

Megaspores and a Palynomorph
from the Lower Potomac Group
in Virginia

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ABSTRACT

Hueber, Francis M. Megaspores and a Palynomorph from the Lower Potomac Group in Virginia. *Smithsonian Contributions to Paleobiology*, number 49, 69 pages, 1 figure, 24 plates, 1982.—A plant microfossil assemblage comprising seven species of megaspores; *Verrutritetes carbunculus* (Dijkstra) Potonié, *Echitritetes* cf. *E. lanatus* (Dijkstra) Potonié, *Erlansonisporites erlansonii* (Miner) Potonié, *Thylakosporites retiarius* (Hughes) Potonié, *Arcellites disciformis* (Miner) Ellis and Tschudy, *Arcellites* cf. *A. pyriformis* (Dijkstra) Potter, and *Paxillitritetes* species Hall and Nicolson; two species of the microspore *Crybelosporites* Dettmann, *C. striatus* (Cookson and Dettmann) Dettmann adherent to specimens of *Arcellites disciformis*, and *Crybelosporites* species adherent to specimens of *Echitritetes* cf. *E. lanatus*; and the palynomorph *Dictyothylakos pesslerae* Horst; is recorded from the Patuxent Formation, Potomac Group, Lower Cretaceous (Barremian-Aptian) in Virginia, USA. A preliminary analysis of the enclosing matrix for microspores and pollen has related the collection site closely to lowermost Zone I of the Potomac Group as described by Hickey and Doyle (1977). The megaspore assemblage supported by acceptance of the oldest possible date derived from the microspore and pollen analysis suggests correlation with the Barremian-Aptian horizons in the English Wealden, Lower Cretaceous, and specifically with the “Arcellites Flora” of Hughes. Megafossils comprising two seed cones belonging to the Pinaceae, *Pityostrobus hueberi* Robison and Miller and *Pityostrobus virginiana* Robison and Miller have been reported from the site. A fruit or cupule of *Caytonia* has been found along with numerous seeds, fern fragments, coniferous woods, and cycadopsid cuticles. This array of megafossils is not described or illustrated herein. A backswamp area of sedimentation and type of habitat is suggested on the basis of the lithofacies and generalized composition of the flora. The writer fully agrees with Tschudy (1976) as to the importance of searching for megaspores in continental Mesozoic rocks to aid in correlating and subdividing the deposits more effectively.

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Introduction

The present study grew out of finding specimens of the megaspore species *Arcellites disciformis* (Miner) Ellis and Tschudy 1964 during a routine examination of a collection of fossil plants I made in 1973. My original interest in the collection centered on the woods and gymnosperm cones; however, the beauty of the megaspore diverted my attention and led me to research the literature for any records of its occurrence in the Cretaceous Potomac Group. The search was a very brief one. I found the summary paper for the genus by Ellis and Tschudy (1964), in which there is citation of the occurrence of the species in the Patuxent Formation based on a written communication from W. G. Chaloner. The occurrence represented stratigraphically the earliest for the genus, but no subsequent photographic documentation was published.

I had obtained only three specimens from my original preparation of the matrix. I mounted the best one for viewing by means of the scanning electron microscope. The results were excellent; however, the additional details of anatomy and morphology needed to fully substantiate the identification of the species required more specimens.

Preparation of three more samples of the matrix and careful search yielded 84 well-preserved specimens and 15 badly distorted ones. The even more significant results of those preparations was the accumulation of other species of megaspores in adequate numbers to form the basis for this expanded and hopefully more useful report.

Tschudy in 1976 and in later conversation gave added inspiration regarding the significance of this small assemblage of megaspores. In addition, an analysis of a sample of the matrix for microspore and pollen content was made by J. A. Doyle, whose findings served as the key to the stratigraphic correlations discussed later herein.

Tschudy (1976) was correct when he wrote:

I am convinced that once megaspores have been routinely searched for in continental Mesozoic rocks they, and the smaller palynomorphs accompanying them, will provide for the stratigraphic subdivision of non-marine rocks as effectively as ammonites and baculites now serve to subdivide marine rock sequences.

LOCALITY.—Stratum 2 to 2½ feet (60–76 cm) thick and undetermined areal extent, comprising lignitized logs and other plant debris enclosed in a medium gray clay, with irregularly distributed pockets of silt and medium to coarse sand grains. Exposed in 1973 during construction of new sections of the road bed of Henry Shirley Memorial Highway, Alexandria City, Virginia, on the slope between Seminary Road and Richenbacher Av-

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enue at Lat. 38°49'46" N, Long 77°07'07" W, 7.5' Alexandria Quadrangle.

The locality is given USNM Locality No. 14252.

Age is Lower Cretaceous (Barremian-Aptian), Potomac Group, Patuxent Formation, Lower Zone I of Hickey and Doyle (1977).

MATERIALS AND METHODS.—The collection comprises lumps of clay and sandy clay matrix containing lignitized woods, cones, leaf fragments and a large array of seeds. Preparation of a small sample was made, immediately after the collection was obtained, in order to evaluate the quality of the fossil material before the matrix became dry. Most of the larger plant fragments disintegrate after drying, even if the matrix is allowed to dry slowly within its protective paper wrappings. The first specimens of the spore genus *Arcellites* were observed and notes made indicating the importance of documenting photographically the presence of the spores in the Potomac Group. The collection was stored until time for additional preparations was available.

The matrix when fresh and moist was a medium gray color; however, on drying a noticeable change to dusky yellow took place. I suspect that the change was due to oxidation of finely divided pyrite that contributes significantly to the original gray color. An efflorescence of melanterite is present on most of the samples, which are now quite dry, and its presence as an oxidation by-product lends credence to the probable explanation of the color change of the matrix.

The sand and silt grains, distributed in irregular pockets throughout the clay, primarily are angular, transparent to translucent quartz. A small fraction of the silt grains are euhedral zircon, along with mineral fragments tentatively identified as ilmenite and garnet. No attempt was made to carry out a complete qualitative and quantitative analysis of the matrix.

The matrix will gradually disintegrate when soaked in water for at least one week. Unfortunately, however, the plant fossils remain coated with clay particles and sand grains. Complete maceration of the matrix with subsequent free

and clean release of the plant material was best accomplished with concentrated (48%) hydrofluoric acid.

Transparent, polystyrene, lidded containers, the type used for food storage, were used to hold the acid and matrix samples during maceration. A platform to support the matrix was constructed from plastic containers of the type used in marketing fruits such as strawberries. Polyester screen of standard 0.5 mm mesh was placed on top of the supporting platform and then the specimen of matrix. The container was filled with concentrated (48%) hydrofluoric acid in sufficient quantity to cover the matrix sample. The chemical reaction was exothermic and it was necessary to keep the containers in a cold water bath during the early part of the maceration. The macerations and first washings were done in a chemical fume hood.

After 18 to 24 hours the maceration was complete. The larger fragments of plant remains were left lying on the screen while the smaller particles settled through to the bottom of the container. The screen was slowly lifted from the container by holding opposing edges with large, long forceps. Particular care was taken to avoid disturbing the fossil plant fragments more than necessary. A one gallon polyethylene cylinder, filled with tap water and fitted with a plastic supportive platform positioned about one inch below the water surface, was close at hand. The screen and plant fragments were carefully lowered into the water and placed on the platform. After one hour the water in the container was siphoned off and discarded. The container was immediately refilled with fresh tap water. This washing was repeated four times. Sediment at the bottom of the container was not removed during the siphoning process but saved to be combined later with the sediment that had settled through the screen during maceration. Additional washing of the larger plant fragments was accomplished by inverting the supportive screen into a 0.5 mm mesh plastic sieve that was partially submerged in a constant-flow water bath set up in the laboratory sink. The plant fragments generally settled in a

single area in the sieve but by sweeping the piece of supportive screen forcefully through the water and near the specimens they were eventually well separated from one another. Washing continued for five hours. The washed material was then distributed among large (14 cm) petri plates for sorting and picking of the specimens.

The sediment in the maceration containers was treated differently from the coarse fraction. First the supernatant liquid was carefully decanted into another plastic container for subsequent disposal. The container holding the sediment was then filled with tap water, the filling being done forcefully in order to lift the sediment and disperse it. The sediment was allowed to settle completely, until the wash water was clear. The water was decanted and forcefully replaced again. This process was repeated ten times. The washed material was distributed among several small, shallow, white glass containers for sorting and picking the specimens.

Sorting was done at $\times 20$ magnification, using a binocular dissecting microscope. Picking was facilitated by using a dropper pipette or a small scoop-shaped piece of 0.25 mm mesh copper screen. Significant large fragments of plant material were sorted into storage vials filled with distilled water and the megaspores were placed in small petri plates. No further chemical treatment was given to the sorted materials except to include granules of thymol in order to prevent growth of bacteria and fungi. This measure is important because the fossil remains are attacked by bacteria within 24 hours and only a short while later by aquatic fungi.

It should be noted that at least 40% of the *Arcellites* were found floating along the margin of the meniscus in the sieve frame or plastic wash containers. The spores were held in place by surface tension and capillary action of the water. Several specimens of *Thylakosporites* were also found under the same circumstances, including the tetrahedral tetrads of the species as described herein. I recommend that future workers pay particular attention to this peculiarity, otherwise

many megaspores will be lost during the washing and decanting processes.

After isolation, the megaspores were transferred to distilled water and then further cleaned by being transferred rapidly from the distilled water to 100% ethyl alcohol and back to distilled water. The micro-convection currents caused by the immersion of the spore in the water after immersion in the alcohol swept away all of the minute debris that still may have clung to the spore body. This process was repeated four times, ending with transfer of the spore into the alcohol bath. The transfers were facilitated by supporting the spore or several spores at a time on a scoop-shaped, 0.25 mm mesh, copper screen. This technique also works extremely well for cleaning larger plant fragments. The spores were individually removed from the alcohol bath, air dried and gently dropped into a depression slide for storage. They were generically and specifically sorted at that time.

Manipulation of the spores for mounting on cover slips was facilitated by using a single eyelash attached with acetate glue to a round toothpick. The tip of the hair is extremely finely pointed and when moistened with distilled water can be used to pick, move, and position spores at will. Circular coverslips were coated on one surface with a thin film of white glue (Elmer's brand) that was allowed to dry. The individual spore was picked up with the moistened hair. The moisture absorbed by the spore from the hair in turn served to moisten the surface of the glue when the spore was touched to it. Drying was rapid and the spore remained firmly attached. By this means spores and spore fragments can be oriented for scanning electron microscopy as illustrated in the specimens of *Arcellites*.

Dissections of *Arcellites* illustrated herein were accomplished by sharpening the point of an insect pin into the form of a microknife blade. The spore was moistened slightly with distilled water and then cut open in order to reveal the Y-mark. The dissected specimens were air dried and mounted in the same manner as the whole spores.

The coverslips with the spores were mounted

on aluminum stubs. The spores were sputter coated first with carbon and then with gold-palladium. They were viewed and photographed using Cambridge Mark—IIA, Cambridge S4-10, and Coates and Welter 106B scanning electron microscopes.

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Systematics

The descriptions of the seven megaspores and two microspore species presented herein are arranged according to the morphologic system of classification proposed by Potonié (1956). The single specimen of *Dictyothyllakos pesslerae* Horst, 1954 is treated as a species of uncertain affinities because its position within Potonié's orderly arrangement remains obscure.

- Anteturma Sporites Potonié, H., 1893
 Turma Triletes (Reinsch, 1881) Dettmann, 1963
 Subturma Azonotriletes Lubert, 1935
 Infraturma Apiculati (Bennie and Kidston, 1886)
 Potonié, 1956
 Genus *Verrutrilletes* Potonié, 1956

- Verrutrilletes carbunculus* (Dijkstra, 1949)
 Genus *Echitrilletes* Potonié, 1956
Echitrilletes cf. *E. lanatus* (Dijkstra, 1951)
 Infraturma Muronati Potonié and Kremp, 1954
 Genus *Erlansonisporites* Potonié, 1956
Erlansonisporites erlansonii (Miner, 1932)
 Infraturma Perinotriletes Erdtman, 1947
 Genus *Thylakosporites* Potonié, 1956
Thylakosporites retarius (Hughes, 1955)
 Genus *Crybelosporites* Dettmann, 1963
Crybelosporites striatus (Cookson and Dettmann, 1958)
Crybelosporites species
 Subturma Pyrobolospores Potonié, 1956
 Genus *Arcellites* Miner, 1935
Arcellites disciformis (Miner, 1935)
Arcellites cf. *A. pyriformis* (Dijkstra, 1951)
 Turma Barbates Mädlar, 1954
 Genus *Paxillitriletes* Hall and Nicolson, 1973
Paxillitriletes species
 Uncertain Affinities
 Genus *Dictyothyllakos* Horst, 1954
Dictyothyllakos pesslerae Horst, 1954

Verrutrilletes Potonié, 1956

Verrutrilletes carbunculus (Dijkstra) Potonié

PLATES 1-3

- Triletes carbunculus* Dijkstra, 1949:10, pl. I: fig. 12.
Triletes cf. *carbunculus* Dijkstra, 1951:10, pl. 2: fig. 11.
Verrutrilletes carbunculus (Dijkstra).—Potonié, 1956:28, pl. 3: fig. 26.

DESCRIPTION (from Dijkstra, 1949:22).—

Shape spherical. Diameter 600–1000 μ (the mean being 820 μ , 4 spores measured). Tri-radiate ridge conspicuous, 50 μ broad, 40 μ high, its length being ca. 0.6 of the radius of the spore. Arcuate ridges lacking or scarcely visible. Spore wall, inclusive of the tri-radiate ridges and with exception of the contact faces, covered with hemispherical, red translucent 5–30 μ broad objects. Some specimens have but a few of such objects, which lie single or are joined to small groups; on other specimens they have been united to great complexes. Spore wall 30–36 μ thick, dark brown.

The description given by Dijkstra in 1951 for another specimen, but from the English Wealden, varies little from the original one as presented above.

Potonié's description (1956:28), when he established the new combination, translates as follows:

The type, ca. 940 μ , has been shown to me. Equator more or less round to slight triangular. The "carbuncles" adhere irregularly distributed on the dull exine like solidified, globular, glassy, translucent, red, liquid droplets. They look like outflowed resin, which becomes more conspicuous by the fact that they occur in groups, leave asymmetrical spaces and are of very variable sizes. The form may be only provisionally placed in the series here. Similar ones in Hughes' collection.

REMARKS.—The two complete, although distorted, specimens and the fragment illustrated herein conform to the descriptions given by Dijkstra and Potonié with exceptions of the breadth and height of the tri-radiate ridge and the thickness of the spore coat. The tri-radiate ridge, as clearly evident in Plate 1 (figures 1, 2, and 4), is 28 μ m broad and \approx 21 μ m high, just over one-half the dimensions given for the type specimen. The thickness of the spore coats illustrated in vertical section in Plate 2 (figures 1 and 3) and Plate 3 (figure 2) is 15 μ m and 32 μ m respectively. These exceptions cannot be attributed totally to shrinkage of the spores during dehydration by reason that the dimensions of the spore bodies are well within the range of size given in the description of the type. The dimensions of the tri-radiate ridge, I feel, do not have so much significance as to be critical in species determination. The thinness of the spore coat of the fragment shown in Plate 1 (figure 6), which serves as the source for the photographs in Plate 2 (figures 1–3), is probably attributable to corrosion and degradation of the wall following fragmentation of the spore. Its more porous structure is in obvious contrast to the dense structure of the spore coats of the complete but distorted spores shown in Plate 1 (figures 1–5) and Plate 3 (figures 1 and 2).

The specific epithet, *carbunculus*, is exceptionally appropriate. Viewed through a binocular microscope at magnifications of 40 to 60 diameters, the spores seem encrusted over most of their surfaces with minute, lustrous, ruby cabochons. The ornamentations, best defined morphologically as gemmae (Plate 1: figure 3), are not present on the contact areas (Plate 1: figures 1 and 2; Plate 2: figure 4; Plate 3: figure 1). They are greatly reduced in size and number or are altogether

absent on the distal surface of the spore body (Plate 2: figure 5). Potonié's allusion to them as resin that had flowed out onto the spore surface is appropriate. The gemmae appear to have been exuded from within the spore as a resinous substance, retaining its glossy surface and viscous appearance after solidifying (Plate 1: figures 3 and particularly 5; Plate 2: figures 1 and 2). Structurally there is a smooth, thin film covering a foam-like inner layer (Plate 3: figures 2 and 4), the whole of which is subtended by a papilla of the outer exoexine (Plate 2: figure 2, papilla at arrow; Plate 3: figure 2). Viewed from the interior of the spore, in this instance the partially degraded spore wall fragment (Plate 2: figure 3), a depression marks the position of a gemma on the outer surface. This characteristic cannot be seen when the endexine is intact (Plate 2: figure 6). Circular holes in the thin film covering the foam-like inner layer of the gemmae is a common feature seen on the spores that have been partially eroded (Plate 2: figure 7).

OCCURRENCES.—Boring Sm. Maurits No. 554, South Limburg, Netherlands; Upper Cretaceous (Aachenian (Senonian)); Dijkstra, 1949.

Epen and Vaals, South Limburg, Netherlands; Upper Cretaceous (Aachenian (Senonian)); Dijkstra, 1949.

Bore, D'Arcy Expl. Co. Kingsclere No. 1, 466: Weald, southern England; Lower Cretaceous (Barremian-Aptian); Dijkstra, 1951.

This report, USNM Locality No. 14252, Patuxent Formation, Potomac Group; Lower Cretaceous (Barremian-Aptian).

SPECIMENS.—GG-7A, USNM 304311; GG-7B, USNM 304312; GG-7C, USNM 304313.

Echitriletes Potonié, 1956

Echitriletes cf. *E. lanatus* (Dijkstra) Potonié

PLATES 4, 5

Triletes lanatus Dijkstra, 1951:11, pl. 2: fig. 22.

Echitriletes lanatus (Dijkstra).—Potonié 1956:36, pl. 4: fig. 36.

DESCRIPTION (from Dijkstra, 1951:11).—

Spore hemispherical, top area flattened. Diameter 600–800 μ (the mean being 700 μ , 4 specimens measured). Tri-radiate ridges nearly as long as the spore radius, 20–30 μ broad, 50–100 μ high. Arcuate ridge not clearly distinguishable. Spore coat covered with 10 μ large papillae bearing hair-like wooly appendages, 150 μ long, 3–5 μ thick. Spore coat brown, 25 μ thick.

Potonić (1956:36) described the species as follows:

Genotype around 780 μ (from the illustration); trilete, simple megaspores, equator subtriangular to circular, trilete rays not always present, exine ornamented on all sides with capilli to spinae, in the genotype provided with rounded verrucae, which subtend more or less long, hair-like, contorted capilli, otherwise with simple or hook-like spinae (translated by author).

REMARKS.—Morphologically the two specimens illustrated herein conform to the descriptions given for the species, with the exceptions of the density of the capilli on the specimens (Plate 4: figures 1, 2; Plate 5: figures 1, 3) and the low or poorly developed tri-radiate ridges. Accurate measurements of the spore body are precluded by the density of the capilli. Measurements excluding the capilli can be estimated as low as 800 μ m or, including the capilli, can be obtained as high as 1066 μ m. These dimensions exceed the range given for the type specimen. I am assuming that the measurements of the type specimen did not include the capilli, that is, the dimension was of the spore body alone. If, however, one were to add the given length of the capilli, 150 μ m, to the diameter of the spore body, 780 μ m, the total of 930 μ m would then fall within the measurable size given for the two specimens at hand. The specimens in this report are larger, but not so much so as to be excluded from the species.

The capilli, which range from 65 to 135 μ m long, are proximally broadened, in which case it could be interpreted that they are subtended by verrucae (Plate 4: figures 3, 4). Their apices are either pointed or simply to several times divided (Plate 5: figure 4). This latter character is not described for the type-species; however, most of the forked apices, because of their fragility, can be easily broken off during processing and thus are not readily observed (Plate 5: figure 3).

A finely reticulate pattern can be seen as characteristic of the outer exoexine between the bases of the capilli (Plate 4: figure 4; Plate 5: figure 2).

I have only two specimens of this megaspore and although their morphological differences from the type-species are probably significant enough to establish a new species, I prefer to designate them as *E. cf. E. lanatus*. Acquisition of additional specimens will permit more significant analysis of the similarities and differences than is possible at this time. Commonly, in both specimens, microspores, herein assumed to be related to this species, are found among the matted capilli. They are all of the same morphology and dimensions (Plate 4: figures 5, 6; Plate 5: figures 5, 6). Description of these microspores appears later, where they are assigned to *Crybelosporites* Dettmann, 1963 as *Crybelosporites* species.

OCCURRENCES.—Boring B; Bore, D'Arcy Expl. Co. Kingsclere No. 1 at 706 feet and (?) 466 feet, Weald, southern England; Lower Cretaceous (Barremian-Aptian); Dijkstra, 1951.

This report, USNM Locality No. 14252, Patuxent Formation, Potomac Group, Lower Cretaceous (Barremian-Aptian).

SPECIMENS.—HH-1A, USNM 304314; HH-1B, USNM 304315.

Erlansonisporites Potonić, 1956

Erlansonisporites erlansonii (Miner) Potonić

PLATE 6

Selaginellites erlansonii Miner, 1932:500, fig. 1.

Erlansonisporites erlansonii (Miner).—Potonić, 1956:46, pl. 5: fig. 53.

DESCRIPTION (from Miner, 1932:500).—

Body of exine round, 465–1000 μ in diameter the mean being 690 μ ; exine reticulate with irregular diaphanous appendages, 17–122 μ in width, giving the spore a total diameter of 500–1,155 μ with the mean at 790 μ ; no commissural ridges or clefts visible.

