within the columns and encircle the pores and canals. Those lining the grooves and canals (or cavaedia) tend to be horizontal relative to the canal axis. Sometimes adjacent ophirhabds are strictly parallel and have identical sinuosities. Some appear to be “draped” over underlying irregularities, suggesting an initially flexible, adhesive but lubricated condition, rather like spaghetti, presumably as axial filaments of collagen prior to silica secretion. The central spicules of the longitudinal columns are essentially straight and can be called oxeas, though a remnant sinuosity in some indicates their relation to the more typical ophirhabds. Most ophirhabds are irregularly sinuous and many are more or less C-shaped with curled-in ends, or even hairpin-shaped. Though intertwined, each ophirhabd is separate and there are no zygomata. The tips are generally pointed as in oxeas. Although most ophirhabds are parallel to the external surfaces, occasionally their tips curl outward, rendering the surface locally hispid, usually at the bottoms of depressions on the exhalant side. The ophirhabds are 500–2,500 µm long and 25–62.5 µm thick. The oxeas coring the columns are up to 6,000 µm long, perhaps more, and 25–63 µm thick. Interspersed among the ophirhabds are very small triactins (trioids)

with three coplanar rays at 120°. They are 100–563 µm in diameter (mostly around 200 µm) and 12.5–50 µm in ray thickness. They are invariably minutely spinose though there is a question whether the “spines” may not be diagenetically precipitated quartz crystals, for similar, but less closely spaced protuberances, which seem to be secondary quartz, occur on the surfaces of ophirhabds as well as of other sponge spicules in the associated matrix. These triactins are almost certainly parts of the sponge: they occur on every specimen; they are widely disseminated throughout each specimen; one of their rays is generally parallel to the nearest ophirhabd; the plane of their three rays is usually parallel to the surface; and most significant, on several specimens they are locally organized in overlapping groups with all three rays mutually parallel (or in some cases, enantiomorphous) and with one ray of each spicule parallel to the longitudinal axis of the sponge. They thus resemble in form and arrangement the triactins of a calcareous sponge. They seem to have no trace of a fourth ray, though they could have originated as the cladome of an orthotriaene with the rhabdome suppressed. One might also consider them as very large oxyaster microscleres. There is a small patch of surface on one specimen in which there is a superficial layer of fine tangent oxeas 187–538 µm long and 12–25 µm thick. This could be a dermal layer that has been lost on most specimens, a local development on this one specimen, or a small patch of encrusting monaxonid sponge. This last is possible for the oxeas curve about pores that are somewhat smaller and more closely spaced than elsewhere on these specimens. Calthrops, 350–650 µm in diameter and 38–75 µm in ray thickness are found occasionally on the surface of many specimens, usually partly embedded in interstitial matrix. These may be foreign but they could be part of the sponge. Speaking in favor of their belonging to the sponge is the fact that they are usually oriented with one ray perpendicular to the surface, either pointing up or down; on one specimen two adjacent large ones occur between longitudinal columns in the same ray-down orientation. On the other hand this could be merely the most stable position for them to come to rest in. Supporting their foreign nature is the fact that obviously foreign spicules often lie beside them. These include hexactinellid spicules (including fragments of dictyonal nets), the dichotriaenes of *Stolleya*, the sterrasters of *Geodia*, isolated rhizoclones, and various spicules that may or may not be foreign. This last category includes anchor-shaped anatriaenes which are not common but two of which, in at least one instance, occur near one another, tangent to the surface in the same orientation. It also includes the cladomes of irregularly branching orthodichotriaenes, approaching phyllotriaenes, with rhabdome broken off. When they occur, which is not often, these cladomes are tangent to

the surface. They are probably from *Achrochordiella*. Last, but not least, are oxyasters, and oxysphaerasters, sometimes found in interstices of the net and fairly frequent among the loose spicules shaken from the specimens during ultrasonic cleaning. They may come from the associated *Geodia* and/or *Stolleya* but also could belong to the present specimens. Most are oxyasters about 160 µm in diameter with perhaps 24–30 conical, pointed rays, though a few may be blunt-tipped (or broken); the rays are about 18 µm thick at their bases. A few are sphaerasters of the same size and ray number, with a centrum about 75 µm in diameter. They are closer to those of *Geodia harmatuki* than to those of *Stolleya silvigera* but have a somewhat larger number of rays. They are quite consistent in their characters, which suggests that they may belong to the present species.

**DISCUSSION:** The general form of this sponge, and the spatial arrangement of its ophirhabds, is in agreement with those of members of the family Cephalorhaphiditidae Reid 1968. However, it lacks the radial triaenes found in the Cretaceous, and so far, only, members of that family. In their place, so to speak, are the small triactins. The living *Ophirhaphidites* Carter 1876, has only ophirhabds (but is known only from macerated fragments). The living *Jaspis serpentina* Wilson has euasters in addition to ophirhabds. It is tempting to see in the present Eocene species an intermediate stage in the loss of triaenes, especially in view of the association of euasters (oxyasters and sphaerasters) with the present specimens and their occurrence in the living *Jaspis serpentina*. Microscleres are not known from the Cretaceous species. If this phylogeny is correct, the present genus and species, as well as the Cretaceous cephalorhaphiditids and the living *Ophirhaphidites* and *Jaspis serpentina*, would belong to the Choristida in the restricted sense used herein. However, if we regard the present species as unrelated to the Cretaceous cephalorhaphiditids with triaenes, the triactins and the possibly associated calthrops suggest a relationship to the Carnosa, and in particular to the Calthropellidae Von Lendenfeld 1906, if the euasters belong, or else to the Pachastrellidae Carter 1875. None of the Carnosa have anything like ophirhabds, however, and a connection based on the small triactins would be very tenuous. It seems best to place this species with the cephalorhaphiditids.

The gross arrangement of the skeleton into flat, plate-like fibers, cored by oxeas and oriented longitudinally, perpendicular to the outer surfaces, seems not to be present in other fossil ophirhabd-bearing sponges. The presence of triactins is another unique feature. The absence of triaenes is shared with the Cretaceous *Alloiorhaphium* Schrammen 1912; that genus differs in

that it has internal styles and strongyles along with ophirhabds and oxeas, and its gross construction is radial. *Polytretia* Schrammen 1912, and *Cephalorhaphidites* Schrammen 1912, share a similar ear-shaped form with similarly differentiated ostia and postica, thus resembling the present form externally, but they have dermal triaenes, and *Cephalorhaphidites* also has styles. The ophirhabds of the present species are shorter and slenderer than any reported by Schrammen (1912) (the Cretaceous ophirhabds run up to 5,000 µm long, or more, and 100–200 µm thick).

Rigby (1981, p. 127 ff.) described what is apparently this species as *Ophirhaphidites infundibuliformis* Schrammen 1899. He does not note the presence of triactins but does describe orthotriaenes of the same size and position. The question is therefore whether a proximal ray is present or not. It is possible that both triaenes and triactins are present. In that case the new genus would still be valid on the basis of the presence of triactins. There is little doubt that at least some of these spicules are triactins (see pl. 10, Fig. 1). Where they are in place (as in USNM 133139) a proximal ray is not visible in quite good lateral views of the spicules. The protriaenes illustrated in Rigby's text-figure 1, C-G, Q, and R, are almost certainly from *Stolleya silvигera*. The dichotriaenes-phyllostriaenes in his text-figure 1, A, B, H, I, and O, are considered here to be from *Achrochordiella vokesi*. The anatriaenes (L, M) were also noted here and may belong. The species *Ophirhaphidites hadros* Rigby 1981, was established for massive specimens from the same locality in which the exhalant surfaces are apparently on large cavaedia. These could be individual variants of the present species. Their specific distinction is maintained here for the time being.

The species name refers to the predominant earlike shape of the specimens.

**MATERIAL:** 13 fragments, of which the largest seems nearly complete. They are all siliceous including a certain amount of secondary silicification.

**TYPES:** Holotype USNM 133133, paratypes 133134–133142.

**LOCALITY:** USGS 21849.

#### Family ANCORINIDAE Gray 1867

**DIAGNOSIS:** Choristida with generally radial arrangement of spicules and a well-developed cortex pierced in life by chones leading to subdermal spaces; cortical spicules include triaenes or dichotriaenes; microscleres include various forms of euasters but not sterrasters or aspidasters.

**DISCUSSION:** This family differs from the Geodidae in lacking sterrasters or aspidasters, although a dense cortical skeleton may be attained by other means, such as close-packed triaenes, or sand.

#### Genus STELLETTA Schmidt 1862

**DIAGNOSIS:** Massive to cup-shaped ancorinids with oxeas, usually radial, in the endosome, and radial oxeas with triaenes and/or dichotriaenes in the cortex; microscleres euasters, usually of more than one kind, and often concentrated at the surface or lining the canals; sand may be incorporated into the cortex.

**DISCUSSION:** The genera *Stellella* Schmidt 1862, and *Stolleya* Schrammen 1899, are very similar. Both have as megascleres, oxeas and triaenes, with the triaenes of *Stolleya* being dichotriaenes with their secondary cladi in a plane perpendicular to the main shaft. The microscleres of *Stellella* are euasters, with either pointed ends (oxyasters) or blunt ends (tylasters or strongylasters). The microscleres of the type species of *Stolleya* are unknown. The body-form of *Stellella* is spheroidal to cup-shaped with a differentiated outer-layer or cortex, and the megascleres are radially-arranged within the body. The complete body-form of the type-species of *Stolleya* is not known, but appears to be more-or-less crust-like, with oscules at the summits of low elevations.

The species described below has dichotriaenes with the secondary cladi in a plane perpendicular to the main shaft, as is found in the type-species of *Stolleya*, giving the spicule the appearance of a well-opened tulip.

The close similarity of the spiculation of *Stellella* and *Stolleya* implies that they are related, and the peculiar tulip-shaped dichotriaenes of the present species implies a relationship to the type-species of *Stolleya*. We propose to recognize these relationships of the two genera by considering them two subgenera of a single genus. Inasmuch as *Stellella* has priority, we are using that name for the genus, and dividing the genus into two subgenera, one bearing the generic name *Stellella* and the other being *Stolleya*. The species described here, with its tulip-shaped dichotriaenes, clearly belongs in the subgenus *Stolleya*. Oxyaster microscleres associated with the specimen support its relationship to *Stellella*.

We have taken the broad view of *Stellella* adopted by Bergquist in 1968 in admitting forms which have only one category of microsclere (though some *Stolleya* sphaerasters have partly blunted rays and might be considered semi-strongylosphaerasters). De Laubenfels (1936, p. 170) for example, defined *Stellella* as having always two distinct categories of euasters, as opposed to *Myriastrea* Sollas with only chiasters (=tylasters). The name *Stolleya* is available from three Cretaceous species which belong in our subgroup. We include also a new species described here, as well as the living species *Stellella lithodes* Bergquist 1968, and possibly the living *Stellella pyriformis* (Sollas 1886). We discuss this more fully under the species *Stolleya silvигera* below.

Subgenus STELLETTA Schmidt 1862, emend.

**DIAGNOSIS:** *Stelletta* with triaenes (and/or dichotriaenes) and oxeas grouped in discrete radial fibers, and not bearing densely-packed, thick dichotriaenes with forwardly curving primary cladi and short, stubby, subhorizontal secondary cladi.

Subgenus STOLLEYA Schrammen 1899, emend.

**DIAGNOSIS:** *Stelletta* with dense cortical skeleton of closely packed, stout plago- to pro-dichotriaenes with distally concave primary cladi and short, stubby secondary cladi that often lie in a plane perpendicular to the rhabdome, together with comparable triaenes without secondary cladi; development of cladi often irregular; endosome of closely packed radial oxeas often not separated into discrete fibers; microscleres oxy-sphaerasters (and semi-strongylosphaerasters?). Shallow, cortex-free, circular depressions, surrounded by sharp rims of radial triaenes and oxeas, are present on the exterior surface in some species.

**TYPE SPECIES:** *Stolleya microtulipa* Schrammen 1899.

**STOLLEYA SILVIGERA** Finks, Hollocher and Thies,  
new species

pl. 21, Figs. 1–4; pl. 22, Figs. 1–9; pl. 23, Figs. 1–6; pl.  
24, Figs. 1–6; pl. 25, Figs. 1–2

**DIAGNOSIS:** *Stolleya* with crocus-like, large pro-triaenes along with more numerous tulip-like pro- to plago-dichotriaenes, the latter with relatively broad cladomes (like a well-opened tulip).

**DESCRIPTION:** The single specimen is nearly complete; an irregular, elongate mass about 100 × 45 × 25 mm, with a rounded protrusion about 25 mm in diameter at one end. Most of the specimen consists of parallel, long, stout, gently to abruptly curving oxeas tightly packed together in an irregularly twisted, radiating mass. Their diameters are 50–175 µm (mostly around 125 µm); the length of one 175 µm in diameter that could be traced was about 6,000 µm. The large oxeas are paralleled by very fine ones often no more than 25 µm in diameter but of considerable length, though some may be as short as 1,425 µm. Of those shaken loose by ultrasonic cleaning, most lengths are in the range of 4,000–5,000 µm. At the sponge surface these oxeas are accompanied and replaced by stout, radial dichotriaenes of similar size, whose tightly packed, interlocking cladi form a dense cortical zone, some 2 mm thick, at the surface. They are plago- to pro-dichotriaenes with stubby, short, conical secondary cladi. Their primary cladi almost invariably curve forward, sometimes so much as nearly to parallel the rhabdome. The short, thick secondary cladi are usually bent outward relative to the primary cladus. The upper

surfaces of all six secondary cladi thereby often lie, or very nearly lie, in a common plane that is perpendicular to the rhabdome. The silhouette of the cladome approximates that of a well-opened tulip. Slenderer dichotriaenes with shorter secondary cladi, found slightly below the sponge surface, may represent developmental stages. Unbranched protriaenes comparable in size to the dichotriaenes, also occur in the cortex; these are not developmental stages of the dichotriaenes because they are as stout as fully-developed dichotriaenes, and their cladi are quite consistently forwardly directed, sometimes parallel to the rhabdome. Small examples, probably developmental stages, of the protriaenes have also been found. Cladomes of the large dichotriaenes are 375–600 µm across, the rhabdomes 100–150 µm in diameter, total length of the spicule 2,000–3,400 µm. Diameter of the primary cladi 75–150 µm, and length of secondary cladi 75–175 µm. Developmental stages of dichotriaenes are as small as 250 µm across the cladome, 75 µm in rhabdome diameter, 1,225 µm in total spicule length, 50 µm in primary cladus diameter, and 37 µm in secondary cladus length. The large protriaenes have cladomes 275–475 µm across, and 400–525 µm long, with cladi 100–150 µm in diameter, rhabdomes 125–175 µm in diameter, and a total length in excess of 2,000 µm (rhabdomes broken off). The small developmental stages of the protriaenes are as small as 225 µm in cladome diameter, 200 µm in cladome length, 50 µm in cladus diameter, 75 µm in rhabdome diameter, and 825 µm in total spicule length. Intermediates between protriaenes and dichotriaenes are often found among the large cortical spicules, that is, spicules with one branched cladus and two simple cladi, or vice versa. They are perhaps as common as pure protriaenes, though less so than dichotriaenes. This suggests that the protriaenes are the result of suppression of the secondary cladi of a dichotriaene. There would appear to be a connection between such suppression and a more forwardly directed emergence of the primary cladi from the rhabdome. In all spicules in which one or more primary cladi are unbranched, the cladi leave the rhabdome at angles greater than 135°. Possibly crowding of the spiculoblast between previously formed spicules leads to such suppression. Occasionally, simple cladi will have abnormalities such as irregular bends, again implying restrictive conditions during spiculogenesis.

Among the spicules shaken loose from this sponge by ultrasonic cleaning are oxysphaerasters, some 100–150 µm in diameter, with centra 50–88 µm in diameter. They have also been found adherent to the surface of the sponge itself. Inasmuch as oxysphaerasters are among the common types of microscleres found in many living species of *Stelletta*, and in particular are the

only kind of microsclere found in *Stelletta lithodes* Bergquist, which is the living species closest to the present fossil, one might assume that they are the microscleres of this sponge. Unfortunately, many obviously foreign spicules also occur in the removed material and in the remaining matrix adherent to the specimen. These include fragments of hexactinellid dictyonalia, as well as demosponge spicules of varying degrees of probable non-relationship to the specimen, including rhizoclones, ophirhabds, phyllotriaenes, orthodichotriaenes with delicate, curving secondary cladi (the last two probably from *Achrochordiella*), anatriaenes, calthrops, and sterrasters. The last are probably from the co-occurring *Geodia harmatuki* and the oxysphaerasters could possibly be from the same source. However there are some differences between those associated with the present specimen and those associated with the specimens of *Geodia harmatuki*. All those associated with *Stolleya silvigera* have a well developed centrum sharply marked off from the rays; that is, they are true sphaerasters. Associated with *Geodia harmatuki*, along with similar sphaerasters, are oxyasters without a well developed centrum. The *Geodia* spicules run to larger sizes than those of *Stolleya*; the sphaerasters up to 175 µm and most of the oxyasters in the range of 175–200 µm, while the sphaerasters of *Stolleya* do not exceed 150 µm. In addition, the rays are slenderer and more numerous in *Stolleya* than in *Geodia* in sphaerasters of comparable size. Ray bases emerging from a centrum 88 µm in diameter in *Stolleya* are about 15 µm thick, while those emerging from the same sized centrum in *Geodia* are about 25 µm thick. These consistent differences between the asters associated with the *Geodia* specimens and those associated with the specimen of *Stolleya* suggest that the asters may be proper to their respective sponges. We therefore tentatively consider these oxysphaerasters as part of the spicule complement of *Stolleya silvigera*. The number of rays on these spicules is estimated as 10–24; one spicule however may have considerably more (perhaps 40). Most are sharply pointed but a few have some or all of the rays more or less blunt-tipped. It is not certain whether this is original or because of breakage. One such spicule, if unbroken, might be considered a partial strongylosphaeraster.

The specimen representing this species is fractured at one end, revealing a silicified interior, and the whole sponge may have been considerably longer. The cortex of interlocking dichotriaenes is preserved in patches, but so generally distributed that the present surface must be very nearly the original surface of the sponge. The rounded end of the specimen is essentially completely covered with the cortex. On one side there is an area of sinuous to circular depressions, each some 10 mm wide and half as deep, that are bordered by sharp ridges of

cortex but lack dichotriaenes within them. This may represent the mold of some object, or objects, on the substrate, perhaps a small ramosc sponge. They may correspond to the crater-like depressions of the same size, reported by Schrammen (1910, p. 53) which he interpreted as cloacas and compared to those of *Cinachyra barbata* Sollas 1886 (see Sollas 1888, pl. 3). Elsewhere on this same surface is an adherent, small ovoid mass, some 7 mm long, composed of tightly packed ophirhabds. It is probably a juvenile of *Ophirhaphidites*, and the depressions may have a similar origin. There are no clear indications on the specimen of *Stolleya* of the sites of oscules or canals, unless the sharp-rimmed crater-like depressions are oscules.

**DISCUSSION:** The fossil species closest to the present one are *Stolleya microtulipa* Schrammen 1899, from the Cretaceous of Germany, which is the type species of *Stolleya*, and the associated *S. florida* Schrammen 1910 and *S. ornatissima* Schrammen 1899. Among living species, the closest is *Stelletta lithodes* Bergquist 1968, from New Zealand. Bergquist (1968, p. 48) notes that it is unique in the genus for its large principal oxeas and for the compact radial arrangement of spicules in the endosome rather than an arrangement in separate tracts. She notes further (*ibid.*, p. 46) that it was so stony as to be impossible to section. The compact dense endosome, and large oxeas, are also features of the present species. Another feature the two share is the short, stumpy nature of the secondary cladi on the dichotriaenes, and their tendency to be bent sharply outward from the primary cladius so as to lie very nearly in a plane at right angles to the rhabdome (see Bergquist 1968, p. 47, fig. 19). The large oxysphaeraster microscleres are also similar to those associated with the present specimen, in large size (58–106 µm), in number of rays (12–20), and in the shortening and blunting of some rays. The unusually large sizes of the spicules of *Stelletta lithodes* agree in general with those of the present specimen, except that the rhabdomes and cladi of the dichotriaenes of the present specimen are longer and thicker (*S. lithodes* only up to 1,480 × 69 µm), while the large oxeas of *Stelletta lithodes* are longer and thicker (up to 6,800 × 500 µm). The large oxysphaerasters of the present specimens also run to somewhat larger sizes. They share a common property that some sphaerasters may have partially blunted rays. The lack of protriaenes, or any simple triaenes, in *Stelletta lithodes* is another significant difference, although Bergquist notes (1968, p. 46) that "many irregular and deformed conditions occur among the dichotriaenes." The strong forward curvature of the primary cladi of the dichotriaenes is perhaps related to the development of protriaenes, and is found in both species; however, this feature is common to many species of *Stelletta* for example, *S. maori* Bergquist (1968, p. 51, fig. 23).

Protriaenes are present in the Cretaceous *Stolleya florida* Schrammen, and that species is perhaps closest of all to the present specimen, in terms of spicule complement and spicule shape, except that microscleres are not known.

The three Cretaceous species of *Stolleya* named by Schrammen (1899, 1910) differ in the form and size of their dichotriaenes. In *S. ornatissima* the cladi have a nearly straight profile making an angle of 45° with the shaft and terminating in a flat horizontal surface. In *S. florida* they emerge from the shaft at a slightly wider angle, then curve forward nearly parallel to the shaft and finally curve outward again to terminate in a not-quite-horizontal surface; they thus resemble a well-opened tulip. In *S. microtulipa* the cladi emerge at right angles to the shaft, immediately curve forward parallel to it, then bend abruptly outward and terminate in a horizontal surface; they thus resemble a just-opened tulip. The shaft of *S. microtulipa* is cylindrical with little taper except near the tip. The other two species have tapering shafts whose widest point is just beneath the cladome; in *S. florida* there is almost a bulge, or a wide, non-tapering part, at this point. In size, those of *S. microtulipa* are distinctly the smallest (length up to 3,000 µm), those of *S. ornatissima* next (up to 5,000 µm) and those of *S. florida* largest (some in excess of 7,000 µm). *S. microtulipa* differs also in its remaining spicules; it lacks simple protriaenes, its oxeas are often angulated and are half the size of those of the other two (length 5,000 µm versus 10,000 µm).

In 1924 (Schrammen 1924, pl. 8, figs. 1, 4, and 7) Schrammen illustrated other Cretaceous *Stolleya* dichotriaenes occurring as isolated spicules, which differ from those of the three named species. He deliberately attached no specific names to them (*ibid.*, p. 40). In their wide cladomes and large size they are closest to *S. florida*; one spicule (*ibid.*, fig. 4) has two simple cladi and one dichotomous one, a semi-protriaene like those in the present species.

The spicules of the present species are closest in form to those of *S. florida* but in size are much smaller, in the range of *S. microtulipa*. Unlike *S. microtulipa* the present species includes simple protriaenes. It does resemble *S. microtulipa*, however, in having occasionally angulated oxeas, and in having crater-like depressions of centimeter size on the surface of the sponge. (The other two species of Schrammen were not sufficiently well preserved for such structures to be seen.) According to Schrammen (1899, p. 7) the internal radial oxeas of *S. ornatissima* and *S. microtulipa* are grouped into bundles. His illustration of *S. ornatissima* (*ibid.*, pl. 1, fig. 4) shows rather obscure bundles that are closely apposed. The present species has no discrete bundles at all.

Schrammen (1910, p. 51) called attention to the fact that *Anthastra pyriformis* (Sollas 1886; see Sollas 1888, p. 146 ff., pl. 15) has *Stolleya*-like dichotriaenes. De

Laubenfels (1936, p. 170) considered *Anthastra* a synonym of *Stelletta*. This living species has a dense but discretely fibrous skeleton. The fibers consist of straight or curved oxeas and protriaenes; near the surface there are also dichotriaenes, rather like those of *Stolleya ornatissima*, as well as anatriaenes, some of which have one or two cladi missing. The microscleres are anthasters (spiny-rayed euasters with 4–7 rays) and chiasters (tylasters). The oxeas are up to 4,000 µm long, the dichotriaenes slightly less (the rhabdome to 3,720 µm), the protriaenes to 2,860 µm (rhabdome), the anatriaenes to 2,100 µm, the diameter of the anthasters 26 µm, and that of the chiasters 16 µm. The microscleres and anatriaenes set this species apart from the others considered here. The other spicules are similar in size to those of the present species, but the cladomes are relatively broader and the cladi not as curved forward. It would also seem that the dichotriaenes are not densely packed to form a continuous, stony surface layer as they are in *Stelletta lithodes*, in the Cretaceous species of *Stolleya* and in the present species.

The intergradation of *Stelletta lithodes* Bergquist with other species of *Stelletta*, as well as its obvious resemblances to the present specimen and to the three Cretaceous species of *Stolleya* Schrammen, implies that *Stolleya* is but a massive end-member of a highly variable complex of species which are normally assigned to *Stelletta*. Nevertheless, there is a complex of characters that seems to have a consistent association: massive endosome of large oxeas either not grouped in discrete bundles or with bundles closely apposed; dense cortex of interlocking dichotriaenes; dichotriaenes thick, with forwardly-curved primary cladi and stubby, horizontally-bent secondary cladi; a tendency to irregularity in the development of cladi; and microscleres solely, or largely, oxysphaerasters. We propose to recognize this common association, as well as its relationship to the larger group of *Stelletta* species, by considering *Stolleya*, with this complex of characters, as a subgenus of *Stelletta*. We would include the living *Stelletta lithodes* Bergquist in *Stolleya*, along with the present species, and the three Cretaceous species, including the type, *Stolleya microtulipa* Schrammen. The present species, *Stolleya silvigera*, differs from the Cretaceous species of *Stolleya* as noted earlier, and from *Stolleya lithodes* (Bergquist) in the presence of protriaenes, thicker dichotriaenes, with some of them distinctly prodichotriaenes, and thinner oxeas. Unfortunately, the absence of microscleres in the Cretaceous species of *Stolleya* means that this particular subgeneric character must be based on species other than the type (and their presence in the present species, though not in *S. lithodes*, is less than absolutely certain).

The living *Stelletta pyriformis* (Sollas) stands apart from this group in its different microscleres, its

anatriaenes, and the apparent lack of crowding of the dichotriaenes into a tightly-packed cortical armor. The shape of the dichotriaenes is its main point of contact with the *Stolleya* group. We would exclude this species from our concept of the subgenus. Unfortunately, this implies that isolated dichotriaenes of *Stolleya*-type cannot be assigned to the subgenus.

The Jurassic *Prostolleya cylindrata* Lagneau-Herenger 1952, was established for a large (almost a meter long) cylindrical sponge with oxeas, triaenes, and dichotriaenes. Although the large dichotriaenes were described as having thick, stubby cladi ("branches épaisses et trapues") the illustration (Lagneau-Herenger 1952, p. 32) shows that, while this is true, they do not have the typical *Stolleya* form, but are simple plagiodichotriaenes with non-curved primary cladi and non-horizontal secondary cladi. As Lagneau-Herenger noted (*ibid.*, p. 33) the sponge differs in size and shape from *Stolleya* and *Stelletta*. Moreover, the spicules are not radially arranged. Lagneau-Herenger (*ibid.*, p. 32) notes that they are now more or less oblique to one another, but were probably originally arranged parallel to the axis of the sponge. We would not include this sponge in our concept of *Stolleya*.

The species name *silvigera* (Latin: "forest-bearing") refers to the resemblance of the interlaced cortical dichotriaenes and protriaenes to a forest canopy.

The massive interior and dense cortex of this sponge is consonant with the heavy construction of associated species and may be adaptive to rough water conditions. It is possible that the constellation of characters here defined as constituting *Stolleya* is the only way the genetic material of a *Stelletta* can meet the challenge of thickening its skeleton, and that it therefore represents iterative evolution or heterochronous convergence, rather than a single line of descent.

Another specimen (USNM 133145) of about the same size, from the same locality, may belong to this species, but if so it is completely decorticated and bears no trace of the stout triaenes. It consists entirely of a swirling mass of closely-packed, subparallel monaxons, which resembles the interior of either *Stolleya* or *Geodia*. In their slenderness they are closer to those of *Geodia harmatuki*, but there is no trace of the thick, sterraster-packed cortex, or of the subjacent large triaenes, that occur in *Geodia*. A few sterrasters, ophirhabds, calthrops, and *Achrochordiella*-like delicate dichotriaenes, were shaken loose from the specimen during ultrasonic cleaning, but they are probably foreign and from the associated *Geodia*, *Cerberorhaphidites*, and *Achrochordiella* at the same locality. It is nevertheless possible that this specimen is a decorticated *Geodia*, instead of a *Stolleya*, or perhaps some other choristid sponge entirely, or even a root tuft.

**HOLOTYPE:** USNM 133144; this is the sole specimen except for the dubious one discussed above.

**LOCALITY:** USGS 21849.

#### Family GEODIIDAE Gray 1867

**DIAGNOSIS:** Choristida with an endosomal skeleton of radially arranged monaxons (oxeas and/or strongyles) accompanied by large radial triaenes just beneath the cortex; dense, stony cortex packed with either sterrasters or aspidasters and pierced in life by sphinctrate inhalant and exhalant openings (chones) that lead to subcortical spaces; other microscleses oxyasters, accompanied or replaced by sphaerasters, spheres, or microrhabds.

**DISCUSSION:** The presence of sterrasters or aspidasters is the unique feature of this family. However, the inclusion of radial architecture and monaxons in the diagnosis would eliminate the Jurassic *Rhaxella* Hinde which has only sterrasters and which lacks radial architecture. This would be accommodated by the family Rhaxellidae Hinde. The Placospongiidae Gray (*Placospongia* Gray) is homeomorphic to the Geodiidae, but tylostyles replace oxeas, strongyles and triaenes, selenasters replace aspidasters or sterrasters, and spinispires replace oxyasters and sphaerasters.

#### Genus GEODIA Lamarck 1815

**DIAGNOSIS:** Geodiid with radial oxeas in endosome and also in cortex; radial triaenes (mainly plagiо- to orthotriaenes, but variously including dicho-, ana-, and protriaenes) are concentrated in outer part of endosome with cladomes just beneath cortex; cortex packed with true sterrasters; oxysphaerasters (or strongylosphaerasters) and oxyasters scattered throughout, and sometimes also concentrated about canals.

**DISCUSSION:** Other geodiids include *Geodinella* Lendenfeld, in which the triaene cladi are variably aborted; *Caminus* Schmidt, in which tiny spheres occur among the microscleses; *Pachymatisma* Bowerbank, with microrhabds, especially in the outer cortex and strongyles in the endosome; and *Erylus* Gray, with flattened aspidasters replacing the ellipsoidal sterrasters, and strongyles replacing the endosomal oxeas. Several other genera (*Cydonium* Fleming, *Isops* Sollas, *Sidonops* Sollas) sometimes considered subgenera or synonyms of *Geodia*, are distinguished on the arrangement and relative size of inhalant and exhalant openings. *Geodites* Carter (= *Geoditesia* Zhuravleva) and *Geodiopsis* Schrammen have been used for isolated large triaenes found as fossils and thought to be geodiid, but they could belong to other families. The Jurassic *Rhaxella* Hinde consists only of sterrasters and differs from other geodiids in that the sponge is labyrinthine and lacks the usual radial architecture. The hadromerid *Placospongia* has a cortex packed with selenasters, which are homomorphs of *Erylus* aspidasters but arise from crescentic

spinispines rather than from sphaerasters; the main megascleres are tylostyles rather than triaenes. It is apparent from the foregoing discussion that isolated spicules, even sterrasters, cannot be assigned to *Geodia*. Previous fossil occurrences of *Geodia* in the literature (except that of Hurcewicz 1966) appear to have been based on such incomplete material.

**GEODIA HARMATUKI** Finks, Hollocher and Thies,  
new species  
pl. 25, Figs. 3–5; pl. 26, Figs. 1, 2; pl. 27, Figs. 1, 2; pl.  
28, Figs. 1–6; pl. 29, Figs. 1, 2; pl. 30, Figs. 1–3

**DIAGNOSIS:** Discoidal *Geodia* with large sterrasters of 250  $\mu\text{m}$  major axis, and cortex as much as 10 mm thick; stout subcortical orthotriaenes (rhabdomes 6,000  $\times$  200  $\mu\text{m}$ ); endosome a radiating mass of tightly packed oxeas; less closely spaced radial oxeas penetrate cortex and protrude from surface; other probably belonging megascleres include slender plagiotriaenes, dichotriaenes and anatriaenes; other probably belonging microscles include large oxysphaerasters and oxyasters (up to 191  $\mu\text{m}$  in diameter).

**DESCRIPTION:** As preserved, the sponges are irregularly discoidal objects ranging in size from as large as 127  $\times$  100  $\times$  42 mm to as small as 34  $\times$  33  $\times$  10 mm. They were probably compressed to some extent from a more nearly hemispheroidal shape, which is a common shape in the genus. Three individuals seem to be represented, the largest in two pieces. The interior is composed of a radiating mass of closely packed spicules, the center of radiation being approximately at the center of the sponge but closer to what is probably the lower side. They may have a parallel sinuosity like wavy hair. These spicules appear to be very long oxeas; their length could not be measured but it would appear to be less than the distance from center to surface, for spicules frequently begin and end along the radius (they are several mm long, however). They are 50–100  $\mu\text{m}$  in maximum diameter. In the outer part of this zone there are radially arranged, very large, stout orthotriaenes whose cladi lie immediately beneath the cortex. The rhabdomes are 5–6 mm long, with a maximum diameter of 0.2 mm; the cladus length is about 0.8 mm. The rhabdomes, are spaced about 1–2 mm apart. Smaller, slender plagiotriaenes (approaching orthotriaenes) also occur, sometimes in the cortex; their cladome diameter is 0.10–0.75 mm. Dichotriaenes of similar size occur rarely, and one fragmental anchor-shaped anatriaene was found (in radial orientation, cladome outward), 0.10 mm across the cladome and with the shaft broken 0.35 mm from the cladome. In the case of these rarer spicules the question arises whether they belong to the sponge, but they are to be expected in *Geodia*, and it seems reasonable to consider them tentatively as belonging.

The cortex is unusually thick, ranging from 3 to 10 mm, and is packed with ellipsoidal sterrasters that are large for the genus. Fully formed ones, which are the majority, are rather uniformly 250  $\times$  200  $\mu\text{m}$  and bear a hilum on one long side about 37.5  $\mu\text{m}$  in diameter. The surface is minutely tuberculate. Less frequent smaller sterrasters, down to about 150  $\mu\text{m}$  major axis also occur (a dubious one of 83  $\mu\text{m}$ ). Developmental stages of these sterrasters, in the form of oxysphaerasters with a solid centrum, also are present. A typical example has a solid centrum 62.5  $\mu\text{m}$  in diameter with numerous rays projecting some 25  $\mu\text{m}$  beyond its surface to make a total diameter of 112.5  $\mu\text{m}$ . Oxyasters without a well-developed solid centrum also occur, perhaps even more abundantly; they range in diameter from 88 to 191  $\mu\text{m}$ . They tend to have fewer rays than the sphaerasters (estimated at 8–20, the sphaerasters overlapping this range but running to more than 20). The rays are about 25  $\mu\text{m}$  in basal diameter. They may be early stages of sterrasters or more likely they are part of the regular complement of oxyaster microscles characteristic of *Geodia*, especially as they are mostly larger than the sphaerasters with centra. Most of the sterrasters are found in the cortex, but a few, along with at least one sphaeraster, are scattered in the endosome (sometimes in radial trains of two or three), where they are produced in living *Geodia*. The sphaerasters measured were shaken loose from the specimen during ultrasonic cleaning. The possibility exists that some, or all; may have been foreign ones derived from the matrix. However, they are to be expected in *Geodia*, and tentatively we consider them as belonging to it. (See also the discussion under *Stolleya silvigera*). The cortex is penetrated by radial oxeas similar to those of the endosome but less closely spaced. They are spaced 0.2–1.5 mm apart (mostly about 0.5 mm) and protrude slightly above the surface. The tips of most are broken off but enough are preserved to reveal that they are oxeas. Their lengths are in excess of 6 mm. Very small, fine oxeas, down to 125  $\times$  10  $\mu\text{m}$ , parallel the larger ones in both cortex and endosome. Subcircular pits, 2 to 14 mm in diameter, are scattered irregularly over the surface of the largest specimen. They may represent the sites of large, exhalant chones, or in the case of the largest, of a cloacal depression.

**DISCUSSION:** These specimens are sufficiently complete, in structure and spiculation, to be assignable to the living genus *Geodia*. The only diagnostic features that living material would supply would be the smaller sphaerasters and the structure of the exhalant and inhalant pores and canals. The presence of the larger sphaerasters renders the smaller unnecessary. Subgenera of *Geodia*, recognized by some as full genera, have been established on differences in the distribution and relative size of exhalant and inhalant chones (aquiferous

openings through the cortex). The presence of large sized openings in the cortex of the present specimens, if they represent large exhalant chones, or cloacal depressions, would place this species in *Geodia* sensu stricto.

This species of *Geodia* is characterized by its extremely thick cortical layer of sterrasters and the extremely dense packing of endosomal oxeas, in which they are not organized in separate bundles or fascicles, as well as by the thickness of the subcortical orthotriaenes, the large size of the sterrasters, and the large size of the oxyasters. The predominance of orthotriaenes over other forms of triaenes, while not unique, should also be considered a species character in conjunction with the rest. These specimens to our knowledge are the first nearly complete individuals of *Geodia* reported from the fossil state. Hurcewicz (1966, p. 25–26, pl. 1, figs. 1, 2; text-fig. 3) described a Cretaceous *Geodia* sp. from three fragments of coherent skeleton, the only other coherent fossil material known to us. The sterrasters were smaller than ours but similarly ellipsoidal ( $90\text{--}195 \times 90\text{--}150 \mu\text{m}$ ). The thickness of the cortex is not given. Megascleres in the cortex include oxeas and radial orthodichotriaenes; those in the endosome include oxeas, protriaenes and prodichotriaenes, grouped in obliquely disposed, numerous, large bundles. The cortical oxeas are  $300 \mu\text{m}$  long, those of the endosome are as large as  $5,000 \times 30\text{--}210 \mu\text{m}$ . The endosomal protriaenes and prodichotriaenes are up to  $2.5 \text{ mm}$  in rhabdome length with cladus length  $150 \mu\text{m}$ ; the rhabdome thickness is not given but the illustration (*ibid.*, text-fig. 3) shows it to be the same as the oxeas. The cortical orthodichotriaene rhabdome length is not given but the cladome diameter is stated to be  $150\text{--}210 \mu\text{m}$ . The triaenes attain, and the oxeas exceed, the stoutness of those of the present species, but the cladomes are much smaller in diameter with stubby rays, and the cortical triaenes are orthodichotriaenes rather than the simple, but broader-cladomed, orthotriaenes of the present species. Hurcewicz compares the endosomal prodichotriaenes to the dichotriaenes of *Stolleya ornatissima* Schrammen (see the discussion herein under *Stolleya silvigera*). Her illustration (*loc. cit.*) shows them to lack the horizontal flattening of the secondary cladi seen in the *Stolleya* species of Schrammen, but there is a certain resemblance. We cannot find a clear side view of the dermal orthodichotriaenes in her illustrations. There seems little doubt that her species of *Geodia* is different in spicule form and interior arrangement (criss-crossing bundles) from the present species.

Among living species, *Geodia rex* Dendy 1924, merits comparison (Dendy 1924, p. 311–312; pl. 6, fig. 4; pl. 8, figs. 23–28). This has the thickest cortex and largest spicules of any known geodiid. Its cortical sterraster layer is 6 mm thick, comparable to that of the present

species. The sterrasters themselves are even larger, being  $480 \times 400 \mu\text{m}$ . Cortical orthotriaenes have a longer rhabdome than those of the present species ( $1,000 \mu\text{m}$ ) but the rhabdome is thinner ( $100 \mu\text{m}$ ) and the cladi shorter ( $630 \mu\text{m}$ ). The internal oxeas are of about the same size though not as densely packed. The large oxysphaerasters (diameter  $20 \mu\text{m}$ ) and small oxyasters (diameter  $10 \mu\text{m}$ ) are much smaller than the corresponding microscleres of the present specimens. Anatriaenes are present but not dichotriaenes. *Geodia rex* also differs from the present species in having a cup-like external form, but it is perhaps the closest of any known species in spiculation and spicule size. The living *Geodia (Cydonium) hirsutus* (Sollas; see Sollas 1888, p. 218) and *Geodia (Synops) macandrewii* (Bowerbank; see Sollas 1888, p. 265) have cortices approaching that of the present species in thickness, and sterrasters even larger, but orthotriaenes are replaced by less thick dichotriaenes, and at least the first species has a very open endosome. *Geodia macandrewii* is from Norway at 100 fathoms, *G. hirsutus* from the Ki Islands, Indonesia, at 140 fathoms, and *G. rex* from New Zealand (off Three Kings Islands or North Cape) with no depth given.

The unusually large spicules, thick cortex, and dense endosome of the present species, would seem to be adaptive to high mechanical stress. This is probably significant in view of its association with other unusually heavily constructed species such as *Stolleya silvigera*, and *Sheldonia syndocus*, as well as the relatively onshore paleoposition of the locality. It must be admitted that two of the living species with heavy cortices come from relatively deep water (depth of *G. rex* is not known) but they all lack the dense endosome of the present species.

We name this species in honor of Mr. Peter J. Harmatuk, who guided us to field localities and provided part of the collections studied.

**MATERIAL:** Three, possibly four, silicified specimens. The largest (USNM 133146) is essentially a complete sponge with cortex preserved all around; it is fractured subsagittally to reveal the interior radial structure. The smallest (USNM 133148) is half a spheroidal sponge with cortex on one side and a sagittal section through the center of radiation on the other; it reveals a particularly fine radial section through the cortex. The intermediate-sized specimen (USNM 133147) is approximately the median half of a discoidal sponge, with essentially a complete cortex preserved on the two flat sides, but fractured transversely at opposite ends. A fourth very small specimen (USNM 133149) consists largely of radial monaxons, but a few adherent sterrasters probably belong and would make it a decorticated *Geodia*.

**TYPES:** Holotype USNM 133146, paratypes USNM 133147, 133148.

LOCALITY: USGS 21849.

Subphylum NUDA Bidder 1929

DIAGNOSIS: Mesoglea absent; spongin fibers absent; choanocytes form a syncytial sheet; spicules silicious.

Class HEXACTINELLIDA Schmidt 1870

DIAGNOSIS: Prindipal spicules with rays that follow the axes of a cube.

Subclass HEXASTEROPHORA F. E. Schulze 1887

DIAGNOSIS: Microscleres hexasters.

Order HEXACTINOSIDA Schrammen 1903

DISCUSSION: Following Reid (1958), this order includes all hexactinellids whose principal (parenchymal) skeleton is formed of linear series of fused hexactins (dictyonal strands) which lack open octahedral (lychnisc) nodes. Reid (1964) divides hexactinosan skeletal architecture into three types: *farreoid*, *euretid*, and *aulocalycoid*. The *farreoid* skeleton is formed of a single sheet of parallel dictyonal strands, to which a secondary layer may be attached. The *euretid* skeleton consists of many parallel dictyonal strands that are not organized into sheets and are oblique to the body wall. The *aulocalycoid* skeleton is formed of non-parallel dictyonal strands that are irregularly interwoven within layers parallel to the sponge surface. Most hexactinosans are *euretid*.

Family EURETIDAE Zittel 1877, emend. Reid 1964

DIAGNOSIS: Hexactinosida with euretid skeletal net and absence of canalization in principal skeleton; canals, and/or ostia and postica, if present, are confined to a cortex or other secondary layer.

Genus VERRUCOCOEOLOIDEA Reid 1969, emend

DIAGNOSIS: Cylindrical to funnel-shaped euretids with short lateral tubes in quincuncial arrangement; each lateral tube bearing an axillary oscule on the upper side in addition to the terminal oscule; lateral tubes confluent with an internal system of plexiform (and spiral?) longitudinal tubes that are only partly skeletalized; a cortex with ostia developed on the dermal side.

TYPE SPECIES: *Verrucocoeloidea burtoni* Reid 1969.

Subgenus VERRUCOCOEOLOIDEA Reid 1969  
(*nomen translatum*), new subgenus

DIAGNOSIS: Funnel-shaped *Verrucocoeloidea* (as emended above) in which the internal system of longitudinal tubes forms a lining to the interior of the funnel; lateral tubes terminally open by a single oscule but may be contracted or hood-shaped; dermalia and gastralia pentactins; microscleres uncinate, scopules,

oxyhexasters, discohexasters, and variants approaching diasters.

TYPE OF SUBGENUS: *Verrucocoeloidea burtoni* Reid 1969.

Subgenus EURETELLA Finks, Hollocher and Thies, new subgenus

DIAGNOSIS: *Verrucocoeloidea* (as emended above) in the form of narrow, branching cylinders, in which the internal system of longitudinal tubes occupies the entire axial space; lateral tubes flaring and either terminally open or covered by a low dome that bears one or more circular oscules side by side; dermalia, gastralia, and microscleres unknown.

DISCUSSION: This subgenus is intermediate between *Eurete* Semper 1868, which consists of simple, branching or anastomosing tubes, and *Verrucocoelium* Etallon 1864, which consists of a central tube or funnel, emitting short lateral tubes that usually contract terminally. It is very close to *Verrucocoeloidea* Reid 1969. It differs in not being funnel-shaped but rather narrowly cylindrical and branching. Reid (1969, p. 489) considered the presence of branching protuberances projecting into the lumen of the central funnel to be the "main distinctive feature" of *Verrucocoeloidea*. These were said to arise from "local longitudinal plications of the axial wall between adjacent external out-growths" and their inner ends "spread out to form an incomplete secondary lining" (*ibid.*, p. 485). The internal structures of the present genus completely bridge the interior space. This could be the consequence of the much narrower axial space of the present subgenus. Reid notes that the spaces between the internal protuberances "form incompletely enclosed and laterally intercommunicating longitudinal tunnels" (*loc. cit.*). This suggests that we are dealing with the same kind of internal structure in the two subgenera. Nevertheless, we will maintain this as a separate subgenus on the basis that the axial space of the present genus seems nothing more than the incompletely separated bases of the lateral tubes together with possible spirally wound tubes connected with them. The possibly equivalent structures in *Verrucocoeloidea* form a peripheral ring about a central open space. The flat terminal caps on some of the flaring lateral tubes of the present genus, with their multiple oscules, also appear to be peculiar to the subgenus, although the "beaklike outgrowth tending to divide the terminal oscula" in some species of *Periphraggella* Marshall 1875, though not the type, (Reid 1969, p. 490) may be incomplete equivalents. The branching habit, with cylindrical branches, not only distinguishes this subgenus from *Verrucocoelium*, but likewise from *Verrucocoelium* Etallon 1864, *Heterochone* Iijima 1927, *Periphraggella* Marshall 1875, and *Proeurete* Schrammen 1902. The last two, as interpreted by Reid (1969, p. 491),

are characterized by terminal anastomosis of the lateral tubes. It should be noted however, that the presence of axillary oscules on the upper surfaces of the lateral tubes is a peculiar feature which the present genus shares with *Verrucocoeloidea*. The arrangement of lateral tubes in horizontal whorls at first appears to be unique to the present subgenus. Their occurrence in whorls of three at 120°, with alternate whorls rotated by 60° so that the tubes of every other whorl line up in longitudinal rows, is here treated as a specific character. It is worth noting, however, that lateral tubes of *Verrucocoeloidea* were reported to "occur partly in rough longitudinal series, but some alternate in position" (Reid 1969, p. 486). The illustration (*ibid.*, figs. 1, 2) shows a quincuncial arrangement which automatically yields horizontal whorls in alternating position. The narrowness of *Euretella* emphasizes the whorled arrangement, but it is also a quincuncial one. The location of the internal protuberances in *Verrucocoeloidea* between the lateral tubes can be interpreted as a consequence of their outlining longitudinal tubes *opposite* the lateral tubes. Such an arrangement of the internal tubes is also present in *Euretella*. In both subgenera the lateral tubes may be given off from internal longitudinal tubes, perhaps spiral, perhaps plexiform, in arrangement. In *Euretella* these tubes (three in number in the only known species) occupy the entire interior space. *Verrucocoeloidea* is also larger than the present subgenus both in overall size and in the size of lateral tubes. A basal, cylindrical stalk approximates the size of *Euretella* cylinders but it is significant that that part does not bear lateral tubes. Thus *Euretella* cannot be considered merely an immature *Verrucocoeloidea*.

TYPE OF SUBGENUS: *Euretella corallina* Finks, Hollocher and Thies, new species.

EURETELLA CORALLINA Finks, Hollocher and Thies, new species

pl. 30, Figs. 4–6; pl. 31, Figs. 1, 2; pl. 32, Figs. 1, 2; pl. 33, Figs. 1, 2; pl. 34, Fig. 1

DIAGNOSIS: Lateral tubes emitted in whorls of three at 120°; alternate whorls offset by 60° so that lateral tubes in every other whorl line up to form a longitudinal series.

DESCRIPTION: The largest (USNM 133150) of the five known specimens consists of a zig-zag series of six straight cylindrical branches, each approximately 8 mm wide and 20 mm long. Each branch is emitted at approximately midlength of the preceding branch, at an acute angle or at 90°, and except for the distalmost branch, nearly in the same plane. A second specimen consists of a single curving stock of approximately the same dimensions as one of the branches of the preceding specimen; it was found with its two ends in contact with, but not firmly attached to, the upper surface of the

holotype of *Robinia striatopunctata*. Three other specimens were discovered subsequently, two unbranched fragments, and a larger two-branched specimen. Arising from the central axis of each branch are separate lateral tubes, of circular to elliptical cross section, mostly about 3 mm in diameter (range: 2.5–6.0 mm) and about 2 or 3 mm long. The walls of these tubes are less than 1 mm thick (mostly about 0.7 mm) and flare outward. Some are covered terminally by a relatively flat sheet of skeletal net, similar to that of the wall, and pierced by a large circular opening, 1 or 2 mm in diameter, which may be flanked by one or two smaller circular openings about half that size. The majority of the tubes are completely open terminally. Nearly all the tubes bear a single circular opening near their base, a so-called axillary parietal osculum 1.0–1.5 mm in diameter, penetrating the wall on the side facing upward or distally relative to the growth of the sponge. Branching appears to take place, though this is not totally certain, by extension of one of the lateral tubes well below the distal end of the preceding branch. The distal ends of the last three branches of the large specimen are open to the interior and indicate that there is no well-defined axial tube. The axial ends of the lateral tubes intercommunicate in such a way as to suggest that each arises from one of three spirally wound interior tubes that are only incompletely separated from one another so that the curving tubular walls form interconnecting bridges that cross the interior space and coalesce in the center. The pitch of the spiral would appear to be fairly high and wound in a counterclockwise direction as viewed from the top. The simplest model would have lateral tubes emitted along each spiral tube at 60° intervals radially and at the same horizontal level in each tube. This would produce whorls of three at 120° with successive whorls offset by 60°. If one follows the lateral tubes around the outside of the present specimen they occur at 60° radial intervals along a spiral of about 60° pitch angle, which agrees with what can be observed of the interior tubes. They are spaced along this spiral at about 7 mm intervals, the whorls at 5 mm vertical intervals. Emission of lateral tubes at 180° radial intervals would also give whorls of three with successive 60° offsets, but the pitch angle would have to be much lower than seems to be the case in order to produce the observed spacing of lateral tubes.

The dictyonal strands of the tube walls emerge to the dermal side (and possibly also to the gastral side) at a low angle. The gastral surface seems to have only the longitudinal dictyonal strands of the principal skeleton, with predominantly quadrate mesh spaces. The dermal surface at the tube rim reveals end views of the dictyonal strands with predominantly triangular mesh spaces, but most of the exterior surface seems to be covered with a secondary dermal cortex including possible paratangen-

tial dictyonal strands that curve about circular to elliptical, ostia-like openings up to 0.55 mm in diameter (mostly 0.3–0.4 mm). These ostia do not lead into canals, and in some the dictyonalia of the underlying skeleton cross beneath them. The cortical mesh spaces are partly quadratic but mostly less regular and frequently smaller than those of the inner net. Short distal rays project slightly above the surface. Nodes throughout the skeleton are slightly enlarged; this is more pronounced in the dermal cortex where all the rays are noticeably thickened and the corners of the mesh spaces rounded. All spicule rays are smooth. The spicule rays of the dermal cortex lie closer than the usual net spacing to those of the underlying principal net. The cortical spicule rays sometimes lie at an angle both to the surface and to the underlying rays, and sometimes slant beneath one another.

**DISCUSSION:** The general appearance of the sponge is strikingly similar to that of the scleractinian coral *Oculina*, with the lateral tubes corresponding to the corallites, whence the specific name. It also bears a superficial resemblance to the lychniscosan *Polyblastidium* Zittel 1877, but the internal structure is quite different.

The basal end was determined from the direction of branching. The sponge terminates at this end along a slanting surface at an angle to the central axis. One would tend to consider this a broken surface because it truncates two, possibly three, lateral tubes, reducing them to hemicylindrical flanges. Nevertheless, it is possible that this was the original base. The outer, flaring ends of some lateral tubes are partly closed over by skeletal net; this appears to be related to incipient branching, for in some cases two circular openings are left.

Fragments of *Druidia* and twiggy bryozoa were found in the matrix cleaned from the sponge but not directly overgrown by the sponge. A patch of bryozoa encrusts the sponge in one place and serpulid(?) worm tubes in two others; all three occurrences are near the lips of lateral tubes suggesting the possibility that they were commensal.

**MATERIAL:** Five specimens, siliceous.

**HOLOTYPE:** USNM 133150; paratypes USNM 133151–133153.

**LOCALITY:** USGS 22389.

**MEASUREMENTS:** (Additional to those in the description; all in millimeters.)

Lateral spacing of dictyonal strands: 0.2–0.3.

Spacing of nodes along dictyonal strands: 0.2–0.3.

Diameter of dictyonal strands: 0.05.

Diameter of nodes: 0.10.

Diameter of strands in cortex: 0.0375–0.0750.

Diameter of nodes in cortex: 0.15.

Spacing of nodes in cortex: 0.175–0.425.

Diameter of cortical mesh spaces: 0.050–0.550.

Family CRATICULARIIDAE Rauff 1893, emend.  
Reid 1964

**DIAGNOSIS:** Hexactinosida with euretid skeletal net and diplorhytic canal system in which radial epirhyses and aporhyses are arranged in alternating longitudinal rows, generally with canals of each kind having a quadrate arrangement and both kinds together having a quincuncial arrangement (thus ostia and postica each have a quadrate arrangement), scopules present in living forms.

Genus LAOCOETIS Pomel 1872

**DIAGNOSIS:** Craticulariid in the form of a thin-walled cone built of dictyonal strands emerging to both dermal and gastral surfaces; both surfaces covered by a thin, superficial meshwork, which may contain synaptilae and may cover the ostia; a root-like or tuber-like basal mass is formed of an irregular dictyonal net which may extend a variable distance up the side of the sponge, covering the dermal superficial meshwork; the basal mass may contain sinuous longitudinal grooves passing downward into similar canals; ostia and postica circular and in regular quadrate arrangement on their respective surfaces.

**DISCUSSION:** According to Reid (1964, p. cliii) *Laocoetis* differs from the very similar *Craticularia* Zittel in lacking stauractins as a component of the superficial dermal mesh.

LAOCOETIS SP. cf. L. CRASSIPES Pomel 1872  
pl. 34, Figs. 2–5; pl. 35, Figs. 1–3

*Laocoetis crassipes* Pomel 1872, p. 93.

**DESCRIPTION:** The specimens are all molds in a marly matrix. One (USNM 133156) consists of a fairly complete internal mold of the gastral surface (a steinkern of the cloacal cavity) to which adheres a small patch of about half the thickness of the wall having a mold of the dictyonal net. A smaller fragment (USNM 133158) preserves, as a mold, part of the gastral surface and the entire thickness of the wall seen in section. Other fragments include a small piece of the wall that preserves the dermal as well as the gastral surface (USNM 133157) and two large fragments that may preserve a basal skeleton (USNM 133154, 133155).

One of the latter is a nearly complete smaller sponge that preserves the upper rim of the cup (USNM 133154). Both sponges (USNM 133154, 133155) have the form of thin-walled cones. The wall is about 5 mm thick, the whole sponge may be in excess of 195 mm high and 120 mm wide at the top (the dimensions of the largest specimen, USNM 133156, which lacks about 50 mm of the basal end and an unknown length of the upper end). The cone angle is about 50° near the base and widens upward. The largest specimen (USNM 133156) is

considerably flattened and broadly collapsed inward near the upper end.

The smaller, but nearly complete, specimen (USNM 133154) that preserves the upper rim is strongly fluted near this upper end. This may not be because of collapse but may be a natural feature of the sponge. Circular postica, 1.0–1.5 mm in diameter, are arranged quadrately in longitudinal and transverse rows, 2.0–2.5 mm apart in both directions. They are surrounded by a partly irregular but mostly quadrate gastral mesh, with rounded to square mesh spaces 0.1–0.2 mm in diameter. In places this mesh can be seen to grow part way across the opening of the posticum. These gastral spicules are hexactins, and possibly pentactins, as indicated by molds of the proximal ray on the small fragment preserving the surface of the wall, and by the frequent presence, but occasional lack, of a distal ray on the steinkerns. (It is possible the lack is because of poor preservation.) Stauractins seem not to be present. The wall is composed of longitudinal dictyonal strands that curve gently upward and toward the gastral surface in the inner half of the wall, and toward the dermal surface in the outer half of the wall. They are spaced 0.2–0.3 mm apart, the transverse beams are spaced 0.3–0.4 mm apart. The small fragment of dermal surface available has an almost continuous fine, regular quadrate mesh, with mesh spaces about 0.2 mm in diameter. These spicule molds are poorly preserved but a proximal ray seems to be present, making them hexactins (or pentactins). Stauractins seem not to be present. The ostia seem to penetrate this mesh as small circular openings, 0.5 mm or less in diameter, and arranged in quadrate pattern 1.5–2.0 mm apart. Where this mesh is abraded, canals of diameter 0.5–0.8 mm are visible in quincuncial arrangement about 1.0 mm apart, and appear to represent both epirhyses and aporhyses, each of which extends nearly the whole thickness of the wall. Immediately beneath the dermal and gastral fine outer mesh the main dictyonal net is seen to be non-quadrata, presumably owing to triangular mesh spaces outlined by the beams connecting the emerging dictyonal strands. Preservation is not good enough to see whether this irregular aspect is the equivalent of the fine "lacework" reported by Moret (1924, p. 21) between the cortex and the interior net, but his photograph (*ibid.* pl. 4, fig. 1) suggests not, as it is much finer than the main net, and also reportedly does not occur beneath the gastral surface. The root-like or tuber-like basal mass characteristic of this genus is not preserved. However, a large fragment of wall having a less regular dictyonal net than usual may be part of a basal mass, for it contains in one place four subparallel, sinuous canals, longitudinally oriented within the plane of the wall, about 1 mm in diameter and separated laterally by their diameter or more, which coalesce in an upward direction. Moret

(1924, pp. 21–22, pl. 3, figs. 3, 7, 8) described similar structures from the basal mass of *Laocoetis crassipes*. Another poorly preserved but largely complete specimen contains similar, but relatively straight and unbranched longitudinal canals in the lower part of the wall.

