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MEGASPORES OF THE TURMA ZONALES FROM THE CARBONIFEROUS OF POLAND. PART I — CORONATE MEGASPORES

Contents

Abstract. — Eight Carboniferous coronate megaspores species, assigned to the genera *Radiatisporites*, *Rotatisporites*, and *Zonalesporites*, structure of the spore wall and mesospore ornamented by numerous cushions are described. Corona has equatorial appendages connected by a membrane and displays two centrifugal channels. Structure of the spore wall, corona and that of laesurae were studied in SEM and in transmitted light. The structure of the corona is of basic taxonomic value for determining genera and species. The main evolutionary trends are changes of the corona; the main types appear in the Upper Viséan and develop at a different evolution rate along four lines: 1. *Rotatisporites solidus* — *Radiatisporites radiatus*; 2. *Rotatisporites tulensis* — *R. rotatus* — *R. dentatus;* 3. *Zonalesporites mucronatus* — *Z. superbus*; 4. *Z. brasserti.* A peculiar state of preservation of *Z. brasserti* f. *circum-textus* is described and explained.

INTRODUCTION

Coronate megaspores are an important component of Carboniferous microfloras, whereas spores of such structure are unknown from other geologic systems. These megaspores occur in large numbers in some beds and have great stratigraphic value. Until now, the coronate megaspores were studied mostly in reflected light, which does not permit recognition of the structure of the spore wall and the corona. Due to the lack of detailed descriptions of these megaspores there was a lot of confusion concerning their taxonomy and also some controversy as to their generic affiliation.

The present paper is based upon a very large collection of one hundred thousand megaspores. The author has reexamined the megaspores from the original collection of Zerndt and has elucidated their systematic position. The spores from Tula, derived from the same collection, are newly described.

The examination of the megaspores was by scanning-electron and transmitted-light microscopy. It has been established that all the coronate megaspores possess a well developed mesospore. The laesurae and the corona have also been studied in detail; a membrane connecting the equatorial appendages and two centrifugal channels of the corona have been discovered. The author has also presented the main evolutionary trends of the coronate megaspores.

The first attempts at studying the megaspores in transmitted light were by Bartlett (1929), and then Arnold (1950) and Winslow (1959). Mortimer and Chaloner (1967) described some Devonian megaspores bearing a superficial resemblance to the Carboniferous coronate ones: the megaspores *Wybostisporites* (somewhat similar in structure to the microspores *Densosporites*) and one coronate form which was assigned to *Zonalesporites*. Spinner (1965) described some coronate megaspores from the Westphalian D of England: he presented some transmitted-light photomicrographs of the megaspores, one of which showed a fragment of the corona of *Z. brasserti* (most probably the distal view). All the species described were assigned by Spinner to *Zonalesporites*. Butterworth and Spinner (1967) described megaspores from the Lower Carboniferous of England. It is apparent that the spores they described as *Z. conacies* sp.n. belong to *Z. brasserti*, only the state of the corona preservation is not as usually described. Subsequently Spinner (1969) described Viséan megaspores from Scotland. In the present author's opinion, the spore *Z. fusinatus* sp. n., described as a new species based on the structure of the corona, is identical with the species described earlier by Nowak and Zerndt (1936) as *T. mucronatus*. Chaloner (1962) described the cones *Sporangiostrobus ohioensis* Chaloner; he examined the megaspores from the fructification in transmitted light and suggested that they were identical with those called, when dispersed, *Zonalesporites superbus* (Bartlett).

All the papers hitherto have given only a fragmentary description of megaspore structure. The most detailed and comprehensive megaspore studies using transmitted light are of the Lower Permian microfloras of Gondwana. The cushions on the mesospore were discovered by Høeg, Bose and Manum in 1955 in megaspores from the Lower Gondwana formations of the Congo. Pant and Srivastava (1961) described, in a similar way, an assemblage of megaspores from the Lower Gondwana formations of India.Comparisons were made with megaspores of Recent heterosporous Pteridophyta. In 1962, the same authors examined some Permian megaspores from Africa and also reexamined some previously described megaspores from Brasil. The newly established megaspore genera were based on the layering of the spore wall. The most comprehensive study of megaspores, based on the transmitted and reflected light microscopy, is by Bharadwaj and Tiwari (1970). These authors discovered the presence of the mesospore in all Permian megaspores from Gondwana. The spore systematics used by Bharadwaj and Tiwari was based on exine ornamentation, structure of the laesurae, relation between the laesurae and the contact faces, and presence or absence of cushions on the mesospore. The major deficiency in these studies was the lack of similar investigations on the Carboniferous megaspores from the northern hemisphere, especially from Europe.

Due to the common interest in the coronate megaspores, the Working Group of the CIMP [1] was formed, which was joined by the following palynologists: S. Dybova-Jachowicz, J. Karczewska, G. Lachkar, S. Loboziak, P. Piérart, and Z. Żołdani. The reunion took place in 1974 in Sosnowiec (Poland). During this meeting a full list of synonyms for the particular species was prepared, and the stratigraphical ranges of the coronate megaspores in the Carboniferous of Europe were established. It was also agreed that the megaspores described from the Viséan of the Moscow Basin as *Triletes mucronatus* (Dijkstra, 1971) (= *T. brasserti* (Dijkstra & Piérart, 1957)) do not belong to any known species; these were described and named *Rotatisporites tulensis*. The number of genera of coronate megaspores was reduced to three: *Radiatisporites, Rotatisporites,* and *Zonalesporites*. The results of the meeting are published in Dybová-Jachowicz *et al.* (in press).

The present paper was prepared in the Institute of Geology, the Warsaw University. The material is housed in the same institution, the collections are marked: Kr. No. Zonal. I/.

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[1] Commission Internationale de Microflore (Microfossiles organiques) du Paléozoique.

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MATERIAL AND METHODS.

This study is based upon material from the Upper Silesian Coal Basin, Lublin Coal Basin and Zerndt's collection which comprises specimens from various regions.

1. The samples from the Upper Silesian Coal Basin representing the whole sections were taken from the following mines: Mysłowice, (37 samples) — the seams 405—510, i.e. Namurian B to Westphalian A; Brzeszcze, (35 samples), Namurian A to Westphalian B/C; Silesia (35 samples), Namurian C to Westphalian C; Chwałowice, 18 samples from various coal seams of the Upper Carboniferous; Wieczorek (18 samples), Westphalian A; Grodziec (19 samples) Lower Namurian A. 20 samples were taken from the coal seam no 510 (Namurian B) from the Sosnowiec and Milowice mines and some samples were taken from the Spytkowice 103 borehole, Westphalian C/D.

2. The materials from the Lublin Coal Basin were taken from the Chełm 1 IG borehole (18 samples), from a section comprising the Upper Viséan to the Westphalian A deposits. Some samples of the Viséan and the Namurian coals were taken from the Sawin 1 IG and Mircze 1 IG boreholes.

3. The megaspores fro mthe collection of Zerndt are those from the Saddle and Marginal beds (Namurian) from the following mines: Renard (Sosnowiec), Wujek, Wolfgang, Saturn (Czerwona Gwardia), Kazimierz, Juliusz, Ferdynand (Katowice), Modrzejów, Paryż (Generał Zawadzki), Waleska, Ema (Wieczorek), Koszelew, Grodziec, Kleofas, Fryderyk. Also, the Viséan megaspores from Tula (The Moscow Basin) are derived from the Zerndt's collection.

The present author studied a total of one hundred thousand well preserved dry specimens and over five hundred slides. Megaspores from the Carboniferous deposits of Czechoslovakia, Holland, Spain, and Turkey were studied for comparison.

The common practice of using only reflected light for investigations on megaspores does not permit recognition of their structural organization. The best results can be obtained by the use of reflected and transmitted light, and scanning-electron microscopy. These three methods were employed for the present study. Especially, the observations of megaspores by transmitted light and scanning-electron microscopy are complementary.

The standard methods were used for maceration of coal. The megaspores were kept dry. A stress was put upon the study of megaspores in transmitted light in order to recognize the structure of the wall layers, leasurae, and equatorial features. The single spore specimens were oxidized with the Schultz's is solution (HNO_3+KClO_3), and then washed with water. If the megaspores still remained dark, they were treated with 5% NH_4OH, and again washed with water. In some cases, it was possible to obtain transparency of the spores solely by the use of 5% NH_4OH. The megaspores were mounted in glycerine-jelly. As the spore specimens react in different ways when treated with chemicals, depending on their structure, the degree of coalification, and the state of preservation, each specimen requires an individual treatment. The specimens which are chosen for the additional oxidation and observations in transmitted light should be well preserved. The differences in the state of preservation of the specimens belonging to the particular species may explain some changes of the particular spore wall layers resulting from fossilization factors. The examination of megaspores in different states of preservation may enable one to recognize a species even from megaspore fragments such as fragments of the corona.

TERMINOLOGY EMPLOYED

The definition of the corona, which has been accepted until now, is applicable to microspores but not to megaspores. The observations of the corona in transmitted light reveal that it is much more complicated than in microspores. (Text-fig. 1, 2, 4, 5)

Corona. The corona in megaspores is an equatorial or slightly proximal--equatorial structure composed of several layers of equatorial appendages, which are simple, or (more often) more or less branched; the appendages are connected proximally by a membrane and by two concentrically arranged channels: the marginal channel and the intracoronal ones. The tips of appendages are interweaving and fused at the outer margin of the corona. Then they form a rim with small or larger dissections, like those in megaspores of *Zonalesporites*. In other cases, the appendages are fused below the tips, which then are left at the outer margin of the rim forming cones, spines, or baculae, as in megaspores of *Rotatisporites*. In some extreme cases, the equatorial appendages may be single and discrete, as in *Radiatisporites*. The corona encircles the entire spore body and is often widest opposite the laesurae, while in microspores it is best developed at the interradial regions (cf. *Reinschospora*).

Mesospore. The term mesospore (= mesosporium, inner body, endexine, intexine) has been used in this paper to denominate the inner, very thin (up to 10 μm) easily detachable wall layer of the megaspores belonging to the Carboniferous Lycopsida. It is probably comparable to the "nexine 2" of Erdtman (1969, p. 46). The term mesospore or mesosporium seams to be more adequate for this membrane, which is more closely related to the intine and the plasma of the living spores than to the exine. This membrane reveals different structure than that of the exospore, when examined in transmitted and reflected light. In transmitted light, the mesospore is thicker over the proximal surface, infragranulate or spongy with triradiate mark and with cushions between its rays. Proximally, the mesospore adhears to the exospore; distally, it is developed as a very thin, hyaline, homogenous layer, usually detached (at least in part) from the exospore. When examined in reflected light (in split specimens), the mesospore appears as a thin and shining layer distinctly different from the exospore. The mesospore is not two-layered, as suggested by Høeg and Bose (1960); these authors described the mesospore in megaspores of *Duosporites multipunctatus* as a layer consisting of an outer spongy part and an inner hyaline one. This observation is not accurate: the outer, supposedly spongy mesospore layer represents the proximal mesospore part while the inner, hyaline part corresponds with the thinner, homogenous and shining distal part of the mesospore.

Intracoronal channel. The channel running radially from the base of the laesura forks approximately within the middle part of the corona, giving rise to the more or less centrifugally arranged intracoronal channel connecting the equatorial appendages.

Marginal channel. The radial channel runs from the base of the laesura to the outer margin of the corona, where it bifurcates and runs along this margin.

Marginal rim. This rim is formed by fusion of the tips of the equatorial appendages. The marginal channel runs inside the marginal rim.

Marginal projections. The elements of ornamentation at the marginal rim. These may be cones, spines, baculae, etc.

Marginal dissections. Dissections occurring near the outer margin of the corona, between the interweaving and fused tips of the equatorial appendages.

POSSIBLE NATURAL RELATIONSHIPS

The megaspores with corona belong undoubtedly to the Lycophyta, but till now it has not been possible more closely to establish their affinity. Potonié and Kremp (1956) suggested tentatively that the megaspores of *Radiatisporites*, *Rotatisporites*, *Zonalesporites*, and *Superbispo-*

rites belong to the Sigillariaceae. More recent investigations established that the megaspores of the Sigillariaceae were smooth or ornamented and azonate. The Lepidodendraceae, which possess megaspores with a gula, are also out of question.

The affinities of the coronate megaspores have been discussed for a long time. It seems that the present state of knowledge on this subject permits some suggestions to be made.

Some coronate megaspores were found in the cones *Sporangiostrobus* (Bode, 1928) Leisman, 1970 of an unknown relationship. According to Chaloner (1962), these fructifications may belong to the long-leafed Lycophyta (excepting Sigillaria), such as *Ulodendron* Lindley & Hutton, 1931, or some related forms. The megaspores which were found in connection with *Sporangiostrobus* are known in the dispersed state as *Zonalesporites*. For example, the cones *Sporangiostrobus feistmanteli* (Feistmantel) Nemejc, 1931, *S. langfordi* Chaloner, 1956, and *S. chioensis* Chaloner, 1962, contained spores which were compared to *Z. superbus* (Bartlett) on the basis of their size, structure of the corona, and exine ornamentation. Leisman (1970) incorrectly assigned the spores found in cones *S. kansanensis* to *Z. superbus*; the spores found by Leisman are smaller than those of *Z. superbus*, possess lower laesurae, narrower and more massive corona, and have no ornamentation on the distal hemisphere. They are, moreover, distinctly triangular, with elongated apices. The corona is thin, and dissected only at the outer margin. These megaspores have about the same size range and similar corona structure as those of *Z. brasserti* (Stach & Zerndt) Potonié & Kremp; their position is intermediate between *Z. superbus* and *Z. brasserti*, which is shown in the table below.

	Z. superbus (Bartlett) (dry)	Megaspores from cones *S. kansanensis*	*Z. brasserti* (Stach & Zerndt) (dry)
Diameter (in microns) of spore	3000—4000	2500—3000	1065—2625
Diameter of spore body	1500—2600	ca 1500	675—1750
Width of corona	625—1000	ca 600	250— 625
Height of laesurae	250—600	145—410	125— 450

No megaspores comparable to those of *Radiatisporites radiatus* were found in situ. Their evolution is very rapid; it trends towards megaspores with reduced ornamentation (the reduction of the number and length of appendages) and may possibly lead to some tuberculate or laevigate megaspores. Also, the megaspores of the genus *Rotatisporites* have not yet been described in connection with fructifications, but there is a possibility that they belong to the Bothrodendraceae. The megaspores found in cones *Bothrodendrostrobus watsonii* Chaloner, 1967, were compared to *Setosisporites praetextus* (Zerndt) Potonié & Kremp. The megaspores from the cones *Bothrodendrostrobus* Hirmer, 1927, are known only from peel sections. However, the megaspore *B. watsonii*, as shown in figs. 451 and 452 (Boureau, 1967) possesses high laesurae, equatorial corona, ornamented distal surface, and finely sculptured proximal surface. These megaspores were assigned to *Setosisporites* due to the high laesurae. However, the appearance of the laesurae (Boureau, 1967, fig. 451) is not that of the gulate megaspores; on the contrary, it is typical of the megaspores belonging to *Rotatisporites*. The spores figured by Boureau seem to be most similar to *R. tulensis* (pl. XVI fig. 4). Thus it is not impossible that the megaspores *Rotatisporites* may be related to *Bothrodendrostrobus*. But only when the megaspores are extracted from the cones and examined in reflected and transmitted light will it be possible to recognize the true structure of the corona and the laesurae [2].

The observations made by the author suggest that the coronate megaspores, the structure of which is quite uniform within the group, may represent one taxonomic unit of a higher rank. It seems probable that they belong to the Lycophyta from the family Bothrodendraceae or from a closely related group. The stratigraphic range of the genus *Bothrodendron*, Lower Carboniferous to Lower Stephanian (Boureau, 1967), conforms with the vertical distribution of the coronate megaspores. There is also a possibility that these megaspores belong to the arborescent plants of the genus *Lepidophloios*, the stratigraphic range of which is similar to that of *Bothrodendron* and the coronate megaspores; the fructifications of *Lepidophloios* are not yet known.

STRUCTURE OF CORONATE MEGASPORES AND ITS TAXONOMIC VALUE

It has been ascertained by the present author that all the coronate megaspores possess double-layered walls; i.e., the thick exospore and the very thin mesospore. The existence of the mesospore in megaspores of some species of the Carboniferous Lycopsida was observed a relatively long time ago, but it was only in 1970 that Bharadwaj and Tiwari suggested, on the basis of their studies on the Permian megaspores from India, that "an inner body is universally present in lycopsid megaspores". This suggestion has not been accepted by all authors. According to Potonié (1973) "it is rather an unusual state of preservation of megaspores belonging to the European fossil Lycopsida." The present author observed,

[2] Similar problems were met by Leisman (1970, p. 170) when he tryed to recognize the spore structure from peel sections: "when the spores were first noticed on peel sections, an initial comparison with *Bothrodendron* megaspores was made. Only after maceration was the true zonal nature of fimbria revealed."

and was able to isolate, the mesospore in specimens of all coronate species which were studied; this corroborates in full extent the observations made by Bharadwaj and Tiwari. However, these authors considered the presence of the mesospore to be a feature of taxonomic value and they introduced a system of megaspore classification based on the structure of the mesospore, which does not seem correct. The type of mesospore structure is characteristic of the higher-rank taxa; all the species of the coronate megaspores possess a mesospore of the same type with numerous cushions arranged in regular rows in interradial regions. The only differences between the particular species are in the number of rows of cushions. This feature is not easy to observe due to various states of spore preservation. Moreover, the mesospore may be developed in different ways in various ontogenetic stages. In ripe megaspores, probably in the stage before opening, when the prothalium is developed, the cushions are absent, and the spores are filled with some spongy-retiform substance of the shape of mesopore, with the triradiate rays marked only slightly. This phase of megaspore development was observed in spores belonging to all the species which are described in the present paper. When observed in transmitted light, the mesospore of such megaspores may appear

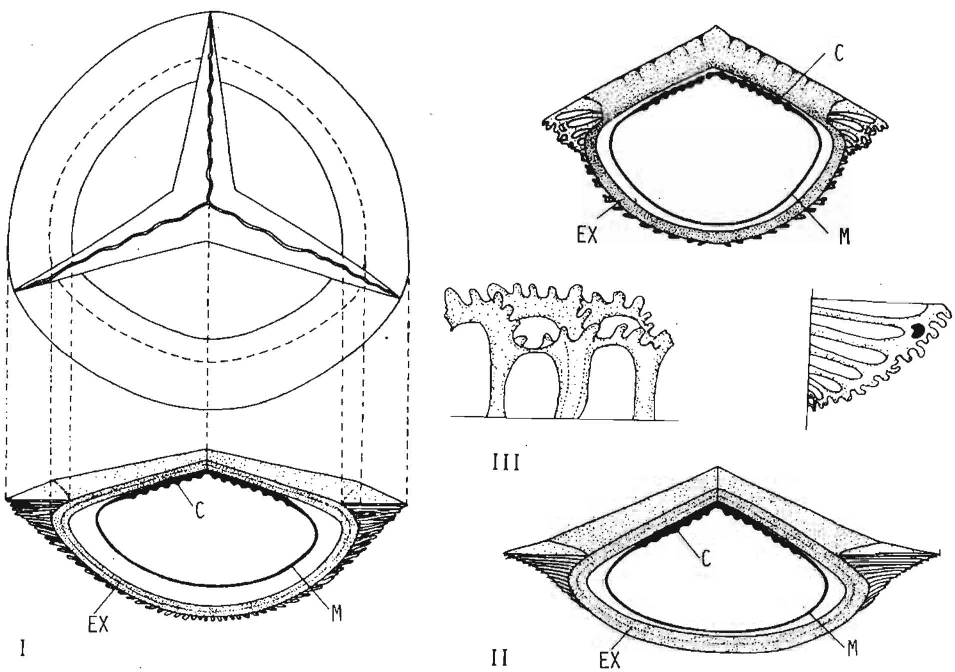

Fig. 1. Reconstructions of megaspores. I — *Rotatisporites tulensis* CIMP: *above* — polar view, proximal surface, *below* — equatorial view, median section; II — *Zonalesporites brasserti* (Stach & Zerndt, 1931) Potonié & Kremp, 1954: equatorial view, median section; III — *Rotatisporites dentatus* (Zerndt, 1938) CIMP: *above* — equatorial view, median section, *left* — marginal part of corona, *right* — corona in median section. *C* — cushions, *EX* — exospore, *M* — mesospore.

different and it would be possible to distinguish at least two taxa within one species, when judging only by the mesospore structure. It is possible that this was the case when the three species of *Duosporites* were distinguished by Bharadwaj and Tiwari (1970). These species (*D. congoensis*, *D. multipunctatus*, and *D. irregularis*) have identical structure except for the mesospore; especially in megaspores of *D. irregularis*, the mesospore seems to represent a different ontogenetic stage.

In normally developed and well preserved megaspores, the cushions are arranged very regularly. This regularity becomes obliterated when the prothalium is developed. Also, the state of spore preservation influences the appearance of the mesospore. In specimens which are split or filled with sediment, the mesospore is most often destroyed. In thick-walled and proximally ornamented megaspores, the mesospore is difficult or impossible to observed. Thus, the structure of the mesospore can not be considered to have taxonomic value within the lower taxonomic levels (species, genus). On the other hand, it may be important for tracing the relationships between the groups of higher taxonomic levels and some evolutionary changes.

In all Carboniferous coronate megaspores, the laesurae extend to the outer margin of the corona, but the commisurae do not reach the arcuate ridges, and their length equals that of the triradiate rays on the mesospore. The radial channel begins at the base of the laesura; it forks within the corona, giving rise to the two centrifugal channels — the marginal one and the intracoronal one. Inside all appendages, there is always a channel, or even a few channels (when the appendage originates from fusion of several appendages); all these channels connect the appendages with the spore body. During the life of the megaspores, all these channels (the ones inside the appendages and those within the corona) must have been filled with gas, which made the spores lighter, and thus facilitated the megaspore dispersal (by air and water).

All coronate megaspores are characterized by ornamented proximal surface; the ornamentation consists most frequently of spinose projections, which are, however, not always preserved. The ornamentation is better preserved in the megaspores which are not mature; in the mature ones, especially in those with open sutures, the ornamentation of the proximal surface is usually absent. It is possible that the proximal projections served to hold the microspores in the vicinity of the tetrad scar. The same purpose may have been served by the spines on the upper part of laesurae, which occur in the megaspores of all the species which are described in the present paper. According to Seward (1910), all sorts of proximal projections, such as hair or hooks, served to catch the microspores. Potonié (1955) did not agree with this concept of Seward; he suggested that only the spines on laesurae, such as those occurring in Lower Liassic megaspores from cones *Lycostrobus scotti* (Nath.), might have been

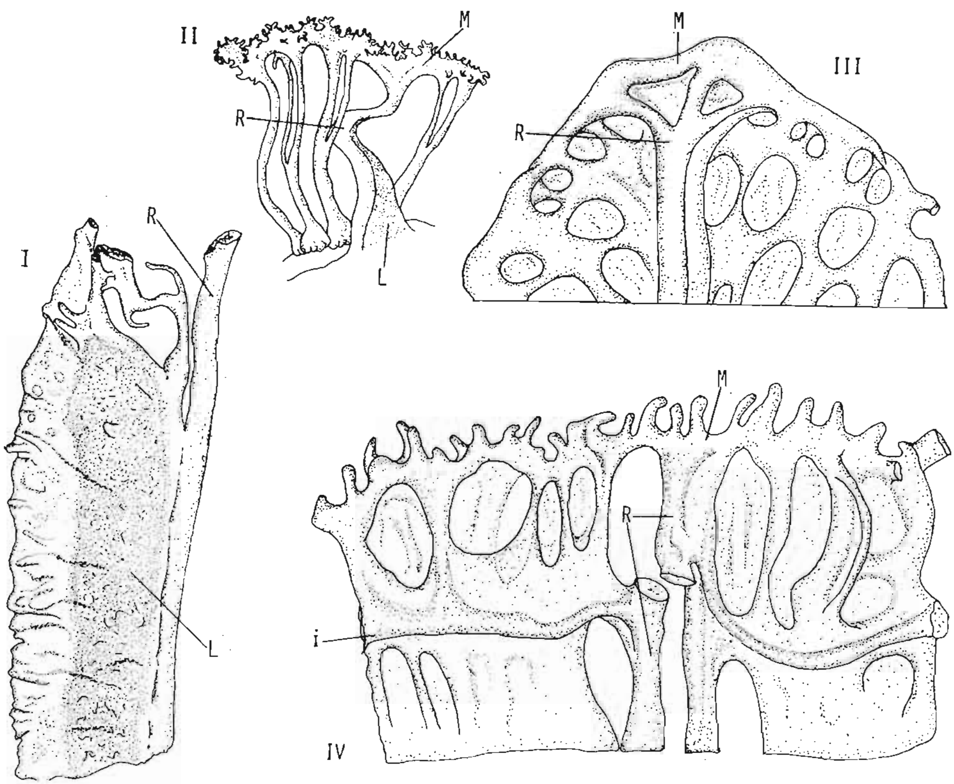

Fig. 2. Drawing of coronate megaspores showing the arrangement of intracoronal and marginal channels. I — *Rotatisporites solidus* (Dijkstra, 1957) CIMP; II — *R. rotatus* (Bartlett, 1929) Potonié & Kremp, 1954; III — *Zonalesporites brasserti* (Stach & Zerndt, 1931) forma *circumtextus* (Zerndt, 1934) f. nov.; IV — *Rotatisporites tulensis* CIMP. *I* — intracoronal channel, *L* — laesura, *M* — marginal channel, *R* — radial channel.

useful in detaining the microspores, but (according to this author) no such projections, or only very small ones, occur in the Carboniferous megaspores. The finding of spinose projections on contact faces and laesurae in all coronate megaspores supports, however, the opinion of Seward. The equatorial appendages were also in some way involved in catching microspores, because in the material studied there were numerous microspores sitting between the appendages, and among these there was always one dominant species.

Potonié (1955), in his paper on spore biology, suggested that the function of the corona in the Carboniferous megaspores was facilitating wind transport and flotation, but he said that the open-work form of the corona was not quite clear. The present study disclosed the presence of the membrane connecting the equatorial appendages, even in such megaspores as *R. rotatus* (Bartlett). It seems, therefore, that the living megaspores possessed a more complete corona which could enable the megaspores to stay on the water surface for quite a long time.

EVOLUTION OF CORONATE MEGASPORES

The coronate megaspores appear in large numbers in the Viséan. The observations of the corona structure permit not only the precise definition of the genera, but also the delineation of evolutionary changes. All these megaspores belong probably to plants of a higher taxonomic unit which is implied by the following spore features: the same structure of the spore wall, the same development of the mesospore, very similar pattern of the corona and the laesurae structure.

Generally, the evolution of these megaspores led towards the reduction of the number of corona layers, some reduction of distal ornamentation, and the increase of spore-body size. Four evolutionary lines may be distinguished among the coronate megaspores: from 1. *Rotatisporites solidus* (Dijkstra) to *Radiatisporites radiatus* (Zerndt); 2. *Rotatisporites tulensis* to *R. rotatus* (Zerndt), and then possibly to *R. dentatus* (Zerndt); 3. *Zonalesporites mucronatus* (Nowak & Zerndt) to *Z. superbus* (Bartlett); 4. a line represented by one conservative species, *Z. brasserti*, occurring almost throughout the whole Upper Carboniferous.