Potonić (1956:47) describes the species as follows:

Genotype apart from the membranes of the muri 899 μ

(from the photograph); equator circular, trilete mark not or poorly discernible probably because of the heavy reticulation. The muri of the reticulum merge into filmy lamellae that may be uniformly developed on the entire exine, however, in the photograph of the genotype they become visible chiefly on the periphery of the spore (translated by the author).

REMARKS.—One spore from among five specimens that were obtained from the prepared samples is shown in Plate 6 (figures 1–6). It is 800 μm in diameter and is representative in form and structure of all of the specimens. The size range of the five specimens is 695 to 840 μm in diameter. The location and general size of the trilete mark is visible (Plate 6: figure 1), probably because of increased height of the muri of the reticulum along the laesurae instead of an extension of lips along the laesurate margins. Support for this observation requires microtome preparations and such are not within the scope of this report. The muri range from 14 to 45 μm in height between the bastion prongs, the prongs reaching as much as 78 μm in height.

The outer exoexine is psilate (Plate 6: figure 4). Bastion prongs and the diaphanous muri connecting them are quite obvious in Plate 6 (figures 1–3, 5). Sculpture of the muri is reticulate with minute, $\approx 1.5 \mu\text{m}$, clavae rising from the intersections of the muri of the reticulum (Plate 6: figure 6).

A precious opal-like iridescence of the spore coat is a notable characteristic of the species. Structural details of the spore coat relevant to this phenomenon were not obtained; however, I shall presume that they are identical to those described and discussed for *Thylakosporites retarius* (Hughes) Potonié, the next species in this report. In that discussion it will be noted that the spore coat structure of this species and *T. retarius* is compared to that of the two modern species of *Selaginella*. This evidence strongly suggests that it would be appropriate to return *E. erlansonii* to the original taxon *Selaginellites*, as proposed by Miner in 1932. However, the transfer will not be made herein because neither isotype material from Miner's collection nor additional specimens from

the site described herein have been obtained for direct comparison and confirmation.

OCCURRENCES.—Skansen, east of Disko Island, Greenland; Upper Cretaceous (?Campanian); Miner, 1932.

This report, USNM Locality No. 14252, Patuxent Formation, Potomac Group; Lower Cretaceous (Barremian-Aptian).

SPECIMENS.—GG-10B, USNM 304316; depression slide with four unmounted specimens, USNM 304317.

Thylakosporites Potonié, 1956

Thylakosporites retarius (Hughes) Potonié

PLATES 7–10

Triletes retarius Hughes, 1955:213, pl. 11: figs. 3, 4.

Thylakosporites retarius (Hughes).—Potonié, 1956:49, figs. 55–57 [not 57 in text. Type-specimen not designated. Lecto-type designated by Jansonius and Hills, 1976, fig. 3 of Hughes.]

DESCRIPTION (from Hughes, 1955:213).—

Trilete megaspore probably spherical but the whole upper (apical) surface may be preserved infolded [figure citation]. Diameter 520–700 μ (mean 620 μ , 6 specimens). Tri-radiate ridges 200 μ long, 10 μ broad, and 30 μ high; contact faces smooth except in one specimen where the perispore covers the whole spore surface. Distal hemisphere entirely covered [figure citation] with a mesh-like (net) perispore sometimes in different layers of different mesh size. The chief mesh strands are 15–35 μ wide and 10 μ thick [figure citation] but may also be circular in cross-section exactly as described and figured by Horst (1954) and figured by Michael (1936). Spore coat is brown but shows a red luminous effect in places; thickness of exoexine 15 μ , intexine very thin 2–3 μ and continuous with tri-radiate lips.

Potonié (1956:49) gives an abbreviated description that translates as follows:

Genotype ca. 650 μ (from the illustration), trilete megaspore, probably spherical, however the entire proximal hemisphere can be strongly folded, Y-radii extending nearly to the equator; exine smooth, however always surrounded on the whole distal side, in one specimen of the genotype also on the proximal side, by a perispore. The latter consists of an often multilayered reticulum [figure citation] similar to that which is described by Horst 1954, page 610, as *Dictyo-*

thylakos pesslerae. *Dictyothylakos* is found in the German Wealden coals of southern Mecklenburg and Odenwald.

It was correct not to equate *Dictyothylakos* and *Thylakosporites* because there could be other spore genera that have a similarly constructed perispore. (In *Cystosporites* no perispore is present, but at the same time the exine shows a felt-like and densely matted, many layered reticulum; compare Potonić and Kremp, 1955, Plate 10, figure 79.) Detached fragments of perispores belonging to *Thylakosporites* are found (translation by the author).

REMARKS.—Thirty-four specimens of this species were obtained from the samples prepared for this report. This number afforded the opportunity to observe a wide range of structural details as well as various degrees of mechanical and chemical degradation of the spore body and its ornamentation.

Three specimens were recovered in which the spores are still united in the form of tetrahedral tetrads; a typical one is illustrated in Plate 7 (figures 1, 2). A very thin, amorphous layer of organic material covers the whole tetrad and nearly completely masks the reticulum of the outer exoexine on the distal portions of the spores. The layer is thickened along the margins of the contact areas and becomes more evident when a single spore is broken away from the tetrad (Plate 7: figures 3, 4). When the thin, amorphous, outer layer is degraded or eroded the reticulum becomes more prominent (compare Plate 7: figures 5 and 6). The reticulum on some specimens is partially lost to degradation or erosion (Plate 8: figures 2–4), or completely missing except for individual points of attachment to the spore body (Plate 9: figures 1, 3).

The diameter of the spore body, excluding the reticulum, ranges from 600 to 785 μm , or, including the reticulum, ranges from 640 to 950 μm . No meaningful measurements of the height of the extension of the reticulum above the spore body can be given because the variation is a function of the amount of compression that the layer has undergone. The specimens at hand tend to exceed the size range given for the type material; however, I do not consider the difference so great as to suggest establishing a new species.

A tri-radiate ridge is prominent on the spores.

It varies from 185 to 210 μm long, 12 to 23 μm wide, and 24 to 32 μm high. The variation appears to be due to the degree of compression, the more convex, less compressed specimens have narrower and higher ridges than those that have been distorted by compression.

Three layers from the spore coat (Plate 8: figures 1, 5–8; Plate 9: figures 2, 4–6; Plate 10: figure 3). The reticulate, outer exoexine layer on the spore body varies from 1.5 to 4 μm thick. The outer exoexine layer extends into and forms the coarse reticulum that covers the equatorial and distal portions of the spore body (Plate 8: figure 4; Plate 10: figure 4). The fine reticulate structure of the individual elements of the reticulum is shown in Plate 10 (figures 5, 6). The next layer, inner exoexine, with an opal-like structure, averages 16.75 μm in thickness. The reticulate endexine varies from 1 to 2 μm in thickness; the average being 1.4 μm . The contact areas are free of the ornamental reticulum (Plate 9: figures 1, 3; Plate 10: figure 1).

The opal-like quality of the spore wall is, beyond question, the most striking characteristic of the species. I feel that the characteristic is briefly alluded to in Hughes' comment: "... spore coat ... shows red luminous effects in some places." The spore stands out, sparkling with the colors of a fine, precious opal, against the blackness of the surrounding carbonized plant debris. I regret that it is not possible to reproduce a color photograph to illustrate this phenomenon. The structure of the inner exoexine (Plate 8: figures 5, 7; Plate 9: figures 4, 6) is precisely that which has been shown by Sanders and Darragh (1971) for the structure of precious opal. Rows of contiguous spherules, each spherule averaging 0.25 μm in diameter, are uniformly and alternately aligned, giving the appearance of stacked lead shot, or on a grander scale, stacked cannon balls. The alignment can be seen to change direction (Plate 9: figure 4) through an angle approximating 60°. This alignment of spherular bodies produces a diffraction grating effect by separating and reflecting incident light into the spectrum colors. The various alignments of the spherules produce

the various colors seen as the spore body is rotated. At first it was thought that the spore had been preserved through permineralization of the spore wall by opal. However, only this species and *Erlansonisporites erlansonii* from among all of the other species found at this site exhibit the precious opal effect and it would be quite unusual for such selective preservation to take place. I made the assumption that the organic layers of the outer exoexine and the endexine had protected what I thought was the siliceous inner exoexine from attack by the hydrofluoric acid solution. This assumption was encouraged by the specimen illustrated in Plate 10 (figures 1–3), which exhibits a peculiar corrosion of the inner exoexine layer of the spore wall.

Electron dispersive x-ray (EDX) analysis of the inner exoexine layer produced the results shown in the spectrograph reproduced in Figure 1. Silicon should be the primary element recorded if the inner exoexine layer were composed of opal. Instead, only a minor amount of silicon is indicated. Analyses of five different specimens of the spore yielded essentially the same results as shown here. The analyses clearly indicated that the inner exoexine layer in *Thylakosporites retiarus* is not composed of opal, even though its microstructure and light refractive qualities parallel those of precious opal. All of the elements indicated in the

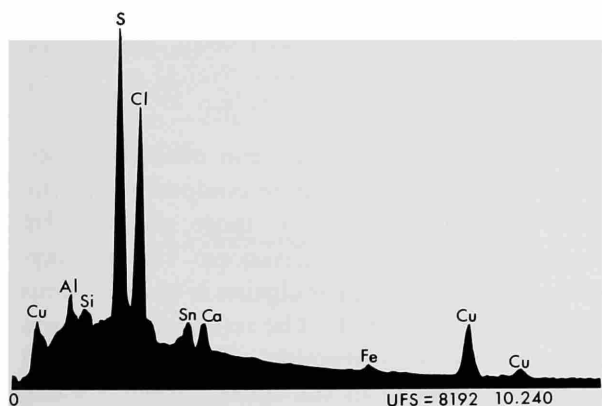


FIGURE 1.—Electron dispersive x-ray spectrograph showing analysis of inner exoexine layer in spore coat of *Thylakosporites retiarus* (Hughes) Potonié (specimen KK-1B, USNM 304318).

analyses can be anticipated as components of the structure of the spore coat, with the exception of the copper (Cu), aluminum (Al), and tin (Sn), which are interpreted herein as contaminants derived from the metal screening used in the isolation, cleaning, and drying of the individual spores. Taylor, et al. (1976) present analysis of the spore walls of the liverwort species, *Conocephalum conicum*, and discuss the significance of the various elements found there. Their bibliography contains several additionally useful references for the interpretation of the results of spore wall analyses. I recommend that the interested reader consult Taylor, et al. Further discussion of the subject is beyond the scope of this report.

An exciting and completely unexpected body of information relevant to the structure of the inner exoexine of *T. retiarus* was found in a paper by Tryon and Lugardon (1978). The writers discuss the structure and mineral content of the spore coats of the megaspores of two species of *Selaginella*. They illustrate their paper with SEM and TEM photographs as well as EDX spectrographs. The SEM photographs in their pl. IV (fig. 1) and pl. V (fig. 1) are so similar in appearance to those in my Plate 8 (figure 5) and Plate 9 (figure 4) as to appear to be the same specimens. However, their photographs are of the megaspore wall of *Selaginella galeottii* Spring, a modern, tropical, American species. Their EDX analyses of the opal-like inner exoexine of the spores indicate, as did my analyses, the presence of only a minor amount of silicon. Their analyses are more detailed than mine and include spectrographic mapping whereby they are able to demonstrate that the silicon is concentrated in the outer limits of the inner exoexine layer. The silicon, presumably as the oxide mineral quartz, is randomly distributed among the interstices of the rows of spherular bodies that form the layer. The opal-like iridescence of the spore coat of the megaspore of *S. galeottii* is not mentioned by Tryon and Lugardon; however, I have observed the phenomenon in specimens from Veracruz, Mexico filed in the United States National Herbarium.

Pierre Martens (1960a) illustrates, by means of

TEM photographs, the same opal-like wall structure in the megaspores of another modern species of *Selaginella*, *S. myosurus* (Swartz) Alston. In a second paper on the same species (1960b) he describes the iridescent quality of the spore wall when observed microscopically in reflected light. This is the only reference to the phenomenon that I have been able to find in the literature. *Selaginella myosurus* is native to the region of Zaire, Africa.

Françoise Stanier (1965, 1967) presents additional details regarding the structure of the megaspore wall of *S. myosurus* and quotes the observation made by Martens on the iridescent quality of the spore wall. The TEM photographs in her pl. 1: figs. 3, 4 (1967) lend supportive evidence for the interpretation of the structure of the spore wall of the fossil *T. retarius*, illustrated herein with SEM photographs.

Additional, refined EDX analyses and preparations, such as sections for transmission electron microscopy of the spore coat of *T. retarius*, are required. Certainly, precisely the same study of the spore coat structure of *Erlansonisporites erlansonii* is also required when one considers the significance of the iridescent quality of the spore coats of the two fossil species. Nevertheless, despite lack of elaborative details, the evidence at hand strongly indicates that the spore species, *T. retarius* and *E. erlansonii*, are fossil evidence for the existence of ancestral forms of some of the modern species of *Selaginella* during the Lower Cretaceous of eastern North America.

As a final note, I agree completely with Potonié's opinion (1956) that *Dictyothylikos* and *Thylakosporites* are not to be combined. I illustrate a specimen of *Dictyothylikos* late in this report to show that structurally there is some similarity between the reticulum of the outer exoexine of *Thylakosporites* and the morphology of *Dictyothylikos*. I present a conjectural analysis of *Dictyothylikos* in the discussion of the specimen.

OCCURRENCES.—Hughes' locality S 7; Cliffs of Compton Bay, Isle of Wight: Wealden Marls, Bed 11; Lower Cretaceous (Barremian-Aptian); Hughes, 1955.

This report, USNM Locality No. 14252, Patuxent Formation, Potomac Group; Lower Cretaceous (Barremian-Aptian).

SPECIMENS.—BB-12A, USNM 304319; GG-8A, USNM 304320; GG-10A, USNM 304321; GG-10C, USNM 304322; GG-10D, USNM 304323; HH-2B, USNM 304324; KK-1B, USNM 304318; KK-2A, USNM 304325; KK-2B, USNM 304326; and 26 specimens stored in a depression slide, USNM 304327 for use in further study.

Crybelosporites Dettmann, 1963

Crybelosporites striatus (Cookson and Dettmann) Dettmann

PLATE 11

Perotrilites striatus Cookson and Dettmann, 1958, 4(1):43, pl. 1: figs. 8–12.

DESCRIPTION (from Dettmann, 1963:80).—

Microspores trilete, spheroidal. Sclerine stratified, cavate proximally, 4–5 μ thick (inclusive of sculptural/structural elements), consisting of a smooth, homogeneous, inner layer (1–1.5 μ thick) and a ruffled, proximally cavate, two-layered sculptine, the outer of which forms a conical gula-like projection over the proximal pole. Sculptine 3 μ thick in optical section, striated proximally, reticulate distally and equatorially; reticulum composed of membranous muri (1.5–3 μ high) which enclose circular to polygonal lumina 1–3 μ in diameter. Laesurae developed on two inner wall layers only; straight, length 3/4 spore radius with weakly thickened lips.

Dimensions: equatorial diameter 28(37)45 μ ; polar diameter 34(45)56 μ ; diameter of inner layer 20(29)29 μ .

REMARKS.—Scanning electron microscope observations preclude complete comparison of the spores illustrated herein to those observed by means of optical light microscopy. The two-layered, proximally cavate sculptine is quite obvious in Plate 11 (figures 3, 4). The reticulate sculpture is rather faintly discernible on the distal and equatorial portions of the spore body. The size range of the specimens among the folds of the acrolamellae on specimens of *Arcellites disciformis* in Plate 11 (figures 1, 3) and Plate 14 (figure 3) is 30 to 42 μ m in equatorial diameter, which is

within the size range given for the type of the species.

Significantly this microspore has been found adhering to the type specimen of the megaspore species *Arcellites disciformis* and on subsequent specimens illustrated by Ellis and Tschudy (1964). Also, the specimen of *A. disciformis* sent by Garland Upchurch, Jr., mentioned later herein, has two of these same microspores adhering to the base of the acrolamellae. This repeated association clearly indicates that these megaspores and microspores will eventually be identified with a single sporophyte species. However, the sporophyte is certain to be a delicate aquatic fern of which the remains will be found only as a result of ideal conditions of burial and preservation.

I am not convinced that the natural position of occurrence of these microspores is within the neck formed by the acrolamellae of the megaspore as described by Ellis and Tschudy (1964). Instead, their position appears to have been one of adhesion to the smooth outer surface of the folds of the acrolamellae. Additional discussion of this question is presented later in the remarks on *Arcellites disciformis*.

OCCURRENCES.—Aptian through Albian in Australia and New Guinea; Dettmann, 1963.

No. 1 Mann well, 4686 feet, Fall River Sandstone; Upper Cretaceous (Albian); Ellis and Tschudy, 1964.

This report, USNM Locality No. 14252, Patuxent Formation, Potomac Group; Lower Cretaceous (Barremian-Aptian).

SPECIMENS.—BB-11C, USNM 304328; GG-6A, USNM 304329.

Crybelosporites species

PLATES 4, 5

DESCRIPTION (incomplete).—Trilete microspores; equatorial outline of spore body circular; structure of the spore coat requiring thin sections for transmission electron microscopy or examination by optical, light microscopy for complete description; however, sculptine of two layers is

suggested by folded, cavate, outer layer (Plate 4: figure 5) that covers and masks the sculpture of the inner layer; sculpture of inner layer may be granular as described for *C. punctatus* Dettmann, 1963 (Plate 4: figure 6); Y-mark small (Plate 5: figure 6), rays approximately one-half of spore radius; diameter of the spore 23 to 25 μm (14 measured).

This microspore was found lodged among the capilli on *Echitriletes* cf. *E. lanatus*, described herein, in relatively large numbers and to the apparent exclusion of other species. I suggest that these spores, the megaspore as well as microspores, were produced by the same sporophyte, which, unfortunately, is yet to be identified.

OCCURRENCE.—This report, USNM Locality No. 14252, Patuxent Formation, Potomac Group; Lower Cretaceous (Barremian-Aptian).

SPECIMENS.—HH-1A, USNM 304314 and HH-1B, USNM 304315.

Arcellites Miner, 1935

Arcellites disciformis Miner emend. Ellis and Tschudy

PLATES 12-19

Arcellites disciformis Miner, 1935:600, pl. 20: figs. 61, 64-66.

Arcellites disciformis Miner, emend. Ellis and Tschudy, 1964: 75.

DESCRIPTION (emendation by Ellis and Tschudy, 1964:75).—

Nearly spherical spore body having an equatorial diameter of 185-350 μ (mean 259 μ); neck consisting of six leaf-like folded appendages forming a long flamelike organ; length of neck 261-477 μ (mean 357 μ). Each "leaf" folded lengthwise and inward, characteristically crenulate or fimbriate on its margin. "Leaves" commonly exhibit torsion of about 180°. Spore body bearing a variable number (11 to 26, mean 16) of blunt tubelike appendages, which are usually constricted at their bases. Appendages possess a thick, probably originally spherical, reticulate bladder on their extremities. Spore coat of three layers; exoexine about 11 μ thick, thinning at neck and appendages and divisible into two layers, outer about 8 μ thick and inner about 3 μ thick, sometimes seen detached from the exoexine. The inner layer of the exoexine and the intexine are continuous across the floor of the neck. A tri-radiate scar is present on the floor of the neck.

Exoexine penetrated by characteristic pits which are somewhat elliptical in cross section; intexine smooth.

REMARKS.—Nearly all specimens examined for this report are preserved in three-dimensional, undistorted form. The equatorial diameter of the spore bodies varies from 188 to 245 μm , which places the variation below the mean given in the original description. The measurements I have taken are from dry spores. I did not measure specimens in wet mounts wherein I am sure the measurements would be higher due to swelling of the spore walls as a result of absorption of water. Movement can be observed as the spores dry or as they are remoistened during the mounting processes, suggesting that a certain amount of shrinkage does take place during dehydration. The flame-like organ varies in length and width, as can be seen in the equatorial and proximal views of the examples in Plates 11–13 and Plate 19 (figures 1, 3). Again the variation falls below the mean given in the original description, and the reason for that is probably the same as for the spore body variation.

Morphologically and anatomically the specimens are identical to those described and illustrated by Ellis and Tschudy (1964). Three layers form the spore coat and are clearly demonstrated in Plate 17 (figure 2). Pits in the outer exoexine layer, illustrated in surface view in Plate 16 (figures 1–4), penetrate the outer exoexine layer, as can be seen in Plate 17 (figures 2–4). The inner exoexine layer has a reticulate structure while the endexine (intexine) is compact and almost amorphous. The tubular appendages (Plate 18: figure 1) are formed by extension of the outer exoexine layer (Plate 18: figure 3). In some instances formation of the appendages was not complete as indicated by protuberances on the spore surface (Plate 16: figure 4). The inner exoexine extends very slightly into the base of each appendage (Plate 17: figures 3, 4; Plate 18: figures 3, 5). The apices of the appendages are reticulate (Plate 18: figures 1, 2, 4) and I agree that they probably were formerly slightly expanded in bladder-like form (Plate 18: figure 2). The reticulation is similar to that of the margins of the acrolamellae.