**DISCUSSION:** These specimens, so far as they are preserved, are close to the type species, *Laocoetis crassipes* Pomel 1872, from the Miocene of Algeria. The material is not sufficiently well preserved to separate this as a new species, though it may in fact prove to be separable when better material is studied, or, perhaps, when the same material is studied better. The fine siliceous net beneath the dermal cortex, reported by Moret, seems not to be present.

Traces of encrusting bryozoa and worm tubes occur on both gastral and dermal surfaces.

**HYPOTYPES:** USNM 133154-133158.

**LOCALITY:** Ideal Cement Co. Quarry (9 specimens).

Family CRIBROSPONGIIDAE F.A. Roemer 1864,  
emend. Reid 1964

**DIAGNOSIS:** Hexactinosida with euretoid skeletal net and diplorhytic canal system; longitudinal rows of canals include alternating epirhyses and aporhyses; the canals usually alternate laterally between adjacent rows so that the openings of each type of canal have a quincuncial pattern on their respective surfaces.

**DISCUSSION:** The Family Craticulariidae Rauff 1893, emend. Reid 1964, differs from this one in that each longitudinal row consists only of epirhyses or aporhyses, usually arranged so that the openings of each form a quadrate pattern on their respective surfaces. Critical to Reid's separation of the two families is the ability to recognize longitudinal rows, that is, rows perpendicular to the growing edge of the sponge, for if one pattern is turned through 45° it becomes indistinguishable from the other. For sponges preserved only as fragments, such as *Haynespongia*, this may present a problem. However, one can use the direction of emergence of the dictyonal strands as a pointer towards the growing edge of the sponge. On this basis *Haynespongia* would appear to be a Cribrospongiid but it must be admitted that clear rows, in any direction, do not exist. It would seem not to fit into the Euretidae as characterized by Reid (1964, p. cxlv) in which epirhyses and aporhyses are limited to external secondary meshwork or to a cortex. Reid does admit forms without linear arrangement of canals into his Cribrospongidiidae (e.g., *Andreaea*, *ibid.*, p. cv). On this basis, and especially because of its resemblances to *Guettardiscyphia*, we assign *Haynespongia* to the Cribrospongidiidae. Also some cribospongidiids have a complex system of branching, and even labyrinthine, epirhytic, and aporhytic canals as in *Haynespongia*, such as *Polyopnesia* Schrammen 1902, (see Reid, *ibid.*, p. cvi). Likewise the

Eocene *Pseudoguettardia* Moret 1925, otherwise like *Guettardiscyphia*, has an irregular arrangement of canals.

Genus HAYNESPONGIA Rigby 1981

*Haynespongia* Rigby 1981, p. 138.

**DIAGNOSIS:** Cribrospongiid with differentiated central cone surrounded by radial, hollow, vertically oriented fins passing into radial, branching tubes; terminus of each tube a large circular opening; large elliptical openings (parietal gaps) along sides of tubes and edges (especially basal?) of fins; central cone with a single vertical row of large, horizontally elongate elliptical openings, separated by narrow bridges, opposite the inner end of each fin, and fused to outer body wall opposite each interfin angle, where it bears sharply outlined aporhytic pits scattered over its inner surface. Canal system diplorhytic with partial epidiarhysis, and separate (?) epihytic and aporhytic branching canal systems, perhaps labyrinthine; neither prosopores nor apopores in regular rows; dictyonal strands beginning sub-tangential to gastral surface of fins and tubes and curving to run perpendicular to dermal surface where they protrude as conical spines; a separate layer of tangential dictyonal strands may be present on gastral surface; dictyonal strands perpendicular to central cone surface.

**DISCUSSION:** This differs from *Guettardiscyphia* De Fromentel 1860, and *Pseudoguettardia* Moret 1925, in the presence of the differentiated sieve-like central cone, in the presence of the branching tubes, in the less regular distribution of the aporhytes and epihytes, and in the failure of the latter to open also on the gastral surface. The number of radial fins is probably considerably larger than the four or so usually seen in *Guettardiscyphia* and *Pseudoguettardia*. The branching tubes are like those of the related genus *Hillendia* Reid 1964, but that genus does not have a stellate form or a central cone. It differs from the similarly stellate *Druidia*, new genus, here assigned to the Family Aphrocallistidae, in lacking the honeycomb-like diarhyses, in lacking a thickened dermal cortex, in lacking the more finely-porous sieve over the inner ends of the fins, in the larger parietal gaps, in the branching tubes which are emitted from the edges of the fins, and in the more regular dictyonal net with a hispid dermal surface formed by protruding distal rays. Our material is more complete than Rigby's and enabled us to recognize the central cone and fins, and to reconstruct the external shape more completely.

**TYPE SPECIES:** *Haynespongia vokesae* Rigby 1981.

*Haynespongia vokesae* Rigby 1981

pl. 35, Figs. 4, 5; pl. 36, Figs. 1–8; pl. 37, Figs. 1–

*Haynespongia vokesae* Rigby 1981, p. 140, pl. 2, figs. 1, 3, 4, 6.

**DIAGNOSIS:** *Haynespongia* with numerous (viz., 9–24) subtriangular(?) radial fins and broad central cone. Dermal surface with skeletal pores, rounded by curving and/or thickening of dictyonal rays, quadrate, triangular, or hexagonal-stellate mesh spaces, and prominent hispidation caused by protruding perpendicular rays that are conical and sharply pointed; prosopores leading into epihytes circular, not in regular rows; smaller circular pores lead into intradictyonal spaces (or smaller canals of labyrinthine epihytic system?). Gastral surface lining fins and tubes more delicate-meshed than dermal surface, with irregularly criss-crossing pattern of tangent dictyonal strands, or else parallel subtangent dictyonal strands of main mesh, and without the hispidation of the dermal surface, though occasionally with irregularly oriented protruding rays; apopores larger than prosopores, circular to elongate parallel to strands, but not in clear rows, separated by smaller circular pores that are internal openings of epidiarhyses, but total number of pores per unit area about the same as on dermal surface. Cone surface with dictyonal net like that of dermal surface but with greater thickening of rays and spheroidally enlarged nodes without hispidation; aporhytic pits larger than gastral apopores, their circular to irregular outline sharply defined by curving continuous strand or rays; margins of exhalant openings opposite fins similar.

**DESCRIPTION:** This species is known only from fragments and the shape of the entire sponge must be inferred. It appears to consist of a broad central cup or cone surrounded by radial fins that may be prolonged into branching tubes. The tubes terminate in a rounded end bearing a large circular opening. Elliptical openings of similar size occur along the length of the tubes and along the edges of the fins. The central cone is a distinct entity that is differentiated from the rest of the body wall. It is in direct contact with, and fused to, the body wall opposite each interfin angle, and forms a series of horizontal bridges across the internal opening of each fin. This results in a vertical series of very large elliptical openings opposite each fin, the ellipses being elongate horizontally. Despite its functional position as an exhalant surface, the central cone is closer in dictyonal structure to the dermal surface, and may originate in a downfolding of the outer dermal surface over the upper rim of the cup, rather than being merely a cortical extension of the gastral surface. Or it may be a separate structure entirely, as its canalization is unique. Where it is in contact with the gastral surface of the interfin angle there is a very sharp change in dictyonal structure between the (buried) gastral surface and the cone wall itself. Unfortunately the upper rim of the cone is not preserved in any of the fragments. Neither is its base or lower apex. The total number of radial fins was estimated as nine in one specimen and twenty-four in

another (see below). New fins were intercalated as the sponge expanded upward. The shape of the fins is somewhat uncertain. The one whose outline is most completely preserved is widest at the base, where its edge is pierced by three confluent elliptical openings, and tapers upwards, having a somewhat triangular (or trapezoidal—the top is incomplete) vertical profile. The upward direction was determined by the direction in which the dictyonal strands are convex, curving upward and outward from the gastral to the dermal surface. This form corresponds to that of the fins of *Druidia wilsoni*, including the presence of parietal gaps on the basal edge and, on the largest, the commencement of the fin above the apex of the cone. On the largest fragment of *Haynespongia* the fins are not completely preserved, but appear to expand gradually upward with an undulatory vertical profile. In this case the upward direction was determined by the direction in which a new fin was intercalated between two existing ones; the direction was confirmed by rather obscure dictyonal strand evidence. The tubes appear to have emerged from the edges of the fins, some near the base and others well above the base. Short, rounded protuberances, of the same diameter as a tube, and bearing a circular opening at the rounded end identical to that on a tube, would appear to be incipient or aborted tubes. They occur on fin edges and on the tubes themselves. Like the more fully-developed branches of tubes, they emerge at angles from 45° to 90°, and most often occur on the sides of the tubes, that is, on the narrow edges of the usually elliptically flattened tube. More elongate or elliptical openings occur in the same positions but are more nearly flush with the tube surface; they may represent an earlier stage in the development of branches.

The dictyonal net is euretoid. The strands begin at an oblique angle to the gastral surface, generally at a high angle but in some fragments almost parallel to it, and then curve to meet the dermal surface perpendicularly. Most of their course is subperpendicular to the dermal surface. The convex side of the strand is thus in the direction of sponge growth. When viewed in a section perpendicular to the dermal and gastral surfaces, the net reveals predominantly quadrate spaces, although in the curving canal walls triangular spaces may be present. The dermal surface, which is at right angles to the strands, has both quadrate and triangular spaces, as the strands are in a partly cubic, partly hexagonal, packing. Often there are stellate, usually hexagonal, patterns of rays around each strand. As one approaches the dermal surface the strands and their cross-connections exhibits increasing secondary thickening with enlarged nodes, though a relatively finer outermost layer may be present (it is possible that this outermost layer represents fused dermalia, but it seems to be dictyonal and conforms to

the underlying tetragonal and trigonal mesh spaces). The dermal surface is hispid from the strongly protruding ends of the dictyonal strands, and can be distinguished thereby from the gastral surface. It is possible but not certain, that these ends are microspinose. The mesh spaces of the gastral surface are more irregular in appearance than the dermal because of the oblique course of the strands; when these are subparallel to the surface the most noticeable features are the parallel strands themselves. These are elongate in the direction of growth, which is parallel to the length of tubes, but may be diagonally upward and outward in fins. There is an indication that there may be a superficial layer of single dictyonal strands criss-crossing in random directions over the gastral surface and independent of (but attached to) the main dictyonal net beneath. The resulting irregularly criss-crossing pattern gives a characteristic appearance to the gastral surface. At one spot on one fragment there is a possible stauractin or pentactin with oblique proximal ray seemingly crossing an aporhytic opening. Possibly this is a remnant of a layer of gastralia, but it is more likely merely the end of an oblique dictyonal strand. The dictyonalia are not thickened as they are on the dermal surface. Occasionally very short rays protruding obliquely from a center might be taken for irregularly oriented separate hexactins of a gastral layer fused to the dictyonal net, but they are more likely merely the ends of oblique dictyonal strands with partly developed lateral rays. The gastral surface is irregular but not regularly hispid like the dermal surface; it also has a more delicate appearing mesh owing to the lack of secondary thickening. The central cone has a distinctive dictyonal mesh. It is even more strongly thickened throughout than the dermal surface, with prominent spherically enlarged nodes. The dictyonal strands are uniformly perpendicular to the surface, and with the continuous, thickened lateral connections between them, make the mesh strongly quadrate when viewed from the side, as in the walls of the large exhalant openings or of the aporhytic pits (see below). When viewed from the inner surface of the cone the mesh has partly quadrate, partly triangular spaces like that of the dermal surface, but differs in the absolute lack of any protruding rays and in the absence of the regular circular ostia of the dermal surface. In their place are larger, usually elliptical, but ranging from circular to irregular, aporhytic pits with very sharp boundaries outlined by a continuous, curving, series of lateral connections between dictyonal strands. The same sort of outline marks the edges of the larger elliptical exhalant openings opposite the fins. The lateral walls of both types of these neatly outlined openings are perpendicular to the surface, giving them a "punched-through" appearance. Where the dictyonal net of the central cone is in contact with the body wall between the

fins, it is completely fused to the gastral surface of the net of the body wall, but there is an abrupt change between the patterns of the two dictyonal nets.

The canal system is somewhat difficult to interpret but it appears basically diplorhytic. The dermal surface bears more or less evenly spaced circular openings of epirhyses which follow the dictyonal strands almost to, or in many cases quite through, the gastral surface. These canals are not arranged in regular rows, and one cannot call them either quadrate or quincuncial in pattern. The circular outlines of the prosopores, and of the apopores as well, are produced by the curving of the dictyonalia around them. The remainder of the pores on the dermal surface are also rounded, but by secondary thickening of the dictyonal angles; among this group, somewhat larger "intermediate pores" may be distinguished from the regular intradictyonal spaces or "small pores." Some epirhyses clearly terminate short of the gastral surface in a rounded, finger-like end, others penetrate the gastral surface by a slightly smaller pore, still others maintain their width through the gastral surface. It is not always possible to tell whether the last case is because of abrasion of the gastral surface (sometimes it is), and the filling of most canals with matrix gives us a restricted sample. It is certain that the walls of at least some epirhyses have circular openings of smaller branch canals leaving them. The canals when seen have either a tangential or oblique course. In one, possibly two, cases such a canal appears to connect with an aporhysis (USNM 128050), but all other epirhyses and aporhyses, when side by side, have no cross-connections. The aporhyses are generally of somewhat wider diameter than the epirhyses and are often elliptical in cross section, being elongate in the direction of sponge growth. On the tubes this is often parallel to their length but it may be oblique to length in the neighborhood of branches. They generally terminate considerably short of the dermal surface in a rounded, finger-like end, and frequently bear circular openings of branch canals in their walls. When seen, these canals are either tangential or oblique. There is no documented case of an aporhysis opening directly to the dermal surface unless it be through one of these branch canals, of which none has actually been so traced. The aporhyses are often elongate parallel to the dictyonal strands, but frequently distort or interrupt them. The gastral surface contains two sizes of pores: larger elliptical openings of the aporhyses (averaging  $0.4 \times 0.5$  mm in diameter) and smaller, more circular pores between them, 0.2–0.3 mm in diameter. When traceable, these smaller pores are seen to be gastral openings of epirhyses that penetrate the entire body wall (epidiorhyses of Reid 1964). The dermal surface has circular pores ranging in diameter from 0.2 to 0.4 mm. The spacing of these pores is approximately 0.5–0.7 mm,

center to center. The spacing of the larger elliptical aporhyses of the gastral surface is approximately twice this value, about 1.0–1.4 mm, center to center. Both surfaces have approximately the same total number of pores per unit area. There are two possible conclusions from this evidence: either some of the smaller pores of the dermal surface are dermal openings of the aporhyses, or not all epirhyses penetrate the gastral surface. We favor the latter interpretation because no aporhysis has been seen in section penetrating the dermal surface, while epirhyses have been seen both penetrating the gastral surface and ending blindly. Except for the two instances of apparent direct connection between an epirhysis and an adjacent aporhysis on one specimen (it is difficult to tell whether or not this is because of breakage of the net) there is no evidence of connections between the epirhytic and aporhytic canal systems (other than the mesh spaces of the dictyonal net) nor of labyrinthine anastomosis within a canal system.

The canal system of the central cone is special. Where the cone is in contact with the outer body wall at the interfin angles the cone wall is almost completely penetrated by very large aporhytic pits, of circular to elliptical or submeandriform outline, their small-diameters ranging from 1/2 to 2 mm. They are often but not always, elongate longitudinally. Openings in the rounded bottoms of these perpendicular-walled pits, are of the size of the regular gastral apopores and lead obliquely, sometimes curving, to the aporhyses of the body wall subjacent. There are sometimes similar openings in the side walls of the pits that may connect with adjacent pits, or may lead into tangential canals within the cone wall whose course is obscure. The 1 or 2 mm wide strips of cone inner surface between the pits is remarkably devoid of pores other than intradictyonal mesh spaces, except for a few small (0.2–0.3 mm diameter) circular pores, each leading into a short canal ending blindly, and probably representing an incipient or aborted aporhytic pit, though they could be epirhyses if the cone had its own choanocyte membrane. The bridges crossing the inner open ends of the radial fins have the same appearance as the strips between the aporhytic pits; the occurrences on them of the same small circular pores perhaps strengthens the interpretation of the latter as epirhyses. The bridges are mostly 2–4 mm wide and outline horizontally elongate irregularly elliptical openings, 3–11 mm high, and up to 12 mm wide. (Almost all are incomplete or broken laterally so that the widths are uncertain.) The best proof that these large openings are functionally related to the fins is the fact that where a new fin is intercalated on the largest specimen, the single vertical row of openings splits into two, a vertical bridge dividing what would have been the uppermost opening, into two, smaller openings side by side (see pl. 37, Fig. 2). The outer surface of the inner cone, that is, the

surface of the bridges on the side facing the fin, appears to be the same as the inner surface, that is, revealing only the dictyonal mesh spaces with the exception of the occasional small circular pore of 0.2–0.3 mm diameter. This surface has been prepared out only in a few places for fear of losing the delicate bridge when unsupported.

The best interpretation of the general canal system of this sponge seems to be a diplorhytic one with partial epidiarhysis, and with separate epirhytic and aporhytic branch canal systems that do not seem to be labyrinthine but could be. There is a possibility of a partly developed labyrinthine interconnection between the two systems but the evidence is slight and equivocal. On one specimen (USNM 128052) the aporhyses are locally elongate into schizorhysis-like slits. It is not clear whether this is because of post-mortem damage or to some local abnormality of the specimen.

Available material consists of a large fragment of the central cone with five attached fins (incomplete), an interfin fragment of the central cone with two attached fins (incomplete), a similar fragment but much less complete (though exquisitely preserved), a substantial fragment of a fin wall, two fin edges bearing attached tubes, eleven fragments of tubes, some of them branching, and nine miscellaneous fragments. At least some of this fragmentation took place on the sea floor prior to burial, for a broken edge has been found overgrown by bryozoa. One fragment (see below) may have been broken while still alive, as it exhibits abnormal growth from the broken edge. In addition, there is widespread local fracturing with slight dislocation and re-cementation; in one case (see below) it appears related to post-burial compaction, and this may be the cause of all such dislocation, as there is no indication of healing in life.

The largest fragment (USNM 128036) was prepared with tools out of solid marlstone matrix, unlike the rest which were weathered out and covered merely with residual clay. It is a fragment of the central cone about 90 mm high and includes three vertical rows of large elliptical openings and three intervening prism-face-like strips. The three exterior fins corresponding to the three rows of exhalant openings are also partly preserved, as is one side of a fourth fin. A fifth fin makes its appearance between two of the others about 10 mm below the upper broken edge of the specimen. Opposite it, the uppermost exhalant opening of the row corresponding to the adjacent fin is split vertically by a bridge, one of the two openings thus formed apparently corresponding to the new fin. The fin on the other side of the center fin from the new one also appears to have arisen newly about halfway up the preserved specimen. Thus new fins may possibly be added rather regularly between each two preexisting fins. There has been post-burial deformation of this specimen apparently by compaction,

leading to fracturing and overlapping of most of the bridges separating the exhalant openings, as well as fracturing of the fin walls so that they are now subparallel, presumably in the plane of bedding (see pl. 37, Figs. 2, 3). Despite this deformation, lines drawn perpendicular to the plane of each of the three exhalant-opening rows intersect nearly at a common point and the two intervening angles are consistently 15°. If the sponge was radially symmetrical this would give 24 fins and a central cone radius of approximately 110 mm. The greatest preserved length (incomplete) of a fin is 40 mm. Thus the total diameter of this sponge could be well in excess of 300 mm. Such an extrapolation is of course quite uncertain, as the sponge may not be radially symmetrical and the fragment may be distorted and unrepresentative. The height was certainly in excess of the preserved 90 mm as both top and bottom are broken off. Only the central fin has part of its outer edge preserved. Its margin is undulatory with an amplitude of about 10 mm and a wavelength of about 45 mm. The distal edge is 25–35 mm from the central cone and may expand slightly towards the top. No parietal gaps are preserved. The fins are about 1 cm thick, separated by about 15 mm interspaces at the central cone, their body wall being about 2 mm thick, but thinning to perhaps a millimeter at the interfin angles where it fuses with the millimeter-thick central cone net to make a composite wall of about 2 mm thickness. The central cone wall thins at the bridges and at the margins of the exhalant openings to as little as 0.5 mm. The bridges are straps about 2 or 3 mm across (maximum 6 mm). The elliptical openings they separate are 5–11 mm high, or roughly, one per centimeter of vertical fin height. Their widths cannot be measured accurately because of fracturing and overlapping except in one area, that where the new fin is added. The opening immediately below the new fin is 12 mm wide and 11 mm high. That immediately above it, opposite the new fin, would have been 14 mm wide and 6 mm high, but is divided by a 2 mm wide vertical strap into two openings, 7 mm wide and 5 mm wide. Other openings appear to have fallen within this general size range. The strips of central cone between the fins are each about 15 mm wide. The surface of each is largely convex toward the interior of the central cone but is undulatory. Aporhytic pits are mostly 1–2 mm in diameter (range 0.3–3.0), subcircular but sometimes elongate in various directions, and irregularly scattered but in obscure vertical rows. Part of a tubular root (USNM 128036B) was prepared out of the same block of matrix. It was lodged between two of the fins but its attachment site on the main specimen cannot be determined. Some intervening fragments appear to be missing; they may have been lost during preparation, but the original position of the root in the matrix relative to the rest of the specimen suggests that it may

have been broken off prior to consolidation or even to have belonged to another sponge. It is about 4 cm long, flattened ( $9 \times 13$  mm diameter) and bears two elliptical parietal gaps ( $3 \times 5$  mm and  $4 \times 7$  mm) near one narrow side. A similar opening on the opposite side may also be a parietal gap, or else breakage.

The second largest specimen (USNM 128037) consists of one lateral wall of a nearly complete fin, the adjoining central cone strip and a small portion of the next adjacent fin wall. The central cone strip is 80 mm high but is obviously incomplete. Its width ranges from 5 to 10 mm between exhalant openings. The fin begins some 12 mm above what appears to be the lowermost preserved part of the central cone. (The trace of the adjacent fin, however, extends to the apical end, which may not be complete.) Its lower border extends outward from the central cone at an angle of approximately  $20^\circ$ , continuing more or less straight to its maximum radial extension of about 50 mm, thence running parallel to the central cone for about 30 mm and then running toward the central cone at about  $40^\circ$  to it. It is broken off diagonally at this upper end. The original profile would be basically triangular with a slightly truncated outer angle. If the presumed lower border is assumed to have been horizontal, the central cone apical angle would have been approximately  $40^\circ$  ( $30^\circ$ – $50^\circ$  depending on how one draws a line through the somewhat undulatory lower border). There are traces of two or three elliptical parietal gaps on this lower border, the most complete is  $3 \times 8$  mm, the others of similar size. The presence of parietal gaps on the lower border of the fin corresponds to their undoubtedly position in *Druidia wilsoni*. That this is the lower border is also confirmed by the direction of curvature of the dictyonal strands in the broken edge of the adjacent fin. It must be admitted, however, that this interpretation conflicts with the pattern in the presumably related *Guettardiscyphia*, in which the triangular fins are widest at the upper end which also bears parietal gaps. It also conflicts with the shape of the incomplete fins on the largest specimen, which seem to expand very gradually upward rather than abruptly. The aporhytic pits on the central cone are comparable in size and shape to those on the largest specimen, though they seem more consistently elongate vertically. The broken ends of the bridges and intervening margins of the exhalant openings on the sides of the central-cone strip are also comparable in size and shape to those of that specimen. There is evidence that the present specimen was broken into much its present condition during life. Two of the broken bridges (see pl. 36, Fig. 5) expand at their ends into spheroidal masses of dense and irregular dictyonal net bearing only a few small circular pores. On the other side, an irregular mass, seemingly a fragment of the central cone, is fused to one, possibly two, of the broken bridge-ends. This last may possibly be post-mortem

breakage and diagenetic fusion, but the first two can only be explained by continued abnormal growth from the broken ends of the bridges, which implies that the sponge remained alive after these bridges were broken off, unless one wishes to assume the unlikely case that two larvae of another species of hexactinosan with an irregular net each settled precisely on the broken end of a bridge. The abnormal pattern of the net in these excrescences suggests either that the sponge was moribund, or that the normal pattern of the dictyonal net depends upon its position in a larger intact structure. A portion of normal bridge protrudes from the outer end of the larger spheroidal growth. If the bridge is continuous through the center of the spheroidal mass, then most of the growth was from the intact sides of the bridge rather than from its broken end. It is also possible that there is a break within the spheroidal mass and that the protruding end was still attached at the time to the opposite fin wall. The single interfin angle on this specimen is approximately  $40^\circ$ , which if repeated symmetrically, would give nine fins, considerably fewer than the 24 fins calculated from the  $15^\circ$  interfin angles of the largest specimen.

The relation of the tubes to the rest of the sponge is given by two fragments (USNM 128039, 128042) of fin edges with attached tubes. They demonstrate that tubes could arise from well above the base of the fin (pl. 36, Figs. 3, 4, 8). USNM 128039 has three incipient tubes arising at a single level from what is assumed to be the basal part of the fin from this circumstance (dictyonal strand evidence is equivocal on this fragment owing to the multiplicity of growth vectors). This same fragment (pl. 36, Fig. 4) has a bryozoan colony overgrowing a broken edge, indicating that fragmentation took place on the sea floor prior to burial. Branching of tubes is exhibited by USNM 128040 (pl. 36, Fig. 2).

A small fragment (USNM 128038) of the central cone, an interfin strip with small remnants of the adjacent fin walls, was found wedged between two branches of a specimen of *Achrochordiella vokesi*. It reveals the dictyonal net most clearly of all the specimens. It appears to come from a small, perhaps juvenile, sponge. The central cone strip width is 6–8 mm (between exhalant openings), its (incomplete) height 20 mm, and the exhalant openings are only some 3 mm high, considerably smaller than on the other two specimens. The aporhytic pits are mostly 0.8–1.0 mm in diameter, again smaller than the other specimens. The canals leading into the aporhytic pits and the form of the pits are best seen on this specimen. The gastral surface exhibits, in strongly developed form, a feature seen on some other specimens, namely dictyonal strands running parallel to each other, almost parallel to the gastral surface and very obliquely through the rest of the body wall. Their course on the gastral surface is diagonally

upward and radially outward in relation to the whole sponge, the upward direction being inferred from the direction of widening of the central cone strip.

**DISCUSSION:** The homeomorphy of this species with *Druidia wilsoni* is striking, extending even to such seeming details as the similarity of the epidiarhyses of *Haynespongia* to the true diarhyses of *Druidia*. These similarities and the fact that *Haynespongia vokesae* is a geographic vicariant of *Druidia wilsoni*, the occurrences being mutually exclusive, suggests at first that they might be more closely related than classified here. However, when examined in detail, it is apparent that there is a fundamental difference in canalization, and in the structure of the central cone. The *Druidia* central cone has many small openings over the inner edge of the fin, and no major canalization on the narrow strips in contact with the interfin angles. *Haynespongia* has a single row of very large openings opposite the fins, and numerous aporhytic pits on the relatively broad areas in contact with the interfin angle. Tubes of *Druidia* end blindly and the parietal gaps are small and circular, occurring not only on the tube and fin bases but also on the sides of the fin at the interfin angles. The tubes of *Haynespongia* are terminated by a large circular opening, and the parietal gaps on tubes and fin edges are large and elliptical. Moreover, the canal systems are radically different, with the complex epirhytic and aporhytic branching systems of *Haynespongia* contrasting (despite the epidiarhyses) with the typically aphrocallistid diarhytic system of *Druidia*. Nevertheless there is an interestingly similar correspondence between the size of the parietal gaps and the exhalant openings on the central cone opposite the fins; both are similarly large and elliptical in *Haynespongia* and similarly small and circular in *Druidia*. This suggests that they are connected functionally within the sponge and that they serve the same functions in the two species. Thus they are at least analogous, and possibly homologous. One can only speculate as to the cause of the size differences; it may be related to the different canal systems, or it may be related to the environment, with the larger openings of the possibly nearer-shore *Haynespongia* permitting external currents of the rougher water to pass through the sponge without displacing it.

*Guettardiscyphia* De Fromentel 1860, and *Hillendia* Reid 1964, appear to be closest to the present species. The tubular branches of the latter, in particular, resemble those of the present species with their circular, terminal parietal gaps. However, both published genera lack a differentiated central cone that extends across the inner edge of the radial fins. The main body of *Hillendia* is a saccular structure, corresponding to one of the fins of the present species, from which tubular branches are emitted in all directions. *Guettardiscyphia* has radial fins bearing large parietal gaps on the outer edges and either

open or closed on the top. The fins are open to a central tube which may terminate well below the tops of the fins, or may be coterminous with them; in the latter case, if the fins are closed on the top, a central osculum remains (see Reid 1964, p. lxiii, text-fig. 32). In the last case (*G. stellata* (Michelin) var. *angularis* T. Smith) Reid states (*loc. cit.*, text-fig. 32B) that "there is commonly also a distinct axial funnel" but it is not clear whether this is composed of a differentiated dense dictyonal net that spans the inner edges of the fins as in the present species. A more significant difference from *Guettardiscyphia* may be the more complex arrangement of canals in the present species, although the presence of epidiarhyses is a point of similarity. The epirhyses and aporhyses of *Guettardiscyphia* are apparently unbranched and the epirhyses uniformly penetrate the gastral surface as epidiarhyses. Furthermore both sets alternate within both vertical and horizontal rows, so that the dermal surface bears a quincuncial pattern of prosopores and the gastral surface a quadrate pattern of twice as many pores, apopores alternating with epidiarhytic openings. In *Haynespongia* both surfaces bear approximately the same number of pores and they are not arranged in any regular pattern. The dermal surface bears prosopores, the gastral surface bears apopores plus the openings of those epirhyses that are epidiarhytic. In addition, the possibly labyrinthine branching of both systems is something not seen in *Guettardiscyphia*. A closer genus among the cribrospongiids in the structure of its canal system is *Andreaea* Schrammen 1902, but in that genus aporhyses retain a quincuncial pattern and also penetrate the dermal surface and there are no epidiarhyses. *Stereochlamis* Schrammen 1912, is less regular, but according to Reid (1964, p. cv) of similar canal system. *Polyoplesia* Schrammen 1902, has a more elaborate labyrinth but again the aporhyses penetrate the dermal surface while the epirhyses do not penetrate the gastral. None of these has a stellate form or specialized central cone. *Stichmaptyx* Schrammen 1912, included by Reid (1964, p. cxlvii) in the Cribrospongiidae, has a similarity in gross structure in that the body wall is folded into fin-like and tube-like structures, but there is apparently no central cone or regularly radial fins. The canal system is diplorhytic with larger aporhyses, but no mention is made by Schrammen of branching canals, and the arrangement of prosopores and apopores is more regularly quincuncial than in *Haynespongia*. The Jurassic *Stauroderma* Zittel, placed by Reid (*loc. cit.*) in a separate family, has a highly labyrinthine diplorhytic canal system which is more irregular than that of *Haynespongia*, with less well defined principal epirhyses (see Reid 1964, text-fig. 52d). It has certain similarities, however, namely, the opening of the epirhytic system on the gastral as well as the dermal surface, and the pit-like appearance of the main

aporhyses. The external form (funnel-like) and the furrowed surfaces partly or wholly covered by fused dermalia and gastralria, seem unlike those of *Haynespongia* (see Reid 1964, text-fig. 57a-d).

The Eocene genus *Pseudoguettardia* Moret 1925, merits serious comparison because of its contemporaneity. It was established for the species *Guettardiscyphia thiolati* (D'Archiac 1846) and *G. quinquelobata* (D'Archiac 1848) from the Eocene of the vicinity of Biarritz, France, amplified by details of skeleton and canalization in specimens from Gurb, near Barcelona. These species share with *Haynespongia* an irregular disposition of the epirhysial and aporhysial openings in contrast to *Guettardiscyphia* in the strict sense. They differ from *Haynespongia* in the apparent absence of a differentiated central cone (cf. D'Archiac 1846, pl. 5, fig. 15; pl. 8, fig. 6) and in the absence of lateral tubes. It should be noted that lateral bridges across the internal opening of the fins are present in both genera and also occur in *Guettardiscyphia* (see Moret 1925, p. 17). The number of fins ranges from 4 to 7 in the complete specimens illustrated by D'Archiac (*loc. cit.*); this is much smaller than that estimated for *Haynespongia*, whose largest specimen, though incomplete, could hardly have had fewer than twice this number. The branching nature of the internal canal system seen in *Haynespongia*, as well as the presence of epidiarhyses, has not been reported from *Pseudoguettardia*; Moret (1925, p. 16) reports a condition of simple diplorhysis, with alternating blind inhalant and exhalant canals perpendicular to the surface. Because of the non-linear arrangement of the pores, there is difficulty in determining whether *Pseudoguettardia* follows a cribrospongiid or a craticulariid pattern of canalization. Inasmuch as Reid recognizes irregular arrangements in the cribrospongiids, but not in the craticulariids, *Pseudoguettardia* would best fit in the cribrospongiids. The variety described by Moret (1925, p. 16-17, pl. 1, fig. 9) from Catalonia, *Pseudoguettardia thiolati* var. *gurbensis*, has pores separated by less than their own diameters, thus more closely spaced than those of *Haynespongia*; the parietal gaps are also smaller than those of *Haynespongia*, being 1-2 mm in diameter. These last two differences are probably best regarded as of the species level, but the presence in *Haynespongia* of lateral tubes, central cone, branching canals and epidiarhyses, as well as the larger number of fins, we would consider as justifying a generic separation. Moret (1925, p. 16, pl. 1, fig. 9) also mentions and illustrates shallow circular depressions in *Pseudoguettardia* from Catalonia, about 2 mm in diameter as illustrated, regularly spaced about 5 mm apart on the external surfaces of the fins; they presumably do not penetrate the wall and their nature is unknown. Perhaps they are because of epizoans, but their spacing is so regular that they seem an integral part of the sponge.

**MATERIAL:** One large fragment including four fins, one wall of a fifth, and the corresponding parts of the inner cone; another large fragment, including portions of two fins and the inner cone; one large, and six small, fragments of fin walls; two fragments of fins with attached branches; 13 fragments of tubular branches, including two with side branches; and a small, but exquisitely preserved, fragment of the interfin strip of the central cone, fused to the corresponding part of the outer wall (it was found in its fragmental state, wedged between two branches of a specimen of *Achrochordiella vokesi*, and was freed from the matrix). All are preserved as silica locally permineralized with silica. Adherent, rusty-colored, clayey matrix is full of spicules, including stout triaenes and ophirhabds.

**TYPES:** Hypotypes USNM 128036, 128036A, 128036B, 128037-128056.

**LOCALITY:** USGS 21849.

**MEASUREMENTS:** (in mm; measurements separated by semicolons are from different specimens).

Height of sponge (to top of cone): 20+; 84+; 90+.

Diameter of sponge (to edge of fins): approx. 120; approx 300.

Radial length of closed fins: 25-35; 55.

Height of fins: 62+; 90+.

Thickness (double wall) of fins: 6-9.

Number of fins: 9; 24 (both estimated).

Interfin angles: 15°; 40°.

Diameter of top of cone: approx. 50; approx. 110.

Cone apical angle: 30°-50° (estimated).

Width of interfin strips of central cone: 5-15.

Diameter of exhalant openings of inner cone opposite fins: vertical, 3; 5-11, horizontal, 5-12.

Width (vertical) of bridges between exhalant openings: 2-6 (mostly 2-4).

Thickness (radial) of bridges: 0.5-1.5.

Diameter of parietal gaps (on fins and roots): (elliptical 2 × 4-3 × 8; 4 × 7.

Spacing: 15-23.

Diameter of terminal openings of roots: (circular) 4-6.

Diameter of tubular roots: 10-15; 9 × 13.

Length of tubular roots: 50+.

Length of branches on roots: 1-20 (complete), 27+ (incomplete).

Thickness of body wall of fins and roots: 1.0-2.5.

Thickness of central cone wall: 1.0-1.5 (thinning to 0.5 at margins of exhalant openings).

Diameter of aporhytic pits in central cone: 0.8-1.0 (elongate or meandriform ones up to 2.5); 0.3-3.0 (mostly 0.8-1.6); 0.3-2.3.

Interspaces between above (respectively): 0.2-2.2; 0.4-2.6; 0.7-1.2.

Diameter of small circular pores on inner cone surface: 0.2-0.3. Spacing: 0.4-2.2+ (irregular and very sparse).

Skeletal net spaces (non-circular) of all surfaces and interior: 0.05–0.20.

Diameter of large circular dermal pores: 0.2–0.5. Spacing: 0.5–1.0 (center to center).

Diameter of small circular dermal pores: 0.05–0.20. Spacing: 0.15–0.50 (center to center).

Diameter of large circular (or elliptical) gastral pores: 0.2–0.5 (elliptical ones average  $0.4 \times 0.5$ ). Spacing: 0.6–1.4 (center to center).

Diameter of small circular gastral pores: 0.10–0.15. Spacing: 0.4 (center to center).

Diameter of gastral pores known to be openings of epidiarhyses: 0.2–0.3.

Diameter of epidiarhyses within wall: 0.15–0.35. Length: 1.1–1.7. Spacing: about 0.7 (center to center).

Diameter of blind epirhyses within wall: 0.2–0.3. Length: 0.6–1.2. Spacing: 0.7–0.9 (center to center).

Diameter of aporhyses within wall: 0.25–0.50 Length: 0.7–2.0. Spacing: 0.6–0.7 (center to center).

Thickness of partitions between epidiarhyses, epirhyses, and aporhyses: 0.1–0.8.

Diameter of horizontal branch or labyrinthine canals and circular pores within these partitions: 0.1–0.2.

(NOTE: Discrepancies between ranges of diameter, spacing and length of rhyses and those of surface pores and wall thickness are because of the smaller sample of canals from fractured edges.)

Diameter enlarged dictyonal nodes: Dermal surface: 0.06–0.14. Inner Cone surface: 0.06–0.12. Gastral surface: 0.04–0.12.

Interior net: 0.04–0.10.

Diameter dictyonal rays: Dermal surface: 0.02–0.06. Inner cone surface: 0.02–0.08. Gastral surface: 0.013–0.040. Interior net: 0.02–0.06.

Internode distance: Dermal surface: 0.12–0.20. Inner cone surface: 0.10–0.30. Gastral surface: 0.013–0.30. Interior net: 0.10–0.26.

#### Family APHROCALLISTIDAE Gray 1867, emend. Reid 1964

**DIAGNOSIS:** Hexactinosida with euretoid skeletal net and diarhytic canal system.

**DISCUSSION:** This family is unique in having diarhyses, that is, tubular passages completely through the dictyonal net. In the living species of the type genus *Aphrocallistes* Gray 1858, each diarhysis is occupied by a complexly lobate choanocyte chamber. In all known species the body wall remains thin, but may become complexly folded or protruded into closed tubes or fin-like lobes. The simplest species, as in the Cretaceous *Aphrocallistes alveolites* Schrammen 1912, are cylindrical, sometimes branching, tubes capped by an oscular sieve. Besides the Cretaceous to Recent genus *Aphrocallistes*, there is the Miocene *Badinskia* Pomel 1872, the Eocene *Ceriosymplegma* Rauff 1924, and the new

Eocene genus *Druidia* proposed here. Reid (1964, p. cviii, cxlvii) also includes the Cretaceous to Recent *Heterochone* Ijima 1927.

We discuss the relationships of *Druidia* to species of *Aphrocallistes*, *Ceriosymplegma*, and *Badinskia* under the discussion of the species *Druidia wilsoni* below. *Druidia*, To generalize from that discussion, differs from *Badinskia*, from *Ceriosymplegma*, and from most species of *Aphrocallistes* in the possession of a dermal cortex. It is also unique in having a broad central cup lined by a sieve homologous to an oscular sieve, surrounded by numerous radial lobes and occasional blind tubes, both bearing parietal gaps on their undersides. *Badinskia* has similar lobes and tubes but lacks the central cup as well as a cortex. *Ceriosymplegma* probably has a central sieve, definitely possesses radial tubes, may have radial fins, but lacks a cortex. *Aphrocallistes* varies from simple open cylindrical tubes, sometimes branching, and with or without an oscular sieve, to strongly plicate sheets, to central tubes (with terminal sieve) bearing radial blind tubes and/or lobes. Parietal gaps are not present. Neither is a cortex present, except in two Cretaceous species, *A. cylindrodactylus* and *A. lobatus*, which bear radial tubes and lobes respectively. We believe these species are part of the ancestral stock of *Druidia* but would not transfer them to *Druidia*, because, although they possess a dermal cortex, lobes, and tubes, they do not have the differentiated central cup with its lining, nor the regular radial vertical fins, nor the parietal gaps. The lineage leading to *Badinskia* could have split off from this same stock of *Aphrocallistes* after radial vertical fins with parietal gaps had developed, but before a central cup or cortex had. Alternatively, it could have arisen from a separate stock, such as perhaps leads from the Cretaceous *A. alveolites* to the living species of *Aphrocallistes*, and developed radial fins with parietal gaps. It is much less likely that *Badinskia* arose from *Druidia*, despite the appropriate sequence in time, because in that case the elaborately developed central cup, as well as the cortex, would have to be lost. *Ceriosymplegma*, roughly contemporaneous with *Druidia*, lacks a cortex but has a central sieve (but not necessarily the complete cup of *Druidia* involving the outer wall) and in overall form is either like the Cretaceous *Aphrocallistes cylindrodactylus* or like *Druidia*, the published material being insufficient to decide. If the presence of a cortex is phylogenetically significant, *Ceriosymplegma* would be a parallel development to *A. cylindrodactylus* and *Druidia*, arising from a non-corticate Cretaceous *Aphrocallistes* like *A. alveolites*. Another possibility is that *Ceriosymplegma* is a close relative of *Druidia*, and/or *A. cylindrodactylus*, that has lost the cortex. *Heterochone* has a cortex on the gastral side (see description in Reid 1964, p. cviii) and the rest of the sponge is organized quite differently from the other

genera mentioned; it consists of a central funnel without an oscular sieve, from which short, open tubes radiate.

**Genus DRUIDIA Finks, Hollocher and Thies,  
new genus**

**DIAGNOSIS:** Aphrocallistid with numerous radially arranged, more or less uniform lobes or fins, accompanied by, or extending into, radial tubes with rounded, closed terminations, surrounding a broad central cup, with a distinct lip formed of the folded-over body wall, but the cup lined by a differentiated, densely skeletonized, coarsely polygonal-meshed sieve (homologous to an oscular sieve); the exterior (dermal) surface with a thickened cortex pierced by circular openings of the diarhyses, generally one pore for each diarhysis, narrower than the interior diameter of the diarhysis and of more than one size; small circular parietal gaps localized on basal edges of fins, the basal surface of tubes, and in a vertical row on either side of the angle between fins.

**DISCUSSION:** This genus differs from *Aphrocallistes* Gray 1858, in the presence of the broad central cup with its distinct double-walled lip and its oscular-sieve-like inner wall, in the presence of a distinct dermal cortex with several sizes of dermal pores opening into the diarhyses, in the presence of parietal gaps, and in the relatively symmetrical arrangement of radial fins. It differs from *Badinskia* Pomel 1872, in the presence of the central-cup complex, and in the presence of the dermal cortex, as well as possibly species differences in details of fin number and shape. Certain Cretaceous species of *Aphrocallistes* (*A. cylindrodactylus* Schrammen 1912, and *A. lobatus* Schrammen 1912) have a dermal cortex (with uniform pores?) but differ in the other diagnostic features mentioned. It differs from *Ceriosymplegma* Rauff 1924, in the presence of a cortex, and in larger size and more numerous fins, if that genus indeed has fins. For further comment on related genera see the discussion of the family Aphrocallistidae above and of the species *Druidia wilsoni* below.

**TYPE SPECIES:** *Druidia wilsoni* new species.

**DRUIDIA WILSONI Finks, Hollocher and Thies,  
new species**

pl. 38, Figs. 1–4; pl. 39, Figs. 1–4; pl. 40, Figs. 1, 2; pl. 41, Figs. 1–3; pl. 42, Figs. 1–4; pl. 43, Figs. 1–6; pl. 44, Figs. 1–4; pl. 45, Figs. 1–3; pl. 46, Figs. 1–5; pl. 47, Figs. 1–4; pl. 48, Figs. 1, 2; pl. 49, Figs. 1–5; pl. 50, Figs. 1–3. Text-Figs. 4, 5, 6

**DIAGNOSIS:** Entire sponge approximately twice as broad as high; central cup approximately half as broad as high, more or less elliptical in cross-section and prismatic, with faces corresponding to fins; cup with sigmoidal profile and everted lip rising well above tops of fins; inner sieve attached to external wall and

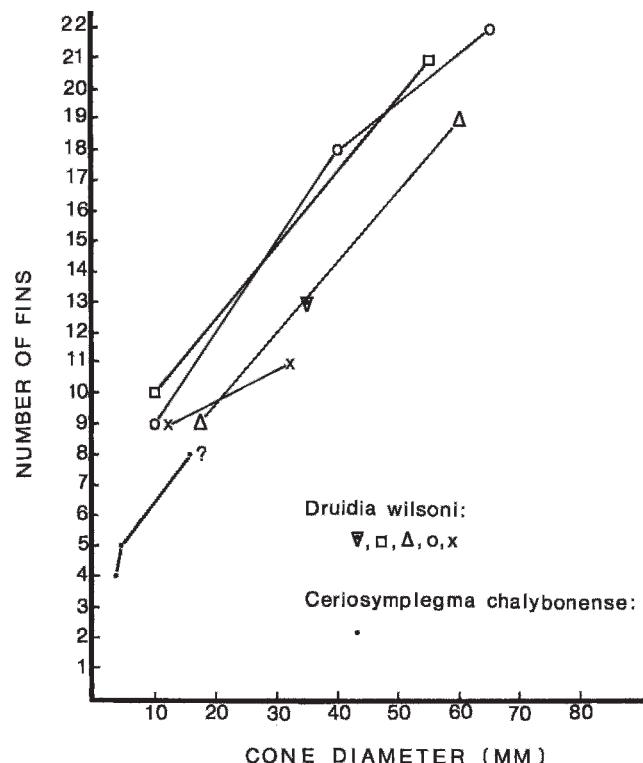


FIG. 4. Number of fins vs. inside diameter of central cone (semi-major axis) in *Druidia wilsoni* n. gen., n. sp., and in *Ceriosymplegma chalybonense* Rauff 1924. The specimens of *Druidia wilsoni* are each represented by a separate symbol. They are from left to right: USNM 127672 (top rim), USNM 127697 (base and rim), USNM 127700 (slightly above base and rim), USNM 127698 (base, middle, and rim), and USNM 127701 (base and rim) (see Table 1 for values). The data points for *Ceriosymplegma* are based on three specimens from Rauff (1924, plate 4, figures 2, 3, and 6; see text for values).

imperforate opposite angles between fins; fins numerous (9–22).

**DESCRIPTION:** Sponge body composed of a central cone, apex down, surrounded by 9–22 radial, slab-like extensions or fins, their flat sides vertical. Their edges are rounded, as is the upper rim of the central cone. Their tops begin a short distance below the rim of the central cone, and in profile exhibit a distinct shoulder as they slope outward and downward to the base. New fins are intercalated as the central cone expands upward, the earlier ones continuing beside them. There is no discernible pattern or symmetry in their insertion, such as there is with the septa of corals. Three specimens (USNM 127697, 127698, 127701) preserve the base essentially complete; two of these have nine fins at the base, the other ten. The specimen with ten initial fins (USNM 127697) is apparently the most complete, for it has a flat basal surface to the central cone (here preserved only as an internal mold), 15 × 20 mm in inside diameter, that bears the same kind of pores as elsewhere on the cone. No specimen has been found with fewer than nine fins; the maximum observed at the

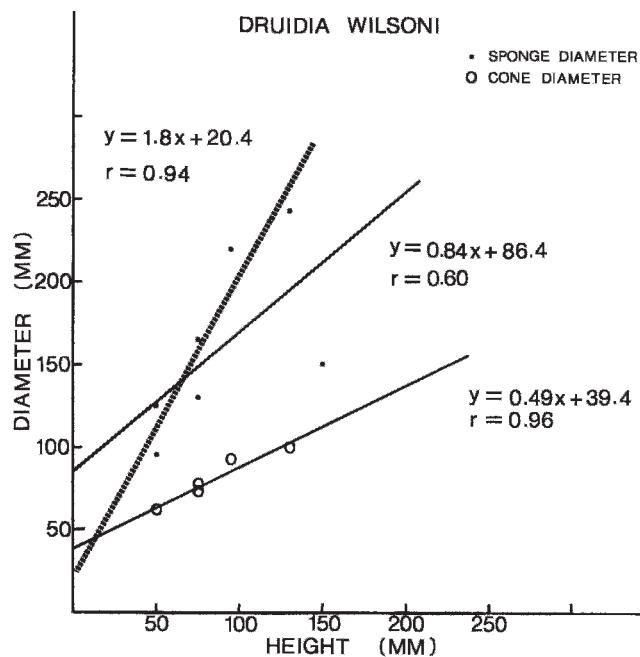


FIG. 5. Maximum sponge diameter (to outermost edges of fins) and mean diameter (semimajor axis) of top of central cone in *Druidia wilsoni* n. g., n. sp., plotted against sponge height. A least-squares equation and correlation coefficient ( $r$ ) are given for each bivariate plot. The dotted line is the least-squares line for sponge diameter with the one data point (150, 150) eliminated; it is obviously a tighter correlation. The best-fit power function for sponge diameter against height is  $y = 13.9x^{0.54}$  ( $r = 0.71$ ) for all points, and  $y = 3.2x^{0.89}$  ( $r = 0.93$ ) with (150, 150) omitted, and for cone diameter is  $y = 8.1x^{0.52}$  ( $r = 0.97$ ). Except for the two regressions that include the (150, 150) data point, all correlation coefficients are valid at the 99% confidence level.

upper lip is 22. When the number of fins is plotted against the inside diameter of the central cone an essentially linear relationship is shown (Text-Fig. 4) with roughly one fin added per centimeter of increased diameter (major axis). The most complete specimen from the point of view of vertical continuity is USNM 127698 which is an internal mold of the central cone. It has 9 fins at the 20 mm diameter base, 18 fins at 80 mm above the base (diameter 60  $\times$  80 mm) and 22 fins at the upper rim, 150 mm above the base (diameter 100  $\times$  130 mm). Of the specimens that preserve the upper rims sufficiently completely to count the fins (USNM 127672, 127697, 127700, 127698, 127701) the values are (respectively) 13, 21, 19, 22, and 11 fins. On USNM 127672, one and possibly two of the counted fins are cylindrical tubes. Such tubes are found as fragments in the matrix or radiating out from incompletely preserved specimens. The best preserved one in place is on USNM 127697. It arises from the central cup with a vertically elongate cross-section, like a small fin, but soon becomes cylindrically tubular and extends outward and downward in the manner of a prop root. The ends of these tubes, where preserved, are bluntly rounded. They may

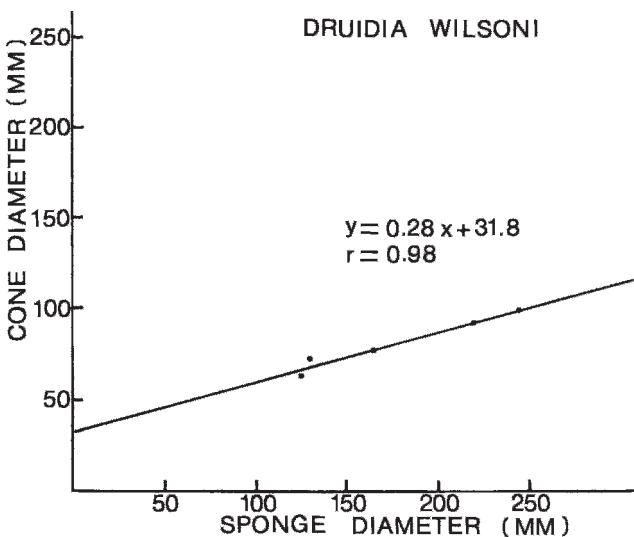


FIG. 6. Ratio of mean diameter of top of cone to diameter of sponge in *Druidia wilsoni* (specimens USNM 127672, 127696, 127699, 127700, 127701).

terminate well above the base of the sponge. No branching has been seen. One tube fragment (USNM 127681) has the smaller end closed over by a skeletal net like that of the inner honeycomb layer. There is no sign of a cortex over it, and a bryozoan colony has

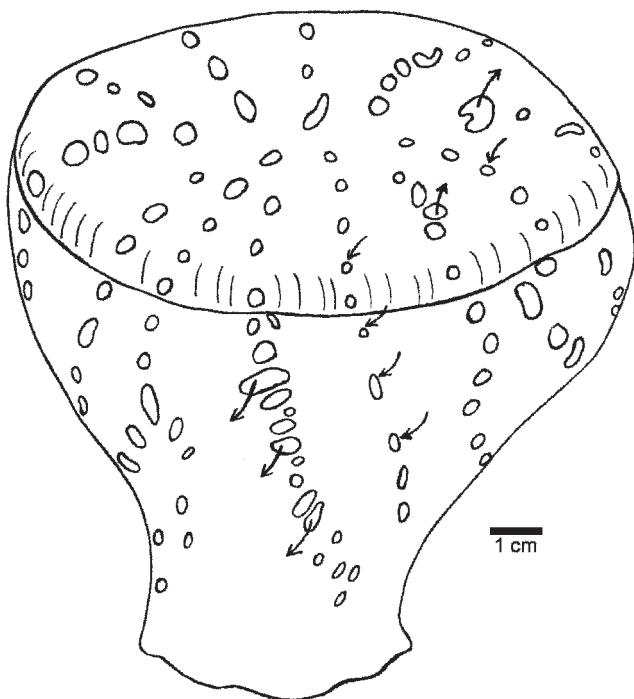


FIG. 7. Reconstruction in life-position of *Robinia striatopunctata* n. gen., n. sp. Arrows indicate direction of currents in the alternating rows of exhalant and inhalant openings through the siliceous envelope into the underlying exhalant and inhalant cavaedia. Drawn by R. M. Finks.

overgrown both the exposed edge of the tube cortex and part of this infilling, suggesting that there never was a cortex. This may be a repair by the sponge to a broken tube. These tubes may alternate locally with the regular fins. The regular fins are often sinuous in both surface and profile; they may be extended as a horizontal tube continuous with the base of the fin. Most sponges are wider than high, sponge diameter being generally nearly double the height of the sponge (1.8:1 with a correlation coefficient of 0.94,  $n = 6$ , neglecting one specimen in which they are equal; see Text-Fig. 5 and Table 1). Each fin of the sponge is thus approximately as high as its greatest radial extent, which is generally near the base of the sponge. The overall shape and size of this sponge is like that of an ice cream sundae glass, minus the stem and base, to which are attached a dozen or so radial fins of quarter-circle profile. Cone diameter maintains a constant ratio to sponge height of almost exactly one-half (0.49 with a correlation coefficient of 0.96,  $n = 5$ ) implying a constant mean cone apical angle of approximately 28° (see Text-Fig. 5). (This is borne out by actual measurement of the apical angle, though ellipticity of cone cross-section, as well as curvature of longitudinal profile, cause considerable variability.) Cone diameter consequently also maintains a constant ratio to sponge diameter (fin edge to fin edge) of slightly more than one-quarter (0.28 with a correlation coefficient of 0.98,  $n = 5$ ; see Text-Fig. 6). Power functions (allometric equations) can be fitted to the same data with similarly high correlation coefficients. In the case of sponge height against sponge diameter, again neglecting the one anomalous value (150, 150), the exponent of the least-squares best-fit curve is close to unity ( $y = 0.62x^{0.95}$ ,  $r = 0.93$ ; or  $y = 3.2x^{0.89}$ ,  $r = 0.93$  for the inverse relationship shown in Text-Fig. 5) and the difference from a linear function is negligible. When sponge diameter is plotted against cone diameter, it gives an exponent close to 1.5 ( $y = 0.19x^{1.55}$ ,  $r = 0.97$ ) implying that cone diameter is increasing approximately as the square while sponge diameter is increasing approximately as the cube. (This is the inverse of the plot of Text-Fig. 6, which gives  $y = 3.5x^{0.61}$ ,  $r = 0.97$ .) One possible functional interpretation is that cone diameter (which is osculum diameter) is keeping up with the increase in exhalant surface area, while sponge diameter is responding to the increase in sponge volume (and therefore mass) in order to distribute weight more widely and prevent sinking into the mud (see Text-Figs. 5, 6). The central cone is always laterally compressed to varying degrees, so that it has an elliptical cross-section (see Table 1). This may be the result of compaction on burial or it may be an inherent property of the sponge. The ellipticity varies from 0.55 to 0.93 in individual specimens (mean 0.71,  $n = 7$ ). A bivariate plot of minor against major axis of cone tops ( $n = 7$

yields a least-squares regression line of slope 0.75 (equals ellipticity) with a correlation coefficient of 0.84.