The first stage of evolution of the coronate megaspores is a sort of "explosive evolution", as in the Upper Viséan all the three genera (*Radiatisporites*, *Rotatisporites*, and *Zonalesporites*) appear almost simultaneously. The oldest genus is *Rotatisporites*, represented by *R. tulensis*, characterized by a corona consisting of several layers of appendages which are narrow at the base and strongly widened at the apices. They are cone-shaped, with the outer margin terminated by thin marginal projections. The equatorial appendages are connected by a membrane. The distal side of the spore is strongly ornamented. The stratigraphic range of *R. tulensis* is restricted to the lower part of the Upper Viséan, where it is represented by numerous megaspores and several morphological types. In the upper part of the Upper Viséan, this species is replaced by *R. rotatus*, the corona of which appears as the proximal corona layer of *R. tulensis*. It consist of one or two layers of appendages only; these are narrow at base, strongly widened at apices, and terminated by spinose marginal projections (pl. XI fig. 2ab). The equatorial appendages in *R. rotatus* often retain the conical shape (pl. X fig. 4) which is so characteristic of the corona in megaspores *R. tulensis*. The corona in megaspores *R. rotatus* developed by the reduction of the corona layers; the remnants of the reduced layers are represented possibly by the numerous, more or less spinose marginal projections. In fossil megaspores of *R. rotatus*, the connecting membrane is often destroyed; then the corona appears more like open-work, and the similarity to the megaspores *R. tulensis* is obscured. Also, the distal appendages are reduced in the megaspore *R. rotatus*: they are not frequently present, and when they are present they occur in the form of short cones. The further development of the corona might have led to the forms cha-

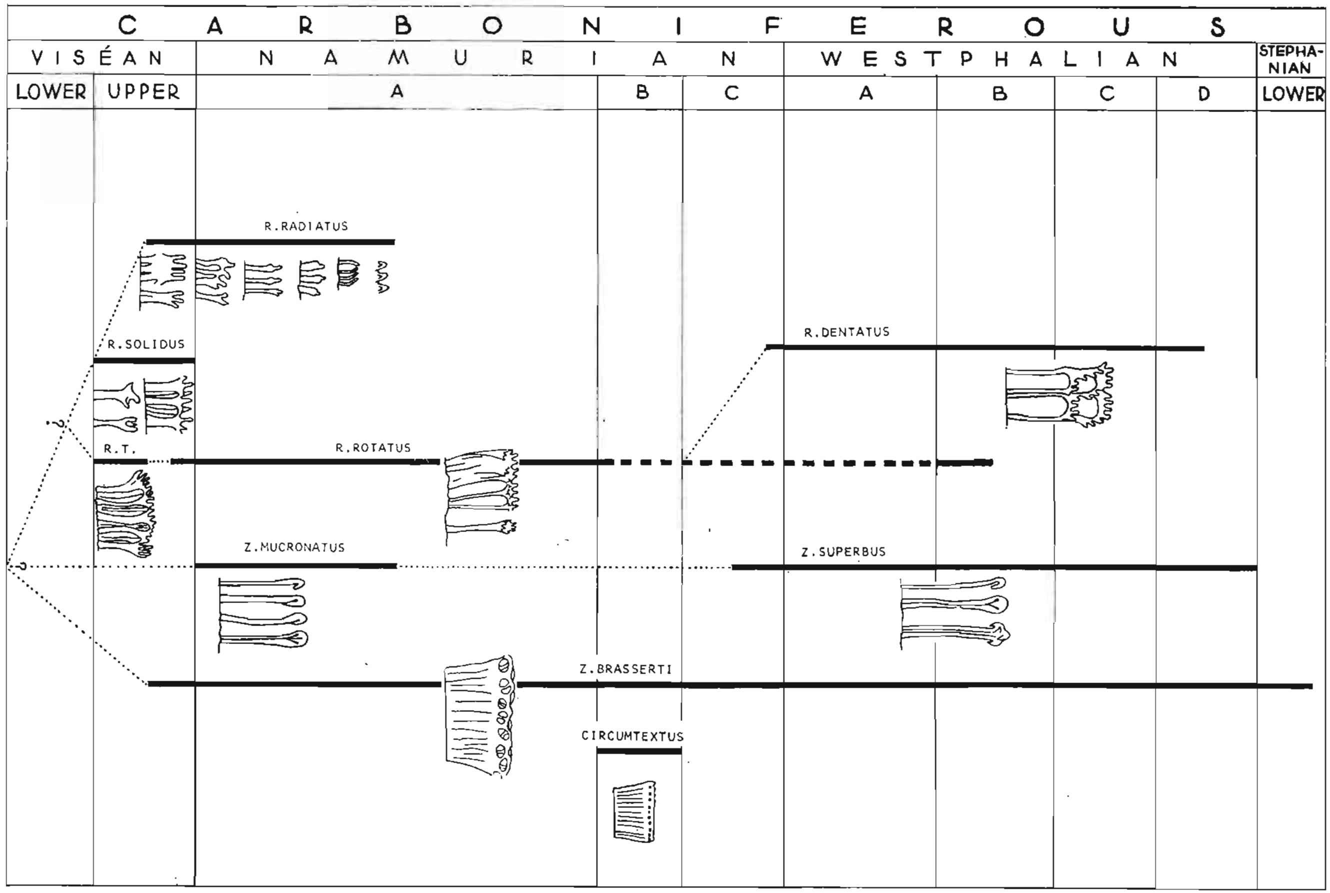

Fig. 3. Postulated phylogeny of coronate megaspores from Carboniferous. R.T. — *Rotatisporites tulensis.*

racterized by wide equatorial appendages connected by a very thin membrane, such as in *R. dentatus*. However, the relation between the latter species and those mentioned above is not as obvious as that between *R. tulensis* and *R. rotatus* and there are no intermediate forms. In the Carboniferous deposits of Poland, *R. rotatus* disappears in the Namurian C while *R. dentatus* appears only in the Westphalian C/D. Moreover, the megaspores of *R. dentatus* are characterized by an ample ornamentation of the distal side which seems to be the characteristic feature of the Westphalian forms. A similar rich distal ornamentation is the property of the typically Westphalian megaspores of *Z. superbus* (Bartlett) Karczewska.

The megaspores of *R. solidus* (Dijkstra) Dybová-Jachowicz *et al* are contemporary with *R. tulensis*. They differ from the latter species in having narrower corona, lower laesurae, less branched (up to three times) equatorial appendages, and not so strongly ornamented distal surface. It seems that these two species, which are of very similar structure, may have had common ancestors, but their evolution led in different directions. The changes in megaspores of *R. solidus* concerned not only the reduction of the corona layers and the decrease of the corona width, but also the decrease of number of the equatorial and distal appendages, and some reduction of the connecting membrane. The megaspores which developed in this way were characterized by a narrow corona, and simple or forked equatorial appendages, which may be discrete or connected by a rudimentary membrane. These are the features of *R. radiatus* (Zerndt), which is linked with *R. solidus* by several intermediate forms. The evolution of the megaspores *R. radiatus* is most remarkable, and its rate is high. Within the short period of time from the upper part of the Upper Viséan to the Lower Namurian A, these megaspores changed from the forms having the several layered corona (up to 6 layers) with equatorial appendages still connected by a rudimentary membrane and a relatively densely ornamented distal side, through forms with a three- to four layered corona composed of discrete appendages and with a slightly ornamented distal surface, to the forms characterized by equatorial appendages reduced to low cones, an almost smooth distal surface, and arcuate ridges, which were not developed earlier in this group. The evolution of the megaspore *R. radiatus* led also to forms with lower laesurae. The reduction in number of the equatorial appendages was due to fusion of the neighboring ones (pl. I figs 2—4), whereas the decrease in length of the distal appendages was caused by stopping their development, which is implyed, for instance, by the occurrence of hooked appendages in the megaspores of the morphological type III (pl. III fig. 3). The last evolutionary stage of the species *R. radiatus* is represented by megaspores of the morphological type VI. It seems possible that the equatorial and distal appendages might have led to the development of laevigate forms such as, for instance, *Laevigatisporites glabratus* (Zerndt).

The third trend of evolution of the coronate megaspores is that leading from *Z. mucronatus* to *Z. superbus*. The megaspores of *Z. mucronatus* are characteristic of the lower part of the Namurian A (?the uppermost part of the Upper Viséan). The corona of these megaspores consists of relatively simple appendages connected by a membrane. The appendages are discrete, with hooked tips, or consist of two fused appendages; the hooking of appendages was prior to fusion (pl. XXXII, figs 2-4). The megaspore *Z. mucronatus* might have developed from some unknown Viséan ancestors, or from some spores of the *R. tulensis* type, in which the equatorial appendages were separated and hooked at the tips. This last possibility seems to be less probable. The megaspores *Z. mucronatus* are most similar to those of *Z. superbus*, which are characterized by a similar type of hooked equatorial appendages (Text-fig. 6 *III*). In *Z. superbus*, the corona is very complicated, the appendages are fused in twos and threes or in greater numbers (Text-fig. 6 *I*, *III*). Thus, the evolution of the megaspores of this group was expressed by fusion of the equatorial and distal appendages. The appendages forming the corona in *Z. superbus* are strongly interwoven, which is not the case in the megaspores of *Z. mucronatus*; but there is a considerable period of time between the occurrences of these two species, and there are no intermediate forms between them. The megaspore *Z. superbus* are characterized by their large size. This is characteristic for all coronate Westphalian megaspores; *R. dentatus*, *Z. brasserti*, and *Z. superbus* are the largest megaspores with a corona, and are almost the largest megaspores of all (excepting the Lepidocarpaceae). The size range of these megaspores is 1000 to 4000 μm.

An exceptional position in the evolution of the coronate megaspores is that of *Z. brasserti*. This species appears by the end of the Viséan, and persists almost throughout the whole Upper Carboniferous. This long--ranging, conservative species is represented by megaspores which increase in size in the succesively younger strata; whereas the Namurian and Westphalian megaspores were up to 3000 μm in diameter, those of the Lower Stephanian were more than 4000 μm. *Z. brasserti* is the only Carboniferous coronate species which is known from above the Westphalian. The probable trends of evolution of the coronate megaspores are presented in Text-fig. 3.

An interesting problem is the mass occurrence of megaspores *Z. brasserti* f. *circumtextus* in the Namurian B strata of Upper Silesia. These megaspores frequently constitute 90% of the total spore populations in the coal seams 501—510. Detailed observations of the corona structure show clearly that these megaspores belong to *Z. brasserti s.s.* They differ from the typical forms in being smaller and in having more weakly developed corona and lower laesurae. The distal surface in these megaspores is not smooth, but is covered with tubercles, which are very densely spaced in the vicinity of the corona, forming a pseudo-reticulum. In some extreme cases, the corona is very weak, appearing as if not fully developed (pl. XXXI, fig. 6). These megaspores occur in masses, and only a few represent the forma typica; it does not seem likely that they represent abortive specimens, particularly because, when found in tetrads, these megaspores are always of equal size. It seems probable that they represent unripe specimens in various ontogenetic stages. This is implyed by the fact that the size range of these megaspores is very great and the corona and the ornamentation are in the course of development. The corona and the ornamentation are formed by the tapetal tissue of the sporangium, and during the growth of the megaspores, the equatorial appendages become larger. The outermost layer of the spore wall is stretched as the spore grows, until there remain on the distal side, only some small tubercles, which are definitely absent in the ripe specimens. The exospore of the megaspore *Z. brasserti* f. *circumtextus* is thinner than that in the forma typica, which supports the idea of the unripe state of the megaspores in question. Within the corona of these megaspores, there are globules of brown color, which may represent the remnants of the substance which filled the spore-bearing cones. The megaspore *Z. brasserti* f. *circumtextus* is very well preserved, in spite of its thin exospore; it is possible that the substance filling the cones had some preserving properties such as those of resin in coniferous plants.

The occurrence of such large numbers of unripe megaspores implies that the cones must have been drowned and buried before becoming ripe. Therefore, the mass occurrence of *Z. brasserti* f. *circumtextus* is distinctly connected with some change in environmental conditions.

Distinguishing the megaspore *Z. brasserti* f. *circumtextus* seems to be advisable in view of its distinctive mode of occurrence and its value for the identification of the Reden Coal seams (the Namurian B).

DESCRIPTIONS

Anteturma **Proximegerminantes** R. Potonié, 1970
Turma **Zonales** (Bennie & Kidston, 1886) R. Potonié, 1954
Subturma **Zonotriletes** Waltz, 1935
Suprainfraturma **Zonati** Potonié & Kremp, 1954
Infraturma **Fimbriaezonati** Piérart, 1974
Subinfraturma **Simplifimbriati** CIMP [3]
Genus *Radiatisporites* Potonié & Kremp, 1954

Type species: *Radiatisporites radiatus* (Zerndt, 1937) Potonié & Kremp, 1954

Radiatisporites radiatus (Zerndt, 1937) Potonié & Kremp, 1954
(Pls I—VII)

1931. Type 22, Zerndt; J. Zerndt, p. 174, pl. 6, fig 22.

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[3] Commission Internationale de Microflore (Microfossiles organiques) du Paléozoique. Dybová-Jachowicz, Karczewska, Lachkar, Loboziak, Piérart and Żołdani: "Revision de Mégaspores à corona du Carbonifère" (in press).

1931. Type 23, Zerndt; J. Zerndt, p. 174, pl. 6, fig 21.
1937. Type 22, *Triletes radiatus* sp.n.; J. Zerndt, pp. 3, 10, fig. 7; pl. 13, figs 1—5.
1954. *Radiatisporites radiatus* (Zerndt) nov. comb.; R. Potonié & G. Kremp, p. 163, pl. 14, fig 63.
1955. *R. radiatus* (Zerndt) Pot. & Kr.; U. Horst, p. 188, pl. 19, figs 21—23.
1962. *Megacapillarizonales radiatus* (Zerndt) nov. comb.; A. M. Ishchenko & E. V. Semenova, p. 86, pl. 17, fig. 1.
1966. *Radiatisporites radiatus* (Zerndt) Pot. & Kr.; A. Jachowicz, p. 119, pl. 5, figs 10—11.
1967. *Zonalesporites radiatus* (Zerndt) Spinner; J. Karczewska, p. 316, pl. 6, figs 11—12.

Material. — Approximately 3000 specimens.
Dimensions in microns (100 specimens):

	dry	wet
Diameter of spore	630-1400	—
Diameter of spore body	375-887	500-1200
Height of laesurae	20-95	—
Length of equatorial appendages	40-200	14-230
Length of terminal parts of equatorial appendages	—	11-90
Basal width of equatorial appendages	11-37	11-50
Length of distal appendages	5-82	16-92
Basal width of distal appendages	5-40	17-45
Length of proximal projections	7-62	—
Basal diameter of proximal projections	8-35	—
Thickness of exospore	15-50	—
Length of spines on laesurae	—	13-47
Diameter of mesospore	—	220-500
Diameter of cushions	—	12-25

Description. — *Megaspores examined in reflected light.* Megaspores trilete; amb circular or subtriangular. Spore body encompassed by equatorial corona. Corona narrow or very narrow (1/6 to 1/4 of spore radius), consisting of several (2—6) layers of elongated, cylindrical appendages which are discrete or fused at the base and/or in the middle part of corona; terminal parts of appendages always free. Laesurae almost uniformly high along their length, always more or less sinuous, extending to spore body margin, terminated with several equatorial appendages. The upper part of laesurae thicker than the basal part, shining and covered with spines. No thickened arcuate ridges or only weak ones represent the curvaturae. Contact faces laevigate, or ornamented with coni, tubercles or spines.

Distal surface laevigate or covered with usually widely spaced appendages of various types. These vary in length and are usually discrete, occasionally fused in twos or, (exceptionally) in threes. Exospore thickness usually 30 to 40 μm.

Megaspores examined in transmitted light. Double-walled megaspores with thick exospore and very thin mesospore. Proximal part of mesospore granulate, with distinctly triangular amb and with trilete mark, one third to one-half spore radius in diameter. Between the rays of the trilete mark there are three to four rows of cushions. Distal side of mesospore very thin, hyaline, homogenous.

Laesurae consist of two distinctly different parts: basal part one-third to one-half of the total height, straight; upper part sinuous, ornamented with numerous spines. Each ray of trilete mark terminated with two or four long appendages which are components of the corona.

Corona consists of several layers of elongated, cylindrical appendages tapering distinctly near the tip; appendages with furcate tips are very rare. Near extremities of triradiate rays there are more layers of the corona elements; they are longer and more densely spaced than in interradial regions. Proximal surface ornamented with variably spaced, rounded tubercles, cones and/or spines. These are relatively loosely connected with the spore surface and are often chipped away leaving only a mark of connecting channel. Distal surface smooth or covered with rounded or conate elements or elongated appendages which may be pointed, blunt or coiled (pl. III, fig. 3). Distal appeandages usually discrete, sometimes fused in twos or threes; in some cases two appendages are fused at basis forming one tubercle (pl. V. fig. 1, 2).

Variability. — *Radiatisporites radiatus* is a most variable species. The variability affects: the number of appendage layers in the corona, the length of equatorial appendages, the length and shape of distal appendages, the shape of proximal projections, and exospore thickness. The megaspore *R. radiatus* display distinct evolutionary changes during the time from the Viséan to Lower Namurian A; it is possible to discern six morphological types.

Morphological type I. The oldest (Viséan) megaspores are characterized by the largest number (4 to 6) of appendage layers in the corona. The appendages are very long (87 to 230 μm) often connected at the proximal side by a rudimentary membrane (pl. I, figs 3, 4) and fused, two to four together, in the middle part. The terminations of appendages are free (the length of terminations 33—90 μm) and have an appearance of glove fingers. In megaspores of this type the contact faces are usually smooth or covered with rounded tubercles, 10 to 30 μm in basal diameter. Distal surface ornamented with appendages 5 to 82 μm long, 5 to 35 μm wide; the length of these increases from the center towards the corona. Laesurae 25 to 95 μm high. (Pl. I).

Morphological type II. The megaspores of this type appear in strata of the early Namurian A. They are similar to those of the type I. The number of layers of the corona is still high (4 to 6), the rudimentary membrane is present and the equatorial appendages are long (65 to 200 μm) and densely spaced. The appendages may be connected by the intracoronal channel, they may be discrete or fused in twos, some may have furcate tips. Distal appendages shorter (8 to 47 μm) than those in spores of the type I; projections on contact faces elongated but not spiny. The height of laesurae varies between 35 to 87 μm. (Pl. II).

Morphological type III. The megaspores appearing in younger strata are characterized by a smaller number of appendage layers 3 to 4 in the corona. Equatorial appendages quite long (72 to 200 μm) discrete, distinctly tapering near the tip (where they are 11 to 22 μm long), and relatively thin (11 to 27 μm). Proximal surface covered with cones or tubercles 22 to 47 μm high, 15 to 30 μm wide at basis. Distal surface covered with widely spaced, thick (12 to 40 μm) appendages with coiled terminations (pl. III, fig. 3), 35 to 92 μm long. The height of laesurae varies between 45 and 80 μm. (Pl. III).

Morphological type IV. The megaspores of this type are similar to those of the type III. They are characterised by shorter (55 to 137 μm) and thicker (20 to 50 μm) equatorial appendages, which are not fused. Proximal side densely covered with cones and spines. Distal surface with regularly distributed conate elements 35 to 65 μm high, 17 to 45 μm wide at basis, originating possibly from fusion of two adjoining appendages; the mark of fusion is visible at the base of tubercles (pl. V, fig. 2). Height of laesurae varies between 45 to 77 μm. (Pls IV, V).

Morphological type V. The megaspores of this type appear suddenly in large numbers (for instance the seam Grodziec F III, sample 12). These are characterized by shorter (14 to 120 μm), thin (11 to 22 μm), discrete equatorial appendages; short (up to 35 μm) and thin (10 to 22 μm) distal appendages and widely spaced tubercles of the contact faces. Leasurae low (20 to 50 μm). The exospore in spores of this type is thinner than that in the spores described above (15 to 30 μm). (Pl. VI).

Morphological type VI. The megaspores of this type appear in the youngest strata of the profile. These are characterized by discrete, very short (40 to 80 μm) and thick (25 to 37 μm) equatorial appendages, very small distal tubercles (7 to 12 μm in basal diameter) and low leasurae. The arcuate ridges in these megaspores are quite distinct. (Pl. VII).

Remarks. — The megaspores *R. radiatus*, and especially spores of the type I, are somewhat similar to those belonging to *Rotatisporites solidus* (Dijkstra) but the appendages of the corona are usually not forked in *R. radiatus*, the membrane is more weakly developed and the particular layers of the corona are not connected with each other.

Occurrence. — Poland, Upper Silesian Basin: Dinantian to Lower Namurian A; Lublin Coal Basin: Viséan to Namurian A. Czechoslovakia: Namurian A. USSR: Viséan.

Subinfraturma **Limbifimbriati** CIMP

Genus *Rotatisporites* Potonié & Kremp, 1954 emend. CIMP

Type species: Rotatisporites rotatus (Bartlett, 1929) Potonié & Kremp, 1954

Rotatisporites rotatus (Bartlett, 1929) Potonié & Kremp, 1954

(Pls VIII—XI; Text-fig. 2 *II*)

1929. *Triletes rotatus* sp. nov.; H. H. Bartlett, p. 21, pl. 9; pl. 10, figs. 1—2; pl. 11, fl. 12.
1937. *T. brasserti* Stach & Zerndt; J. Zerndt, only pl. 12, fig 1.
1973. *Zonalesporites rotatus* (Bartlett) Spinner; E. Spinner & G. Clayton, pl. 2, figs 2, 4.

The full synonymy of this species can be found in Dybová-Jachowicz *et al.* (in press).

Material. — Over five-hundred well preserved specimens.

Dimensions in microns (30 specimens):

	dry	wet
Diameter of spore	550-1750	—
Diameter of spore body	375-750	—
Height of laesurae	37-80	—
Width of corona	87-500	—
Length of distal appendages	15-70	—
Basal width of distal appendages	7-52	—
Length of proximal projections	25-30	—
Basal width of proximal projections	20-28	—
Length of marginal projections	—	10-40
Basal width of marginal projections	—	6-20
Length of spines on laesurae	—	3-25
Thickness of exospore	20-45	—
Diameter of mesospore	—	300-500
Diameter of cushions	—	8-10

Description. — *Megaspores examined in reflected light.* Megaspores trilete; amb more or less circular. Spore body encompassed by equatorial corona. Corona composed of several long appendages, which wide and fuse near their terminations forming the marginal rim. The appendages may be connected by a membrane along their length or only within some part of the corona. Outer margin of the rim of corona covered with fine spines or cones. Width of corona 1/2 of spore radius. Laesurae low (up to 80 μm), straight or slightly sinuous, almost equally high along their length, extending to the outer margin of corona. No arcuate ridges or only weak ones represent the curvature. Contact faces smooth or covered occasionally with conate or spinose projections. Distal surface usually laevigate, occasionally ornamented by irregularly distributed rounded or conate tubercles. Exospore thickness 20 to 45 μm.

Megaspores examined in transmitted light. Megaspores with thin exospore in comparison with spores of other species of *Rotatisporites*. Mesospore with trilete mark, proximal faces covered with numerous circular cushions 8 to 10 μm in basal diameter. Corona composed of one to three layers of equatorial appendages. These are cylindrical, long and forked near terminations. The side branches of appendages are fused forming the marginal rim. Equatorial appendages may be connected by a membrane which is rarely preserved as a whole. Occasionally, in the same specimen some equatorial appendages are connected by membrane, while others are not. Outer edge of marginal rim covered by densely spaced cones or spines arranged in two or three concentric rows. The neighboring appendage layers of the corona are connected by a membrane and by side branches near the marginal rim. In the specimens with a preserved membrane the intracoronal and marginal channels may be observed; the radial channels run from the base of the triradiate mark on the central body towards the spore margin. Near the spore body the radial channel forks for the first time forming the centrifugal intracoronal channel. The second forking of the radial channel takes place near the margin of the corona, where the marginal centrifugal channel is formed, running inside the marginal rim (pl. X, fig. 3a).

Variability. — The megaspores of the *R. rotatus* (Bartlett) are weakly variable. The differences occur in the composition of the corona. Small specimens usually posses two to three layered corona with appendages which are densely spaced and connected by a membrane along the whole length. Larger specimens are characterized by a more open-work corona, which is often composed of thin, widely spaced appendages connected only by the marginal rim. There are various intermediate forms linking these two morphological types. The small specimens with compact corona occur more frequently in older deposits.

Comparisons. — The megaspores *R. rotatus* (Bartlett) is similar to *R. dentatus* (Zerndt), from which it differs in having smaller dimensions, thinner equatorial appendages, laevigate or weakly ornamented distal surface and thinner exospore. The structure of the corona in *R. rotatus* is the same as that of the most proximal layer of the corona in *R. tulensis*. This similarity is discussed in detail on p. 458—460.

Occurrence. — Poland, Upper Silesian Basin: Dinantian — Lower Namurian B; Lower Silesian Basin: Viséan — Namurian C; Lublin Coal Basin: Tournaisian?, Viséan — Namurian A. Czechoslovakia: Namurian A. USSR: Viséan. France: Westphalian A—B. Holland: Westphalian B. Scotland: Lower Carboniferous. Belgium: Lower Westphalian B. Turkey: Namurian A—C. USA, Michigan: Carboniferous coal pebbles at Ann Arbor; Illinois: Early Pennsylvannian.

The greatest stratigraphical range of this species is Viséan to Lower Westphalian B, but is most common in the Namurian A.

Rotatisporites tulensis CIMP
(Pls XII—XVII; Text-figs 1 *I*, 2 *IV*, 4, 5)

1957. *Triletes brasserti* Stach & Zerndt; S. J. Dijkstra & P. Piérart, p. 10, pl. 4, figs 61—78; pl. 14, figs 185, 186; pl. 19, figs 236—239.
1971. *Triletes mucronatus* Nowak & Zerndt; S. J. Dijkstra, p. 26.

Material. — Over 50000 well preserved specimens.
Dimensions in microns (90 specimens):

	dry	wet
Diameter of spore	600-1750	—
Diameter of spore body	500-1070	—
Height of laesurae	57-212	—
Width of corona	100-500	—
Length of distal appendages	15-220	—
Basal width of distal appendages	12-65	—
Length of proximal projections	30-82	—
Basal diameter of proximal projections	20-50	—
Length of spines on laesurae	—	20-52
Length of marginal projections	8-55	10-58
Basal width of marginal projections	4-25	6-27
Thickness of exospore	30-62	—
Diameter of mesospore	—	393-440
Diameter of cushions	—	11-15
Thickness of distal mesospore side	—	2-3

Description. — *Megaspores examined in reflected light.* Megaspores trilete; amb circular or triangular. Spore body encompassed by equatorial corona. Corona consisting of several layers of appendages attached slightly proximal to the equator of the compressed spore body. Width of corona up to one-half of spore radius. Laesurae raised, narrow, straight to sinuous, extending to the outer margin of the corona, highest at the corona/body zone of attachment, diminishing in width and height over the corona towards its margin. Upper part of laesurae somewhat wider than the basal one, ornamented by fine spines (20—52 μm). Arcuate ridges usually weakly developed. Contact faces laevigate or covered with tubercles or spinose projections, often strongly convex. This protrusion of contact faces is the reflections of the proximal mesospore side, which is thickest and closely

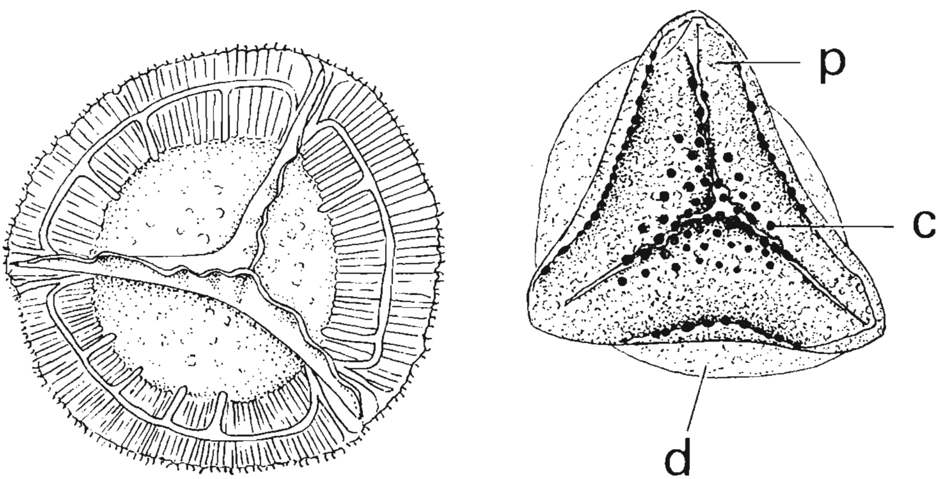

Fig. 4. *Rotatisporites tulensis* CIMP: *left* arrangement of intracoronal channel; *right* mesospore, Kr. No. Zonal. I/AB-8; *c* — cushions, *d* — distal part of mesospore, *p* — proximal part of mesospore.

adhering to the exospore over this area. Distal spore surface ornamented by more or less densely spaced appendages of various kinds, the length of which increases towards the equator, where they overlap and fuse with the corona. The distal appendages are cylindrical, slightly tapering near tip, often fused in the middle or in region of termination, occasionally forked. Exospore consists of two distinctly different layers; the sculptural elements are formed entirely by the outer layer. Mesospore adhers closely to inner surface of exospore but is easy to detach; it is thin, covered with fine cushions of uniform size (diameter 11—15 μm).

Megaspores examined in transmitted light. Megaspores double-walled, exospore thick or very thick. Proximal part of mesospore triangular with straight or concave sides, infragranulate, with trilete mark, the rays of which extend to mesospore margin. Between the triradiate rays there are numerous, circular cushions (4 rows); one row of cushions encircles the proximal mesospore side close to equator. Distal part of mesospore thin, hyaline, homogenous.

Corona consists of several (up to 10) layers of strongly forked appendages which are longest and connected by a membrane in the most proximal layer and diminish gradually in size and the degree of forking in the succeding more distal layers. The particular appendages are narrow near the base, strongly widened and forked (up to six times) near the tip. The neighbouring appendages are connected by the side branches forming at the equator the marginal rim. The rim is overgrown by the thinnest tips of appendages arranged more or less radially, these are the so called marginal projections. The appendages of the neighbouring layers are also connected by the additional complicated branches. The particular appendages are formed by the outermost layer of the exospore with which they are connected by several channels. Two centrifugally arranged channels are present within the corona. The radial channels run from the base

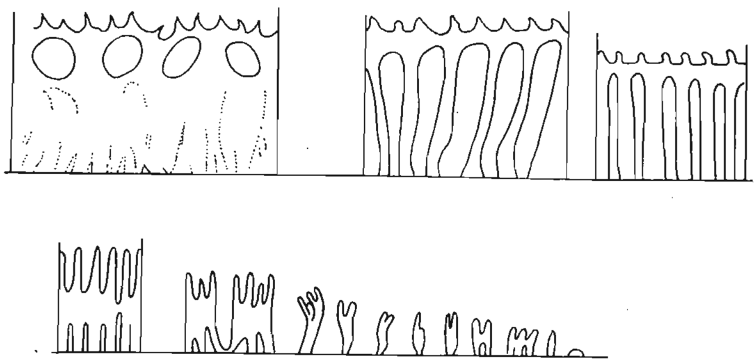

Fig. 5. *Rotatisporites tulensis* CIMP: *above* — diagram to illustrate variation in structure of each layer of corona; *below* — details of distal sculpture

of triradiate rays on the central body towards the spore margin. They fork once at one-third or one-half of their length, forming the centrifugal intracoronal channel; the second forking takes place within the marginal rim, where the centrifugal channel is formed. Distal surface ornamented by cylindrical appendages, short and simple in the central part, increasing in length towards the equator, simple or forked, discrete or connected two or three, rarely more than three, by a channel; the longest appendages are forked and overlap the corona.

Variability. — *R. tulensis* is very variable. Three main morphological types are discernible. There are also various intermediate forms linking these types. The variable spore features are: the corona/spore ratio = Z/R, height of laesurae, appearance of equatorial and distal appendages, thickness of the exospore (to a lesser degree).

Morphological type I. This type is characterized by the relatively narrow corona, lowest mean Z/R = 0.45. The mean width of corona is 230 μm, mean height of laesurae only 106 μm. Corona almost evenly wide all round, consisting of very densely spaced appendages. Marginal projections very regular, more or less parallel to each other, relatively thick; length of projections 17 to 37 µm, width 10 to 25 µm, Distal appendages narrow (12 to 40 µm) and long (up to 150 µm) very densely spaced. Proximal surface smooth or covered with tubercles 30 to 70 µm high. Mean thickness of exospore ca 40 µm. (Pls XII, XIII).