Minute, pleat-like folds along the margins of the acrolamellae end in finger-like extensions that appear to be entangled but not fused with those of the neighboring margin (Plate 15: figures 2–4). Pores and fissures are present between the folds and among the elements of the fimbriate margins. They probably gave access to the neck cavity (Plate 15: figure 1) formed by the acrolamellae. Occasionally the acrolamellae are separated from one another (Plate 13: figure 4; Plate 14: figures 1, 2). They, like the appendages, are formed by extension of the outer exoexine (Plate 19: figure 3) as a single layer (Plate 15: figure 2). The Y-mark can be clearly observed only by removal of the flame-like organ or by cutting the spore body in half along its equator. The best results were obtained by cutting the spore body in half (Plate 19: figure 1) and examining the inner surface of the proximal polar area. The Y-mark is clearly visible in the spore coat that forms the floor of the neck cavity (Plate 19: figure 2). The endexine and the inner exoexine are continuous across the floor of the neck cavity (Plate 19: figures 3, 4) but are split by the trilete suture.

Microspores were found adhering to the outer, smooth surfaces of the folds in the acrolamellae (Plate 14: figure 3; Plate 11: figures 1–4). I agree with Ellis and Tschudy (1964:76) that the flame-like organ, the neck, may have had a gelatinous material associated with it that served to trap microspores. The outer layer of the sculptine of the microspore may also have had a sticking quality that would cause it to adhere to the surface of the megaspore after the gelatinous exudate of the megaspore had disintegrated. Germination of the microspore could have occurred outside of the neck cavity and the sperm could have swam through the fissures and pores along the margins of the acrolamellae, into the cavity and to the female gametophyte at the base of the neck.

I have illustrated these megaspores in the position suggested by Ellis and Tschudy as the life position when the spores were released from the sporophyte. This is the position that they assume when found floating in the wash waters during

preparation of the matrix. Note that many can be lost if wash waters are discarded without first being examined for "floaters."

Ellis and Tschudy (1964) place *Arcellites crillensis* Schemel, 1950 and *Arcellites* cf. *A. hexapartitus* (Dijkstra) Potter, 1963 in synonymy with *A. disciformis*. I agree with this decision. I must admit that I am uneasy with *Arcellites hexapartitus* as illustrated by Hughes, 1955 (pl. 10: fig. 4). However, without seeing specimens of the species at first hand I must accept the identification of the specimen.

OCCURRENCES (from Ellis and Tschudy, 1964, table 1).—In descending order of age:

Skansen, Disko Island, Greenland; Upper Cretaceous (Cenomanian); Miner, 1935.

Crill coal, Dakota Group, Iowa, USA; Upper Cretaceous (Albian); Schemel, 1950.

"D" sandstone, 4480 feet, Plains Exploration Company Parker 1; C NW SE Sec. 19, T. 3N., R. 51 W., Washington County, Colorado, USA; Upper Cretaceous (Cenomanian); Ellis and Tschudy, 1964.

"Huntsman" shale, samples 4531 and 4580 feet, Marathon Oil Company Holt 2; SE SE SE Sec. 7, T. 17N., R. 49W., Morrill County, Nebraska, USA; Upper Cretaceous (Albian); Ellis and Tschudy, 1964.

Newcastle Sandstone (type section); NW NW NW Sec. 28, T. 45N., R. 61W., Weston County, Wyoming, USA; Upper Cretaceous (Albian); Ellis and Tschudy, 1964.

"J" sandstone, 4865 feet, Marathon Oil Company Gurschke 1; SW NE SE Sec. 3, T. 14N., R. 50W., Cheyenne County, Nebraska, USA; Upper Cretaceous (Albian); Ellis and Tschudy, 1964.

Glencairn Shale Member of the Purgatoire Formation, Beaver Creek surface section; NW Sec. 10, T. 18S., R. 68W., Fremont County, Colorado, USA; Upper Cretaceous (Albian); Ellis and Tschudy, 1964.

Skull Creek Shale, South Platte Formation, 4698 feet, Marathon Oil Company, Knievel 1; NE SE SE Sec. 2, 15N., R. 49W., Cheyenne County, Nebraska, USA; Upper Cretaceous (Albian); Ellis and Tschudy, 1964.

Fall River Sandstone, 4686 feet, California Company Mann 1; SE NE NW Sec. 27, T. 30N., R. 56W., Sioux County, Nebraska, USA; Upper Cretaceous (Albian); Ellis and Tschudy, 1964.

Patuxent Formation, Potomac Group, Dreyer's Bluff, James River, near Richmond, Virginia; Lower Cretaceous (Barremian-Aptian); W. G. Chaloner, pers. comm. 22 Sep 1980.

Dutch Gap Canal, Virginia; Lower Zone I, Potomac Group, Lower Cretaceous (Barremian-Aptian); specimen sent for examination by Garland Upchurch, Jr.

This report, USNM Locality No. 14252, Patuxent Formation, Potomac Group; Lower Cretaceous (Barremian-Aptian).

SPECIMENS.—BB-11A, USNM 304330; BB-11B, USNM 304331; BB-11C USNM 304328; BB-11F, USNM 304332; GG-3A, USNM 304333; GG-4A, USNM 304334; GG-4B, USNM 304335; GG-4C, USNM 304336; GG-5A, USNM 304337; GG-5C, USNM 304338; GG-6A, USNM 304329; GG-6B, USNM 304339; II-2, USNM 304340; depression slide with 70 specimens unmounted, USNM 304341.

Arcellites cf. *A. pyriformis* (Dijkstra) Potter

PLATES 20, 21

Triletes pyriformis Dijkstra, 1951:14, pl. II: fig. 9

Pyrobolospira pyriformis (Dijkstra).—Hughes, 1955:209, pl. XI: figs. 1, 2.

Arcellites pyriformis (Dijkstra).—Potter, 1963:228.

DESCRIPTION (from Dijkstra, 1951:14).—

Spore pyriform, mostly flattened in lateral direction. Length of spore, including neck-like projection, 375–700 μ (the mean being 591 μ , 17 specimens measured), breadth about 300–700 μ . Neck-like projection to 250 μ long, 300 μ broad. Tri-radiate ridges 250–300 μ long, 50 μ broad, about 60 μ high. Arcuate ridge not distinguishable. Between the tri-radiate ridges some plications running in lateral direction, 100–200 μ long, 30 μ broad, 10 μ high. Spore body covered with numerous bluntly ended appendages, 30 μ long, 20 μ broad. Spore coat black.

Hughes' emendation (1955:209) is as follows:

Spore-body originally nearly spherical but usually equatorial diameter exceeds the axial. Equatorial diameter 290–920 μ

(mean 651 μ , 35 specimens or mean 631 μ including Dijkstra's specimens). The axial measurement with or without the neck is meaningless, as the majority of specimens are asymmetrically laterally flattened; this suggests that the top of the spore below the neck is the most rigid part. Only the maximum neck dimensions are given as the neck is so frequently incomplete; length up to 350 μ , width 350–400 μ at extremity, narrowing to the base. The neck arises from the spore body as three prominent folds and consists basically of three bulging lobes between these folds; the specimen in Plate XI, fig. 2, is a small one with somewhat irregular appendages but it shows at the neck attachment a fold centrally, flanked by two downward bulging lobes, with the two other folds at the margins in this view. In most cases the main part of the neck is opaque and ochreous in colour, and lacking in precise form; broken surfaces reveal the upper part to be composed of a solid mass of sponge-like tissue without any central canal. Certain complete specimens seem to show a six-fold symmetry of leaves of the neck on the top surface, and others in which the neck is reduced to translucency by maceration show the same number. Spore-body covered evenly with blunt simple or compound appendages 30–40 μ broad, and seldom less than 15 μ apart in an average specimen; slight decrease in size of appendages towards the neck.

Spore-coat brown to black, consisting of opaque exoexine layer 25–30 μ thick and intexine 5 μ thick and translucent; exoexine layer is likely to be divided as in *P. vectis* but good confirmatory sections have not been prepared because of the brittleness of specimens. Tri-radiate mark (laesurae 200 μ long) seen on inner side of apex of intexine and inner part of exoexine in broken specimen. Ideally a neck-chamber is present in the base of the neck but it has not been explored; the swollen lobes mentioned above were seen in some good specimens to be hollow.

REMARKS.—Three specimens were obtained but only one of them is complete (Plate 21: figures 1–3). Its diameter is 647 μ m and the range of sizes of the appendages is in agreement with that given in the type-description. However, I cannot be certain of the morphology of the neck. Hughes begins his morphological description saying that “the neck arises from the spore-body as three prominent folds and consists basically of three bulging lobes between these folds.” My specimen shows three folds arising from the spore body but no bulges are present between the folds; the neck remains three-parted (Plate 21: figures 3, 4). I shall withhold judging whether there are only three acrolamellae on my specimen or six that are distorted by preservation. Hughes placed empha-

sis on the presence of six acrolamellae. I cannot prove which number is correct for my specimen. I shall therefore suggest that it be designated *Arcellites* cf. *A. pyriformis* in light of the strong agreement of the other structural details with the type-specimen.

The two fragmentary specimens (Plate 20: figures 1–7, and Plate 21: figures 6–9) exhibit identical morphological characteristics to the intact spore and provide excellent anatomical details. The spore coat comprises three layers (Plate 20: figure 4, and Plate 21: figure 7); the inner exoexine, which is coarsely reticulate, and the endexine, which is very thin ($\approx 1 \mu$ m). The outer exoexine forms the appendages. All of the layers tend to separate from one another (Plate 20: figures 4–6) and, in the case of the fragment in Plate 21 (figure 6), the endexine is missing from most of the inner wall. When preserved, the endexine structure is more finely reticulate (Plate 20: figure 8) than that of the other layers. Evidence for a neck chamber at the base of the neck is illustrated in Plate 20 (figure 3) and Plate 21 (figure 6). Details of the Y-mark were not obtained from the specimens at hand.

I have illustrated this species with the neck pointing downward, suggesting the position of the spore when it was free floating after release from the sporophyte. Unfortunately, no microspores have been found attached to the neck as has been the case with *A. disciformis*. My feeling is that the microspores would most likely adhere to the apex of the neck rather than to the sides. The texture of the apex, in the fossil condition, suggests that it was spongy and thus porous and the probable site of any gelatinous exudate that might have entrapped microspores.

OCCURRENCES.—Lower part Bore B, Netherlands; Lower Cretaceous (Wealden); Dijkstra, 1951.

Cliffs in middle Fairlight Clay below Coast Guard Station, halfmile NE of Fairlight Glen Foot, England; Hughes' Locality 80A; Lower Cretaceous (Berriasian); Batten, 1969.

Wealden Marls of the Isle of Wight, England; Lower Cretaceous (Barremian); Hughes, 1955.

This report, USNM Locality No. 14252, Patuxent Formation, Potomac Group; Lower Cretaceous (Barremian-Aptian).

SPECIMENS.—BB-12, USNM 304342; HH-2A, USNM 304343; HH-2C, USNM 304344.

Paxillitriletes Hall and Nicolson, 1973

Paxillitriletes species

PLATES 22, 23

Paxillitriletes Hall and Nicolson, 1973:319 [type-species *P. reticulatus* (Mädler) Hall and Nicolson].

DIAGNOSIS (from Mädler, 1954:150).—"Macrospores with pilose sculpture along the tetrad rays or only in their immediate region; equatorial flange narrow, rays of Y-mark extending to or slightly beyond it."

REMARKS.—Only two specimens were found and this paucity of material precludes assigning a specific name to these beautifully ornamented megaspores. The specimen shown in Plate 22 (figures 1–4) and Plate 23 (figures 1, 2) is 284 μm in diameter, excluding the equatorial flange. The distal surface has a reticulate sculpture. Short appendages, 5.75 to 17.5 μm long, and truncate bases of longer ones, extend from the contact points of the muri. The exine is uniformly pitted (Plate 23: figure 2). The contact areas on the proximal surface also have a reticulate sculpture with appendages extending from the intersections of the muri. The appendages are 4–6 μm long near the equatorial flange and gradually increase in length to form capilli 57–115 μm long at the border of the laesurae. The Y-mark extends to the outer margin of the equatorial flange and is bordered by labra 58–75 μm high that are formed by the fused, broadened bases of blunt-ended appendages. The equatorial flange is formed in the same way; however, the appendages are much shorter, 23–40 μm high.

The second specimen (Plate 23: figures 3, 4) is laterally flattened and is 325 μm in diameter. The formation, size, and distribution of the appendages is the same as on the other specimen. The

labra seem to be torn or perhaps fimbriate. The spore is not so well preserved as the other.

These specimens, in their form and distribution of sculptural elements, most resemble *P. alatus* (Batten, 1969) Hall and Nicolson and *P. fairlightensis* (Batten, 1969) Hall and Nicolson from among the 12 species listed by Hall and Nicolson (1973). *P. alatus* is larger in all dimensions than the specimens at hand and has capilli over the whole of the distal surface of the spore. The broken or truncated bases of appendages on the distal surface of the first of the two specimens described herein suggest that there were capilli present but that they were eroded prior to burial or subsequent to maceration and processing. *P. fairlightensis* is smaller than the spores at hand; however, in sculptural detail they are very similar. I tend to favor identification of the spores with *P. alatus* but more specimens are required in order to arrive at a convincing analysis and conclusion.

OCCURRENCE.—The genus *Paxillitriletes* ranges from Lower Jurassic, *P. mensurus* (Harris, 1935), to Upper Cretaceous, e.g., *P. dakotensis* (Hall, 1963). A summary of all of the species is given by Hall and Nicolson, 1973.

This report establishes a record of the genus at USNM Locality No. 14252, Patuxent Formation, Potomac Group; Lower Cretaceous (Barremian-Aptian).

SPECIMENS.—GG-3C, USNM 304345; GG-3D, USNM 304346.

Dictyothylakos Horst, 1954

Dictyothylakos pesslerae Horst, 1954

PLATE 24

DESCRIPTION (translated by the author from Horst, 1954:610).—

The structures are uniformly orange colored. In oblique light, dark-field of the ultrapak they appear rosin-like and strongly reflective. They are brittle and break easily.

The photographs [plate citation] clearly show the formation of the body from a net-like framework. The individual meshes are in part three to five cornered, in part polygons are formed through irregular development of the framework;

their inner edges are often rounded. From the thick, 15–35 μm , primary strands depart secondary strands, about 10 μm in diameter, which serve as reinforcement to the meshes.

All strands are nearly round in cross-section. They are hollow, which has been proved during the course of the research.

The fragment, only briefly mentioned by Michael (1936), was found in the coal petrographic collection of the Staatlichen Geologischen Kommission (glycerine-jelly preparation No. 6 from the Osterwald occurrence). The comparison demonstrated a conformity in both accounts. Similar fossils, to my knowledge to this time, have not been described. A classification of the very well-characterized objects into known fossil species is at present still not possible.

Diagnosis: Oblong hollow body, net-like, orange colored framework, 4.5 mm maximum length and average 1.7 mm width. Meshes of net in part three to five cornered, in part polygonal. All strands are hollow inside. Cross-section round. Diameter of the primary strands 15–35 μm , the secondary strands about 10 μm . Weight of a fully preserved specimen 0.192 mg.

REMARKS.—Although only one specimen of this enigmatic palynomorph was obtained from my preparations, I felt that the significance of its occurrence was adequate reason to include illustrations and description of it. The dorsiventral, discoid form of the specimen (Plate 24: figures 1, 2) causes me to hesitate in associating it taxonomically with *Thylakosporites retiaris*. However, structurally the margin of the disc, with its looping and anastomosing elements (Plate 24: figures 1, 2, 4, 5) does recall to a certain degree the sculptural detail of the outer exoexine of *Thylakosporites*. The remainder of the specimen bears no similarity. The surface shown in Plate 24 (figure 1) is interpreted as the outer surface because of the more pronounced relief in the patterns surrounding the pore-like openings (Plate 24: figure 3). The surface comprises strands of structural material laid down in much the way coils of clay would be used to form a decorative ceramic object. The inner surface (Plate 24: figure 2) has less relief, the surfaces between the pores are relatively flat. Particular attention is directed toward the frayed aspect of the margin of the specimen. This characteristic leads me to suggest that this specimen is operculum-like and may have broken away from its parent organ as a result of stresses

applied to the structurally weaker filaments along the margin.

Descriptively, for what it is worth, and I give little value to color in fossil materials, the specimen at hand is orange and quite lustrous. In color and lustre there is agreement with the description of the type-specimen. The strands along the margin of the specimen are clearly comparable, morphologically, to the strands forming the framework of the body of the type-specimen. However, the remainder of the specimen illustrated herein is thicker and of heavier construction overall due to the layering of structural elements around the pores or meshes. Also, all of the strands are solid rather than hollow. This latter characteristic is, unfortunately, not clearly illustrated in the original account of the type-species.

Horst (1954) made every effort to determine the composition of the material through chemical analysis, staining reactions, x-ray analysis, and spectrochemical techniques. None gave a positive indication of the composition. He remained convinced that *Dictyothylakos* was of plant origin and stressed that it probably was the “framework of an alga” and not the remains of a seed coat as suggested by Michael (1936).

Hughes (1955) was strongly of the opinion that some of *Dictyothylakos* illustrated by Horst was identical in form to the perispore he was describing as part of his new species, *Triletes retiaris*, now *Thylakosporites retiaris*. The result was that he placed part of Horst’s material, although he did not state which part, in synonymy with *T. retiaris*. This action has not been accepted by most palynologists.

I should like to present a conjectural analysis of *Dictyothylakos pesslerae* that simply requires the extension of insufficient evidence into a discussion. I shall not go so far as to prepare drawings because they can pass through the veil of reality and miraculously, in some later time, be reproduced as facts.

Horst, in his figures 2 and 3, illustrates individual, apparently hollow, oblong bodies, the walls of which are coarsely reticulate. In his figure 2, one end of the body is tapered to a somewhat

blunt point while the opposite end is truncated, appearing as though broken. In figure 3, one end of the body is broken away and very irregular in outline. The body is split longitudinally for about one-half of its length and would probably exhibit a tapered form if reconstructed. Unfortunately, the end opposite the very roughly broken one is also incomplete. My reason for describing these two bodies is to have a basis for the suggestion that the specimen described in this report represents a covering or closure (operculum) on the broader end of a morphologically similar if not identical body. A reconstruction would represent the complete form as a lidded, cylindrical container reminiscent of a pyxis. The net-like structure would be represented as strands of material laid down on the inner surface of the container. I shall, from here on, refer to the container as a sporangium. Thin-walled cells forming the outer layer of the sporangium were lost to decay. I shall suggest further that, if *Dictyothylakos* were part of a sporangium, the sporangium was a megasporangium.

In summary, *Dictyothylakos*, because of the similarity between its structural components and those of the outer exoexine of *Thylakosporites*, may represent a part of a megasporangium from which a spore like *Thylakosporites* originated. This suggestion is not wholly original, as Hughes (1955: 214) did casually infer such an interpretation. I reinforce the interpretation with the specimen described and illustrated herein. I suggested earlier that *Thylakosporites* is probably the megaspore of an ancient *Selaginella*. No present-day megasporangium of *Selaginella* even approaches the conjectured appearance of *Dictyothylakos*.

OCCURRENCES.—Bore W. III, 870 m, Wealden coal (Lower Cretaceous), south Mecklenburg and Osterwald, Germany; Horst, 1954.

Seven separate but undocumented localities in the Wealden (Lower Cretaceous) of England; Hughes, 1955.

This report, USNM Locality No. 14252, Patuxent Formation, Potomac Group, Lower Cretaceous (Barremian-Aptian).

SPECIMENS.—II-4B, USNM 304347.

Conclusions

Evidence for correlating a part of the Potomac Group with a part of the English Wealden section is a significant contribution of this report. The megaspores described herein, though significant, would not be so effective in correlation were it not for some added precision afforded by the preliminary palynological analysis of the matrix prepared by Dr. J. A. Doyle (pers. comm.). In that analysis he found a large number of ferns, *Eucommidites*, *Vitreisporites* (= *Caytonia*), some saccate conifers, but very few *Classopollis*, bisaccate pollen related to *Decussosporites*, a beautiful suite of angiospermous monosulcates such as *Retimonocolpites peroreticulatus*, *Clavatipollenites*, *Liliacidites* species B and others, familiar to Zone I of the Potomac Group. Although the listing is only a preliminary one, Doyle has no doubt that the Shirley Highway locality is in Zone I, as described by Hickey and Doyle in 1977. The assemblage, as he sees it, resembles most closely the 770–765' level in Delaware Well D12, that is, the lower part of Zone I, which would place the age in the Barremian-Aptian level in the section. As a point of reference I refer the reader to Hickey and Doyle's fig. 3, in which the subdivisions of the Potomac Group and correlations of the fossil localities are shown. The horizon with which the material from the Shirley Highway excavation closely correlates is at the lower right of their figure.

Turning now to the early Cretaceous Wealden of England, Hughes (1958:44) suggests certain megaspore floras as representative of particular stages within the Wealden section. The "*Verrutriletes* Flora" represents Berriasian; the "*Thomsonia* Flora" (now, because of nomenclatural change, "*Paxillitriletes* Flora") is Valanginian; the "*Pyrobolospora* Flora" (now, because of nomenclatural change, "*Arcellites* Flora") is Barremian-Aptian.

A review of the species indicates the presence of *Verrutriletes carbunculus*, which was first reported from the Upper Cretaceous (Senonian) by Dijkstra (1949) and then again by him from the Barremian-Aptian (1951). The Barremian-Ap-

tian occurrence was at 466' in the Kingsclere Bore Hole No. 1 in England that directly associates the species with the "Arcellites Flora" of Hughes. That occurrence and association are also true for *Echitriletes*, to which I compare some specimens in this report. *Thylakosporites retarius*, *Arcellites disciformis*, *A. pyriformis*, and *Dictyothylakos pesslerae* can all be associated with the "Arcellites Flora." Thus most of the megaspores and the palynomorph discussed herein are typical to the Barremian-Aptian stages in the Wealden section. The megaspores, in association with the preliminary analysis of the microspore and pollen flora by Doyle, suggest correlation between lowermost Zone I (Patuxent Formation) of the Potomac Group and the Barremian-Aptian horizons of the English Wealden.