A distinctly denser cortical layer, in which the dictyonal strands are more closely spaced and the larger pores more widely spaced, covers the entire surface of the sponge. This layer is continuous and bounds the entire volume between the gastral surface and the exterior of the fins. Most of this internal volume is now hollow, or rather is filled with sedimentary matrix containing bryozoa and other shell fragments as well as foreign spicules such as ophirhabds (probably from *Cerberorhaphidites*) and dichotriaenes. It is not clear to what extent this volume was occupied by either the skeleton or the flesh of *Druidia* during life. The inner skeletal layer of more widely-spaced dictyonal strands extends inward from the millimeter-thin cortex only for a few more millimeters before terminating along a ragged interface with jumbled shell-hash. The fact that spicule fragments and shell debris lie tangent to this interface suggests that the sponge terminated here in life. None of the spicules now present in this interior space seem clearly to pertain to hexactinellids. If this inner space was hollow in life, it was functionally a cloaca, and the "gastral surface" of the inner cone would be analogous to an oscular sieve. This surface consists of a freestanding cortex-like layer, much thicker than the ordinary cortex of the body wall but thinner than the body wall proper. The side facing the fin is identical to the side facing the inside of the cone, and lacks the inner skeletal layer. This sieve-like structure has a cup-like shape with an apical angle between 25° and 70°. The cup usually has an elliptical cross-section and the apical angle is smallest in the plane of the minor axis and greatest in the plane of the major axis. Outward convexity of the longitudinal profile also increases the apical angle toward the base. This accounts for the large range in values. The cup is fused to the external wall of the sponge at the interangles between fins by vertically elongate strut-like structures of a dense, thickened net intermediate in structure between that of the sieve and that of the body wall. The inner surface of the sieve opposite the strut lacks the large pores, bearing only the very fine pores of the sieve-skeleton. These "imperforate" areas of the sieve have the same form and dimensions as the strut, perhaps a millimeter or so larger, the strut itself contracting somewhat between its attachments to the sieve and to the outer wall. The struts, and/or imperforate areas, range from 3 to 23 mm high (mostly 5–15 mm) in a vertical direction, and 1–5 mm wide (mostly 2–3 mm) in a horizontal direction, tapering in width toward the upper and lower extremities of the strut. The struts are separated vertically in the same row by 3–25 mm (or more) interspaces; their spacing is not uniform in the same row, nor are they at corresponding positions in adjacent rows. The rows are

some 10 to 15 mm apart center to center which of course represents the spacing of the interfin angles. The position of the strut is marked by a depression in the inner sieve surface which is more or less maintained in the same vertical row even between the struts. This gives the inner sieve a somewhat prismatic cross-section which is particularly evident on the internal molds, or steinkerns, of the sieve, where the grooves are represented by prominent ridges. The prism faces represent the coarsely perforate parts of the sieve that cover over the inner openings of the fins. The courses of these grooves, and of the fins themselves, are not perfectly straight, and may have some slight sinuosities.

The pores of the sieve are larger than the largest external pores of the rest of the sponge. They are spaced more closely than their own diameter, whereas the large pores elsewhere are spaced their own diameter or more. Because of the close spacing they have a subpolygonal (often subquadrate) outline. They tend to be arranged in obscurely horizontal and vertical rows. The only other porosity in the sieve area is the space between the individual rays of the dictyonal strands, which form small circular pores equivalent to the smallest pores on the rest of the sponge surface. The dictyonal strands curve about the large pores, here as elsewhere.

The remainder of the sponge surface (the fins, the tubes, and the upper rim of the inner cone, including its inner surface down to the level of the top of the fins) is covered with circular pores of three sizes, each approximately half to a third the size of the next. The largest are approximately half to a third the size of the large pores of the central sieve. They are all approximately uniformly and subquincuncially, or perhaps subcubically, arranged. The largest are separated by interspaces approximating their own diameter. They are surrounded by the intermediate pores. The smallest pores are formed by the spaces between the rays of the dictyonal strands. The pores on the upper rim of the central cylinder above the sieve, on both sides, are smaller than those on the fins and tend to be arranged in rows, along obscure grooves, perpendicular to the rim. On the basal edge of each fin and each tubular root is a single row of large, circular pores, approximately the diameter of the large sieve pores. The circular pores are spaced five or so of their own diameters apart. These completely penetrate the sponge wall and are lined with the dense cortical layer, just like the sieve pores. They may also occur in the vertical row on either side of the angle between fins. Rarely they may occur on the sides of the fins, or elsewhere on the tubes. They occur on one tube fragment in a series of transverse rows on one side (basal?).

The dictyonal net of the interior of the sponge outlines a honeycomb-like structure of rounded polygonal canals in subhexagonal packing. They are perpendicular to the exterior surface of the sponge. The regular

large and intermediate pores of the sponge surface open into these tubular spaces, though the pores are smaller than the diameter of the canals, and some may be partly or completely covered with a sheet of secondary silica. This and the fact that a few of the canals begin just below the cortical layer without direct communication with the exterior, and that all have a rounded or domical exterior end, make them look at first like aporhyses rather than diarhyses. This results from the growth of the cortex over the external surface. A few possible epirhyses may be present, running in from some of the exterior pores and ending blindly in the body wall. All these canals are separated by the thickness of only one or two dictyonal strands. As is typical of aphrocallistids the spicules are irregular with all six rays often in one plane, so that dictyonal strands are scarcely recognizable. The spicule rays are less closely apposed than in the cortical layer, and tend to be parallel to the sponge surface, but also criss-cross irregularly and may possibly be connected by synapticulae. The canals are parallel-sided and open at about the same level to the sponge interior. There is no boundary layer at this level. In the tubular roots the honeycomb cells are elongated parallel to the longitudinal axis of the root and there is a tendency for rather coarse bundles of dictyonal strands, or spicule rays, to run between the cells (canals) in this direction. The cells also slant inwards toward the proximal end of the tube. At the angles between adjacent canals, the spicule rays have branches (synapticulae?) like diagonal struts, making the juncture of rays look like a large and irregular lychnisc node, which of course they are not. The true nodes are often enlarged but are not lychnises.

DISCUSSION: It is a pleasure to name this magnificent sponge after Druid Wilson, who collected most of the Castle Hayne sponge material and made it available to us for study.

This sponge is clearly related to *Aphrocallistes* Gray. It has expanded and regularized the saccular, lobate or plicate body of *Aphrocallistes* by developing the radially symmetrical fins. Concomitantly, the oscular sieve has become depressed into a central funnel. This sponge is larger than *Aphrocallistes* in overall size. Much of its difference from *Aphrocallistes* can be understood as adaptation for this size-increase. The fins serve for mechanical stability, both to prevent overturning, and to spread the weight of the sponge over a larger area so as to minimize sinking into the soft lime mud in which it occurs. In these functions the fins supplement the tubular roots, both of which occur in incipient form in *Aphrocallistes*. It is instructive to compare this sponge with the Ordovician lyssacine *Brachiospongia* Marsh. *Brachiospongia* also developed radial, lobate extensions of the body, in its case more like prop roots than fins, but in general form rather convergent with *Druidia*. Like

*Druidia*, *Brachiospongia* occurs in limestones, and it seems likely that the principal adaptation of the shape was for weight-distribution to prevent sinking. An alternative adaptation would be the development of a root-tuft, as exhibited by *Brachiospongia*'s associate, *Pattersonia*. The occurrence of radially-lobate basiphytic sponges may be presumptive evidence of soft bottom sediments.

Although the interior of the fins is not lined with a differentiated gastral layer, it is likely that the inner space was empty in life. Not only is it now filled with sedimentary matrix, but the known construction of aphrocallistids favors the restriction of the flesh to the preserved thin body wall. In living aphrocallistids the radial, honeycomb-like cells, or diarhyses, are the sites of clusters of choanocyte chambers. Although some of the cells in *Druidia* are closed over externally, as described above, most are open at both ends and qualify as diarhyses. As stated earlier, the sieve-like part of the central cone would be like an oscular sieve, separating an internal exhalant space (the interior of the fins) from the ambient medium.

The function of the large circular pores on the bottom edges and inner angles of the fins and roots is obscure. They are lined by cortex, and completely penetrate the body wall, providing a direct communication with the hollow interior of the fin or root. They would thus be parietal gaps. Their regularity suggests that they had a function and were not merely imposed by chance external circumstances. The term "parietal oscule" sometimes applied to such openings implies an exhalant function which may not be the case. They would bypass the normal inhalant path, and as exhalant openings would be poorly sited and would detract from the concentrative function of the central cone. Perhaps they favorably modified the hydrodynamics of the interior space, by permitting entrainment of ambient water into the exhalant current.

Existence of roots and fins above the base of the sponge requires comment. They may represent merely the addition of new folds to the body wall as the central cone expands upward. The predominance of roots at higher levels may be merely related to their propping function. The fact that some are close to horizontal, however, suggests that the sponge may partly have sunk into the mud, or the mud have risen about the sponge, and that this circumstance may have prompted their development at the then sediment surface. Progressive siltation, or sinking, may account for the existence of several levels of fins and roots according to the time of their origin.

Ontogeny in this sponge raises some problems. A dictyonal net is rigidly fused and is laid down as continuous dictyonal strands. There are no loose spicules to pull apart. Unless we invoke resorption,

growth can only take place at free edges. Specimens of *Druidia* seem to have no free edges. Short and seemingly incomplete tubular roots end in rounded tips the upper rim of the central cone is likewise rounded, and moreover is differentiated with smaller-than-usual pores. However, at least one tubular root fragment has been found with a bryozoan colony overgrowing a free edge, implying that the end of the tube was open on the sea floor. Because the tube tapers down toward the overgrown end, this would appear to have been the distal end. On several specimens distal fin edges are open. The edges break off abruptly and one cannot say they are not broken. The basal edge of one small fin, however, bears a large opening whose edges seem rounded, as though it grew that way. The distal edges of two adjacent fins on another specimen may be naturally open, based on similar evidence. It is possible that the fins grew as two parallel sheets, exhalant surfaces mutually facing, until finally the distal edges curved toward one another and fused. On at least one specimen, also, the upper edge of the cone appears to be naturally open, but the absence of large sieve pores on this portion of the inner layer would seem to require some kind of resorption to form them. The discontinuous nature of the struts connecting the inner sieve to the outer wall may possibly be related to the maintenance of a free growing edge at the top of the inner sieve, by minimizing points of contact between sieve and outer wall.

There are many parallels between the gross structure of *Druidia* and that of *Coelptychium*. *Druidia* resembles a *Coelptychium* whose upper surface has been depressed to form the central cone, and whose folded underside has been expanded laterally to form the radial fins. The row of circular parietal gaps on the underside of the fold corresponds exactly to those on the under-edge of the fin. The strips of large circular sieve-pores opposite the inner edge of each fold, alternating with less porous strips, all in a secondarily thickened surficial layer, corresponds exactly between the upper surface of *Coelptychium* and the inner cone of *Druidia*. Nevertheless, the structure of the skeletal net indicates that the two are unrelated, and the similarities are because of convergence. In *Coelptychium* there are lychnisc nodes and the skeletal net reveals no canalization other than the intradictyonal spaces. However, the similarities tell us that the parietal gaps and the oscular sieve served the same function in both genera, and indeed probably in all hexactinellids, for Zittel has pointed out the correspondence of these same structures in *Coelptychium* with those of *Euplectella* (Zittel 1876, p. 3).

*Spirolophia* Pomel 1872 (*Marshallia* Zittel 1877), is a radially plicate lychniskid even closer in convergent form. Parietal gaps are present at the edges of the fins, but a central sieve, as in *Druidia* is apparently lacking.

*Druidia wilsoni* differs from *Aphrocallistes* in the very regular radial symmetry of its fins and in the well-developed broad central cone that has the structure of, and is homologous with, an oscular sieve. The living *Aphrocallistes vastus* Schulze (1887, p. 317) has a plicate body wall but it lacks a central cone, and though incomplete, exhibits no indication of radial symmetry in the plications. It also exhibits polygonal, rather than circular, external openings to the diarhyses (*ibid.*, pl. 85, fig. 1). The living type species, *A. beatrix* Gray 1858, and the doubtfully distinguishable (according to Schulze 1887, p. 311) *A. bocagei* Wright 1870, also Recent, are constructed of a slightly expanding central tube, with downwardly and outwardly directed radial tubes, opening into it and closed at their outer ends, which may branch; the radial tubes are in many cases arranged in vertical series, and occasionally ("in extreme cases" says Schulze 1887, p. 314) united at their bases to form a longitudinal fold. When such vertical series are present they are most strongly developed near the base of the sponge, where they are four in number, the arrangement becoming indistinct upward (*ibid.*, p. 313). The top of the central tube, which is the same in structure as the radial tubes, is closed off at the top by a slightly concave sieve-plate with rounded polygonal openings of uniform size; similar internal diaphragms may cross the central tube, but their mesh spaces are more sharply angular (*ibid.*, p. 314). Schulze neither describes nor illustrates parietal gaps on the tubes such as exist in *Druidia*. The external openings of the diarhyses, like those of *A. vastus*, seem more polygonal than circular. To derive any living species of *Aphrocallistes* from *Druidia* would require changing a highly-developed or advanced structure (oscular sieve in the form of a central cone, radially symmetrical lobes, external cortex with circular pores) to a less regular or more primitive one (terminal sieve, irregular lobes, polygonal external pores).

The Cretaceous *Aphrocallistes cylindrodactylus* Schrammen 1912, externally very closely resembles the living *A. bocagei* as described by Schulze, or the similar *A. beatrix*. Schrammen (1912, p. 221) states that it differs from the latter in having a differentiated, thickened outer cortical layer ("dichten Deckschicht") and loose interior net ("im Innern ... lockeren Gerüste") rather than the more uniform skeleton of the living species. In this respect *A. cylindrodactylus* is closer to *Druidia*; this also leads to their both having rounded rather than polygonal exterior openings to the diarhyses. Another interesting feature in which *A. cylindrodactylus* resembles *Druidia* lies in the possession of a "funnel-shaped summit-depression ... occupied by a coarse-meshed diaphragm that either spreads homogeneously or consists of alternating finely and coarsely porous radial bands" (*loc. cit.*). This calls to mind the alternating perforate and imperforate strips of the

*Druidia wilsoni* central cone, but the radial bands may not be homologous in the two species, inasmuch as in *Druidia* they are related to the internal openings of the fins. Although Schrammen does not illustrate the summit depression, from the rest of the description and illustrations it is not likely to be as deep, or as wide, as the *Druidia* central cone. Moreover, the four specimens of *A. cylindrodactylus* do not possess radial lobes but only irregularly arranged radial tubes (*ibid.*, text-fig. 1). However, a second Cretaceous species described by Schrammen from a different locality, *A. lobatus*, does possess lobes (*ibid.*, p. 222). This is unfortunately fragmentary. One specimen consists of three attached lobes resembling, in the illustration (*ibid.*, text-fig. 2) the more irregular lobes of *Druidia*. The only other specimen (*ibid.*, pl. 26, fig. 1) is an isolated lobe rather like that of *Druidia*. What the whole sponge was like cannot be inferred from this material. No trace of a sieve-plate is preserved. Schrammen states (*ibid.*, p. 222) that the structure of the wall and canal system is like that of *A. cylindrodactylus*. Parietal gaps as in *Druidia* are not visible on the illustrations (the view should reveal them were they preserved) nor does Schrammen mention any. The external pore sizes and general dimensions of the lobes are approximately as in *Druidia wilsoni*. Although the several sizes of circular dermal pores in *Druidia* does not seem to be present in *A. lobatus*, this species raises an intriguing possibility that development in the direction of *Druidia* had already progressed quite far in the late Cretaceous, and that *A. lobatus* may turn out to be a *Druidia* when more complete material is found. The external cortex and depressed sieve-plate of *A. cylindrodactylus* suggests that it is close to the ancestry of *Druidia*. If one defined *Druidia* on the presence of the differentiated cortex alone, one could assign *A. cylindrodactylus* and *A. lobatus* to that genus. We prefer to require the combination of cortex, radially symmetrical lobes with parietal gaps on their edges, and deep, wide central cone lined by a terminal sieve and with a well-defined lip of its own formed by the folded over body wall. This combination is not present in *A. cylindrodactylus*; whether it is in *A. lobatus* cannot be determined from Schrammen's published material. Schrammen recognized the relationship of these two species and suggested (*ibid.*, p. 222) that they might belong to a morphologic series ("Formenreihe") characterized by an open cup-shape and the lack of a terminal sieve plate, and which is represented today by *Aphrocallistes vastus*. We would suggest that the two Cretaceous species may form a lineage with *Druidia wilsoni* but that *A. vastus* (see above) is not the descendant of *Druidia*. A third Cretaceous species, *A. alveolites* (Roemer 1841) is at the same time more primitive and closer to the living species. It has the polygonal external openings of the

living species, and a simple shape, cylindrical, occasionally branching, with a flat terminal sieve plate (Schrammen 1912). We would consider *Druidia* to lie on a side branch from this main line of *Aphrocallistes*. Reid (1964, p. cviii) notes that the living *A. beatrix* and the Cretaceous *A. alveolites* have such thin partitions between the diarhyses that the dictyonal net becomes distorted and all six rays of the dictyonalia come to lie in the single plane constituting the partition. By contrast the living *A. vastus* and related living species, *A. whiteavesianus* Lambe, *A. yatsui* Okada, and *A. aleutiana* Okada, have thicker partitions with less dictyonal distortion; the last three also have a proximal curvature of the diarhyses near the gastral surface that is less apparent in *A. vastus* sensu stricto (Reid 1964, p. cvii, lxxxiv, text-figs. 47–49). *Druidia* is closer in the structure of its partitions between diarhyses to *A. beatrix* and *A. alveolites* than to the thicker *A. vastus* group, although they partly resemble the latter, on the other hand, in a slight proximal gastral curvature of the diarhyses. *Druidia* appears to retain the probably primitive (with *Aphrocallistes*) thin partitions between diarhyses.

Lastly, we must consider *Ceriosymplegma* Rauff 1924. This sponge was described by Rauff as from Cretaceous chalk, from a locality near Aleppo in Syria. The beds, however, have been remapped as Eocene by Dubertret (1941) according to Avnimelech (1943). Although the spicules themselves have been replaced by finely-porous ocher (Rauff 1924, p. 50), the general form of the skeletal net has been preserved and has the honeycomb structure of an aphrocallistid, and was so interpreted by Rauff. The illustrations (*ibid.*, pl. 4, figs. 2–10) all of which are based on random natural sections through the sponges, show that the sponge has a radially lobate form, that some of the lobes, perhaps all, have the form of cylindroidal tubes (*ibid.* figs. 5, 9), and that there is some form of hollow central structure, thinner-walled than the lobes, that has a polygonal cross-section, that is partly free of the lobes (*ibid.*, figs. 3, 6), partly attached at their interangles (*ibid.*, figs. 2, 6), and that each side corresponds to a lobe. Although Rauff says (*ibid.*, p. 50) that a paragaster and oscula are missing, it is obvious from a knowledge of the better-preserved *Druidia*, that the central structure may well be a prismatic inner-cone sieve as in *Druidia*. It is less certain, but quite possible, that the lobes are vertical fins, although the seemingly near-tangential view in Rauff's plate 4, figure 9, illustrates sections of many cylindroidal structures packed closely together as in *Aphrocallistes cylindrodactylus* Schrammen, and no indications of fins, which would alternate with tubes in a *Druidia*. It should be noted that Rauff's general term for what we have been calling "lobes" is "folds" (Falten) and that he refers to some as becoming "tubes" (Rohren) and others as "blind-sack-like hose or pocket-shaped protrusions of

the wall" (blindsackartig schlauch- oder taschenförmig Vorstülpungen der Wand) as in his figures 2 and 3 (*ibid.*, p. 49–50). Rauff states that the walls of the same fold are parallel or subparallel (*ibid.*, p. 50), which could imply that they are like fins, but if referring only to a two-dimensional section, need not. The folds are (*loc. cit.*) up to 3 cm long and 8 mm wide (thick). This is within the range of radial length of *Druidia wilsoni* fins (25–50 mm) but on the small side. The thickness is definitely smaller than *Druidia* (which is 10–15 mm). The diarhyses are said to be 0.5–1.65 mm (mostly 0.8–1.0) wide with 0.1–0.2 mm thick interwalls (*loc. cit.*). The diarhyses are thus mostly wider (though overlapping in range) than those of *Druidia* (0.4–1.1 mm, mostly 0.6) though the interwall thickness is the same. The thickness of the body-wall, or length of diarhyses, (average 1.0 mm, maximum 1.5 mm) is smaller than *Druidia* (1.5–2.5 mm excluding the cortex). A more significant difference is the total absence of a cortex, which is not seen on either cross-sections or tangential sections; in this respect *Ceriosymplegma* is like typical living *Aphrocallistes*, but not like either *Druidia* or the Cretaceous *Aphrocallistes cylindrodactylus* and *Aphrocallistes lobatus*. The blind end of a lobe in Rauff's plate 4, figure 3 (and possibly figure 5) looks solid or filled-in, which one could argue might be the remains of a cortex, but it is dubious, and Rauff himself explains it as the cells (diarhyses) being "subsequently plastered-over and obscured by ocher and its powdery debris" ("nachträglich durch Ocker und dessen Zerreißsel verklebt und verwischt," *ibid.*, p. 53). The general size of the sponge and the number of lobes in *Ceriosymplegma* is smaller than in *Druidia*. In Rauff's plate 4, figure 6, there are 4 "fins" and the "central cone" inside diameter is 7 × 4 mm; in his figure 3, there are 5 "fins" and the "central cone" inside diameter is 9 × 7 mm; in his figure 2, which appears to be one half, perhaps slightly less, of the sponge, the total number of "fins" would have been 8 or slightly more, the "cone" inside diameter 32 × 20 mm or slightly more. The smallest complete bases in *Druidia* (specimens 14 and 17) have 10 and 9 fins, and cone inside diameters of 15 × 20 mm and 20 × 20 mm, respectively; thus no *Druidia* juvenile (unless we assume resorption and secretion of new skeleton, which is not known in dictyonines) is known to have had as few fins or as narrow a central cone as two of the specimens of *Ceriosymplegma*, and the third just equals the smallest *Druidia*. None of the other specimens of *Ceriosymplegma* illustrated seems any larger (the tubes in Rauff's figure 9 are a mere 5 mm or so in diameter) while *Druidia* cones frequently attain inside diameters of more than 100 mm and tubes are mostly 15 mm or more in diameter. However, if the above-quoted values for *Ceriosymplegma* are plotted on the graph of Text-Figure 4 they would continue the same linear relationship of fin number to cone diameter seen in *Druidia*. This need

not imply an especially close relationship taxonomically, and may merely indicate common functional requirements related to the general shape.

It is now necessary to judge the relationship of *Ceriosymplegma* to *Druidia*. It is almost certain that *Ceriosymplegma* is an aphrocallistid. It is probable, but not certain, that it had a central sieve in the form of a prismatic cone, as in *Druidia*, although there is no material available to determine if this met the outer wall in a well-defined lip to form a double-walled central cup as in *Druidia*. It had short radial tubes, apparently numerous, and closely spaced, as in several species of *Aphrocallistes*, and may have had radial fins as well, apparently smaller in number and size than in *Druidia*. It probably lacked an outer cortex. It would thus appear to differ from *Druidia* in the absence of a cortex, and in smaller size and fewer tubes and/or fins, and to resemble *Druidia* in the possession of a central sieve and possibly in the presence of radial fins. It seems to us that the differences are sufficient to maintain generic separation, and certainly wise to do so until more complete material of *Ceriosymplegma* can permit a better comparison. *Ceriosymplegma* can be distinguished from *Badinskia* by the presence of the inner sieve, even if radial fins are present. This same feature will separate it from *Aphrocallistes*, although it is not clear how much the oscular sieve of *A. cylindrodactylus* resembles a cone. On the other hand, the presence of a cortex in that species and *A. lobatus* suggests that these two species should be separated from *Aphrocallistes*; they could be assigned to *Druidia*, but the absence of a central cup and of known radially symmetrical fins suggests that a new genus would be a better disposition. In any event the absence of a cortex in *Ceriosymplegma* would separate it from the corticate species of *Aphrocallistes*.

There is, however, a possible Miocene descendant of *Druidia wilsoni*, namely *Badinskia lobata* Pomel 1872, which Zeise (1906) assigned to *Aphrocallistes*, as did Reid (1964, p. lxi) but which we would retain as a separate genus. This was described (Pomel 1872, p. 84–86; pl. 2, figs. 7–9) as basiphytous, with the thin body wall folded into 4–6 unequal wings radiating from an axial area in which there does not seem to be any notable cavity. The wings expand (radially) upward. Their outer edges are lobate, and bear parietal gaps. These openings are not visible in the illustrations but are referred to in the text (*ibid.*, p. 85) as: “[*Les lobes*] portent vers leurs angles quelques lacunes peu constantes.” (“The lobes bear some occasional gaps toward their angles.”) It is not likely that “lacune” would refer to the broken lobe of Pomel’s plate 2, figure 6. On the preceding page they are described as “gap-like holes like those of *Guettardia*.” The lower part of the wing often seems to be prolonged into a root-like tube, which from isolated fragments have a rounded, closed end. There seems to

be no cortex, for the openings of the diarhyses on both surfaces are described and illustrated as “rounded to subhexagonal arranged in regular quincuncial series, and separated by thin interspaces.” No mention is made of a terminal sieve-plate and Pomel’s description implies that the wings and central area are open at the top as in most *Guettardia* (= *Guettardiscyphia*) [“One could then define this genus as a *Guettardia* or *Pleurostoma* with diarhysis (*proctides perforants*)”] (*ibid.*, p. 84).

It is clear that *Badinskia* is an aphrocallistid because of the diarhysis. It is also similar to *Druidia* in having radial lobes, tubes and parietal gaps. It differs from *Druidia*, however, in several respects. There is no central cone with raised lip and lined with a special sieve, and there is no dermal cortex. The upward radial expansion of the fins is the opposite of that seen in *Druidia*. Indeed the shape of the fins is closer to those of *Haynespongia* (but again reversed). If we accept the cortex as a fundamental character, then *Badinskia* may be more closely related to the living *Aphrocallistes* species and the Cretaceous *A. alveolites*, than it is to the Cretaceous *A. cylindrodactylus*, *A. lobatus*, and *Druidia*. If *Badinskia* were a descendant of *Druidia* it would not only have to have lost the cortex but also to have de-evolved the central cone as well. It is perhaps better to regard it as a side-branch on the lineage(s) leading from *A. alveolites* to the living species of *Aphrocallistes*. Incidentally, a true species of *Aphrocallistes*, without a cortex, is present in the Miocene of Oregon (Astoria Formation). This was identified (Moore 1963, p. 89, pl. 32, fig. 16; Dall 1909, p. 140, 156) as a possible ophiuroid, but partial preparation of the original specimen (USNM 3683) by us reveals it to be an *Aphrocallistes* of lobate (?) form with relatively well preserved spicules. It lacks a cortex but does have a delicate, partly fused, open mesh of dermal (?) pinular (?) hexactins covering one end of the diarhyses. (The distal pinular rays look like solid clubs, apparently owing to secondary silicification). Druid Wilson called our attention to the similarity of this specimen to *Druidia*.

It remains to compare *Druidia wilsoni* with its geographic vicariant *Haynespongia vokesae*. Both hexactinosans resemble each other in having radial fins and tubes, bearing parietal gaps, around a central cone. A fundamental difference is that the canalization of *Druidia* is diarhytic while that of *Haynespongia* is diplorhytic. Another difference is that the inner wall of the central cone in *Druidia* is a thin, densely-skeletalized open sieve, like (and homologous to) an oscular sieve, and relatively imperforate where in contact with the outer body wall between the fins, while the inner wall of *Haynespongia* is like the body wall itself, but with extra-large aporhyses where in contact with the outer body wall (over a wider strip than in *Druidia*) between the fins, and forming thin bridges that outline large elliptical

gaps (oscules) opposite the fins. These differences make it apparent that their similarities are because of convergence. Additional differences are: in *Haynespongia* the radial length of fin is greater; there are branching tubular roots with round parietal gaps at their tips; the complete branches are shorter than the complete tubes of *Druidia*; elliptical parietal gaps of similar size may occur along sides of tubes and on the lower (?) edge of the fin; these parietal gaps are much bigger and more widely spaced than in *Druidia*. The tubes themselves are similar in diameter but on the small side. The diameters of the epihyces and apophyses are smaller than the diaphyses of *Druidia*; they are spaced about the same as in *Druidia* but the interspaces between them are thicker. The thickness of the dictyonal strands on the exterior are the same but those of *Haynespongia* are thinner on the interior surface; the internode distance is slightly greater in *Haynespongia*. The nodes are enlarged to about the same degree as in *Druidia* and like it there are no open lantern nodes visible. The smallest skeletal pores are about the same but those on the exterior surface in *Haynespongia* are in the higher part of the range, while those on the canal walls are a bit smaller; this may be a reflection of the lack of cortical thickening in *Haynespongia* and of its somewhat denser internal net (though the dictyonal strands of the inner surface are slenderer). On both exterior and interior surfaces, incomplete distal rays are more prominent (longer?) than in *Druidia*, making the surface finely hispid; this may be because of their being buried by secondary silica in *Druidia*.

Bryozoa, serpulid worms, and the thorny oyster *Plicatula* frequently overgrow portions of the sponge surface. It cannot be determined whether this was during the lifetime of the sponge. A *Turritella* has been found in life position in the angle between two fins. This may have been fortuitous.

**MATERIAL:** Twelve nearly whole specimens plus numerous fragments (about 74) were available for study. Five of the nearly whole specimens retained the original silica while the rest were calcified.

**TYPES:** Holotype USNM 127672; paratypes USNM 127673–127710.

**LOCALITIES:** USGS 19020 (3 specimens); USGS 22329 (1 specimen); USGS 22389 (20 specimens); 8-13-1 (3 specimens); 8-13-7 (2 specimens); Ideal Cement Company Quarry (57 specimens).

**MEASUREMENTS:** (All in millimeters except where indicated otherwise.)

Height of sponge (to top of cone): 50–150.

Diameter of sponge (to edge of fins): 95–244.

Radial length of closed fins: 25–50.

Diameter (major axis) of top of cone: 75–130 (range of size: 50 × 75 to 105 × 130; range of ellipticity: 70 × 75 to 55 × 100).

Cone angle: 40–80°.

Thickness of cone wall (measured above fins): 5–8.

Height of cone rim above highest fins: 10–20.

Distance from cone rim to top of inner sieve: 3–10.

Diameter of inner sieve pores: 0.8–1.5.

Width of interspaces between them: 0.3–1.2.

Width of vertical non-sieve-like strips on central cone: 1.5–5.0.

Diameter of pores in sieve interspaces: 0.03–0.10.

Thickness of sieve: 0.5–1.0.

Diameter of large pores on inner cone above sieve: 0.1–3.0.

Spacing (center to center) of large pores on cone above sieve: 0.5–0.7.

Diameter of large pores on fins and tubes: 0.2–0.6.

Spacing (center to center) of large pores on fins and tubes: 0.5–0.9.

Diameter of intermediate pores on fins and tubes: 0.12–0.28.

Spacing (center to center) of intermediate pores: 0.2–0.5.

Diameter of small pores on fins and tubes: 0.02–0.08.

Spacing of small pores (center to center): 0.06–0.12.

Diameter of parietal gaps on fin-edges and tubes: 1.0–3.0.

Spacing (center to center) of parietal gaps: 7–13.

Thickness of cortical layer: 0.35–0.50.

Thickness of inner “honeycomb” layer (measured perpendicular to exterior surface): 1.5–2.5.

Diameter of diaphyses 0.4–1.1 (mostly about 0.6).

Thickness of partitions between them: 0.06–0.20.

Diameter of pores in these partitions: 0.04–0.16.

Total length (perpendicular to surface) of demonstrable diaphyses: 1.2–2.2.

Diameter (coaxial with dictyonal strand) of enlarged nodes: 0.10–0.12.

Thickness of dictyonal strand or ray: 0.02–0.10.

Internode distance along dictyonal strand: 0.08–0.75.

Maximum diameter of tubular roots: 12–27.

Length of closed tubular roots: 35–60.

Length of open or incomplete tubular roots: to 80 (and therefore originally longer). (A poorly preserved structure 150+ mm long may be a root of this species.)

Height of fins (along attachment to cone): (30–?) 40–120.

Thickness of fins: 10–15.

Number of radial fins: 9–22.

#### Order LYCHNISCOSIDA Schrammen 1903

**DISCUSSION:** This order includes hexactinellids in which the central crossing of each hexactin bears struts that outline the edges of an octahedron (a *lychnisc node*). All known members of the group have skeletons composed of dictyonal strands. The lychnisc nodes may be obscured by secondary thickening, which can lead to misidentification as a hexactinosan.

Family DACTYLOCALYCIDAE Gray 1867, emend.  
Reid 1957

DIAGNOSIS: Lychniscosida with a single intradictyonal labyrinthine canal system opening to both dermal and gastral surfaces; lychnisc nodes often suppressed to varying degrees; loose rhabdodiactins present in living forms.

Genus EXANTHESIS Regnard in Moret 1926

DIAGNOSIS: Dactylocalycid whose massive body is composed of anastomosing, thin-walled tubes that outline inhalant and exhalant cavaedial spaces; there is no external siliceous envelope nor central tube; tubes most often in lateral contact peripherally so that their edges form a reticulate pattern at the surface rather than a series of separate circles; a cortex is present especially on dermal surfaces; lychnisc nodes frequently solid in the cortex but open in the rest of the skeleton.

DISCUSSION: This is a homeomorph of *Brachiolites* Smith 1848 (which according to Reid 1962, p. 34–35, is the correct name for species commonly referred in the literature to *Plocoscyphia* Reuss 1846) but it has within the dictyonal net the labyrinthine canal system characteristic of the Dactylocalycidae, while *Brachiolites* is uncanalized. Reid (1957, p. 824; 1962, p. 42) discusses the structure and relationships of *Exanthesis*, and his concepts are used here.

TYPE SPECIES: *Exanthesis reticulatus* (Hinde 1884).

EXANTHESIS OVATUS Finks, Hollocher and Thies,  
new species

pl. 51, Figs. 1–6; pl. 52, Figs. 1–6; pl. 53, Figs. 1, 3, 4

DIAGNOSIS: Ovoid, anvil-shaped, or subcolumnar *Exanthesis* attached by encrustation along a broad side and occasionally supported by pillar-like structures arising from the base; cavaedial tubes, and their wall thickness, small for the genus; cavaedial openings more often subcircular on basal surface, more often meandriform on upper surface.

DESCRIPTION: The sponges are elongate ovoid to possibly subcolumnar, and are relatively small. The smallest complete specimen (USNM 127714) is 25 × 30 × 40 mm; the largest (USNM 127712) is 30 × 35 × 60 mm. They appear mostly to have been attached to the bottom by one of the broad sides rather than by a narrow end. Two (USNM 127711, 127712) appear anvil-shaped, expanding above the attachment area. We consider places where the edges of the tube walls are smooth and regular to have been free, while places where they are rough and irregular we consider to have been attached. Two specimens (USNM 127713, 127720) may perhaps have been attached by a narrow end and therefore have been subcolumnar, but they also have irregularities on a flat side and the evidence is equivocal.

The anastomosing cavaedial tubes, of which the body is built, open to the exterior as circular to meandriform spaces about 4–5 mm in diameter or width (range: 2–6 mm). Only rarely are the tube edges free at the surface. Generally they are laterally fused to one another and sometimes form a reticulate diamond-shaped pattern. The tube walls are 1–2 mm thick. In some cases two subparallel walls of adjacent tubes will have a narrow, 1–1.5 mm wide, meandriform space between them, which corresponds to a cavaedial space but is often discontinuous or crossed by thin bridges of dictyonal net. These narrow meandriform spaces are sometimes, but not always, associated with what we have interpreted as the sites of attachment. They are often, but not demonstrably always, inhalant spaces, the cavaedia they separate being usually lined with a gastral surface. The surfaces that seem to be gastral or exhalant have a more regularly quadrate dictyonal net exposed. There are sometimes rather abrupt changes to a different orientation of strands on these surfaces though generally the strands fan gently toward the free edges of the tube. This net is interrupted locally by circular to submeandriform pores, not much wider than the regular intradictyonal mesh spaces, which represent the openings of the intradictyonal labyrinthine canal system. Patches of an irregular cortical net are developed locally on the gastral surface. The dermal or inhalant surfaces have an irregular, non-quadrata net over most of the surface. Most of this seems because of a widespread cortical meshwork that is locally of considerable thickness, but in part it may be related to the fact that the dictyonal strands meet the dermal surface at an angle. Thin, curving, siliceous filaments participate in the cortical mesh, especially on the dermal side. On both gastral and dermal surfaces of one specimen there are a few small subcircular areas, 0.5–1.5 mm in diameter, that have larger pores than their immediate surroundings. One appears to contain a cluster of circular pores outlined by an irregular mesh; the others appear to reveal the interior dictyonal net but with the strands bowed slightly like the meridians of a globe. Both kinds of circular areas appear to be shallow pits in the surface. It is possible that they are artifacts of preparation. The lychnisc nodes of the irregular cortex on both surfaces are variably filled-in or suppressed; those of the main dictyonal net are well-developed and open. Short distal rays usually project from the nodes on all surfaces; the struts of incomplete lychnisc nodes also project as well, giving a spinose appearance to the surfaces.

The internal intradictyonal labyrinthine canal system opens both to the dermal and gastral surfaces, and also to the free edges of the cavaedial tubes. The rounded canal openings are easily distinguished on the gastral surfaces and tube edges from the quadrate spaces of the regular net. However, it is difficult to identify canal

openings on the dermal surface, with its well developed irregular cortex, since all mesh spaces are rounded.

The side of the sponge considered to be the base may have a preponderance of circular cavaedial openings over meandriform ones, while the other sides have a preponderance of meandriform openings. However, both kinds occur on all surfaces. Visual inspection suggests that the meandriform openings on the basal side are more often inhalant while the meandriform openings on the upper surface are more often exhalant. If it is true, it suggests that the exhalant cavaedia expand upward, while the inhalant cavaedia contract. A parietal-gap-like opening occurs in at least one case, in the wall of a cavaedial tube; this appears to be the initiation of a new branch. The walls of meandriform openings are often connected by thin bridges of wall across the top.

On the probable basal side of the holotype there is an irregular expansion, some  $7 \times 20$  mm, which may represent the actual point of contact of the sponge with an object on the substrate. A cylindrical pillar-like structure rises up at each end of this expansion to join the main body of the sponge. They are parallel to one another and would be vertical if the longitudinal axis of the sponge, and of the basal expansion, were tilted at about  $45^\circ$ . It is possible that this was the life position of the sponge and the cylinders were supporting structures. They are hollow and covered with dermal (?) cortex, thus resembling cavaedial tubes; one is 4 mm in diameter, the other only 1.5 mm, both less than 10 mm long. The cortex differs from that of regular tubes in that dictyonal strands are subparallel to the length of the structure and their beams outline rhombic mesh spaces elongate in this direction. These are the only root-like structures observed on any of the specimens. The larger of the two pillars is partly covered by an encrusting cheilostome bryozoan colony which may have been present during the lifetime of the sponge. The bryozoan covers over a lateral protuberance of the pillar, the growth of which it may have stopped. The bryozoan itself began from this point and spread upward and downward along the main pillar. Another encrusting bryozoan colony nearby, as well as a small encrusting calcareous sponge, both face upwards if the pillars are oriented vertically, thus favoring the proposed orientation of the sponge. The vote is not unanimous, however, for among three other bryozoan colonies, two face laterally and the third faces downward on the underside of an overhang. The last actually is a vote in favor, for if the pillars are vertical the bryozoan will be held above the substrate, while if the long axis of the sponge is horizontal it would lie against the substrate.

A long worm tube (?) winds through several cavaedial tubes, apparently passing at one point through a cavaedial wall, which suggests that it was present during the lifetime of the sponge. There are two species of worm

tube, at least five species of bryozoan, and one calcareous sponge, that are encrusting this single specimen.

**DISCUSSION:** The cavaedial diameters and tube wall thicknesses of these specimens are considerably less than those of the type species *Exanthesis reticulatus* (Hinde 1884). The interior net is also more regularly quadrate and the cortex less strongly thickened. The labyrinthine intradictyonal canals leave no doubt that we are dealing with a dactylocalycid, and the plexiform habit, lack of an external capsule or central tube, and presence of a cortex, fit the concept of *Exanthesis* as developed by Reid (1962, p. 42). The root-like structure seems not to have been reported from other *Exanthesis* species. The circular pits on a paratype are also an unusual feature, but seem too dubious to regard as a distinguishing character.

**MATERIAL:** 6 complete or nearly complete, and 5 partial or fragmental specimens from USGS 22389, and one complete specimen from USGS 19019; all are silicified.

**TYPES:** Holotype USNM 12771; paratypes USNM 127712–127721.

**LOCALITIES:** USGS 22389, 19019.

**MEASUREMENTS:** (All in millimeters, other than those in the description.)

Diameter of intradictyonal labyrinthine tubes and their openings: 0.15–0.40.

Spacing of nodes along dictyonal strands: 0.20–0.30.

Spacing of dictyonal strands: 0.15–0.25.

Diameter of dictyonal beams: 0.03–0.06.

Diameter of dermal cortical mesh spaces: 0.04–0.40.

Diameter of gastral cortical mesh spaces: 0.05–0.30.

Diameter of lychnisc nodes: 0.08–0.12.

Length of struts: 0.06.

Diameter of struts: 0.02.

Diameter of siliceous filaments in cortex: 0.02.

#### Family CAMEROSPONGIIDAE Schrammen 1912

**DIAGNOSIS:** Lychniscida covered externally partly or wholly by a finely-porous siliceous envelope bearing an exhalant opening or openings, and possibly inhalant openings as well; composed internally of anastomosing cavaedial tubes (plexiform structure), with or without a central tube; cortex, lining or covering cavaedial tubes, present or not; intracortical or intradictyonal canalization present or not.

**DISCUSSION:** For the sake of convenience we interpret this family very broadly to include all plexiform lychniscida with an external envelope.

Genus ROBINIA Finks, Hollocher and Thies,  
new genus

**DIAGNOSIS:** Camerospongiid without central tube; body upwardly-flaring conical with flat top, and

completely (?) covered with extremely fine-meshed external envelope that bears sinuous rows of circular to slit-like apertures that run up sides and across top; apertures of exhalant rows more often slit-like and larger, those of inhalant rows smaller and more circular; internal branching and anastomosing cavaedia cylindrical and subparallel at narrow base, becoming expanded, meandriform and obscurely radial (especially exhalant) in upper part; inhalant cavaedia lined with continuous irregular cortex, largely dictyonal but probably including additional hexactins and siliceous filaments; regularly and closely-spaced circular ostia, communicating with labyrinthine epirhyses, are outlined by the curving beams of this dermal cortex; exhalant cavaedia mostly lined with regular quadrate dictyonal net, but extensive patches of irregular cortex contain circular postica that are more widely spaced than the ostia and communicate with shallow aporhyses; similar postica are irregularly scattered over the quadrate parts of the gastral surface, the net becoming irregular in their immediate vicinity; external envelope composed of an extremely fine, three-dimensionally labyrinthine net with meandriform mesh-spaces; the space between the envelope and the nearest cavaedial tube-walls occupied by an irregular net similar to, and seemingly continuous with, the dermal cortex; it contains a system of labyrinthine canals including large, regularly-spaced longitudinal ones immediately beneath the outer envelope; main dictyonal net of the cavaedial walls regular and quadrate, composed of dictyonal strands that diverge upward, outward, and toward the dermal surfaces; lychnisc nodes open in interior net, filled-in on irregular gastral cortex, filled-in and reduced in size on dermal cortex, suppressed or absent in outer envelope; it is not certain whether the labyrinthine epirhytic and aporhytic canal system is wholly intracortical or involves the main dictyonal net, or whether they are continuously connected or separated by regular dictyonal spaces (latter more likely).

**DISCUSSION:** The general structure is similar to that of the living lychniscosan *Aulocystis* Schulze 1886, but that genus does not possess the stalked, trochiform shape and the longitudinal and radial rows of apertures characteristic of the present genus. Among fossils, *Tremabolites* Zittel 1877, is perhaps closest, but the external membrane is confined to its upper surface and the apertures are larger and not organized into rows. Both *Camerospomgia* D'Orbigny 1847, and *Etheridgia* Tate 1865, have a central funnel, unlike the present genus. In *Camerospomgia*, moreover, the external membrane is confined to the upper surface and is pierced only by the large central osculum. In *Etheridgia* it is pierced by lateral openings as well as by the central osculum; the shape of *Etheridgia* is conical, but with the narrow end at the top, just the reverse of the present genus. *Cystispongia* Roemer 1864, is to some extent a

homeomorph of the present genus, but it does not have lychnisc nodes.

*Cameroptychium* Leonhard 1897, has a number of similarities, as well as differences. It is different in having a central tube, lined by a sieve plate, from which the anastomosing cavaedial tubes radiate; the external membrane is confined to the upper surface, as in *Tremabolites*, the tubes being exposed on the underside. A perhaps superficial similarity is exhibited by *Cameroptychium planum* Schrammen 1912 (Schrammen 1912, pl. 39, fig. 2) in which the spaces between tubes on the underside are partly or wholly bridged over by tongue-like outgrowths that resemble the parts of the siliceous membrane between the slit-like apertures on the present specimen. Although most of these bridges on the present holotype are complete, a few are incomplete and tongue-like, occasionally even overlapping (see pl. 58, Fig. 2). The radial elongation of the tubes in the present species is another similarity, but unlike *Cameroptychium*, there is no central tube.

The labyrinthine canal system seen in *Robinia* may separate it from all of the other camerospongiid types. Further pursuit of this matter would involve a revision of the family, which is beyond the scope of this paper. We name this genus after Robin E. H. Reid, the foremost authority on hexactinellid sponges, and note that the botanical namesake is the locust, a tall, upright, graceful and thorny tree.

**TYPE SPECIES:** *Robinia striatopunctata* Finks, Hollocher and Thies, new species.

**ROBINIA STRIATOPUNCTATA** Finks, Hollocher and Thies, new species

pl. 53, Fig. 2; pl. 54, Figs. 1–4; pl. 55, Figs. 1–3; pl. 56, Figs. 1–5; pl. 57, Figs. 1–5; pl. 58, Figs. 1, 2; pl. 59, Fig. 1

**DESCRIPTION:** There are available two partially complete specimens from the same locality whose modes of preservation are complementary. One (USNM 127723) is preserved in the original silica with the siliceous envelope retained on one side from base to top through about 180° of circumference, and across the top from the periphery essentially to the center through an approximately 60° sector. About two-thirds of the entire sponge is preserved. This specimen was carefully cleaned with needle, "Airbrasive" and ultrasonic cleaner, to remove the soft, fine matrix from the internal tubes as well as from the surface. After initial study it was briefly cleaned further with HCl when it became apparent that nothing was calcified. The other specimen (USNM 12774) consists of an internal mold in the marly matrix of essentially all the internal tubes, together with molds of the intervening skeletal net. A small patch of the outer envelope is preserved in the original silica. The second specimen enables one to visualize the form of the tubes more directly.

The sponge is large. The siliceous holotype (USNM 127723) is 65 mm high, 33 mm in diameter at the lower end, and 70 mm in diameter at the upper end (the diameters were measured where the sponge was most complete but the whole sponge may not have been perfectly circular in circumference). The corresponding measurements on the paratype (USNM 127724) are 90 mm high, 50 mm basal diameter, and 85 mm upper diameter, again somewhat approximate owing to irregularity of outline and absence of the external wall. There is no doubt as to the orientation of the sponge, because the top is indicated by the direction in which the dictyonal strands are added, toward which they diverge and toward which the transverse beams are convex; all these are visible on the holotype. This is not an idle question, for *Etheridgia* has a similar external shape but the reverse orientation.

At the base of the sponge there are tubular cavaedial spaces oriented vertically, and more or less parallel to one another. They are some 3–8 mm in internal diameter, mostly nearer the larger size. It seems possible to differentiate these spaces into gastral or exhalant, and dermal or inhalant, on the form of the skeletal mesh at the surface. One set of surfaces has a more nearly quadratic arrangement of spicular beams, the other set a less regular pattern. This seems to be related to the fact that the dictyonal strands are subparallel to the regular side, but meet the less regular side (emerge) at an angle. In the majority of dictyonines, if the beams emerge to one surface primarily, that surface is the dermal one. On this basis the less regular set of surfaces is tentatively taken to be dermal or inhalant and the more regular, gastral or exhalant. This seems to be confirmed by the fact that toward the upper end of the sponge, the presumptively exhalant spaces become longer and more meandriform than the inhalant ones, and are more often followed by rows of apertures in the siliceous membrane across the top of the sponge. At the base of the sponge, on the other hand, it is the exhalant spaces that are smaller, more isolated, and more cylindrical and basally tapering, while the inhalant spaces are somewhat larger and more interconnected, revealing branching and anastomosis upward. These spaces necessarily alternate. At points of branching, of course, two inhalant spaces will be adjacent, but a new exhalant cavaedium will form between them. The walls between them are 1.5–3.0 mm thick at the lower end of the sponge, and 2.0–4.0 mm thick at the upper end. The inhalant spaces at the upper end are more often isolated vertical passages of elliptical cross-section and some 5 mm to 10 mm in diameter, while the exhalant spaces are meandriform in cross-section, only some 2–5 mm wide, but as much as 50 mm in distance along the meander. There are about a dozen cavaedial spaces at the lower end and about twice that number at the top. Where rows of apertures in the

external siliceous membrane can be related to the internal spaces, the rows of larger apertures are associated with exhalant cavaedia, rows of smaller ones with inhalant cavaedia. This is true both on the sides and on the top of the sponge. The exhalant apertures are more often slit-like, the slits being elongate transversely to the row of apertures, and some 3–6 mm long and 1 or 2 mm wide. They are separated in the row by 1.5–3.0 mm interspaces, and are not elongate strictly parallel with one another. The rows take a sinuous course, especially on the sides of the sponge, presumably following a particular cavaedial space. The interspaces may have developed as bridges over a once-continuous slit that followed the course of the exhalant cavaedium. Some are tongue-like and incomplete; occasionally two arising from opposite sides may overlap rather than join (pl. 58, Fig. 2). The inhalant openings on the other hand, are more often circular, 1 or 2 mm in diameter, and separated by 2 mm interspaces along the row. However, circular apertures may occur in the exhalant rows and slit-like ones in the inhalant, but the general size difference between inhalant and exhalant apertures remains noticeable.

The dictyonal mesh is dominantly quadrate when viewed in longitudinal section. Dictyonal strands are about 0.4 mm apart, transverse beams about 0.5 mm. The strands are dominantly vertical but diverge gently toward the presumed dermal side. New strands are added by branching from the side of a preexisting strand. The transverse beams are at the same level in adjacent strands and the resulting transverse lamellae are gently convex toward the top of the sponge. The dictyonal net on the presumed gastral side is also quadrate, fanning out toward the top of the sponge as new dictyonal strands are added.

The presumed dermal, or inhalant surface, is completely covered by a cortex with an irregular, non-quadrangular net. Circular ostia are closely and evenly spaced on this surface, separated by less than their diameters, and in approximate quincuncial arrangement. A labyrinthine system of epirhyses ramifies through the rather thick cortical layer, with the largest epirhysis extending inward perpendicularly from the ostium. The evidence is equivocal whether the system of canals extends into the main dictyonal net. They appear to be confined to the layer of irregular net; if this be considered cortex they are intracortical. Speaking in favor of its being cortex is the fact that the octahedra are filled-in and are also smaller in size. The walls of some of the narrower cavaedial tubes near the base of the sponge seem composed almost entirely of irregular net, and the epirhyses may end just under the gastral layer which is the only regularly quadrate part of the wall; in this case we must either assume that the dermal cortex composes most of the wall, or admit

that the main dictyonal net may be irregular and have filled-in nodes. The space between the outer siliceous envelope and the nearest cavaedial tubes is filled with a similar irregular net, basically finer-meshed than the main dictyonal net (its mesh spaces are about 0.1–0.2 mm in diameter), that contains an even more strongly developed system of labyrinthine canals, many of which are much larger than those found in the cavaedial walls. A series of these, about 0.5 mm in diameter (0.4–0.7), run longitudinally just beneath the outer envelope. They are spaced rather regularly about 2 mm apart and may be connected horizontally by canals of the same diameter. This system is confluent with those of the cavaedial wall proper and may therefore be considered to be developed in a greatly expanded cortical layer. It is also confluent externally with the similar, but very much smaller, system of labyrinthine tubes in the siliceous envelope, from which it is separated by a fairly abrupt transition. The circular postica of the presumed gastral layer are mainly found in the patches of irregular cortex which tend to be developed at more strongly curved parts of the surface. The postica are more widely spaced than the similar-sized ostia, being separated by about one of their diameters, and are approximately quincuncially arranged. Postica also occur more widely scattered, and often of larger size and less regular shape, on the quadrate parts of the gastral surface, where they are outlined by distortion and curving of the dictyonal net. The postica do not seem to connect with aporhyses of any extent, for one can see the regular quadrate net crossing beneath them, but it is possible that there are lateral connections that have escaped notice. Nodal octahedra are filled-in in the presumed gastral cortex, thus supporting the interpretation as cortex, but the nodes are a bit larger and octahedral structure less obliterated than in the presumed dermal cortex. Where the regular quadrate mesh is exposed on the gastral surface, the octahedra are large and open, just as in the interior, with only the distal ray suppressed. Where postica occur on the quadrate parts of the surface, the curving dictyonalia that outline them have filled-in nodes; one might regard them as cortical.

The dominantly labyrinthine nature of the canal system of this sponge seems well-established, but the nature of its relation to the dictyonal net is not clear. We tentatively favor its interpretation as intracortical, with a well-developed labyrinthine epirhytic system, and a separate, more poorly-developed aporhytic one. The cortex in which it is developed is a dictyonal cortex, though adventitious hexactins and siliceous fibers are probably involved in the dermal cortex (and almost certainly in the siliceous membrane). It is possible, however, that it is intradictyonal. (It should be noted here that the mesh spaces are filled with a

soft marly matrix that is partly silicified. It has been removed from most of the surface and from parts of the interior net, but attempts to remove it extensively from the interior net leads to damage which can be misinterpreted as intradictyonal canals.) If intradictyonal, there are two possibilities: (1) there is a continuous single labyrinthine canal system open to both surfaces as in *Exanthesis* and other dactylocalycts; (2) there are separate labyrinthine epirhytic and aporhytic systems connected only by the regular quadrate intradictyonal spaces, that is, a labyrinthine or partly labyrinthine diplorhysis. We would tend to favor the latter if the canals are considered intradictyonal and not intracortical. The siliceous envelope that covers the sponge is about 1.0–1.5 mm thick and extremely fine-meshed. The 0.04–0.36 mm mesh spaces are circular to meandriform and the meandriform pattern is three-dimensional as seen in sections. It is not possible to discern the limits of individual spicules or lychniscs, but the skeletal beams curve to form the meandriform spaces. As in other lychniscosa, it is likely that siliceous filaments in addition to regular spicule rays are involved in the mesh. The meandriform pattern of the mesh spaces is also characteristic of lychniscosan envelopes. However, where rectangular crossings can be seen, they are often parallel over extensive areas, suggesting that the siliceous envelope is constructed by irregular additions to a fundamentally regular net. There are several spicule layers in the envelope and all elements are closer together than in the main net. Where the siliceous envelope is in contact with the dictyonal skeleton of the sponge interior, the two are fused together, but the interior dictyonal strands often meet the surface of the envelope at a considerable angle.

**DISCUSSION:** The main dictyonal mesh spaces of this species are quite coarse, (0.4–0.5 mm) about twice the dimensions of those of the co-occurring lychniscosan *Brachiolites*, indeed, coarser than in any of the other dictyonines of the fauna. Dictyonal mesh spacing, in general, seems to be one of the most constant of specific characters.

Most dimensions, including overall size, cavaedial diameters, lateral aperture diameters, wall thicknesses, and mesh spacing, are approximately the same in the two specimens available. Likewise the general shape, the pattern of cavaedial spaces, and the form of the lateral apertures are the same. Therefore, these features may be taken tentatively as useful species characters.

The apparent preferential siting of larger slit-like apertures over exhalant cavaedia and smaller circular apertures over inhalant cavaedia, seen in the holotype, is an interesting regularity. Not enough of the siliceous envelope of the paratype is preserved to test this preference on that specimen.

The basal attachment of the sponge is not preserved in either specimen. It is possible that there was a stalk. Whether the ultimate attachment was encrusting, or whether there were branching roots, is not known.

Within one of the gastrally-lined cavaedial spaces near the axis of the sponge, and about 2 cm below the top surface, there is a horizontal beam identical in its fine labyrinthine structure to the outer siliceous envelope. It is cylindrical, about 1.7 mm in diameter at its narrowest central portion, expanding toward the ends where it merges with the more coarsely labyrinthine cortex lining the cavaedium. The beams of the cortex are more strongly thickened than usual in the immediate vicinity of the balk. This raises the question whether during the ontogeny of the sponge there is not a siliceous envelope developed at the then top of the sponge, which might later be resorbed and of which this balk is a remnant. (Incidentally, the co-occurring specimens here referred to *Exanthesia ovatus* cannot be juveniles of *Robinia*. Not only are their cavaedia not parallel as in the lower end of *Robinia* but also their dictyonal mesh spaces are half the dimensions of those of *Robinia*; even near the base of *Robinia* they have the same large dimensions.) It is also possible that the balk was a portion of the envelope between two exhalant slits that broke off from the upper surface during the lifetime of the sponge and became lodged in the underlying cavaedium, fusing with the cavaedial walls because it still contained living tissue. This possibility is supported by the occurrence of two other probable fragments of the envelope with clearly broken edges, embedded in debris (and fused to cortex?) in another exhalant cavaedium, separate from the first (though ultimately connected with it through lateral passages). Enough of the top is preserved to see that it is essentially flat.