Morphological type II. This type is characterized by much wider corona (mean width 280 µm), the Z/R value being 0.50. Corona widest opposite the laesurae. Laesurae very high (mean height 160 µm). Corona formed by thick, widely spaced appendages, the number of which is 20 to a maximum of 40. Marginal projections are long (11 to 55 µm), slightly thinner than in spores of the type I (width 7 to 14 µm), Distal appendages very wide (25 to 65 µm) and long (50 to 180 µm), often forked, ones to several times, relatively widely spaced. Proximal side with distinct arcuate ridges, commonly ornamented by spinose projections 30 to 82 µm long. Exospore very thick, often more than 60 µm. (Pls XIV, XV).

Morphological type III. This type is characterized by very wide corona (mean width 313 µm), the Z/R value being 0.55, which is composed of strongly forked appendages (pl. XVI, fig. 2ab). Mean height of laesurae is 125 µm. Distal appendages relatively narrow (12 to 30 µm), usually not longer than 100 µm, densely or very densely spaced, often tangled. Marginal projections very small, 8 to 10 µm long, 4 to 5 µm wide. Proximal surface smooth or covered by thin (20 to 38 µm) spinose projections (up to 75 µm long). Mean exospore thickness 40 µm. (Pls XVI, XVII).

Remarks. — The megaspores *R. tulensis* are most similar to *R. solidus* (Dijkstra), but they are larger (the mean overall diameter of spore in *R. solidus* is 890 µm), having wider corona, narrower laesurae and ornamented distal surface.

The megaspores *R. tulensis* was described for the first time by Dijkstra (Dijkstra & Piérart, 1957) from the Moscow Basin as *Triletes brasserti* Stach & Zerndt. Having seen the collection of Zerndt, Dijkstra (1971) included this species in *Triletes mucronatus* Nowak & Zerndt, 1936. However, the present study of Zerndt's very rich material from Tula (the Moscow Basin) and also of some of Dijkstra's specimens, the thorough observation of the corona in the scanning electron microscope and in transmitted light, and also the comparison with the corona in *Z. brasserti* and *Z. mucronatus* (also from the Zerndt's collection), indicate that the megaspores from Tula can not be assigned to any of these species. *R. tulensis* differs distinctly from *Z. mucronatus* primarily in the composition of the corona which in *Z. mucronatus* is relatively uncomplicated, consisting of appendages which are simple or forked near termination and only within the most proximal layer, where they are connected by membrane. *Z. mucronatus* lack also the marginal projections, the corona is wider (354 to 644 µm) than in *R. tulensis* (100 to 500 µm). The differences in the structure of the corona in the species discussed is so great that they are placed in different genera. At the meeting of the CIMP Working

Group in April 1974, the megaspores in question were named *Rotatisporites tulensis*.

Occurrence. — USSR, Moscow Basin (Tula): Lower Carboniferous (Viséan). Poland, Lublin Coal Basin: Viséan (only atypical forms).

Rotatisporites solidus (Dijkstra, 1971) CIMP

(Pls XVIII—XX; Text-fig. 2 *I*)

1957. *Triletes brasserti* Stach & Zerndt forma *solida* f. nov.; S. J. Dijkstra & P. Piérart, p. 9, pl. 3, figs 39—60; pl. 4, figs 61—64 (65?).

?1962. *Megacapillarizonales ciliatus* Ishchenko & Semenova; A. M. Ishchenko & E. V. Semenova, p. 88, pl. 17, figs 3a, b.

1967. *Zonalesporites brasserti* f. *solida* (Dijkstra) nov. comb.: J. Karczewska, p. 315, pl. 7, figs 10—12.

1971. *Triletes solidus* Dijkstra: S. J. Dijkstra, p. 26.

Material. — Over one thousand well preserved specimens.

Dimensions in microns (33 specimens):

	dry		wet
Diameter of spore	500-1080	(mean: 890)	—
Diameter of spore body	337-960		—
Height of laesurae	40-112	(mean: 70)	—
Width of corona	110-200	(mean: 163)	—
Length of distal appendages	25-80		—
Basal width of distal appendages	10-40		—
Length of proximal projections	15-45		—
Basal width of proximal projections	10-45		—
Length of marginal projections	10-25		20-57
Basal width of marginal projections	4-14		7-25
Length of spines on laesurae	14 30		10-35
Thickness of exospore	30-40		—
Diameter of mesospore	ca 450		393-500
Diameter of cushions	—		11-15

Description. — *Megaspores examined in reflected light.* Megaspores trilete; amb circular, triangular or subtriangular. Spore body encompassed by corona approximately one third of spore radius wide, consisting of several layers of appendages. Laesurae raised, narrow, most often straight, occasionally sinuous, extending to the outer margin of corona. Height of laesurae more or less even along their length with only a slight increase at the corona/body zone attachment. Over the corona laesurae diminishing in height and width towards the spore margin. Upper part of laesurae distinctly wider than the basal part, covered with fine, short spines. Arcuate ridges weakly developed. Contact faces strongly convex, smooth or covered occasionally by rounded or conate elements. Distal surface laevigate or covered with densely spaced, thin and short appendages which are fused to form a complicated structure. Occasionally surface ornamented by thicker and more widely spaced baculate projections these are discrete or fused in twos or threes. Mean exospore thickness approximately 40 μm.

Megaspores examined in transmitted light. Megaspores double-walled; exospore thick and mesospore thin. Mesospore thicker over proximal side, infragranulate, with triradiate mark, between the rays of which they are numerous (up to 4 rows) cushions, 11 to 15 μm in diameter. Distal hemisphere of mesospore very thin (2 to 4 μm), transparent, hyaline and homogenous.

Corona consists of several (6 to 8) layers of forked appendages. These are longest close to the proximal spore side, densely spaced and connected by a thin membrane. Appendages are wide at base, thinner above it, widening again and forking two or three times near termination, where the neighboring appendages fuse to form the marginal rim. This is overgrown by thin and long (up to 57 μm) appendage tips — marginal spines. The neighboring layers of corona are connected by branches of appendages. Two centrifugally arranged channels are present within the corona. The radial channels run from the base of the triradiate rays on the central body towards the spore margin. They fork once at one third of their length forming the centrifugal intracoronal channel; the second forking takes place within the marginal rim, where the marginal centrifugal channel is formed.

Distal surface occasionally ornamented by cylindrical appendages which are shorter in the central part, appendages of the distal equatorial region may be connected, two or three together, by a channel; those closest to the corona are forked, they overlap the corona forming a compact, complicated structure of pseudo-reticulate pattern.

Variability. — The species *R. solidus* (Dijkstra) is highly variable. Three main morphological types are discernible among these spores. These differ in the corona/spore ratio, height of laesurae and appearance of equatorial and distal appendages.

Morphological type I. This type is the most numerous. It is characterized by widest corona (mean width 184 μm), the Z/R value being 0.4 and low laesurae (mean height 66 μm). The corona is in most cases wider opposite the laesurae, giving entire spores a triangular or subtriangular outline. Appendages of the corona very densely spaced. Marginal spines long and thin. Distal surface laevigate or ornamented by thin, forked and fused appendages. Proximal surface often smooth. Exospore relatively thin. (Pl. XVIII).

Morphological type II. Specimens of this type are less common. They are characterized by narrow corona (mean width 142 μm), the Z/R value being 0.3. Equatorial outline of these spores is more or less circular or subtriangular. Laesurae high (mean 83 μm). Corona usually evenly wide all around, consisting of appendages less densely spaced than in spores of type I. Appendages wide at base, narrower above it, widening and forking two to three times near termination. Distal surface smooth or covered with cylindrical appendages connected two or three together, by a channel. Proximal surface laevigate or ornamented by scattered tubercles or cones. (Pl. XIX).

Morphological type III. Megaspores of this type are rare. They are characterized by circular amb and very narrow corona (mean width 131), the Z/R value being 0.3. Laesurae very low (mean height 50 μm), much lower than those in spores of the type II. Proximal surface smooth or covered with rounded tubercles. Exospore relatively thick. (Pl. XX).

Remarks. — The megaspores *R. solidus* are most similar to those of *R. tulensis*; but differ in having smaller mean diameter, narrower corona, lower value Z/R which is less than or equal to 0.4 and lower laesurae. Equatorial appendages are less forked (up to three times). Distal spore side is smooth or has less prominent ornamentation than in *R. tulensis*.

The megaspore *M. ciliatus* Ishchenko & Semenova belongs probably to *R. solidus*, but this may be only anticipated on the basis of the description and schematic drawings; because of the lack of photographs in the paper by Ishchenko and Semenova (1962) this species is tentatively included in synonymy of *R. solidus*.

Occurrence. — USSR, Tula: Lower Carboniferous (Viséan). Poland, Lublin Coal Basin: Chełm 1 — Upper Viséan; Chełm 2, Sawin 1 — Namurian A?

Rotatisporites dentatus (Zerndt, 1938) CIMP

(Pl. XXI; Text-fig. 1 *III*)

1933. Typ 24A; J. Zerndt, p. 4, pl. 1, fig. 5.
1936. Type XII; Sahabi, p. 45, fig. 13, pl. 5, figs 1—11.
1938. Type 37; J. Zerndt, p. 1713.
1938. Type 37; *Triletes dentatus* nov. sp.; J. Zerndt, p. 22.
1969. *Zonalesporites* cf. *ramosus* (Arnold) Spinner; E. Spinner, pl. 86, fig. 7.

The full synonymy of this species can be found in Dybová-Jachowicz, *et al.* (in press).

Material. — Approximately 100 specimens.

Dimensions in microns (15 specimens):

	dry	wet
Diameter of spore	1000-1500	1400-2100
Diameter of spore body	725-1150	1034-1430
Height of laesurae	150-250	150-250
Width of corona	200-350	275-550
Length of distal appendages	60-150	90-240
Basal width of distal appendages	15-35	12-35
Basal width of equatorial appendages	—	12-38 (44-60 opposite the leasurae)
Length of proximal spines	22-40	(basal diameter up to 20)
Length of spines on laesurae	—	25-50
Thickness of exospore	45-75	—
Diameter of mesospore	ca -500	500-625
Width of marginal rim	—	28-40 (ca 110 opposite the leasurae)
Length of marginal projections	25-50	20-55
Basal width of marginal projections	—	12-30
Diameter of cushions	—	25-35

Description. — *Megaspores examined in reflected light.* Megaspores trilete; amb circular or oval. Spore body encompassed by equatorial corona, ca. one third of spore radius wide (mean width 274 μm), composed of cylindrical appendages branched a few times and fused near termination into marginal rim. Outer margin of the rim ornamented by baculate or clavate projections arranged radially. Laesurae distinctly sinuous, equally high along their length, extending to the outer margin of the corona. Upper part of laesurae covered by numerous spines. No arcuate ridges represent the curvaturae which are only marked by bases of equatorial appendages. Contact faces smooth or covered with fine, thin, shining spines. Distal surface laevigate or ornamented by quite long (mean 100 μm), cylindrical appendages with clavate tips. These appendages are simple or forked two to three times. Exospore thick (mean ca. 60 μm). Mesospore with triradiate mark, in profile proximal side pyramidal, distal side convex.

Megaspores examined in transmitted light. Megaspores double-walled. Exospore thick, mesospore very thin. Mesospore with triradiate mark, covered proximally by numerous circular cushions ca 25 to 35 μm in diameter.

Laesurae thick at base, much thinner near top, strongly sinuous, ornamented by relatively long spines (mean length 30 μm). Thicker basal part of laesurae is approximately one-third of the total height.

Corona composed of several layers of equatorial appendages. The appendages cylindrical, slightly wider at the base, branched a few times near termination, connected with the neighbouring ones to form a thick and wide marginal rim (mean width 35 μm). The branches of appendages of the neighboring layers are also fused forming a pseudo-reticulate pattern. In well preserved specimens the membrane connecting the appendages from the proximal side may be observed. Outer margin of the marginal rim covered with clavate projections which are arranged radially and of more or less equal length. Similar elements may be observed on the distal side of corona; they represent the terminations of appendages of the particular corona layers (Text-fig. 1 *III*). The marginal channel runs centrifugally inside the marginal rim; the intracoronal channel is not often clearly visible. Distal surface ornamented by clavate projections, simple or forked in very characteristic way (pl. XXI, fig. 1b); they are shortest near the distal pole, longer and forked even three times close the equator.

Variability. — The megaspore *R. dentatus* are weakly variable. The variable features are: the size range, the width of corona, appearance of equatorial appendages and exospore thickness.

Remarks. The megaspore *R. dentatus* is most similar to *R. rotatus* (Bartlett). These two species differ in having different size ranges (425 to 750 μm for *R. rotatus* and 725 to 1150 μm for *R. dentatus*); different width of corona, which is up to 350 μm the Z/R value being 0.4 in *R. dentatus* when in *R. rotatus* it is up to 500 μm, the Z/R value being 0.5. The mean height of laesurae is larger in *R. dentatus* (166 μm) whereas that in *R. rotatus* is only 54 μm. Moreover, the equatorial appendages in spores of *R. dentatus* are wider and more branched and the marginal projections are wider and have rounded tips.

Occurrence. — Poland, Upper Silesian Basin: Westphalian C/D; Lublin Coal Basin: Upper Part of the Mudstone Series. Czechoslovakia: Westphalian D. France: Westphalian A, Westphalian C—D. Belgium: Westphalian C—D. Great Britain: Westphalian D. USA: Upper Namurian — Lower Westphalian.

R. dentatus is in Europe restricted to the Westphalian deposits, mainly to the Westphalian C—D. In the USA it is also known from the uppermost Namurian and from the Lower Westphalian.

Genus *Zonalesporites* (Ibrahim, 1933) Potonié & Kremp, 1954 emend. CIMP

Type species: *Zonalesporites brasserti* (Stach & Zerndt, 1931) Potonié & Kremp, 1954

Zonalesporites brasserti (Stach & Zerndt, 1931) Pot. & Kr., 1954

(Pls XXII—XXVII; Text-fig. 1 *II*)

1886. Type XVI Bennie & Kidston, p. 113, pl. 5, fig. 16.
1886. Type XVIII Bennie & Kidston, p. 114, pl. 5, fig. 18.

1931. *Triletes brasserti* Stach & Zerndt sp. nov.; E. Stach & J. Zerndt, p. 1123, figs 16, 28—31.
1954. *Zonalesporites brasserti* (Stach & Zerndt) nov. comb.: R. Potonié & G. Kremp, p. 161, pl. 13, fig. 59.

The full synonymy of this species may be found in Dybová-Jachowicz, *et al.* (in press).

Material. — Several thousand specimens.

Dimensions in microns (50 specimens):

	dry	wet
Diameter of spore	1065-2625	—
Diameter of spore body	625-1750	980-2000
Height of laesurae	125-450	—
Width of corona	250-625	450-790
Length of distal appendages	—	16-82
Basal width of distal appendages	—	16-24
Width of marginal channel	—	10-41
Thickness of exospore	87-100	—
Length of spines on laesurae	20-100	22-110
Diameter of mesospore	ca. 550	400-600
Diameter of cushions	—	13-20

Description. — *Megaspores examined in reflected light.* Megaspores trilete; amb subtriangular, more seldom circular. Spore body encompassed by corona consisting of several layers of appendages. The mean width of corona is 465 μm when the Z/R value being 0.45. Laesurae raised, narrow, distinctly sinuous, extending to the outer margin of corona, highest at the body/corona zone of attachment, diminishing in width and height over the corona towards the spore margin. Arcuate ridges occasionally very distinct. Contact faces smooth or covered with tubercles or spines. Distal surface usually smooth, exceptionally ornamented by tubercles or blunt, elongated appendages, which are best preserved near the equator where they overlap the corona. Exospore very thick.

Megaspores examined in transmitted light. Megaspores double-walled; exospore very thick and mesospore thin. Mesospore thicker over proximal side, infragranulate, with triradiate mark, between the rays of which there are numerous (8—9 rows) cushions. Distal hemisphere of mesospore very thin, hyaline, homogenous.

Laesurae thick at basis, granulate, upper part covered with spines which increase in length towards the equator.

Corona consists of several layers (6 to 10) of appendages, it is very compact and thick, thickest at the region of corona/body attachment. The longest equatorial appendages are these of the most extreme proximal layer. They are connected by a membrane. Appendages evenly wide, forked near termination where they interweave with appendages tips of the neighbouring layers (pl XXIII, fig. 1a, b); this part of corona is less compact and is characterized by the presence of small, oval dissections. In the distal region of the corona attachment the elements are fused and connected by a membrane. These appendages are forked and interweaving above the half of their length, forming the complicated structure of the distal part of the corona. The marginal channel is situated closer to the spore center than to the marginal dissections, within the zona of forking and interweaving of the equatorial appendages.

Proximal surface densely covered by tubercles representing the remnants of spines, which are only very seldom preserved as such. Distal surface often smooth, occasionally ornamented by tubercles in the center and by blunt, elongated, straight appendages near equator.

Variability and preservation. — *Z. brasserti* (Stach & Zerndt) Potonié & Kremp is a long ranging species recorded from Viséan to Lower Stephanian deposits. There is a progressive change in the size of these spores during this period; the earliest spores are the smallest and the largest ones are known from the Stephanian deposits of Spain. These were described by Dijkstra (1955) as *Triletes brasserti* forma I (major). The diameter of the spore body in these spores exceeds 2000 mμ. The variability of *Z. brasserti* is also expressed in the width of corona, height of laesurae and corona/spore ratio (Z/R). *Z. brasserti* is characterized by possesing the most massive and compact corona in relation to the other species in this genus. The equatorial appendages are coalescent and connected by a membrane; due to this, the corona is difficult to destroy and is often detached from the spore body as a whole. For this reason the spores of this species were included in Cingulati (Potonié & Kremp, 1954). The corona of these spores, when examined in transmitted light, displays a great variability which is related to the state of preservation and to the phase of development of a particular specimen. In some cases the distal part of the corona is destroyed and the remaining basal parts of the equatorial appendages may be seen as very characteristic protruding elements (pl. XXV fig. 1, 4). Occasionally only the proximal or only the distal part of the corona is preserved. The various states of the corona preservation are shown in pl. XXVI.

In some special cases the spores belonging to *Z. brasserti* may differ from the typical forms. This happens in the spores from the Reden coal seam (No 501 to 510), as was noted earlier by Zerndt (1934). This author described the spores differing from *Z. brasserti* as *Triletes circumtextus*. In his later papers Zerndt did not retain this species for practical reasons but included it in *T. brasserti*. However the present material from coal seams 501—510 permits to trace the intermediate forms linking the typical specimens of *Z. brasserti* with those of *T. circumtextus* and with the spores belonging to *Z. brasserti s.s.* from the younger coal seams (the four-hundreds). It is suggested, therefore, that all these spores represent one species. Nevertheless, the spores described by Zerndt as *T. circumtextus* differ from the typical forms of *Z. brasserti* in the size range and the structural organisation. Thus, it seems reasonable to distinguish them as some endemic forms (ecological types) which are very characteristic of the particular coal seams in which they occur. These spores are called here *Zonalesporites brasserti* forma *circumtextus.*

Remarks. — The megaspore *Z. brasserti* is most similar to those of the species *Z. superbus* (Barlett) Karczewska, from which they differ in having smaller spore body, narrower corona and lower laesurae. Moreover, the corona in *Z. brasserti* is very compact and the marginal connections between the equatorial appendages are thin and delicate while in *Z. superbus* the corona is more retiform and delicate and the equatorial appendages are most strongly connected within the marginal part of the corona. The megaspores belonging to *Z. superbus* possess also well developed distal appendages which are not characteristic of *Z. brasserti.*

Occurrence. — Poland, Upper Silesian Basin: Dinantian — Westphalian C; Lower Silesian Basin: Namurian A — Lower Westphalian; Lublin Coal Basin: Viséan — Westphalian A?. Czechoslovakia: Namurian A. Westphalian C. Belgium: Westphalian A—D. Holland: Westphalian A—C. Great Britain: Dinantian, Lower Namurian, Westphalian D. Germany: Westphalian B—C. France: Upper Namurian — Westphalian C. Spain: Lower Westphalian — Lower Stephanian. Egypt: Lower Carboniferous. Turkey: Namurian — Westphalian C. USSR: Lower Carboniferous. USA: Upper Namurian — Westphalian C.

Zonalesporites brasserti (Stach & Zerndt, 1931) Potonié & Kremp forma *circumtextus* (Zerndt, 1934) f. nov.

(Pl. IX, fig. 2 and Pls XXVIII—XXXI; Text-fig. 2 *III*)

1931. Type 18; J. Zerndt, p. 173, pl. 6, figs 17-18.
1934. Type 18, *Triletes circumtextus* sp. nov.; J. Zerndt, p. 19, fig. 7, pl. 19, figs 1-11; pl. 21, figs 1-7; pl. 22, figs 1-10; pl. 23, figs 1-14; pl. 31, figs 1, 2, 4-5, 7; pl. 32, figs 1-7, 10.
1947. *Triletes circumtextus* Zerndt; A. T. Cross, p. 301, pl. 3, figs 78-79.
1947. *Triletes brasserti* var. I; A. T. Cross, p. 300, pl. 3, figs 87-90.
1950. *Triletes subbrasserti* sp. nov.: Ch. A. Arnold, p. 71, pl. 2, figs 2, 3.

Material. — Several thousands specimens.

Dimensions in microns (110 specimens):

	Dry	Wet
Diameter of spore	582-1500	—
Diameter of spore body	375-963	495-1000
Height of laesurae	45-162	—
Width of corona	75-390	110-520
Length of distal appendages	10-35	10-50
Basis width of distal appendages	5-24	8-30

Length of proximal projections	10-45	15-50
Basis width of proximal projections	10-15	10-20
Length of spines on laesurae	10-50	10-63
Thickness of exospore	20-45	—
Diameter of mesospore	300-413	200-560
Diameter of cushions	12-20	10-20
Thickness of mesospore (proximal part)	—	5-7

Description. — *Megaspores examined in reflected light.* Megaspores trilete; amb circular or subtriangular. Spore body encompassed by equatorial corona. Laesurae elevated, narrow, slightly sinuous, extending to the outer margin of corona, highest at the body/corona zone of attachment. No arcuate ridges or only weak ones represent the curvaturae. Contact faces smooth or ornamented by spines or cones. Distal surface smooth or covered with tubercles in the central part and with bacula in the equatorial region. Occasionally distal surface covered with densely spaced, coalescent tubercles, which form some sort of an additional layer covering the spores from the outside. Average thickness of exospore is ca. 30 μm.

Megaspores examined in transmitted light. Megaspore double-walled, exospore thick, mesospore thin. Mesospore thicker over proximal side, infragranulate, with triradiate mark, possessing 5 to 8 rows of cushions between triradiate rays. Distal part of mesospore very thin, transparent, homogenous. Base of laesurae wide, upper part narrower, covered with spines, the length of which increases progressively towards the corona. Over the corona laesurae diminishing in width and height.

Corona composed of several (4—6) layers of equatorial appendages: these which are close to the proximal side of the spore fused and connected by a membrane and slightly forked within the marginal part of the corona where they form small dissections. Appendages of the successive layers of the corona diminishing in length towards the distal spore side. They are straight in the basal part but widen and fork above it; they anastomose with the neighboring appendages and with those of the neighboring layers, forming a compact, retiform structure. Marginal channel runs centrifugally along the outer margin of the corona; intracoronal channel is situated close to the spore body and is not often clearly visible. Proximal surface densely covered with spines; distal surface ornamented by tubercles of circular basis outline, baculate appendages or (occasionally) with densely spaced and fused low projections. Surface of some spores covered with an extra layer of granulate, spongy, irregularly perforated structure. (Pl. XXXI, fig. 6a).

Variability. — The megaspore *Z. brasserti* f. *circumtextus* is most variable. Zerndt (1934) distinguished within this group four morphological types on the basis of the differences in size, height of laesurae, structure of the corona and ornamentation of the distal surface. The present detailed measurements and the observations of the spore structure in transmitted light, based upon the very rich material (including also the original material of Zerndt) by the use of the scanning electron microscope, permit recognition of two main morphological types of *Z. brasserti* f. *circumtextus*. The type 18d of Zerndt was erected on the basis of one specimen. Its existence as a distinctive form has not been corroborated by the present study; it is certain that this specimen belongs to *Z. brasserti s.s.* The megaspores of the types 18a and 18c differ from each other by the presence or absence of the distal tubercules and by the more or less compact corona. It seems that the spores of those two types, which were derived from two different mines, differ only in state of preservation. It is, therefore, suggested that the spores of the types 18a and 18c represent one morphological type.

Dimensions in microns	Morphological type I	Morphological type II
Diameter of spore	750-1500	582-1100
Diameter of spore body	570-963	500-840
Height of laesurae	60-167	45-120
Width of corona	162-390	75-200
Z/R	0.4	0.3

Morphological type I (= type 18a + 18c Zerndt). This type includes megaspores which are characterized by wider corona (Z/R = 0.4), higher laesurae (mean height 109 μm) and smooth or ornamented distal surface. (Pls XXVIII, XXIX and XXX, figs 1, 5, 6).

Morphological type II (= type 18b Zerndt). This type includes megaspores with narrow corona (Z/R = 0.3), and low laesurae (mean height 85 μm); the proximal surface in these spores is smooth or conate while the distal surface is most often smooth or ornamented by scattered tubercles. (Pl. XXX, figs 2—4; Pl. XXI).

Remarks. — The megaspore *Z. brasserti* f. *circumtextus* differ from those of *Z. brasserti s.s.* in being smaller and having narrower and more compact corona with smaller dissections in the marginal part. They have also lower laesurae, frequently ornamented distal surface and thinner exospore.

Megaspores with similar features were described by Arnold (1950) as *Triletes subbrasserti*; these were supposed to differ from *T. brasserti* in being smaller and having the exine of lighter colour, and from *T. circumtextus* by having narrower corona. This does not seem correct because (according to Arnold) the width of the corona in *T. subbrasserti* is 150 to 200 μm, whereas that *T. circumtextus* is 97 to 320 μm; the features of *T. subbrasserti* fall within the variation limits of *T. circumtextus*. On the other hand, the differences between *T. subbrasserti* and *T. brasserti* are the same as those between the latter and *T. circumtextus*. Therefore the species described by Arnold is included to the synonymy of *Z. brasserti* f. *circumtextus* (the morphological type II).

Cross (1947, p. 301) found the megaspore *T. circumtextus* "especially Type 18a, 18c and 18d", but he also distinguished some other spores characterized by a narrow corona, which he called *T. brasserti* var. I (pl. 3, figs 87—90). These spores do not differ from *Triletes circumtextus* — Type 18b Zerndt and are believed to represent *T. brasserti* f. *circumtextus* (morphological type II).

Occurrence. — Poland, Upper Silesian Basin: Namurian B (the Saddle) Beds). USA: Upper Namurian — Lower Westphalian.

Zonalesporites mucronatus (Nowak & Zerndt, 1936) CIMP
(Pl. XXXII)

1936. *Triletes mucronatus* nov. sp.; J. Nowak & J. Zerndt, p. 59, pl. 1, fig. 2.
1937. *Triletes mucronatus* Nowak & Zerndt; J. Zerndt, p. 16, text-fig. 12.
1946. *Triletes mucronatus* Nowak & Zerndt; S. J. Dijkstra, p. 42.
1969. *Zonalesporites fusinatus* Spinner; E. Spinner, p. 452, pl. 86, figs 1—4.

Material. — More than ten specimens (from the original collection of Zerndt).
Dimensions in microns (14 specimens):

	Dry	Wet
Diameter of spore	1120-2000	—
Height of laesurae	160- 390	—
Width of corona	250- 644	—
Length of equatorial appendages	—	550-720
Width of equatorial appendages	—	11- 24
Length of distal appendages	—	70-360
Basal width of distal appendages	—	15- 28
Length of spines on laesurae	—	30- 37
Thickness of exospore	up to 40	—

Description. — *Megaspores examined in reflected light.* Megaspores trilete; amb mor or less circular or subtriangular. Spore body encompassed by corona one-third to one-half of spore radius wide, consisting of several layers of appendages. Laesurae raised, narrow, straight or slightly sinuous, extending to the outer margin of corona. No arcuate ridges represent the curvaturae which are only marked by bases of equatorial appendages. Contact faces smooth or ornamented by tubercles. Distal surface covered with clavate appendages. Length of distal appendages increases towards the equator; the appendages close to equator overlap the corona. Exospore thickness does not exceed 40 μm.

Megaspore examined in transmitted light. Corona consisting of several (6—10) layers of clavate appendages connected from the proximal side by distinct membrane. The appendages long, narrow, evenly wide along their length, widened and rounded at termination. The widened terminations originate from hooking of the appendage tip and its fusing with the adjoining lower part of the appendage. The neighboring appendages are fused within the widened parts. Appendages of the neighboring layers are connected by membrane or only by fused tips (pl. XXXII, figs 2, 4, 5). The intracoronal channel is relatively wide; it runs centrifugally in more or less half of corona width. The marginal channel is weakly developed.

Distal surface covered with appendages which are similar to those of the corona. These are short at distal pole, the longest near equator where they overlap the corona. They may be discrete or fused, in twos or threes, in the middle part or at termination.

Laesurae ornamented by spines, which are the longest in the region of the corona attachment.

Remarks. — The megaspore *Z. mucronatus* (Nowak & Zerndt), when examined in reflected light, is most similar to *Z. brasserti*, from which it differs in the structure of the corona and the ornamentation of the distal surface. The corona in *Z. mucronatus* is simple, the appendages are not forked and the particular layers are not so strongly connected as in *Z. brasserti*. The distal surface is laevigate or weakly ornamented in *Z. brasserti* while in *Z. mucronatus* it is densely covered by long appendages.

The structure of corona and the ornamentation of the distal hemisphere are similar in *Z. mucronatus* and *Z. superbus*, but the equatorial appendages are forked and fused in spores of the latter species and the structure of the corona is more complicated. Moreover these spores are larger, and possess a wider corona and very high laesurae.