Of the species recorded herein that are not directly associated with the "Arcellites Flora," *Crybelosporites striatus* may be added by reason of its relationship as the microspore belonging with *Arcellites disciformis*. Also *Paxillitriletes* can be anticipated as a member of the "Flora" because its range is from Lower Jurassic to Upper Cretaceous and certainly one or more of the 12 species will be shown to be of Barremian-Aptian age. On the other hand, *Erlansonisporites erlansonii* to this time is known only from the Upper Cretaceous (?Campanian) on Disko Island, Greenland, and this report extends its range considerably downward in the section. I am concerned about my identifications of *Echitriletes* cf. *E. lanatus*, *Arcellites* cf. *A. pyriformis*, and *Paxillitriletes* species because I have had too few specimens and have relied on SEM studies alone for the analyses.

Among the megafossil remains from this locality *Pityostrobus hueberi* Robison and Miller and *P. virginiana* Robison and Miller (1977), assigned to

the Pinaceae, represent the first species of this genus to be reported from the North American Atlantic Coastal Plain. The age in Robison and Miller was given as Albian, which, at the time, was based on correlations projected from outcrops of known age. The pollen and spore analysis, although preliminary, indicates that the site is within the Barremian-Aptian Patuxent Formation of the Potomac Group.

A cupule or fruit belonging to *Caytonia*, comparable morphologically to *C. nathorsti* (Thomas) Harris (1964), was found during the sorting of the plant remains for megaspores. Seeds comparable to those found in the cupule were also isolated from the debris.

The megafossil flora is rich in fern, cycadopsid, and conifer remains and accordingly deserves further attention. The collection of the matrix is available in the paleobotanical collections of the National Museum of Natural History, Smithsonian Institution, as a study resource for qualified researchers.

Interpretation of the lithofacies of the site, along with the general composition of the megafossil flora, suggests a backswamp deposit as discussed by Hickey and Doyle (1977). It is unfortunate that there was very little time to collect from the deposit before it was destroyed. The megafossil flora can only be hinted at on the basis of the collection at hand. Potentially some of the sporophytes may have been found that were the sources of the sporomorphs described herein. It would have been particularly exciting if sporophytes of *Selaginella*, similar to the modern species *S. galeottii* and *S. myosurus*, were found and shown to be the sources of *Erlansonisporites erlansonii* and *Thylakosporites retarius*.

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PLATES

PLATE 1

FIGURES 1-6.—*Verrutriletes carbunculus* (Dijkstra) Potonié: 1, Proximal view, $\times 100$; 2, equatorial view, $\times 100$; 3, area x in figure 1, $\times 500$; 4, area y in figure 1, $\times 1000$; 5, surface of exine between gemmae on ornamented portion of spore, $\times 1000$. (Specimen GG-7A, USNM 304311.)

6, Fragment, source of subsequent views of structure of wall and ornamentations, $\times 75$ (Specimen GG-7C, USNM 304313).

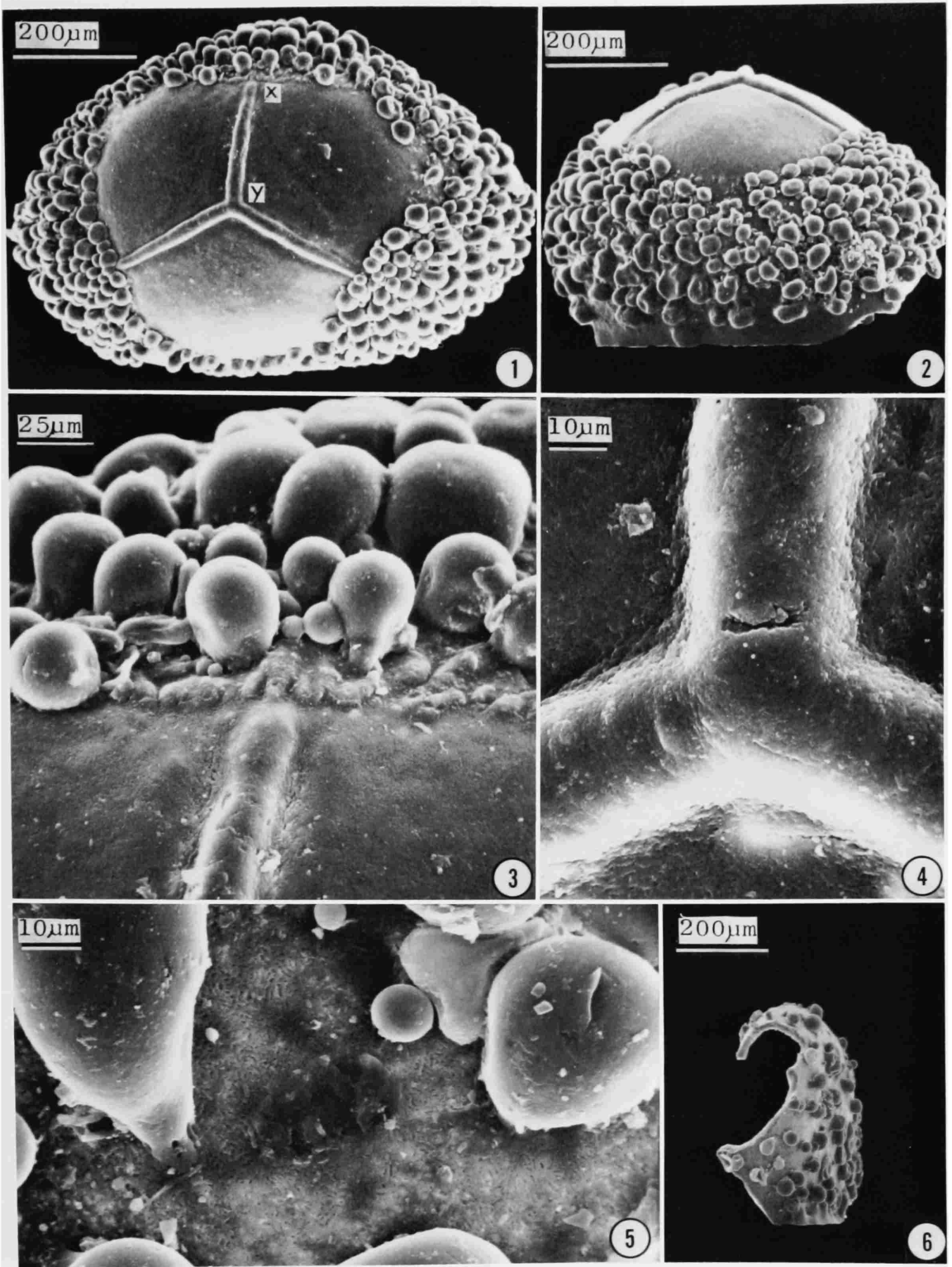


PLATE 2

FIGURES 1-7.—*Verrutriletes carbunculus* (Dijkstra) Potonié: 1, Vertical section of spore coat with gemma in place, $\times 2000$; 2, outer exoexine surface with gemma and former site of gemma attachment (arrow), $\times 1000$; 3, oblique view of inner surface of spore coat showing depression immediately beneath gemma, $\times 1000$. (Specimen GG-7C, USNM 304313.)

4, Proximal view, $\times 85$; 5, distal view $\times 85$; 6, view at x in figure 4 at 45° tilt, $\times 500$; 7, view of sculpture at y in figure 5, $\times 350$. (Specimen GG-7B, USNM 304312.)

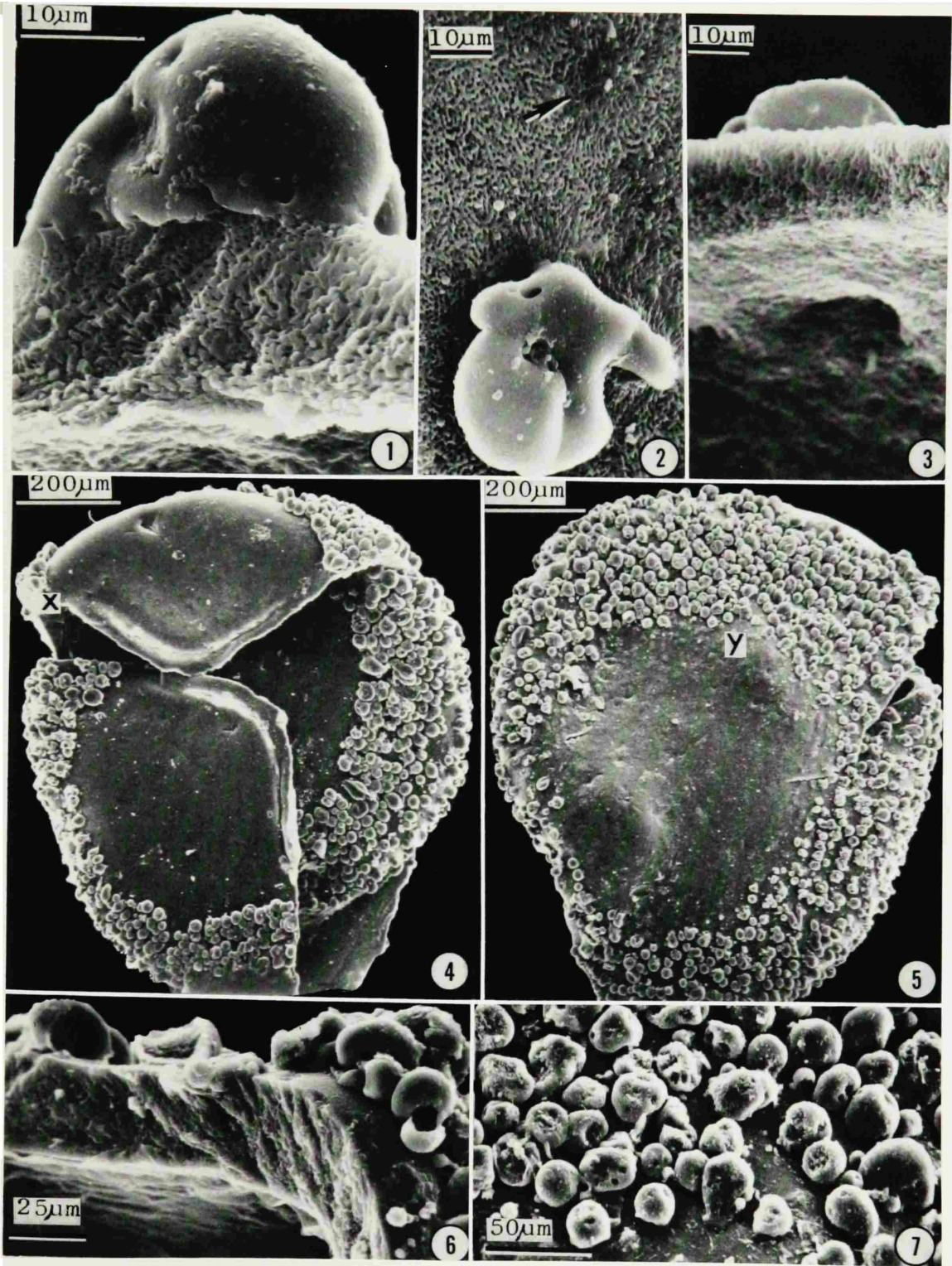


PLATE 3

FIGURES 1-4.—*Verrutriletes carbunculus* (Dijkstra) Potonié: 1, View of broken margin of one of laesurae and of morphology of gemma, $\times 200$; 2, vertical section of sporoderm (end = endexine, i-ex = inner exoexine, g = gemmae), $\times 1000$; 3, fused gemmae with rupture revealing inner structure, $\times 3500$; 4, corroded gemma showing interior structure, $\times 3000$. (Specimen GG-7B, USNM 304312.)

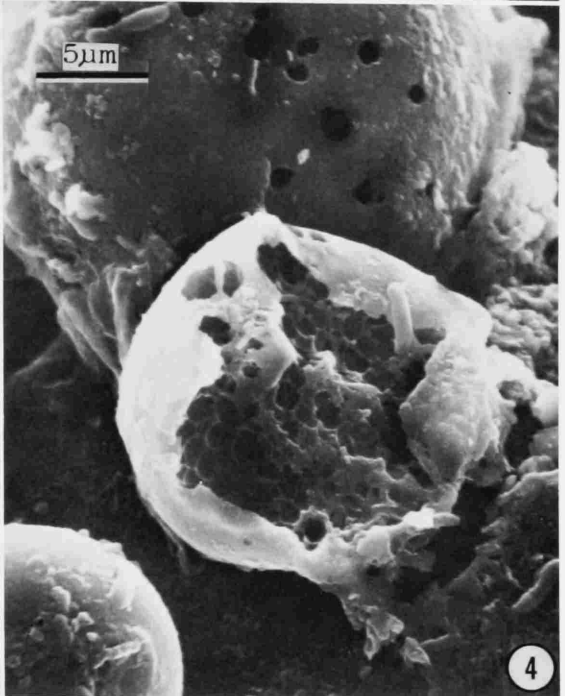
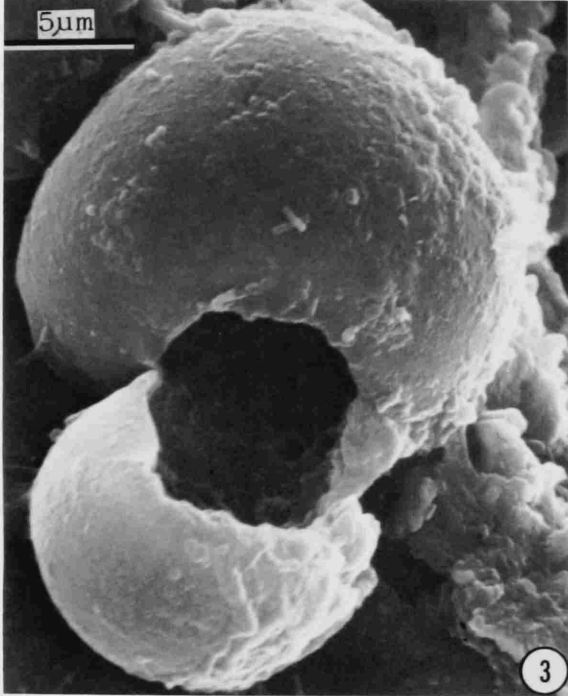
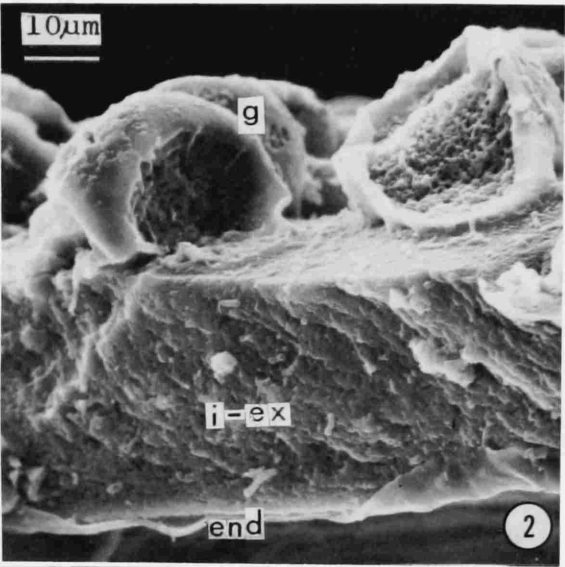


PLATE 4

FIGURES 1-4.—*Echitriletes* cf. *E. lanatus* (Dijkstra) Potonié: 1, Assumed proximal view, $\times 75$; 2, assumed distal view, $\times 75$; 3, view at x in figure 1 showing density and morphology of capilli, $\times 150$; 4, view at y in figure 1 showing bases of capilli and surface of outer exoexine, $\times 1000$. (Specimen HH-1A, USNM 304314.)

FIGURES 5, 6.—*Crybelosporites* species: 5, Microspores lodged among capilli at z in figure 2 (note folds of outer layer of sculpture (perine) on lower-most spore), $\times 1000$; 6, single microspore showing granulate surface of inner layer of "sculptine" impressed on outer layer of sculptine (perine), $\times 3000$. (On specimen HH-1A, USNM 304314.)

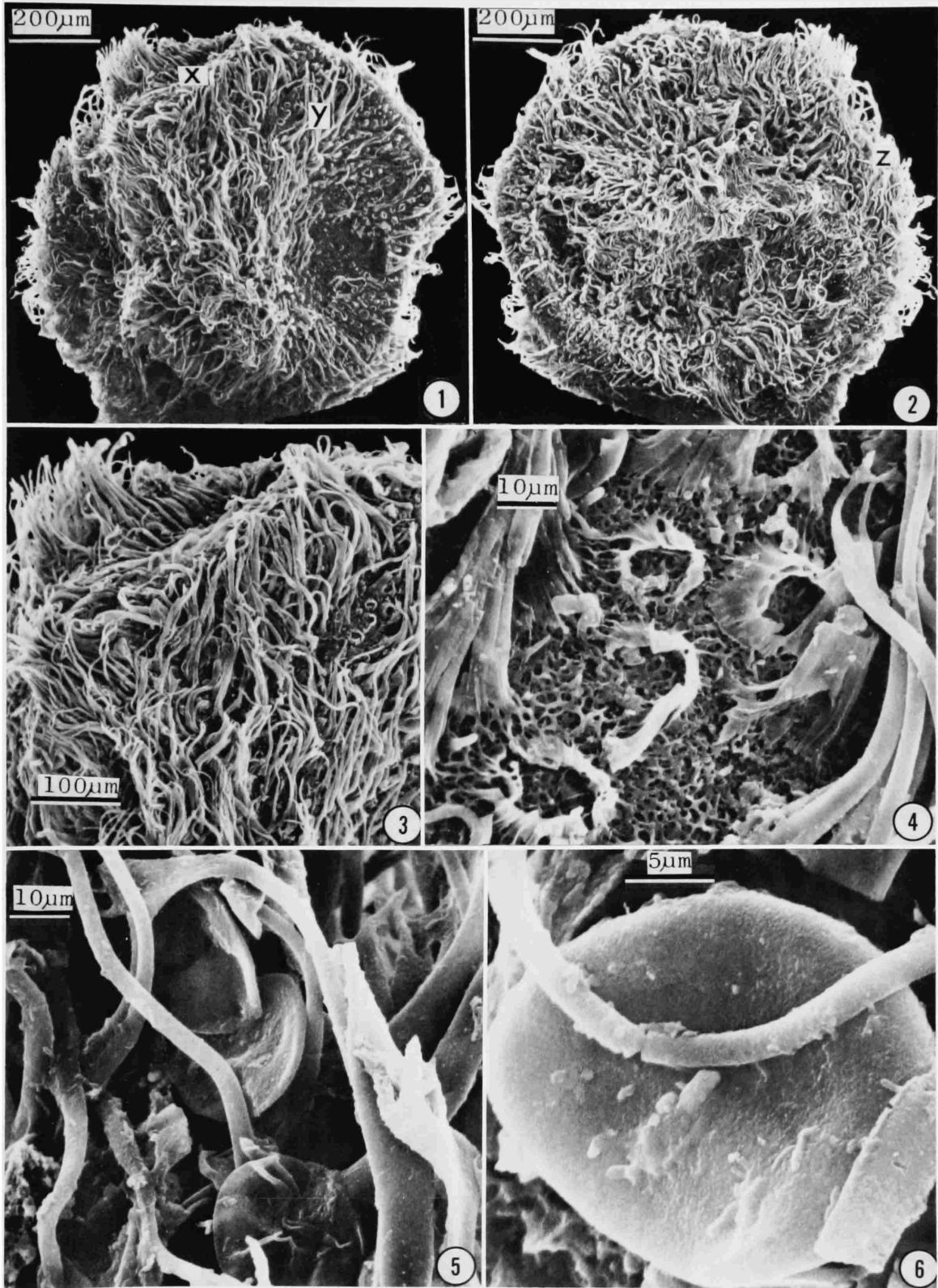


PLATE 5

FIGURES 1-4.—*Echitriletes* cf. *E. lanatus* (Dijkstra) Potonié: 1, Assumed proximal view, $\times 75$; 2, outer exoexine surface at x in figure 1, $\times 1000$; 3, assumed distal view, $\times 75$; 4, divided tips of capilli at y in figure 3, $\times 150$. (Specimen HH-1B, USNM 304315.)

FIGURES 5, 6.—*Crybelosporites* species: Microspores lodged among capilli at z in figure 3, $\times 1000$; 6, distal view of microspore collapsed, and with Y-mark evident as depression; outer layer of sculptine (perine) suggested by folds on left and lower right margins of spore, $\times 3000$. (On specimen HH-1B, USNM 304315.)