The linings of several cavaedia bear encrusting bryozoa (at least 3 spp.) and encrusting worm tubes (2 spp.?). In no case do they cover broken edges, but rather are themselves broken, as are similar encrusting species on the outside of the siliceous envelope where this is broken. They thus predate the present damage to the specimen, but there is no evidence from overgrowth by the sponge that they were there during the life of the sponge. They are probably penecontemporaneous, however, since they are buried in matrix. Other sponge spicules, including large dichotriaenes and ophirhabds, are common in the matrix. A small porosphaerid calcisponge encrusts the side of one cavaedium, probably *Bactronella incrassans*.

**TYPES:** Holotype USNM 127723; paratype USNM 127724.

**LOCALITY:** USGS 22389 (2 specimens).

**MEASUREMENTS:** (additional to those in the description; in mm):

Diameter of lychnisc nodes (diagonal) 0.20–0.35 (as small as 0.10 in dermal cortex).

Diameter of struts: 0.03 (in a 0.3 diameter node).

Length of struts: 0.15 (in a 0.3 diameter node).

Diameter of dictyonal beams in main skeleton: 0.06–0.14 (higher values result from secondary thickening and are associated with infilled lychniscs.)

Diameter of dictyonal beams in dermal cortex: 0.04–0.08.

Diameter of dictyonal beams in gastral cortex: 0.04–0.08.

Diameter of beams in siliceous envelope: 0.03–0.10.

Diameter of ostia: 0.4–0.6.

Diameter of postica: 0.4–0.8.

Spacing of nodes along dictyonal strands: 0.4–0.6.

Spacing of dictyonal strands: (0.25) 0.4–0.5 (the smallest number represents distance at first node after origination of strand.)

Diameter of dermal cortex mesh spaces: 0.08–0.60 (includes ostia).

Diameter of gastral cortex mesh spaces: 0.08–0.80 (includes postica).

Diameter of siliceous envelope mesh spaces: 0.04–0.25.

Number of inhalant cavaedia at lower end of holotype: 7.

Number of inhalant cavaedia at upper end of holotype: 12.

Number of exhalant cavaedia at lower end of holotype: 6.

Number of exhalant cavaedia at upper end of holotype: 11.

#### Order LYSSACINOSIDA Zittel 1877

**DISCUSSION:** This includes Hexasterophora whose skeleton is *not* built of dictyonal strands. The non-dictyonal type of skeleton is termed *lyssacine*. However, not all lyssacine sponges are Lyssacinosida; the Subclass Amphidiscophora are also lyssacine. Certain assignment requires the presence of microsceres (hexasters vs. amphidiscs) which are usually missing from fossil material. We are thus thrown back on an assessment of other characters which may suggest a particular family or other lower level taxon.

#### Family EUPLECTELLIDAE Gray 1867

**DIAGNOSIS:** Lyssacinosida in which autodermalia are hexactins whose proximal ray is very much longer than the other rays; no hypodermalia; parietal gaps numerous; synapticular rigidification of the skeleton common; shape and basal attachment various.

Genus SHELDONIA Finks, Hollocher and Thies,  
new genus

**DIAGNOSIS:** Skeleton built up mainly of beam-like structures (syndoka) each of which consists of a bundle

of parallel subequal rhabdodiactins held together by closely spaced synapticulae; body wall built of layers of syndoka running parallel to surface and arranged in two diagonal series outlining a rhombic net, plus a less pervasive longitudinal and transverse series; an elliptical, canal-like parietal gap occupies the center of each rhombic space; smaller rhabdodiactins, not organized in bundles, parallel the syndoka, form an incomplete surface layer on one side (gastral?), and line the parietal gaps; a fine irregular net of curving siliceous filaments coats the syndoka and the surface layer of rhabdodiactins; no other spicules known; shape of sponge tabular, without root-tuft, but may be incomplete.

TYPE SPECIES: *Sheldonia trabecula* (Rigby 1981)

DISCUSSION: The spicular net and parietal gaps are organized rather like those of *Regadrella* Schmidt 1880, *Proeuplectella* Moret 1927, and *Purisiphonia* Bowerbank 1869. It differs from the first in not being tubular, from the first two in not being thin-walled, and from all three in that the principal skeletal elements are syndoka rather than separate rhabdodiactins and hexactins. It also lacks hexactinal or pentactinal dermalia and gastralria, but it is possible these may have been lost.

*Taegeria* Schulze 1887, is another thin-walled euplectellid with a rather more irregular arrangement of spicule bundles and parietal gaps. *Walteria* Schulze 1887, is a related thin-walled genus with a more open net in which the polygonal spaces between the irregular spicule bundles serve as parietal gaps instead of the more circular ones of *Taegeria*. In both these genera, as in *Regadrella*, as well as in some species of *Euplectella*, the spicule bundles of the lower part of the body are united into syndoka-like structures by synapticulae, although these appear to lack the lacy investiture seen in *Sheldonia*. They are also not composed of rhabdodiactins alone but include hexactin derivatives with more numerous rays, as do their comitalia. The present species represents an extreme development of the thickening and fusion of the skeletal net seen in these other euplectellids.

*Sheldonia* is placed in the Euplectellidae on the basis of its resemblance to the genera cited above, and of the pervasive development of synapticulae, which, to some extent, is characteristic of the family. There is no assurance, however, that it belongs to this family or even to the Hexasterophora. The hexactin dermalia with long proximal rays, characteristic of the Euplectellidae, are not present, and of course we have no microscleres whatever, which are necessary for any certain assignment of a lyssacine to subclass, order or family.

We name this genus after Dr. Richard P. Sheldon who gave support and encouragement to our work.

SHELDONIA TRABECULA (Rigby 1981)  
pl. 59, Figs. 2, 3; pl. 60, Figs. 1, 2; pl. 61, Figs. 1–3; pl. 62, Figs. 1–3; pl. 63, Figs. 1, 2

*Regadrella trabecula* Rigby 1981, p. 136, pl. 1, figs. 3, 4.

DESCRIPTION: The shape of the whole sponge is unknown; the largest specimen (USNM 127725) is approximately 70 × 80 × 10 mm thick and essentially flat.

The parenchymal skeleton appears to consist entirely of rhabdodiactins; large principal ones and smaller comitalia. The principal rhabdodiactins are organized into subcylindrical bundles of about a dozen parallel spicules of more or less equal size; they are held together within the bundle by closely and evenly spaced synapticulae that resemble tiny spines. The bundles run parallel to the flat surface of the wall in several layers (about a half-dozen). Within each layer they criss-cross rhombically and bundles are connected at points of crossing by similar synapticulae. Much smaller rhabdodiactins parallel the bundles as comitalia. They may also bear the same kind of synapticulae, but many are smooth and unconnected. The wall is penetrated by closely-spaced elliptical parietal gaps; because of the thickness of the wall they resemble large canals. Each gap occupies a rhombic space between criss-crossing bundles. The long axes of the ellipses are parallel to one another and perpendicular to one edge of the specimen, which may be the growing edge (see below). The gaps are arranged in obscure rows more or less parallel to this edge. On one side of the wall (dermal?) the superficial bundles are parallel to the long axis of the parietal gaps. They are especially concentrated and closely spaced near one edge, to which they are perpendicular, and which may be the growing edge of the sponge. A few millimeters below this edge another group of bundles parallels it. The other side of the sponge (gastral?) lacks the concentration of bundles perpendicular to the edge, most of them being diagonal to the edge and forming the rhombic pattern alluded to earlier. In addition, a substantial number of bundles are parallel to this edge. Another feature of this surface is a greater concentration of the small rhabdodiactin comitalia. In the area farthest from the presumed growing edge they form a nearly continuous smooth surface layer between the parietal gaps and mask the underlying large bundles. Rows of small closely-spaced, circular pores alternate in this area with the rows of parietal gaps. The small rhabdodiactins of this layer are connected by numerous synapticulae but they are not all parallel and are not organized into discrete bundles. The synapticulae seem also to unite with one another to form an irregular, round-meshed net of fine, curving siliceous filaments. On the opposite "dermal" side of the wall, the large rhabdodiactin bundles are often completely coated with such a lace-like net. Similar filaments are seen throughout the interior skeleton.

The walls of the canal-like parietal gaps are lined with small rhabdodiactins, mostly subparallel to the outer surfaces of the sponge and therefore transverse to the walls of the "canal." The larger rhabdodiactin bundles also form part of the gap walls, again mostly subparallel to the outer surface. However, some bundles are subperpendicular to the surface as are some of the smaller spicules. There may be lateral canal-like openings in the wall of the gap. The opening of a particular gap is usually, but not always, slightly larger on the "gastral" surface. All of the spicules in this sponge appear to be rhabdodiactins together with their connecting synapticulae. No certain examples of hexactins, pentactins, stauractins, or tauactins could be found. Although no constituent spicule of a bundle could be traced completely end to end, all apparent crossings of rays proved to be cases of one spicule or spicule bundle, passing beneath another with fusion at the point of contact. Two instances of T-junctions in the same plane, however, were found; one rectangular, the other oblique. It is possible that they are tauactins; it is also possible, and perhaps more probable, that they are fortuitous contacts of the tip of one spicule with the side of another, with the usual fusion at the point of contact. The spicules involved were not components of bundles. Two or three small calthrops-like, or orthotriaene-like, spicules were found in the net, partly buried in matrix. Their consistent symmetry suggests that they are choristid spicules that were washed into the net prior to burial, possibly from the co-occurring *Geodia*.

**DISCUSSION:** The principal structural unit of this skeleton is the rhabdodiactin bundle, which behaves structurally as a single large spicule. The synapticulae are so closely spaced within it that it resembles more a porous cylinder than a bundle of separate spicules, appearing rather like certain echinoid spines. We here name this structure a *syndokon*, and define it as follows:

**Syndokon** (pl. *syndoka*): A bundle of parallel, subequal rhabdodiactins united by closely and regularly spaced synapticulae so as to form a single, rigid, cylindroid body (from Greek *syn*, together; *dokos*, a beam, plus a neuter ending, thus a "together-beam-thing").

The constituent rhabdodiactins are often so close together that at first glance the syndokon looks like a single large spicule ray until one notes the longitudinal corrugations on its surface produced by the component spicules. Often the synapticulae project from the surface of the syndokon as short spines; it is possible that they were once connected to the filaments of a lace-like net such as invests other syndoka. When an individual syndokon is followed, and its end can be seen, it terminates abruptly, perhaps by breakage. A few rhabdodiactins can be seen to terminate within the syndokon, but most cannot be followed to their

terminations (they are longer, however, than the comitalia). Occasionally the constituent spicules splay apart somewhat, and many syndoka are more strap-like than cylindrical, being flattened parallel to the sponge surface. Where syndoka cross, they generally maintain their identity, passing over or under one another as a unit. One instance of interpenetration has been seen, however; here the component spicules pass through in smaller bundles, rejoining to form a single syndokon again on the opposite side. Two instances were also seen of two subparallel syndoka joining to form a single larger one. Some syndoka are preserved as hollow tubes of silica, presumably as a result of diagenesis. In one case one can see individual spicules emerging from the broken end of such a tube. Other tubes still bear the external form of the syndokon, with the outlines of component spicules and synapticulae, even though the interior is hollow. Still others are completely smooth and the question arises whether they could not be single rays of very large spicules. The fact that they are hollow and resemble similarly preserved undoubted syndoka suggests that they represent a further stage in which silicification has obliterated traces of the component spicules. An undoubted single spicule the diameter of one of the smaller syndoka (0.24 mm) has been found, but none as large as the larger syndoka (0.5–0.6 mm in diameter).

The largest specimen (USNM 127725) (which is in two pieces that fit precisely) appears to be incomplete. It is tabular and so flat and without curvature that the entire sponge is not likely to have been tube-like or even cup-shaped. Since some living lyssacines are known to be tabular, that may have been its shape. There is no obvious attachment structure preserved.

The heavy and rigid construction of this species suggests an adaptation to rough water conditions. Its occurrence at the inlandmost locality places it closer to the paleoshore and supports such an inference. Rigby (1981, p. 136) described a conspecific fragment from the same locality. His fragment revealed curvature enough for him to estimate the diameter of the complete conical or cylindrical sponge to be approximately 16 cm. Wall thickness was the same as in our specimens but thinned toward one end, which he therefore interpreted as oscular. It would appear that the surface we have interpreted as gastral does indeed correspond to that on the inside of Rigby's curved specimen, to judge from expansion of parietal gaps toward this side. Rigby says small hexactins are present, but we were unable to demonstrate any with certainty.

**MATERIAL:** One large specimen (in two pieces that fit exactly), plus two small fragments; all may have come from the same individual.

**TYPES:** Hypotypes USNM 12772, 127726, 127727.

**LOCALITY:** USGS 21849.

**MEASUREMENTS:** (All in millimeters.)

Diameter of parietal gaps:  $1.2 \times 1.8$  to  $2.6 \times 4.2$ .  
 Interspaces within rows: 0.3–3.5 (mostly around 1.5).  
 Interspaces between rows: 4–7.  
 Diameter of small pores in “gastral” surface layer: 0.2–0.5 (interspaces: 0.5–2.5).  
 Diameter of syndoka: 0.15–0.60.  
 Length of syndoka (incomplete): 3–22.  
 Diameter of rhabdodiactins in syndoka: 0.03–0.24 (majority 0.04–0.06).  
 Diameter of synapticulae in syndoka: 0.02–0.04.  
 Length of synapticulae in syndoka: 0.02–0.04.  
 Spacing of synapticulae along syndokon: 0.06–0.10.  
 Spacing of syndoka in diagonal series: 2–5 (mostly about 3).  
 Length of rhabdodiactins on “gastral” surface: 0.65–2.00.  
 Diameter: 0.02–0.06.  
 Length of rhabdodiactins lining gaps: 0.75–2.25+.  
 Diameter: 0.02–0.06.  
 Diameter of siliceous filaments: 0.01–0.02.  
 Diameter of mesh spaces in filamentous net: 0.04–0.08.  
 Diameter of canal openings in walls of parietal gaps: 0.4–0.7 (mostly 0.7).

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## PLATES

### PLATE 1

Figs. 1–5. *Plectroninia pertusa* n. sp., Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 1. Upper surface of a larger specimen. Paratype, USNM 133084. 2. Upper surface of a smaller specimen. Paratype, USNM 133086. 3. Upper surface showing exhalant pores and oblique, radial exhalant canals near periphery. Note encrusting cheilostome. Holotype, USNM 133081. 4. Thin-section approximately parallel to upper surface, showing the skeletal net with the pattern made by the proximal rays of the tetraradiate spicules. Paratype, USNM 133082. 5. Thin-section approximately perpendicular to upper surface showing the skeletal net with the pattern made by the three obliquely-downwardly-directed proximal rays, and the short upwardly-directed distal ray of the tetraradiate spicules. Paratype, USNM 133083.

### PLATE 2

Figs. 1–3. *Bactronella womblei* n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Close-up of triactins around oscule. Holotype, USNM 133089. 2. Close-up of dermal layer near base. Paratype, USNM 133090. 3. Thin-section perpendicular to surface, showing layers of tetractins with prominent parallel distal rays. Paratype, USNM 133102.

Fig. 4. *Bactronella incrustans* n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 4. Close-up of patchy dermal layer of individual growing on a specimen of *B. womblei* n. sp. Smaller gaps in dermal layer, as at lower center. May represent oscules. Note partly radial arrangement of monaxons about the gap cited. Paratype, USNM 133102.

### PLATE 3

Figs. 1–11. *Bactronella womblei* n. sp. Figs. 1–10, Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389; Fig. 11, Ideal Cement Company test pit, south of North Carolina Route 53 on dirt road, about 13 km (8 miles) east of bridge over Northeast Cape Fear River, Pender County, North Carolina, 8-13-7. 1. Side view. Paratype, USNM 133095. 2. Side view. Holotype, USNM 133089. 3. Side view. Paratype, USNM 133090. 4. Side view showing dermal layer in rings. Paratype, USNM 133100. 5. Side view. Paratype, USNM 133093. 6. Side view. Paratype, USNM 133099. 7. Side view. Paratype, USNM 133094. 8. Side view of root-like base. Paratype, USNM 133098. 9. Top view of hollow branch (apparently surrounding an encrusted object). Paratype, USNM 133096. 10. Basal view of same hollow branch as Fig. 9. Paratype, USNM 133096. 11. Side view. Paratype, USNM 133104. Figs. 12–17.

Figs. 12–17. *Bactronella incrustans* n. sp. Figs. 12–14, 16–17, Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389; Fig. 15, Rocky Point, North Carolina (Pender County), USGS loc. 7794. 12. Upper surface. Paratype, USNM 133110. 13. View of top. Holotype, USNM 133109. 14. Left: Top surface. Paratype, USNM 133113. Right: Surface of dermal layer. Paratype, USNM 133111. 15. View of base. Paratype, USNM 133119. 16. Close-up of two oscular protuberances, (note three exhalant openings in left-hand osculum). Paratype, USNM 133111. 17. Close-up of basal oxeas. Paratype, USNM 133112.

### PLATE 4

Figs. 1–4. *Cliona* sp. Ideal Cement Company Quarry. 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina, on north side of County Road 1002, opposite the end of County Road 2023. Upper 9 m (30 feet) of Castle Hayne Formation. 1. Internal mold of *Cliona* galleries in a thick bivalve shell, (therefore equivalent to the shape of the sponge body) showing an encrusting cheilostome in cross-section at top completely covering a former papilla (viewed from exterior of host shell). Hypotype, USNM 133124. 2, 3. Two scanning-electron photomicrographs of the surface of the internal mold of a gallery, showing molds of individual chips excavated by the sponge from the gallery walls. Each chip is produced by, and is the size of a single amoebocyte. USNM 133124. 4. Outer surface of cheilostome encrusting the shell that contained the sponge, showing depressed openings in the zoarium over two of the sponge papillae, implying growth of the bryozoan while the sponge was alive. Hypotype, USNM 133124.

### PLATE 5

Figs. 1, 2. *Cliona* sp. Ideal Cement Company Quarry. 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina, on north side of County Road 1002, opposite the end of County Road 2023. Upper 9 m (30 feet) of Castle Hayne Formation. 1. Close-up of internal mold of galleries (viewed from interior of host shell) showing tiny spine-like beginnings of new galleries. Hypotype, USNM 133124. 2. General view (from interior of host shell) of same specimen showing papillae atop major gallery expansions and dendritic shape of intermediate-sized galleries. Note blister-like microtexture of surface, reflecting chips removed by sponge from gallery walls. Hypotype, USNM 133124.

### PLATE 6

Figs. 1–2. *Cliona* sp. Ideal Cement Company Quarry. 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina, on north side of County Road 1002, opposite the end of County Road 2023. Upper 9 m (30 feet) of Castle Hayne Formation. 1. Scanning electron photomicrograph of finest-size initial gallery. Note absence of blister-like chip molds on this gallery (compare chips at bottom of picture). Hypotype, USNM 133124. 2. General view of galleries seen from interior surface of host shell, showing impression of exterior surface of host shell at right with papillar openings. Hypotype, USNM 133123.

Fig. 3. *Achrochordiella vokesi* Rigby 1981. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 3. Dichotriaenes concentrated at edge of sponge overgrowing a hexactinellid previously encrusted by a cheilostome (probably the tubular portion of a *Haynespongia vokesae*) at lower right. This is the basal attachment of the *Achrochordiella*. Hypotype, USNM 133126.

## PLATE 7

Figs. 1–4. *Achrochordiella vokesi* Rigby 1981. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. Side view of large specimen (base at left) showing branches and surface grooves. Hypotype, USNM 133125. 2. Top (?) surface of large, flat specimen, with short branches pointing toward observer. It is not certain whether the openings are oscules or molds of foreign objects. A fragment of *Haynespongia vokesae* is overgrown at lower left. Hypotype, USNM 133127. 3. Edge of sponge (left side) overgrowing *Cerberorhaphidites auriformis* (right side). A large, stellate phyllotriaene (center) overlaps the *Cerberorhaphidites* but belongs to the *Achrochordiella*. Hypotype, USNM 133126. 4. Adjacent area of same specimen. Line separating the two sponges passes down center. Phyllotriaenes are crowded in a surface groove of *Achrochordiella* at left. Hypotype, USNM 133126.

## PLATE 8

Figs. 1–3. *Achrochordiella vokesi* Rigby 1981. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. Scanning-electron photomicrograph of interior spicule net, showing capstan tubercles on tripod spicule. Hypotype, USNM 133125. 2. Complete sponge in side view, base at right, encrusting a tube of *Haynespongia vokesae* partly exposed at lower right. Hypotype, USNM 133126. 3. Other side of same specimen showing two patches (in left half) of I *Cerberorhaphidites auriformis* surrounded by a raised ridge of the *Achrochordiella*. The *Cerberorhaphidites* may have settled on the living *Achrochordiella*. Hypotype, USNM 133126.

## PLATE 9

Figs. 1–2. *Achrochordiella vokesi* Rigby 1981. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. Non-typical specimen in which surface grooves are almost lacking. A few may be seen in the lower part of the photograph. It is not certain whether the irregular openings are cloacas or the molds of foreign bodies. Hypotype, USNM 133129. 2. Close-up of surface of specimen in Plate 7, Fig. 1, showing an area of unusually slender dichotriaenes near the top of the main branch. The tuberculate tripods of the principal skeleton are clearly visible, some of them exhibiting a short distal fourth ray. Hypotype, USNM 133125.

## PLATE 10

Figs. 1–2. *Achrochordiella vokesi* Rigby 1981. South of Stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. Close-up of surface-grooves on specimen in Plate 7, Fig. 1, showing the sharp intergroove crests, and canal openings. Only the principal skeleton is present here, dichotriaenes being absent. Hypotype, USNM 133125. 2. Close-up of broken end of branch of same specimen (a fragment broken from it) showing interior net with radial oxeas perpendicular to outer surface (bottom of photograph). Hypotype, USNM 133125.

## PLATE 11

Figs. 1–4. *Achrochordiella vokesi* Rigby 1981. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. Close-up of surface of specimen in Plate 8, Figs. 2 and 3, showing dichotriaenes in bottoms of surface grooves. Hypotype, USNM 133126. 2. Close-up of surface of specimen illustrated in Plate 7, Fig. 2 showing dichotriaenes (toward left) near edge of sponge that is overgrowing a *Haynespongia* (not visible in photograph). The cluster of subparallel oxeas at lower right is presumably a third sponge. Hypotype, USNM 133127. 3. Close-up of surface of same specimen as Fig. 1 showing dichotriaene near center. Overgrown Cerberorhaphidites at upper right corner. Hypotype, USNM 133126. 4. Close-up of surface of same specimen. The overgrowing margin of the *Achrochordiella* runs parallel to the left and top edges of the photograph. The remainder is occupied by *Cerberorhaphidites*. A dichotriaene of *Achrochordiella* can be seen in the lower part of the photograph overgrowing the *Cerberorhaphidites* in advance of the rest of the growing edge. Hypotype, USNM 133126.

## PLATE 12

Figs. 1–4. *Hazelina bisbifurcata*, n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 1. View of convex inhalant surface. Holotype, USNM 133130. 2. Side view of inhalant surface revealing profile of cup. Holotype, USNM 133130. 3. View of concave exhalant surface. Holotype, USNM 133130. 4. Scanning-electron micrograph of spicular net. The stout tripod at top has somewhat more subdued tuberculation on the primary cladi than most. Holotype, USNM 133130.

## PLATE 13

Figs. 1–4. *Hazelina bisbifurcata* n. g., n. sp. Pender County, North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 1. Cross-section revealing interior net. Inhalant surface at top exhalant surface at bottom. Note fibrous bundles of spicules between exhalant canals. Holotype, USNM 133130. 2. Close-up of exhalant surface. Several of the spicules reveal the central distal knob and the twice-bifurcate cladi. Holotype, USNM 133130. 3. Close-up of inhalant surface. Note the smaller-sized openings than on the exhalant surface. Holotype, USNM 133130. 4. Close-up of exhalant surface. Tuberculation is clearly visible. There are local patches of cheilostomes resting directly on the tripods, suggesting the absence of a substantial dermal skeleton. Holotype, USNM 133130.

## PLATE 14

Figs. 1–2. *Claytonia rayi* n. g., n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. View of concave, exhalant surface. Holotype, USNM 133131. 2. View of convex, inhalant surface. Holotype, USNM 133131.

FIG. 3. *Claytonia rayi* n. g., n. sp. Pender County, North Carolina, 0.3 over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 3. Cross-section revealing canals. The larger canals, exiting to the lower surface are probably exhalant. Paratype, USNM 133132.

#### PLATE 15

Figs. 1–2. *Claytonia rayi* n. g., n. sp. Pender County North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS locality 22389. 1. View of concave, inhalant surface. Paratype, USNM 133132. 2. View of convex, exhalant surface. Paratype, USNM 133132.

Figs. 3–4. *Claytonia rayi*, n. g., n. sp. South of stream in Buck Swamp approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 3. Scanning-electron photomicrograph of smooth dermal dichotriaene. Holotype, USNM 133131. 4. Closeup of concave, exhalant surface showing knobby tetracloines and smooth dermal dichotriaene. Holotype, USNM 133131.

#### PLATE 16

FIG. 1. *Claytonia rayi* n. g., n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. Closeup of convex, inhalant surface showing tetracloines with capstan tubercles and claw-like zygomes; note also a smooth anatriaene (or tripod?). Holotype, USNM 133131.

FIG. 2. *Claytonia rayi* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. Closeup of convex (exhalant) surface showing tetracloines, postica and encrusting cheilostome. Paratype, USNM 133132.

#### PLATE 17

Figs. 1–3. *Claytonia rayi* n. g., n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117, and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. Scanning-electron photomicrograph of tetracloines in skeletal net; note short distal ray at lower left and often multiple capstan tubercles at upper right. Holotype, USNM 133131. 2. Scanning-electron photomicrograph of a broken tetractine showing abrupt change to a non-tuberculate portion at upper right. Holotype, USNM 133131. 3. Scanning-electron photomicrograph of skeletal net; partial stereo-pair showing partly non-tuberculate tetracloines of inner net at upper left. Holotype, USNM 133131.

#### PLATE 18

Figs. 1–6. *Cerberorhaphidites auriformis* n. g., n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117, and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. Concave exhalant surface of fragmentary specimen. Paratype, USNM 133135. 2. Convex inhalant surface of same specimen. Paratype, USNM 133135. 3. Another view of concave exhalant surface of same specimen. Paratype, USNM 133135. 4. Another view of convex inhalant surface of same specimen, (numerous triactins in place are to be found on this surface, particularly in the area below and to the left of the large elongate pore about 2 cm above the bottom center of the photograph, though they are not visible at this scale.) 5. Concave exhalant surface of a cup-shaped fragment. Paratype, USNM 133090. 6. Convex inhalant surface of same specimen. Paratype, USNM 133090.

#### PLATE 19

Figs. 1–5. *Cerberorhaphidites auriformis* n. g., n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117, and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. Exhalant surface of fragment. Paratype, USNM 133137. 2. Concave, exhalant surface of stipitate, hemi-infundibuliform specimen (base at left). Holotype, USNM 133133. 3. Convex, inhalant surface of same specimen. Holotype, USNM 133133. 4. Enlarged view of triactin in place. Paratype. 5. A dichotriaene of Stolleya adherent to the surface of a *Cerberorhaphidites* specimen but clearly not in life position. Paratype, USNM 133135.

#### PLATE 20

Figs. 1–4. *Cerberorhaphidites auriformis* n. g., n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117, and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. Scanning-electron photomicrograph of triactin, removed from specimen. Paratype. 2. Triactins in place (lower left), on a specimen encrusting an individual of *Achrochordiella vokesi* (not visible), Paratype, USNM 133126. 3. Close-up of large exhalant canal opening on concave surface showing arrangement of ophirhabds. Paratype, USNM 133134. 4. More general view of same surface as in Fig. 3, showing pattern of exhalant canal openings outlined by ophirhabds (the opening at bottom center is that seen in Fig. 3 but rotated 180°). Paratype, USNM 133134.

#### PLATE 21

Figs. 1–4. *Stolleya silvigera* n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849, holotype 133144. 1. Side view showing centimeter-sized, subcircular depressions, perhaps xenomorphic, at center and at lower left; the best preserved area of cortical dichotriaenes, shown in Fig. 4, is at the left end. 2. Opposite side. 3. Prodichotriaene removed from specimen. 4. Closeup of surface with forest of densely-packed dichotriaenes in life-position, the circular interruptions at left-center may outline original sponge structures.

#### PLATE 22

Figs. 1–5. *Stolleya silvigera* n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. Holotype, USNM 133144. 1. Side view of dichotriaenes in life-position, same area as Plate 21, Fig. 4. 2. Dichotriaene having one branched and one unbranched cladus. 3. Oxsphaerasters isolated from the specimen, scanning electron photomicrographs. 4. Oxeas isolated from specimen. 5. Closeup of internal oxeas bundles.

## PLATE 23

Figs. 1–6. *Stolleya silvigera* n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. Holotype, USNM 133144. 1–5. Scanning electron photomicrographs of triaene-dichotriaene cladomes, showing variability in bifurcation, thickness, angle, and curvature. 6. Oblique view of triaenes, interspersed with oxeas, in place on specimen.

## PLATE 24

Figs. 1–6. *Stolleya silvigera* n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. Holotype, USNM 133144. Scanning electron photomicrographs of triaene-dichotriaene cladomes showing range of variation in tulip-shape and in number of bifurcated cladi.

## PLATE 25

Figs. 1, 2. *Stolleya silvigera* n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. Holotype, USNM 133144. Scanning electron photomicrographs of dichotriaene and single protriaene with one ray suppressed.

Figs. 3–5. *Geodia harmatuki* n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. 3. Natural radial-section of small discoidal specimen showing radiating oxeas and sterraster-packed cortex (especially at lower left). Paratype, USNM 133148. 4. Scanning electron photomicrograph of sterraster, showing hilum (from specimen shown in Fig. 3). Paratype, USNM 133148. 5. Closeup of natural radial-section showing trains of sterrasters among radiating oxeas of the interior. Holotype, USNM 133146.

## PLATE 26

Figs. 1, 2. *Geodia harmatuki* n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. Holotype, USNM 133146. 1. Natural radial section (along which specimen separated into two parts) viewed from probable lower surface of sponge; the cortex is still adherent at lower right. 2. Opposite, probably upper, surface of same specimen, more or less completely covered by cortex; circular openings may be the sites of exhalant chones penetrating the cortex.

## PLATE 27

Figs. 1, 2. *Geodia harmatuki* n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. Holotype, USNM 133146. 1. Detail of probable upper surface, showing circular openings that may represent exhalant chones penetrating the cortex, or else oscules. 2. Detail of lower surface showing orthotriaenes (upper right, lower left) in cortex with sterrasters and oxeas.

## PLATE 28

Figs. 1–6. *Geodia harmatuki* n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. Holotype, USNM 133146. 1. Closeup of natural radial section (cf. pl. 25, Fig. 3) showing clearly the outer cortical zone packed with sterrasters and penetrated by oxeas (top and left) underlain by subcortical stout orthotriaenes (top center) as well as the interior radial bundles of oxeas (lower center and right); this arrangement is characteristic of living species of *Geodia*. Paratype, USNM 133148. 2. Outer surface of cortex of same specimen exhibiting densely-packed sterrasters with associated oxeas and possible exhalant openings. Paratype, USNM 133148. 3. Oxysphaeraster, representing an early stage in the development of a sterraster, from the same specimen. Paratype, USNM 133148. 4, 5. Oxyasters, from the same specimen. Paratype, USNM 133148. 6. Sterraster exhibiting hilum, from the same specimen. Paratype, USNM 133148.

## PLATE 29

Figs. 1, 2. *Geodia harmatuki* n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. 1. Closeup of parallel monaxons of the interior showing trains of sterrasters migrating toward the cortex. Holotype, USNM 133146. 2. Closeup of radial section of cortex, showing characteristic concentration of orthotriaene cladi at base of sterraster zone, with its perpendicular oxeas. Paratype, USNM 133148.

## PLATE 30

Figs. 1–3. *Geodia harmatuki* n. sp. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. 1. Sterraster. The depression at left is probably where it was molded to an adjacent sterraster, possibly during diagenesis. Paratype, USNM 133148. 2. Sterraster of unusually small size revealing traces of the oxysphaeraster precursor. Paratype, USNM 133148. 3. Sterrasters, the one on the right exhibiting the hilum in the center as well as an unusually well-preserved porous surface which may be original. Paratype, USNM 133148.

Figs. 4–6. *Euretella corallina* n.s.g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 4. Side view of entire specimen, the basal end is at the upper left with the main stem ending at lower center, the first branch extending to lower right, the second branch to upper right. Holotype, USNM 133150. 5. Top view of clay model of three spiraling tubes with successive lateral openings on a single tube (shown by markers) offset by 60°. 6. Side views of same model showing lateral openings at the same level in each tube forming a whorl of three at 120°, with successive whorls offset by 60° (note markers), producing a quincuncial pattern of openings in lateral view; this model reproduces the spacing and orientation of the lateral and longitudinal tubes of *Euretella corallina* (except that the helix is counter clockwise in the sponge and clockwise in the model).

## PLATE 31

FIGS. 1–2. *Euretella corallina* n.s.g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 1. Closeup of dermal cortex showing curving dictyonal strands with spicule-rays passing over and under one another, note short, knob-like distal rays. Holotype, USNM 133150. 2. Closeup of ends of three lateral tubes having domal caps pierced by multiple circular oscules, the tube-rims exhibit end views of the dictyonal strands, producing a spoke-like or triangular mesh. Holotype, USNM 133150.

## PLATE 32

FIGS. 1–2. *Euretella corallina* n.s.g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 1. Two successive lateral tubes (top of sponge to right) offset by 60° and probably attached to the same inner spiral tube, these lateral tubes lack a covering layer. Holotype, USNM 133150. 2. Closeup showing parallel dictyonal strands on inner surface of lateral tube (lower center), note contrast between dominantly rectangular net on this surface, to which dictyonal strands are parallel and the triangular to irregular net on outer surface (upper right) where the dictyonal strands emerge at a high angle and intertwine with a paratangential cortical layer. Holotype, USNM 133150.

## PLATE 33

FIGS. 1–2. *Euretella corallina*, n.s.g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of a bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 1. Lateral branch exhibiting flattened, flaring shape and capping layer with two non-circular oscules. Holotype, USNM 133150. 2. Top end of sponge exhibiting termini of the three longitudinal spiral tubes, and the three last-formed lateral tubes associated with each of them; the counter clockwise spiraling is evident in the views of the interior walls of the two central tubes at left, as well as in the beginning of the next lateral tube (bottom center) offset 60° from its predecessor at lower left. Holotype, USNM 133150.

## PLATE 34

FIG. 1. *Euretella corallina* n.s.g., n. sp., Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of a bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. Axillary parietal oscule on the upper side of a lateral tube, the lateral tube opens to the bottom of the photograph. Holotype, USNM 133150.

FIGS. 2–5. *Laocoetis* sp. cf. *L. crassipes* Pomel 1872. Ideal Cement Company Quarry, 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina, on north side of County Road 1002, opposite the end of County Road 2023. 2. Side view of eroded base (top of sponge is toward bottom of photograph) revealing gastral surface (above) and rows of ostia on dermal surface (below). Hypotype, USNM 133158. 3. Side view of exterior of large, nearly complete specimen showing molds of the quadrately-arranged ostia visible as bumps. Hypotype, USNM 133156. 4. View of narrow side of small fluted specimen showing upper rim. Hypotype, USNM 133154. 5. View of broad side of same specimen showing conical base (the right side of the view seen in Fig. 4). Hypotype, USNM 133154.

## PLATE 35

FIGS. 1–3. *Laocoetis* sp. of *L. crassipes* Pomel 1872. Ideal Cement Company Quarry, 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina, on north side of County Road 1002, opposite the end of County Road 2023. 1. Close-up of gastral surface, showing molds of postica in quadrate rows and irregular interior skeletal mesh beneath eroded gastral layer. Hypotype, USNM 133156. 2. Longitudinal section of wall exhibiting molds of dictyonal strands, gastral surface is to left, dermal surfaces to right. Hypotype, USNM 133156. 3. Close up of gastral surface showing molds of regular gastral mesh which partly covers the postica (compare with Fig. 3 where this layer is eroded to reveal the irregular interior mesh and aporhyses). Hypotype, USNM 133156.

FIGS. 4, 5. *Haynespongia vokesae* Rigby 1981. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. 4. Fragment of tubular root-like process with two parietal gaps and the beginning of a bifurcation at the distal end (left). Hypotype, USNM 128041. 5. Close up of gastral surface showing tangent dictyonal strands and apopores. Hypotype, USNM 128037.

## PLATE 36

FIGS. 1–8. *Haynespongia vokesae* Rigby 1981. South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. View of basal edge of a fin having two elliptical parietal gaps (at bottom and at center); the right side of the fin is missing, the exterior surface is preserved at left. Hypotype, USNM 128037. 2. Fragment of tubular, root-like process exhibiting branching. Hypotype, USNM 128040. 3. Branching “root” (possibly the base of a fin) with four terminal openings (left, center, and two at lower right). Hypotype, USNM 128039. 4. Another view of the preceding with leftmost opening at top, (note adherent spirorbid and cheilostome in center). Hypotype, USNM 128039. 5. Interior surface of part of central cone, attached to fin shown in Figs. 6 and 7, exhibiting lateral gaps on either side, two abnormally (?) developed bridges at right center, and aporhytic pits on inner cone surface. Hypotype, USNM 128037. 6. Exterior surface of fin, base at left, central cone at bottom. Hypotype, USNM 128037. 7. Interior (gastral) surface of same fin, base at right exhibiting parietal gap in center. Hypotype, USNM 128037. 8. Base of a fin with portion of a tubular “root” and the circular terminal opening (lower right) of an incipient “root,” (remainder of fin would be toward lower left). Hypotype, USNM 128042.

## PLATE 37

FIGS. 1–7. *Haynespongia vokesae* Rigby 1981. South of stream in Buck Swamp approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina. USGS loc. 21849. 1. External view of the most complete specimen showing parts of five overlapping fins; the fin seen in profile at left center partly preserves the original outer edge. Hypotype, USNM 128036. 2. Interior of the central cone of the most complete specimen, revealing vertical rows of bridges and intervening gaps across the

gastral spaces of each of three fins; the double gap at upper left marks the beginning of a fourth fin (which is visible on the exterior). Hypotype, USNM 128036. 3. Interior surface of the interfin strip of a fragmentary central cone revealing elongate aporhytic pits and, at left, the scalloped profile of gaps and bridge "abutments." Hypotype, USNM 128038. 4. Exterior view of the same specimen showing outer surface of interfin angle and broken edges of the two adjacent fin walls. Hypotype, USNM 128038. 5. Upper broken edge of the most complete specimen, revealing cross sections of six fins; the incipient fin mentioned in connection with Fig. 2 lies between the complete fin at center and the half-fin at the right edge. Hypotype, USNM 128036. 6. Scanning-electron photomicrograph of gastral surface. Hypotype, USNM 128058. 7. Scanning-electron photomicrograph of dermal surface. Hypotype, USNM 128059.

#### PLATE 38

FIGS. 1–4. *Druidia wilsoni* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 1. Side view showing central cone at left and a small and large fin at right; note encrusting cheilostome on large fin. Paratype, USNM 127674. 2. Same specimen showing edge-on view of the same two fins. Paratype, USNM 127674. 3. Same specimen showing the relation of the central cone to the fins; the flat base of the fins is preserved at right; note turritellid in life-position. Paratype, USNM 127674. 4. Opposite side of same specimen, the struts supporting the central cone are partly visible; note encrusting bivalve on small fin, cheilostome on large. Paratype, USNM 127674.

#### PLATE 39

FIGS. 1–4. *Druidia wilsoni* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 1. Side view showing attenuation of tube or root-like fins, (at a higher level) with regular fins; the distal ends of the fins and tubes are missing (or unclosed). Holotype, USNM 127672. 2. Basal view of specimen in Plate 38, showing the row of large pores along the base of each fin (bottom), and the continuous gastral space surrounding the compressed central cone. Paratype, USNM 127674. 3. Close-up of inner surface of central cone showing finest pores; the strip lacking large openings across the top of the photograph is the site of a strut (top of sponge is to left), imperforate area at bottom of photograph is adherent matrix. Paratype, USNM 127673. 4. End of tube closed by irregular net, possibly repair of injury, (note encrusting cheilostome on outside of tube and cyclostome (?) on part of closure). Paratype, USNM 127681.

#### PLATE 40

FIGS. 1, 2. *Druidia wilsoni* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 1. Top view of nearly complete specimen (margins of fins are missing) showing how top of central cone joins rest of sponge; note imperforate lip (upper right), imperforate strips opposite interfin angles (bottom and left) and *Bactronella womblei* attached to fins (right center and bottom center). Holotype, USNM 127672. 2. Base of same specimen revealing struts supporting central cone. Holotype, USNM 127672.

#### PLATE 41

FIGS. 1–3. *Druidia wilsoni* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Side view of central cone showing lip area (upper right). Paratype, USNM 127673. 2. Top view of same specimen showing attachment of central cone to top of sponge. Paratype, USNM 127673. 3. Side view of tube showing circular parietal gaps and encrusting cheilostome. Paratype, USNM 127678.

#### PLATE 42

FIGS. 1–4. *Druidia wilsoni* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53, at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Base of fin extending leftward into a tube or root (top of sponge is downward). Paratype, USNM 127687. 2. View of strut on outside of central cone; fins visible at right (top of sponge up). Paratype, USNM 127688. 3. View of same specimen from inside central cone showing imperforate strips opposite struts, (top of sponge up). Paratype, USNM 127688. 4. Side views of same specimen revealing strut attached to outer wall (top of sponge up). Paratype, USNM 127688.

#### PLATE 43

FIGS. 1–6. *Druidia wilsoni* n. g., n. sp., Ideal Cement Company Quarry, 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina, on north side of County Road 1002, opposite the end of County Road 2023. Upper 9 m (30 feet) of Castle Hayne Formation. 1. Basal view. Paratype, USNM 127701. 2. Edge view of a sinuous fin. Paratype, USNM 127695. 3. Side view. Paratype, USNM 127701. 4. Top view of same specimen showing upper rim of sponge. Paratype, USNM 127701. 5. Tubular root with transverse rows of parietal gaps. Paratype, USNM 127699. 6. Side view showing axillary parietal gaps in interfin angles. Paratype, USNM 127701.

#### PLATE 44

FIGS. 1–4. *Druidia wilsoni* n. g., n. sp. Ideal Cement Company Quarry, 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina, on north side of County Road 1002, opposite the end of County Road 2023. Upper 9 m (30 feet) of Castle Hayne Formation. 1. Basal view. Paratype, USNM 127700. 2. Side view of same showing incipient fin at higher level (top center) with row of parietal gaps along lower edge. Paratype, USNM 127700. 3. Side view of same (opposite to that in preceding figure) showing outward glaring of body wall; at rim of cup (top center) as well as termination of fin below level of rim (note axillary parietal gap here). Paratype, USNM 127700. 4. Side view (base of sponge up) showing incipient fin referred to in Fig. 2. Paratype.

## PLATE 45

Figs. 1–3. *Druidia wilsoni* n. g., n. sp. Figs. 1, 3. Ideal Cement Company Quarry. 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina, on north side of County Road 1002, opposite the end of County Road 2023. Upper 9 m (30 feet) of Castle Hayne Formation. Fig. 2. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53, at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Side view of internal mold of complete central cone with interfin angles marked; note glaring profile at top and truncate base. Paratype, USNM 127698. 2. Scanning-electron photomicrograph of skeletal mesh of gastral surface of tube showing two parallel dictyonal strands. Paratype, USNM 127728. 3. Basal view of mold of central cone, with interfin angles marked showing diaphragm-like portion of central cone truncating base. Paratype, USNM 127697.

## PLATE 46

Figs. 1–5. *Druidia wilsoni* n. g., n. sp. Figs. 1–4. Ideal Cement Company Quarry. 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina, on north side of County Road 1002, opposite the end of County Road 2023. Upper 9 m (30 feet) of Castle Hayne Formation. Fig. 5. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53, at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Side view of internal mold of central cone showing imperforate rim area and ridges (molds of grooves) corresponding to interfin angles. Paratype, USNM 127699. 2. Side view (top of sponge is to right) showing small lobate fin (lower left). Paratype, USNM 127699. 3. Side view showing rim of inner cone extending well above top of fin at left. Paratype, USNM 127699. 4. Same specimen viewed from above showing well-preserved rim of central cone. Paratype, USNM 127699. 5. Interior (gastral) surface of a tube exhibiting elongate cross sections of diarhyses. Paratype, USNM 127678.

## PLATE 47

Figs. 1–4. *Druidia wilsoni* n. g., n. sp. Figs. 1, 3, 4. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53, at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. Fig. 2, Ideal Cement Company Quarry, 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina, or north side of County Road 1002, opposite end of County Road 2023. Upper 9 m (30 feet) of Castle Hayne Formation. 1. Side view showing central cone at left with two struts at center (connected with fin at right) and at bottom center (fin broken off). Paratype, USNM 127676. 2. Side view of tall wing with rim of cup rising above it. Paratype, USNM 127693. 3. Scanning-electron photomicrograph of dermal surface of tube showing small pores, intermediate pore (bottom center) and large pore (top). Paratype, USNM 127728. 4. Side view showing longitudinal section of lip of cup with its internal space rising above fins at right. Paratype, USNM 127673.

## PLATE 48

Figs. 1, 2. *Druidia wilsoni* n. g., n. sp., Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Scanning-electron photomicrograph, showing interior skeletal net with enlarged nodes in wall of diarhysis. Paratype, USNM 127728. 2. View of diarhyses from gastral surface, showing partial to total closure of the dermal ends of some of them (for example, near lower left). Paratype, USNM 127682.

## PLATE 49

Figs. 1–5. *Druidia wilsoni* n. g., n. sp. Figs. 1, 3–5. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53, at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. Fig. 2, Ideal Cement Company Quarry, 7.2 km (4.5 miles) northeast of Castle Hayne, New Hanover County, North Carolina on north side of County Road 1002, opposite end of County Road 2023. Upper 9 m (30 feet) of Castle Hayne Formation. 1. View of longitudinal section through parietal gap in base of fin, showing inside wall of gap, outer (basal) surface is up. Paratype, USNM 127683. 2. Side view showing tubular prop-root (bottom center), base of sponge is at lower left, central cone at top. Paratype, USNM 127697. 3. Inner surface of central cone exhibiting fine pores. Paratype, USNM 127676. 4. Section through wall of fin revealing inner walls of diarhyses. Paratype, USNM 127683. 5. View of basal surface of same fin showing two parietal gaps and small and intermediate pores. Paratype, USNM 127683.

## PLATE 50

Figs. 1–3. *Druidia wilsoni* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53, at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material. USGS loc. 22389. 1. Scanning-electron photomicrograph of gastral surface of tube, showing curving of dictyonal strands around diarhyses and distortion of hexactins. Paratype, USNM 127728. 2. Another view of same. Paratype, USNM 127728. 3. View of exterior (dermal) surface of tubular root showing small and intermediate pores. Paratype, USNM 127678.

## PLATE 51

Figs. 1–6. *Exanthesis ovatus* n. sp. Figs. 1, 2, 4. Old pit about 5 km (3 miles) south of Maple Hill, Pender County, North Carolina near Angola Creek, USGS loc. 19019. Figs. 3, 5, 6. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Side view, base at top, showing anvil shape. Paratype, USNM 127712. 2. Top view of same, note flaring profile of tube at bottom. Paratype, USNM 127712. 3. Top of sponge (encrusting cheilostome top left). Holotype, USNM 127711. 4. End view (this end at top of Fig. 2 and to left of Fig. 1), note encrusting cheilostome (top center). Paratype, USNM 127712. 5. Side of sponge (top upwards). Holotype, USNM, 127711. 6. Basal view. Holotype, USNM 127711.

## PLATE 52

Figs. 1–6. *Exanthesis ovatus* n. sp. Figs. 1–3, Old pit about 52 km (32 miles) south of Maple Hill, Pender County, North Carolina, near Angola Creek, USGS loc. 19019. Figs. 4–6, Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km

(8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Side view showing anvil shape. Paratype, USNM 127712. 2. Overhanging end of same sponge showing flaring tube. Paratype, USNM 127712. 3. Base of same sponge. Paratype, USNM 127712. 4. Sideview, (with encrusting cheilostome), base at left. Holotype, USNM 127711. 5. Basal view of a specimen in which the inhalant cavaedia have been painted black. Paratype, USNM 127714. 6. Top view of same specimen, note predominance of exhalant (white) surfaces at this end. Paratype, USNM 127714.

#### PLATE 53

Figs. 1, 3, 4. *Exanthesia ovatus* n. sp. Figs. 1, 4, Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. Fig. 3, Old pit about 5 km (3 miles) south of Maple Hill, Pender County, North Carolina, near Angola Creek, USGS loc. 19019. 1. Scanning-electron photomicrograph of exhalant (gastral) surface showing relatively regular net and lychnisc nodes. Paratype, USNM 127717. 3. Closeup of dermal (exhalant) surface (below and left of number in Plate 52, Fig. 1) showing regular interior mesh beneath irregular cortical layer (above, left, below). Paratype, USNM 127712. 4. Scanning-electron photomicrograph of inhalant (dermal) surface showing irregular cortical layer. Paratype, USNM 127717.

FIG. 2. *Robinia striatopunctata* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 2. Close up of body wall showing upward divergence of dictyonal strands and emergence toward dermal (exhalant) side to right. Holotype, USNM 127723.

#### PLATE 54

Figs. 1–4. *Robinia striatopunctata* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Side view (top toward lower left) showing external capsule with rows of inhalant and exhalant openings following the course of interior spaces; the prominent row of slit-like openings at center is exhalant, the circular openings to left at bottom are inhalant; cheilostome and stick-like cyclostome bryozoa visible at top center. Holotype, USNM 127723. 2. Side near base (cross-section of basal area at right) the circular and longitudinally elongate openings (horizontal in photo) follow the inhalant cavaedia, while the transversely elongate ones (vertical in photo) follow the exhalant cavaedia. Holotype, USNM 127723. 3. Side view (top is up) showing capsule carving over (at upper right) onto flat upper surface; note rows of exhalant (slit-like) and inhalant (round) openings. Holotype, USNM 127723. 4. Top view showing exhalant and inhalant cavaedial spaces of the interior defined by the complexly folded body wall, and part of the external capsule preserved at right, the exhalant cavaedia are longer and more meandriform while the inhalant cavaedia are more elliptical. Holotype, USNM 127723.

#### PLATE 55

Figs. 1–3. *Robinia striatopunctata* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. View of base, with cross-section of basal portion at right center, and part of side with capsule missing, exposing cavaedial spaces, (encrusting bryozoa left center) here near the base, the inhalant cavaedia are more interconnected, the exhalant more circular and isolated. Holotype, USNM 127723. 2. Top view of specimen with most of capsule lost. Paratype, USNM 127724. 3. Side view of same specimen showing conical shape (base toward lower right), and patch of preserved capsule at lower left. Paratype, USNM 127724.

#### PLATE 56

Figs. 1–5. *Robinia striatopunctata* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Closeup of gastral (exhalant) surface of cavaedium showing generally regular net, lychnisc nodes are clearly visible. Holotype, USNM 127723. 2. Closeup of dermal (inhalant) surface of cavaedium showing irregular cortex. Holotype, USNM 127723. 3. Closeup of dermal surface of cavaedium where irregular cortex is absent (except for patch at top center) showing regular net with lychnisc nodes. Holotype, USNM 127723. 4. Closeup of cross-section of basal region showing labyrinthine canal system in irregular net that lies between external capsule (at left) and nearest cavaedial tubes; note larger longitudinal canals seen as circular cross-sections (top right and left center) that underlie the capsule in the basal stalk. Holotype, USNM 127723. 5. Closeup of basal region cross-section on a larger scale showing large cavaedial tubes of circular cross-section (top and bottom center and lower right) and the longitudinal canals underlying the capsule (upper left); note the contrast between the regular skeletal net surrounding the cavaedial tubes and the irregular net between them and the capsule. Holotype, USNM 127723.

#### PLATE 57

Figs. 1–5. *Robinia striatopunctata* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Scanning-electron photomicrograph of gastral (?) surface where net is less regular; note lychnisc nodes and suppressed distal rays. Holotype, USNM 127723. 2. Close up of surface of capsule showing meandriform pattern of pores; tiny protuberances, probably representing aborted distal rays, may be seen over some crossings. Paratype, USNM 127724. 3. Scanning-electron photomicrograph of dermal (inhalant) cortex showing irregular close mesh and small, filled-in lychnisc nodes (note suppressed distal rays). Holotype, USNM 127723. 4. Closeup of horizontal balk of capsule material extending across an inhalant cavaedium near top of sponge. Holotype, USNM 127723. 5. Scanning-electron photomicrograph of gastral surface showing regular net, well-developed, large lychnisc nodes and suppressed distal rays. Holotype, USNM 127723.

#### PLATE 58

Figs. 1, 2. *Robinia striatopunctata* n. g., n. sp. Pender County, North Carolina 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Closeup of tongues of the capsule which grow over cavaedial openings to form rows of slits, here a branching tongue has overgrown another tongue beneath it (lower

center) having, so-to-speak, "missed." Holotype, USNM 127723. 2. Closeup of another area on top surface of same specimen, showing tongues of the capsule growing from opposite directions to form a sinuous slit. Holotype, USNM 127723.

#### PLATE 59

FIG. 1. *Robinia striatopunctata* n. g., n. sp. Pender County, North Carolina, 0.5 km (0.3 mile) south of North Carolina Route 53 at a point 13.0 km (8.1 miles) east of bridge over Northeast Cape Fear River, small pit for road material, USGS loc. 22389. 1. Closeup of tongue of capsule partly closing a cavaedial opening, near that of Plate 58, Fig. 2. Holotype, USNM 127723. Figs. 2, 3. *Sheldonia trabecula* (Rigby 1981). South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117, and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. 2. Closeup of cross-section showing side-wall of two parietal gaps (upper left and lower half, gastral surface at right, dermal at left), note large syndoka parallel to plane of body-wall especially in upper parietal gap; individual rhabdodictins tend to run diagonally (about 45°) through body-wall. Hypotype, USNM 127725. 3. Closeup of four syndoka, showing closely spaced synapticulae. Hypotype, USNM 127725.

#### PLATE 60

Figs. 1, 2. *Sheldonia trabecula* (Rigby 1981). South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. 1. Gastral surface of largest specimen (two pieces fitted together) revealing dominance of diagonal syndoka; the possible upper end is toward the bottom of the photograph; note broad flat areas (near top) formed by a surface covering of rhabdodictins; note elongation of parietal gaps parallel to presumed longitudinal axis of sponge. Hypotype, USNM 127725. 2. Dermal surface of same specimen exhibiting dominance of syndoka parallel to the presumed longitudinal axis of the sponge (compare Fig. 1) and more abundant near the possible top end of the sponge (at bottom of photograph). Hypotype, USNM 127725.

#### PLATE 61

Figs. 1–3. *Sheldonia trabecula* (Rigby 1981). South stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. 1. Dermal surface of cleaned half of large specimen, possible top end of sponge toward left; note dominance of syndoka parallel to presumed longitudinal axis of sponge, their greater concentration toward presumed upper end, and a subordinate pattern of diagonal syndoka; note elongation of parietal gap. Hypotype, USNM 127725. 2. Closeup of gastral surface (upper left of Fig. 3) showing surface layer of small rhabdodictins between longer syndoka; note presumed horizontal (relative to sponge) row of parietal gaps. Hypotype, USNM 127725. 3. Gastral surface of same specimen shown in Fig. 1; parietal gaps elongate parallel to presumed longitudinal axis of sponge (top toward lower right), syndoka dominantly diagonal forming a rhombus about each gap, but another prominent series of syndoka is parallel to the obscurely horizontal (relative to the sponge) rows of gaps; note greater prominence of syndoka toward the presumed top of sponge. Hypotype, USNM, 127725.

#### PLATE 62

Figs. 1–3. *Sheldonia trabecula* (Rigby 1981). South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. Route 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. 1. Closeup of syndoka on dermal surface showing lacy outer covering of siliceous filaments and synapticulae. Hypotype, USNM 127725. 2. Closeup of two syndoka; the one on the left has regularly spaced internal synapticulae, the other reveals a lacy outer coating of siliceous filaments. Hypotype, USNM 127725. 3. Cross-section through body wall (dermal surface at top, gastral at bottom) revealing internal arrangement of spicules not involving a parietal gap; note syndoka chiefly in the plane of the body wall cut at various angles (many are preserved as hollow tubes by surface silification); single small rhabdodictins may lie at an angle to the plane of the body wall. Hypotype, USNM 127725.

#### PLATE 63

Figs. 1, 2. *Sheldonia trabecula* (Rigby 1981). South of stream in Buck Swamp, approximately 2.4 km (1.5 miles) west of U.S. 117 and approximately 2.4 km (1.5 miles) south of Dudley, Wayne County, North Carolina, USGS loc. 21849. 1. Closeup of gastral surface (presumed top toward right) showing interweaving of syndoka, mostly belonging to the diagonal sets; they almost always maintain their identity when they pass over or under one another; at lower left corner two are united side-by-side, at center left edge finer rhabdodictin comitalia parallel the larger spicules of a syndokon which passes under another while one of its spicules (appearing fusiform in the photo) protrudes to terminate against the overlying syndokon. Hypotype, USNM 127725. 2. Another part of the same gastral surface (presumed top toward right) exhibiting local development of lace-like coating of siliceous filaments on syndoka (e.g., upper right and bottom center); note small rhabdodictins lining parietal gap (bottom center), although a syndokon below and left of center appears to split around a crossing syndokon. They are actually two separate ones that become superimposed. Hypotype, USNM 127725.