The megaspore *Z. fusinatus* Spinner, described by Spinner (1969) from the Viséan deposits of Scotland, does not differ from those belonging to *Z. mucronatus* and therefore they are included in the synonymy of that species.

Occurrence. — Poland, Rączna, Tenczynek: Lower Namurian A; Scotland: Viséan.

Zonalesporites superbus (Bartlett, 1929) Karczewska, 1967
(Pls XXXIII, XXXIV; Text-fig. 6)

1929. *Triletes superbus* sp. nov.; H. H. Bartlett, p. 20, pl. 7, figs 1, 2; pl. 8, figs 1, 2.
1954. *Superbisporites superbus* (Bartlett) nov. comb.; R. Potonié & G. Kremp, p. 264.
1967. *Zonalesporites superbus* (Bartlett) nov. comb.; J. Karczewska, p. 317, pl. 9, fig. 14.

The full synonymy of *Z. superbus* can be found in Dybová-Jachowicz *et al.* (in press).

Material. — Approximately 500 specimens.
Dimensions in microns (27 specimens):

	Dry	Wet
Diameter of spore	3000-4020	—
Diameter of spore body	1500-2600	—
Height of laesurae	255-600	550-800
Width of corona	625-1000	875-1300
Length of distal appendages	40-250	60-440
Width of distal appendages	25-37	8-51
Lenght of proximal projections	87-250	38-250
Basal width of proximal projections	15-35	21-37
Length of spines on laesurae	50-125	30-220
Width of marginal rim	—	30-300
Thickness of exospore	45-95	—
Diameter of mesospore	1000-1500	1200-1700
Thickness of proximal part of mesospore	—	ca. 5
Diameter of cushions	—	15-20

Description. — *Megaspores examined in reflected light.* Megaspores trilete; amb circular to subtriangular. Spore body encompassed by equatorial corona approximately half of spore radius wide, consisting of several layers of appendages. Laesurae very high, narrow, strongly sinuous, extending to the outer margin of corona, highest near the corona/body zone of attachment, strongly diminishing in width and height over the corona towards the equator. Curvaturae marked by bases of equatorial appendages. Contact faces ornamented by tubercles or spines. Distal surface covered by more or less densely spaced clavate appendages. These are shortest at distal pole, increasing in length towards equator; the outermost appendages overlap the corona. Exospore very thick.

Megaspores examined in transmitted light. Megaspores double-walled: exospore very thick, mesospore thin. Proximal part of mesospore thick, infragranulate, with triradiate mark, between the rays of which there are numerous (8 to 10 rows) cushions; distal hemisphere very thin, homogenous, transparent, hyaline.

Laesurae thick and granulate at base; thin within upper part, strongly sinuous, densely covered with spines arranged in a few rows; spines increasing in length towards the spore body margin.

Corona consists of several (ca. 10) layers of equatorial appendages which are not equally wide. The differences in appendage width are due to their origin, which is by fusion of thinner elements; the wider appendages are formed by fusion of more elements. The single elements are very thin, hooked, fused with the neighboring elements along the whole length; the strongest fusion is that of the hooked tips. Equatorial appendages of the proximal spore side connected by a thin membrane. The fused tips

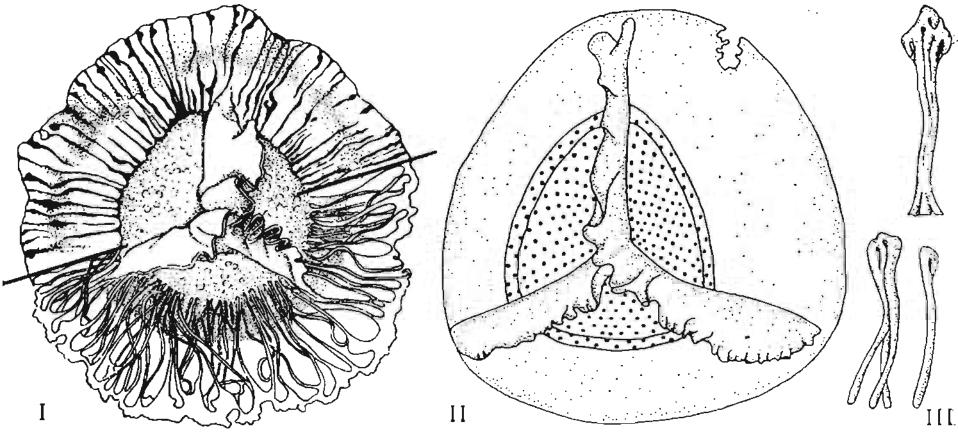

Fig. 6. *Zonalesporites superbus* (Bartlett, 1929) Karczewska, 1967: I — *above* — corona with membrane, *below* — corona without membrane; II — proximal surface showing a mesospore; III — equatorial appendages exposing variation in form.

of equatorial appendages form a marginal rim. The marginal channel runs inside the rim. The appendages of the neighbouring layers are connected by side branches forming a complicated structure. The intracoronal channel runs relatively close to the marginal channel, which makes the outer part of the corona stronger. In the absence of the membrane the appearance of the corona is retiform and its margin is dissected; the dissections are delimited by the marginal rim, side branches of equatorial appendages and intracoronal channel. The appendages of various width are branched and interweaving (Text-fig. 6 *I*). Contact faces covered by densely spaced, long spines with very narrow tips, which may overlap the corona. The tips are often broken, giving the basal parts of projections have a tuberculate appearance. Distal surface ornamented by long appendages with blunt or clavate terminations. The appendages are formed by fusion of two to three elements connected along the whole length or only within the hooked tips (Text-fig. 6 *III*). In most cases the appendages are equally long over the whole distal surface, but occasionally they are shorter and cylindrical near the distal pole; towards the equator the appendages are succesively longer, fused of more elements and overlaping the corona.

Remarks. — *Z. superbus* (Bartlett) is characteristic in appearance. It is most similar to those of *Z. brasserti*, but they differ in being larger and having much higher laesurae, less compact corona and different ornamentation of the distal side. The corona in spores of *Z. superbus* and the ornamentation of the distal side are more similar to those in *Z. mucronatus* (Nowak & Zerndt) but in the former species the corona structure is more complicated.

Occurrence. — Poland, Upper Silesian Basin: Westphalian A—C; Lublin Coal Basin: Westphalian A—C. Czechoslovakia: Westphalian B—C. Germany: Westphalian C. France: Upper Namurian, Westphalian A—D. Belgium: Westphalian B—D. Holland: Westphalian B—D. Turkey: Westphalian C. USA: Westphalian A—B.

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REFERENCES

ARNOLD, A. C. 1950. Megaspores from the Michigan Coal Basin. — *Contr. Mus. Paleont. Michigan*, **8**, 5, 59—111, Ann Arbor.

BARTLETT, H. H. 1929. Fossils of the Carboniferous Coal Pebbles of the glacial drift at Ann Arbor. — *Papers Mich. Acad. Sci. Art., Lett.*, **9**, 11—28, Michigan.

BENNIE, J. & KIDSTON, R. 1886. On the occurrence of spores in the Carboniferous Formations of Scotland. — *Proc. Phys. Soc. Edinb.*, **9**, 88—117, Edinburg.

BHARADWAJ, D. C. & TIWARI, R. S. 1970. Lower Gondwana megaspores. A monograph. — *Palaeontographica*, B, **129**, 1—70, Stuttgart.

BODE, H. 1928. Über eine merkwürdige Pteridophytenfruktifikation aus dem oberschlesischen Karbon. — *Jb. Preuss. Geol. Landesanst.*, **49**, 245—247, Berlin.

BOUREAU, E. 1967. Traité de Paléobotanique, **2**, 5—845, Paris.

BUTTERWORTH, A. M. & SPINNER, E. 1967. Lower Carboniferous spores from North-west England. — *Palaeontology*, **10**, 1, 1—24, London.

CHALONER, W. G. 1956. On Sporangiostrobus langfordi sp. no., a new fossil cone from Illinois. — *Amer. Midl. Nat.*, **55**, 437—442, Notre Dame.

— 1962. A Sporangiostrobus with Densosporites microspores. — *Palaeontology*, **5**, 1, 73—85, London.

— *in* BOUREAU, E. 1967. Traité de Paléobotanique, Lycophyta, **2**, 435—785.

CROSS, A. T. 1947. Spore floras of the Pennsylvanian of West Virginia and Kentucky. — *J. Geol.*, **55**, 3, 285—308, Chicago.

DIJKSTRA, S. J. 1946. Eine monographische Bearbeitung der karbonischen Megasporen. — *Med. Geol. Sticht.*, Ser. C-III-1, 1—101, Maastricht.

- 1955. Megasporas carboniferas españolas y su empleo en la correlación estratigráfico. — *Estud. Geol.*, 11, 27/28, 277—354, Madrit.

— 1971. The megaspores of boring Thad. — *Med. Rijks. Geol. Dienst.* N. S., 22, 25—53, Maastricht.

— & PIÉRART, P. 1957. Lower Carboniferous megaspores from the Moscow Basin. — *Med. Geol. Sticht.*, N. S., 11, 5—19, Maastricht.

DYBOVÁ-JACHOWICZ, S., KARCZEWSKA, J., LACHKAR, G., LOBOZIAK, S., PIÉRART, P. & ŻOŁDANI, Z. (in press). Revision des mégaspores à corona du Carbonifère, Warszawa.

ERDTMAN, G. 1969. Handbook of palynology., 15—486, New York.

HIRMER, M. 1927. Handbuch der Paläobotanik., 1—708, Berlin.
HOEG, O. A. & BOSE, M. N. 1960. The Glossopteris flora of the Belgian Congo. — *Ann. Mus. R. Congo belg. Terv. Sci. Geol.*, **32**, 8, 1—109, Tervuren.
— BOSE, M. N. & MANUM, S. 1955. On double-walls in fossil megaspores with description of Duosporites congoensis n. gen., n. sp. — *Nytt Mag. Bot.*, **4**, 101—107. Oslo.
HORST, U. 1955. Die Sporae dispersae des Namurs von West-Oberschlesien und Mährisch-Ostrau. — *Palaeontographica*, B, **98**, 137—236, Stuttgart.
ISHCHENKO, A. M. & SEMENOVA, E. V. 1962. Megaspory kamennougolnogo vozrasta i ich stratigrafičeskoe značenie. 3—147, Kiev.
JACHOWICZ, A. 1966. Charakterystyka mikroflorystyczna karbonu lubelskiego. — *Prace IG*, **44**, 103—134, Warszawa.
KARCZEWSKA, J. 1967. Carboniferous spores from the Chełm I boring (Eastern Poland). — *Acta Paleont. Pol.*, **12**, 3, 268—345, Warszawa.
LEISMAN, G. A. 1970. A petrified Sporangiostrobus and spores from the Middle Pennsylvanian of Kansas. — *Palaeontographica*, B, **129**, 166—177, Stuttgart.
LINDLEY, J. & HUTTON, W. 1833—1837. The fossil flora of Great Britain.
MORTIMER, M. G. & CHALONER, W. G. 1967. Devonian megaspores from the Wyboston borehole, Bedfordshire, England. — *Palaeontology*, **10**, 2, 189—213, London.
NEMEJC, J. 1931. A study on the systematical position of the fructification called Sporangiostrobus Bode. — *Bull. Int. Acad.*, **32**, 68—79, Prague.
NOWAK, J. & ZERNDT, J. 1936. Zur Tektonik des östlichsten Teils des polnischen Steinkohlenbeckens. — *Bull. Acad. Pol. Sci.*, ser. A, 56—73, Kraków.
PANT, D. D. & SRIVASTAVA, G. K. 1961. Structural studies on Lower Gondwana megaspores. Part. I. — Specimens from Talchir Coalfield, India. *Palaeontographica*, B, **109**, 45—61, Stuttgart.
— & — 1962. Structural studies on Lower Gondwana megaspores. Part II. Specimens from Brazil and Mhukuru Coalfield, Tanganyika. — *Ibidem*, **111**, 96—111.
POTONIÉ, R. 1955. Zur Biologie der karbonischen Sporen. — *Paläont. Ztschr.*, **29**, 1/2, 27—32, Stuttgart.
— 1970. Synospis der Gattungen der Sporae dispersae. Teil V. — *Beih. Geol. Jb.*, **87**, 3—220, Hannover.
— 1973. Phylogenetische Sporologie. — *Forschr. Geol. Rheinld. u. Westf.*, **22**, 1—142, Krefeld.
— & KREMP, G. 1954. Die Gattungen der paläozoischen Sporae dispersae und ihre Stratigraphie. — *Geol. Jb.*, **69**, 111—194, Hannover.
— & — 1956. Die Sporae dispersae des Ruhrkarbons, ihre Morphographie und Stratigraphie ect. — Teil. III. *Palaeontographica*, B, **100**, 65—142, Stuttgart.
SEWARD, A. C. 1910. Fossil plants. Cambridge.
SPINNER, E. 1965. Westphalian D megaspores from the Forest of Dean Coalfield, England. — *Palaeontology*, **8**, 1, 82—106, London.
— 1969. Megaspore assemblages from Viséan deposits at Dunbar, East Lothian, Scotland. — *Palaeontology*, **12**, 3, 441—458, London.
— & CLAYTON, G. 1973. Viséan spore assemblages from Skateraw, East Lothian, Scotland. — *Pollen et Spores*, **15**, 1, 139—165, Paris.
STACH, E. & ZERNDT, J. 1931. Die Sporen in den Flamm-, Gesflamm- und Gaskohlen des Ruhrkarbons. — *Glückauf*, **67**, 35, 1118—1124, Essen.
WINSLOW, M. R. 1959. Upper Mississippian and Pennsylvanian megaspores and other plant microfossils from Illinois. — *Bull. Illinois State Geol. Surv.*, **86**, 7—135, Urbana.
ZERNDT, J. 1931. Megasporen als Leitfossilien des produktiven Karbons. — *Bull. Acad. Pol. Sci.*, Ser. A, 165—183, Kraków.

— 1933. Versuch einer stratigraphischen Bestimmung von Steinkohlen-Gerölen der Karpaten auf Grund von Megasporenstudien. — *Ibidem*, Ser. B, 1—7.
— 1934. Les mégaspores du Bassin Houiller Polonais. — *Acad. Pol. Sci. Lett.*, Trav. Géol., **1**, 1—56, Kraków.
— 1937. Les mégaspores du Bassin Houiller Polonais. — *Ibidem*, **3**, 1—78.
— 1938 *a*. Die Eignung von Megasporen als Leitfossilien. — 3 Congr. Strat. Carb. Heerlen 1935, 1711—1732, Maastricht.
— 1938 *b*. Vertikale Reichweite von Megasporentypen in Karbon des Bassin du Nord. — *Roczn. Pol. Tow. Geol.*, **13**, 21—30, Kraków.

JADWIGA KARCZEWSKA

MEGASPORY Z GRUPY ZONALES Z KARBONU POLSKI. CZĘŚĆ I. MEGASPORY Z KORONĄ

Streszczenie

W pracy niniejszej opisano 8 gatunków megaspor z koroną należących do następujących rodzajów karbońskich: *Radiatisporites*, *Rotatisporites* i *Zonalesporites*. Autorka oparła się na bardzo bogatym materiale megasporowym, pochodzącym z Górnośląskiego i Lubelskiego Zagłębia Węglowego z pokładów badanych po wojnie oraz z oryginalnej kolekcji Jana Zerndta (1931, 1933, 1934, 1936, 1937, 1938 *a*, *b*). Autorka dysponowała w sumie 100 tysiącami okazów bardzo dobrze zachowanych, poza tym wykonała 500 preparatów megaspor do badań w świetle przechodzącym. Jako materiałów porównawczych autorka użyła megaspory z karbonu Czechosłowacji, Holandii, Hiszpanii i Turcji. Z kolekcji Zerndta autorka zbadała na nowo okazy typowe dla gatunków ustalonych przez Zerndta, ponadto opracowała megaspory z Tuły (Basen Moskiewski) które były zgromadzone w tej kolekcji, ale dotąd nie opracowane.

Stosowane dotychczas powszechnie metody badań megaspor w świetle odbitym nie pozwalają na dokładne poznanie ich budowy. Dobre rezultaty daje łączenie badań w świetle odbitym i przechodzącym oraz w skanningowym mikroskopie elektronowym. W pracy niniejszej zastosowano wszystkie trzy metody co pozwoliło autorce na sprecyzowanie poglądu na temat budowy ścian megaspor, na prześledzenie budowy korony i wyodrębnienie poszczególnych jej elementów. Autorka stwierdziła, że u wszystkich megaspor z koroną występuje dobrze rozwinięty mesospor z licznymi „cushions". Korona jest wielowarstwowa, zbudowana z wyrostków równikowych połączonych membraną od strony proksymalnej. W obrębie korony stwierdzono występowanie dwóch kanałów łączących wyrostki równikowe: wewnętrznego i marginalnego. Okazało się, że budowa korony jest cechą diagnostyczną dla rodzajów i gatunków. Stwierdzono również, że u wszystkich megaspor z koroną ramiona znaku zrostowego sięgają do zewnętrznego brzegu korony i w górnej części pokryte są kolcami. Na podstawie budowy korony udało się autorce prześledzić kierunki ewolucji tych megaspor. Główne typy budowy pojawiły się w górnym wizenie, dalsza ewolucja przebiegała w czterech kierunkach: 1. *Rotatisporites solidus* → *Radiatisporites radiatus*; 2. *Rotatisporites tulensis* → *R. rotatus* → *R. dentatus*; 3. *Zonalesporites mucronatus* → *Z. superbus*; 4. *Z. brasserti*. Tempo ewolucji było różne w poszczególnych liniach rozwojowych, np. najszybsze zmiany następowały w linii *R. solidus* → *R. radiatus* a także w obrębie tego ostatniego gatunku; najbardziej konserwatywną i długowieczną formą był *Zonalesporites brasserti* występujący od górnego wizenu do dolnego stefanu. Obok megaspor *Z. brasserti s.s.* stwierdzono występowanie form niedojrzałych, które wydzielono jako *Z. brasserti* (Stach & Zerndt, 1931) f. *circumtextus* (Zerndt, 1934) f. nov. Wysunięto przypuszczenie, że powodem masowego występowania tych ostatnich w pokładach pięćsetnych (namur B) musiały być zmiany środowiska, w którym żyły rośliny macierzyste. Podkreślono znaczenie tej formy megaspor dla stratygrafii i identyfikacji pokładów redenowych. W pracy niniejszej wysunięto przypuszczenie, że megaspory z koroną mogły należeć do roślin widłakowych z rodziny Bothrodendraceae, lub blisko z nią spokrewnionej.

ЯДВИГА КАРЧЕВСКА

МЕГАСПОРЫ ИЗ TURMA ZONALES ИЗ КАРБОНА ПОЛЬШИ
ЧАСТЬ I. МЕГАСПОРЫ С КОРОНОЙ

Резюме

В настоящей работе представлено описание 8 видов мегаспор с короной, относящихся к следующим родам карбонского возраста: *Radiatisporites*, *Rotatisporites* и *Zonalesporites*. Основой работ был очень богатый материал мегаспор из Верхнесилезского и Люблинского угольных бассейнов, добытый в пластах, исследованных в послевоенное время, а также содержащийся в коллекциях Яна Церндта (1931, 1933, 1934, 1936, 1937, 1938 *a*, *b*). В общем в распоряжении автора было 100 тысяч экземпляров хорошо сохраненных видов. Кроме того, было сделано свыше 500 препаратов мегаспор для наблюдений в проходящем свете. В качестве сравнительного материала использовались мегаспоры карбона Чехословакии, Нидерландов, Испании и Турции. Вторично анализировались типичные экземпляры видов, установленных Церндтом, а также содержащиеся в коллекции этого исследователя и до сих пор не изученные мегаспоры Московского бассейна (район Тулы).

Применяющиеся широко методы изучения мегаспор в отраженном свете не дают возможности детально изучить их строение. Положительные результаты

можно получить путем комплексных наблюдений в отраженном и проходящем свете и в электронном сканинг-микроскопе. Применение перечисленных трех методов дало автору возможность уточнить взгляды на строение стенок мегаспор, исследовать строение короны и определить отдельные детали этого строения. Констатировано, что все мегаспоры с короной обладают хорошо развитым мезоспорием с многочисленными „подушками". Корона многослойная, состоящая из экваториальных выростов, соединенных мембраной с проксимальной стороны. В короне наблюдались два канала — внутренний и маргинальный, соединяющие экваториальные выросты. Оказалось, что строение короны является диагностическим признаком в определении родов и видов. Кроме того, констатировано, что у всех мегоспор с короной лучи тетрадного знака достигают внешнего края короны и в верхней части покрыты шипами. На основании строения короны удалось проследить направления эволюции этих мегаспор. Основные типы строения сформировались в поздневизейское время, дальнейшая эволюция происходила по четырем направлениям: 1. *Rotatisporites solidus* → *Radiatisporites radiatus*; 2. *Rotatisporites tulensis* → *R. rotatus* → *R. dentatus*; 3. *Zonalesporites mucronatus* → *Z. superbus*; 4. *Z. brasserti*. Разные линии развития характеризовались разными темпами происходящих изменений. Так, наиболее быстро эволюция совершалась по линии *R. solidus* → *R. radiatus* и внутри последнего вида. Самой устойчивой и долговременной формой был *Zonalesporites brasserti*, распространенный с верхнего визе по нижний стефан. Наряду с мегаспорами *Z. brasserti s. s.* наблюдались незрелые формы, определенные в качестве *Z. brasserti* (Stach & Zerndt, 1931) f. *circumtextus* (Zerndt 1934) f. nov. Высказывается предположение, что массовое распространение этих форм в пятисотых пластах (намюр B) было обусловлено изменением условий среды обитания материнской растительности. Отмечается важное значение указанной формы мегаспор в определении и стратиграфии пластов. В данной работе высказывается предположение, что мегаспоры с короной относились к плауновым растениям семейства Bothrodendraceae или к растениям родственного типа.

EXPLANATION OF PLATES

Plate I

Radiatisporites radiatus (Zerndt, 1937) Potonié & Kremp, 1954
Morphological type I; Chełm I boring, Viséan

Fig. 1. Part of distal side of corona. Kr. No. Zonal. I/CH-24.
Fig. 2. *a*—*b* parts of corona, by transmitted light. Kr. No. Zonal. I/AB-2.
Fig. 3. Equatorial appendages with preserved membrane, by transmitted light. Kr. No. Zonal. I/AB-3.

Fig. 4. *a* equatorial appendages with preserved membrane; *b* one of typical equatorial appendage, by transmitted light. Kr. No. Zonal. I/AB-1.

Fig. 5. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/CH--21.

All figures ×100

Plate II

Radiatisporites radiatus (Zerndt, 1937) Potonié & Kremp, 1954
Morphological type II

Fig. 1. Distal surface, polar compression, by reflected light. Kr. No. Zonal. I/CH-3; ×100. Chełm I boring, Upper Viséan.

Fig. 2. *a* part of specimen illustrating types of ornament on distal surface, *b* part of specimen illustrating ornamentation on distal surface near megaspore margin, scanning electron photomicrograph. Kr. No. Zonal. I/SEM-1 (15); ×300. Chełm I boring, Upper Viséan.

Fig. 3. Part of specimen illustrating ornamentation at megaspore margin, by transmitted light. Kr. No. Zonal. I/AB-4; ×120. Chełm I boring, Upper Viséan.

Fig. 4. *a* megaspore with proximal surface in focus; *b* — megaspore in median focal plane showing equatorial appendages near extremity of triradiate ray; by transmitted light. Kr. No. Zonal. I/AA-2; ×120. Grodziec FI (III), Namurian A.

Fig. 5. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AC-1; ×100. Grodziec FI (III), Namurian A.

Plate III

Radiatisporites radiatus (Zerndt, 1937) Potonié & Kremp, 1954
Morphological type III; Grodziec FI (III), Namurian A

Fig. 1. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AC--13; ×100.

Fig. 2. Equatorial appendages, by transmitted light. Kr. No. Zonal. I/AA-17; ×120.

Fig. 3. Part of megaspore with distal surface in focus showing distal appendages with coiled terminations. Kr. No. Zonal. I/AA-5; ×120.

Fig. 4. Distal surface, polar compression, by reflected light. Kr. No. Zonal. I/AC-14; ×100.

Plate IV

Radiatisporites radiatus (Zerndt, 1937) Potonié & Kremp, 1954
Morphological type IV; Grodziec FI (III), Namurian A

Fig. 1. Part of specimen illustrating laesura and ornamentation on proximal surface, from scanning electron microscope. Kr. No. Zonal. I/SEM-2 (6); ×180.

Fig. 2. Proximal and distal surface showing triradiate lips and ornamentation, by transmitted light. Kr. No. Zonal. I/AA-8; ×50.

Fig. 3. Part of specimen illustrating spines on laesurae and ornamentation on proximal surface, by transmitted light. Kr. No. Zonal. I/AA-19; ×120.

Fig. 4. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AC-3; ×100.

Fig. 5. Part of megaspore with equatorial appendages, by transmitted light. Kr. No. Zonal. I/AA-4; ×120.

Plate V

Radiatisporites radiatus (Zerndt, 1937) Potonié & Kremp, 1954
Morphological type IV; Grodziec FI (III), Namurian A

Fig. 1. Part of specimen illustrating types of ornament on distal surface near megaspore margin, from scanning electron microscope. Kr. No. Zonal. I/SEM-2 (8); ×180.

Fig. 2. Part of megaspore with distal surface in focus showing distal appendages fused in twos, by transmitted light. Kr. No. Zonal. I/AA-18; ×120.

Fig. 3. Part of specimen illustrating laesurae and ornamentation on proximal surface, from scanning electron microscope. Kr. No. Zonal. I/SEM-2 (6); ×60.

Fig. 4. Central part of megaspore illustrating proximal ornamentation and laesurae, by transmitted light. Kr. No. Zonal. I/AA-14; ×120.

Fig. 5. Distal surface, polar compression, by reflected light. Kr. No. Zonal. I/AC-9; ×100.

Plate VI

Radiatisporites radiatus (Zerndt, 1937) Potonié & Kremp, 1954
Morphological type V; Grodziec FI (III), Namurian A

Fig. 1. Megaspore in medial focal plane showing triradiate lips and mesospore with numerous cushions, by transmitted light. Kr. No. Zonal. I/AA-15; ×120.

Fig. 2. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AC-34; ×50.

Fig. 3. Part of specimen with equatorial appendages, by transmitted light. Kr. No. Zonal. I/AA-9; ×120.

Fig. 4. *a* proximal surface; *b* distal surface, polar compression; by reflected light. Kr. No. Zonal. I/AC-20; ×100.

Plate VII

Radiatisporites radiatus (Zerndt, 1937) Potonié & Kremp, 1954
Morphological type VI; Grodziec FI (III), Namurian A

Fig. 1. *a* proximal surface; *b* distal surface, polar compression; by reflected light. Kr. No. Zonal. I/AC-10; ×100.

Fig. 2. *a* proximal surface; *b* distal surface, polar compression; by reflected light. Kr. No. Zonal. I/AC-29; ×100.

Fig. 3. *a* distal part of specimen illustrating ornament at megaspore margin; *b* proximal part of megaspore showing laesurae and equatorial appendages; by transmitted light. Kr. No. Zonal. I/AA-13; ×120.

Plate VIII

Rotatisporites rotatus (Bartlett, 1929) Potonié & Kremp, 1954
Mine Gen. Zawadzki (Paryż); Namurian A

Fig. 1. *a* proximal surface; *b* distal surface, polar compression; by reflected light. Kr. No. Zonal. I/AD-33; ×100.

Plate IX

Rotatisporites rotatus (Bartlett, 1929) Potonié & Kremp, 1954, Namurian A

Fig. 1. Part of specimen illustrating types of ornament on distal surface, by transmitted light. Kr. No. Zonal. I/AF-211; ×120. Mine Kazimierz-Juliusz.
Fig. 3. Megaspore in median focal plane showing equatorial appendages connected by membrane, triradiate lips and mesospore; by transmitted light. Kr. No. Zonal. I/AF-207; ×120. Mine Sosnowiec (Renard).
Fig. 4. Part of specimen, proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AE-26; ×50. Mine Marcel (Ema).
Fig. 5. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AD-36; ×100. Mine Kazimierz.
Fig. 6. Laesura and radial appendage with radial channel inside, by transmitted light. Kr. No. Zonal. I/AF-208; ×120. Mine Wieczorek (Giesche).

Zonalesporites brasserti (Stach & Zerndt, 1931) Potonié & Kremp f. *circumtextus* (Zerndt, 1934) f. nov. Mine Sosnowiec, Namurian B

Fig. 2. Part of megaspore in medial focal plane showing membranous lip and fragment of prothalium, by transmitted light. Kr. No. Zonal. I/AB-45; ×175.

Plate X

Rotatisporites rotatus (Bartlett, 1929) Potonié & Kremp, 1954, Namurian A

Fig. 1. Part of corona, by transmitted light. Kr. No. Zonal. I/AF-210; ×120.
Fig. 2. Part of corona with intracoronal channel visible at the right side of the photo, by transmitted light. Kr. No. Zonal. I/AF-205; ×120. Mircza I boring.
Fig. 3. *a* megaspore fragment with laesura and radial appendage forking near the margin of corona and forming marginal rim with marginal channel inside; ×120; *b* megaspore in median focal plane, ×50; by transmitted light. Kr. No. Zonal. I/AF-209. Mine Sosnowiec (Renard).
Fig. 4. Part of corona with equatorial appendages connected by membrane, with typic conical appendage at the left side of the photo, from scanning electron microscope. Kr. No. Zonal. I/SEM-1 (1); ×200. Mine Kazimierz.
Fig. 5. Part of mesospore with numerous cushions, by transmitted light. Kr. No. Zonal. I/AF-204; ×120. Mine Sosnowiec (Renard).

Plate XI

Rotatisporites rotatus (Bartlett, 1929) Potonié & Kremp, 1954, Namurian A.
All specimens by transmitted light

Fig. 1. Part of corona with laesura and intracoronal channel. Kr. No. Zonal. I/AF-212; ×175. Mircza I boring.