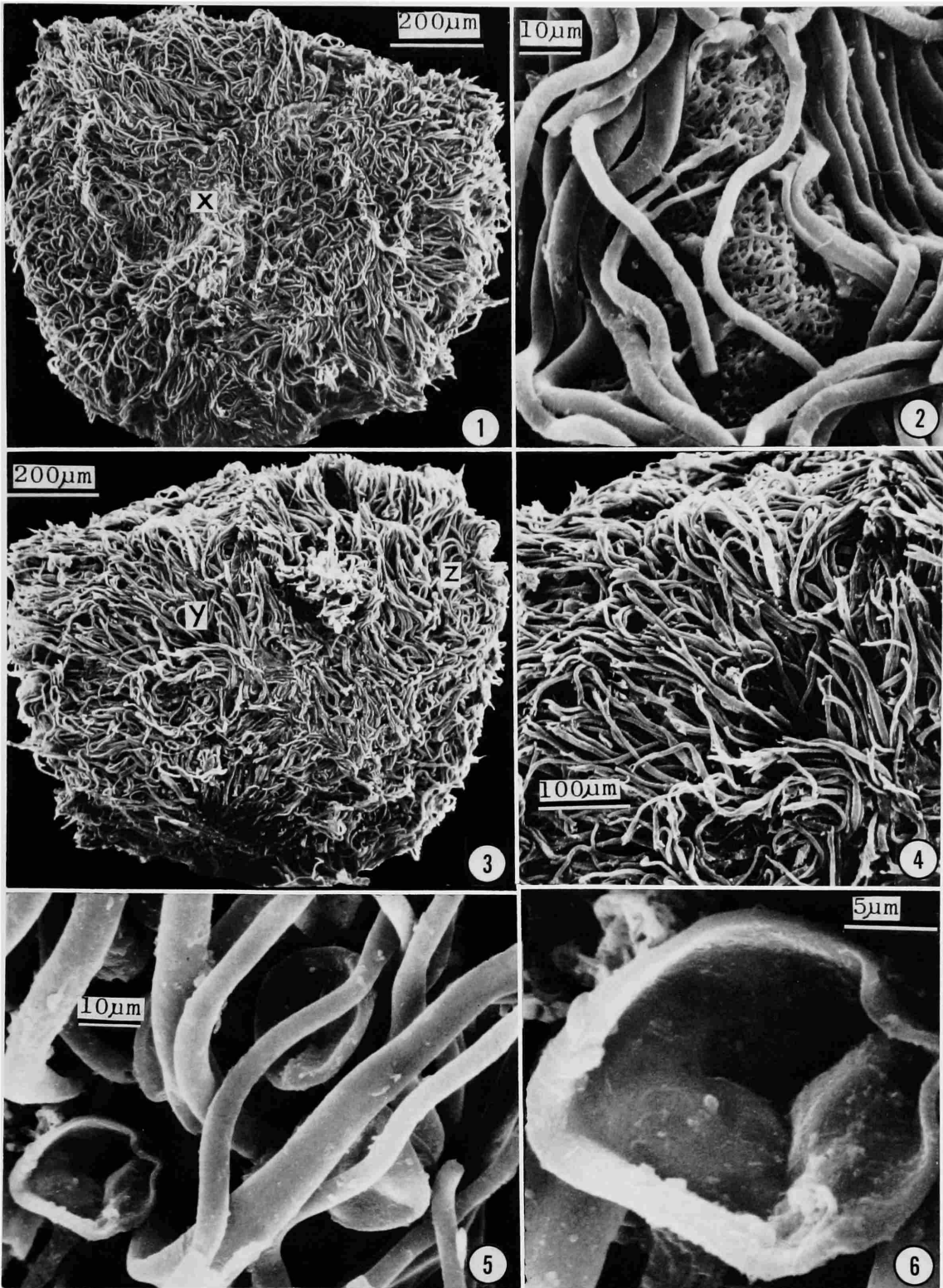


PLATE 6

FIGURE 1-6.—*Erlansonisporites erlansonii* (Miner) Potonié: 1, Proximal view, $\times 115$; 2, equatorial view (clockwise rotation), $\times 115$; 3, distal view, $\times 115$; 4, low murus and texture of outer exoexine at x in figure 1, $\times 2300$; 5, diaphanous muri extending between bastions, apices of bastions rounded, view at y in figure 1, $\times 550$; 6, reticulate surfaces of muri, $\times 1500$. (Specimen GG-10B, USNM 304316.)

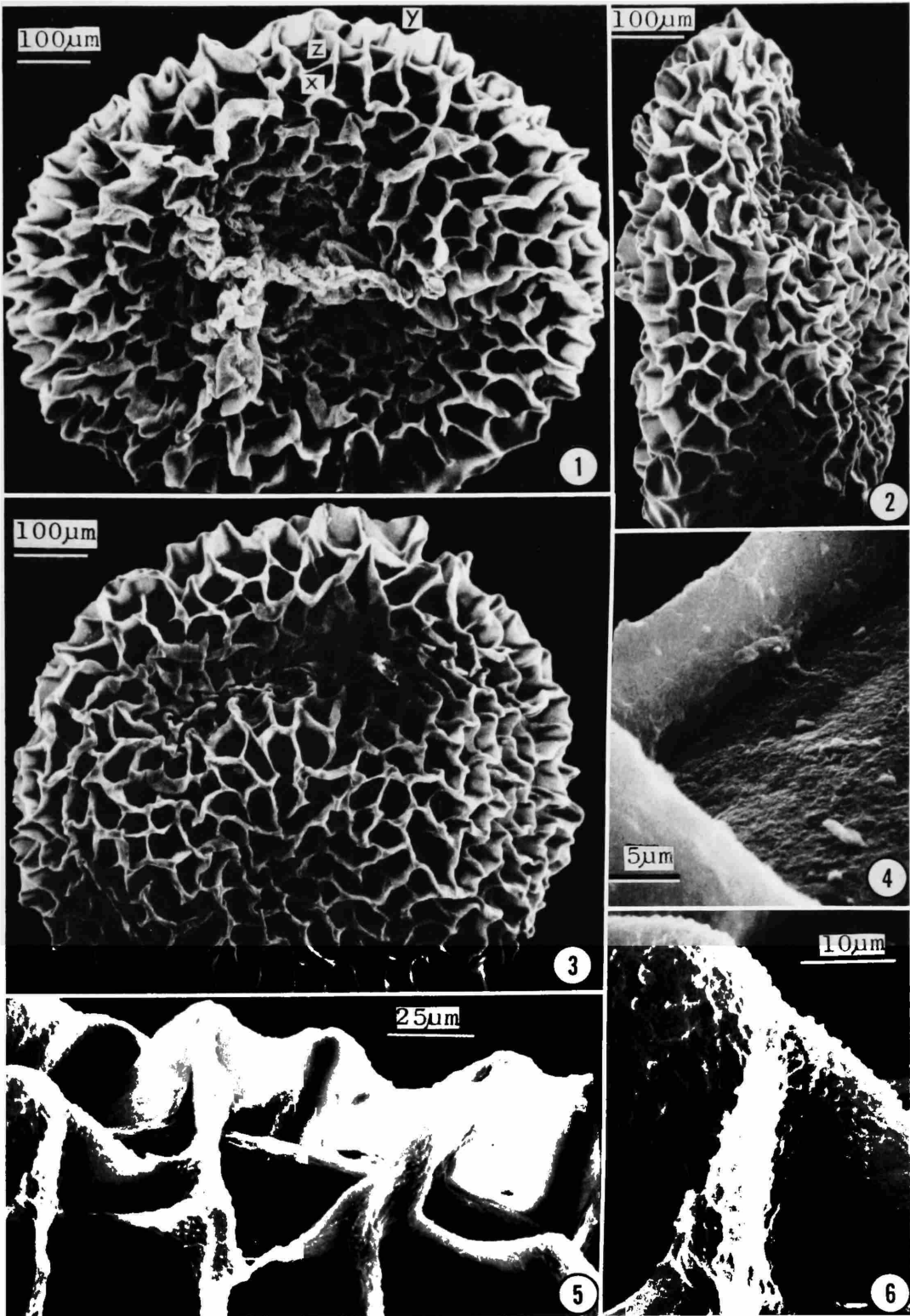


PLATE 7

FIGURES 1-6.—*Thylakosporites retiaris* (Hughes) Potonié: 1, Apical view of tetrahedral tetrad, $\times 40$; 2, basal view of tetrahedral tetrad of spores, $\times 40$; 5, area at x in figure 2 showing reticulum of outer exoexine partially free of layer of organic material that coats whole tetrahedral tetrad, $\times 125$. (Specimen GG-8A, USNM 304320.)

3, Probable equatorial view, broken area in lower left representing margin of contact point in tetrahedral tetrad, $\times 70$; 4, reverse side of specimen, $\times 70$; 6, view of morphology of reticulum at y in figure 3, $\times 200$. (Specimen HH-2B, USNM 304324.)

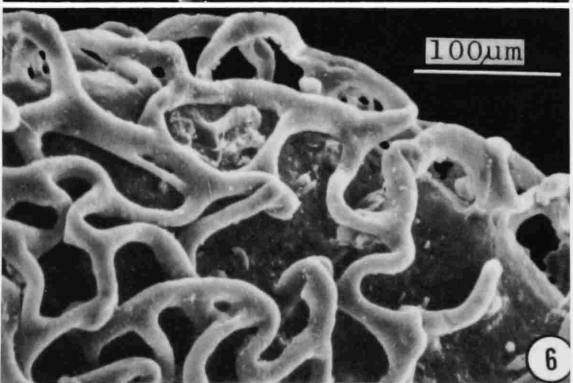
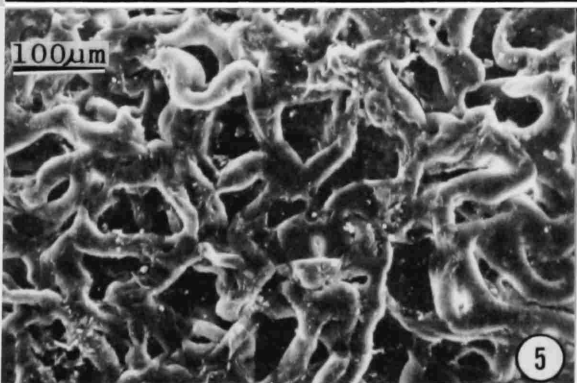
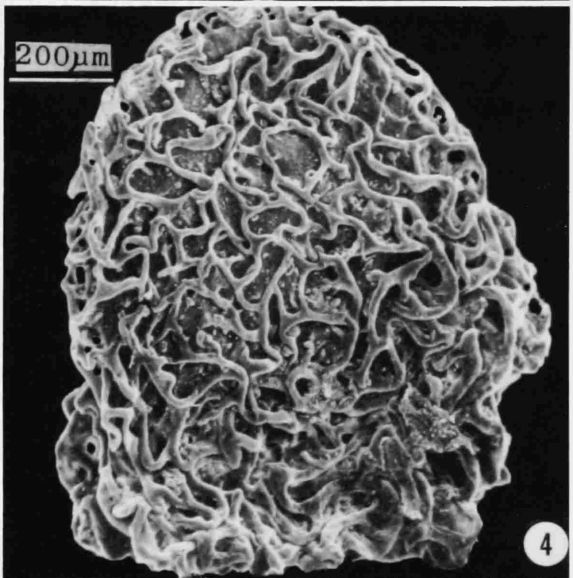
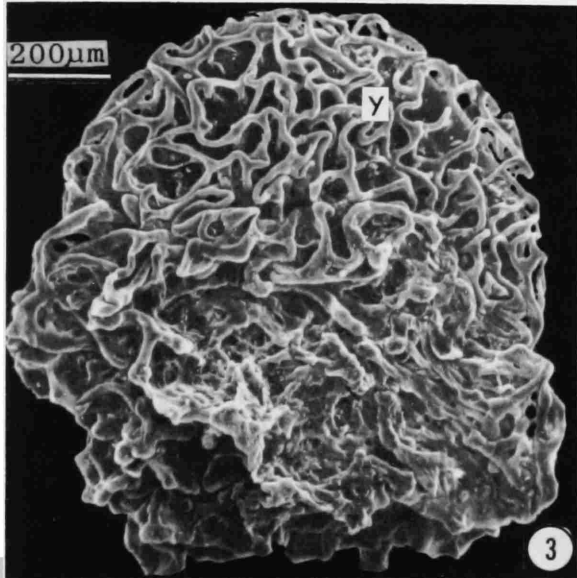
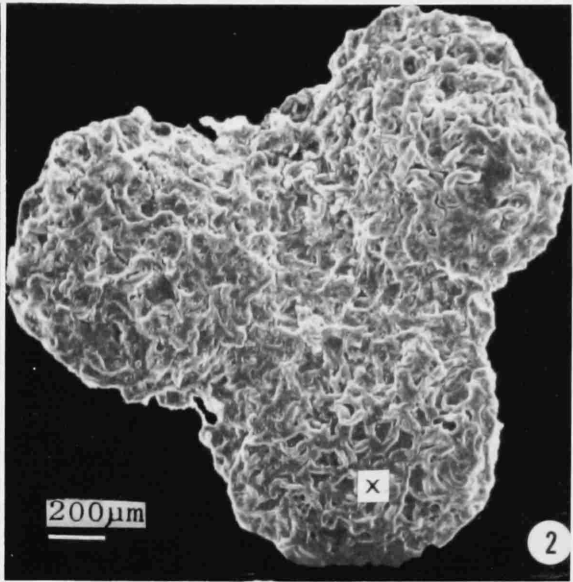
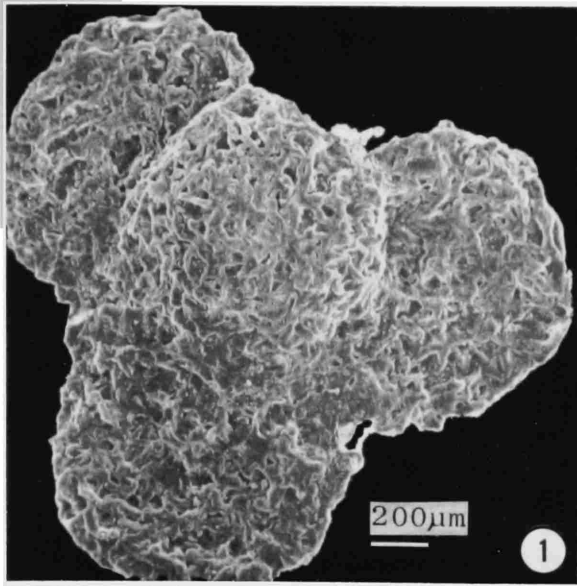


PLATE 8

FIGURES 1-8.—*Thylakosporites retiaris* (Hughes) Potonié: 1, Surface of outer exoexine between elements of reticulum, $\times 5000$ (specimen HH-2B, USNM 304324).

2, Distal view, $\times 100$; 3, proximal view with area of commissure broken away, $\times 100$; 4, view at x in figure 3 with specimen tilted toward viewer at about 30° showing points of attachment of elements of reticulum, both intact and broken, $\times 325$; 5, transverse section of spore coat (o-ex = outer exoexine, i-ex = inner exoexine, end = endexine), $\times 2500$; 6, finely reticulate sculpture of the outer exoexine, $\times 10,000$; 7, orderly arrangement of spherular elements forming inner exoexine, $\times 10,000$; 8, reticulate structure of endexine as seen in surface view, $\times 10,000$. (Specimen GG-10C, USNM 304322.)

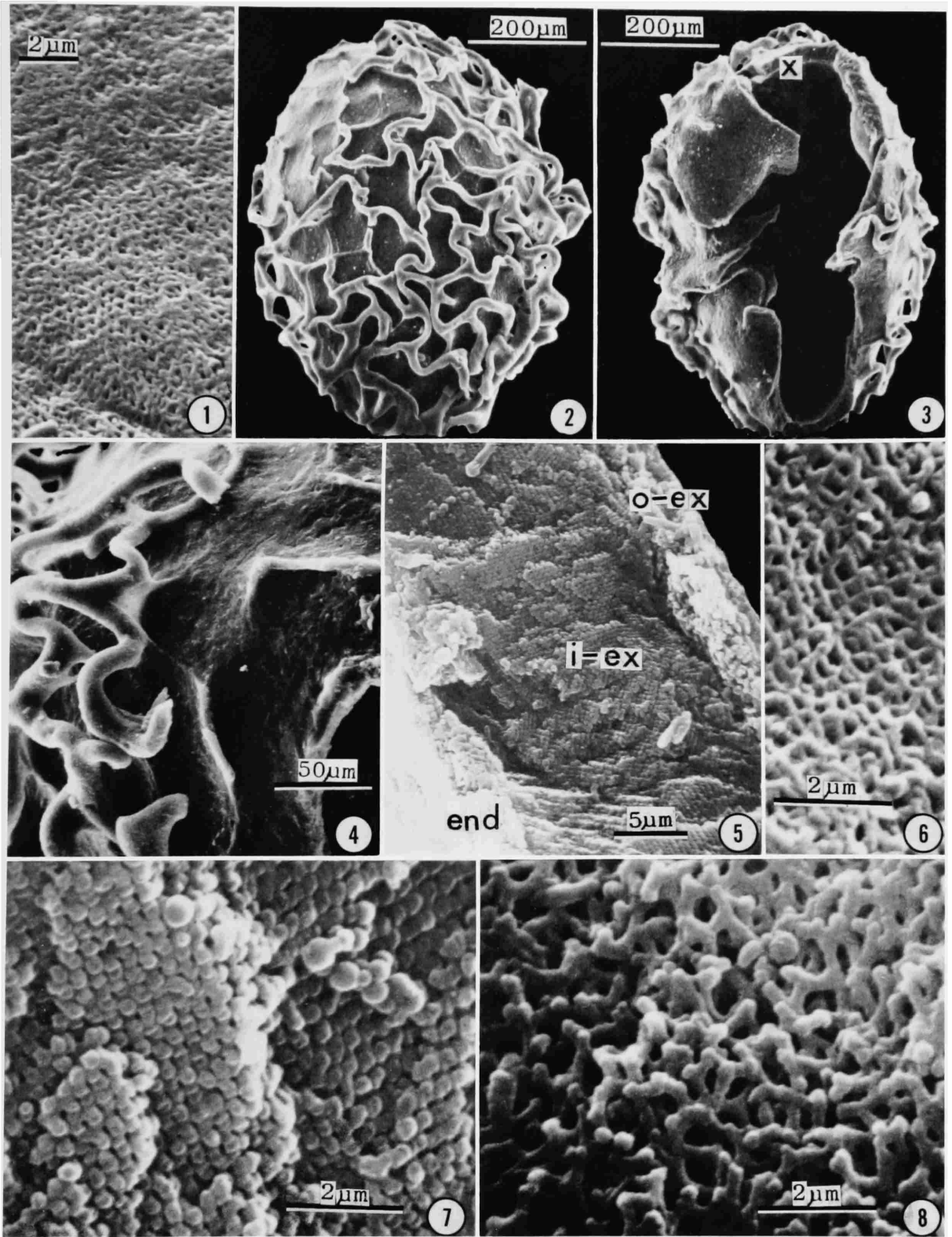


PLATE 9

FIGURES 1-6.—*Thylakosporites retarius* (Hughes) Potonié: 1, Proximal view of crushed and eroded specimen, Y-mark exaggerated due to folding, $\times 150$; 2, transverse section of spore coat at x in figure 1, (o-ex = outer exoexine) eroded except at points of attachment of reticulum (i-ex = inner exoexine, end = endexine) loosened and folded, $\times 600$; 3, near-equatorial view showing remnants of points of attachment of reticulum (Plate 8, figure 4), $\times 140$; 4, orderly arrangement of spherular elements forming inner exoexine and in turn giving rise to opal-like quality of spore coat as seen in reflected light, view at y in figure 2, $\times 5000$; 5, remnants of surface of outer exoexine particularly at arrow, $\times 5000$; 6, additional view of spherular elements seen at y in figure 2, $\times 10,000$. (Specimen BB-12A, USNM 304319.)

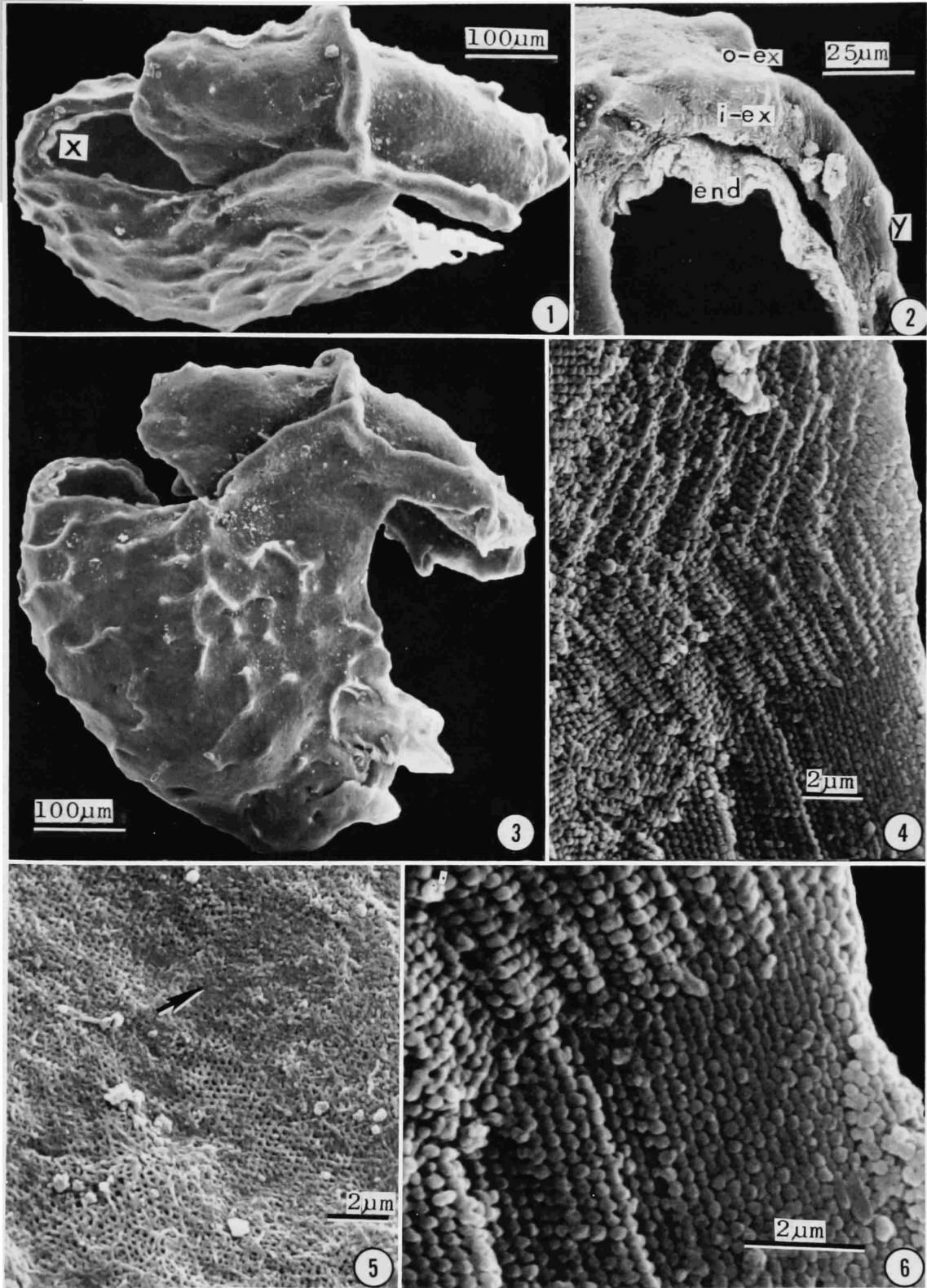


PLATE 10

FIGURES 1-6.—*Thylakosporites retiaris* (Hughes) Potonié: 1, Slightly oblique proximal view showing erosion and corrosion of spore coat, $\times 150$; 2, oblique distal view showing areas of corrosion and separation of spore coat elements, $\times 150$; 3, area x in figure 2 (end = endexine, i-ex = inner exoexine, o-ex = outer exoexine), $\times 500$. (Specimen GG-10A, USNM 304321.)