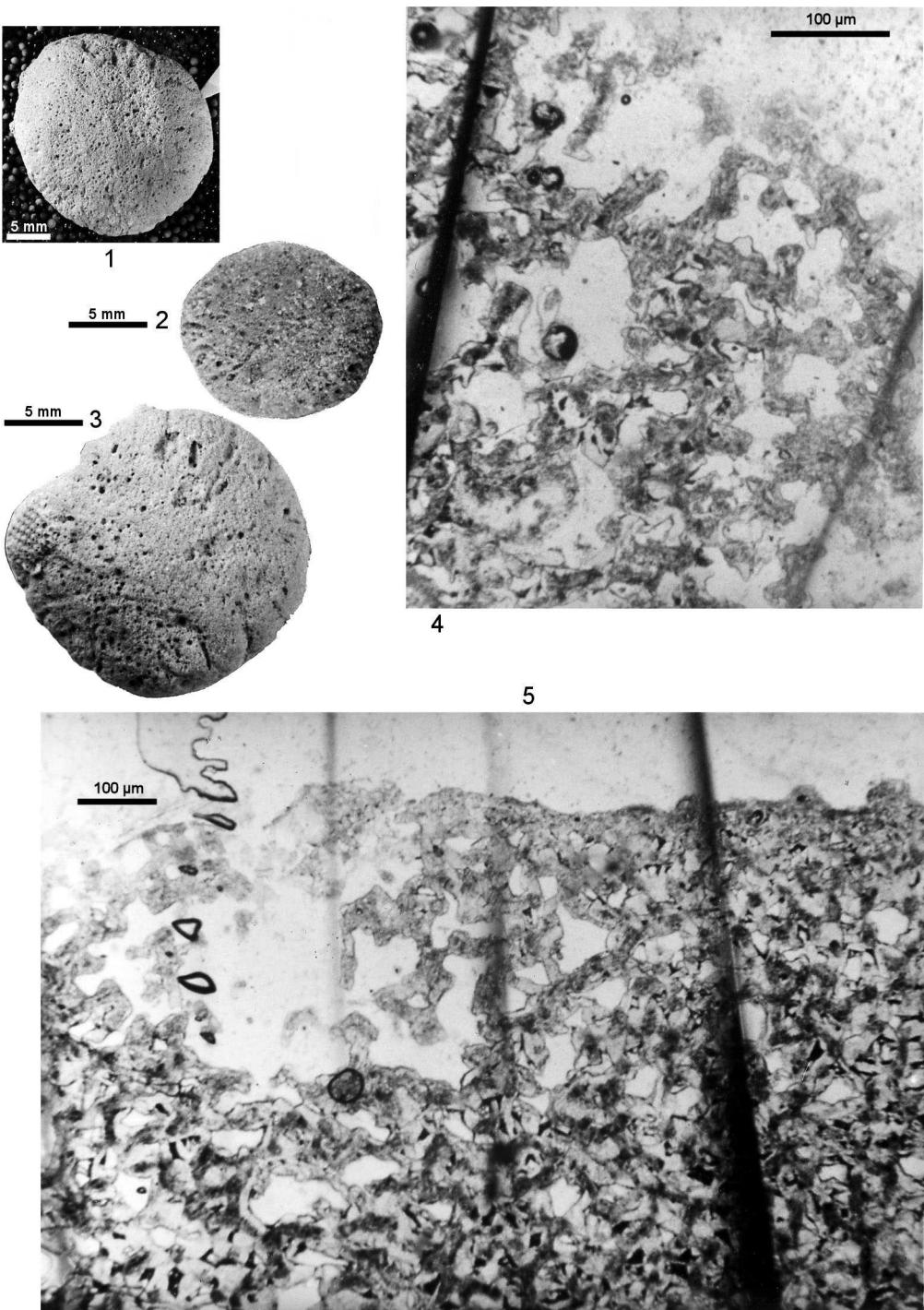


PLATE 1

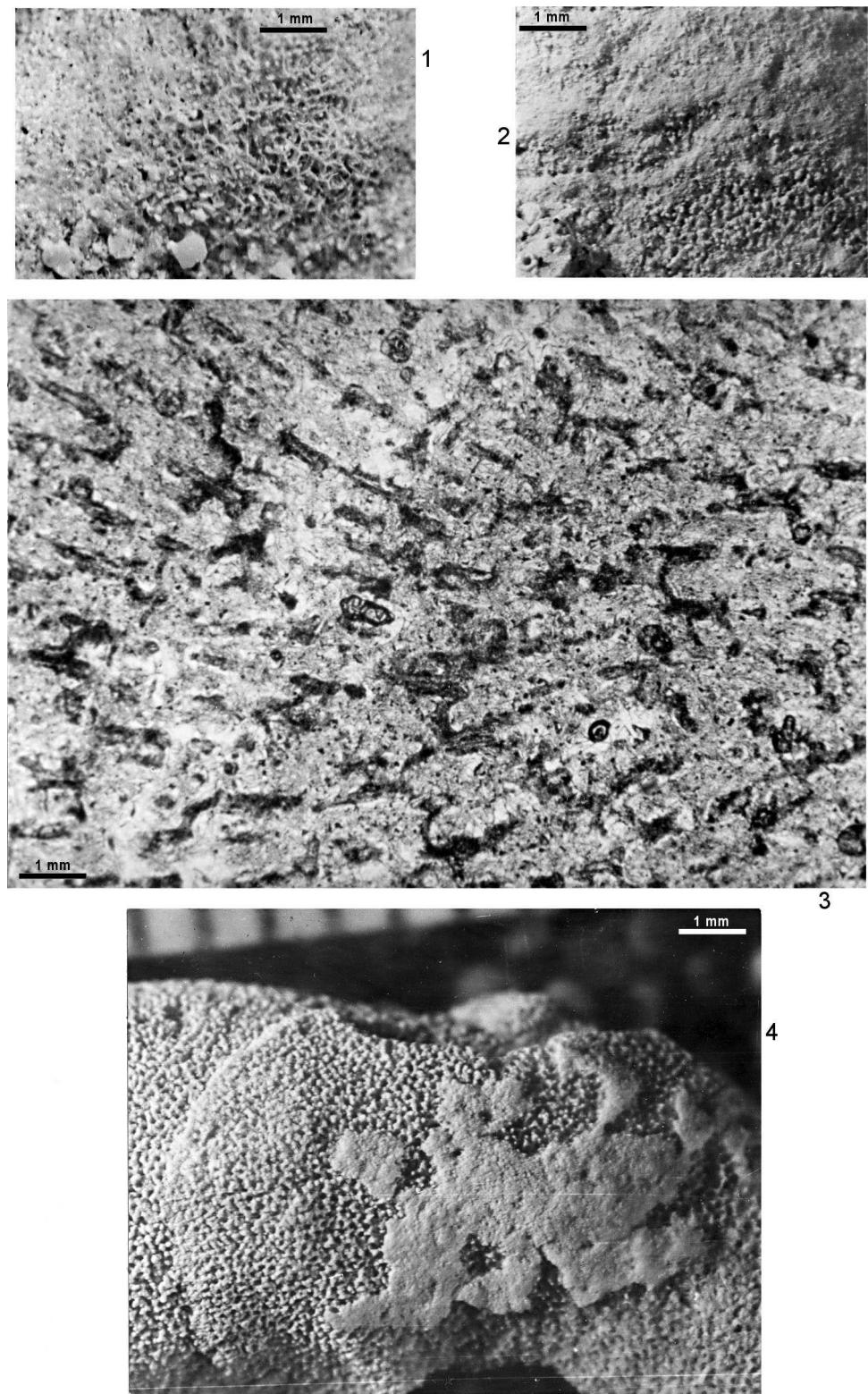


PLATE 2

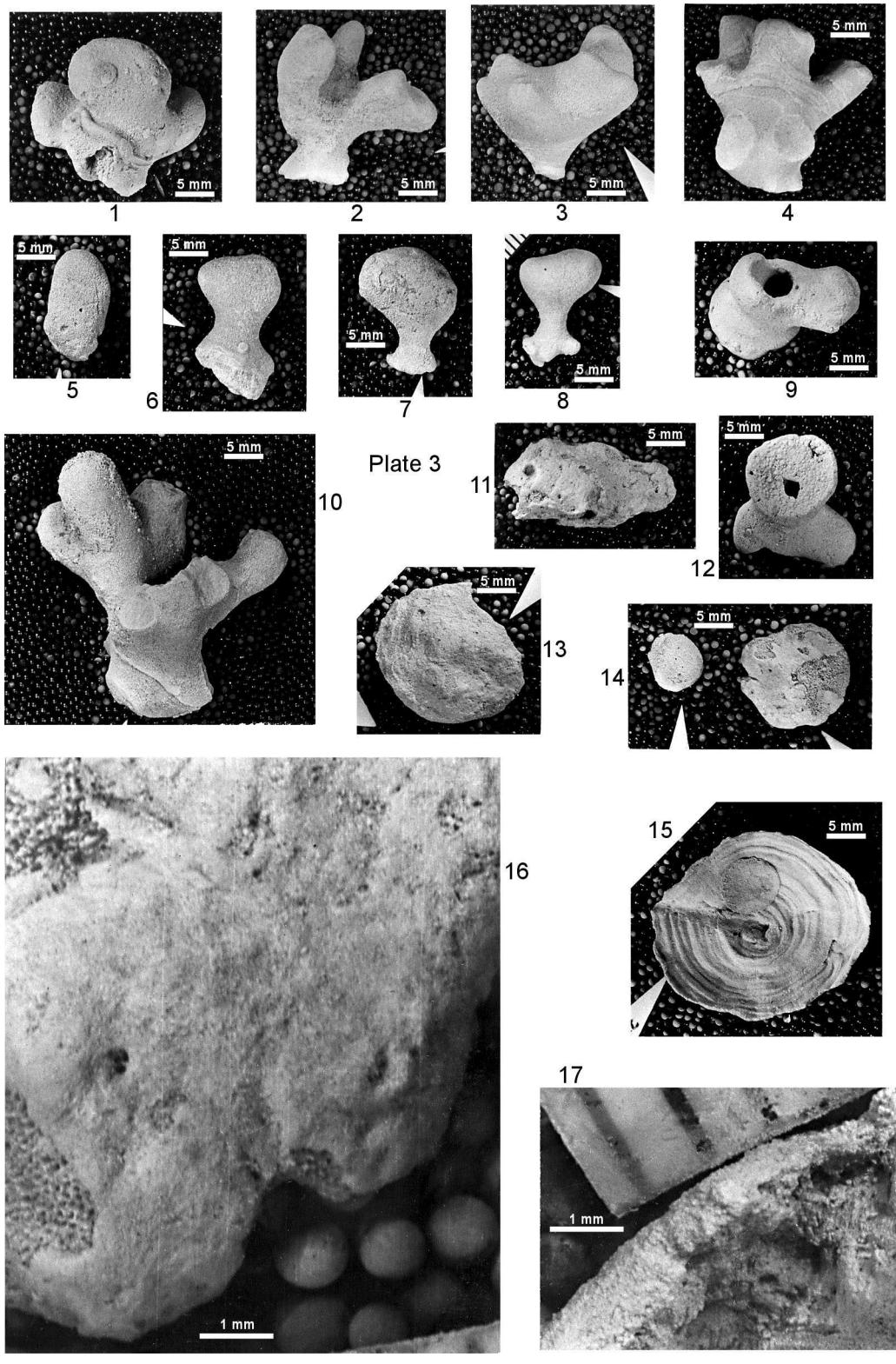


PLATE 3

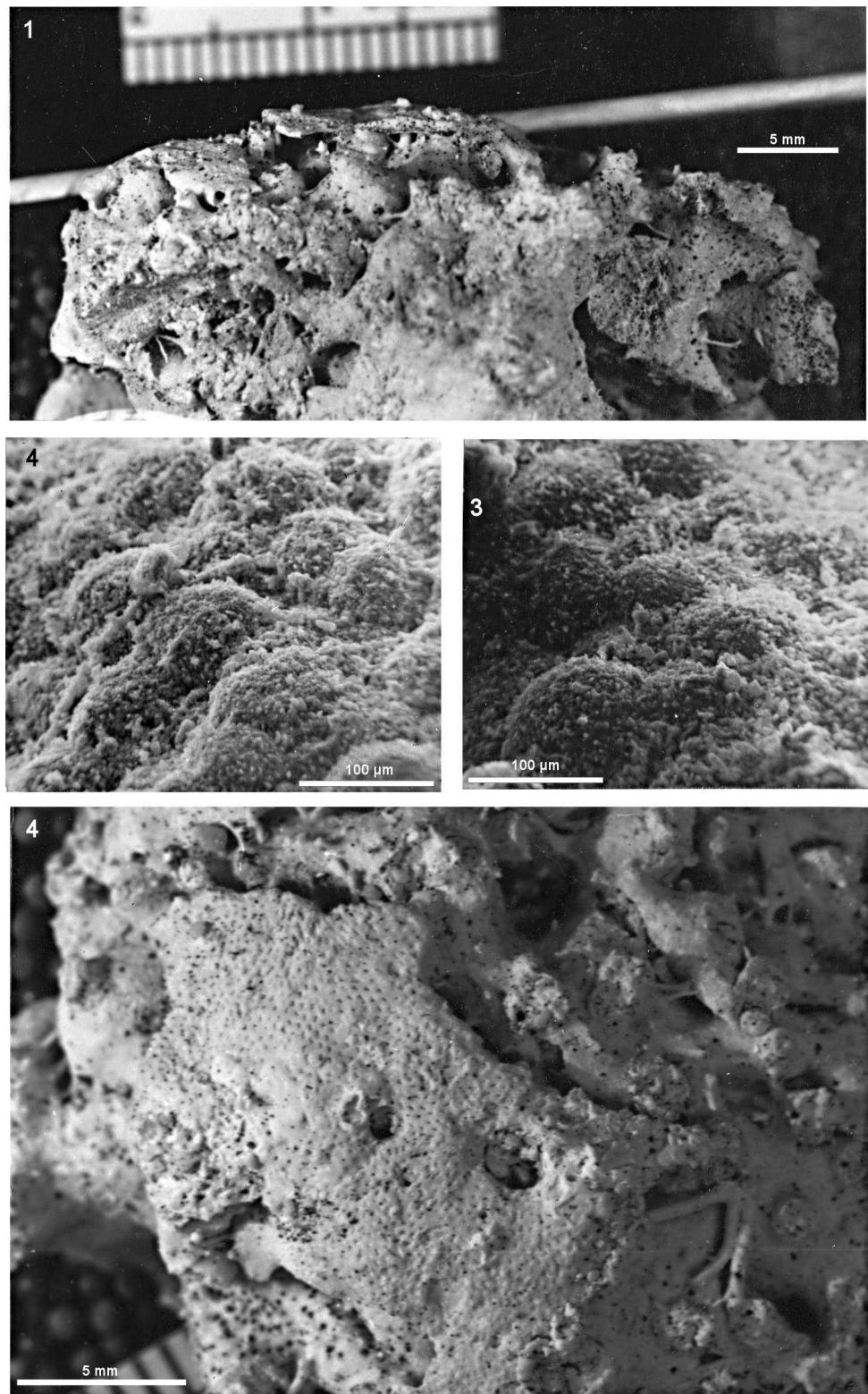
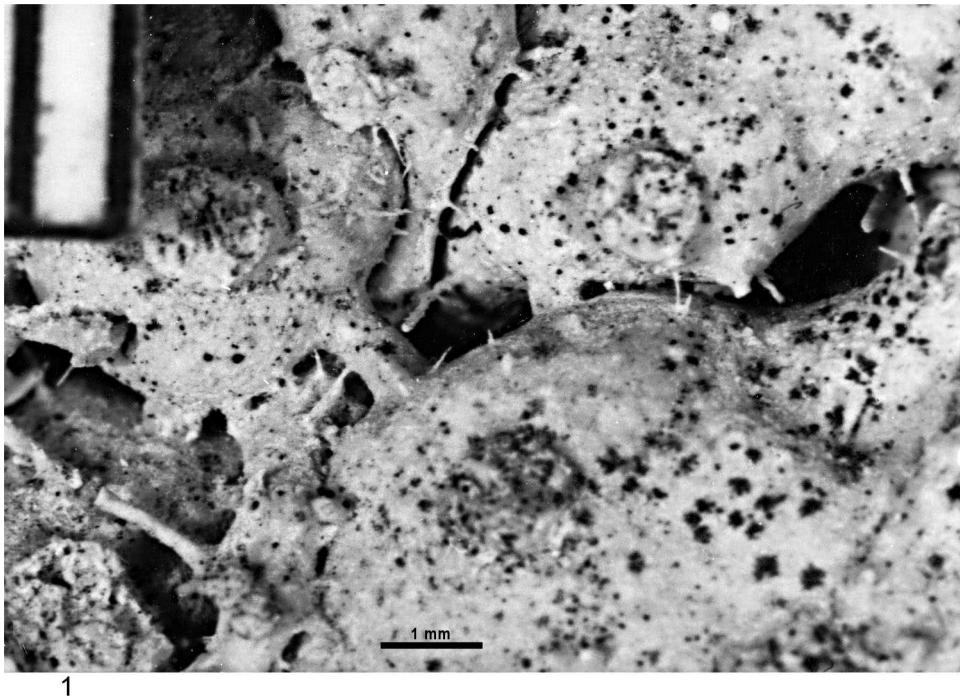
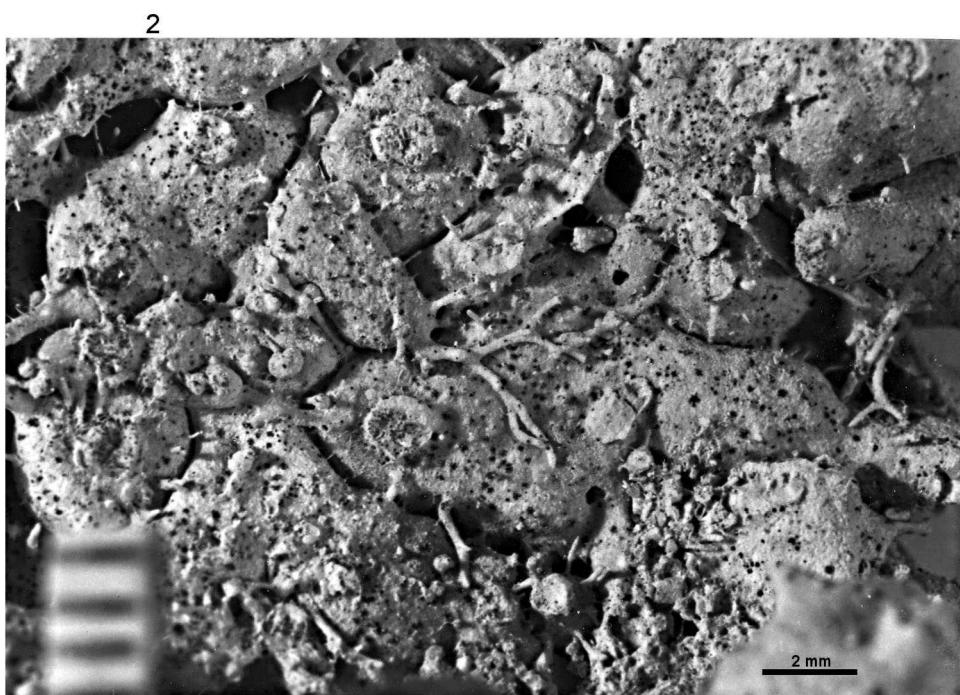


PLATE 4



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PLATE 5

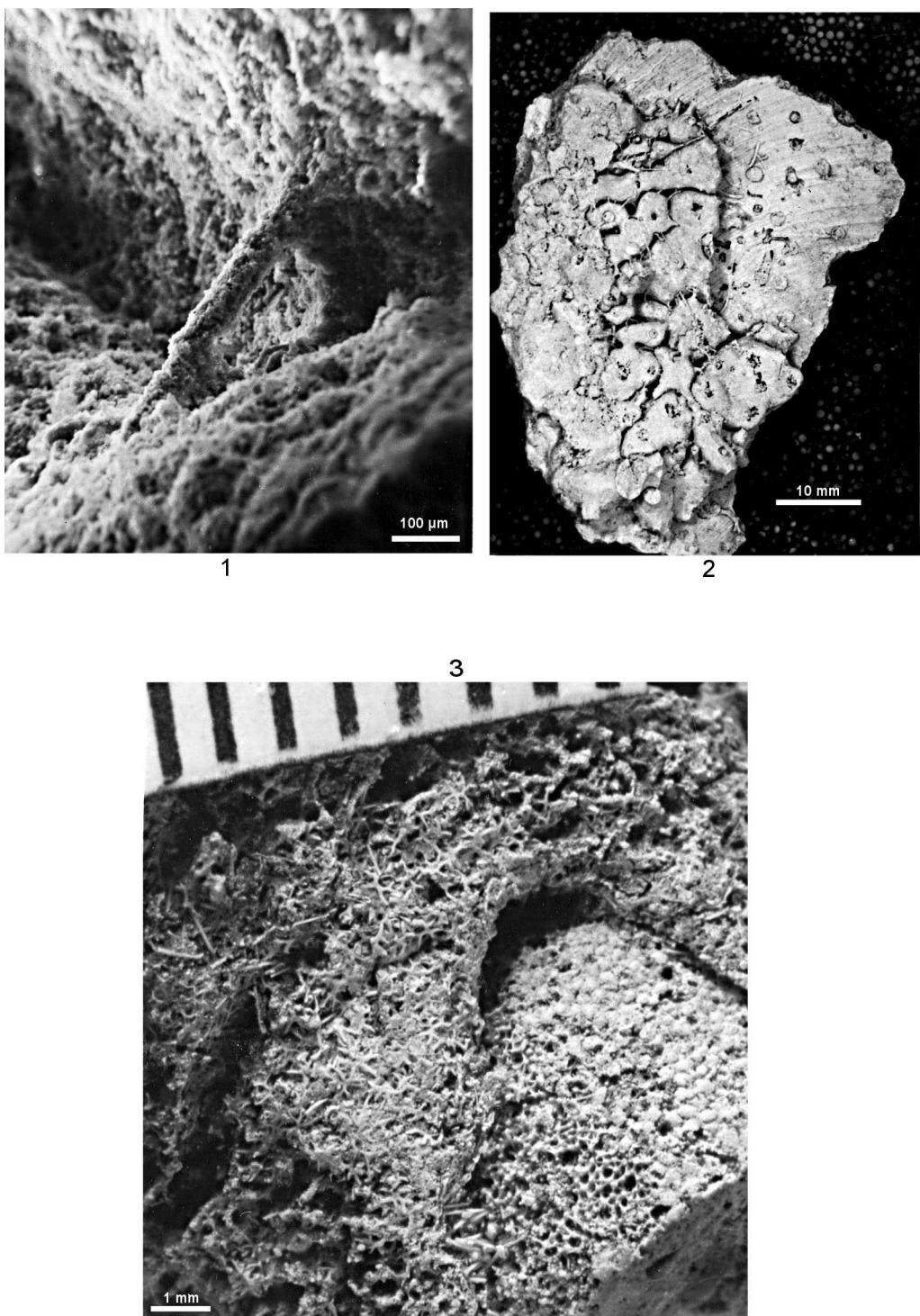


PLATE 6

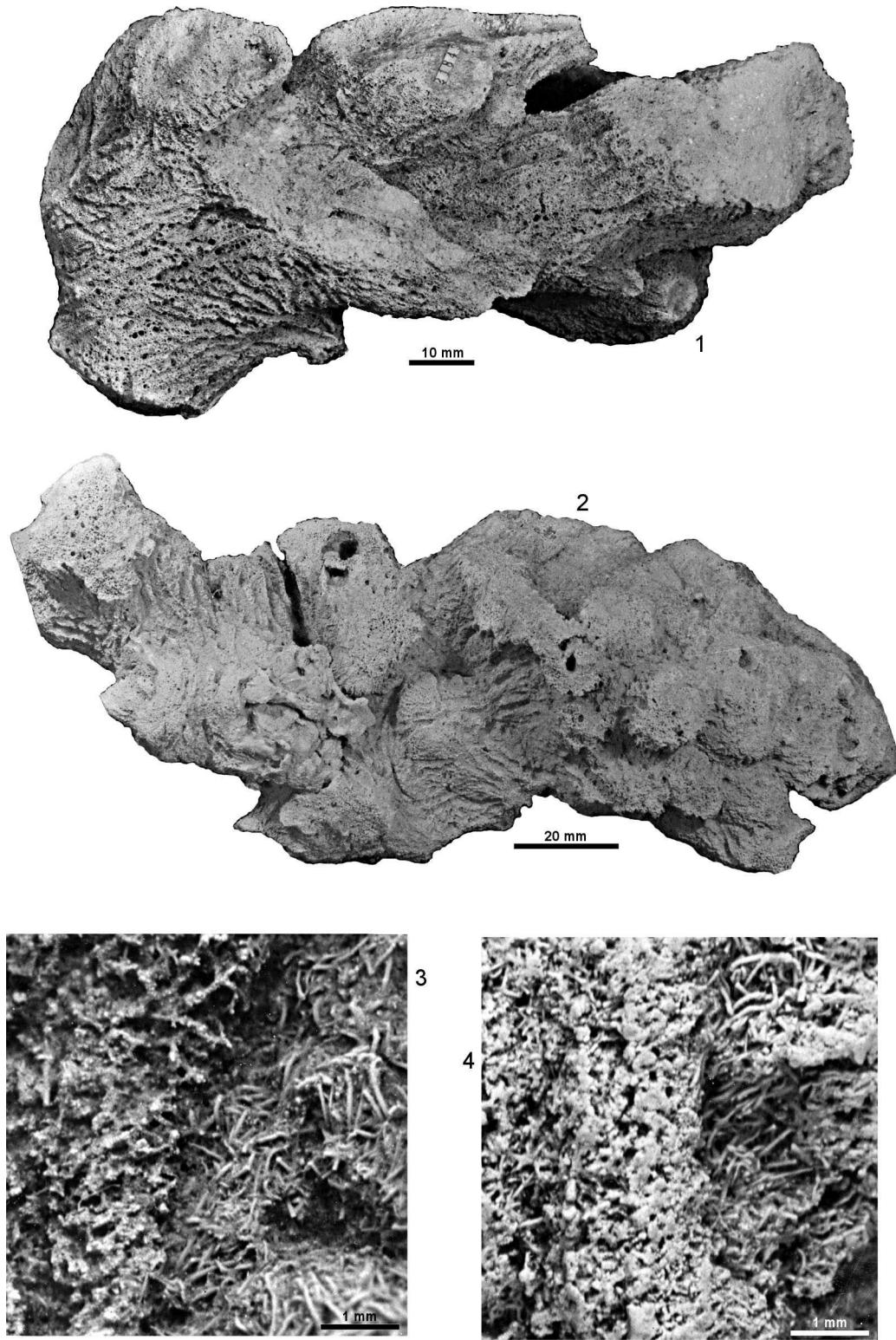


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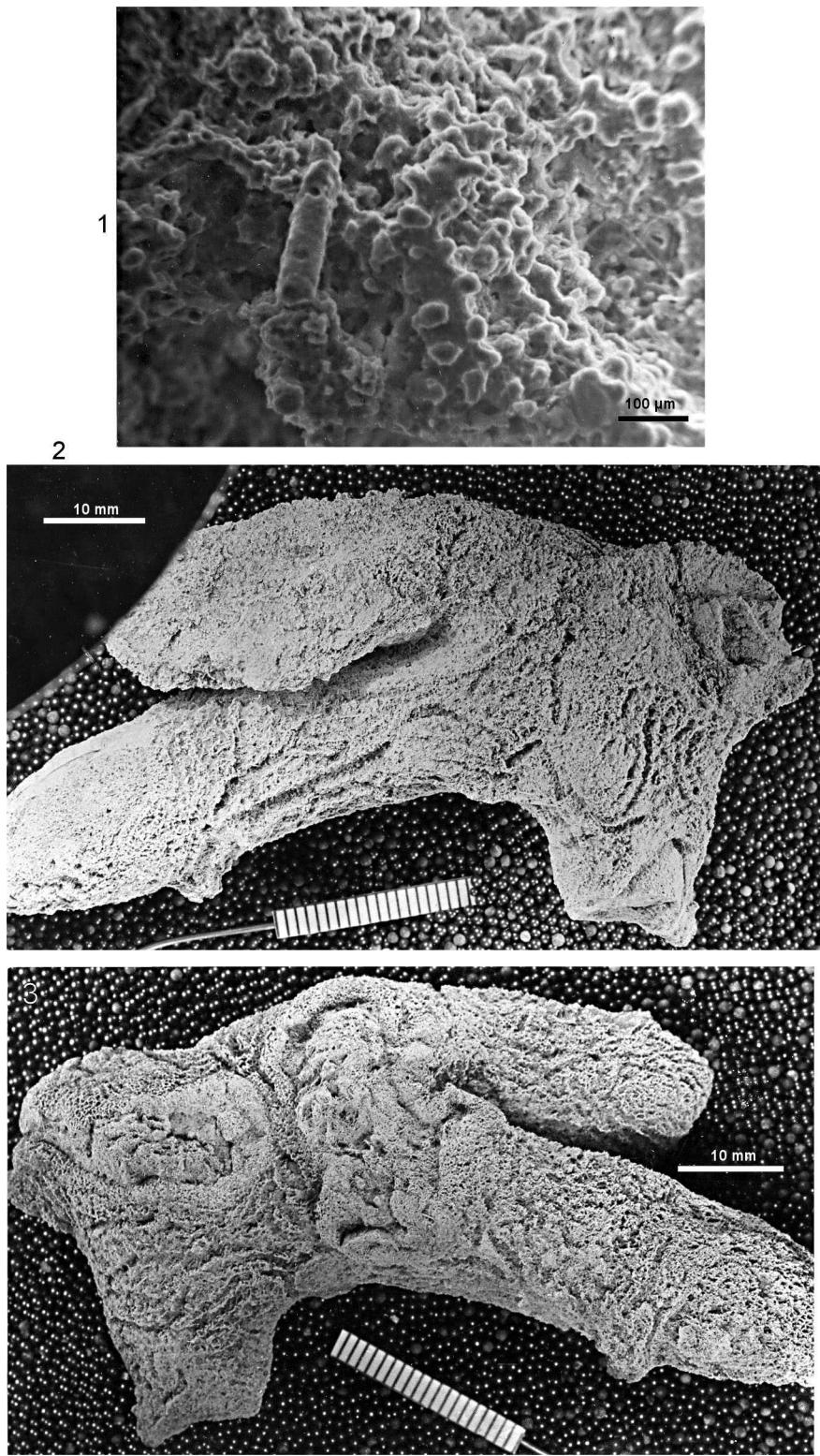


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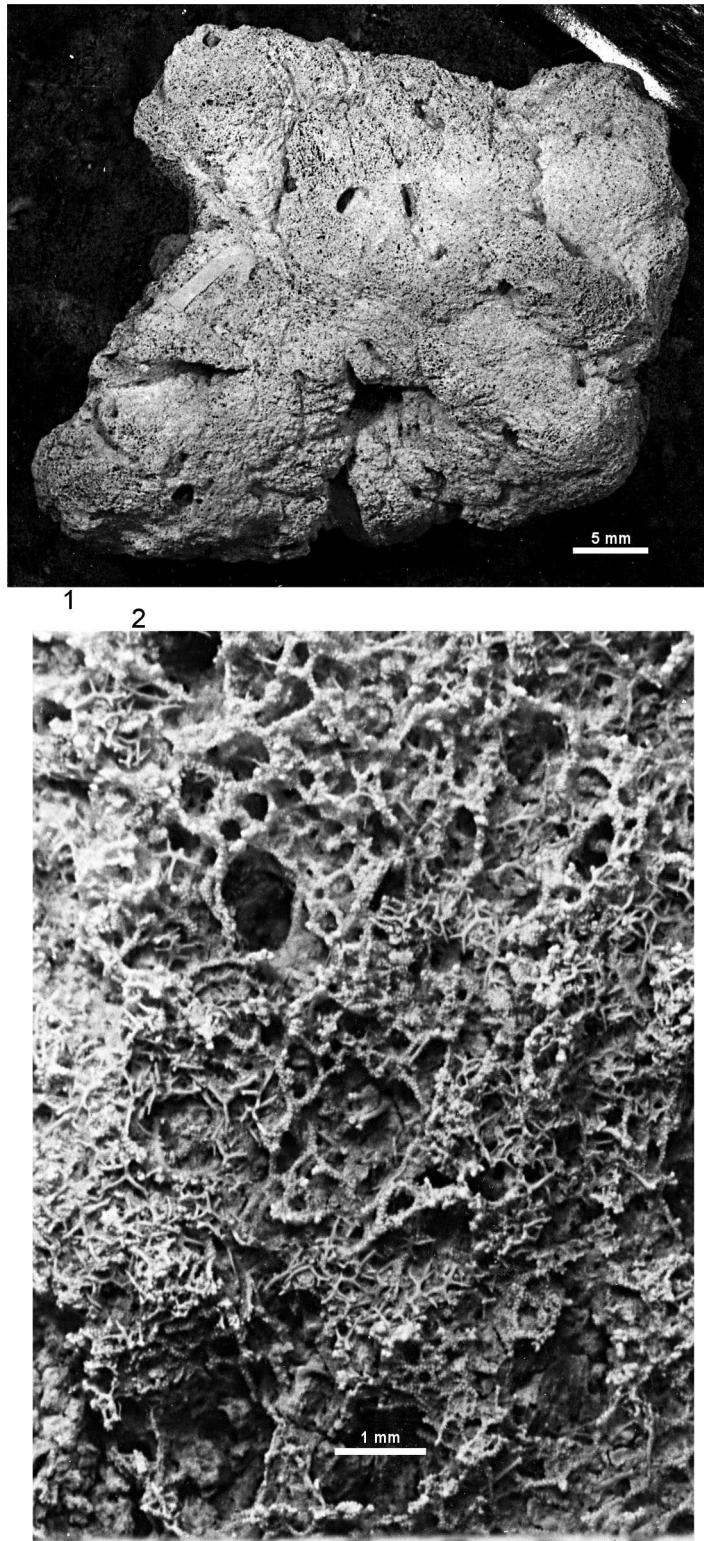


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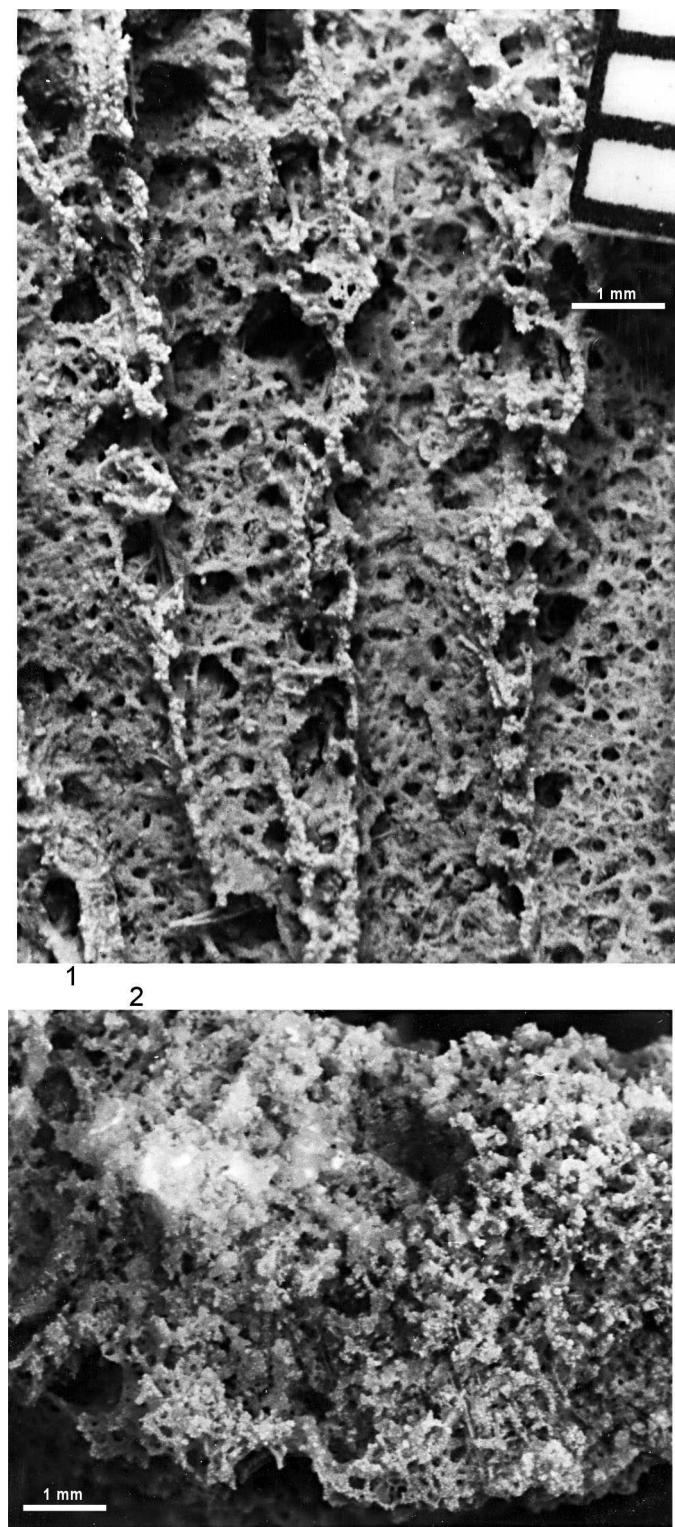


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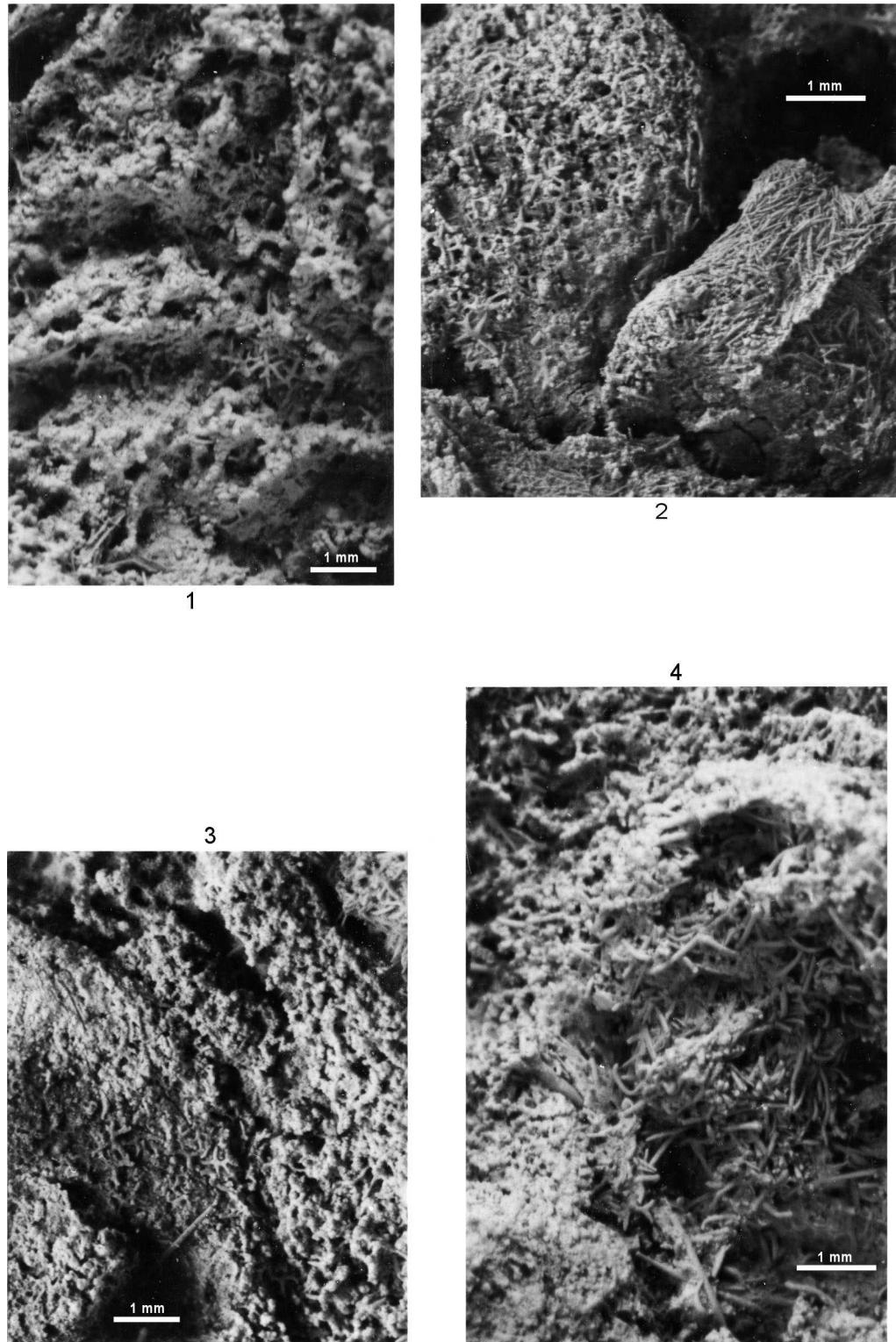


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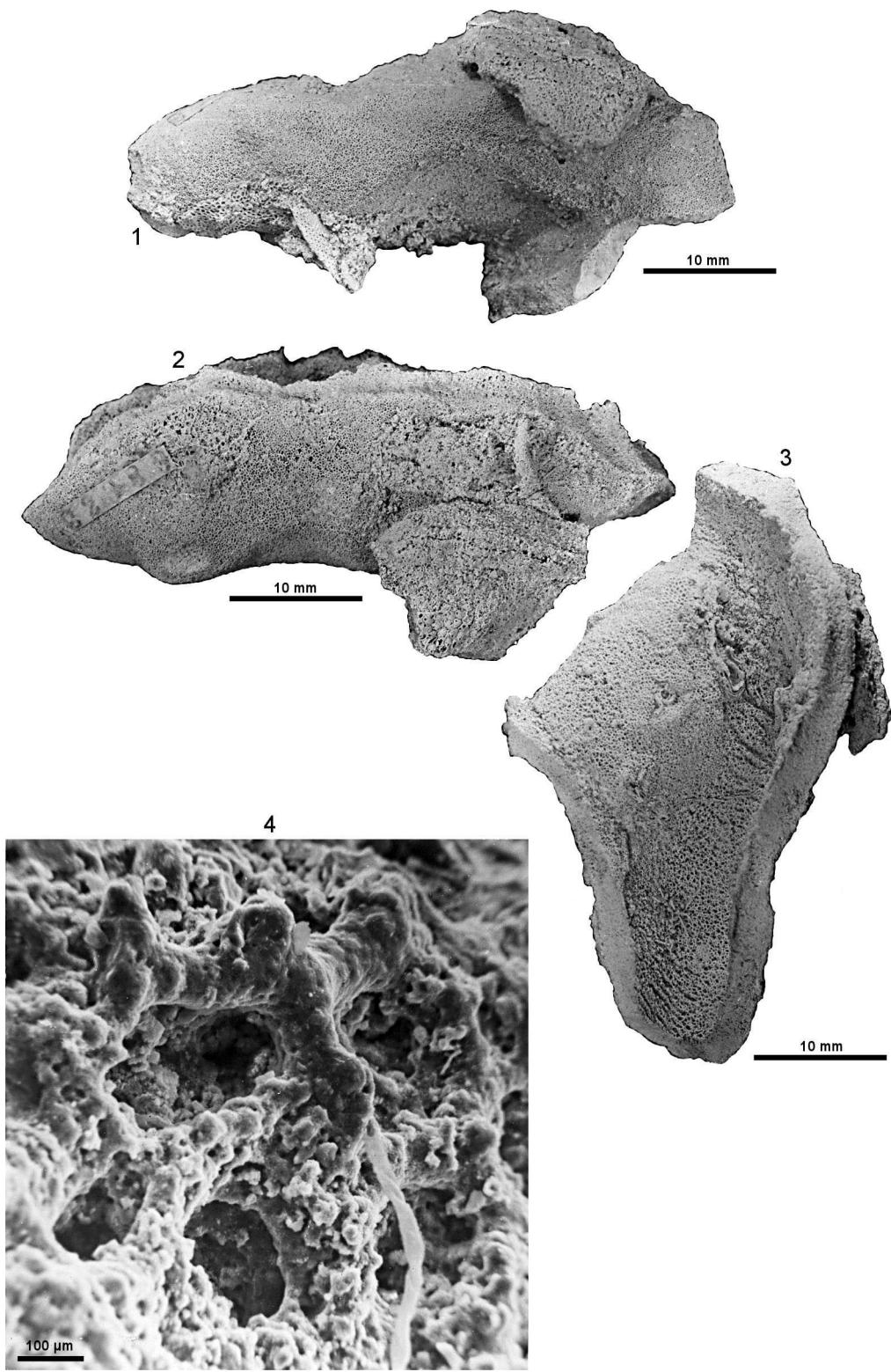


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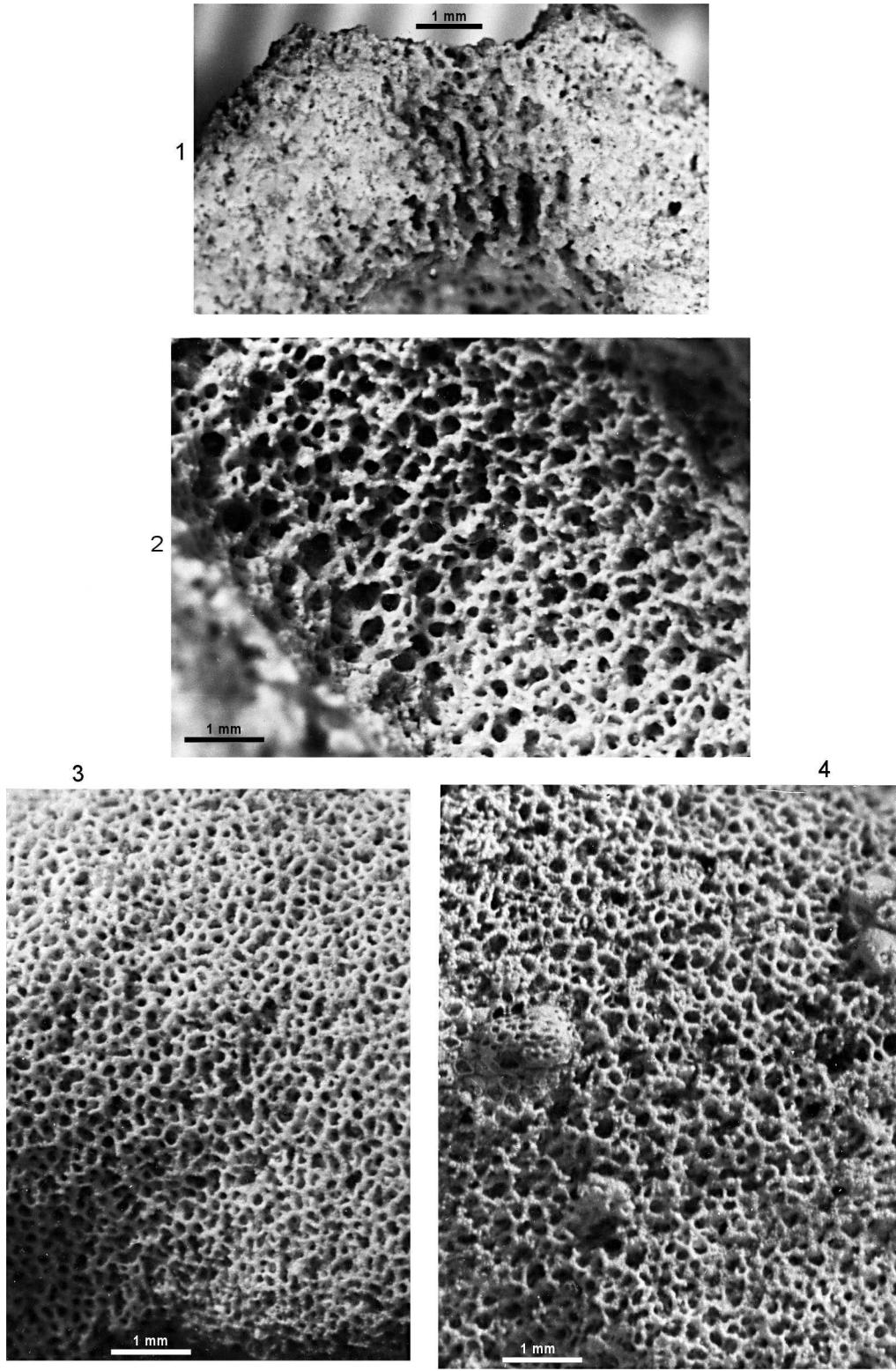


PLATE 13

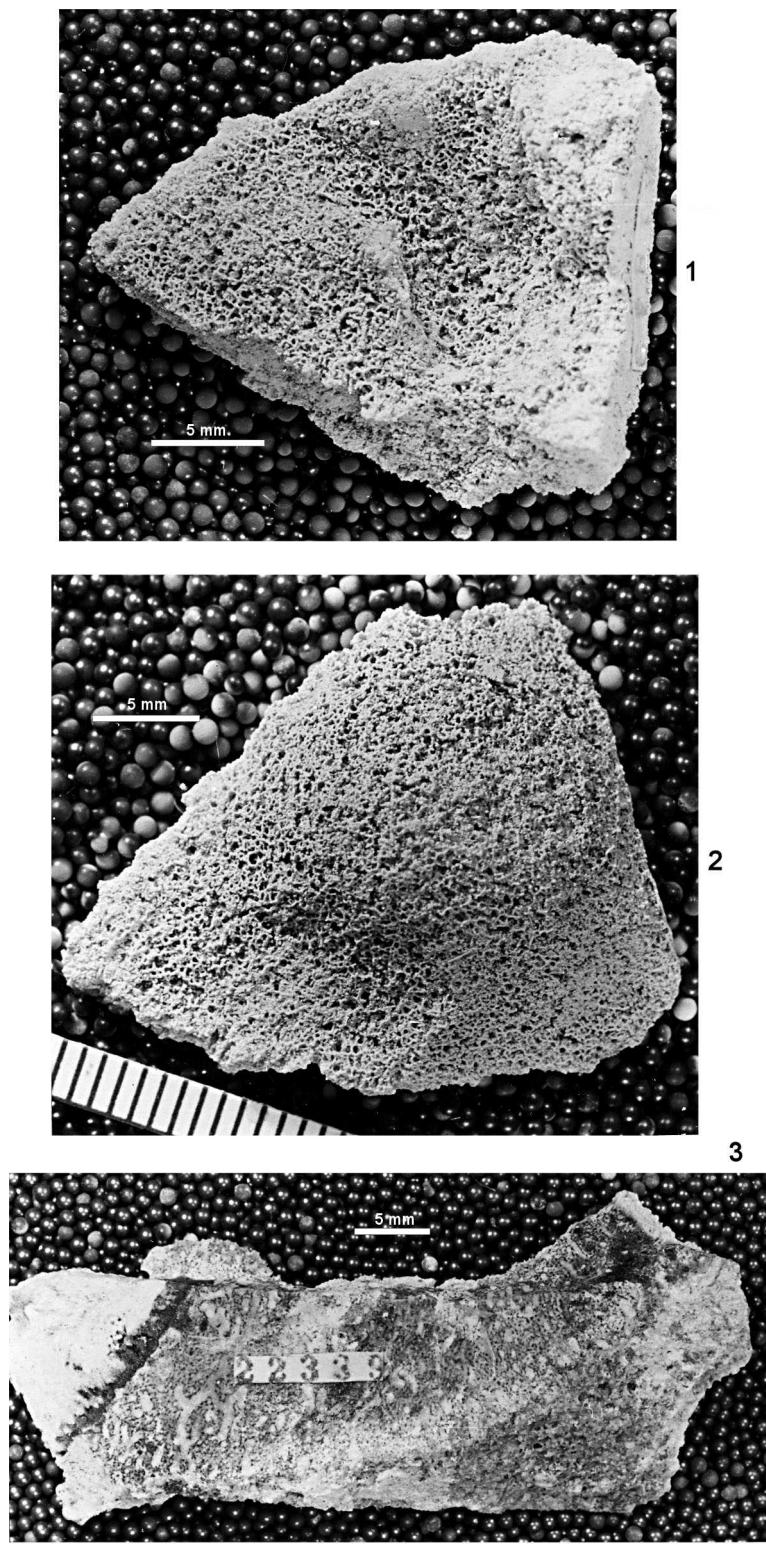


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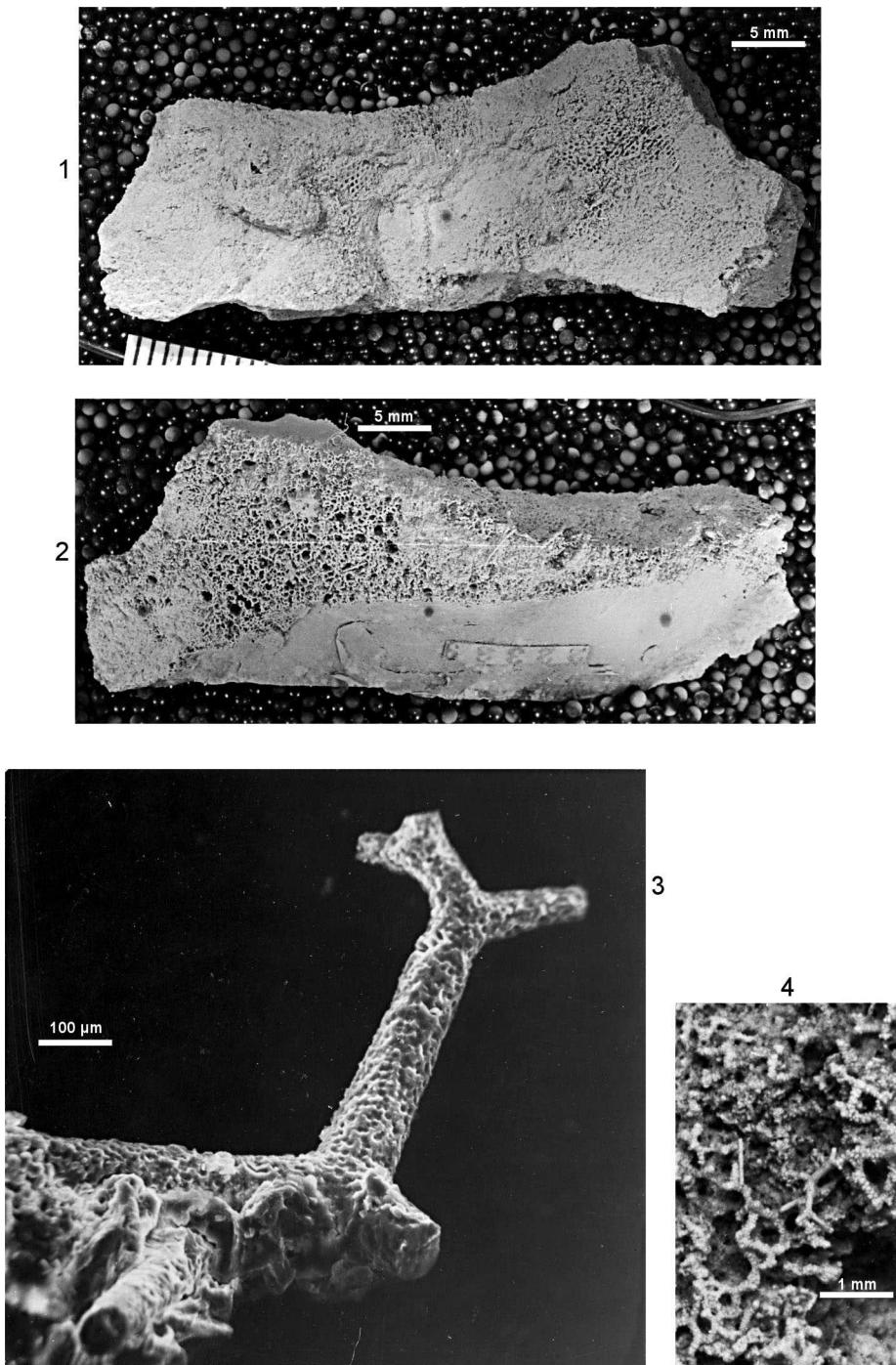


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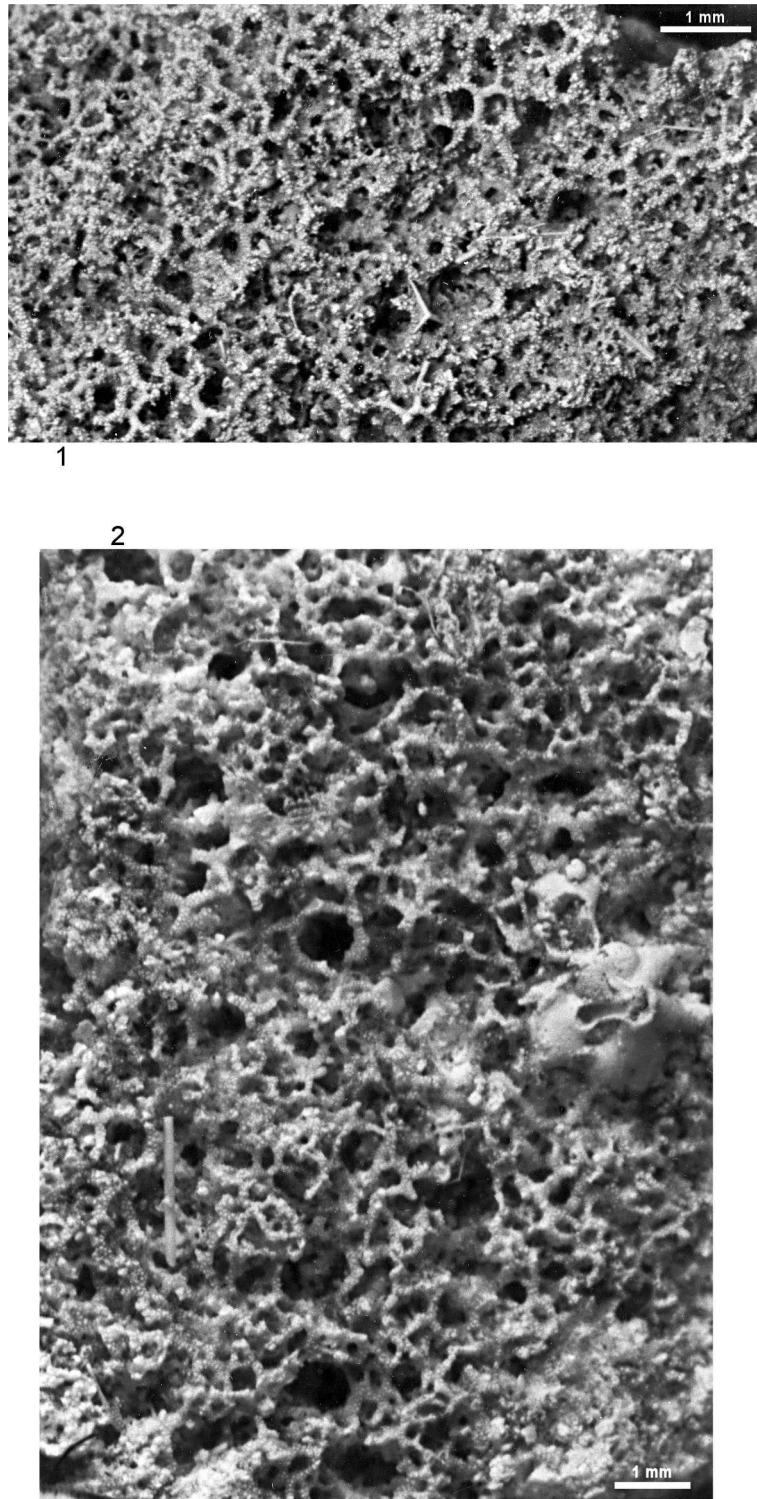