Fig. 2. *a* fragment of corona with marginal rim and marginal channel inside good visible; ×120; *b* part of corona with appendages connected by membrane and with intracoronal and marginal channels; ×175. Kr. No. Zonal. I/AF-202. Mircza I boring.

Fig. 3. Part of megaspore with laesurae connected with radial appendages. Kr. No. Zonal. I/AF-208; ×50. Mine Wieczorek (Giesche).

Plate XII

Rotatisporites tulensis CIMP
Morphological type I; Tula (Moscow Basin), Viséan

Fig. 1. Part of corona with intracoronal and marginal channels, by transmitted light. Kr. No. Zonal. I/AB-7; ×120.

Fig. 2. *a* distal surface; *b* proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AD-26; ×50.

Fig. 3. *a* distal surface; *b* proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AE-17; ×50.

Fig. 4. *a* mesospore with proximal surface in focus; *b* mesospore in median focal plane with thin mesospore side at interradial margins of proximal side; by transmitted light. Kr. No. Zonal. I/AB-8; ×100.

Fig. 5. Part of corona, from scanning electron microscope. Kr. No. Zonal. I/SEM-3; ×200.

Plate XIII

Rotatisporites tulensis CIMP
Morphological type I; Tula (Moscow Basin), Viséan

Fig. 1. *a* part of corona, distal view, by transmitted light; ×45; *b* part of corona with distal surface in focus; ×120. Kr. No. Zonal. I/AB-6.

Fig. 2. Proximal surface, polar compression, from scanning electron microscope. Kr. No. Zonal. I/SEM-3; ×100.

Fig. 3. Distal surface, polar compression, from scanning electron microscope. Kr. No. Zonal. I/SEM-4 (2); ×100.

Fig. 4. Part of specimen illustrating types of ornament on distal surface, from scanning electron microscope. Kr. No. Zonal. I/SEM-4 (2); ×200.

Fig. 5. Part of specimen illustrating types of ornament on distal surface, by transmitted light. Kr. No. Zonal. I/AB-11; ×45.

Plate XIV

Rotatisporites tulensis CIMP
Morphological type II; Tula (Moscow Basin), Viséan

Fig. 1. *a* proximal surface; *b* distal surface, polar compression; by reflected light. Kr. No. Zonal. I/AE-10; ×50.

Fig. 2. Part of proximal layer of corona with preserved membrane, by transmitted light. Kr. No. Zonal. I/AB-13; ×175.

Fig. 3. *a*—*b* equatorial appendages, by transmitted light. Kr. No. Zonal. I/AB-14; ×120.

Fig. 4. *a* proximal surface; *b* distal surface, polar compression; by reflected light. Kr. No. Zonal. I/AD-24; ×50.

Plate XV

Rotatisporites tulensis CIMP
Morphological type II; Tula (Moscow Basin), Viséan

Fig. 1. Equatorial appendages of distal layer of corona, by transmitted light. Kr. No. Zonal. I/AB-15; ×175.

Fig. 2. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AD--31; ×50.

Fig. 3. Equatorial appendages of one of middle layer of corona, by transmitted light. Kr. No. Zonal. I/AB-9; ×175.

Fig. 4. *a* proximal surface, polar compression, ×110; *b* part of corona with intra-coronal channel, ×200; from scanning electron microscope. Kr. No. Zonal. I/SEM-5 (4).

Plate XVI

Rotatisporites tulensis CIMP
Morphological type III; Tula (Moscow Basin), Viséan

Fig. 1. *a* proximal surface; *b* distal surface, polar compression; by reflected light. Kr. No. Zonal. I/AE-19; ×50.

Fig. 2. *a* part of corona, distal view, ×120; *b* megaspore with corona in median focal plane, ×45; by transmitted light. Kr. No. Zonal. I/AB-10.

Fig. 3. Megaspore with mesospore inside, by reflected light. Kr. No. Zonal. I/AD-27; ×50.

Fig. 4. Broken specimen with distal surface and section along laesurae visible, from scanning electron microscope. Kr. No. Zonal. I/SEM-4 (1); ×240.

Plate XVII

Rotatisporites tulensis CIMP
Tula (Moscow Basin), Viséan

Fig. 1. *a* part of corona without membrane, ×200; *b* proximal surface showing spines on laesurae, ×110; from scanning electron microscope. Kr. No. Zonal. I/SEM-5 (1).

Plate XVIII

Rotatisporites solidus (Dijkstra, 1957) CIMP
Morphological type I; Viséan

Fig. 1. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/CH-5; ×100. Chełm I boring.

Fig. 2. Distal surface, polar compression, by reflected light. Kr. No. Zonal. I/AE-3; ×50. Tula (Moscow Basin).

Fig. 3. Part of corona with distal surface in focus, by transmitted light. Kr. No. Zonal. I/AB-18; ×120. Tula (Moscow Basin).

Fig. 4. Part of corona in median focal plane, by transmitted light. Kr. No. Zonal. I/AB-20; ×175 (Moscow Basin).

Fig. 5. Fragment of proximal layer of corona with preserved membrane, by transmitted light. Kr. No. Zonal. I/AB-21; ×120. Chełm I boring.

Fig. 6. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AD--22; ×50. Tula (Moscow Basin).

Fig. 7. Proximal surface, polar compression, from scanning electron microscope. Kr. No. Zonal. I/SEM-4 (3); ×200. Tula (Moscow Basin).

Plate XIX

Rotatisporites solidus (Dijkstra, 1957) CIMP
Morphological type II; Viséan

Fig. 1. *a* proximal surface; *b* distal surface, polar compression, by reflected light. Kr. No. Zonal. I/AD-21; ×50. Tula (Moscow Basin).

Fig. 2. *a* proximal part of broken specimen revealing mesospore, ×150; *b* equatorial appendages, ×300; from scanning electron microscope. Kr. No. Zonal. I/SEM-1 (14). Chełm I boring.

Fig. 3. Equatorial appendages, by transmitted light. Kr. No. Zonal. I/AB-23; ×120. Chełm I boring.

Fig. 4. Broken specimen showing mesospore, by reflected light. Kr. No. Zonal. I/AD-25; ×50. Tula (Moscow Basin).

Plate XX

Rotatisporites solidus (Dijkstra, 1957) CIMP
Morphological type III; Tula (Moscow Basin), Viséan

Fig. 1. *a* proximal surface; *b* distal surface; by reflected light. Kr. No. Zonal. I/AD-20; ×100.

Fig. 2. *a* proximal surface; *b* distal surface; by reflected light. Kr. No. Zonal. I/AE-2; ×50.

Fig. 3. *a* equatorial appendages; *b* fragment of corona, distal view; by transmitted light. Kr. No. Zonal. I/AB-17; ×120.

Fig. 4. *a*—*b* equatorial appendages: *c* distal appendage: *d* equatorial appendages with preserved membrane; by transmitted light. Kr. No. Zonal. I/AB-16; ×120.

Plate XXI

Rotatisporites dentatus (Zerndt, 1938) CIMP
Spytkowice 103, Westphalian C/D

Fig. 1. *a* part of corona with marginal rim, with marginal channel inside and marginal appendages; *b* part of megaspore with distal surface in focus showing distal appendages; by transmitted light. Kr. No. Zonal. I/AH; ×175.

Fig. 2. *a* proximal surface; *b* distal surface; polar compression, by reflected light. Kr. No. Zonal. I/AG-1; ×50.

Fig. 3. Megaspore in lateral view, by reflected light. Kr. No. Zonal. I/AG-2; ×50.

Plate XXII

Zonalesporites brasserti (Stach & Zerndt, 1931) Potonié & Kremp, 1954, Namurian B

Fig. 1. *a* proximal surface; *b* distal surface; polar compression. Kr. No. Zonal. I/AI-38; ×35. Mine Wujek.

Fig. 2. Proximal surface, oblique compression. Kr. No. Zonal. I/m-3; ×50. Mine Mysłowice.

Fig. 3. Proximal surface, polar compression. Kr. No. Zonal. I/AI-36; ×35. Mine Wujek.

Fig. 4. Proximal surface, oblique compression. Kr. No. Zonal I/M-36; ×50. Mine Mysłowice.

All figures by reflected light

Plate XXIII

Zonalesporites brasserti (Stach & Zerndt, 1931) Potonié & Kremp, 1954, Namurian B

Fig. 1. *a* proximal surface with spines on laesurae, radial channels and intracoronal channel well visible; ×100; *b* marginal part of corona ×700; from scanning electron microscope. Kr. No. Zonal. I/SEM-6. Mine Wujek.

Fig. 2. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AI-31; ×35. Mine Wujek.

Fig. 3. Megaspore without corone, oblique compression, by reflected light. Kr. No. Zonal. I/M-74; ×50. Mine Mysłowice.

Fig. 4. Fragment of laesurae with spines, by transmitted light. Kr. No. Zonal. I/AB--25; ×120. Mine Sosnowiec.

Plate XXIV

Zonalesporites brasserti (Stach & Zerndt, 1931) Potonié & Kremp, 1954, Namurian B

Fig. 1. Part of proximal spore side with radial channels and intracoronal channel on corona well visible. Kr. No. Zonal. I/SEM-6; ×250. Mine Wujek.

Fig. 2. Central part of megaspore with proximal surface in focus showing laesurae and ornamentation, by transmitted light. Kr. No. Zonal. I/AB-36; ×175. Mine Mysłowice.

Plate XXV

Zonalesporites brasserti (Stach & Zerndt, 1931) Potonié & Kremp, 1954

Fig. 1. Distal surface, oblique compression from scanning electron microscope. Kr. No. Zonal. I/SEM-2 (7); ×100. Mine Wujek, Namurian B.

Fig. 2. Mesospore with numerous cushions in median focal plane, by transmitted light. Kr. No. Zonal. I/AB-27; ×120. Mine Sosnowiec (Renard), Namurian B.
Fig. 3. Part of corona, by transmitted light. Kr. No. Zonal. I/AB-37; ×175. Mine Chwałowice, Upper Carboniferous.
Fig. 4. Part of corona with distal surface in focus, by transmitted light. Kr. No. Zonal. I/AB-24; ×45. Mine Wujek, Namurian B.
Fig. 5. Marginal part of corona, by transmitted light. Kr. No. Zonal. I/AB-28; ×175. Mine Brzeszcze, Westphalian A.

Plate XXVI

Zonalesporites brasserti (Stach & Zerndt, 1931) Potonié & Kremp, 1954
Various states of corona preservation, by transmitted light

Fig. 1. Median focal plane. Kr. No. Zonal. I/AB-31; ×175. Mine Sosnowiec, Namurian B.
Fig. 2. Distal surface in focus. Kr. No. Zonal. I/AB-35; ×175. Mine Wujek, Namurian B.
Fig. 3. Corona with membrane well preserved. Kr. No. Zonal. I/AB-26; ×50. Mine Brzeszcze, Namurian A.
Fig. 4. Distal surface in focus. Kr. No. Zonal. I/AB-29; ×120. Mine Wujek, Namurian B.
Fig. 5. Fragment of middle layers of corona. Kr. No. Zonal. I/AB-30; ×175. Mine Sosnowiec, Namurian B.

Plate XXVII

Zonalesporites brasserti (Stach & Zerndt, 1931) Potonié & Kremp, 1954 Namurian B

Fig. 1. Central part of proximal side of megaspore showing mesospor with numerous cushions. Kr. No. Zonal. I/AB-46; ×175. Mine Mysłowice.
Fig. 2. Fragment of megaspore in median focal plane showing mesospore and laesurae on corona. Kr. No. Zonal. I/AB-33; ×175. Mine Wujek.
All figures by transmitted light

Plate XXVIII

Zonalesporites brasserti (Stach & Zerndt, 1931) forma *circumtextus* (Zerndt, 1934) f. nov. Morphological type I, Namurian B

Fig. 1. Part of corona with intracoronal and marginal channels, by transmitted light. Kr. No. Zonal. I/AB-43; ×120. Mine Sosnowiec (Renard).
Fig. 2. *a* part of corona with marginal dissections and laesura on corona well visible ×180; *b* proximal surface, slightly oblique compression, ×60; from scanning electron microscope. Kr. No. Zonal. I/SEM-2 1. Mine Gen. Zawadzki (Paryż).
Fig. 3. Part of corona with distal surface in focus, by transmitted light. Kr. No. Zonal. I/AB-42; ×120. Mine Sosnowiec (Renard).
Fig. 4. Proximal surface, polar compression, by reflected light. Kr. No. Zonal/AD-2; ×150. Mine Milowice.

Plate XXIX

Zonalesporites brasserti (Stach & Zerndt, 1931) forma *circumtextus* (Zerndt, 1934) f. nov. Morphological type I, Namurian B

Fig. 1. *a* distal surface, polar compression, ×80; *b* part of specimen illustrating ornamentation on distal surface; ×150; from scanning electron microscope. Kr. No. Zonal. I/SEM-2 (3). Mine Sosnowiec (Niwka).
Fig. 2. Proximal surface, polar compression, specimen without corona, by reflected light. Kr. No. Zonal. I/AD-12; ×50. Mine Milowice.
Fig. 3. Part of corona in median focal plane, by transmitted light. Kr. No. Zonal. I/AB-41; ×20. Mine Sosnowiec (Renard).
Fig. 4. Part of megaspore with corona in median focal plane, by transmitted light. Kr. No. Zonal. I/AB-47; ×45. Mine Sosnowiec (Renard).
Fig. 5. Distal surface, polar compression, by reflected light. Kr. No. Zonal. I/AD-2; ×50. Mine Milowice.

Plate XXX

Zonalesporites brasserti (Stach & Zerndt, 1931) forma *circumtextus* (Zerndt, 1934) f. nov., Namurian B

Fig. 1. *a* proximal surface; *b* distal surface; polar compression by reflected light. Morphological type I. Kr. No. Zonal. I/AD-1; ×50. Mine Sosnowiec.
Fig. 2. *a* proximal surface; *b* distal surface; polar compression by reflected light. Morphological type II. Kr. No. Zonal. I/AJ-4; ×50. Mine Sosnowiec.
Fig. 3. Proximal surface, polar compression, by reflected light. Morphological type II. Kr. No. Zonal. I/AJ-1; ×50. Mine Sosnowiec.
Fig. 4. Part of corona in median focal plane, by transmitted light. Morphological type II. Kr. No. Zonal. I/AB-38; Mine Sosnowiec (Renard).
Fig. 5. Part of megaspore with corona, by transmitted light. Morphological type I. Kr. No. Zonal. I/AB-39; ×45. Mine Sosnowiec (Renard).
Fig. 6. *a* proximal surface; *b* distal surface; polar compression, by reflected light. Kr. No. Zonal. I/AJ-15; ×50. Mine Sosnowiec (Niwka).

Plate XXXI

Zonalesporites brasserti (Stach & Zerndt, 1931) forma *circumtextus* (Zerndt, 1934) f. nov. Morphological type II, Namurian B

Fig. 1. Part of corona in median focal plane, by transmitted light. Kr. No. Zonal. I/AB-40; ×120.
Fig. 2. Part of corona of typical immature specimen, by transmitted light. Kr. No. Zonal. I/AB-44; ×175. Mine Sosnowiec.
Fig. 3. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/M-77; ×50. Mine Mysłowice.
Fig. 4. *a* proximal surface; *b* distal surface; polar compression, by reflected light. Kr. No. Zonal. I/AD-18; ×100. Mine Sosnowiec.
Fig. 5. Proximal surface, polar compression, by reflected light. Kr. No. Zonal. I/AJ-25; ×50. Mine Sosnowiec (Niwka).

Fig. 6. *a* distal surface with outermost layer of spore wall, well visible; *b* proximal surface; polar compression, by reflected light.[4] Kr. No. Zonal. I/AJ-22; ×50. Mine Sosnowiec (Niwka).

Plate XXXII

Zonalesporites mucronatus (Nowak & Zerndt, 1936) CIMP
Tenczynek -T3, Lower Namurian A

Fig. 1. Part of megaspore illustrating ornamentation on distal surface. Kr. No. Zonal. I/AH-13.
Fig. 2. Part of corona (distal layers). Kr. No. Zonal. I/AH-16.
Fig. 3. Equatorial appendages with hooked tips. Kr. No. Zonal. I/AH-14.
Fig. 4. Equatorial appendages with membrane. Kr. No. Zonal. I/AH-11.
Fig. 5. Part of corona with membrane and marginal channel well visible. Kr. No. Zonal. I/AH-12.

All figures by transmitted light and ×175

Plate XXXIII

Zonalesporites superbus (Bartlett, 1929) Karczewska, 1967

Fig. 1. Distal surface, polar compression. Kr. No. Zonal. I/AD-34; ×32. Mine Silesia, Westphalian B.
Fig. 2. Part of corona without membrane. Kr. No. Zonal. I/AK-34; ×22. Mine Brzeszcze, Westphalian B/C.
Fig. 3. *a* proximal surface; *b* distal surface; polar compression. Kr. No. Zonal. I/AD-35; ×22. Mine Brzeszcze, Westphalian B/C.
Fig. 4. Part of corona — *a* distal surface; *b* proximal surface. Kr. No. Zonal. I/AK-31; ×22. Mine Brzeszcze, Westphalian B.

All figures by reflected light

Plate XXXIV

Zonalesporites superbus (Bartlett, 1929) Karczewska, 1967
Mine Brzeszcze

Fig. 1. Fragment of middle part of corona. Kr. No. Zonal. I/AB-48. Westphalian B.
Fig. 2. Fragment of marginal part of corona with marginal channel well visible. Kr. No. Zonal. I/AB-51. Westphalian B/C.
Fig. 3. Fragment of membranous lip. Kr. No. Zonal. I/AB-52. Westphalian B.
Fig. 4. Part of specimen illustrating ornamentation on distal surface. Kr. No. Zonal. I/AB-49. Westphalian B/C.
Fig. 5. Part of specimen illustrating ornamentation on distal surface near megaspore margin. Kr. No. Zonal. I/AB-50. Westphalian B/C.

All figures by transmitted light and ×115

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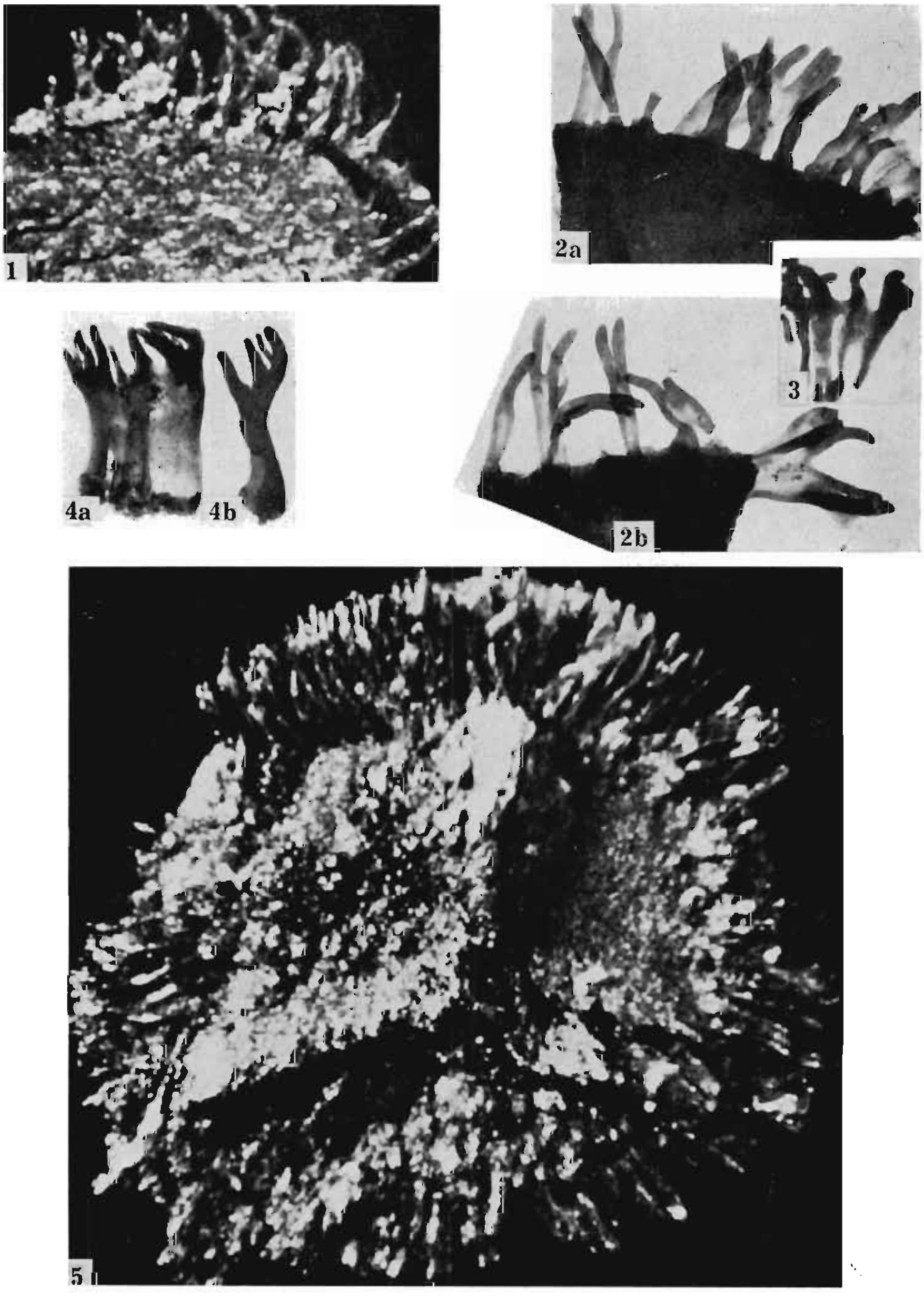
[4] typical immature specimen.



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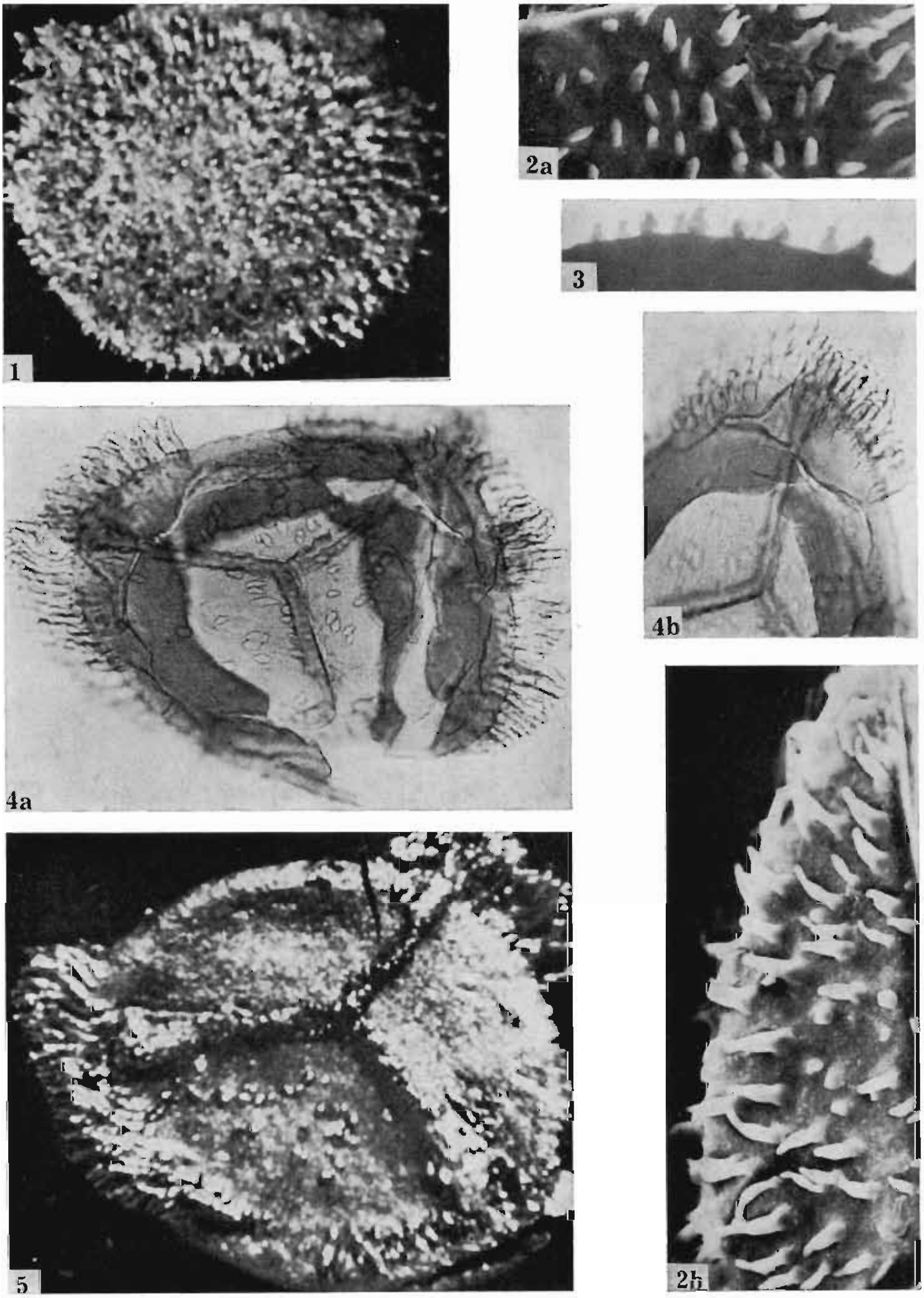

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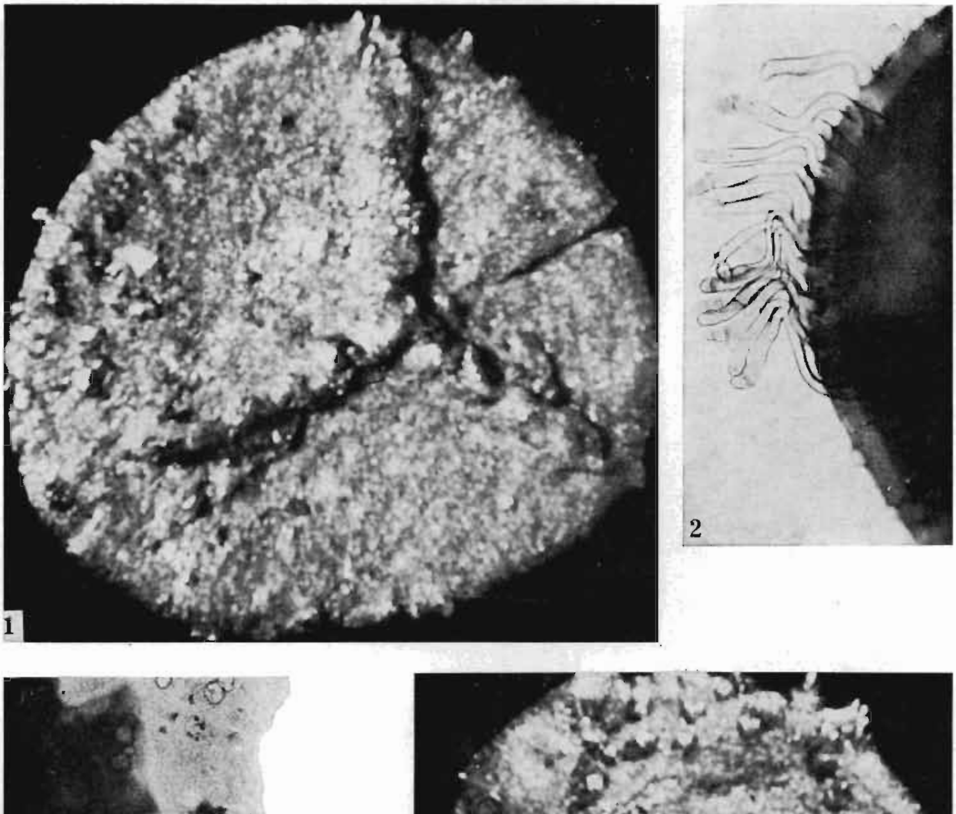