4, Fragment of distal portion of spore with reticulum intact, $\times 130$; 6, transverse section of strand of reticulum viewed at y in figure 4, $\times 3000$. (Specimen GG-10D, USNM 304323.)

5, Reticulate surface structure of one reticulum strand, $\times 4500$. (Specimen GG-10C, USNM 304322.)

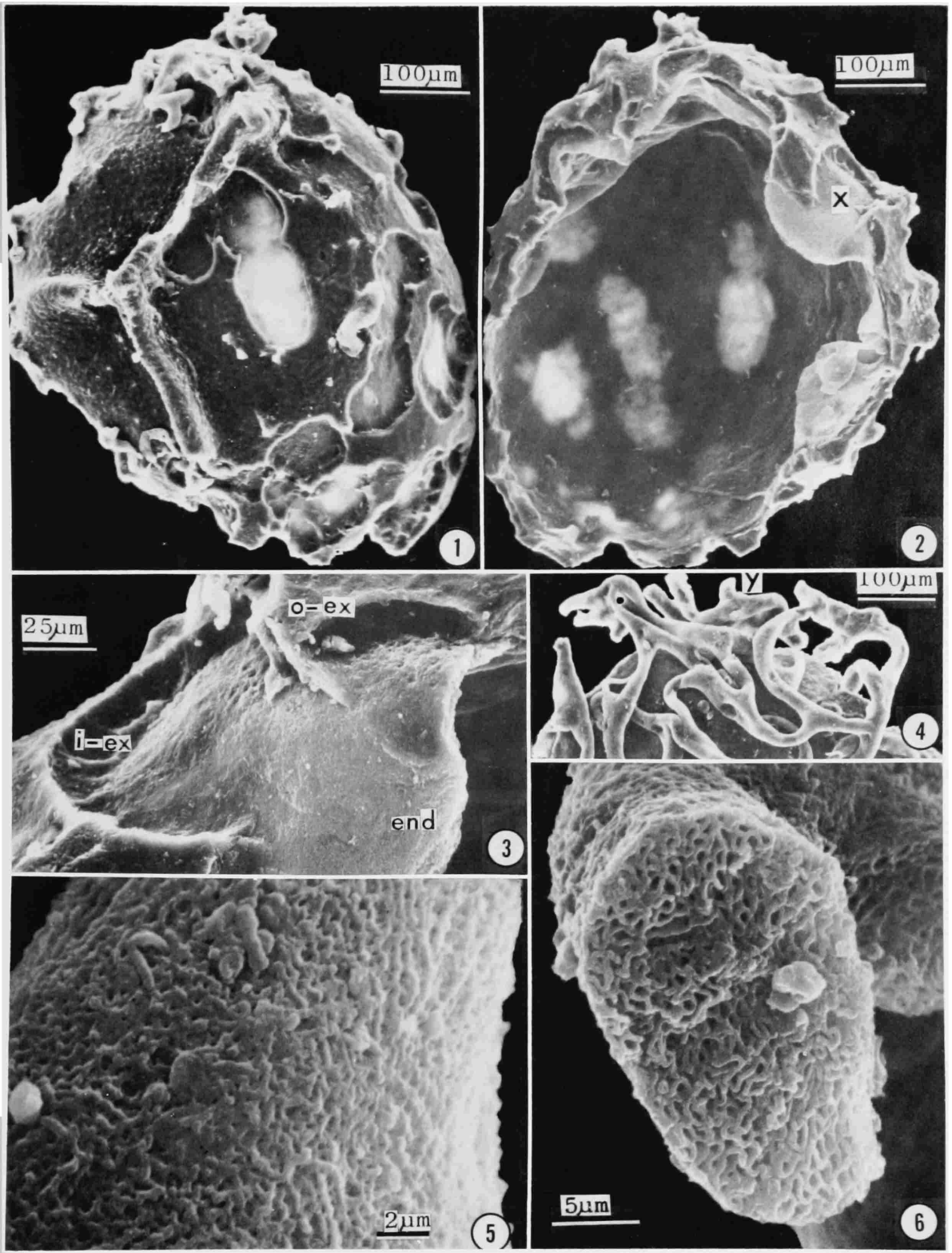


PLATE 11

FIGURES 1-4.—*Crybelosporites striatus* (Cookson and Dettmann) Dettmann: 1, Microspores resting in folds of acrolamellae of megaspore, $\times 170$; 2, folding of outer exoexine (perine) of spores, $\times 750$; 4, single spore at x in figure 2 showing reticulate surface of inner exoexine and outer cavate exoexine, $\times 2000$. (Specimen of *Arcellites disciformis* (Miner) Ellis and Tschudy, GG-6A, USNM 304329 with seven adherent microspores.)

3, Additional examples of this microspore on second specimen of *Arcellites disciformis*, $\times 1250$. (Specimen of *Arcellites disciformis* (Miner) Ellis and Tschudy, BB-11C, USNM 304328, with adherent microspores.)

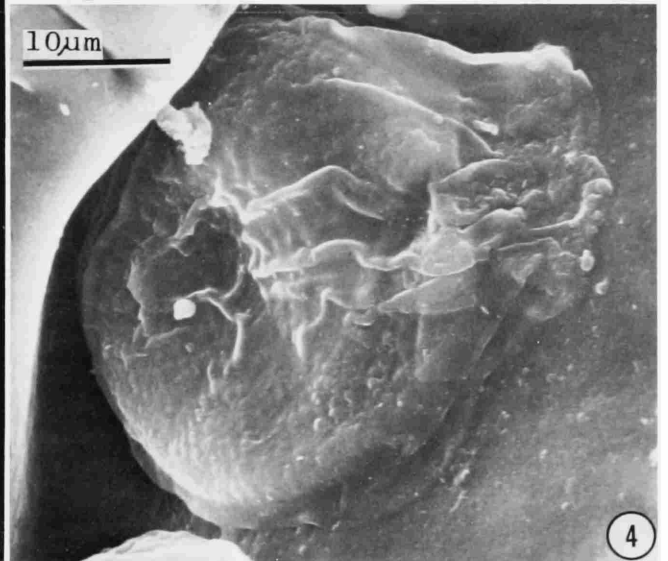
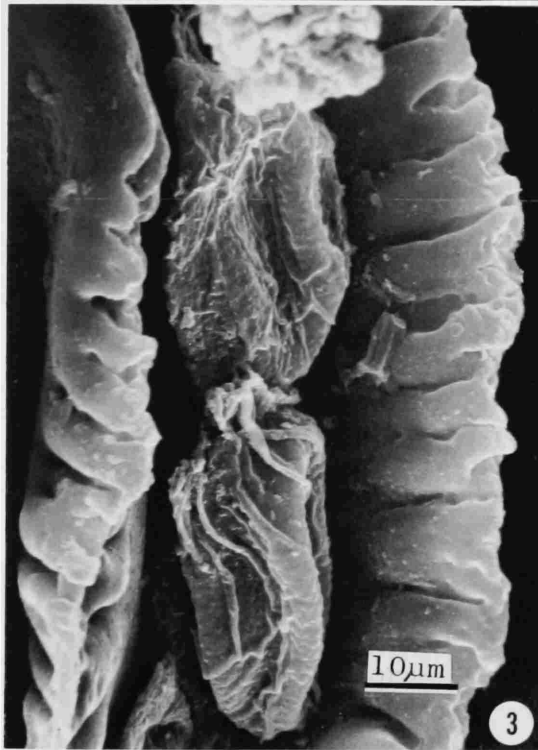
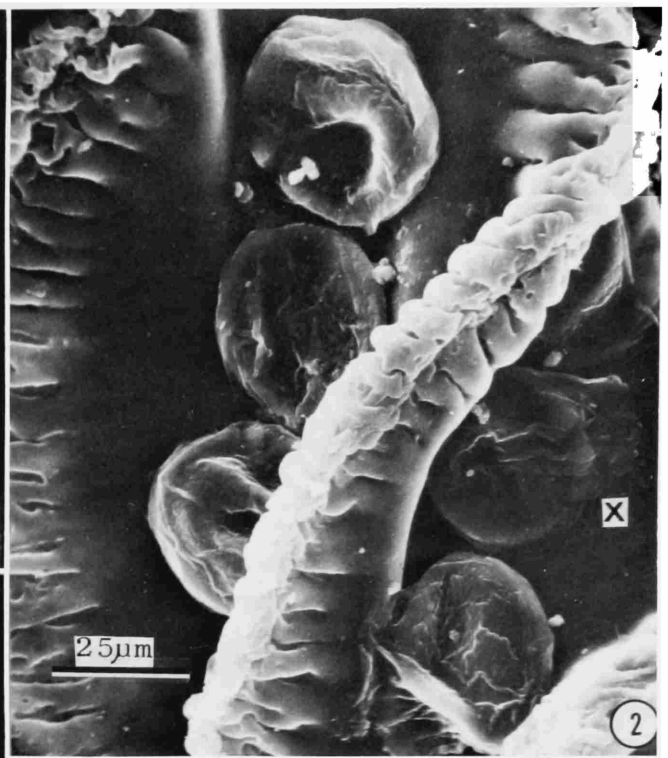
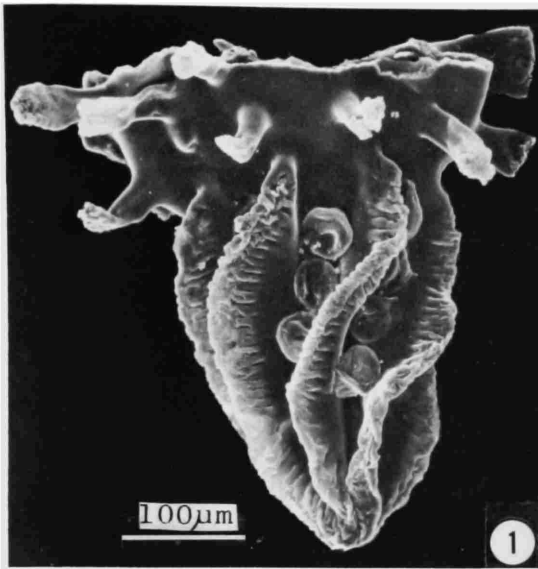


PLATE 12

FIGURE 1-4.—*Arcellites disciformis* (Miner) Ellis and Tschudy: 1, Equatorial view showing tube-like appendages ornamenting body of spore and plicate, crenulate-margined acrolamellae forming neck and chamber above Y-mark, $\times 170$; 2, proximal view showing torsion of acrolamellae forming neck, $\times 240$. (Specimen BB-11B, USNM 304331.)

3, Equatorial view of extremely well-preserved specimen except for flattening of tube-like appendages, $\times 170$; 4, proximal view shows greater expansion of acrolamellae forming neck, $\times 240$. (Specimen BB-11A, USNM 304330.)

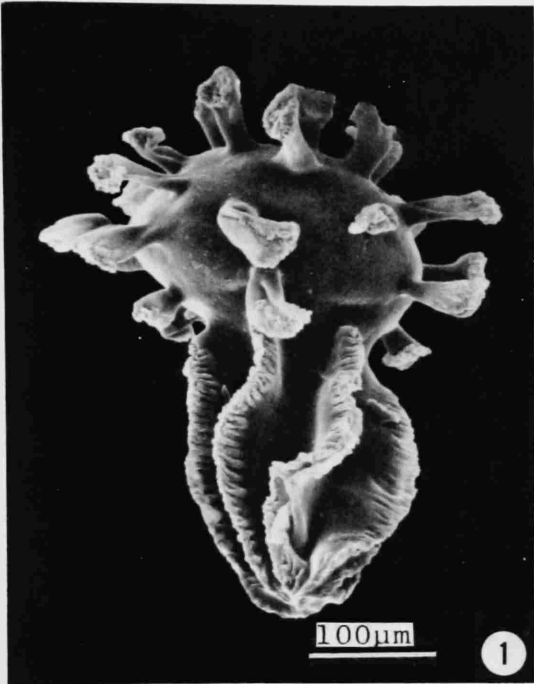


PLATE 13

FIGURES 1-4.—*Arcellites disciformis* (Miner) Ellis and Tschudy: 1, Equatorial view of specimen mounted by apices of acrolamellae, tubular nature of body appendages clearly demonstrated, $\times 170$; 2, distal view showing distribution of body appendages and punctate texture of outer exoexine, $\times 170$. (Specimen GG-5C, USNM 304338.)

3, Equatorial view showing narrow, elongate neck, $\times 170$; 4, proximal view showing separation of crenulate margins of some of acrolamellae, $\times 280$. (Specimen GG-5A, USNM 304337.)

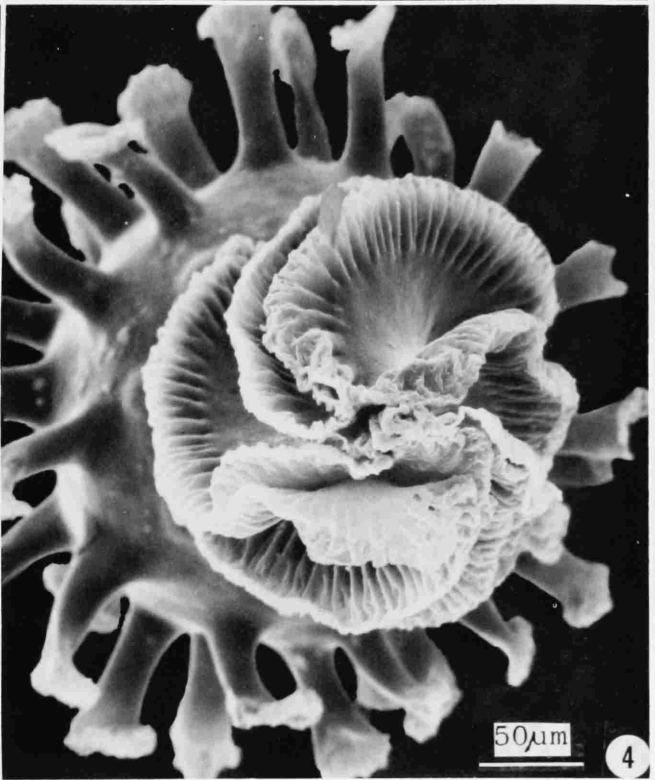
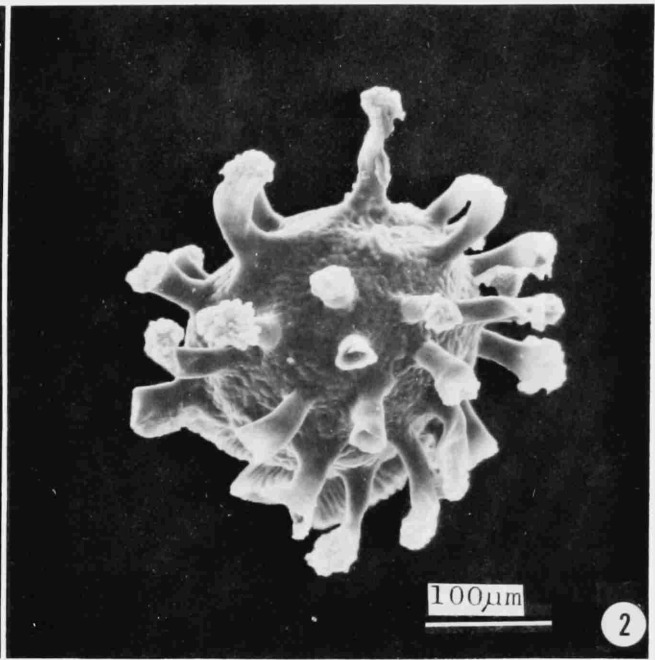


PLATE 14

FIGURES 1-4.—*Arcellites disciformis* (Miner) Ellis and Tschudy: 1, Crushed specimen showing separation of individual acrolamellae, $\times 170$; 2, enlarged view to show detail of morphology of margins of acrolamellae, $\times 350$. (Specimen GG-4B, USNM 304335.)

3, Equatorial view of obliquely crushed specimen showing microspores (*Crybelosporites striatus*) lodged in plications of acrolamellae, $\times 170$; 4, proximal view showing pronounced torsion of acrolamellae, $\times 280$. (Specimen BB-11C, USNM 304328.)

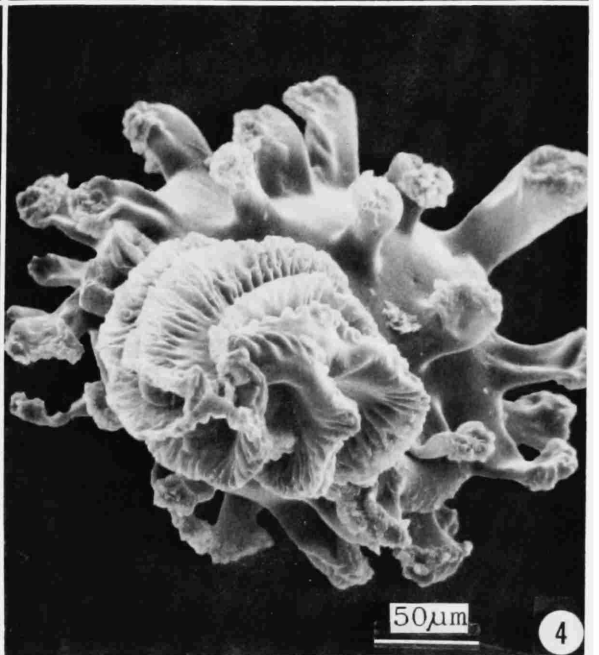
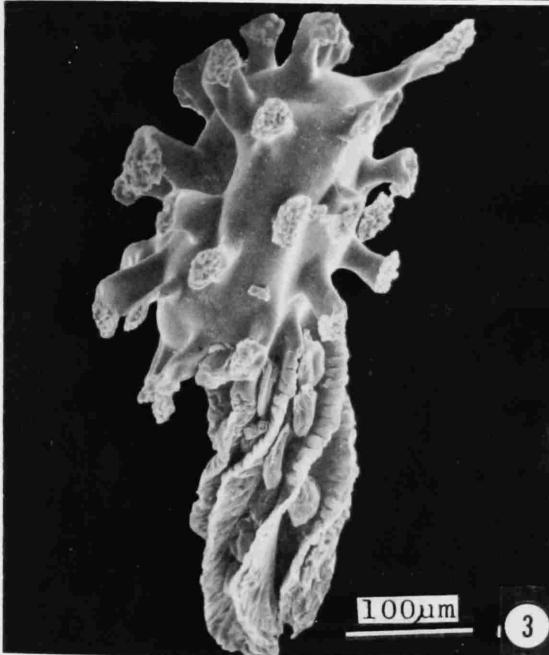
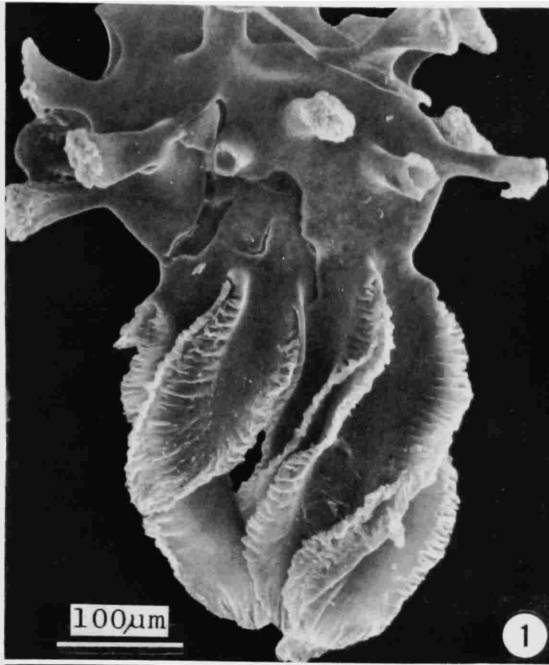


PLATE 15

- FIGURE 1-4.—*Arcellites disciformis* (Miner) Ellis and Tschudy: 1, Proximal view showing chamber or neck cavity formed by acrolamellae, apices of acrolamellae were removed by dissection, $\times 340$; 2, separation of acrolamellae and demonstration of single-layered construction of individual acrolamellae, $\times 1700$. (Specimen II-2, USNM 304340.)
- 3, Marginal contact of two acrolamellae showing intertangement of fimbriate margins and pores and interstices between crenae, $\times 2000$ (specimen GG-5A, USNM 304337).
- 4, Base of acrolamellae at point of origin from body of spore, $\times 1325$ (specimen BB-11A, USNM 304330).