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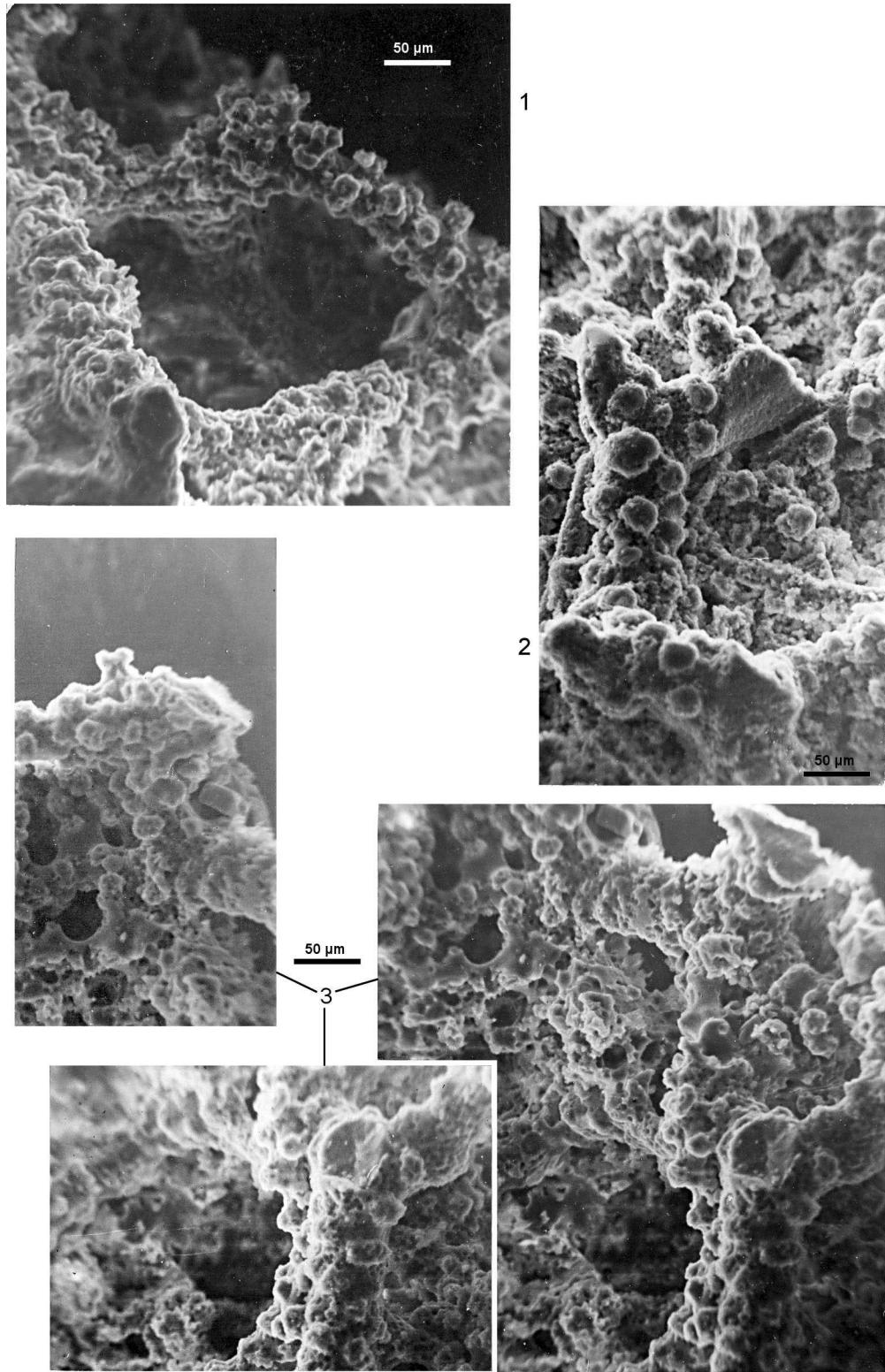
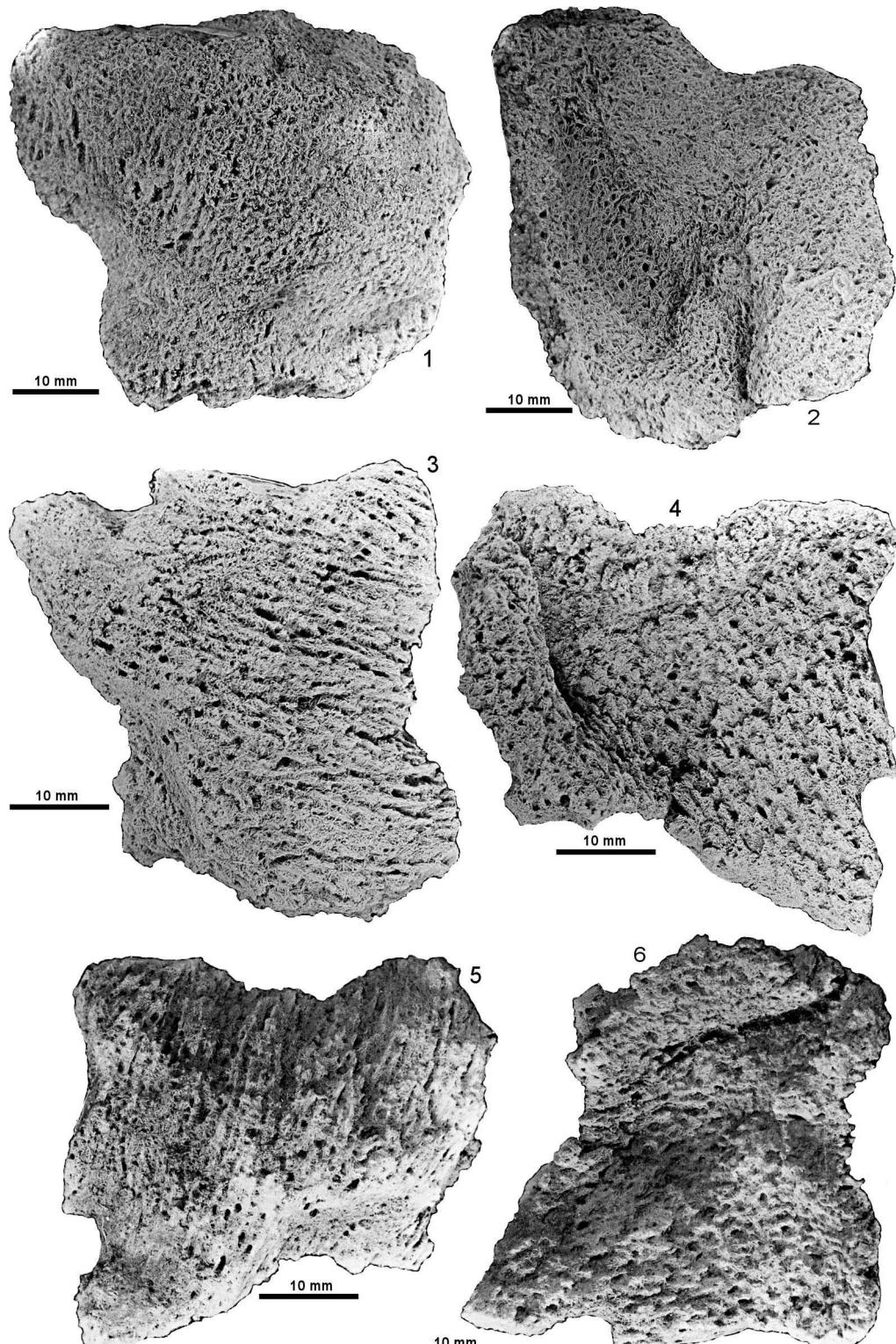


PLATE 17



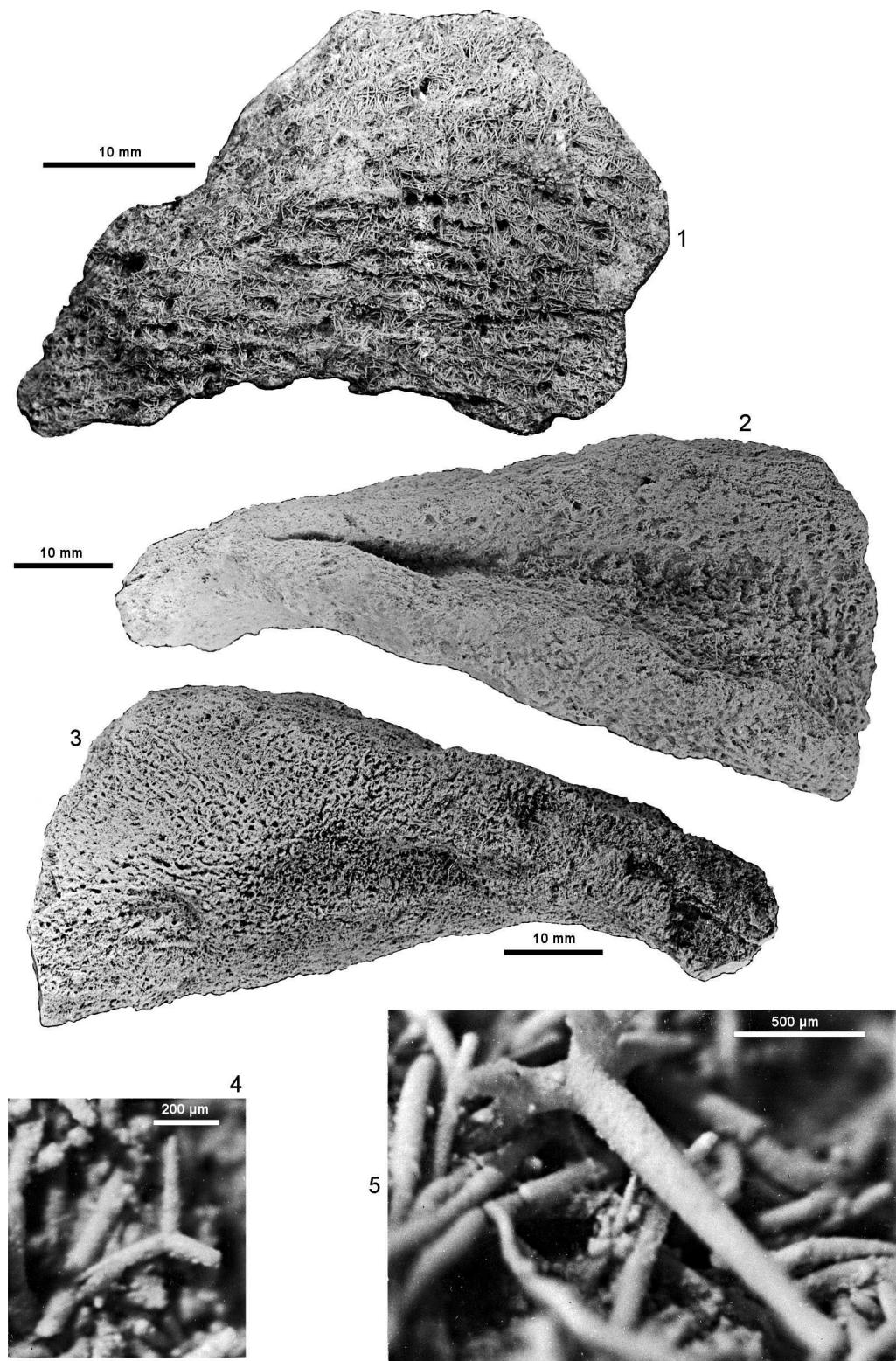


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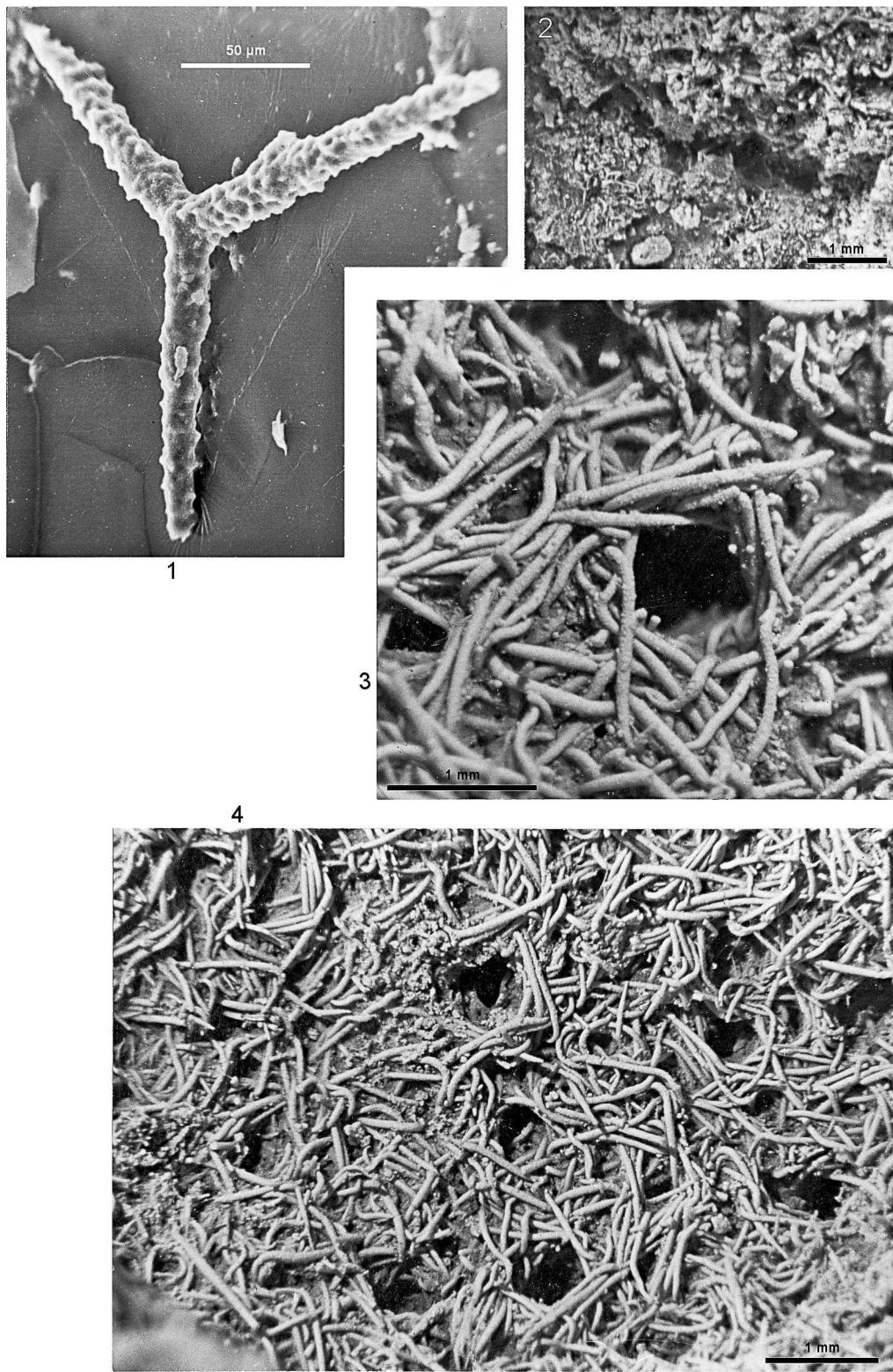


PLATE 20

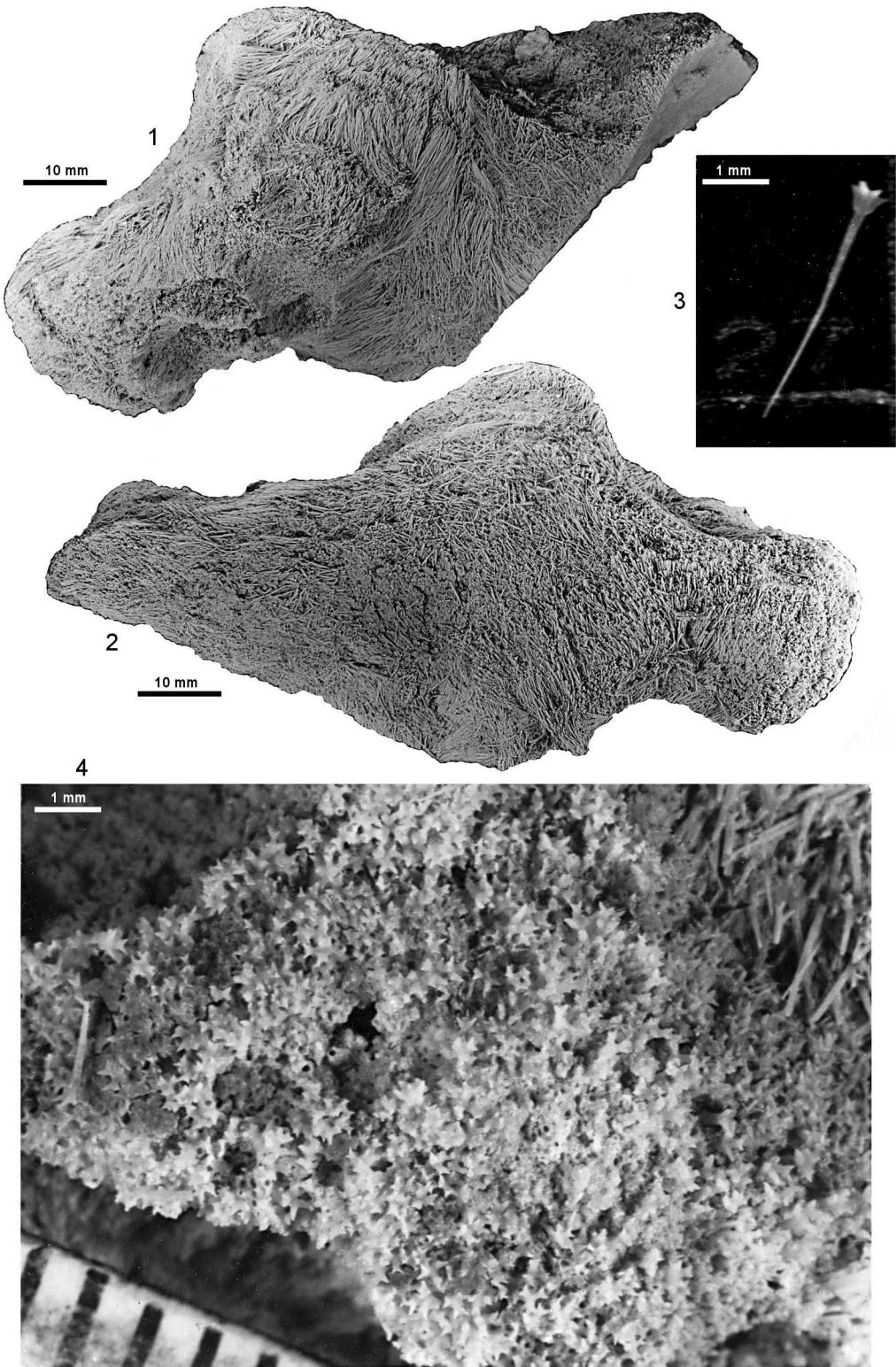


PLATE 21

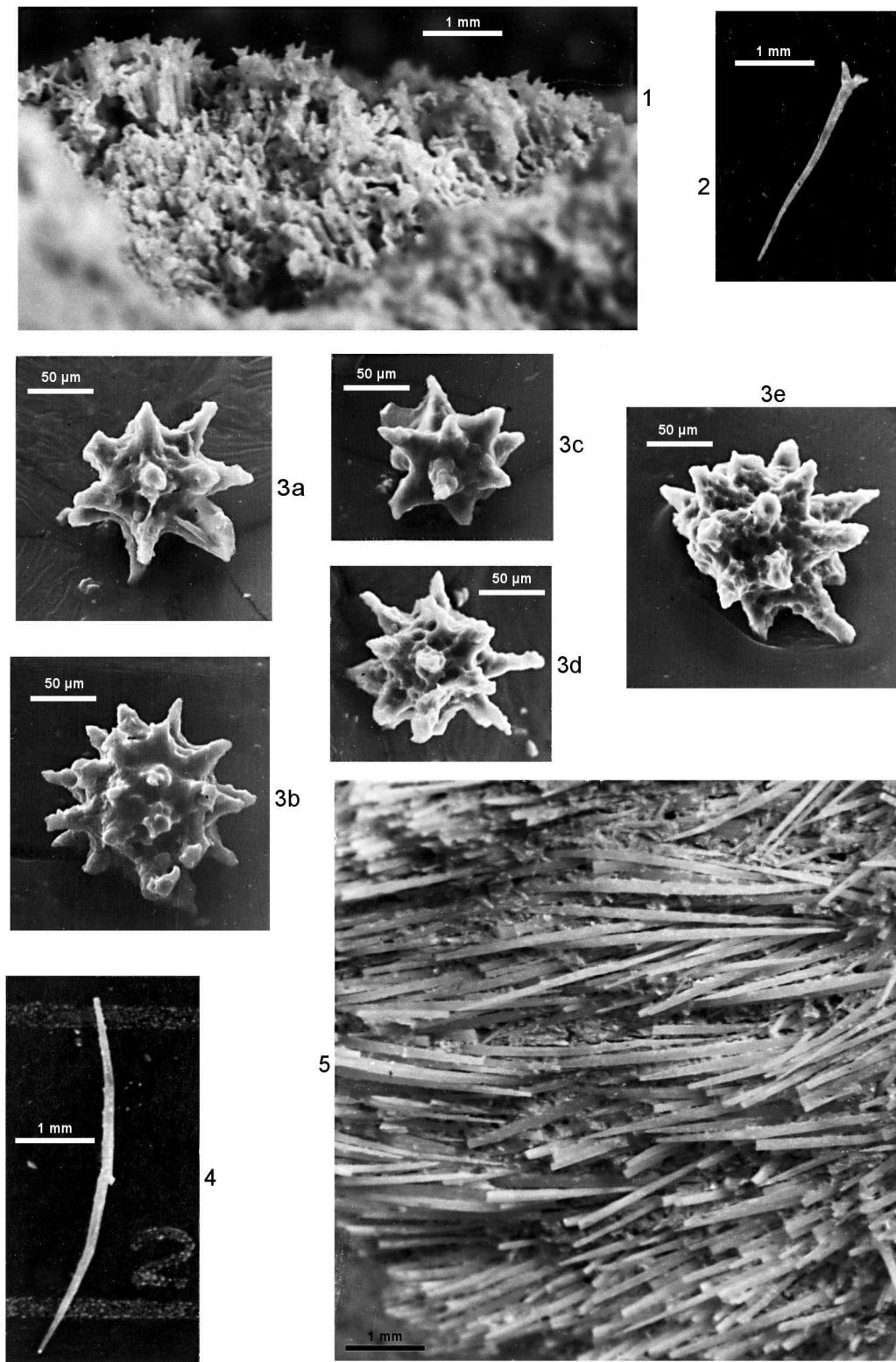


PLATE 22

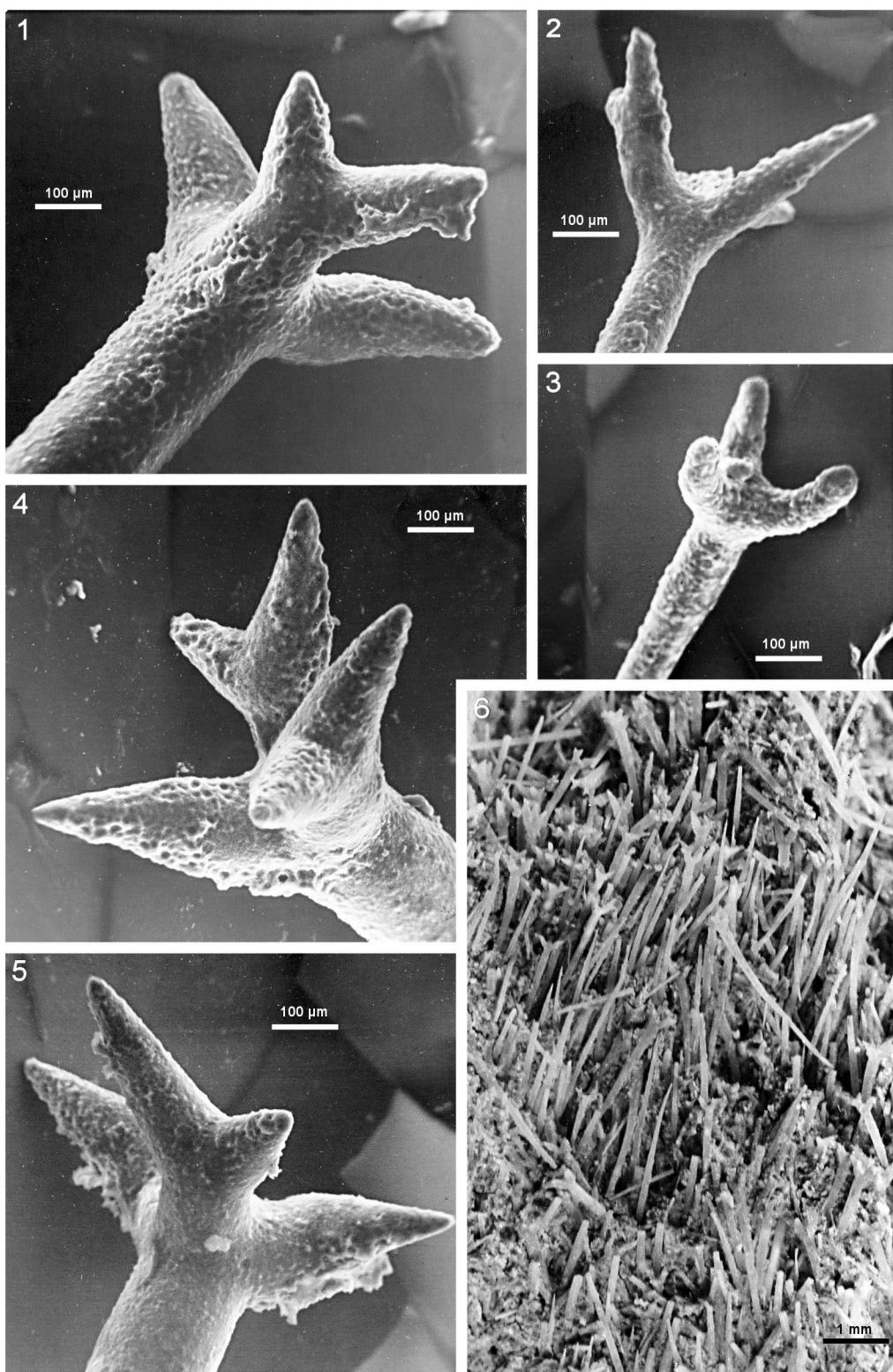


PLATE 23

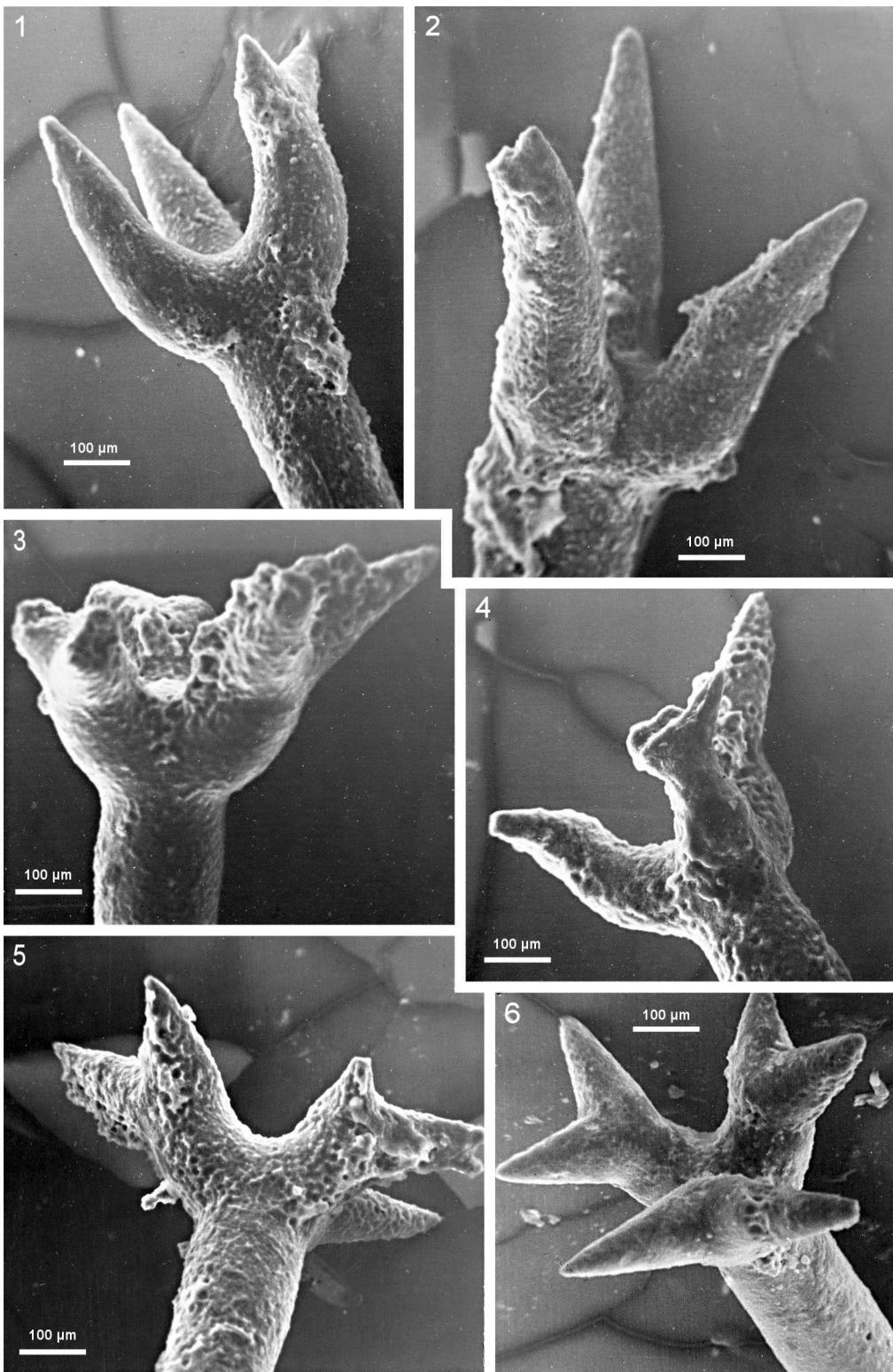


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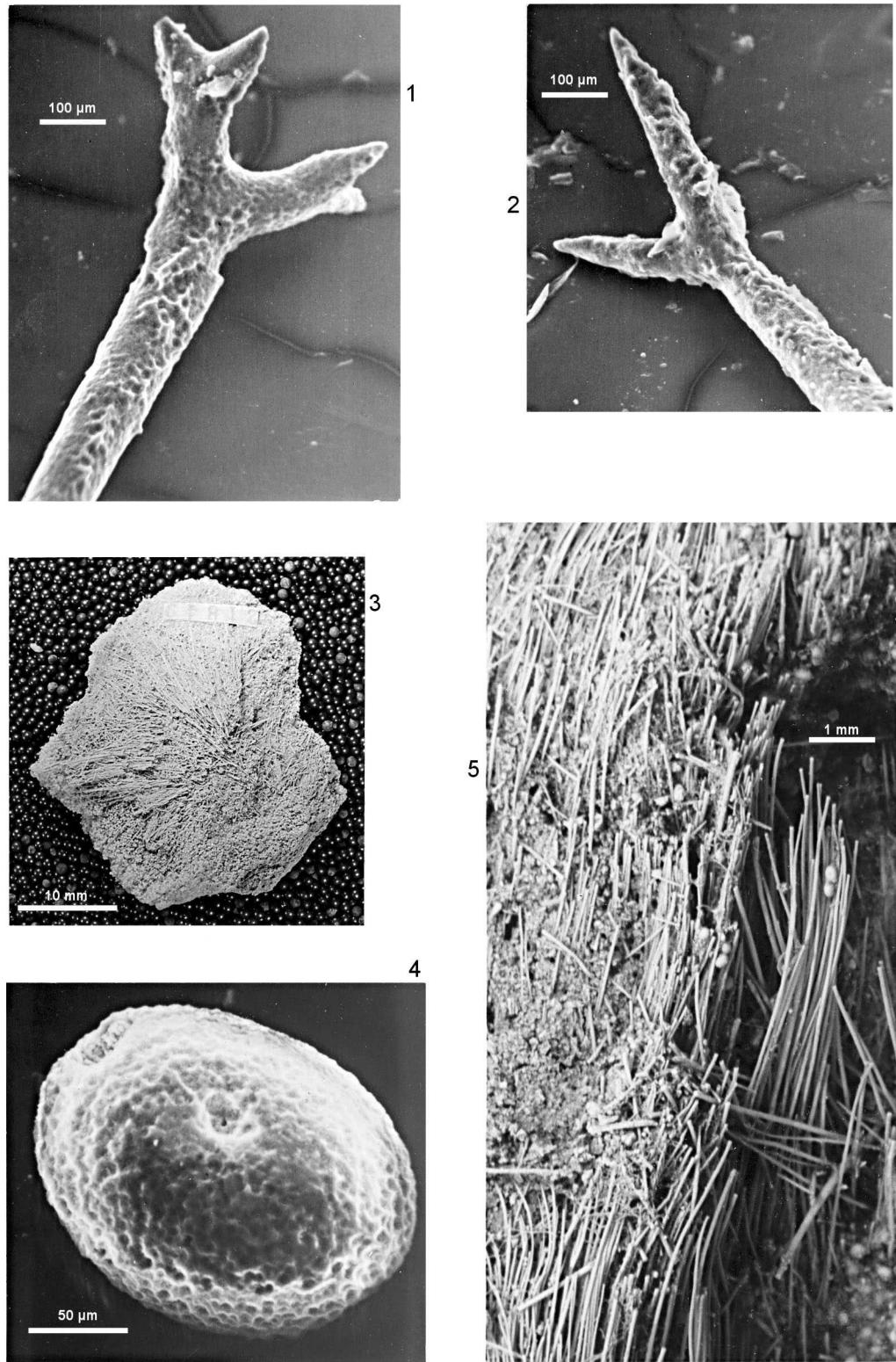


PLATE 25

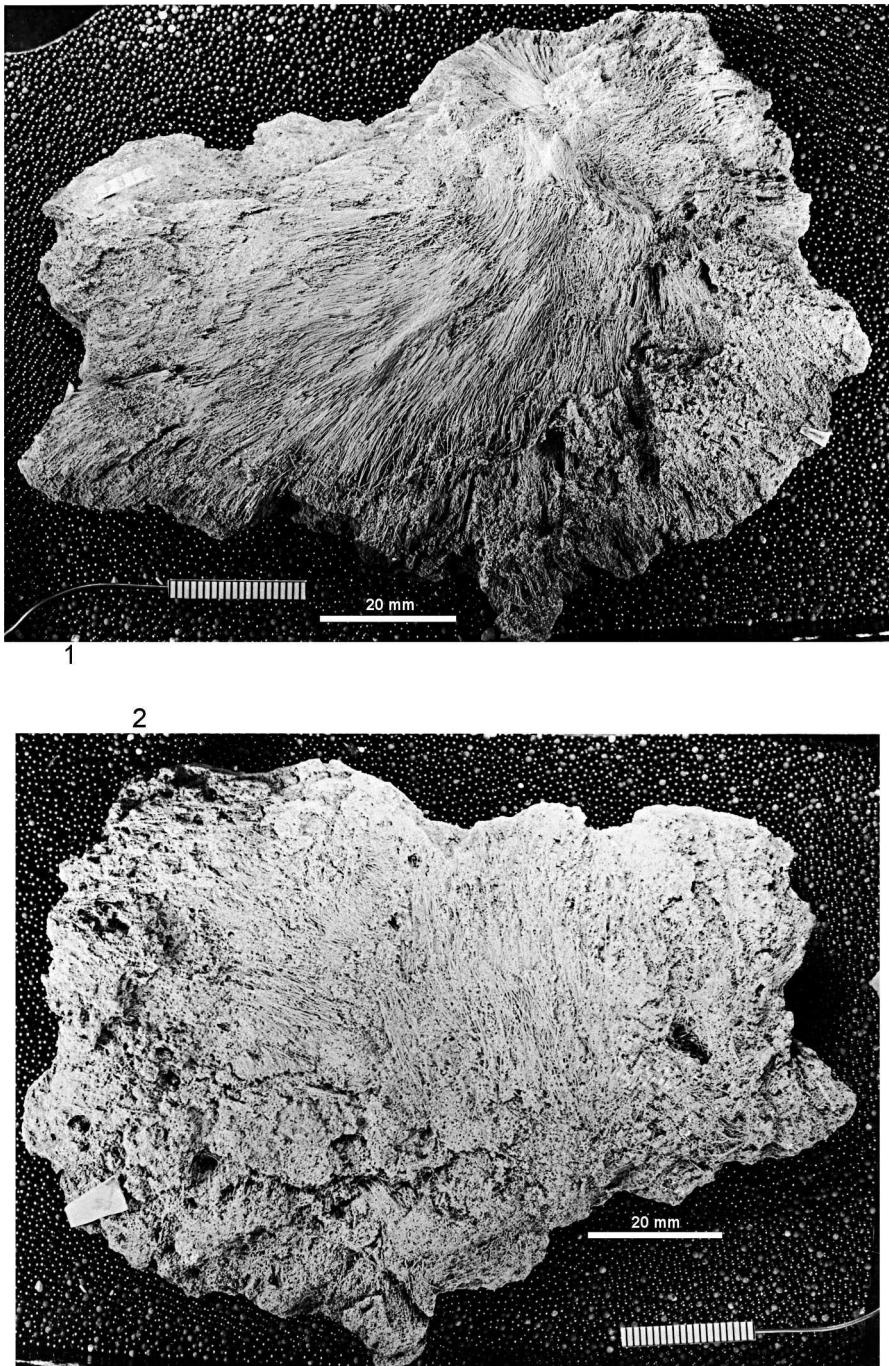


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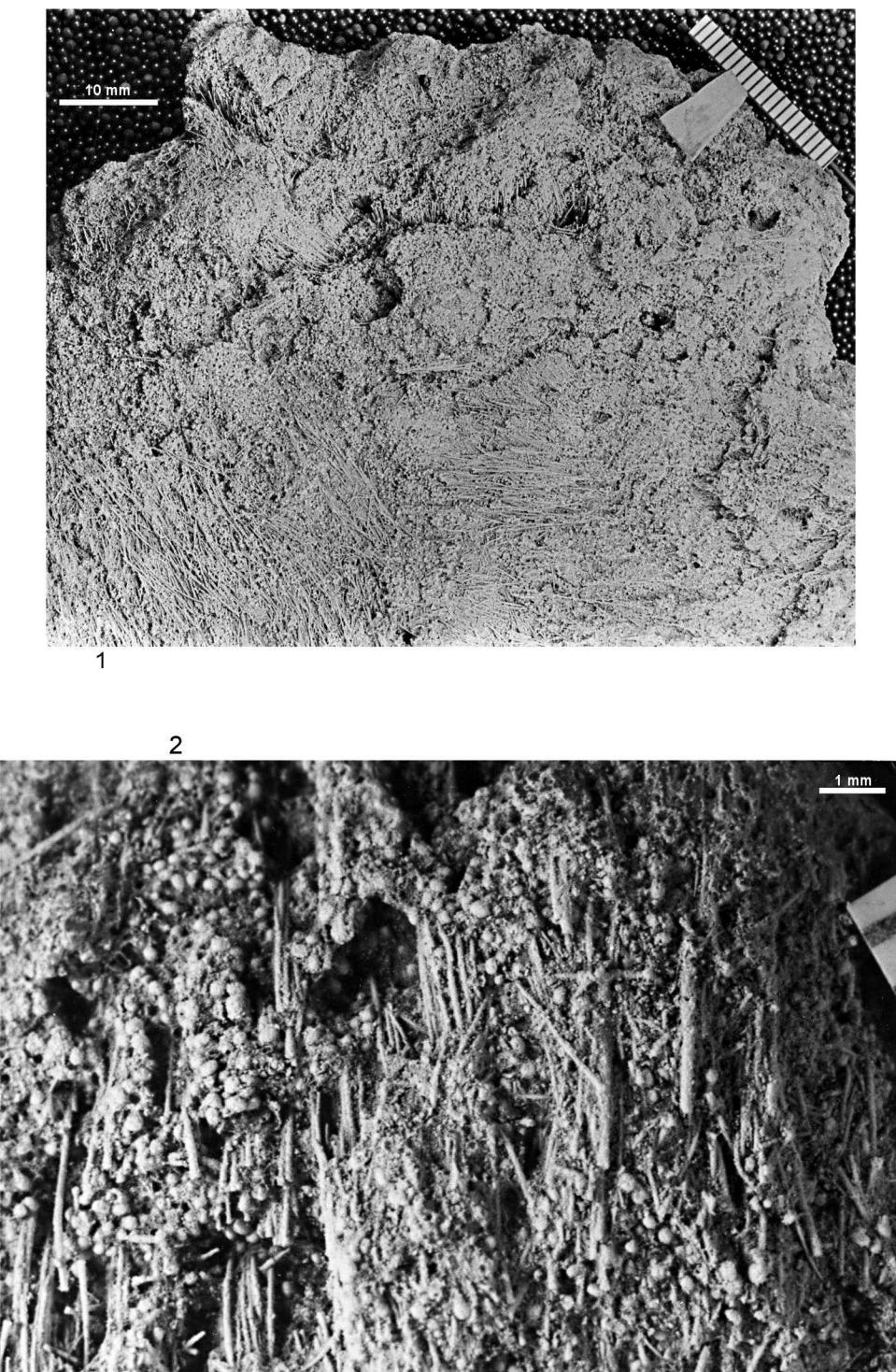


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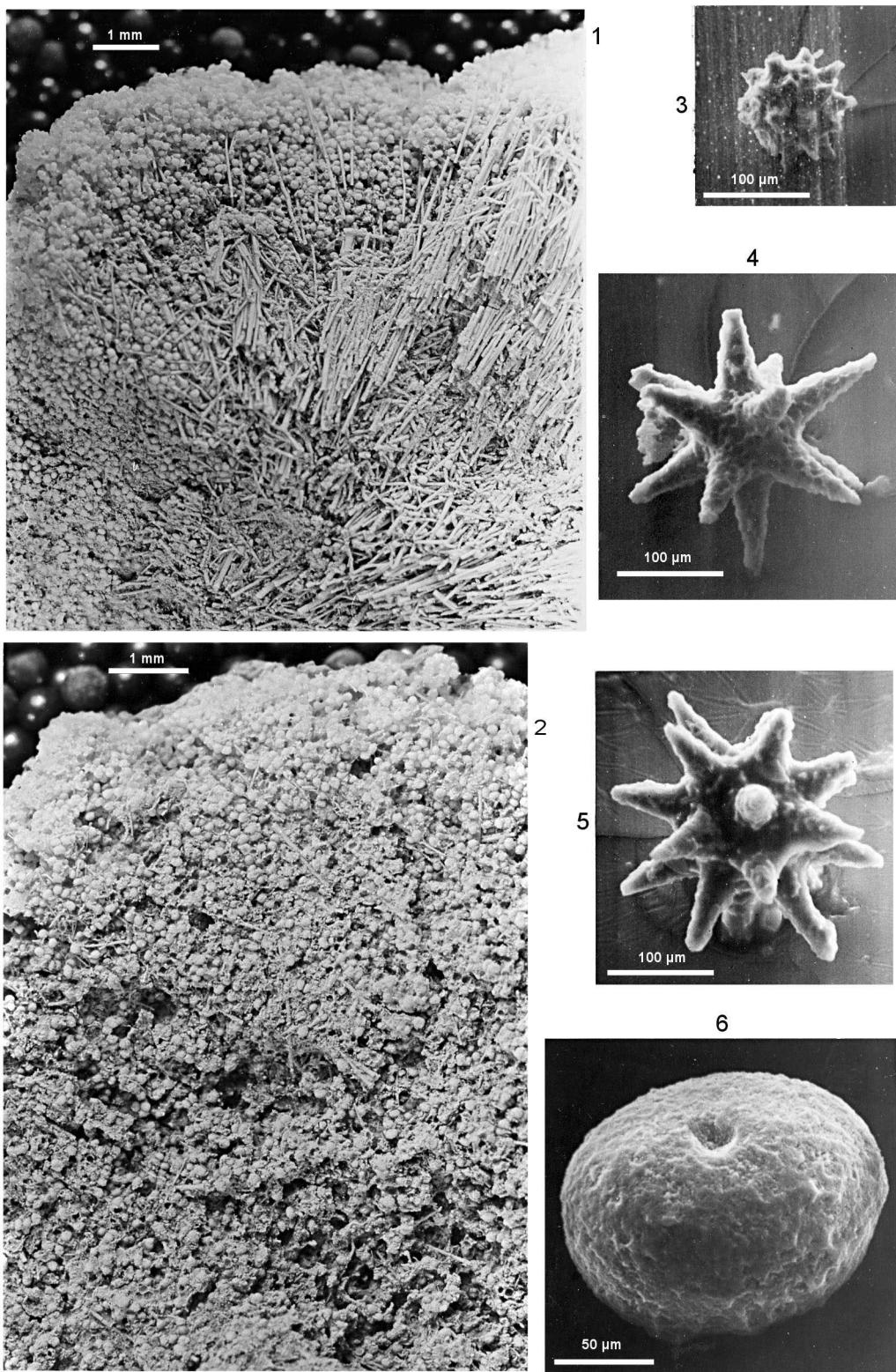


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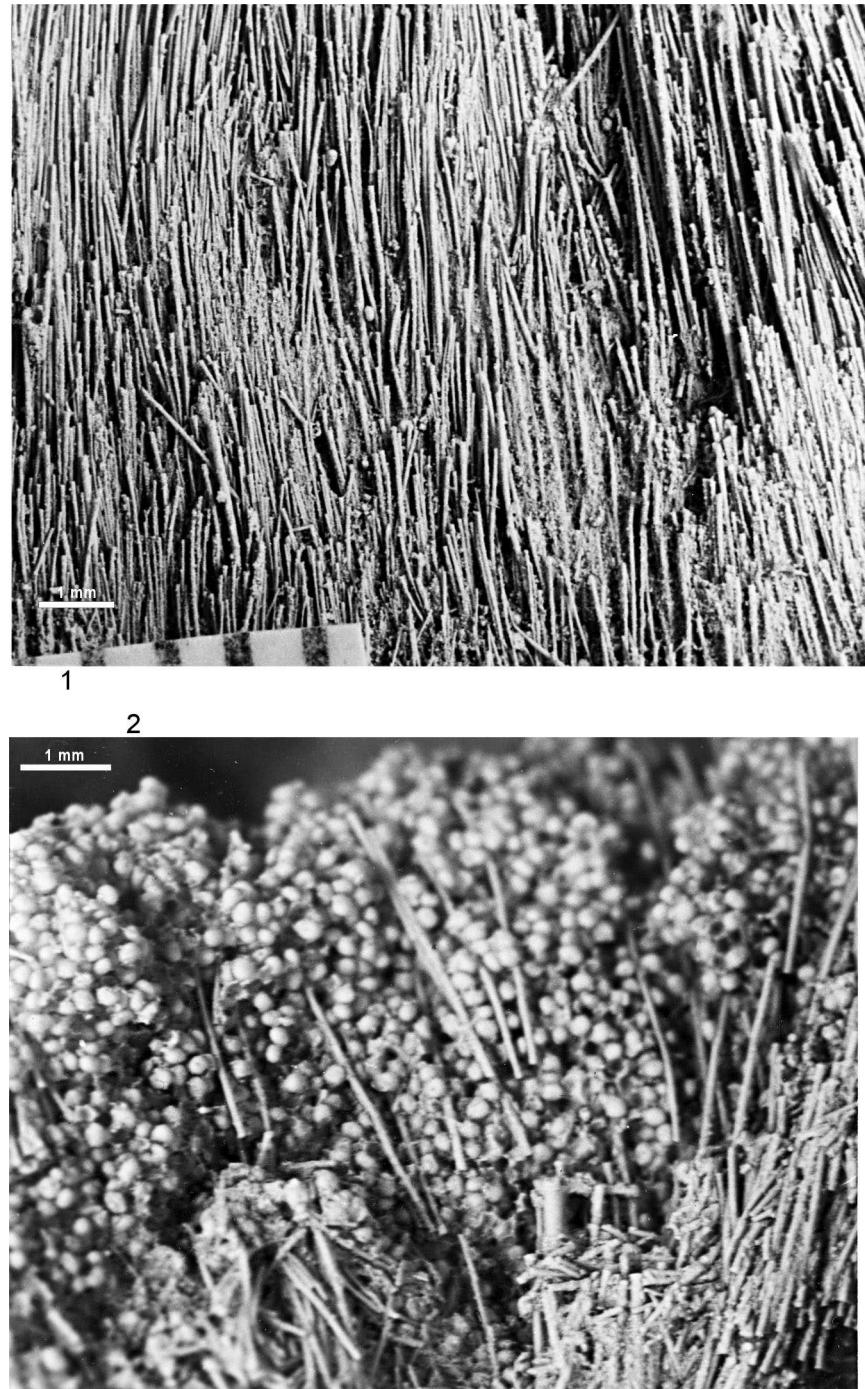


PLATE 29

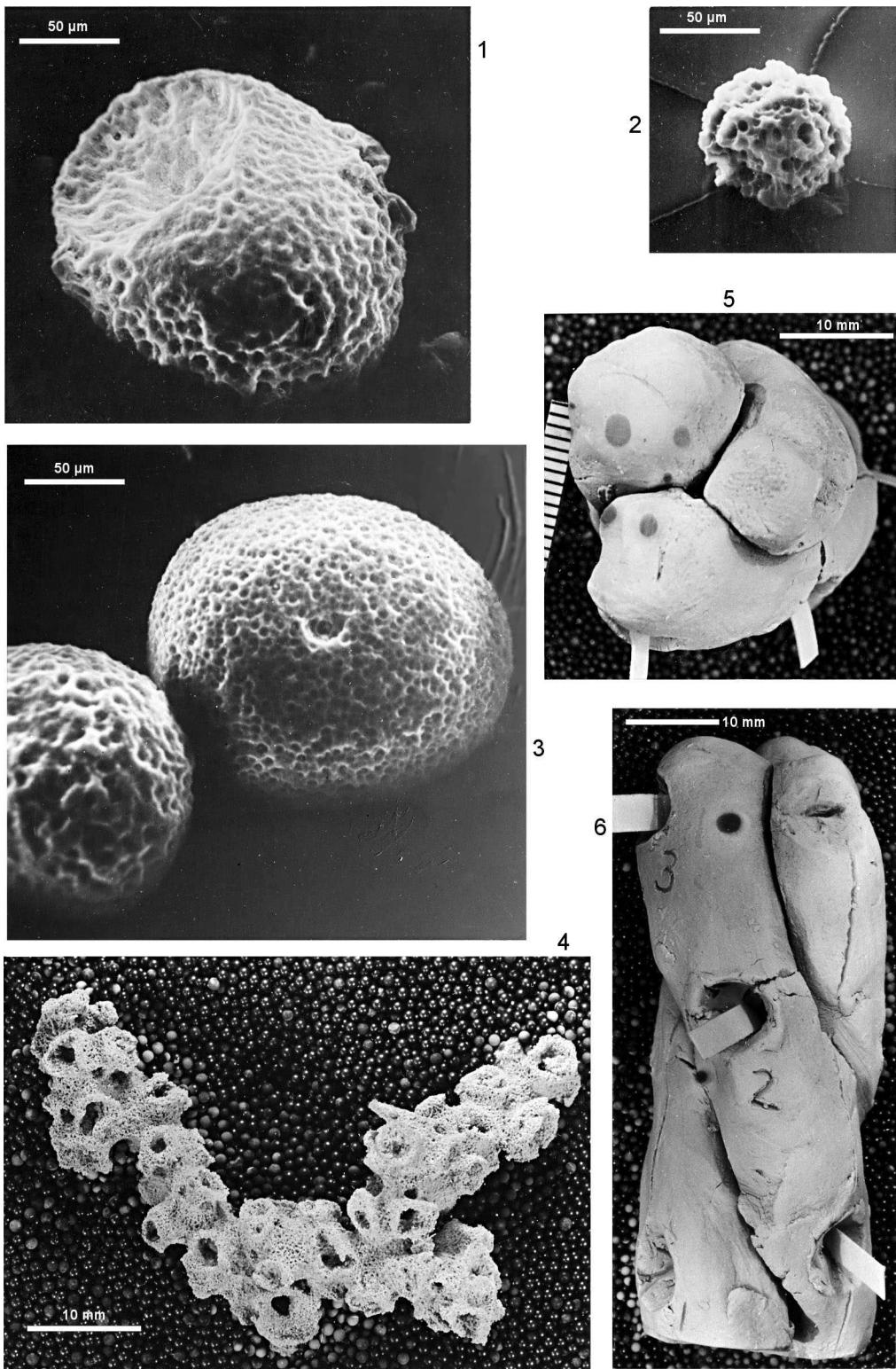


PLATE 30

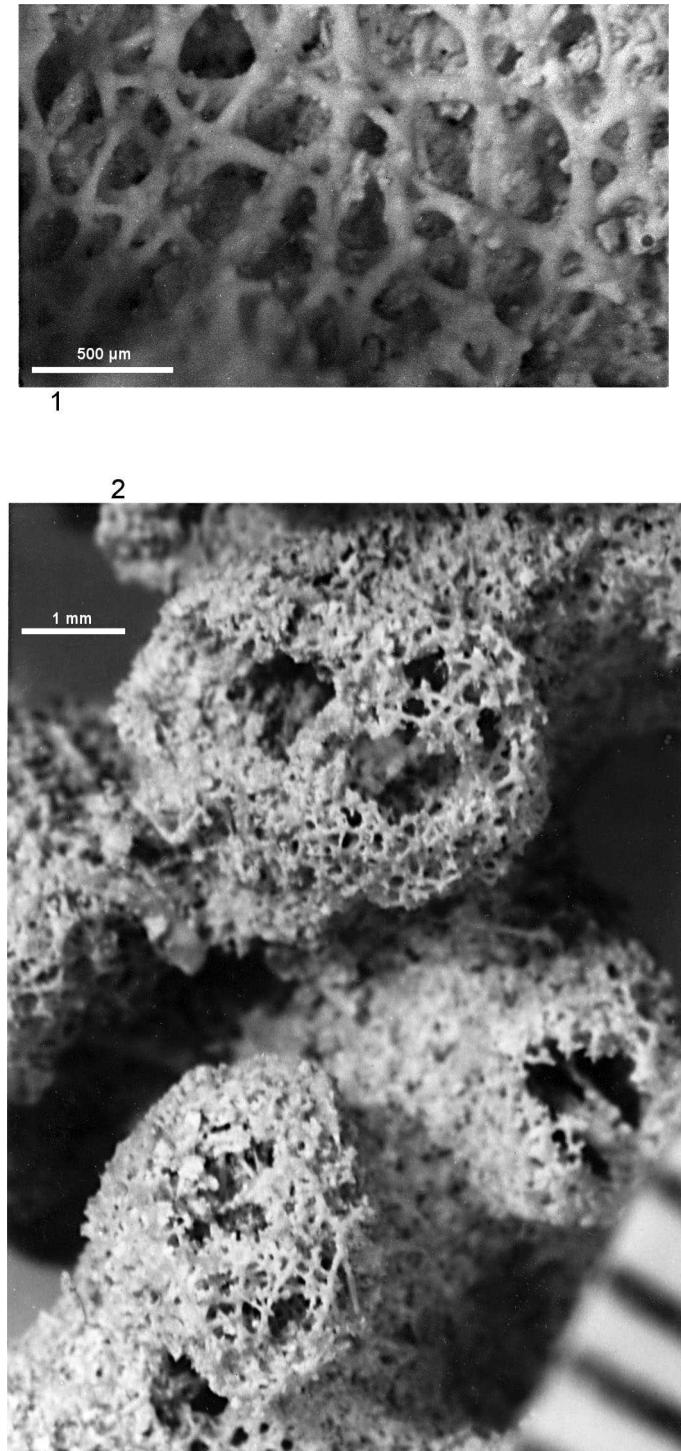


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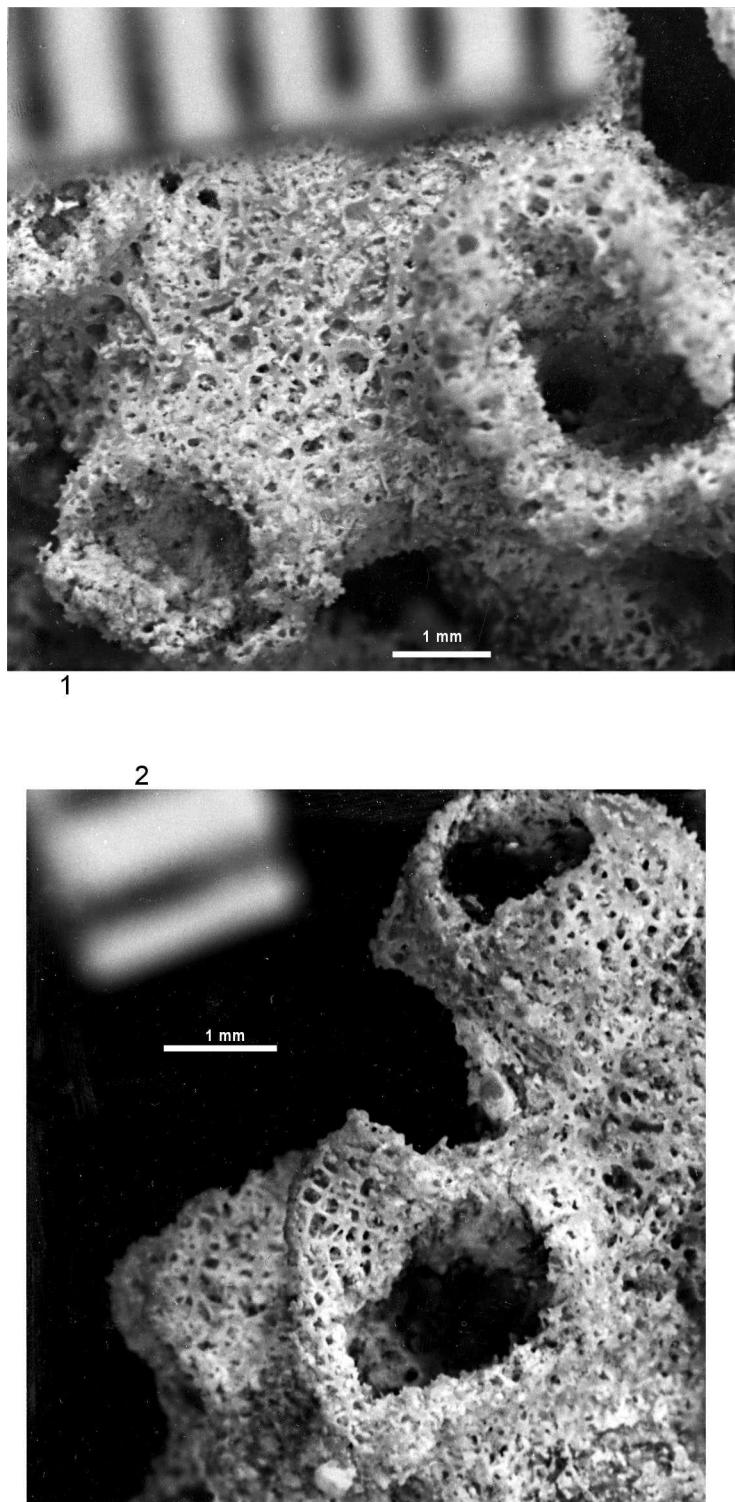