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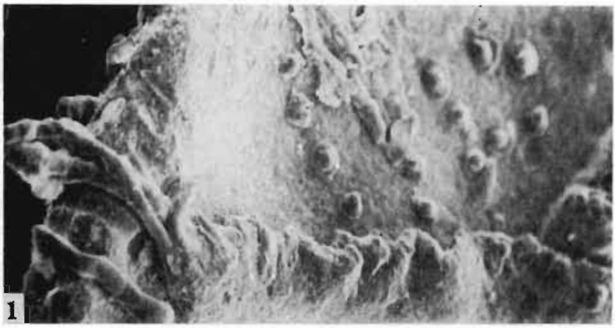
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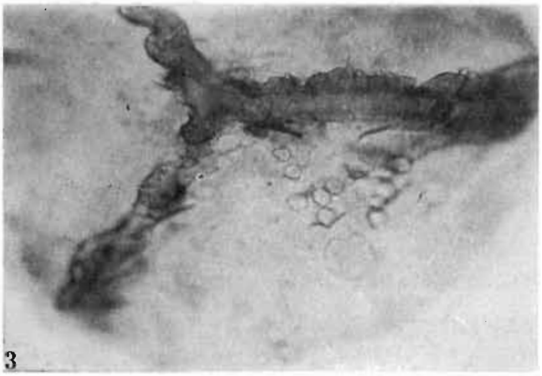
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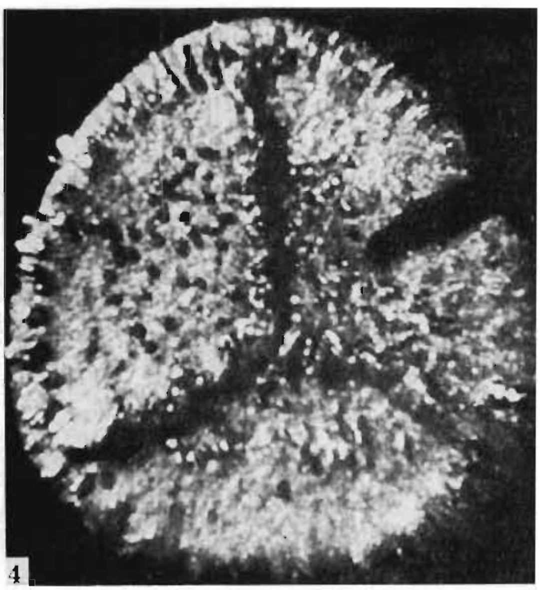
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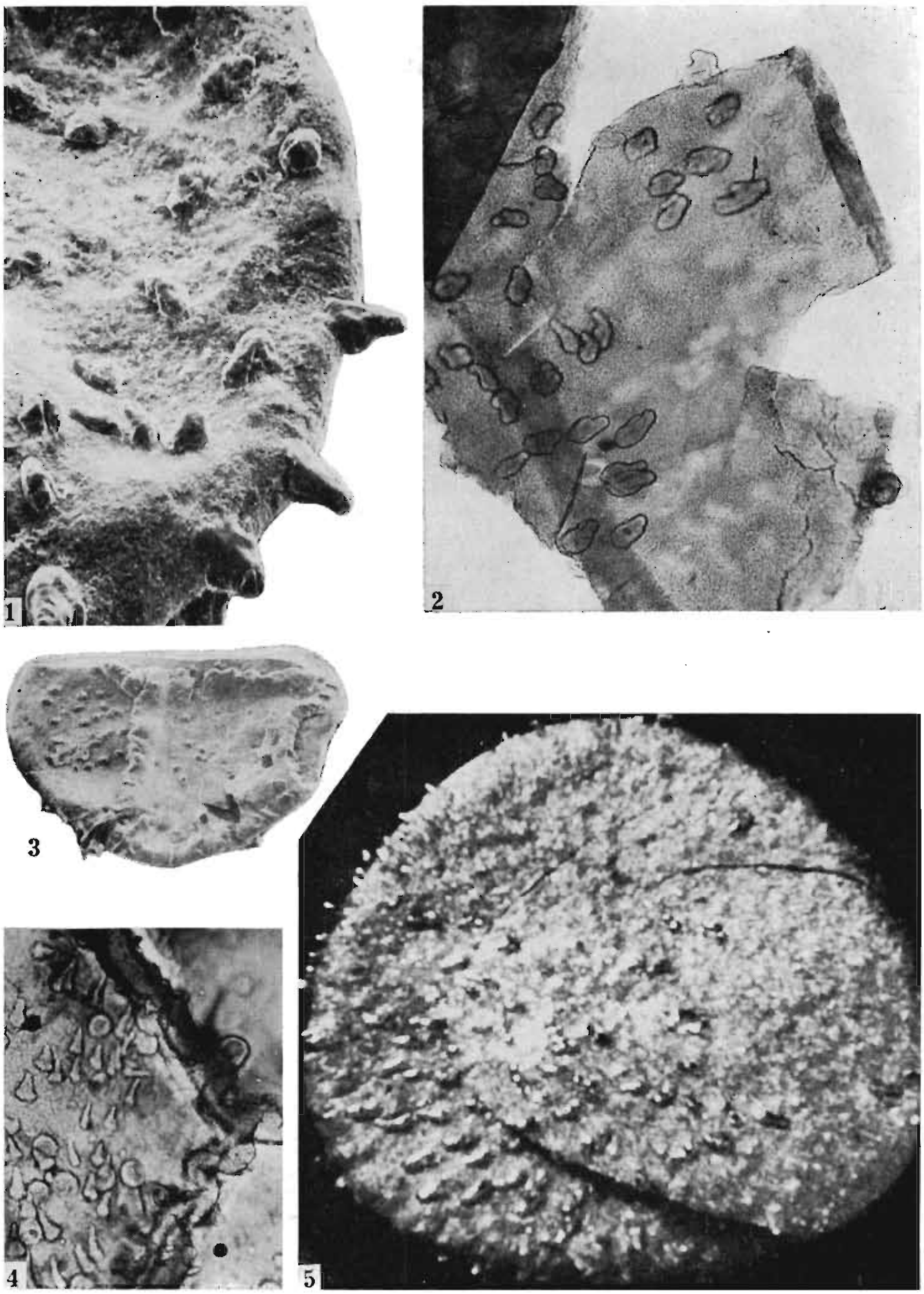

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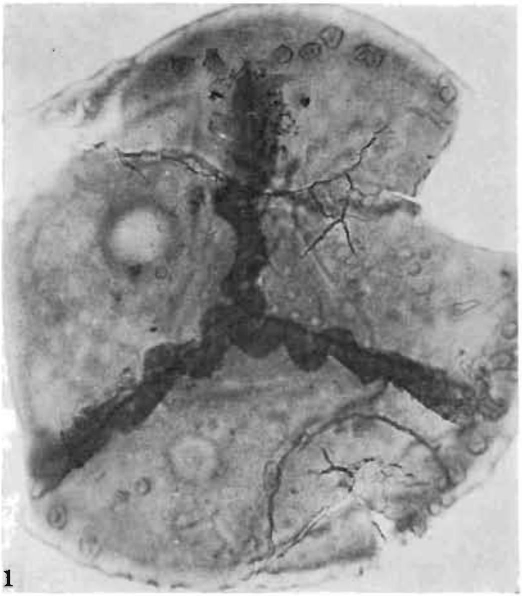
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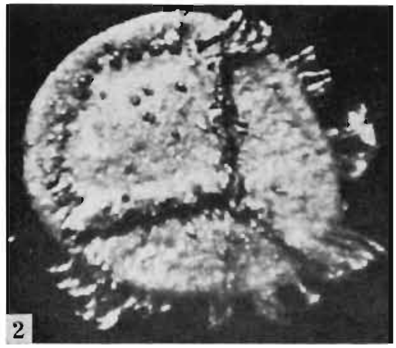
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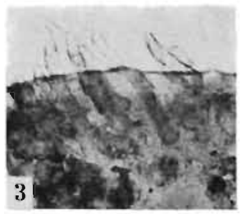
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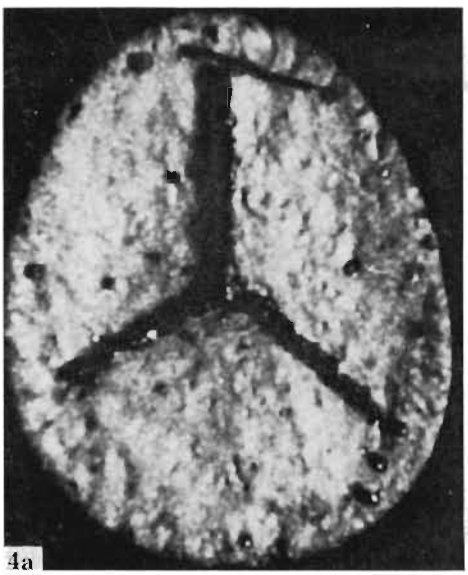
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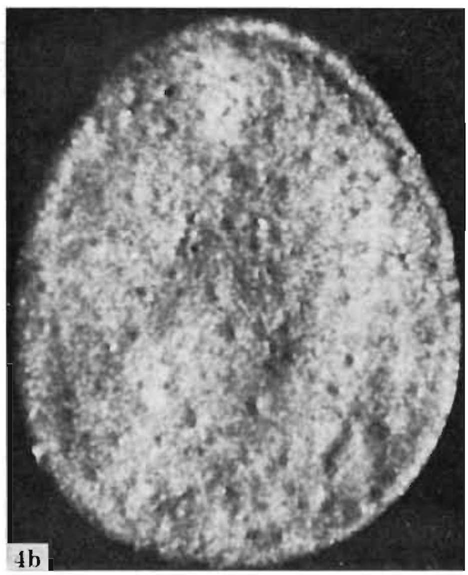
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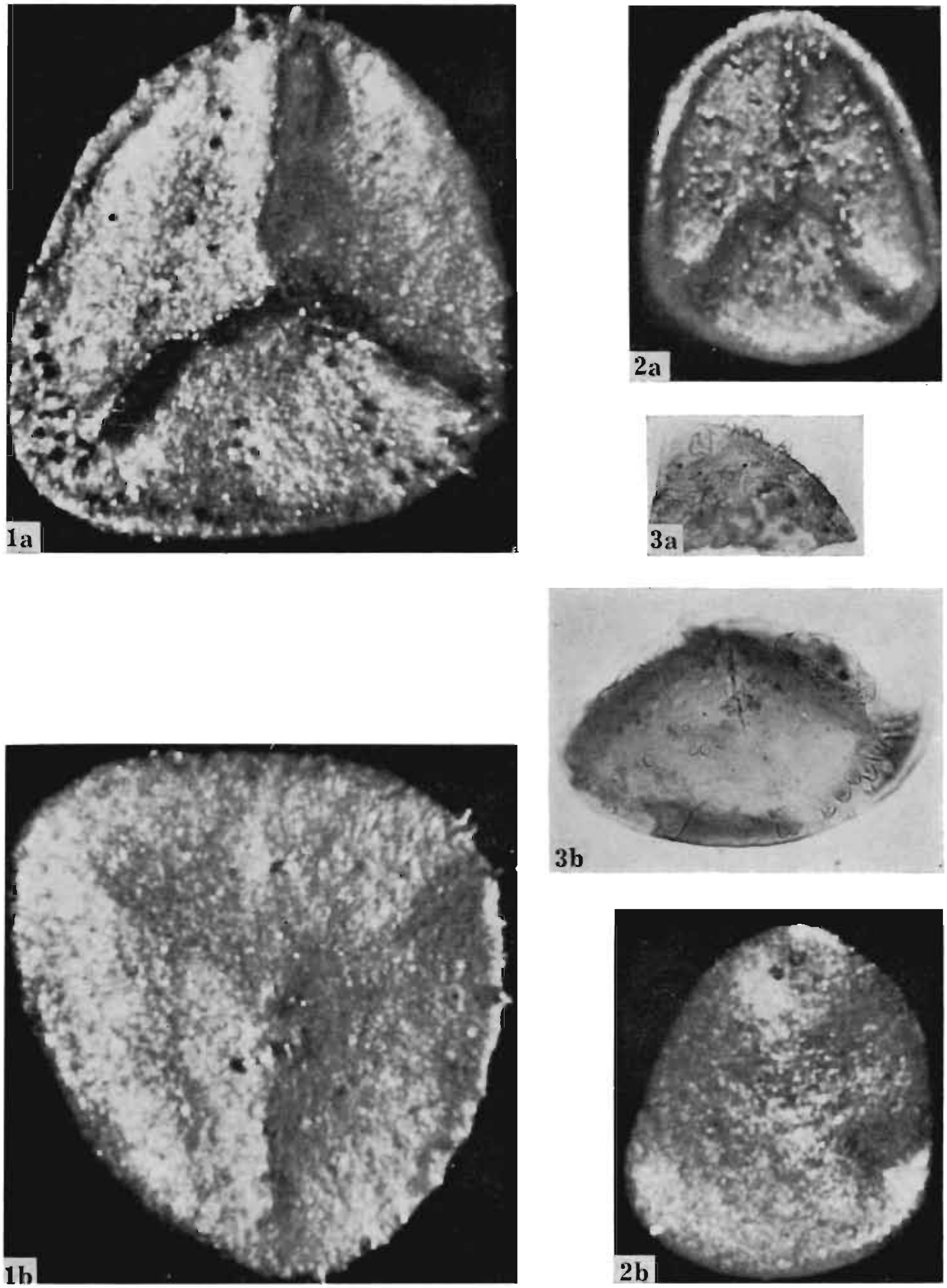

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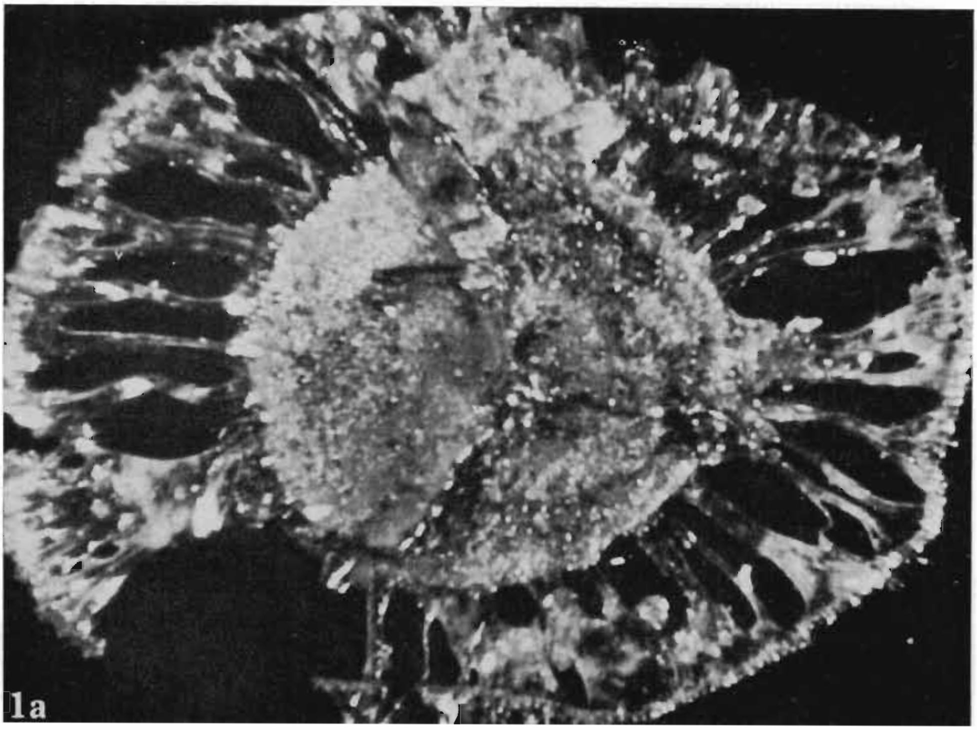

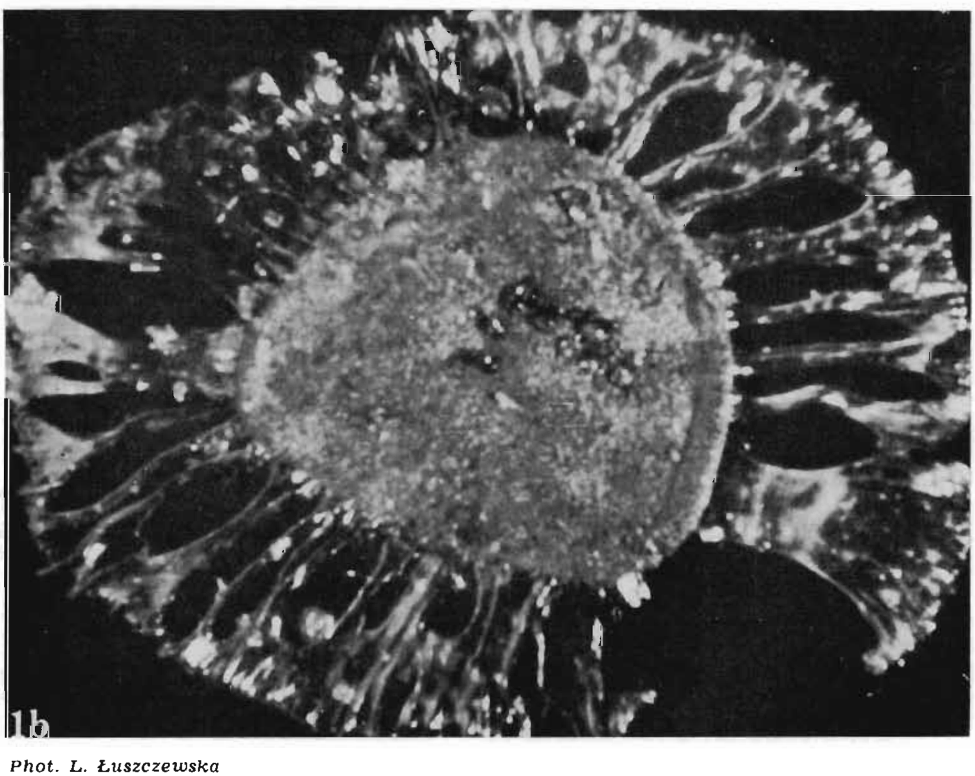

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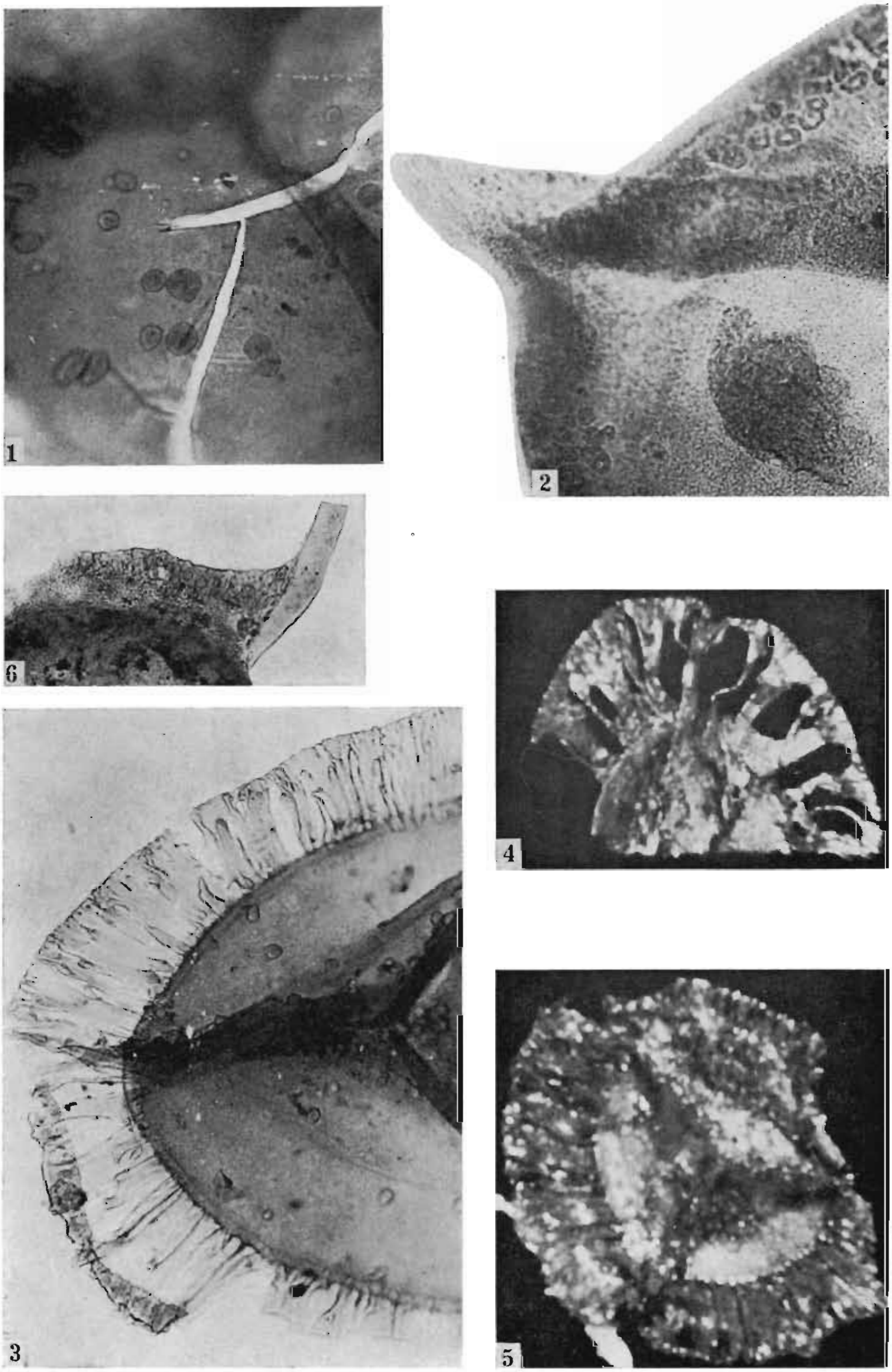

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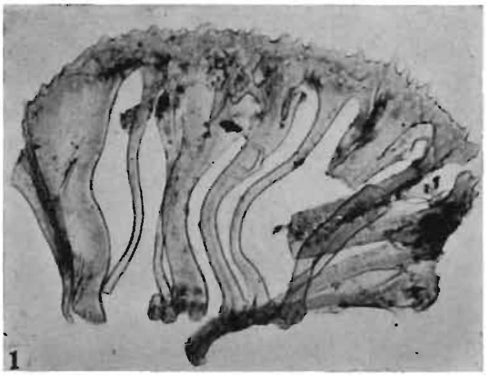

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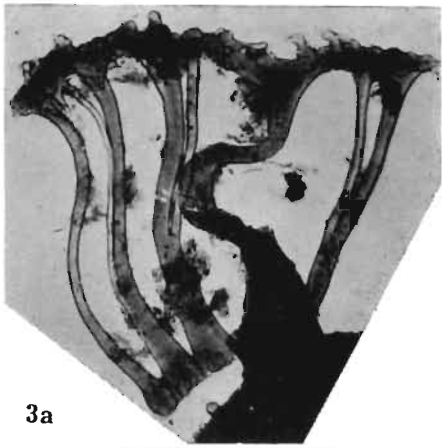

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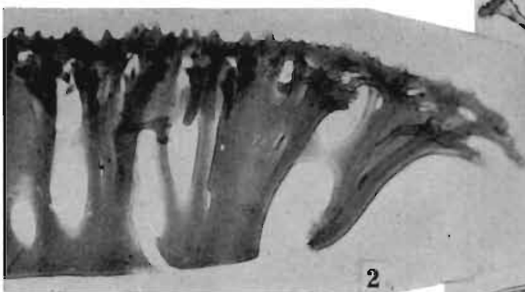

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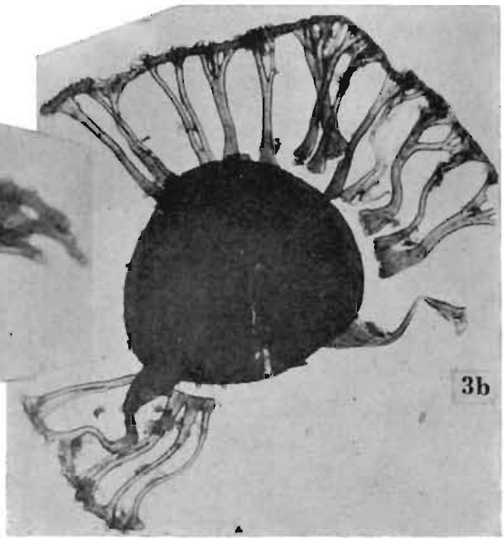

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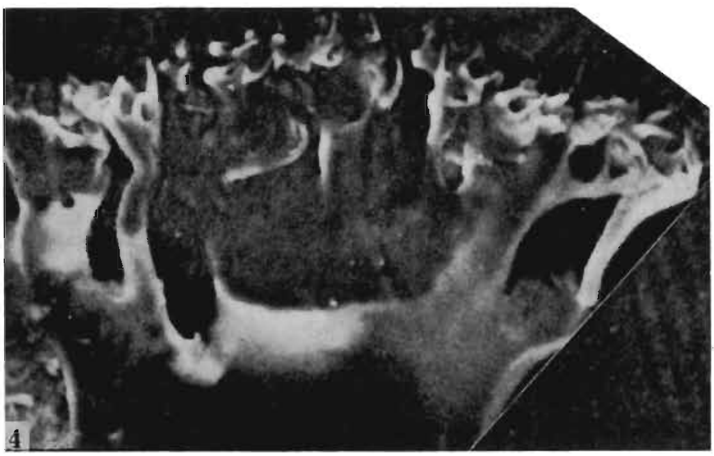

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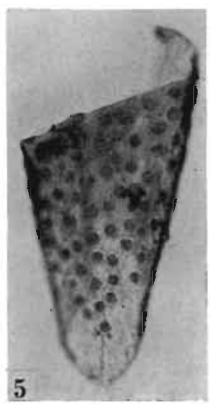

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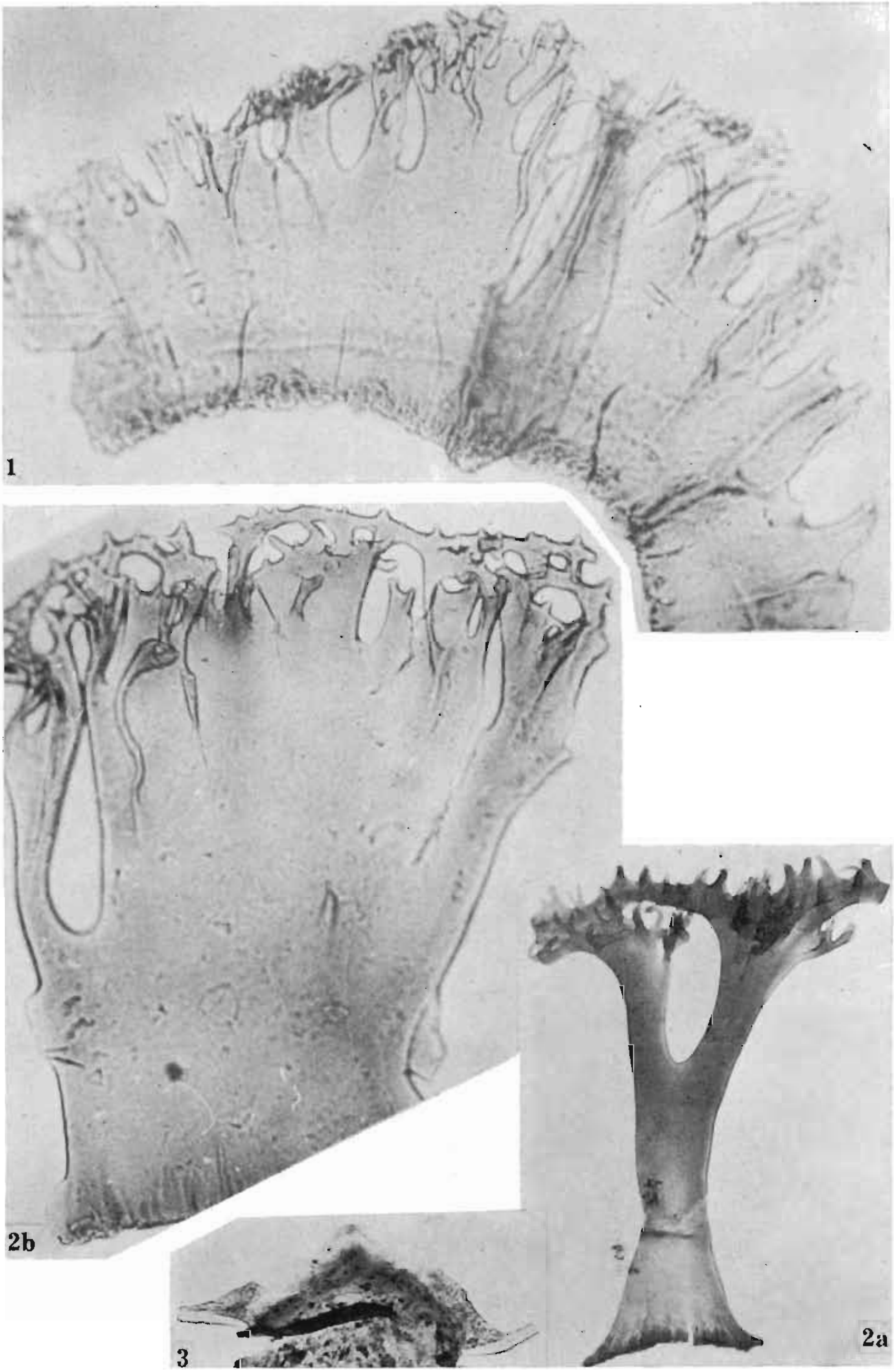

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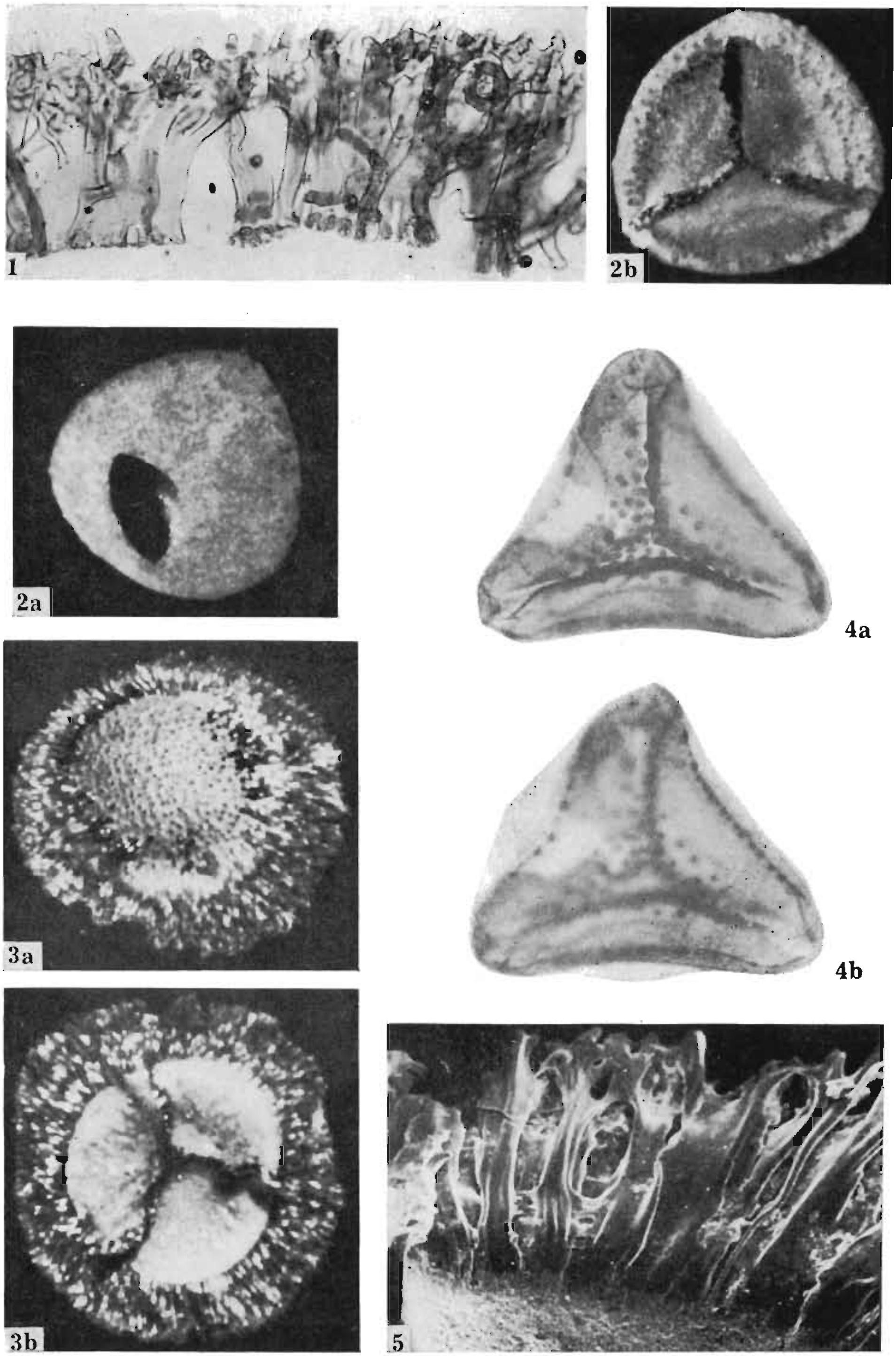