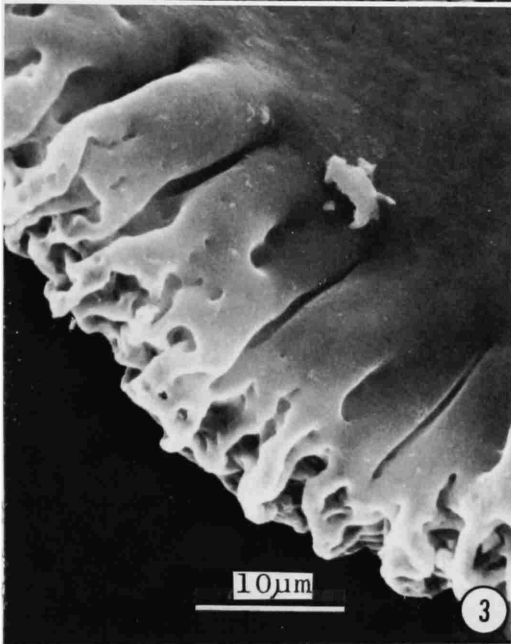
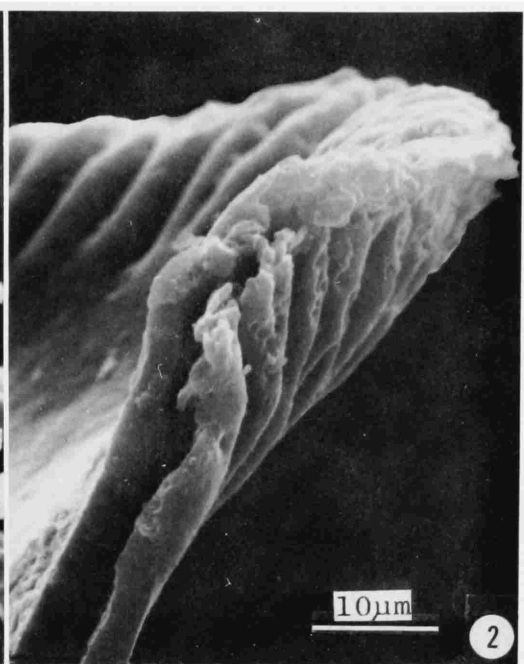


PLATE 16

- FIGURES 1-4.—*Arcellites disciformis* (Miner) Ellis and Tschudy: 1, Pitted structure of outer exoexine of spore body and continuation of structure into tubular appendage, $\times 1000$; 2, pitted surface structure of outer exoexine $\times 5500$. (Specimen BB-11A, USNM 304330.)
- 3, Irregularity in size of pits possibly due to corrosion as shown by thinned areas that transmit electron beam through specimen, $\times 4000$ (specimen GG-5A, USNM 304337).
- 4, Pitted surface structure of outer exoexine clearly visible as well as undeveloped body appendages represented by rounded protuberances from body surface, $\times 1600$ (specimen BB-11F, USNM 304332).

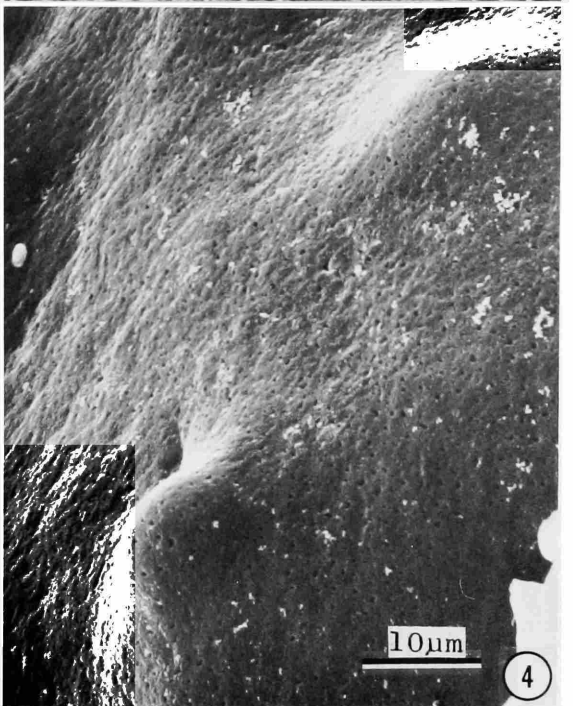
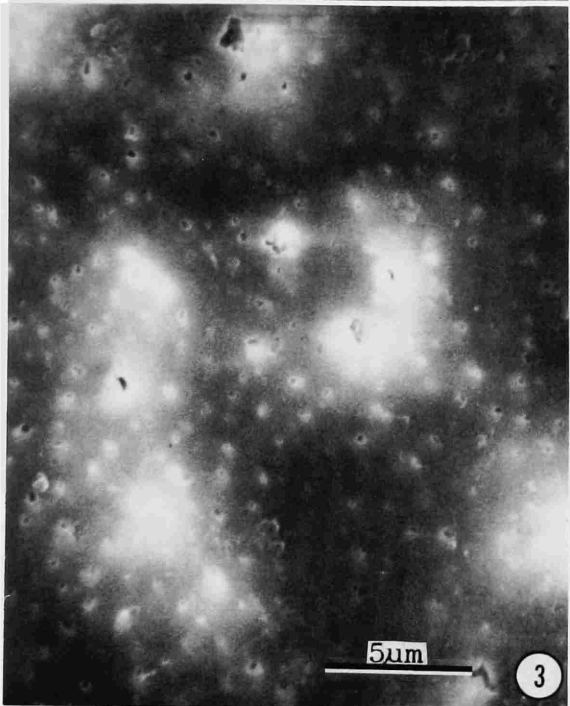
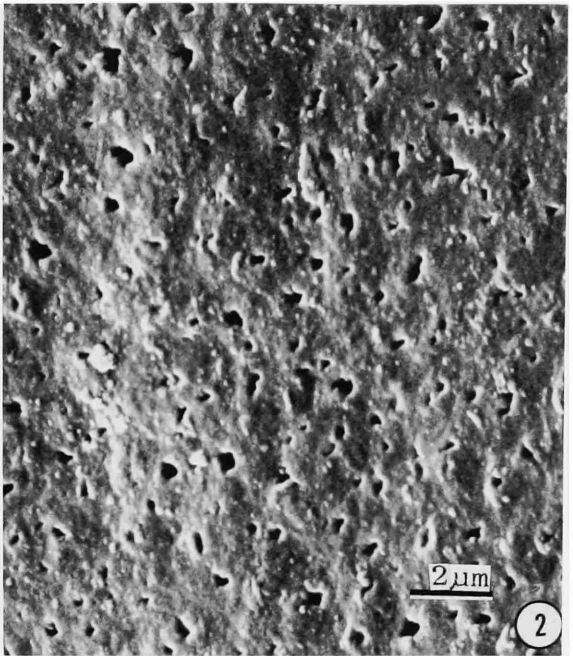
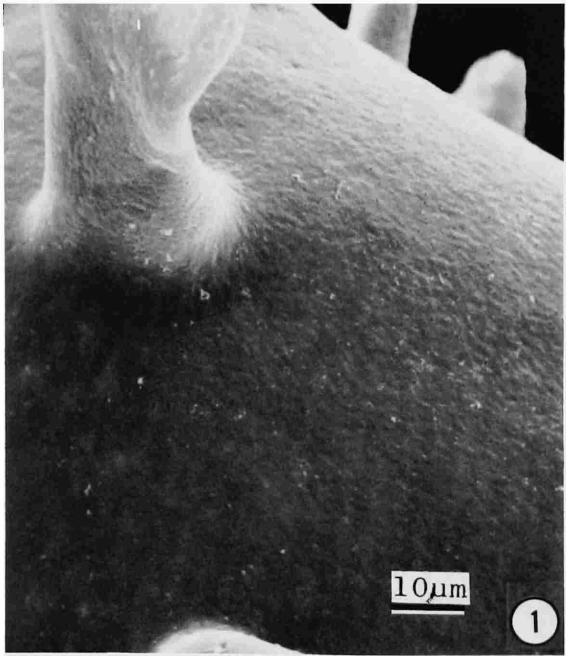


PLATE 17

FIGURES 1-4.—*Arcellites disciformis* (Miner) Ellis and Tschudy: 1, Spore body sectioned transversely to demonstrate spore coat structure, $\times 240$; 2, view at x in figure 1 (o-ex = outer exoexine, i-ex = inner exoexine, end = endexine), $\times 4000$. (Specimen GG-4A, USNM 304334.)

3, Vertical section through base of body appendage and onward through spore wall (note outer exoexine and inner exoexine rising into base of appendage, endexine layer seen at lowest level of section), $\times 3000$ (specimen GG-4C, USNM 304336).

4, Transverse section of base of body appendage showing outer exoexine and limit of extension of inner exoexine into appendage, $\times 3500$ (specimen GG-5C, USNM 304338).

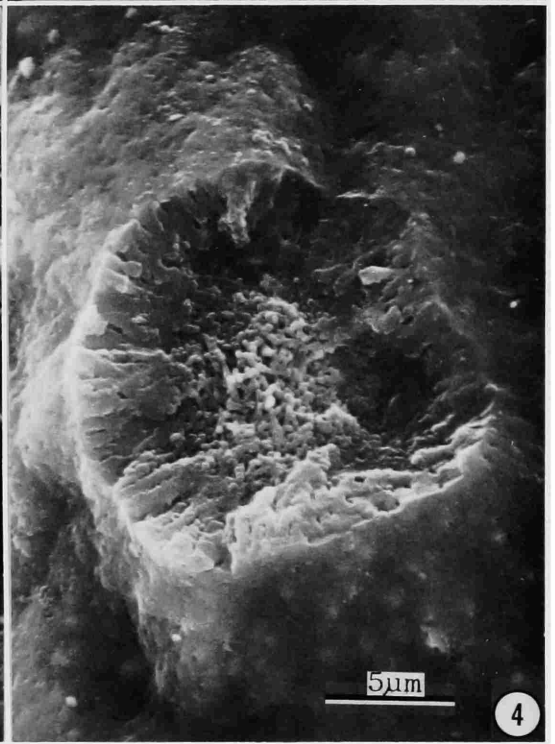
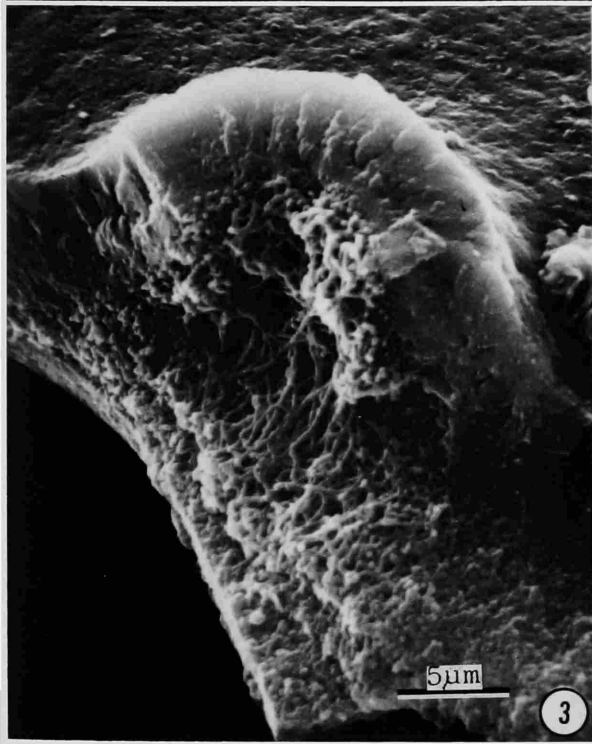
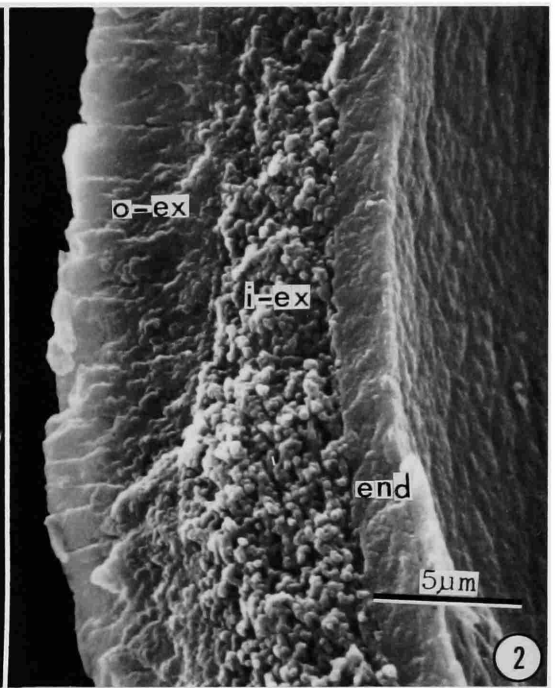
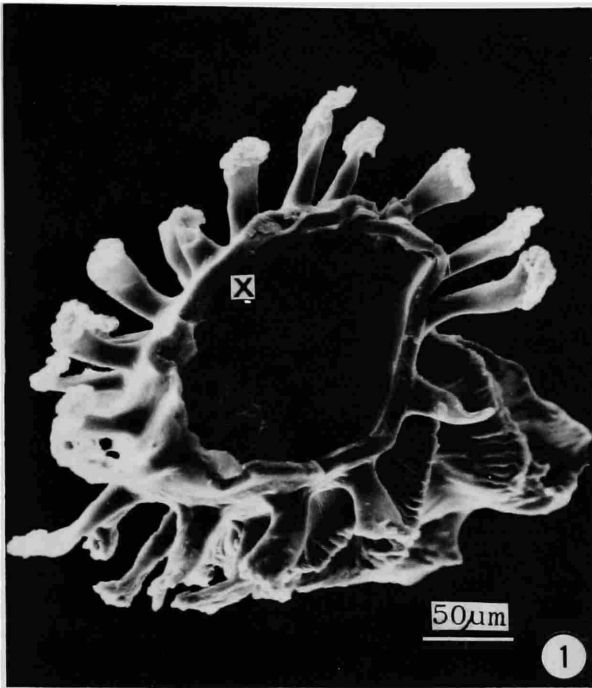


PLATE 18

FIGURES 1-5.—*Arcellites disciformis* (Miner) Ellis and Tschudy: 1, Body appendages, intact and with broken apex, $\times 750$; 2, appendage with ruptured apex, suggesting partially collapsed bulbous tip, $\times 1500$; 5, view downward into interior of body appendage showing reticulate structure of inner exoexine at bottom and characteristic structure of outer exoexine, $\times 3200$. (Specimen GG-5C, USNM 304338.)

3, Longitudinal section through body appendage showing outer exoexine forming wall of appendage and inner exoexine extending only slightly into base, endexine clearly discernible, forming inner layer of spore coat, $\times 1000$ (specimen GG-6A, USNM 304329).

4, Inwardly contracted apex of body appendage with structure similar to fimbriate margins of acrolamellae, $\times 7000$ (specimen GG-5A, USNM 304337).

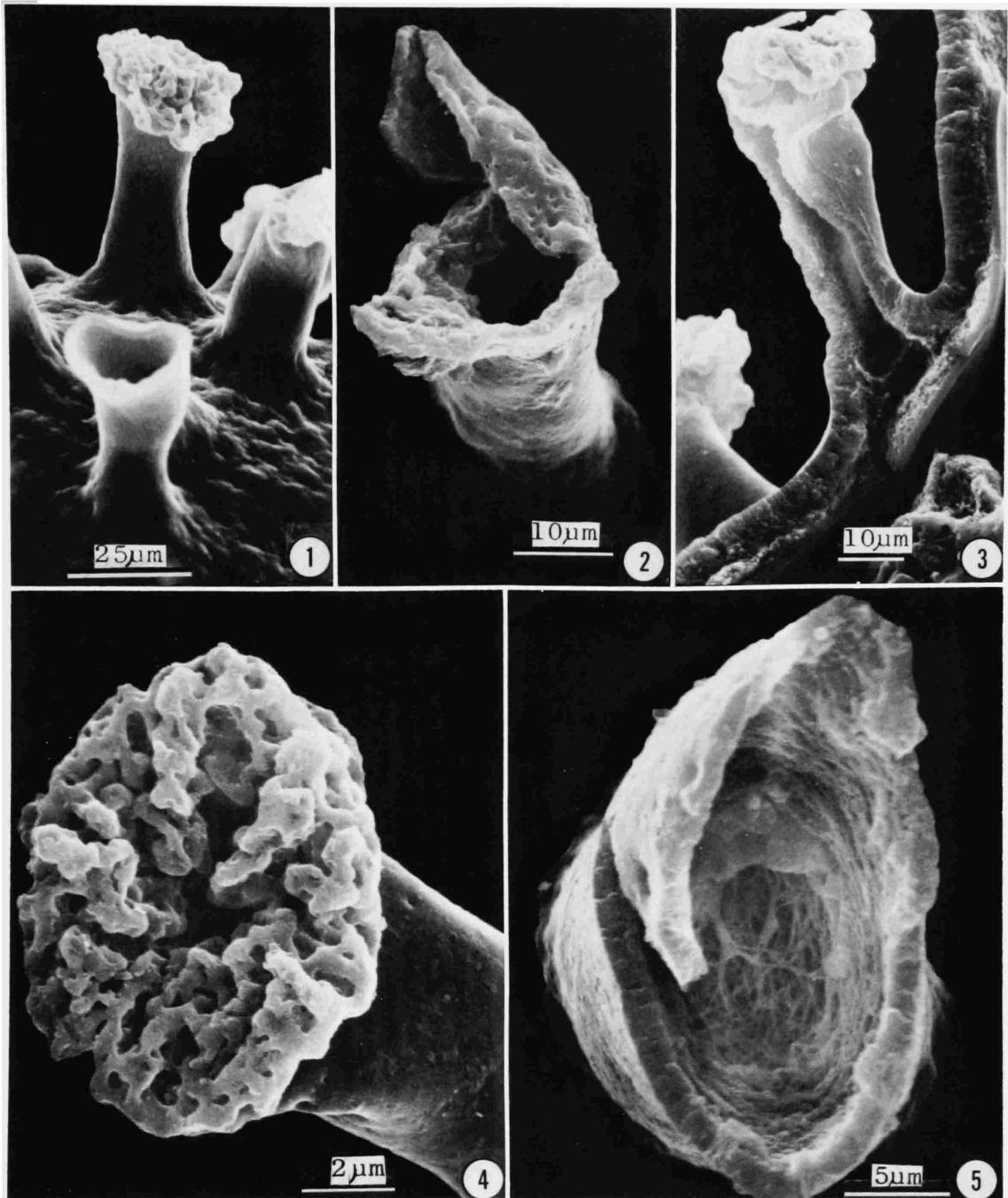


PLATE 19

FIGURES 1-4.—*Arcellites disciformis* (Miner) Ellis and Tschudy: 1, Equatorial view of specimen showing level of section required to reveal position of Y-mark, $\times 170$; 2, view into spore body cavity with Y-mark in position that corresponds to area directly beneath the cavity formed by acrolamellae, $\times 350$. (Specimen GG-3A, USNM 304333.)

3, Equatorial view of specimen badly broken during attempt to prepare transverse sections, chamber formed by acrolamellae imperfectly demonstrated but can be interpreted in this view, $\times 230$; 4, view into spore body cavity showing Y-mark and layering of spore coat, $\times 480$. (Specimen GG-6B, USNM 304339.)