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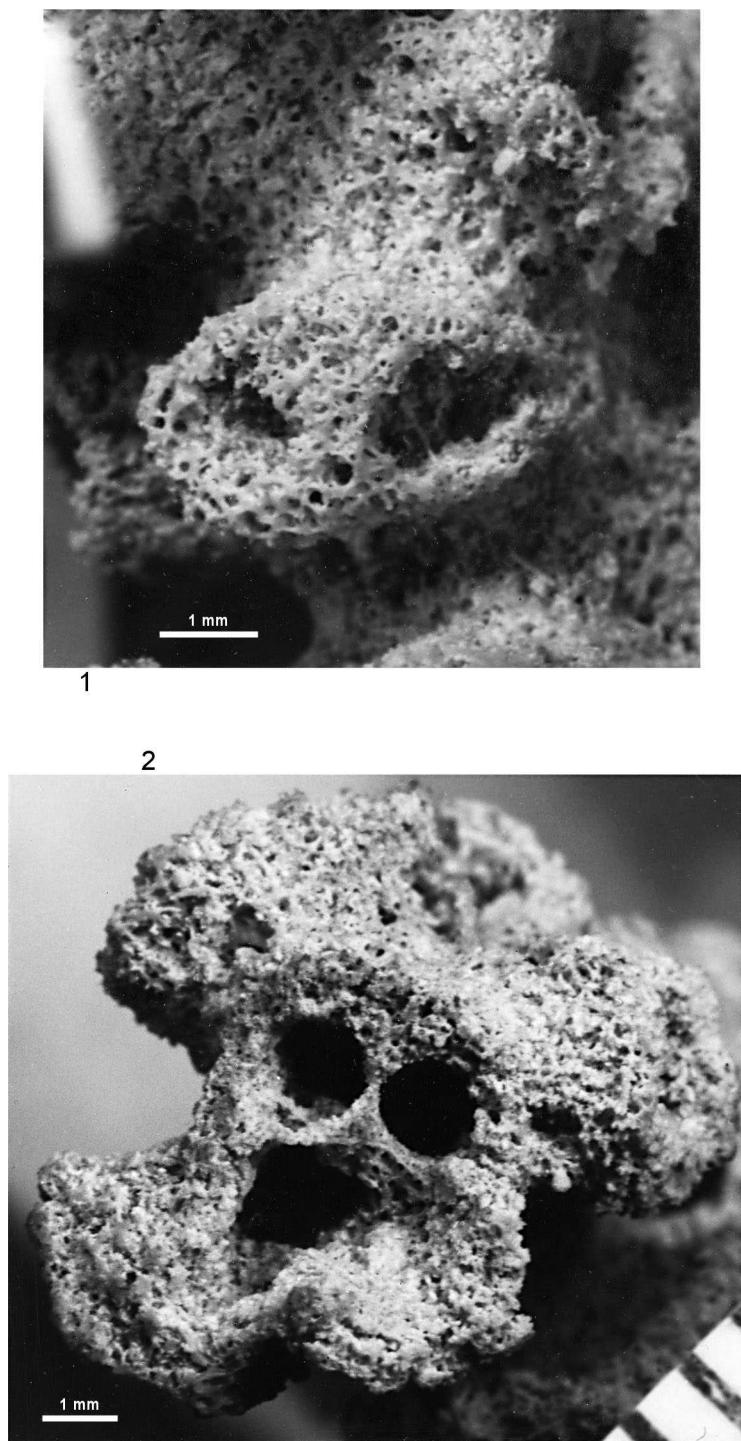


PLATE 33

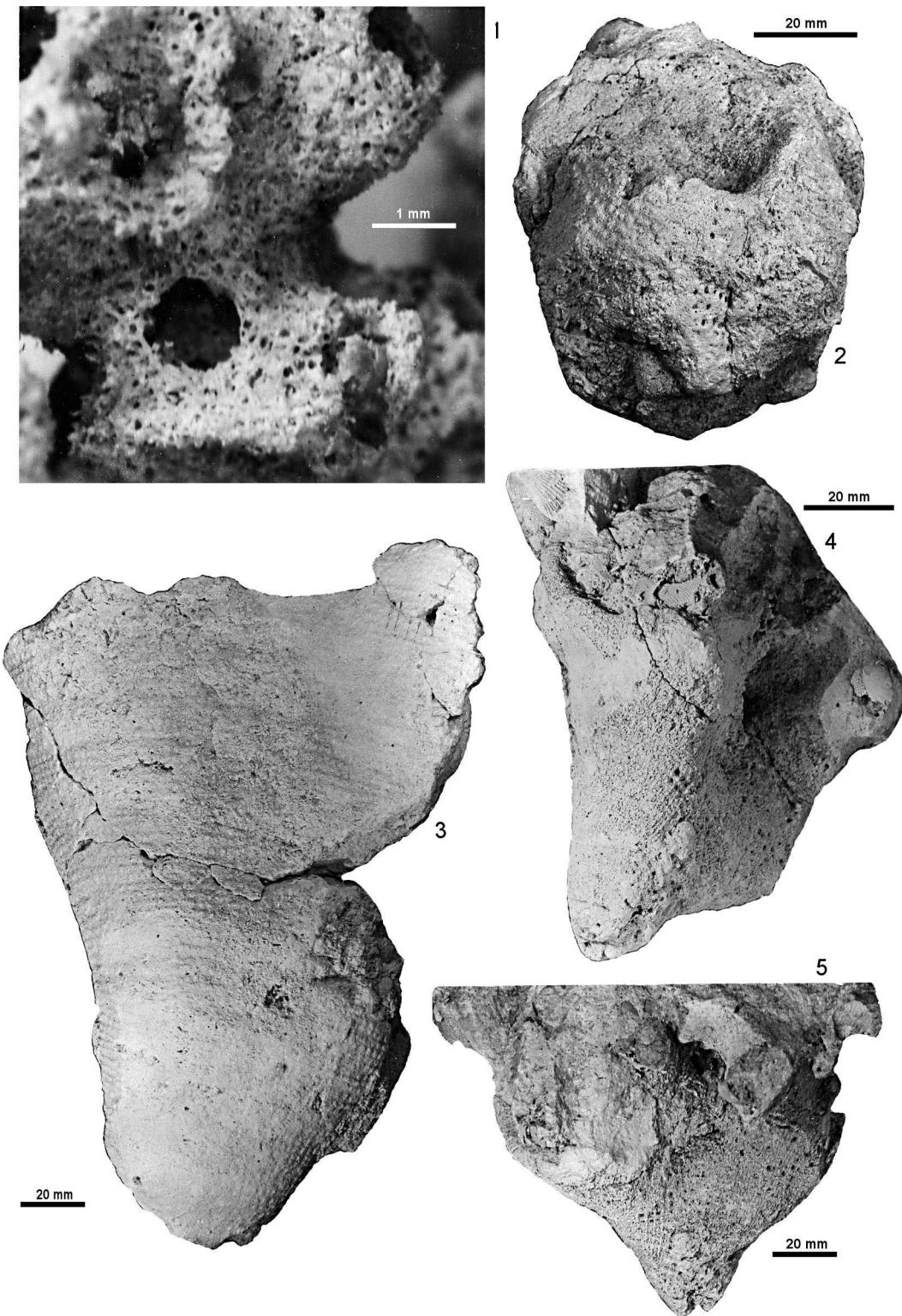


PLATE 34

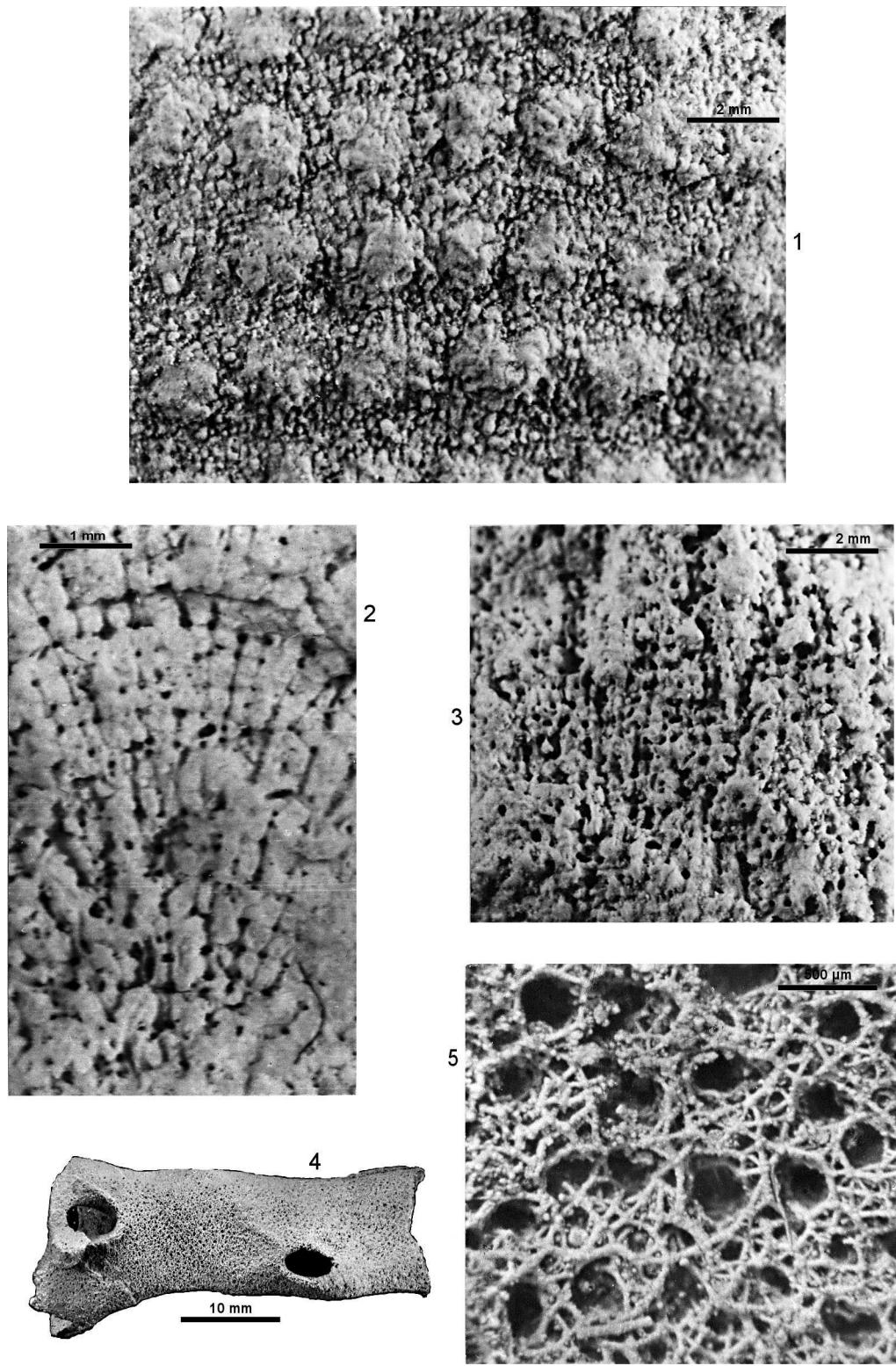


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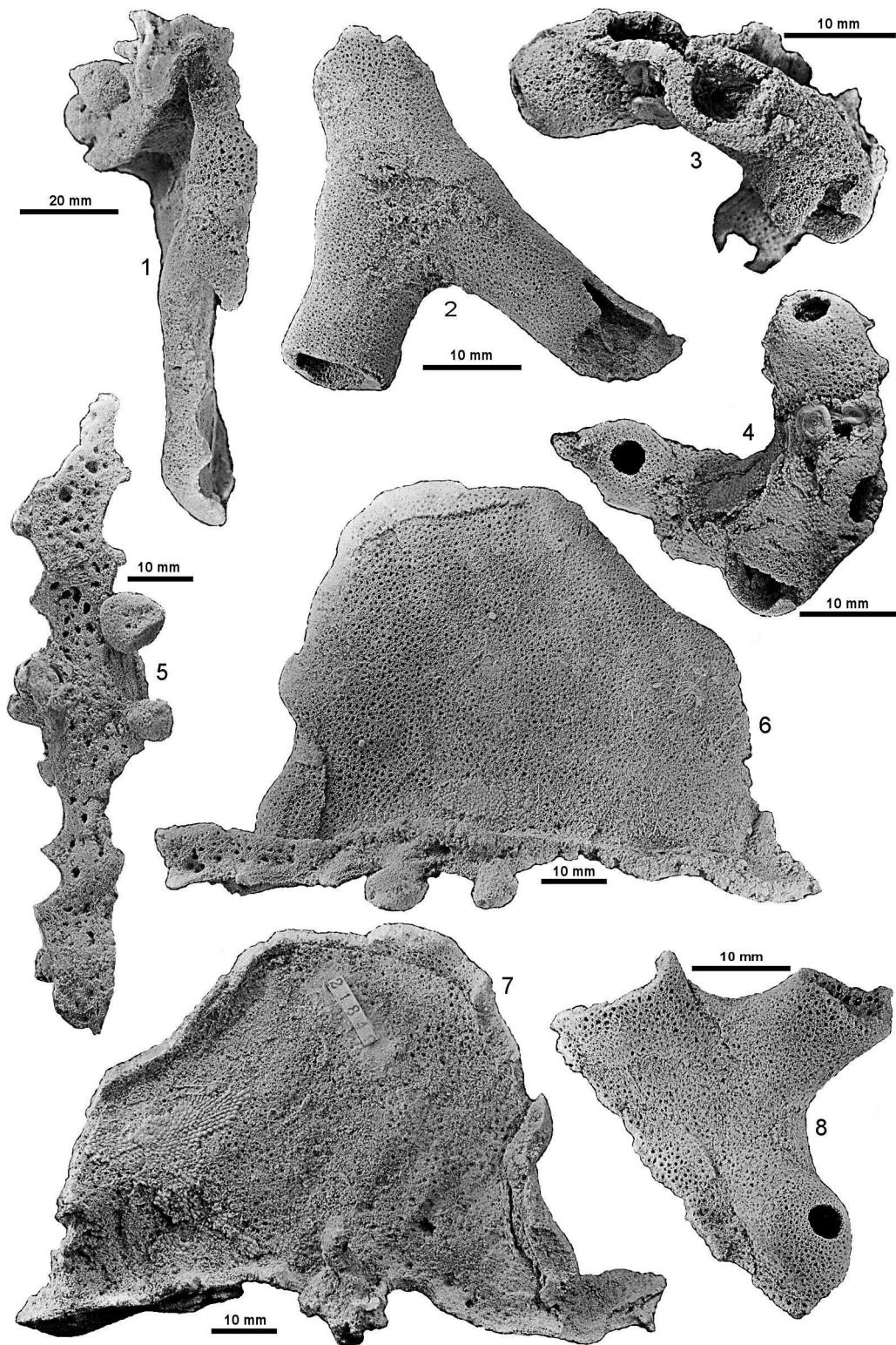
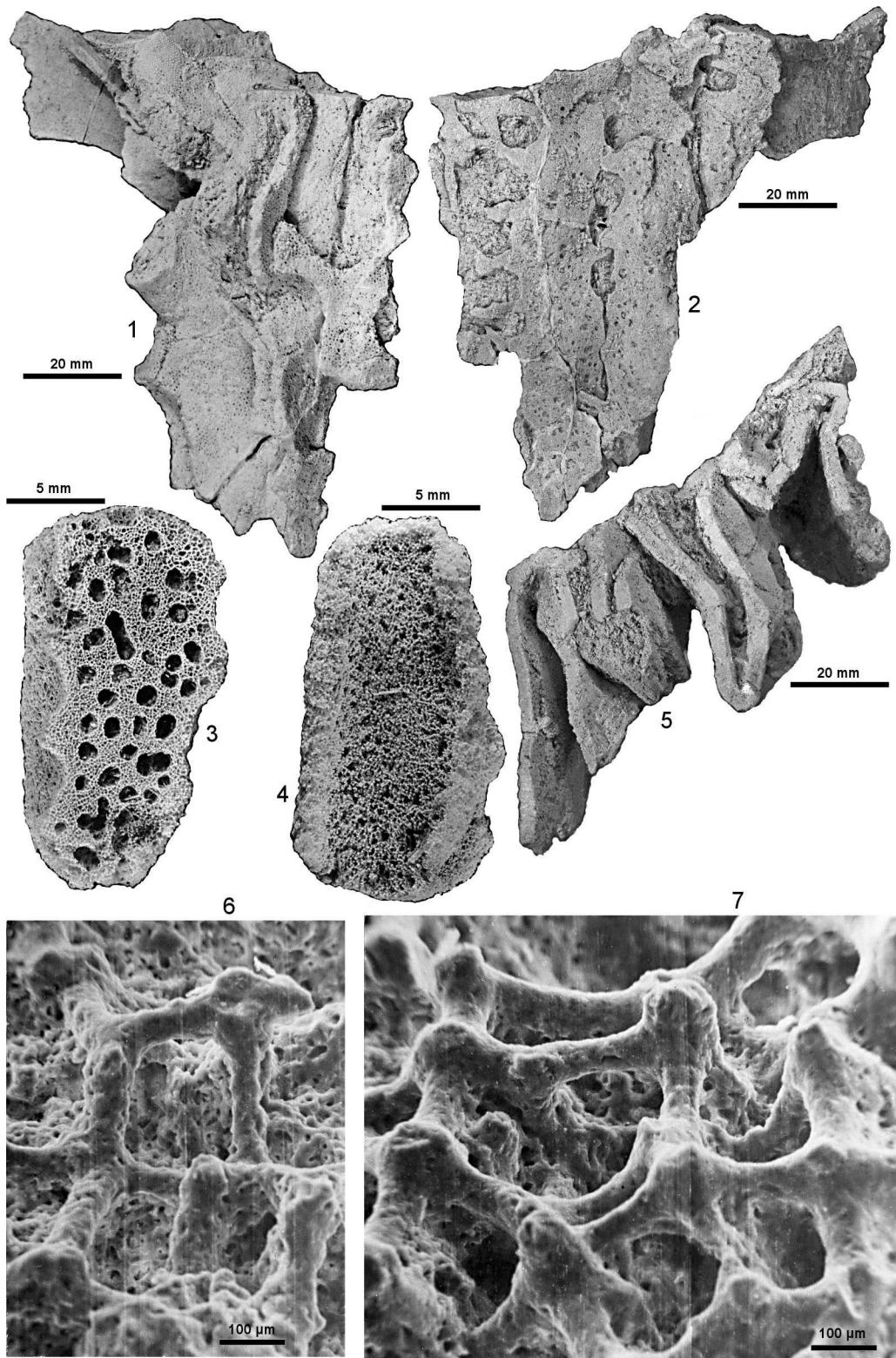


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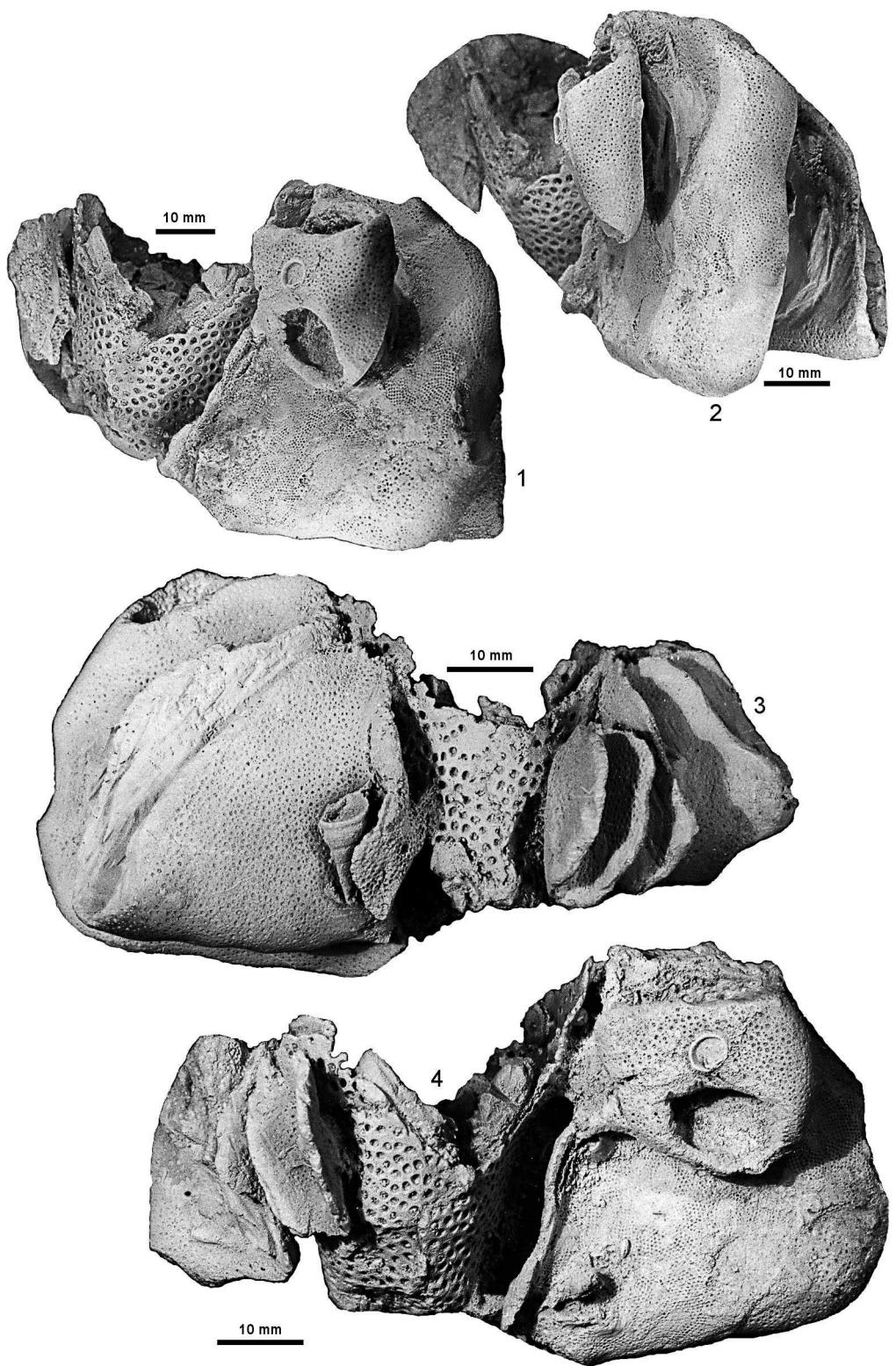


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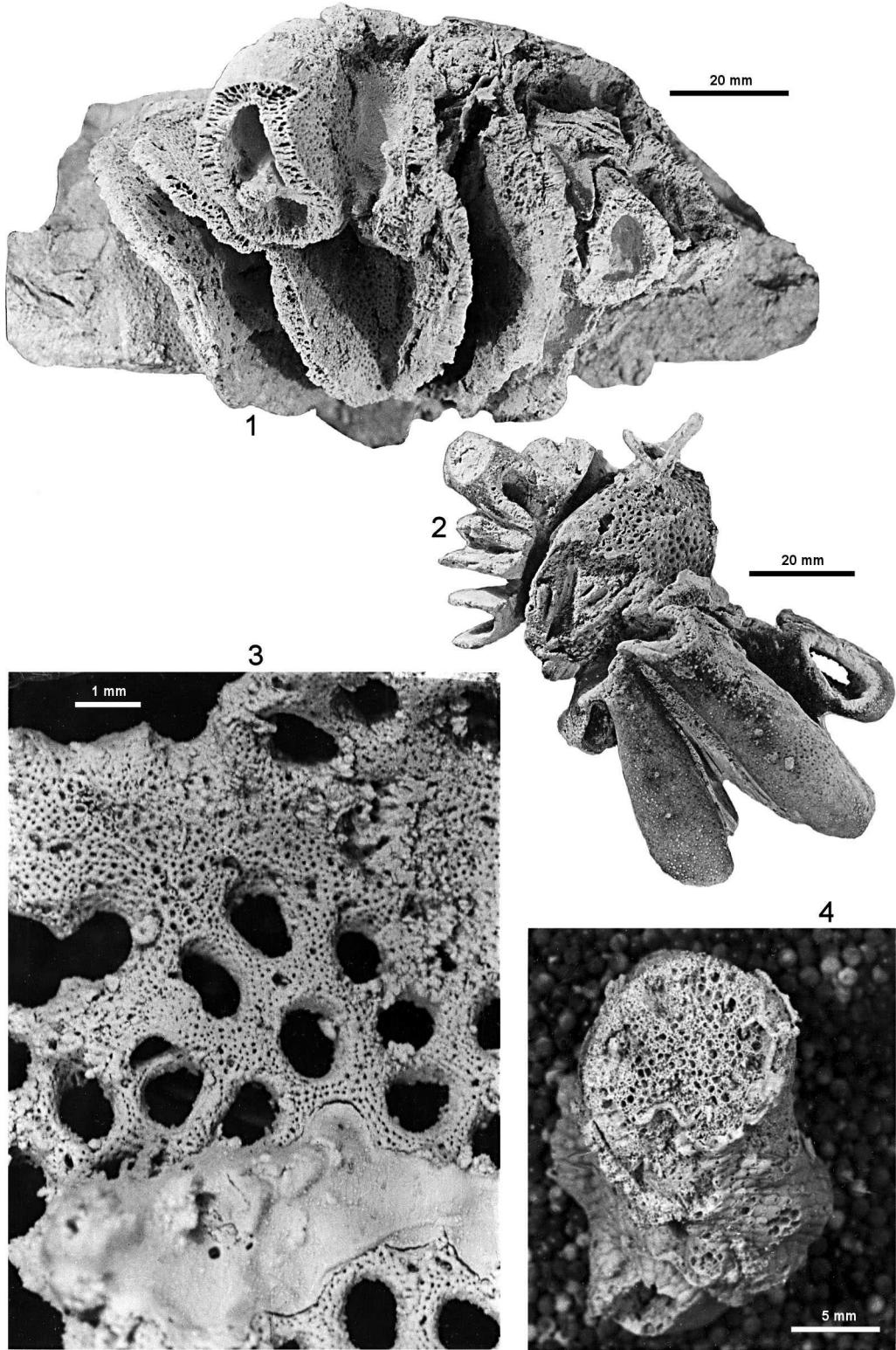
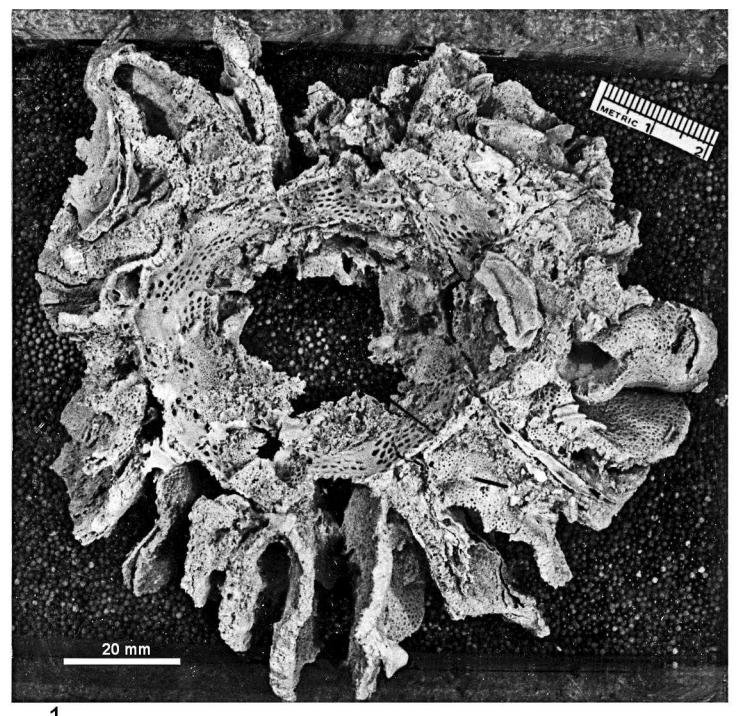


PLATE 39



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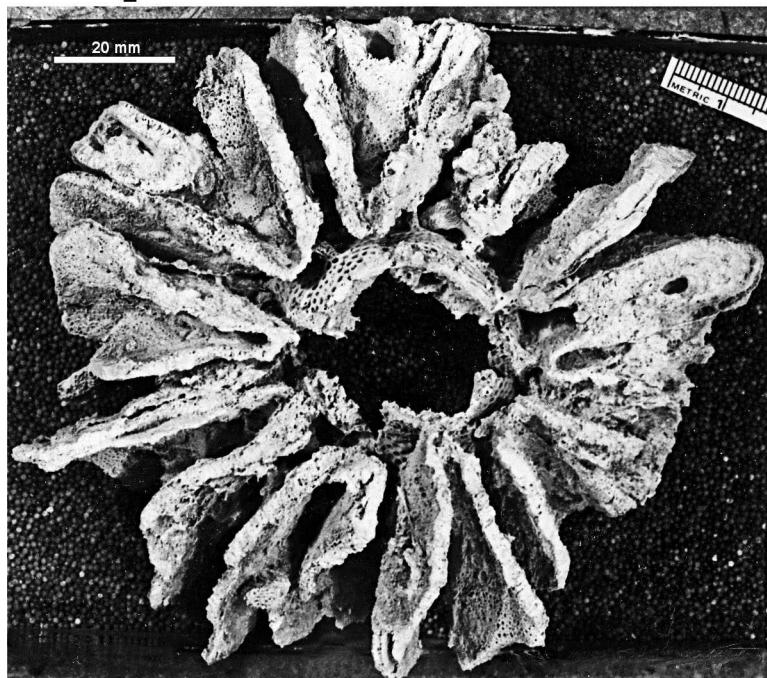


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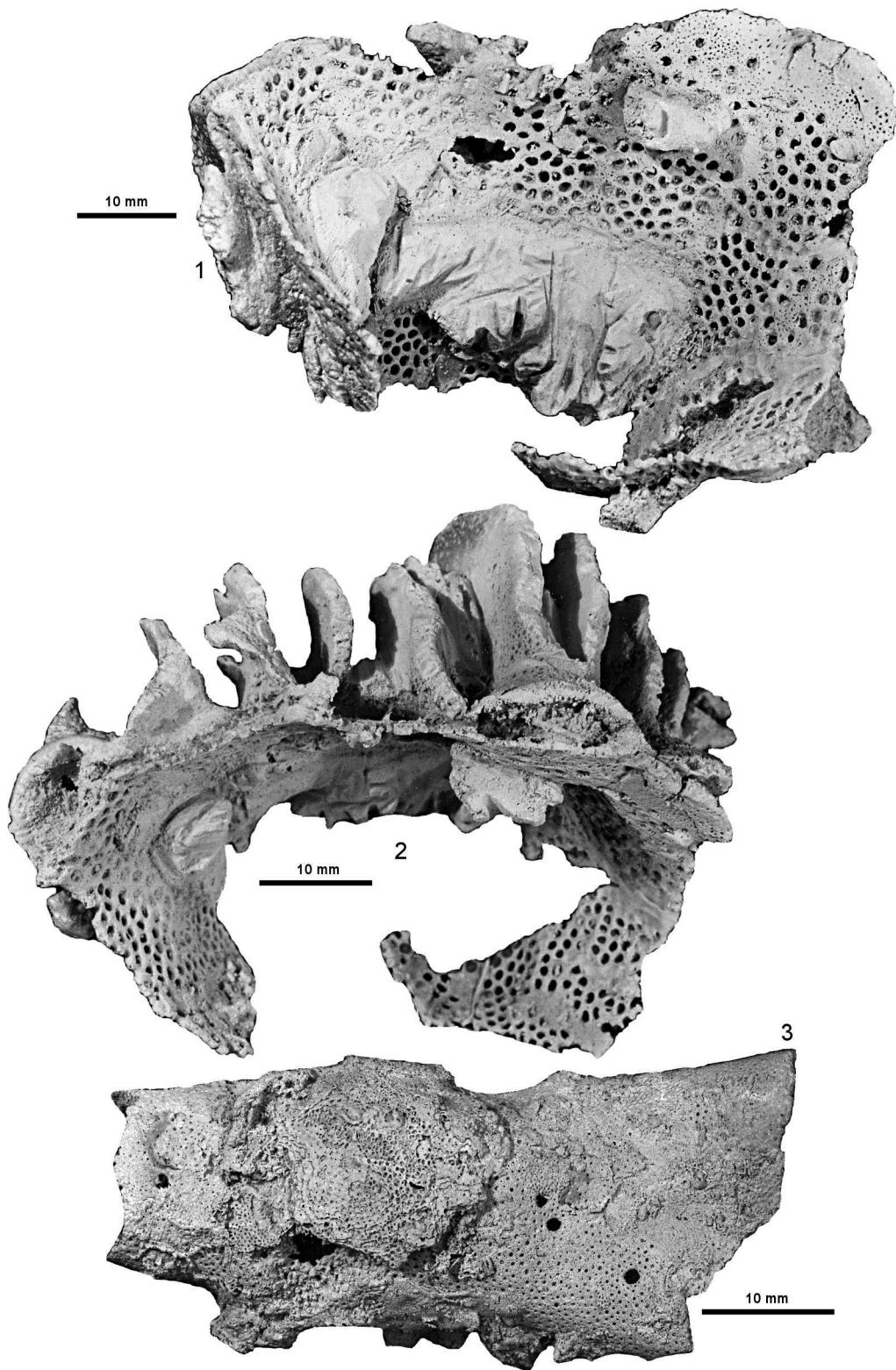


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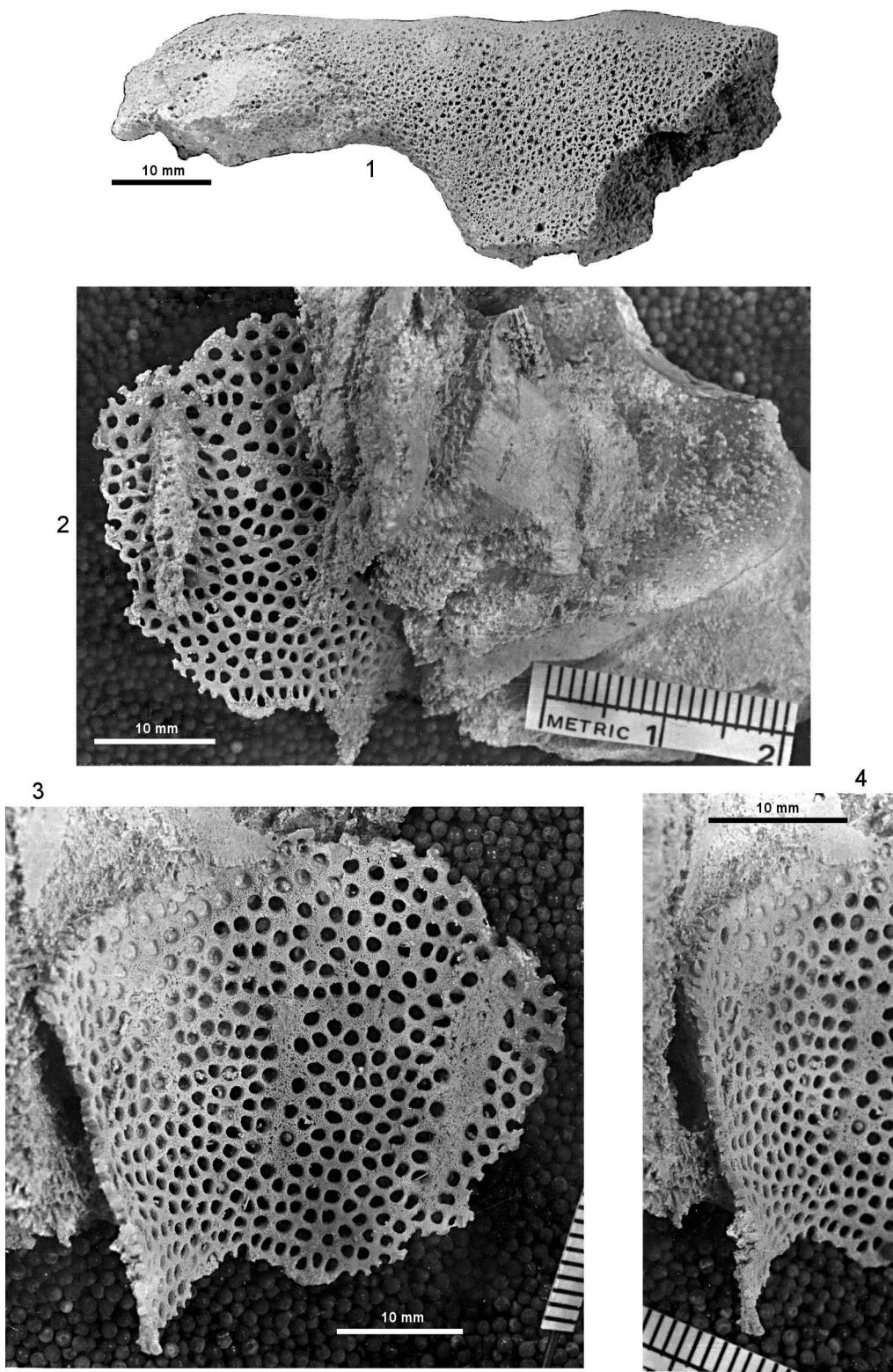


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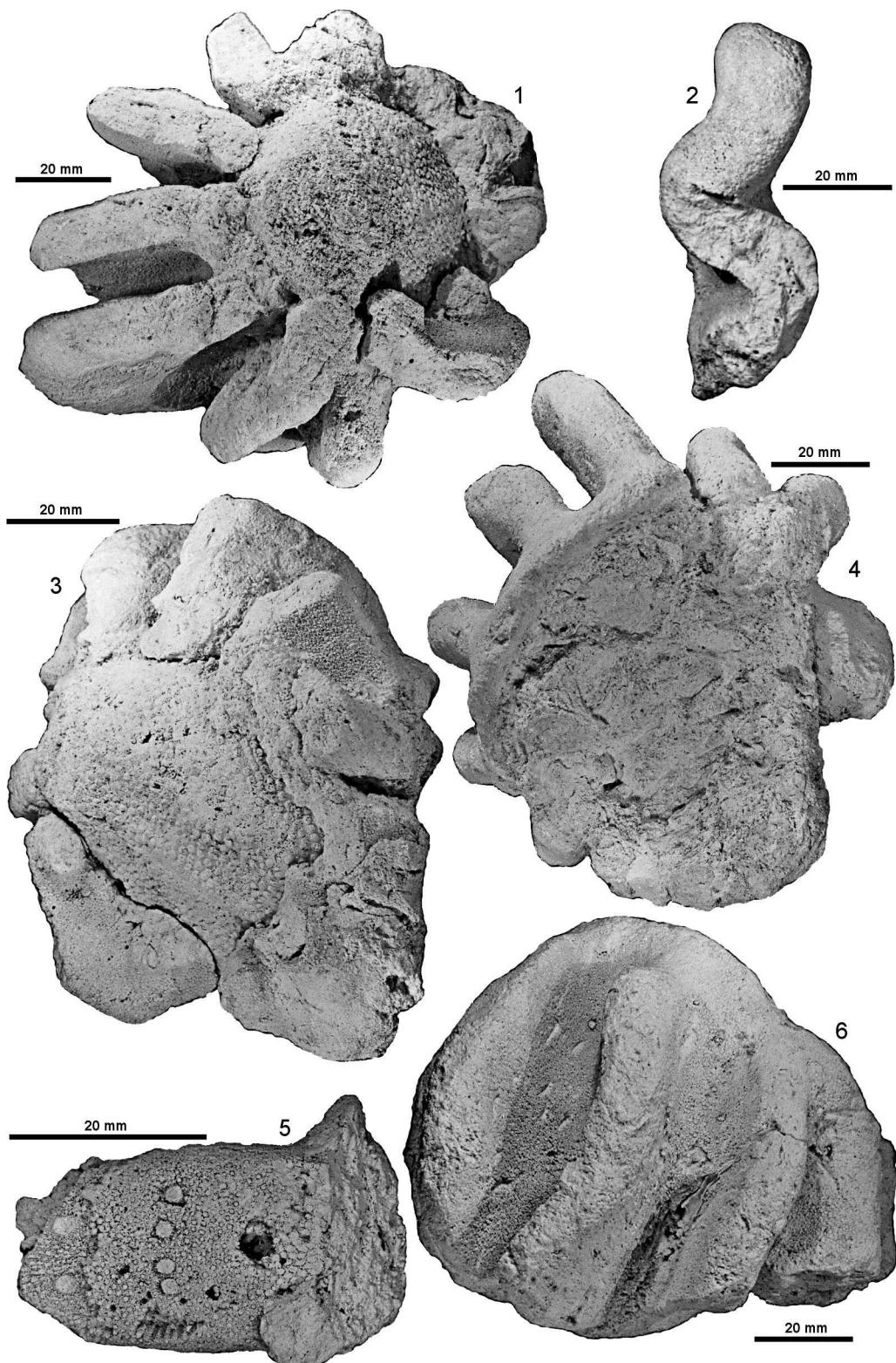


PLATE 43

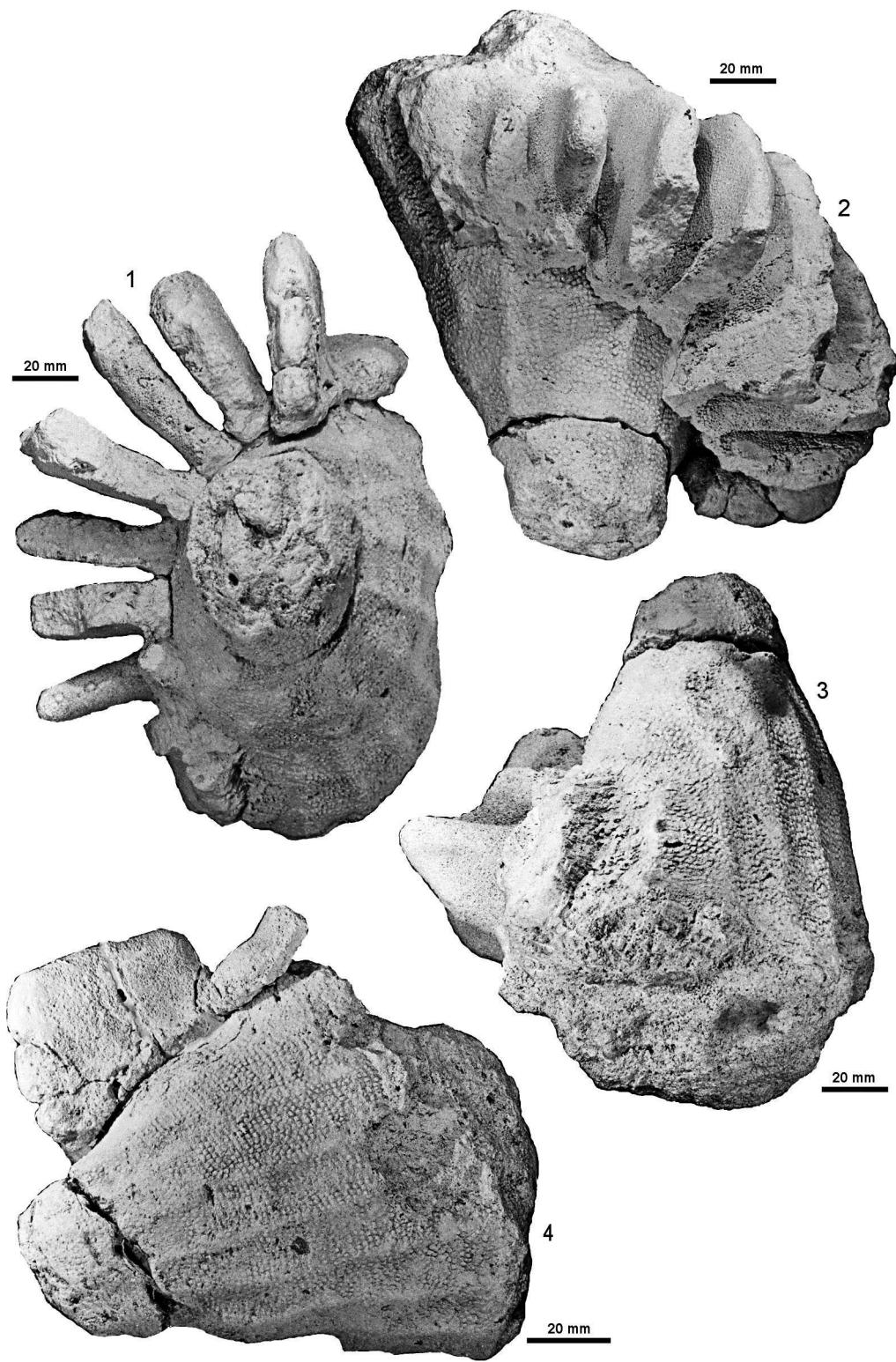


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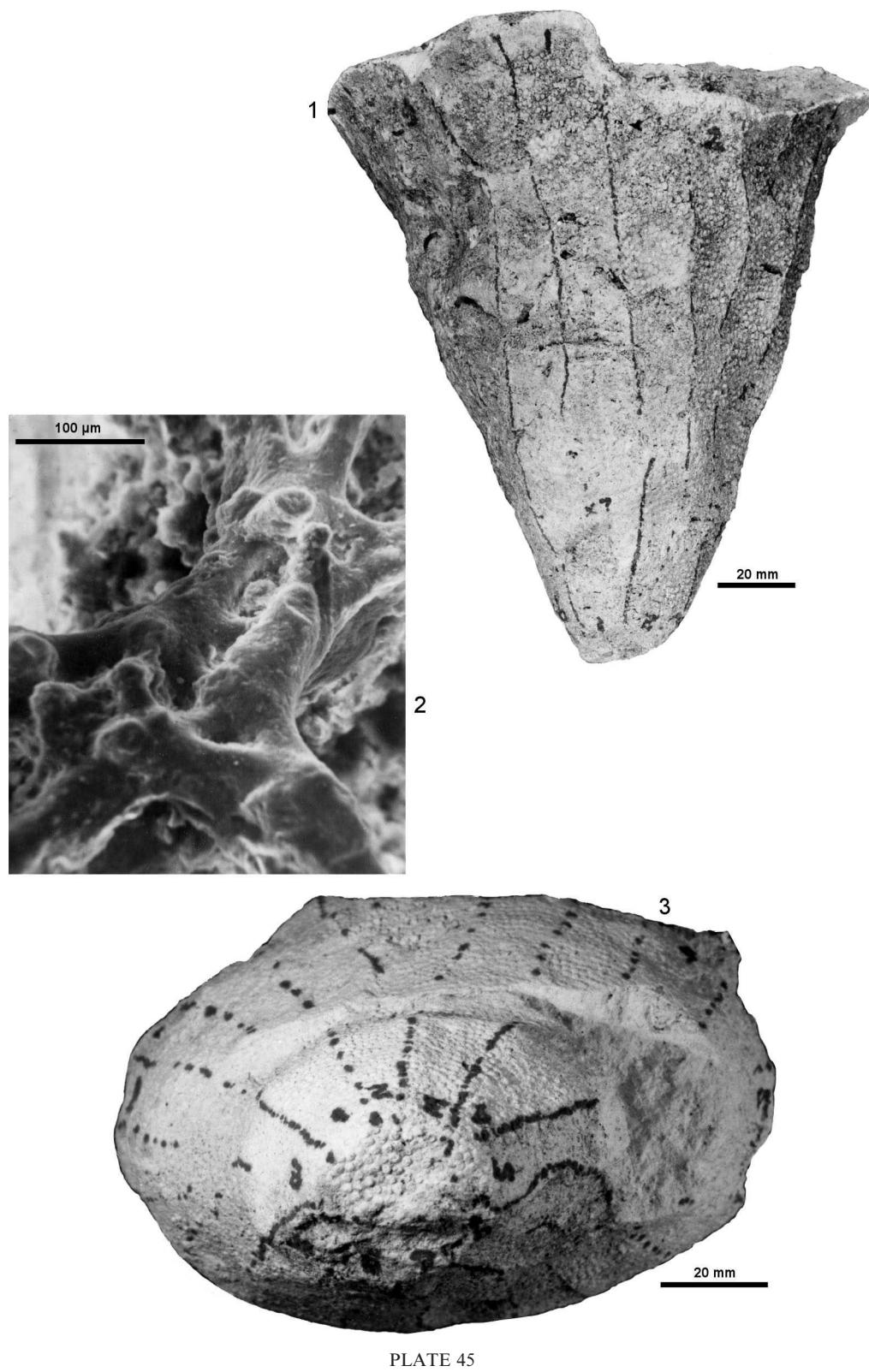


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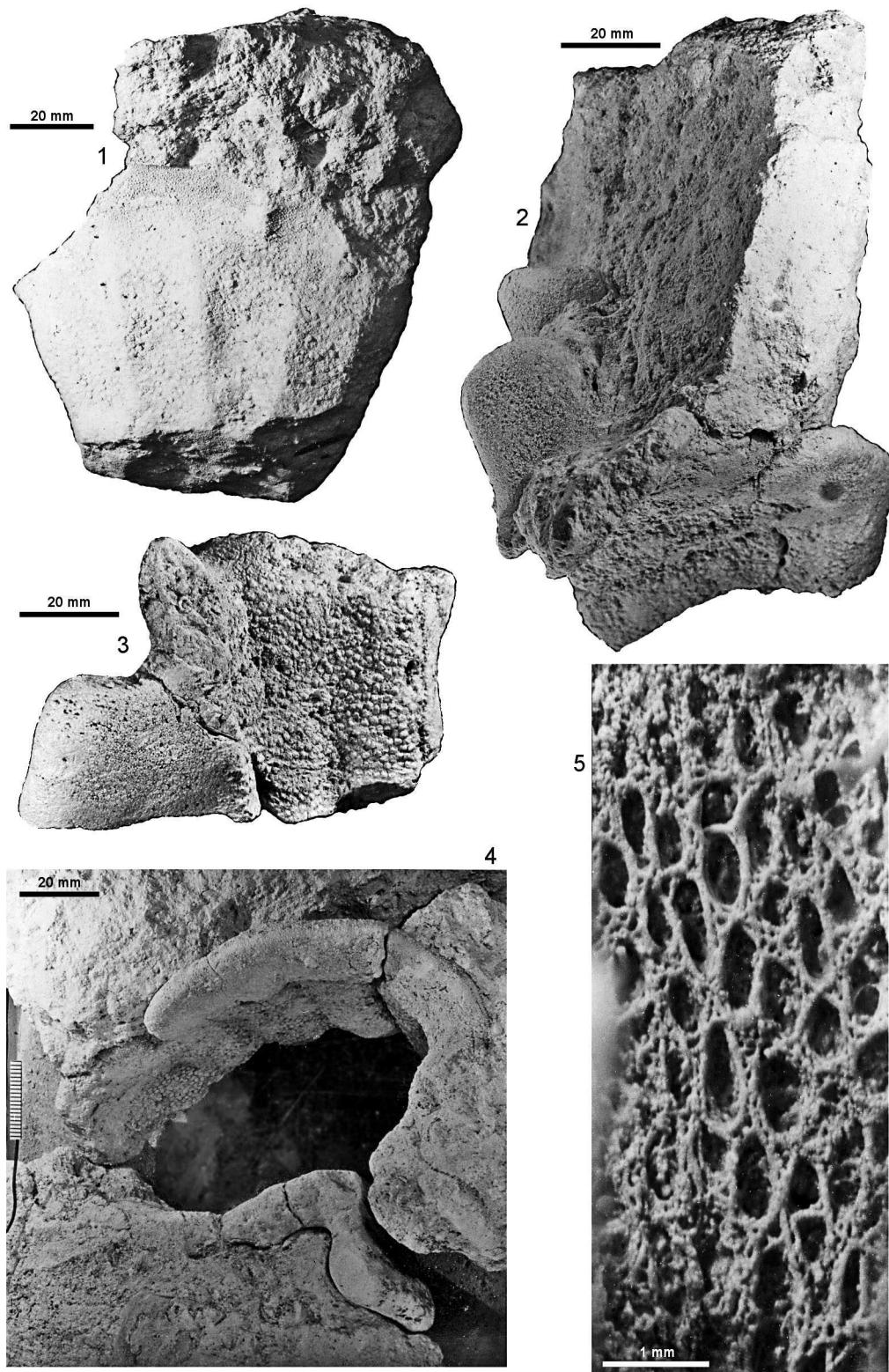