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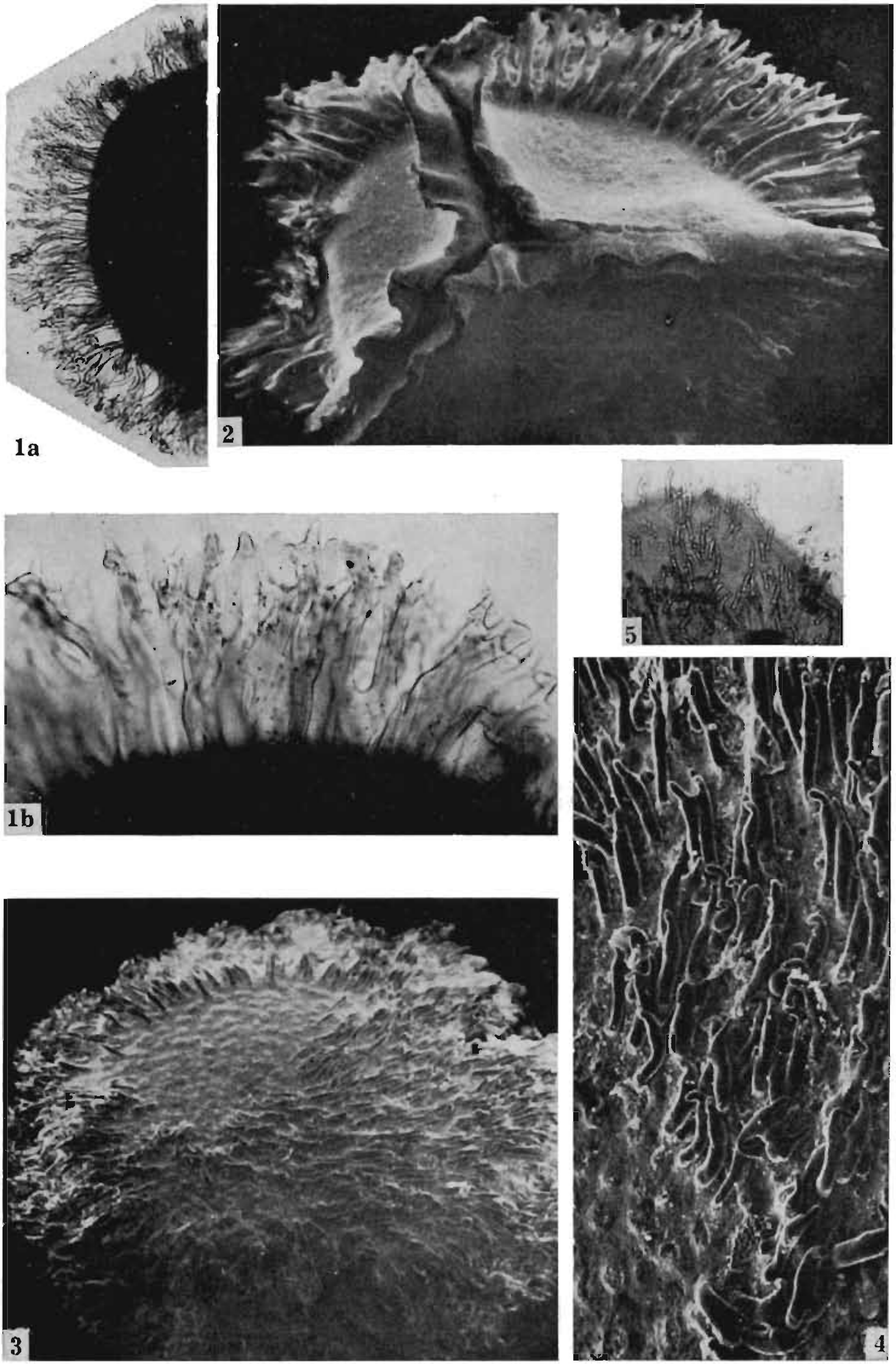

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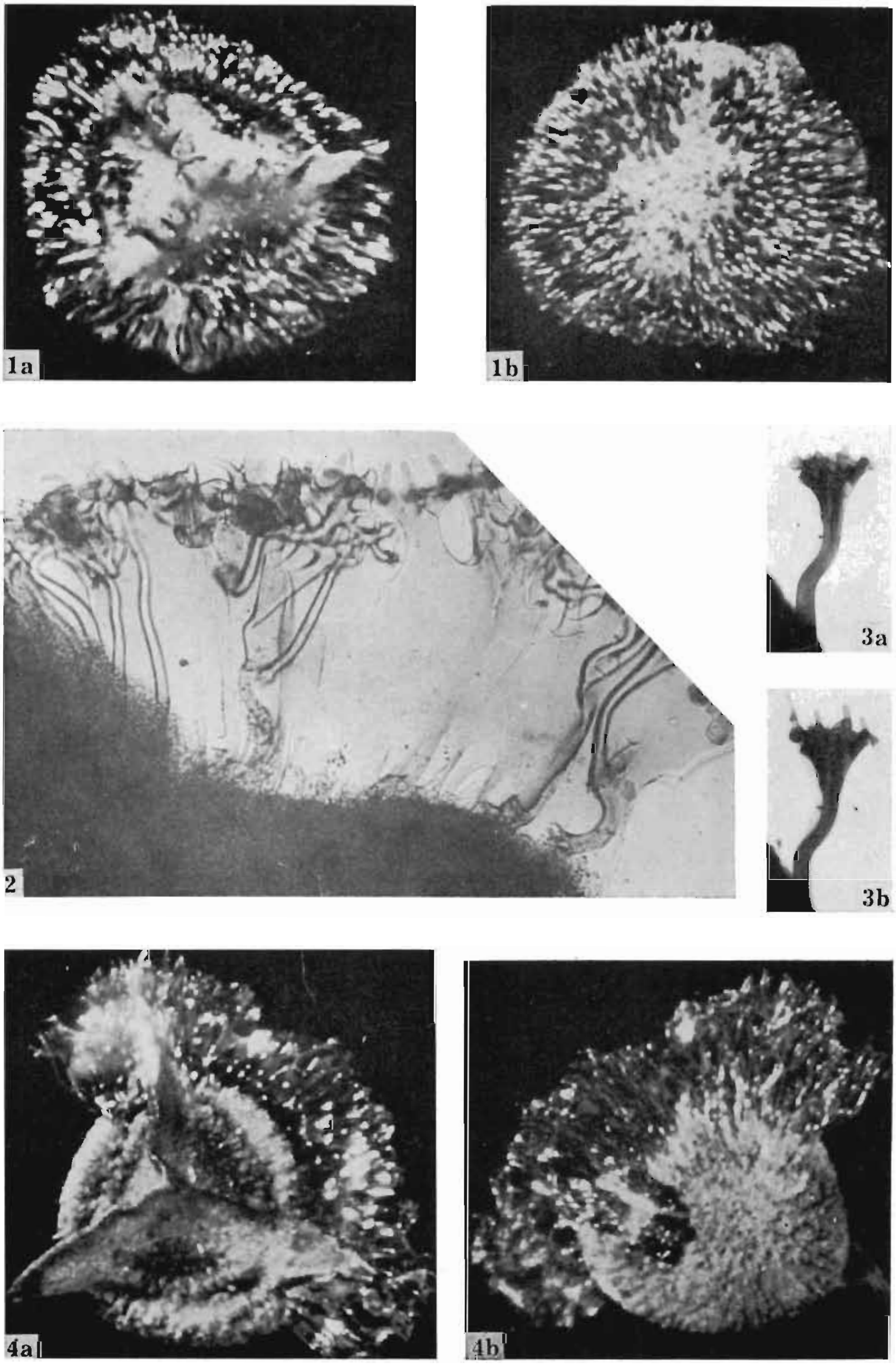

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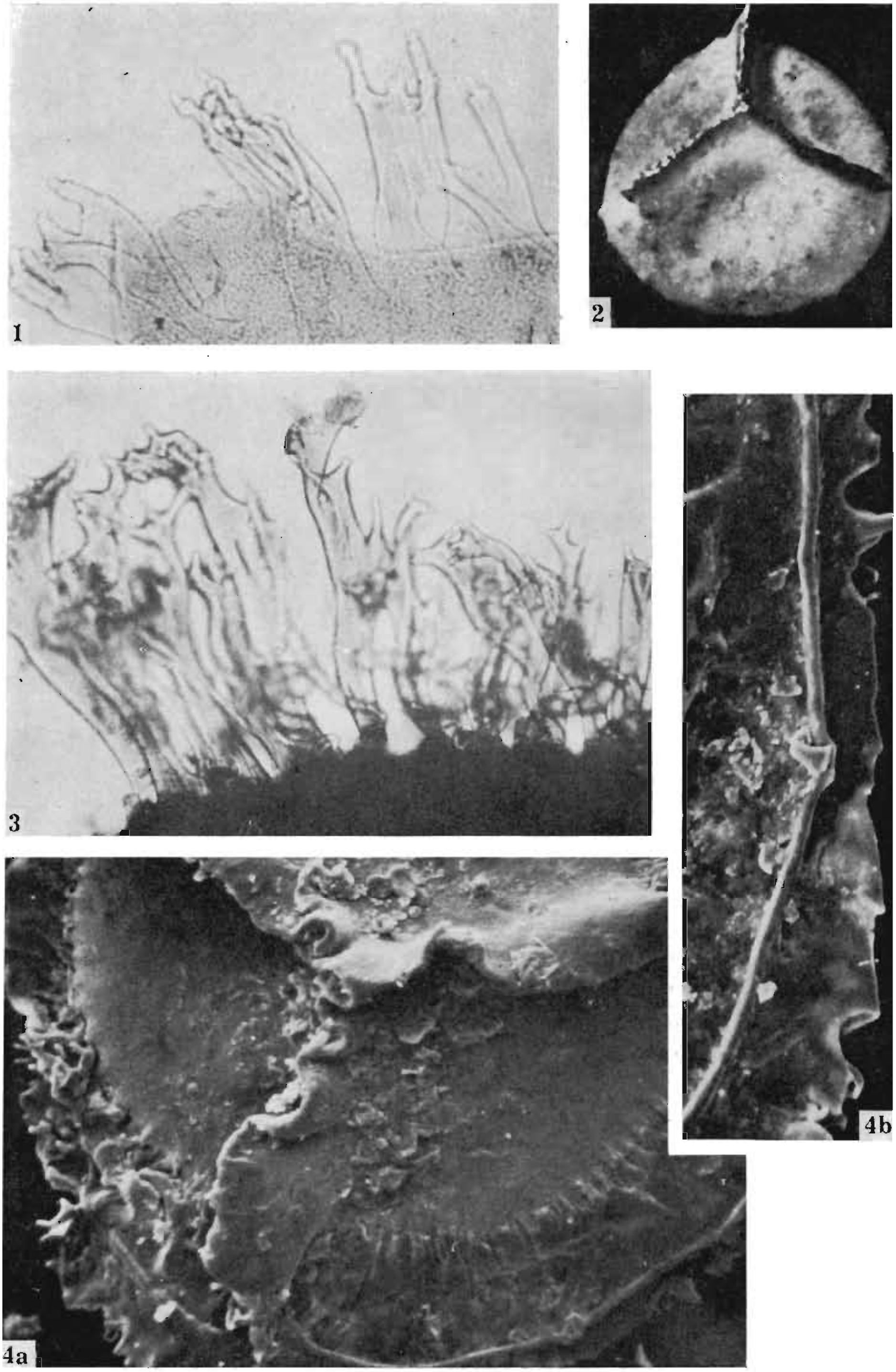
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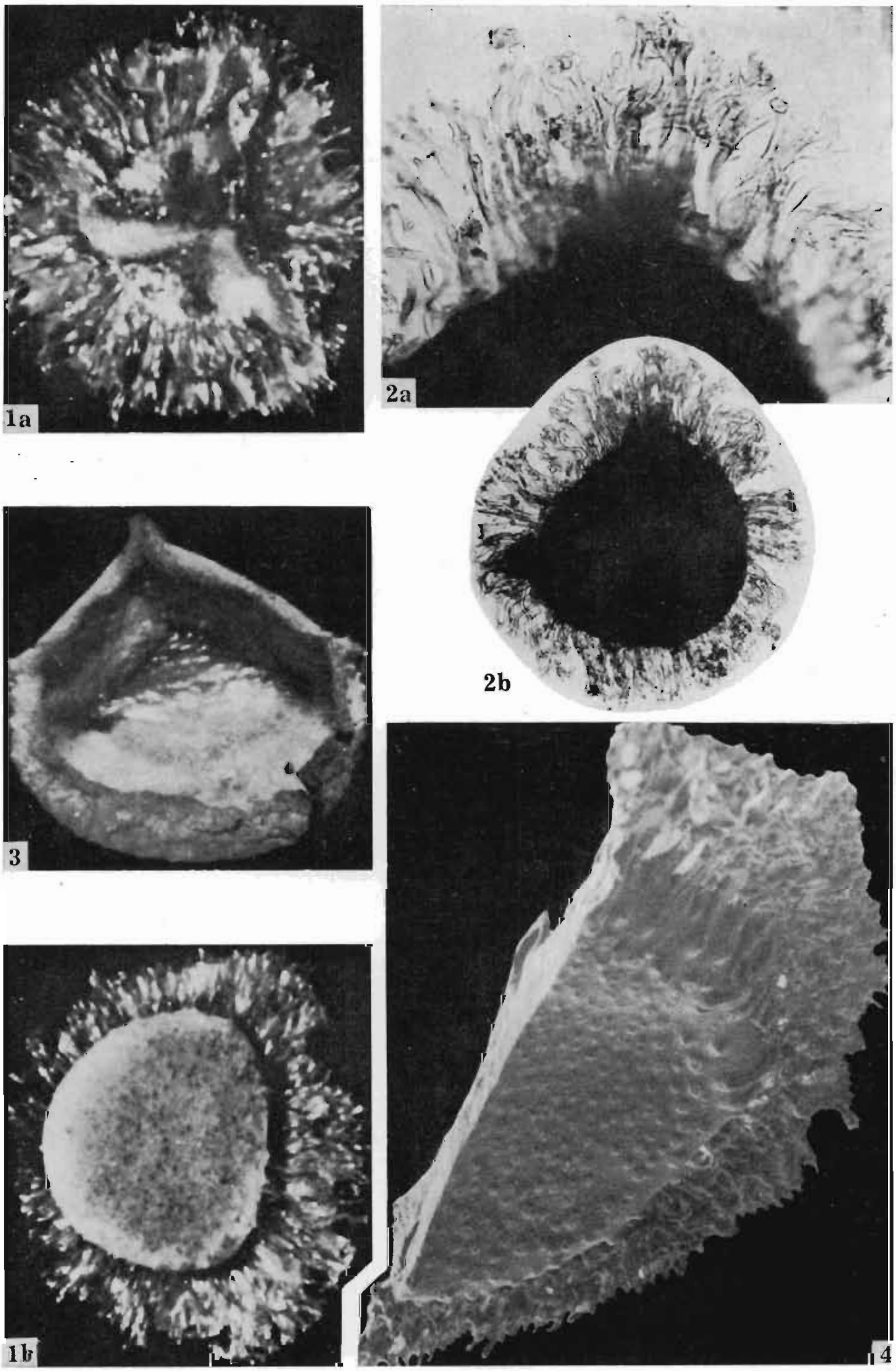

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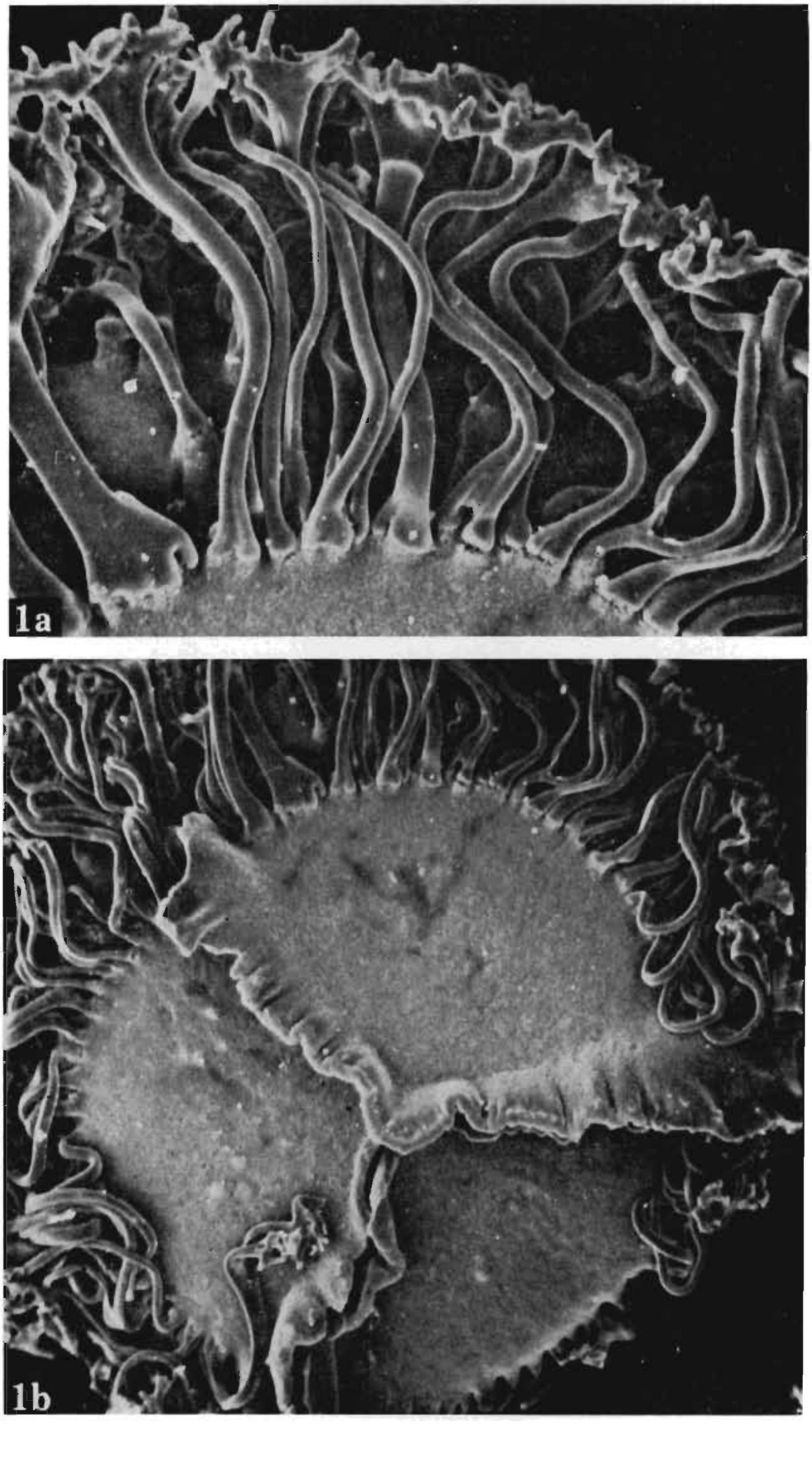
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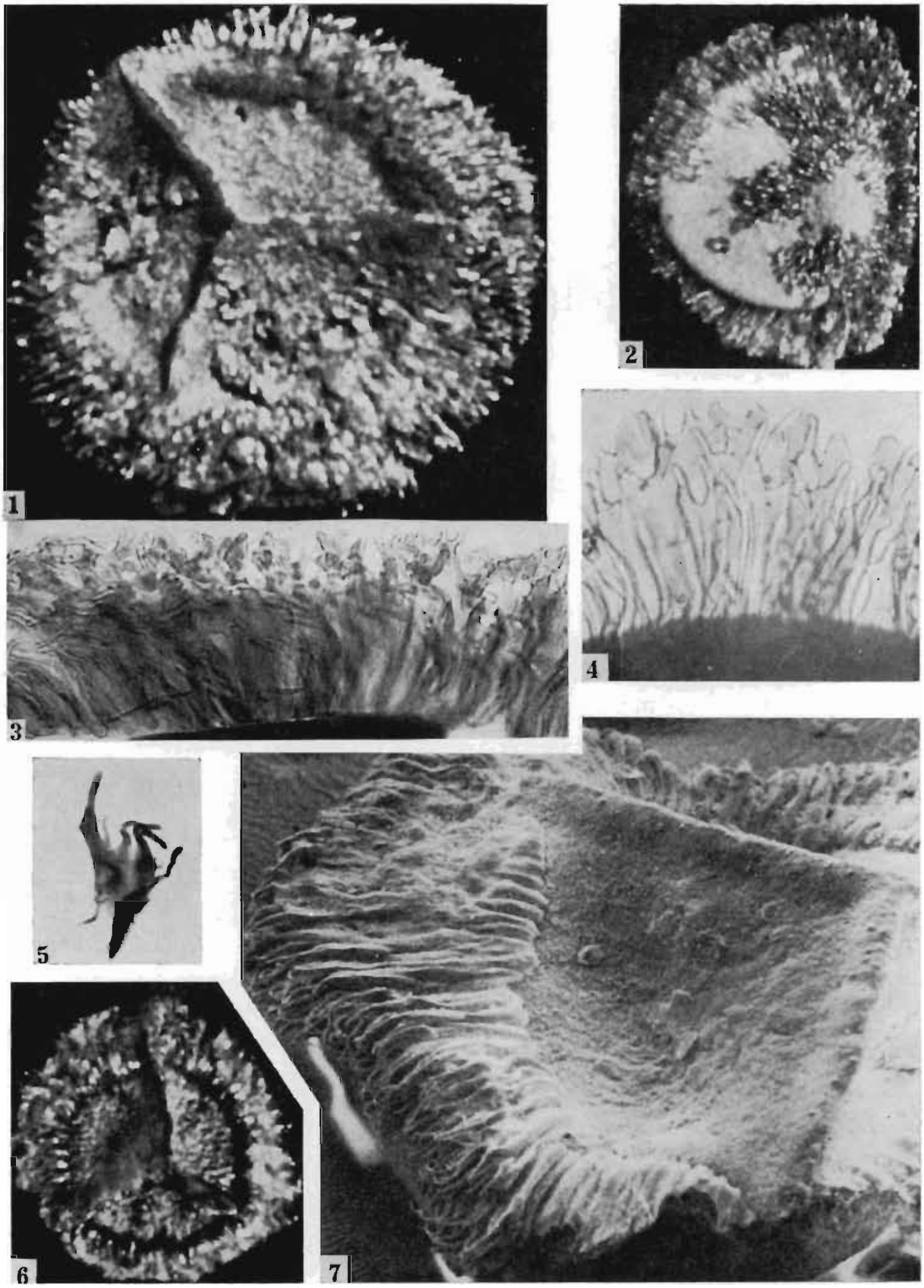

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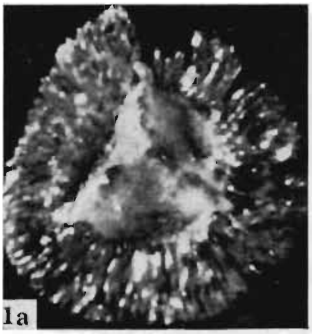
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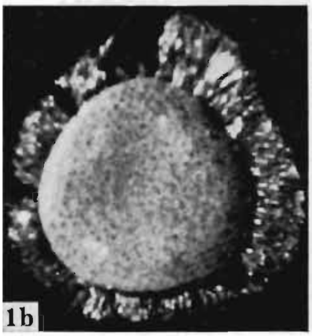
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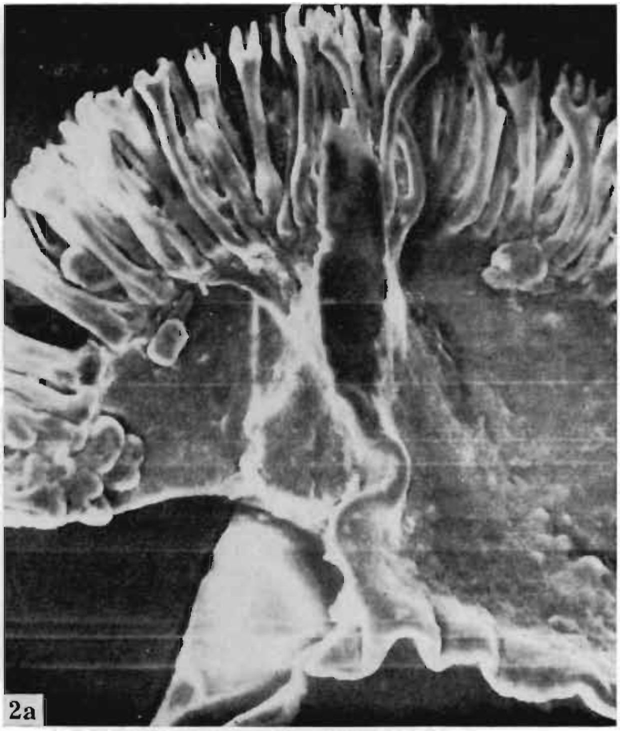
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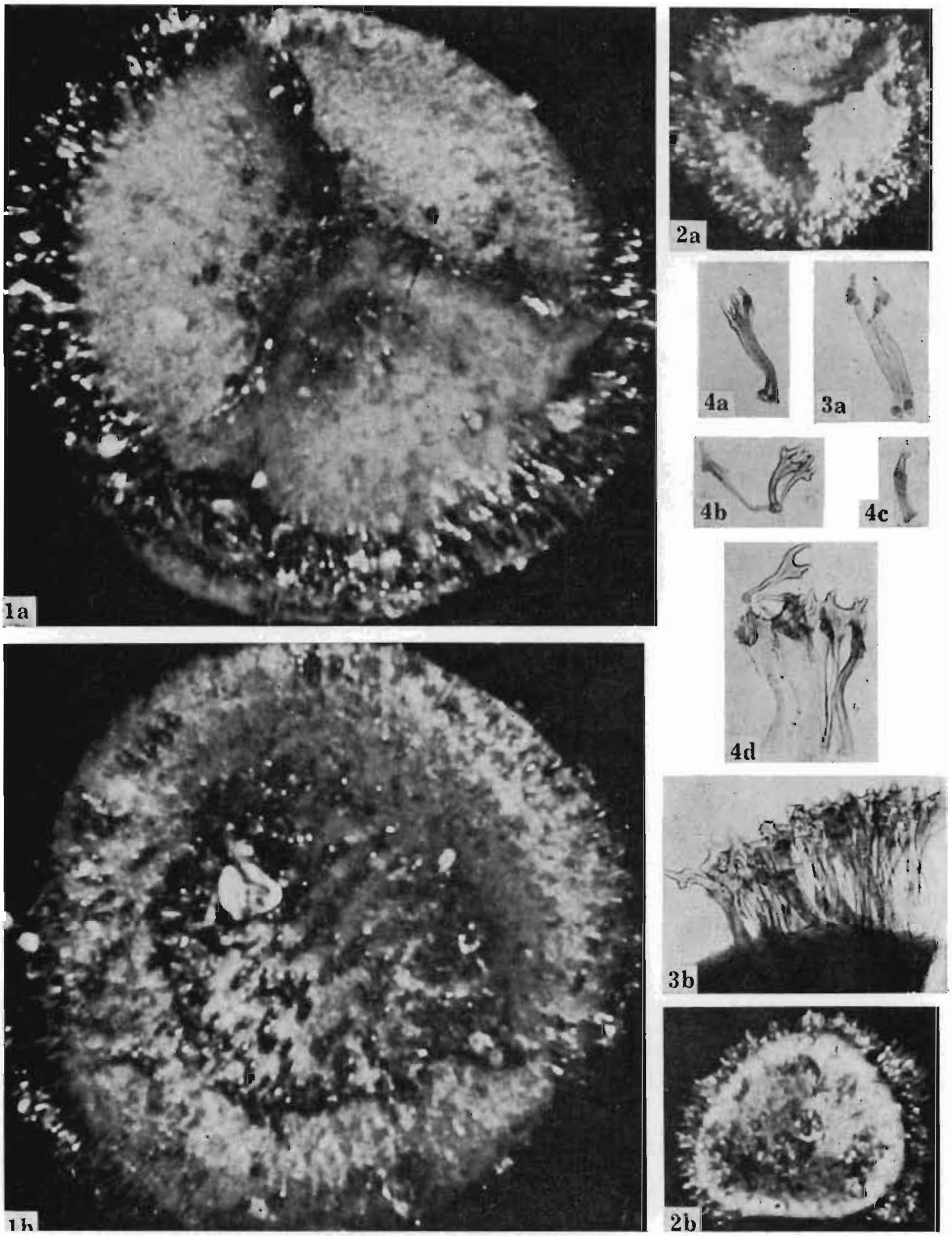