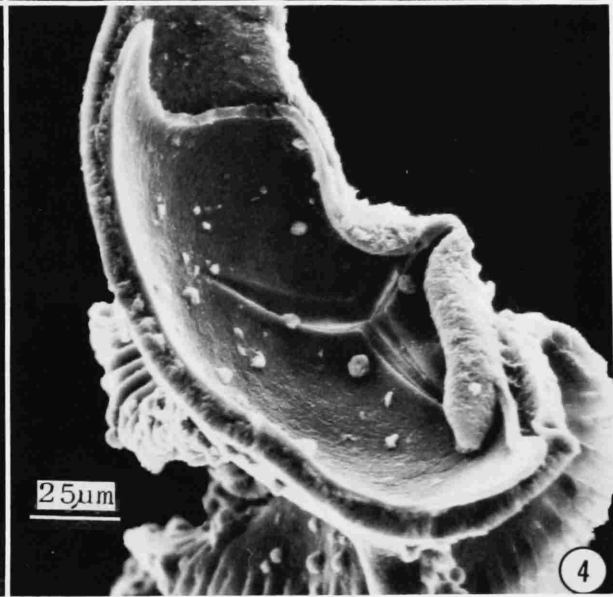
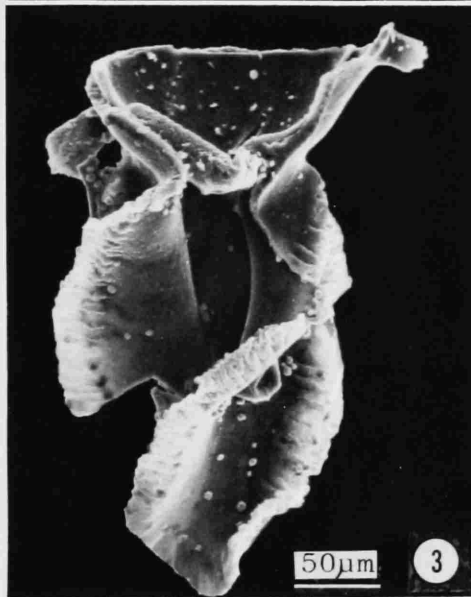
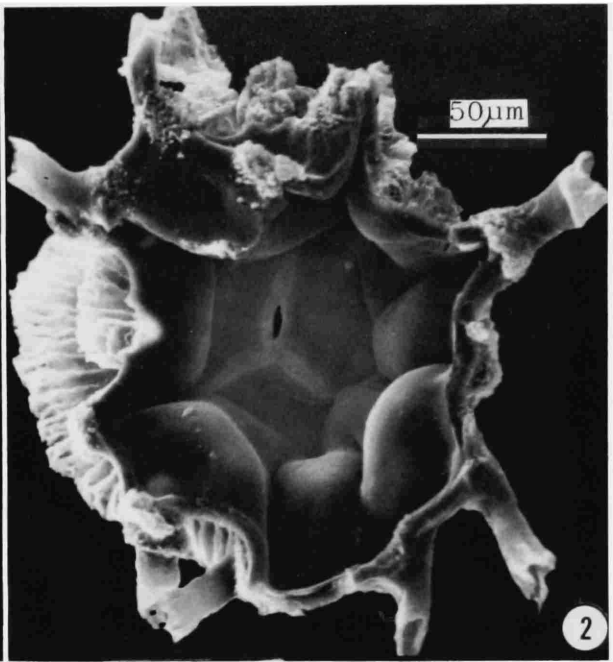
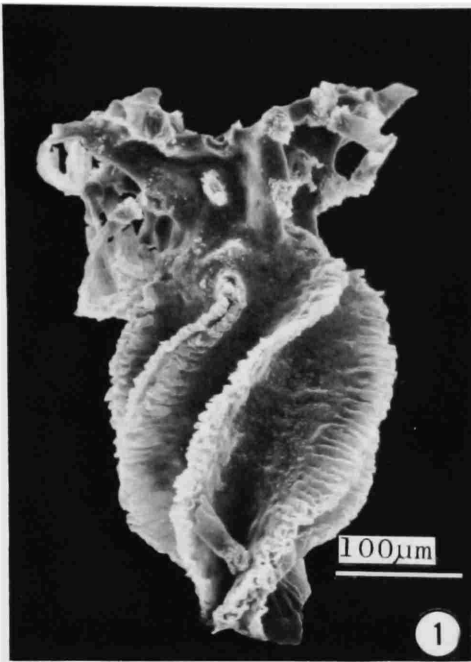


PLATE 20

FIGURES 1-7.—*Arcellites* cf. *A. pyriformis* (Dijkstra) Potter: 1, Near equatorial view, folds of neck-like projection broken away at lower left, $\times 90$; 2, view at x in figure 1 showing texture of outer exoexine surface and variation in morphology of the body appendages, $\times 180$; 3, broken side of spore from which some details of spore coat structure were obtained, $\times 90$; 4, detail at y in figure 3, the o-ex (outer exoexine) quite thick and forming body appendages seen in section; a thinner, i-ex (inner exoexine) appearing more loosely structured and end (endexine) seen as extremely thin layer, $\times 1000$; 5, detail at z in figure 3, $\times 500$; 6, detail at arrow in figure showing sculpture of exoexine and separation between outer exoexine and inner exoexine (note textural differences), $\times 5000$; 7, detail of outer exoexine surface texture in figure 5, $\times 8,500$. (Specimen BB-12, USNM 304342.)

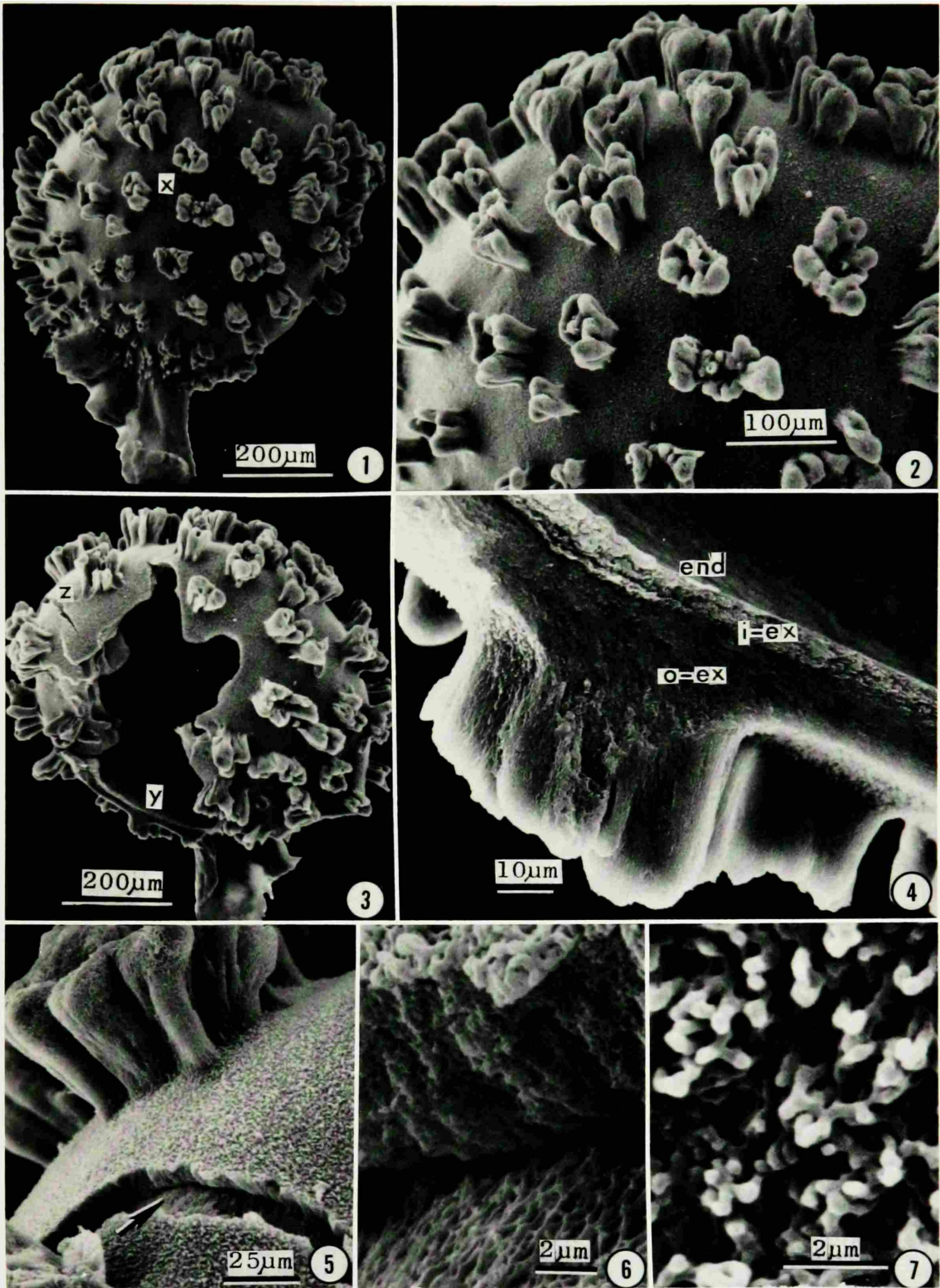


PLATE 21

FIGURES 1-9.—*Arcellites* cf. *A. pyriformis* (Dijkstra) Potter: 1, Equatorial view, $\times 85$; 2, equatorial view, specimen rotated 90° counter-clockwise, $\times 85$; 3, equatorial view, 180° rotation from position in figure 1, $\times 85$; 4, proximal view, $\times 85$; 5, area at x in figure 1 after rotation of specimen few degrees toward viewer, $\times 300$. (Specimen HH-2A, USNM 304343.)

6, Fragment of spore in near-equatorial view, $\times 85$; 7, section of spore coat (o-ex = outer exoexine, i-ex = inner exoexine), $\times 4000$; 8, structure of inner-most surface of endexine, $\times 2000$; 9, surface texture of outer exoexine, $\times 950$. (Specimen HH-2C, USNM 304344.)

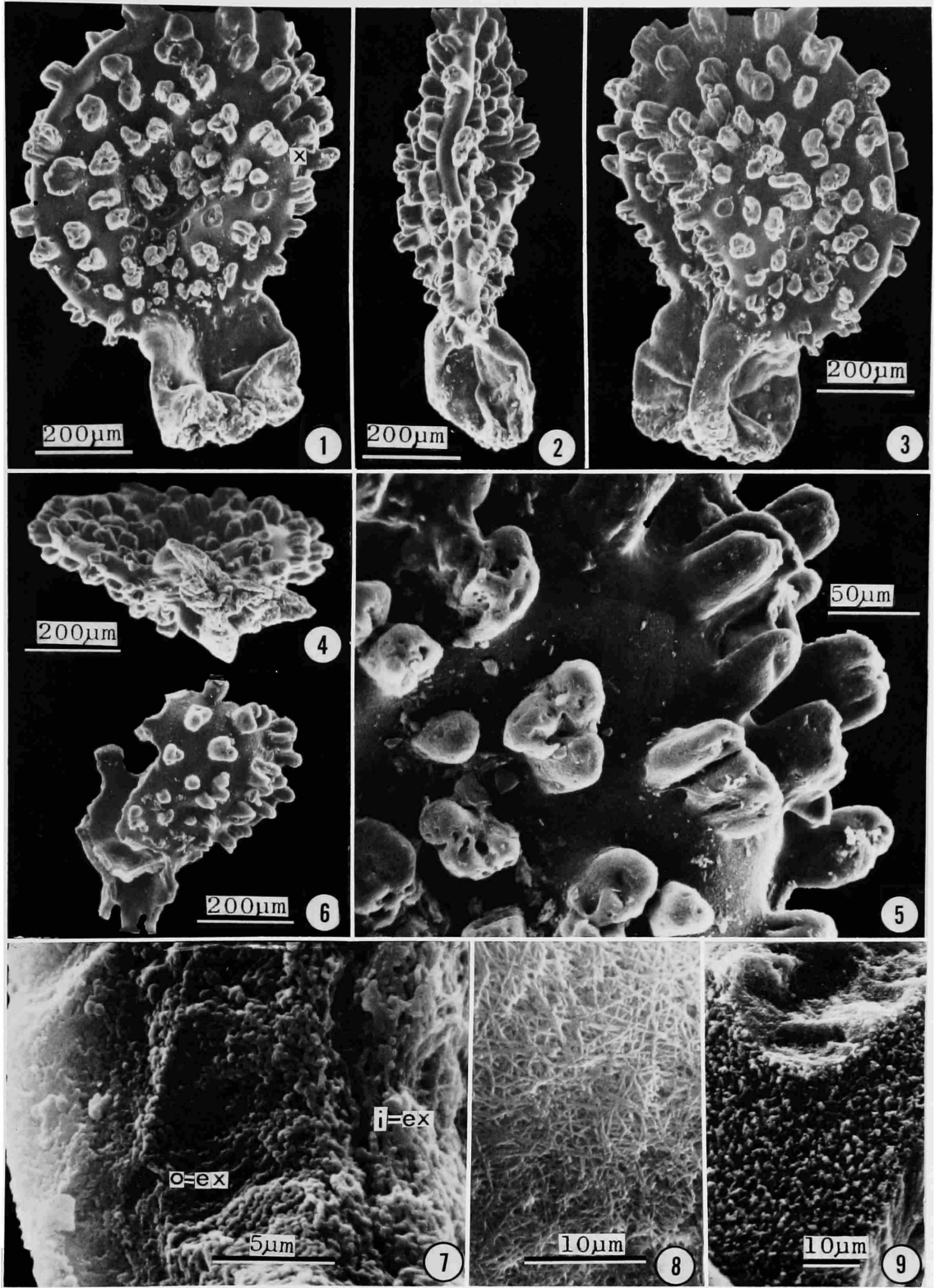


PLATE 22

FIGURES 1-4.—*Paxillitriletes* species Hall and Nicolson: 1, Proximal view, $\times 260$; 2, equatorial view, 90° rotation, counter-clockwise, on equatorial axis, $\times 260$; 3, distal view, $\times 260$; 4, equatorial view, 90° rotation, counterclockwise on equatorial axis, $\times 260$. (Specimen GG-3D, USNM 304346.)

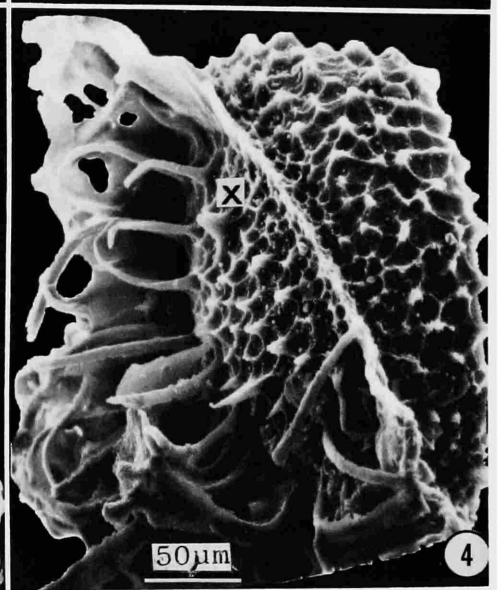
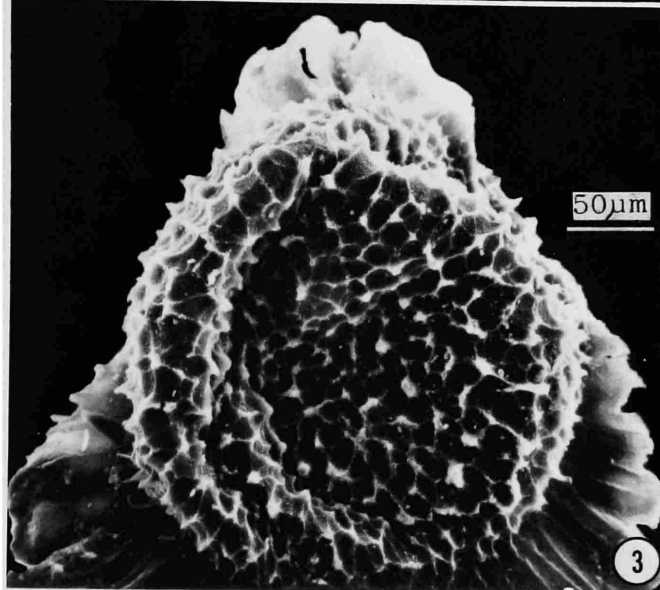
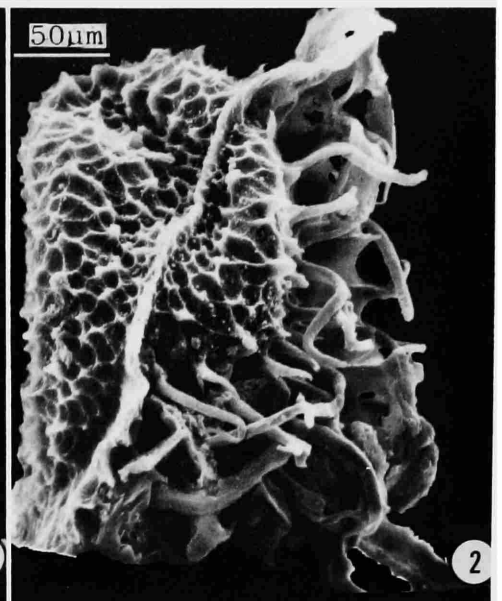
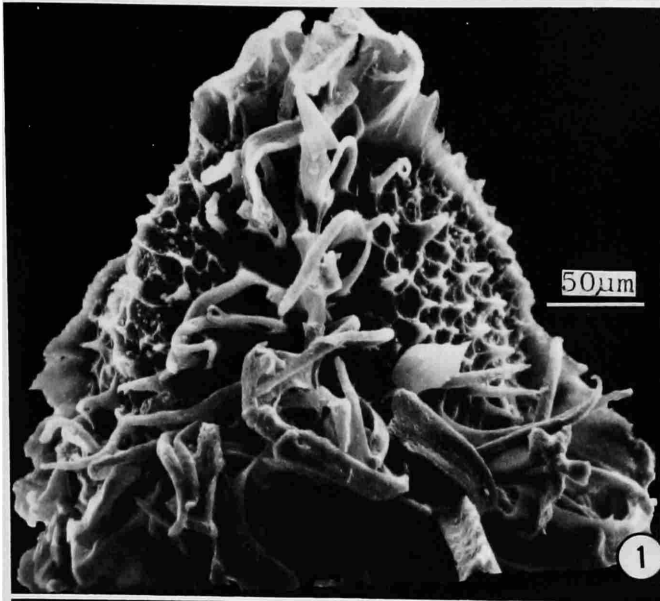


PLATE 23

FIGURES 1-4.—*Paxillitriletes* species Hall and Nicolson: 1, View at x in Plate 22 (figure 4) showing long capillae along margins of laesurae, shorter capillae arising at connecting points of muri, part of equatorial flange (lower right) and fused bases of appendages immediately bordering laesurae, $\times 600$; 2, detail at x in figure 1 showing reticulate sculpture of surface of outer exoexine, $\times 2200$. (Specimen GG-3D, USNM 304346.)
3, Equatorial view, $\times 175$; 4, proximal view, $\times 175$. (Specimen GG-3C, USNM 304345.)

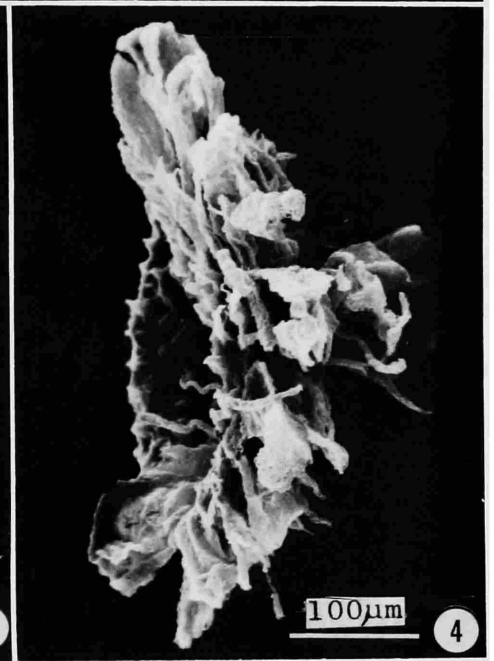
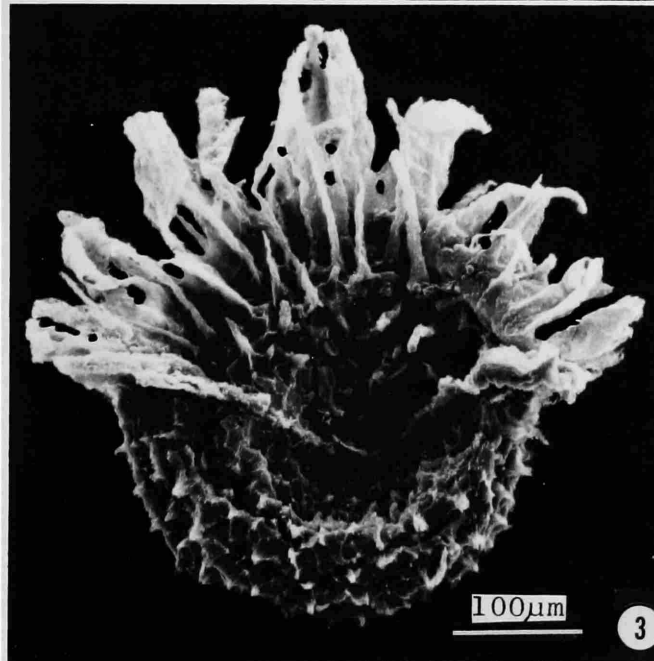
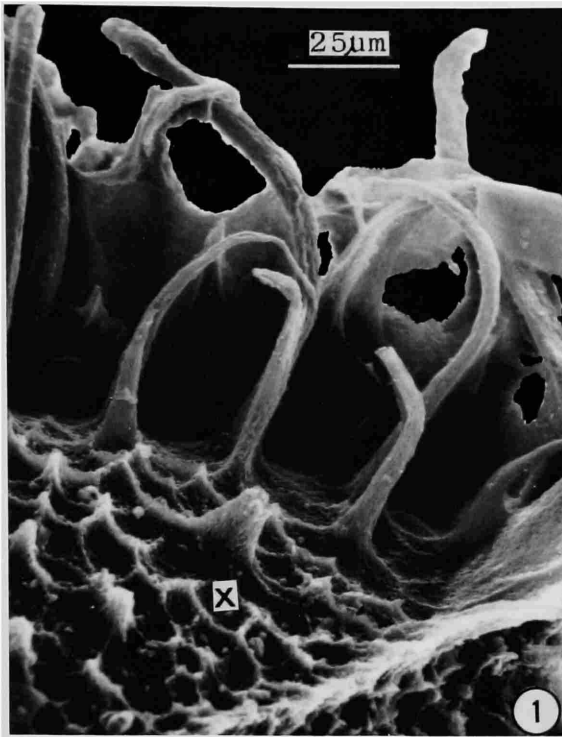


PLATE 24

FIGURES 1-5.—*Dictyothylakos pesslerae* Horst: 1, View interpreted as upper or outer surface of specimen (note “frayed” margin), $\times 90$; 2, slightly oblique view interpreted as lower or inner surface, $\times 90$; 3, detail of surface at x in figure 1, $\times 375$; 4, margin of specimen at y in figure 1, showing broken elements and structural detail, $\times 200$; 5, view at z in figure 2 showing broken structural elements rounded in cross-section and apparently not hollow, $\times 350$. (Specimen II-4B, USNM 304347.)