PLATE 46

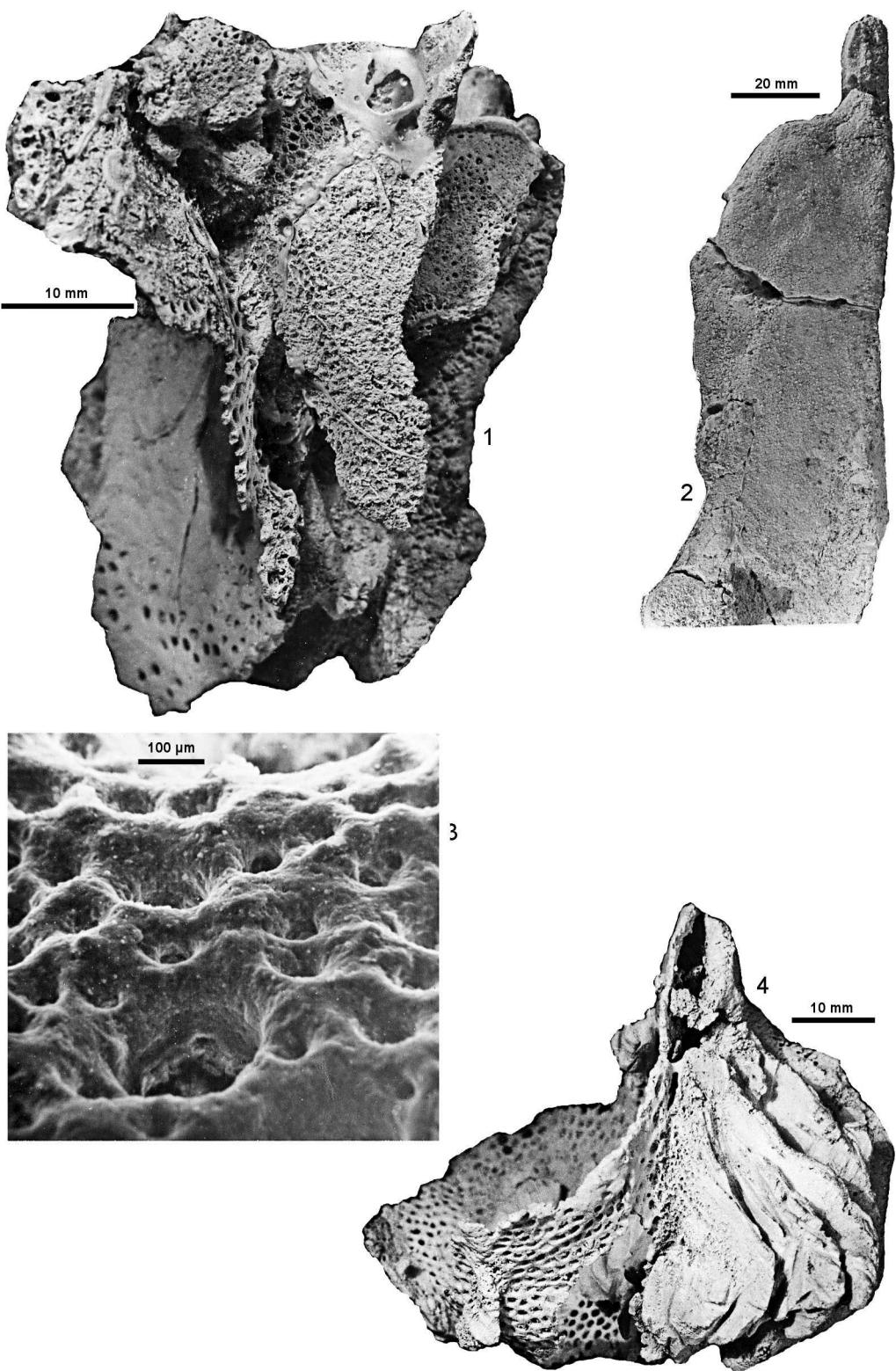
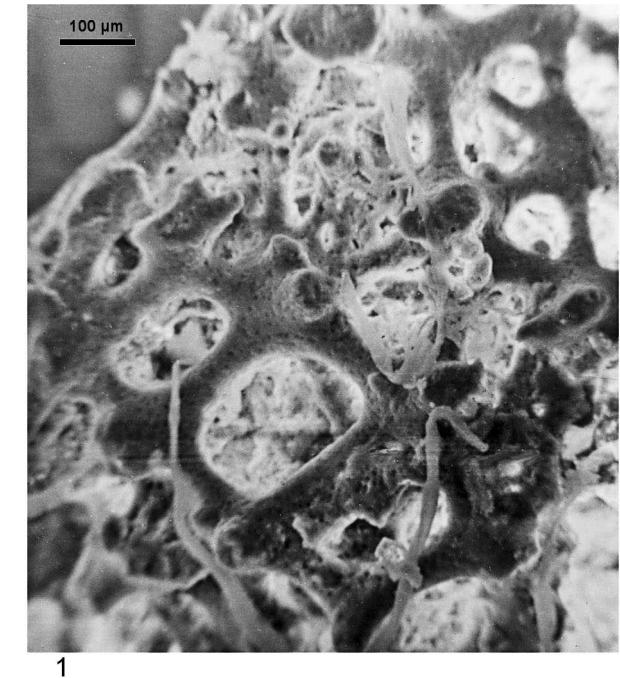
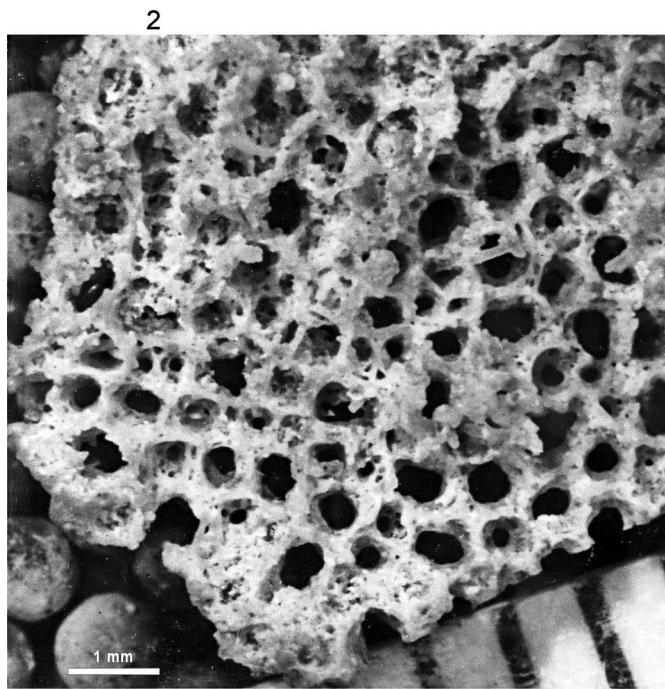


PLATE 47



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PLATE 48

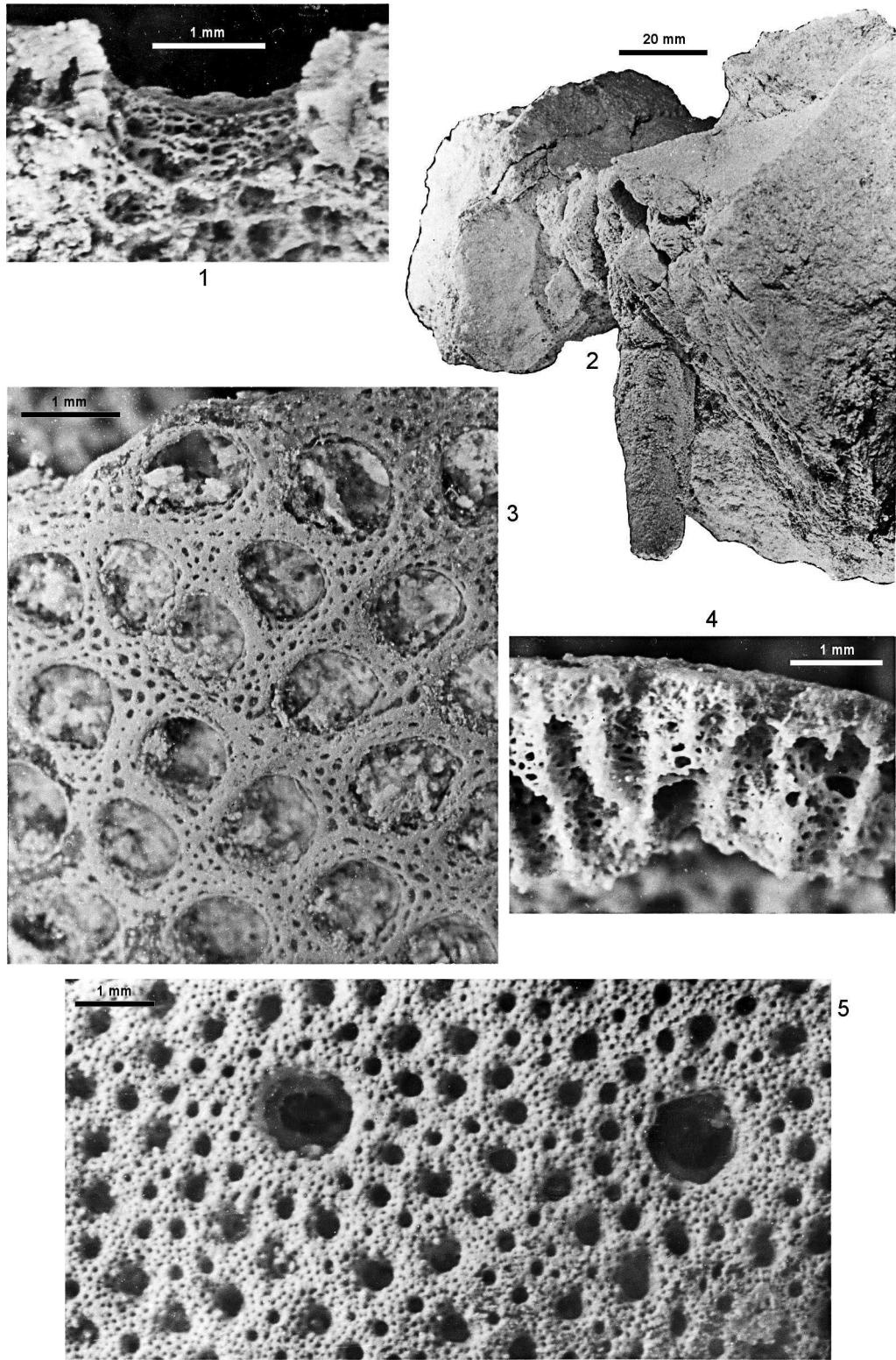


PLATE 49

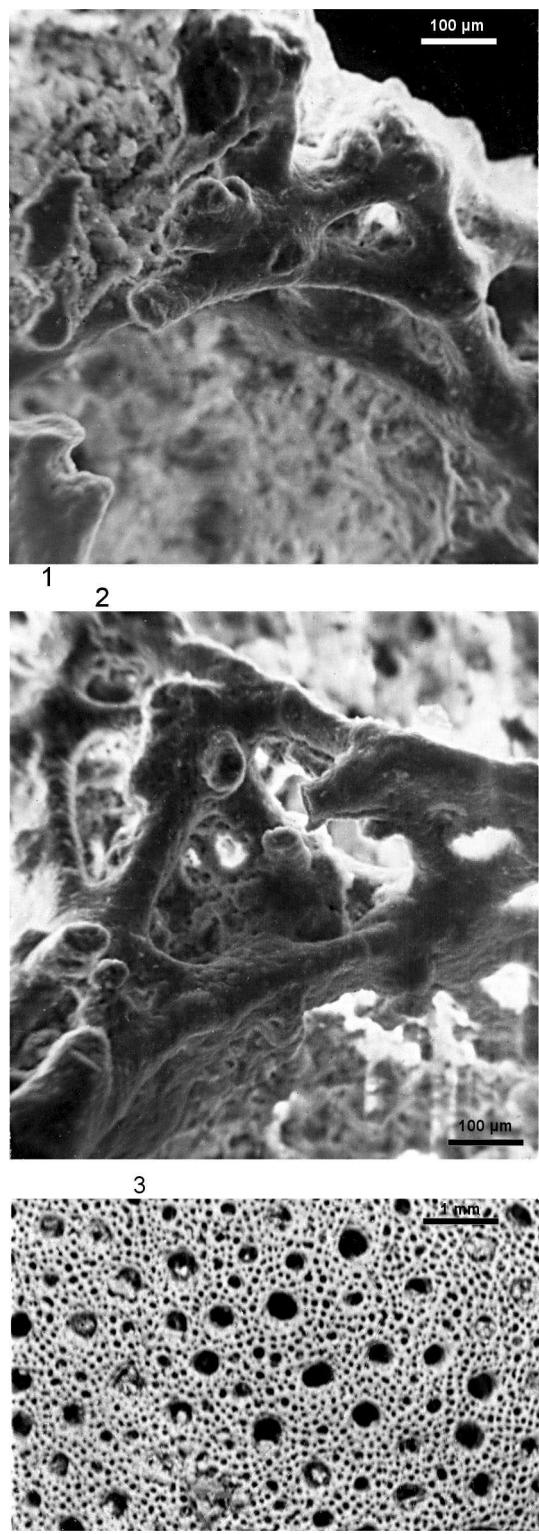


PLATE 50

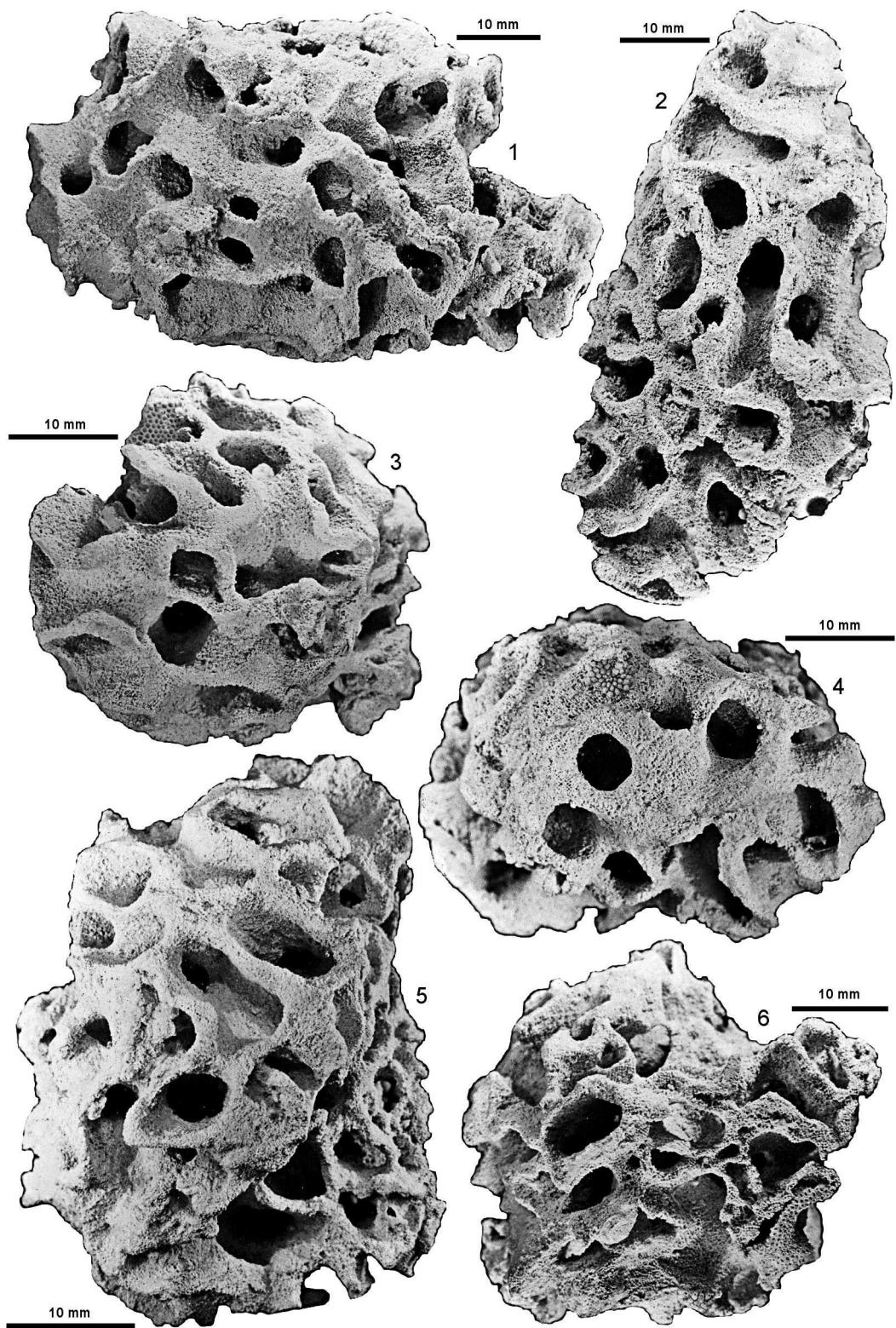


PLATE 51

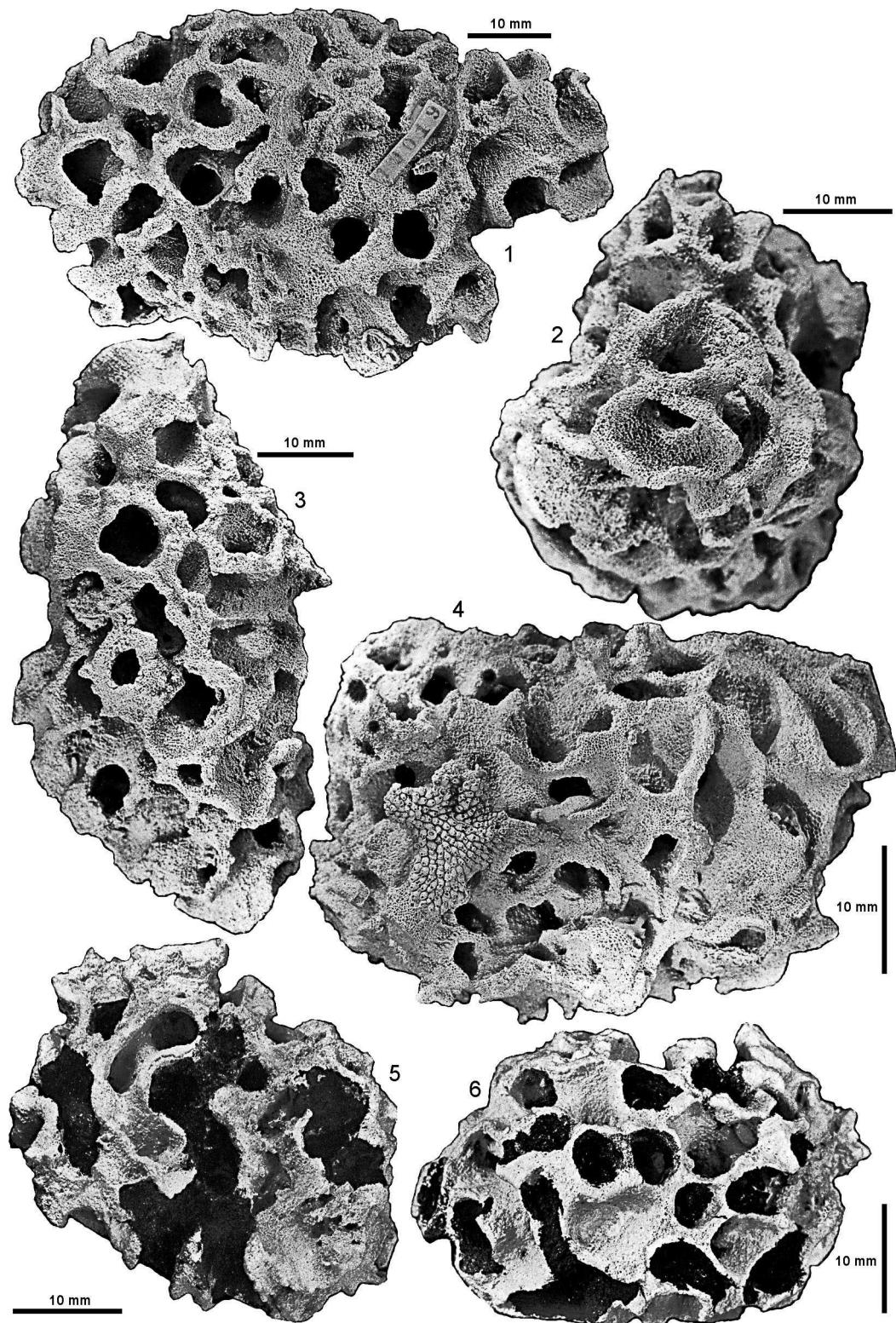


PLATE 52

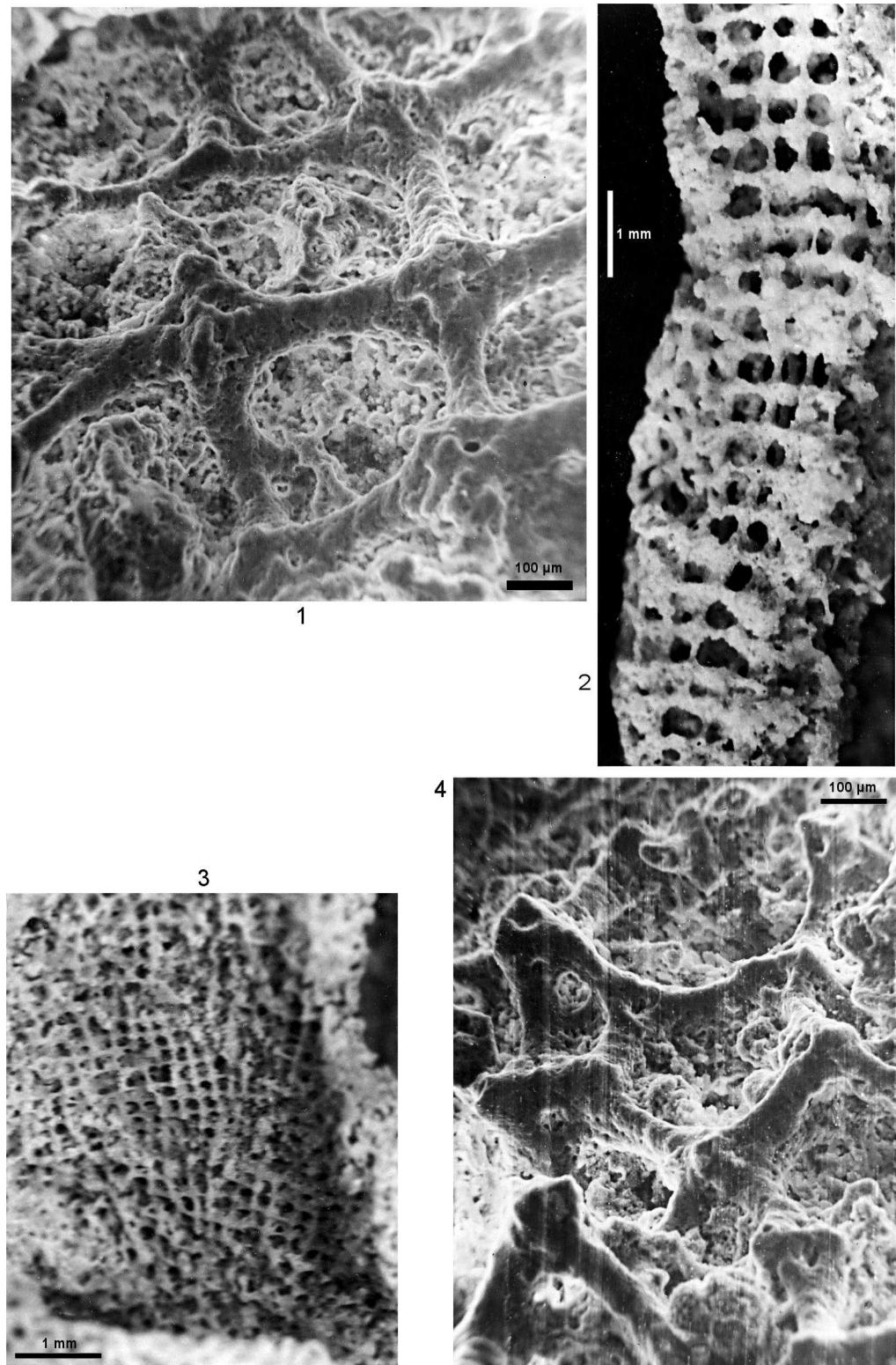


PLATE 53

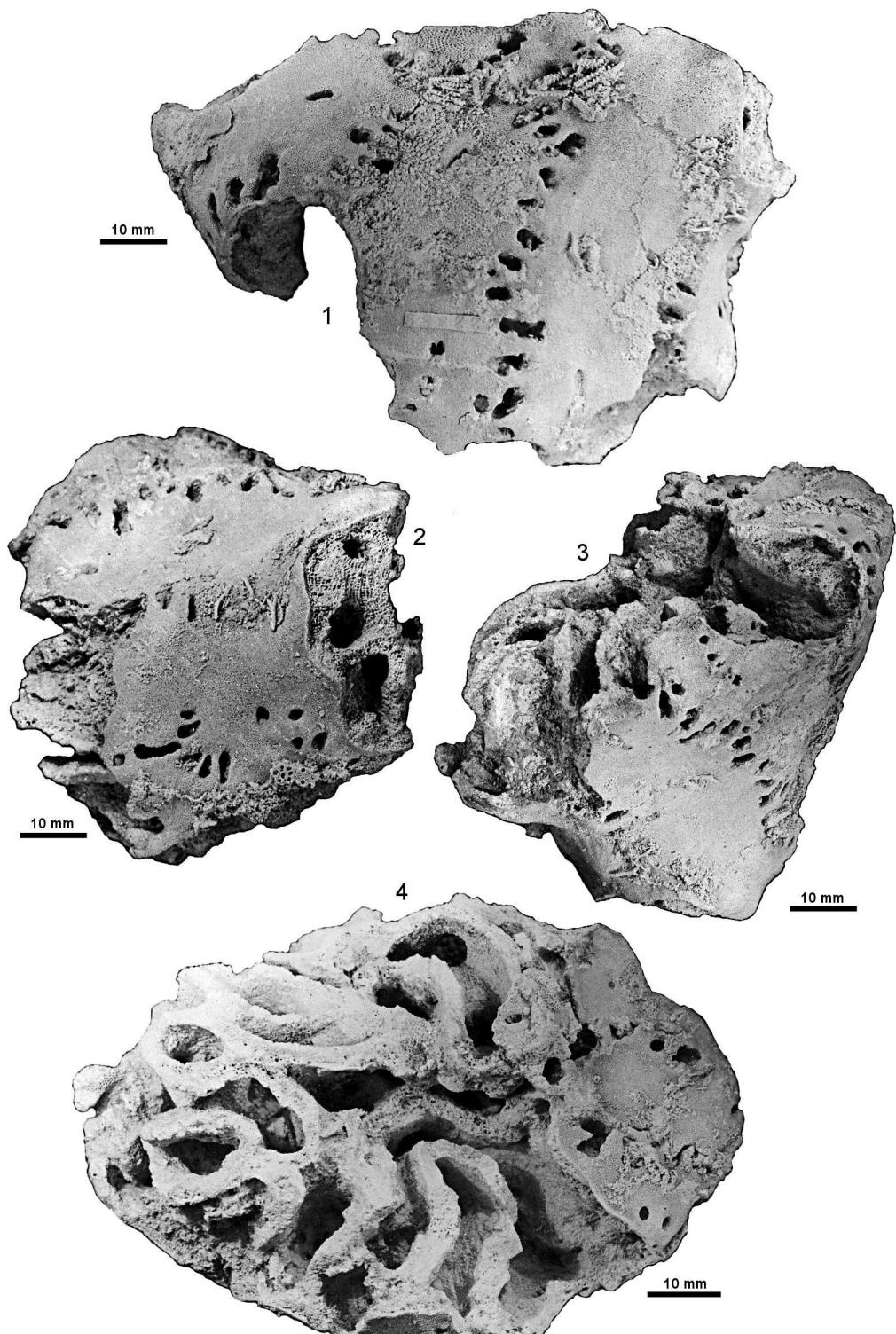


PLATE 54

Plate 55

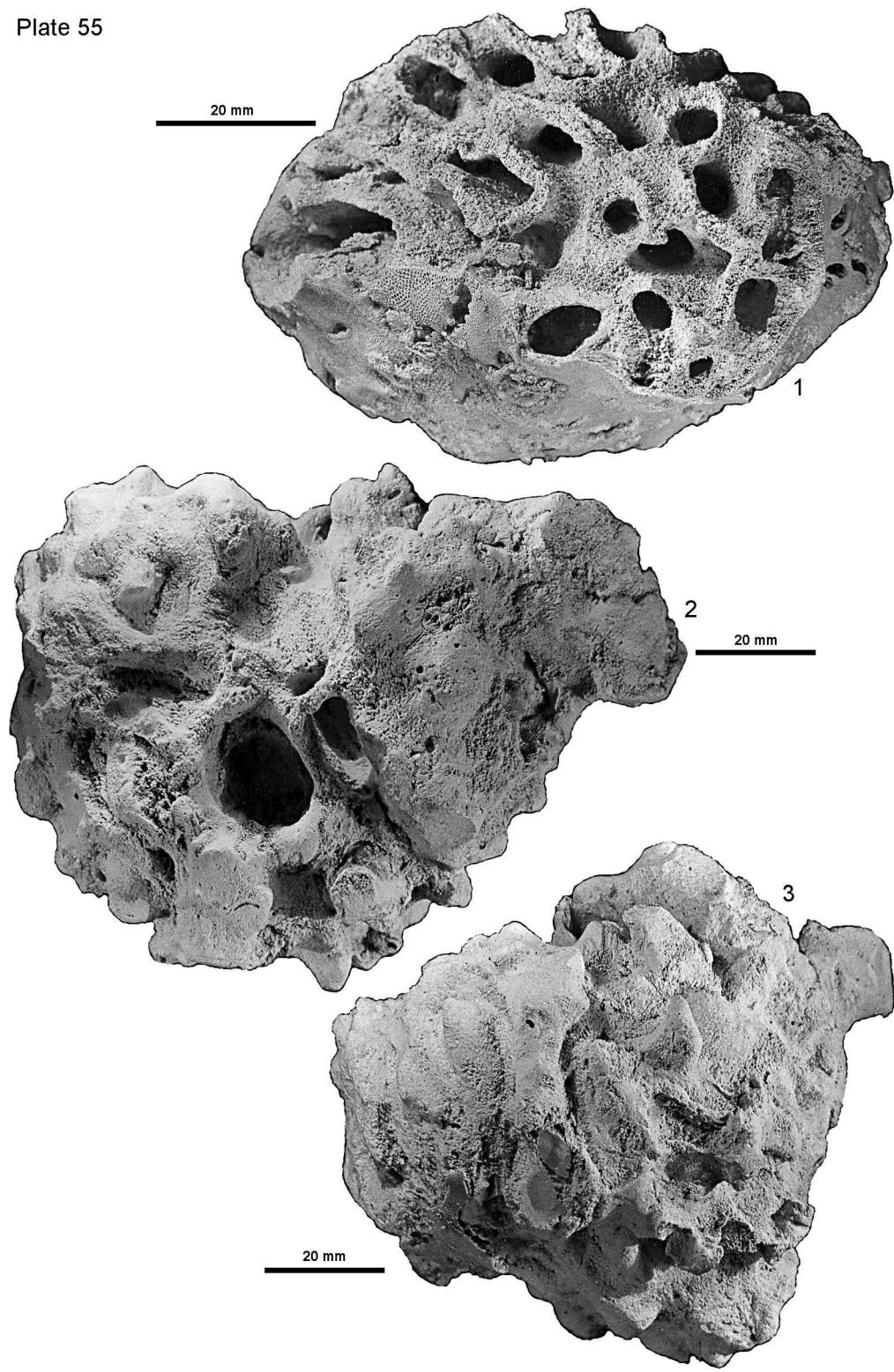


PLATE 55

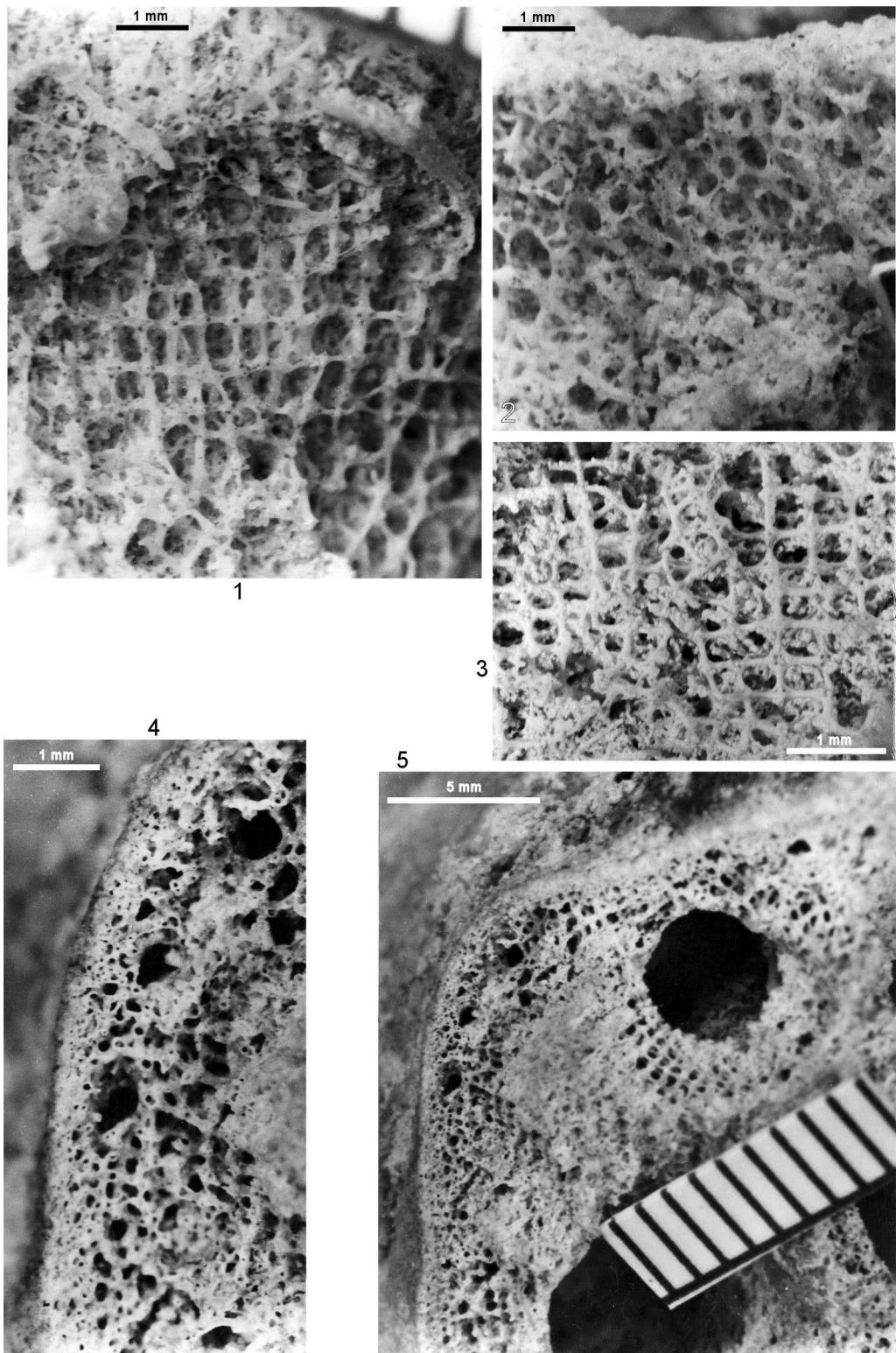


PLATE 56

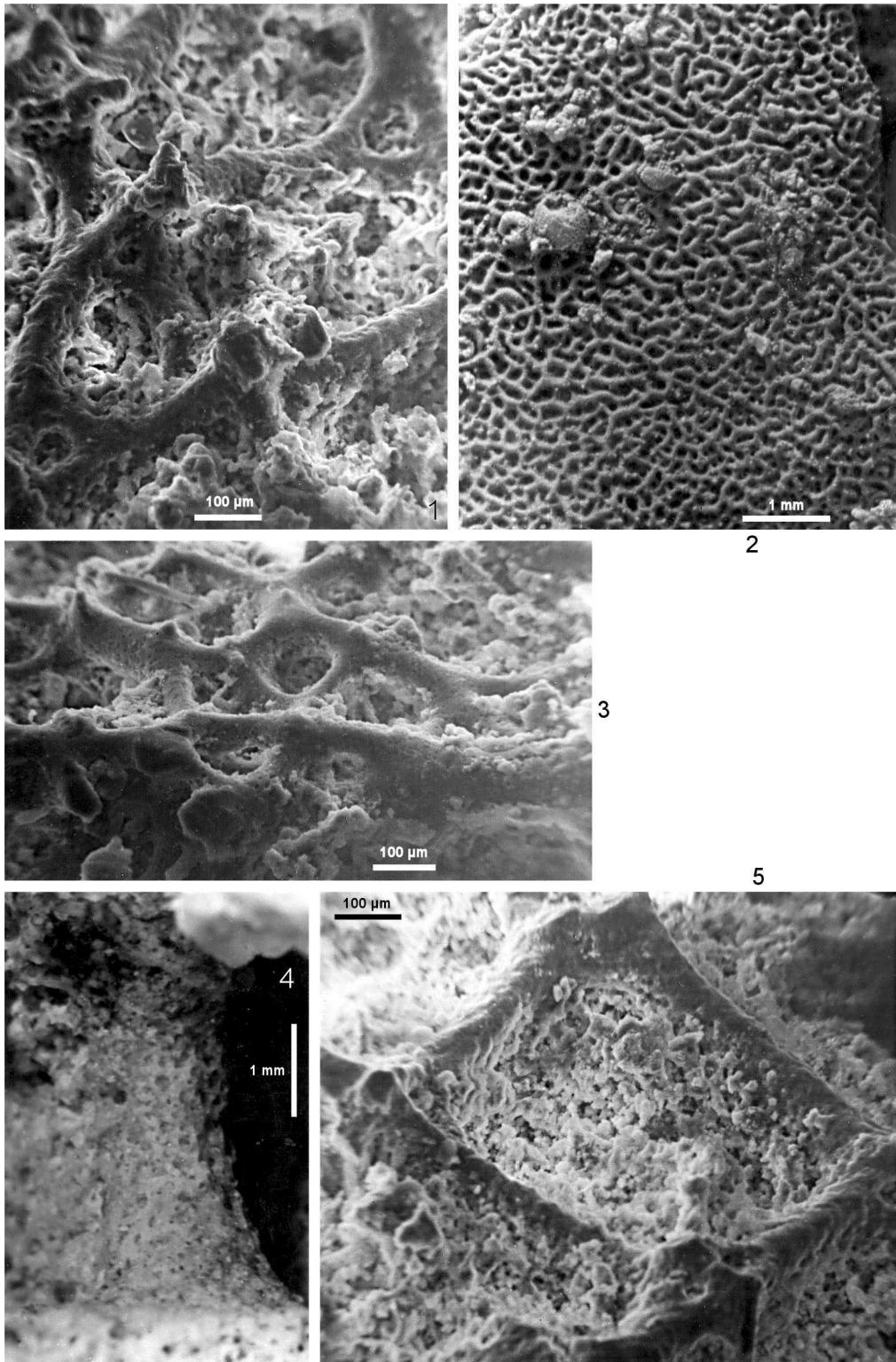


PLATE 57

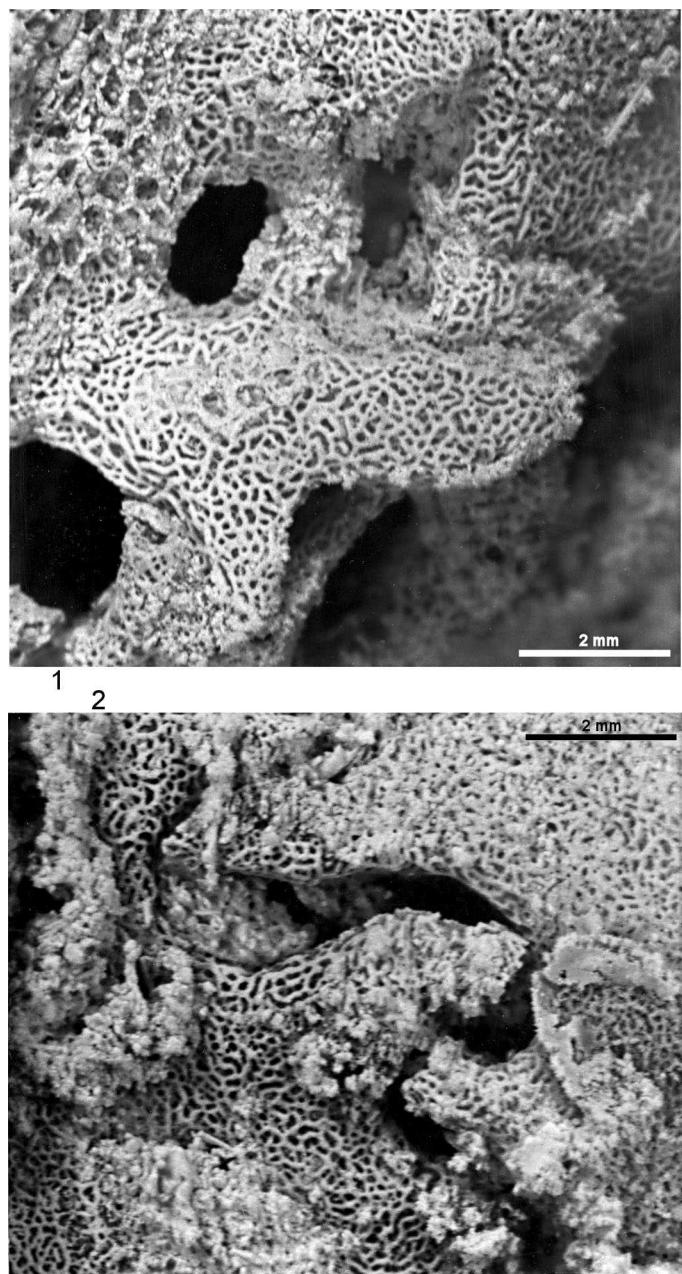
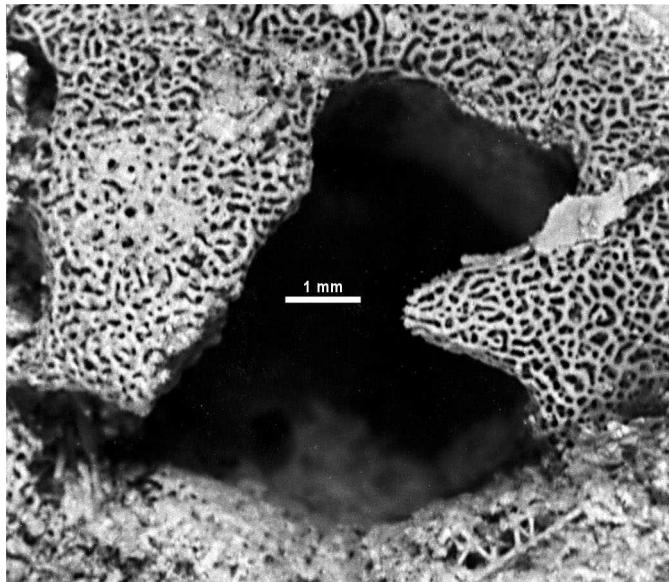
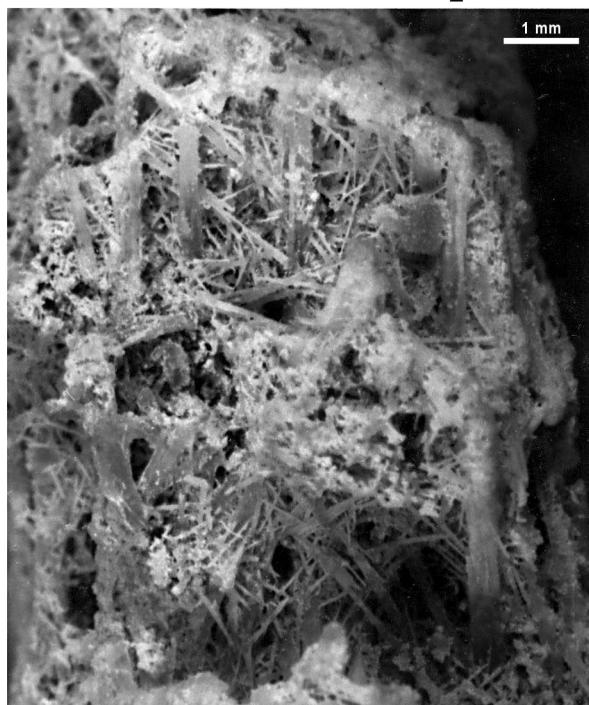


PLATE 58



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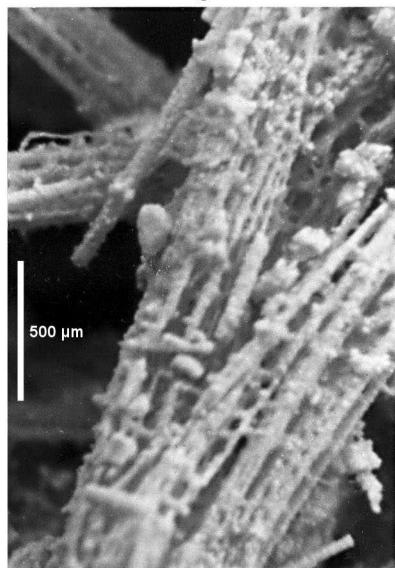


PLATE 59

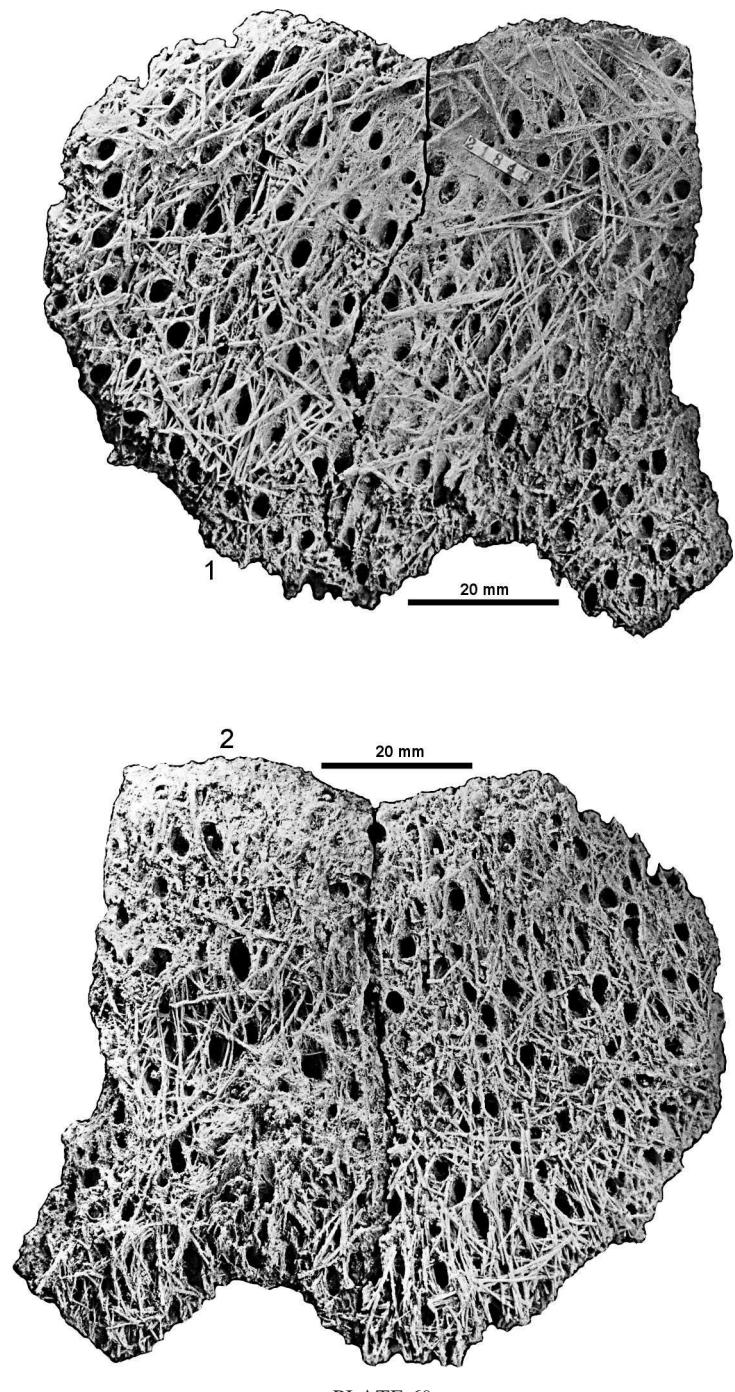


PLATE 60

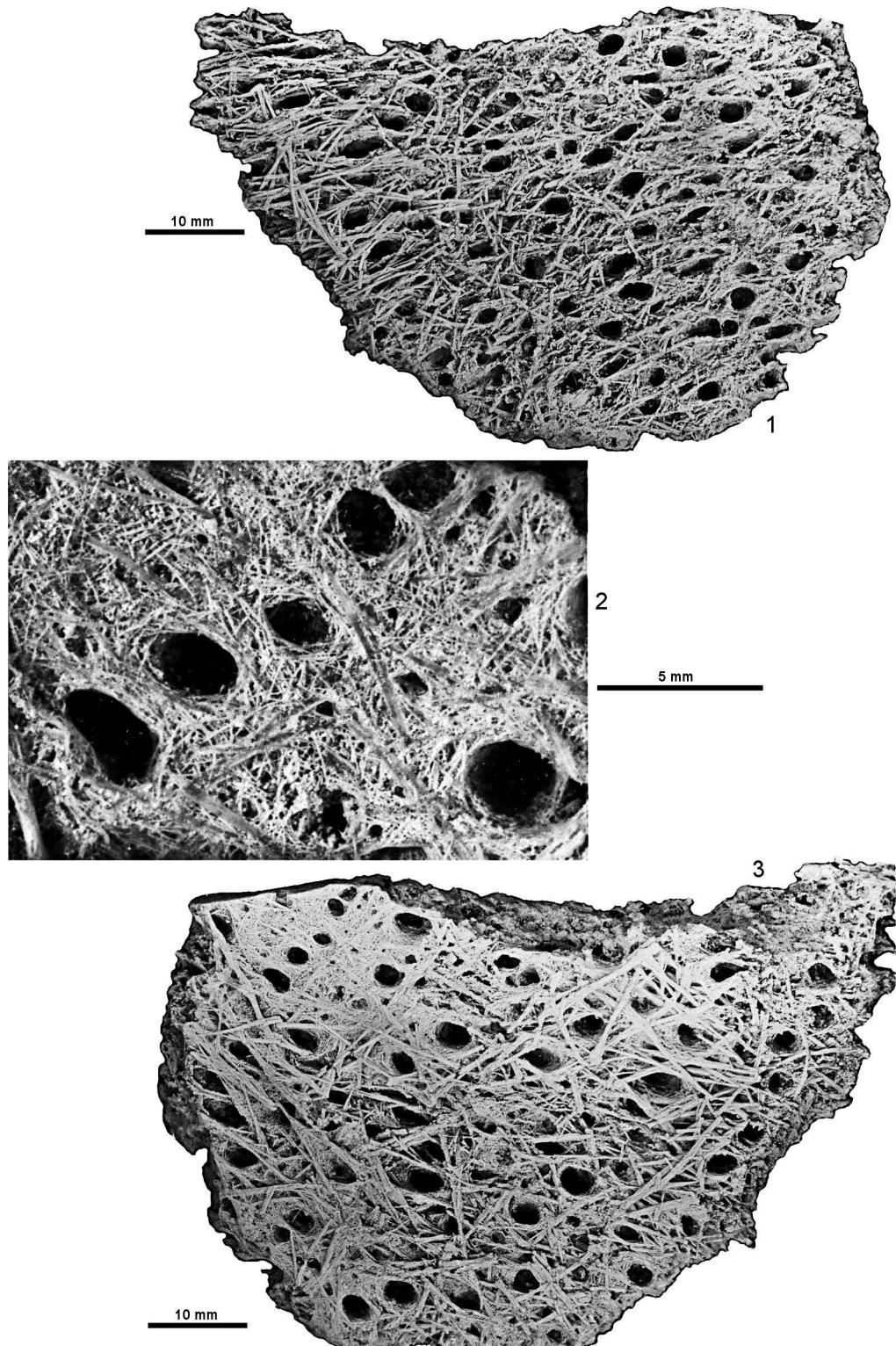


PLATE 61

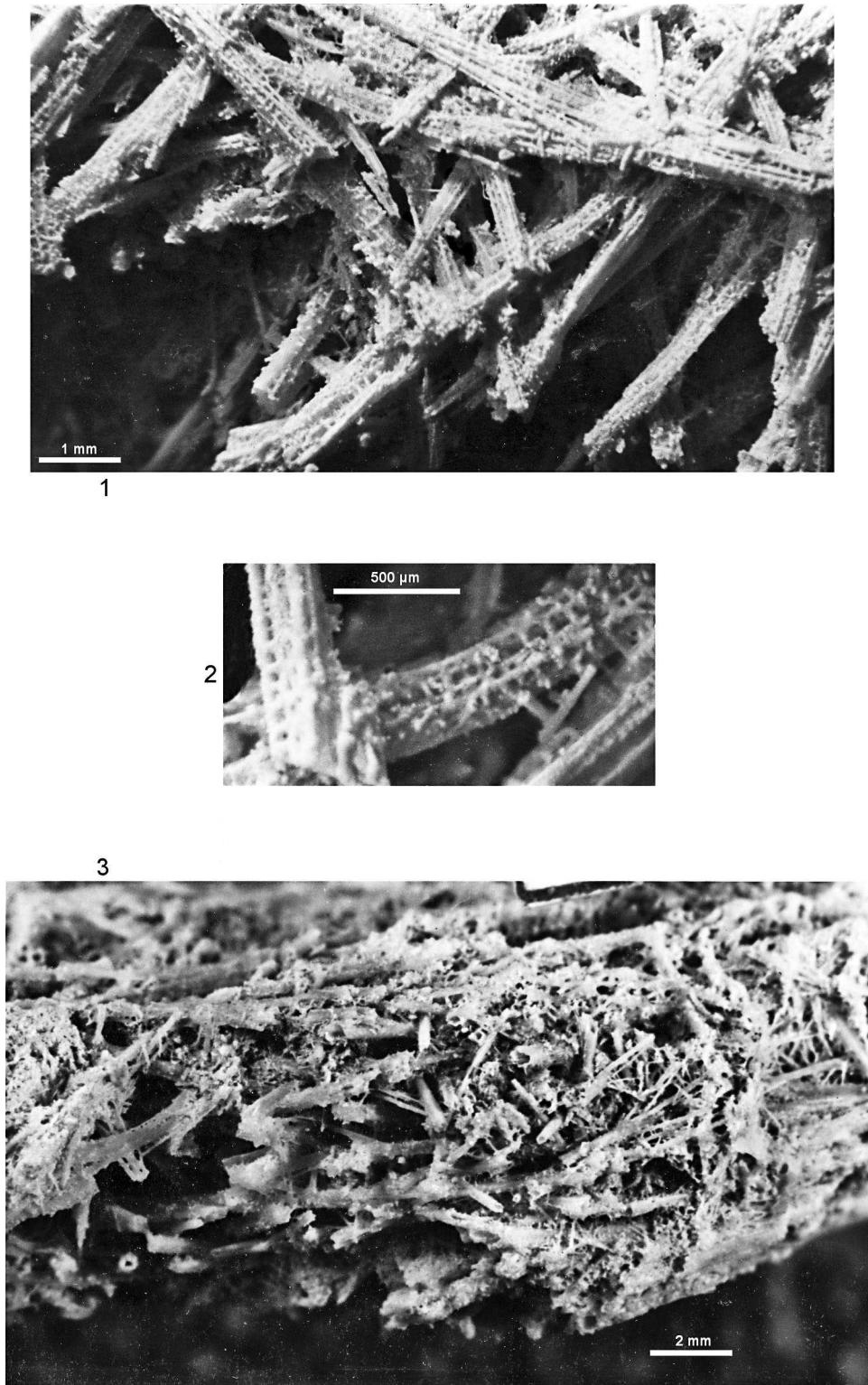


PLATE 62

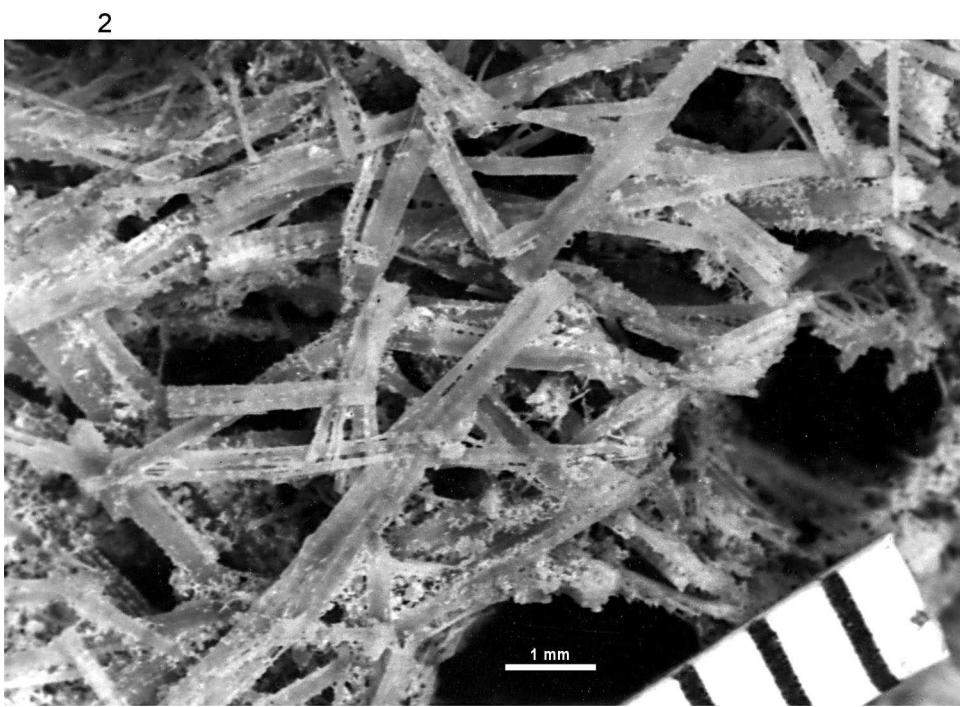
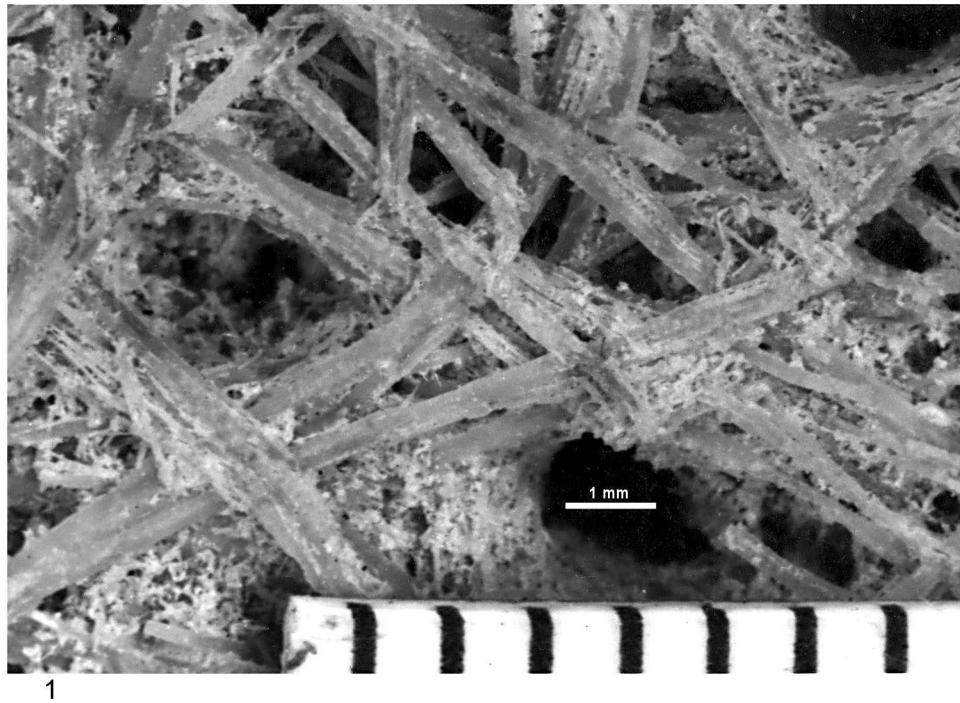


PLATE 63