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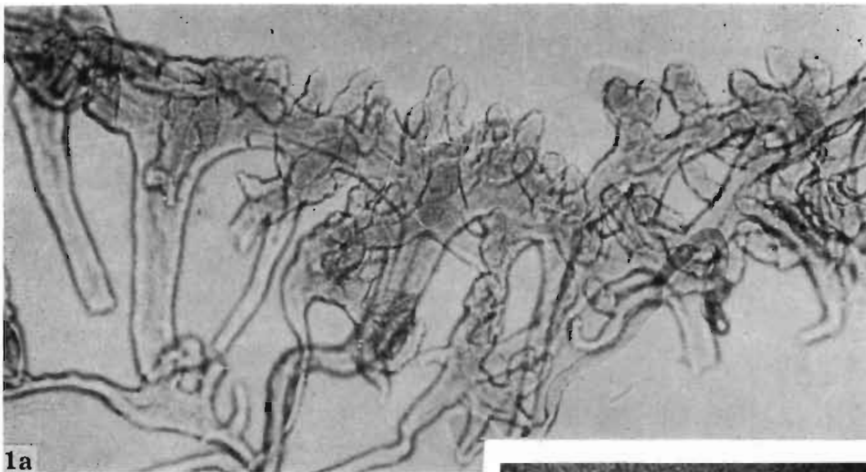

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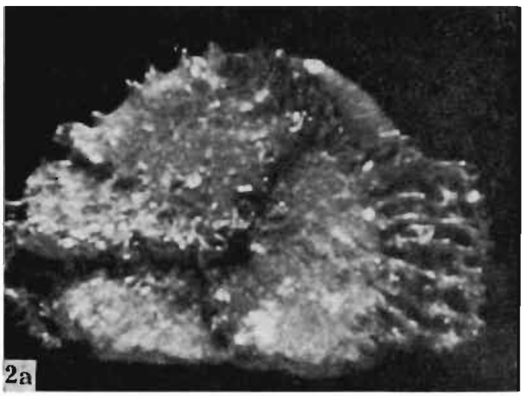

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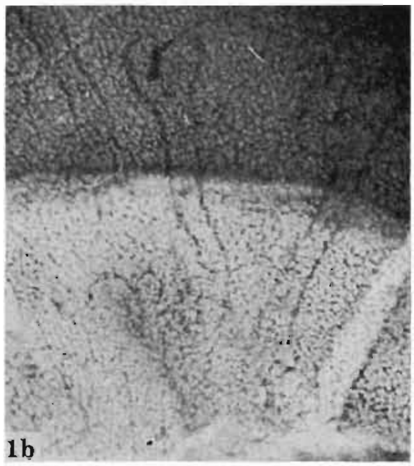

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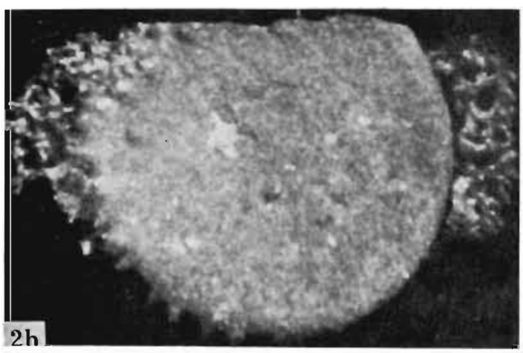

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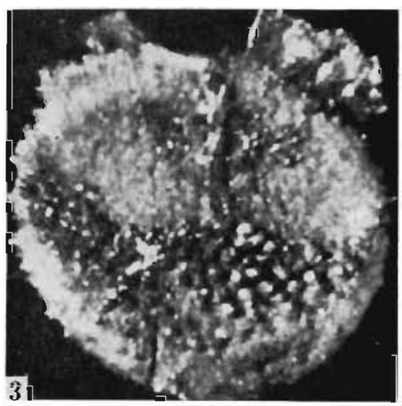

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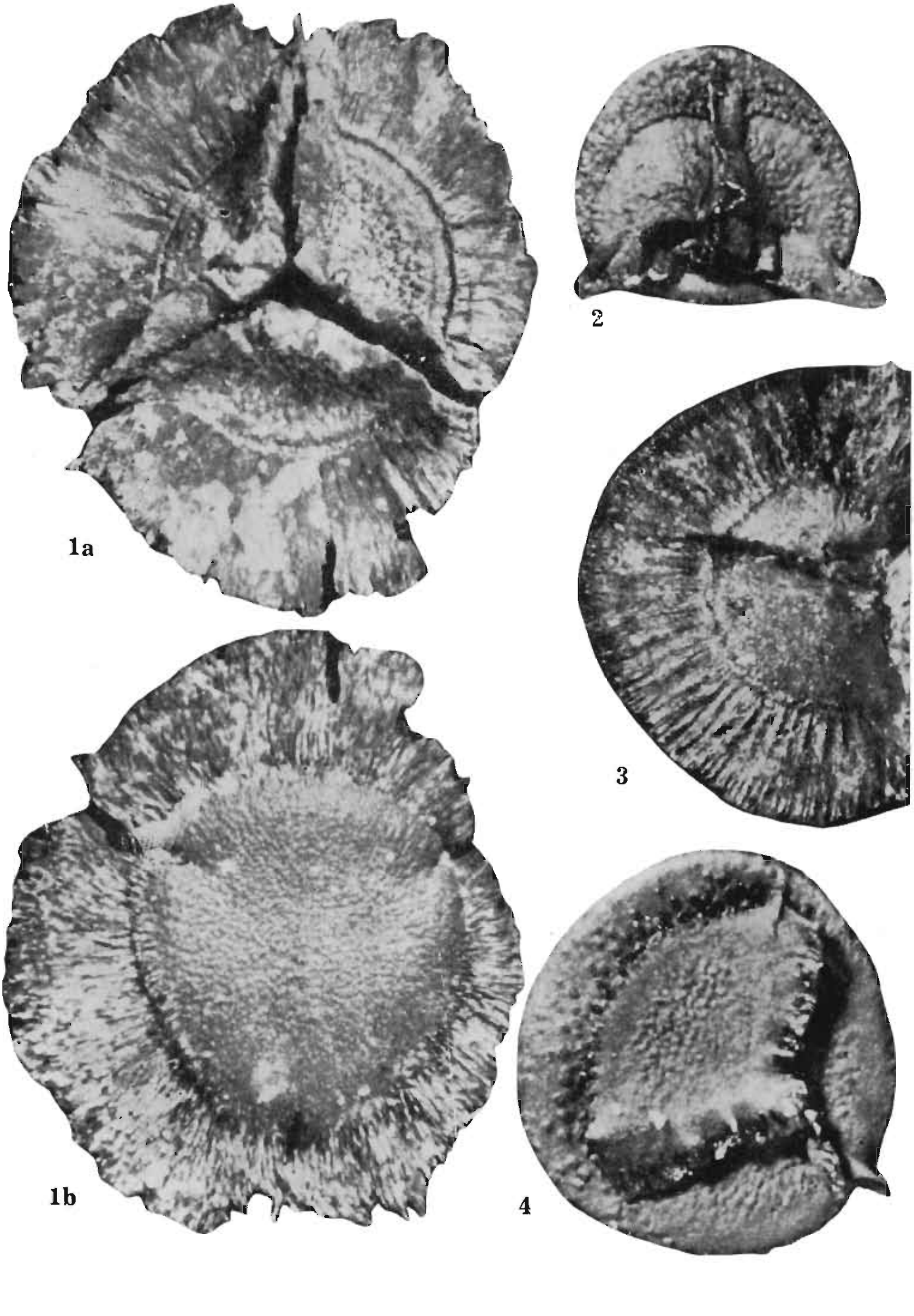

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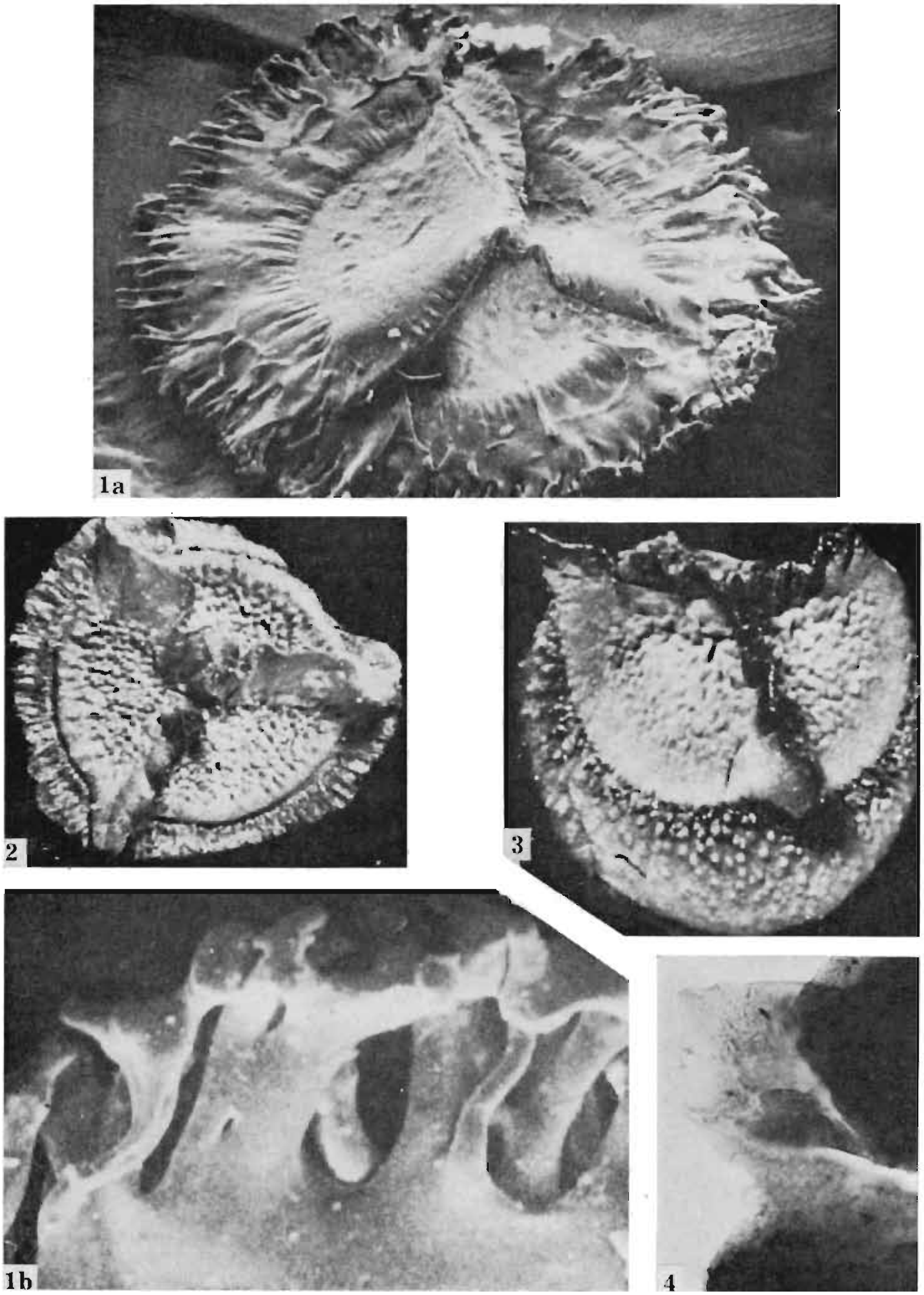

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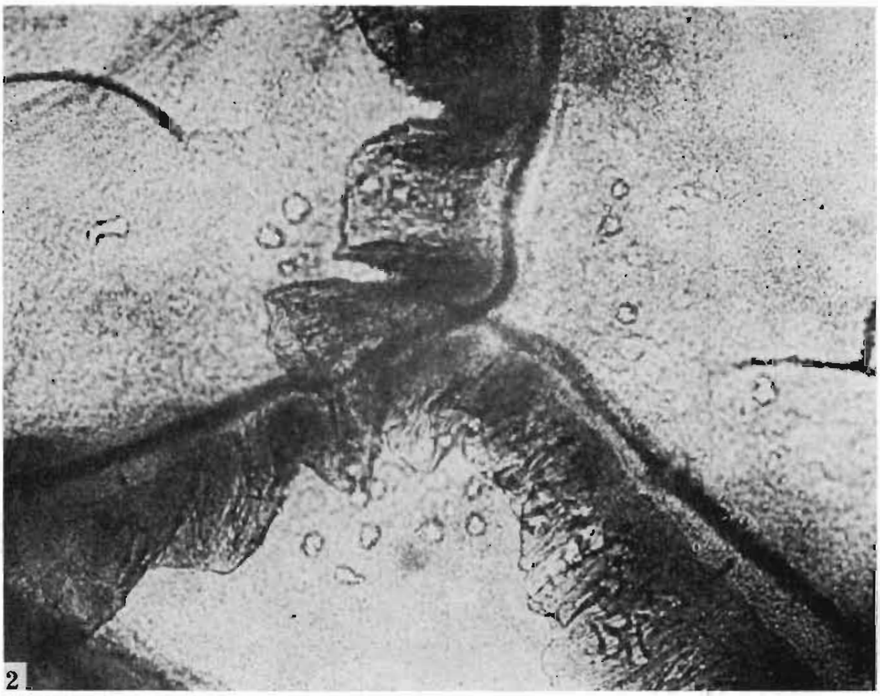
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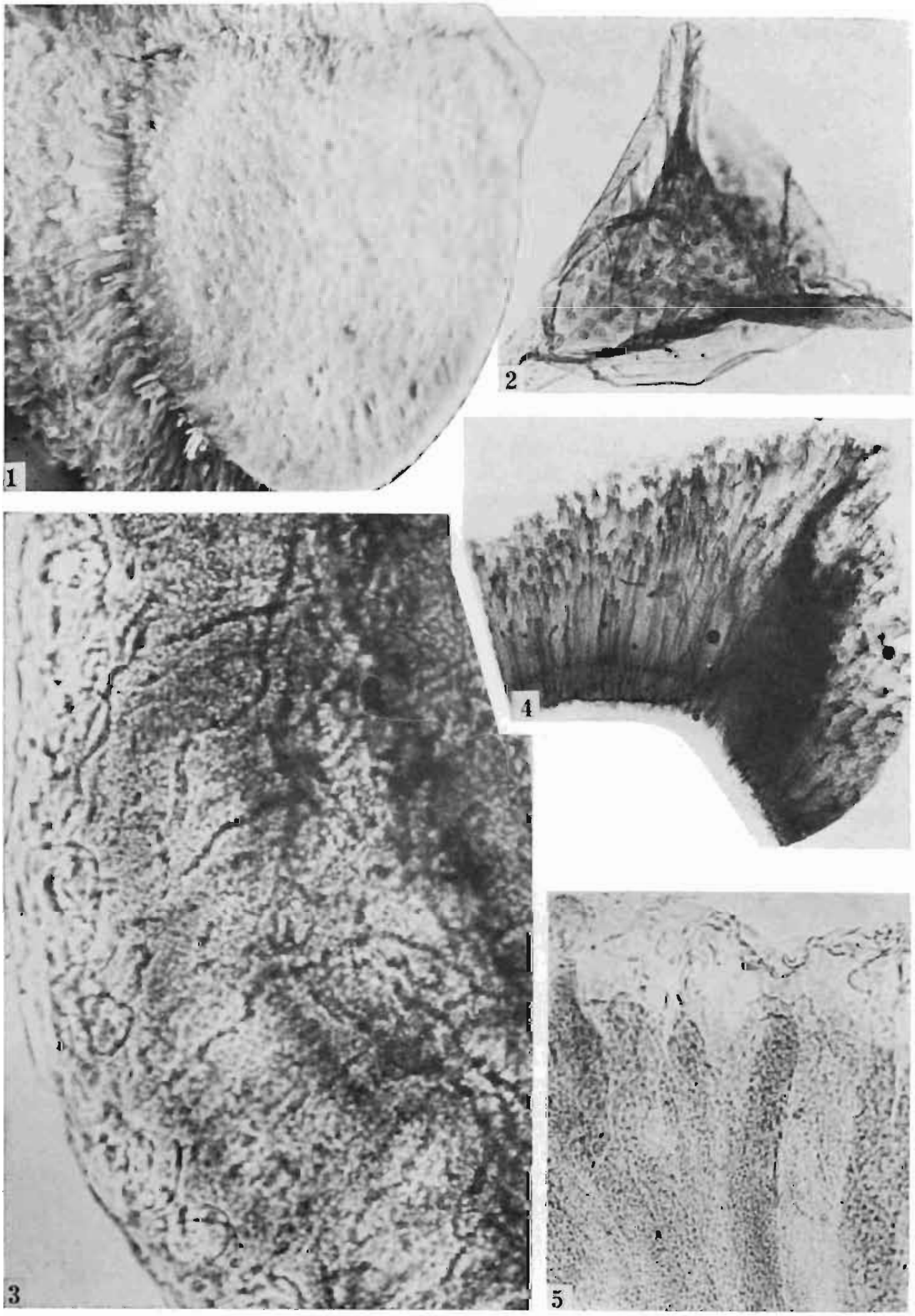

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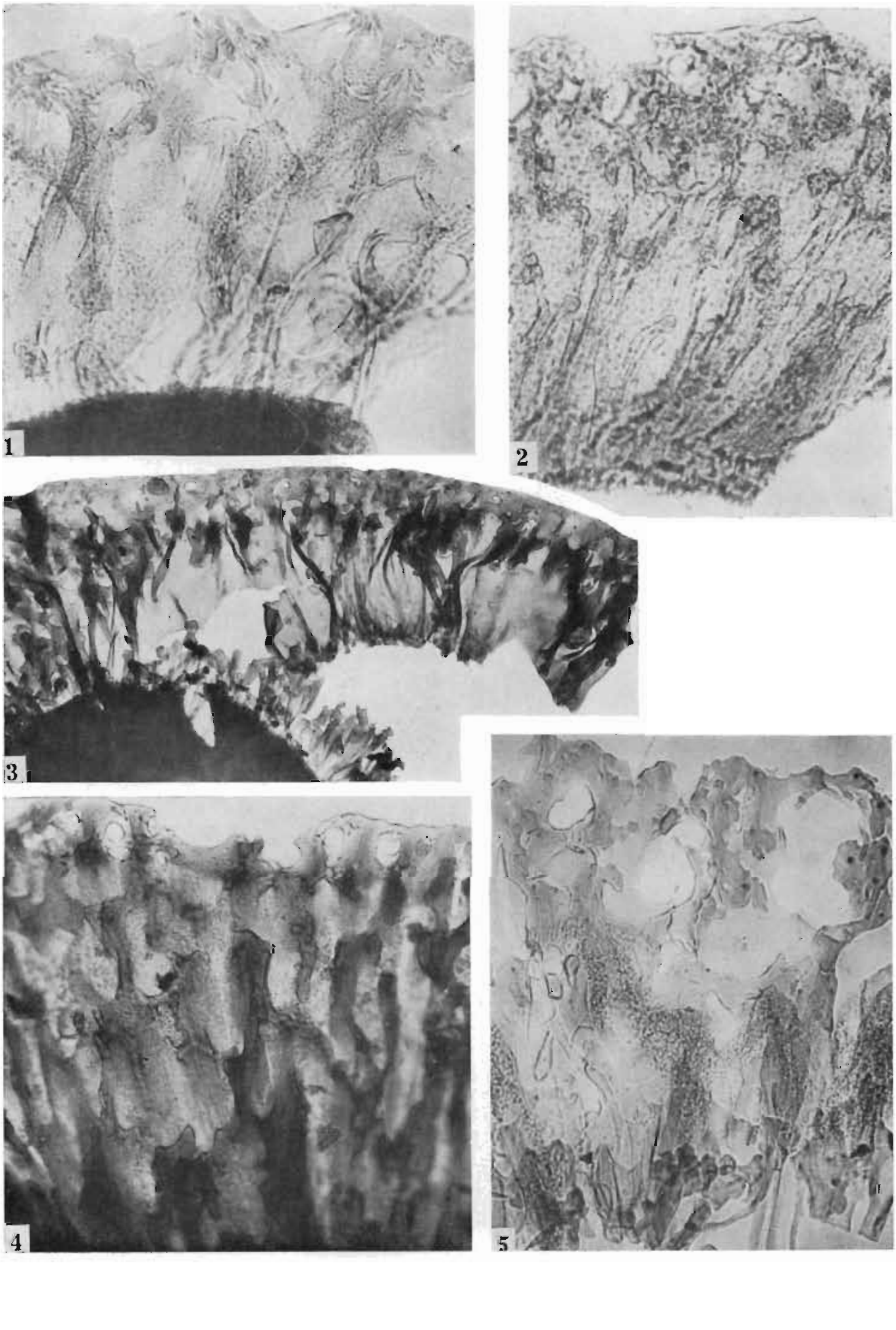

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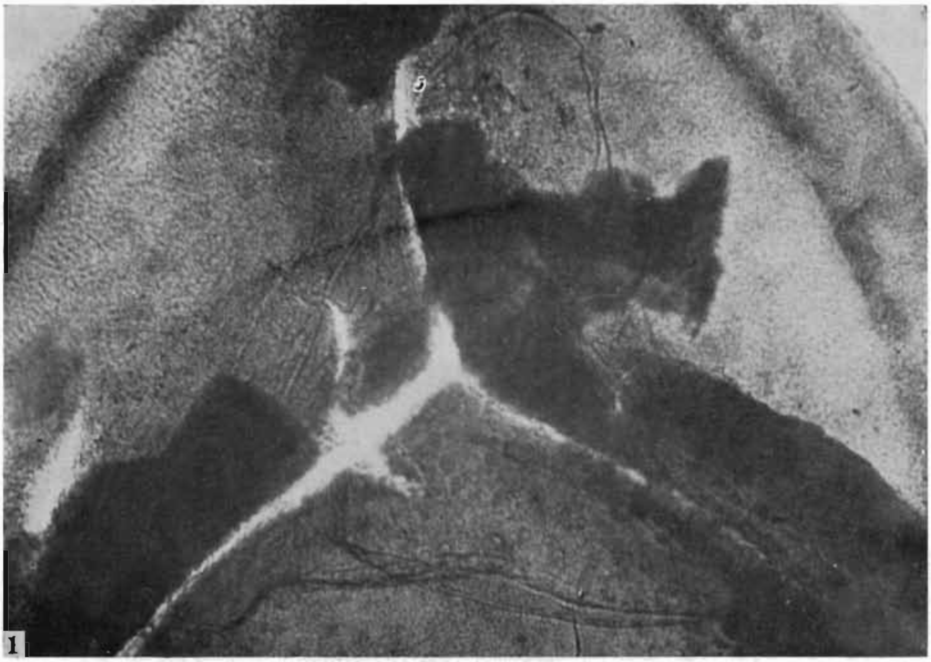

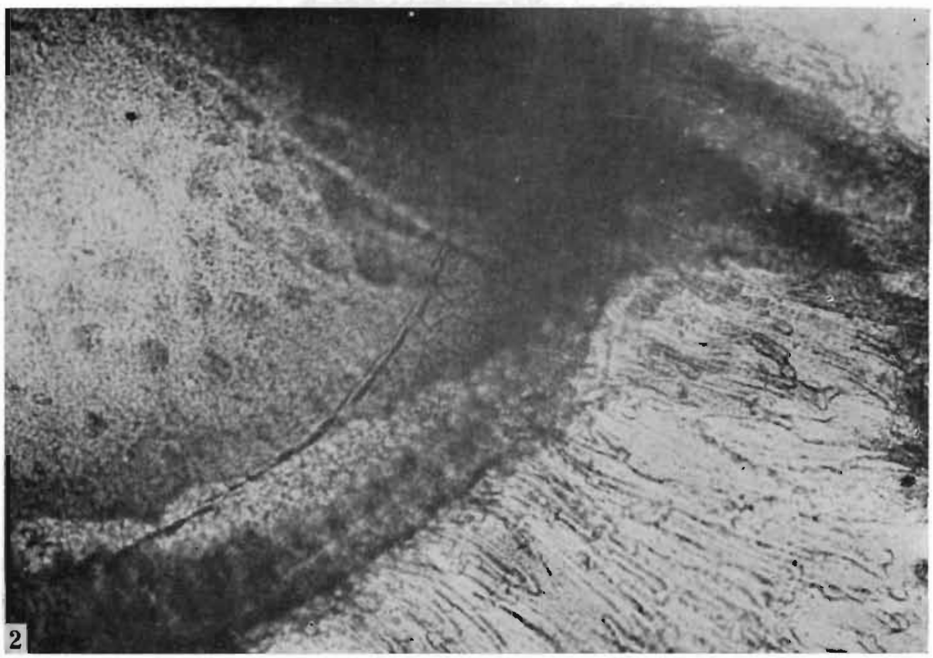

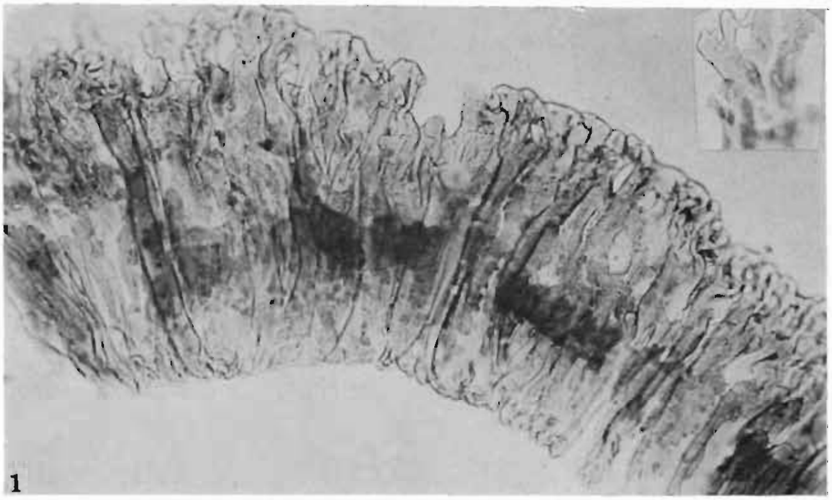

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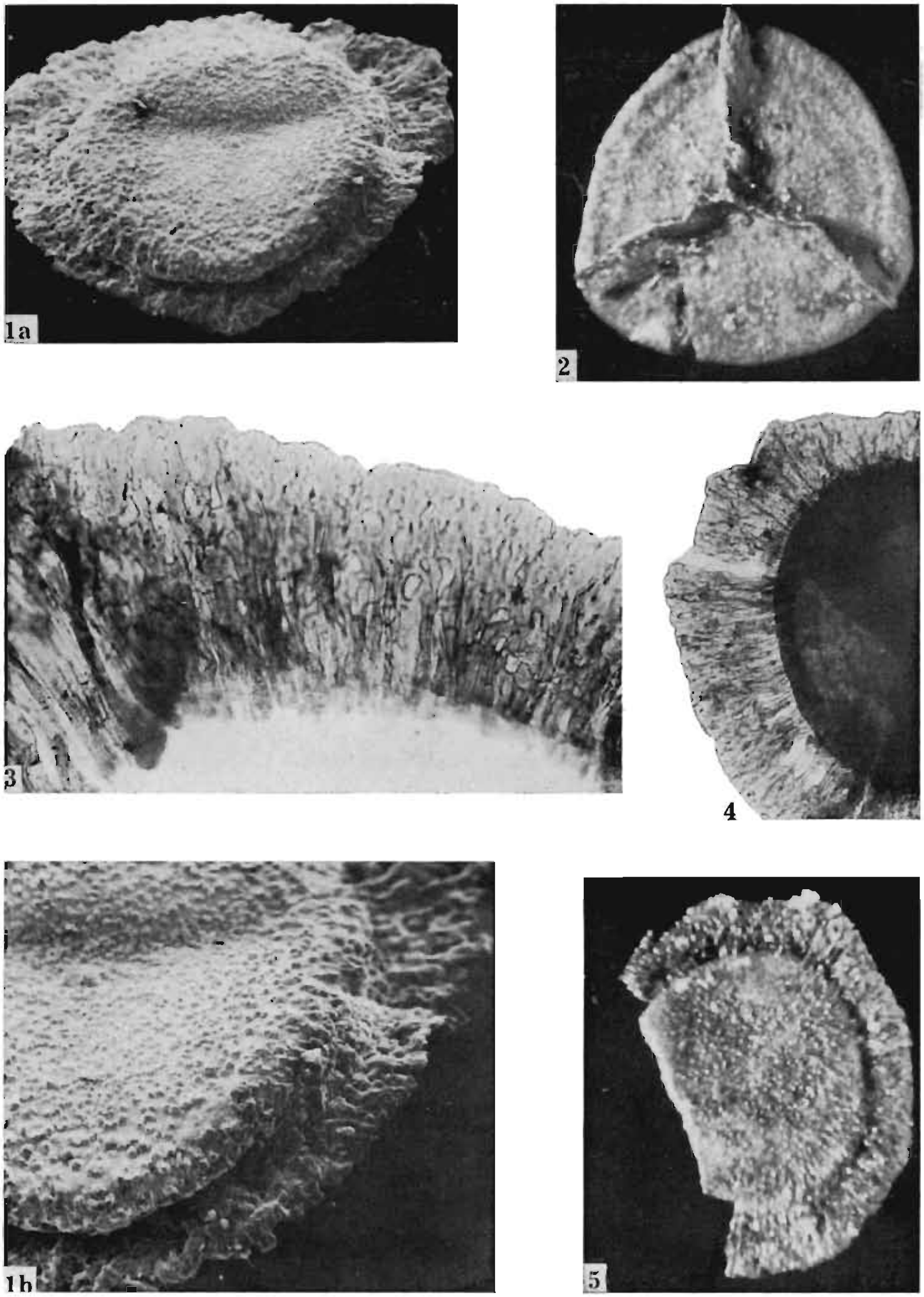

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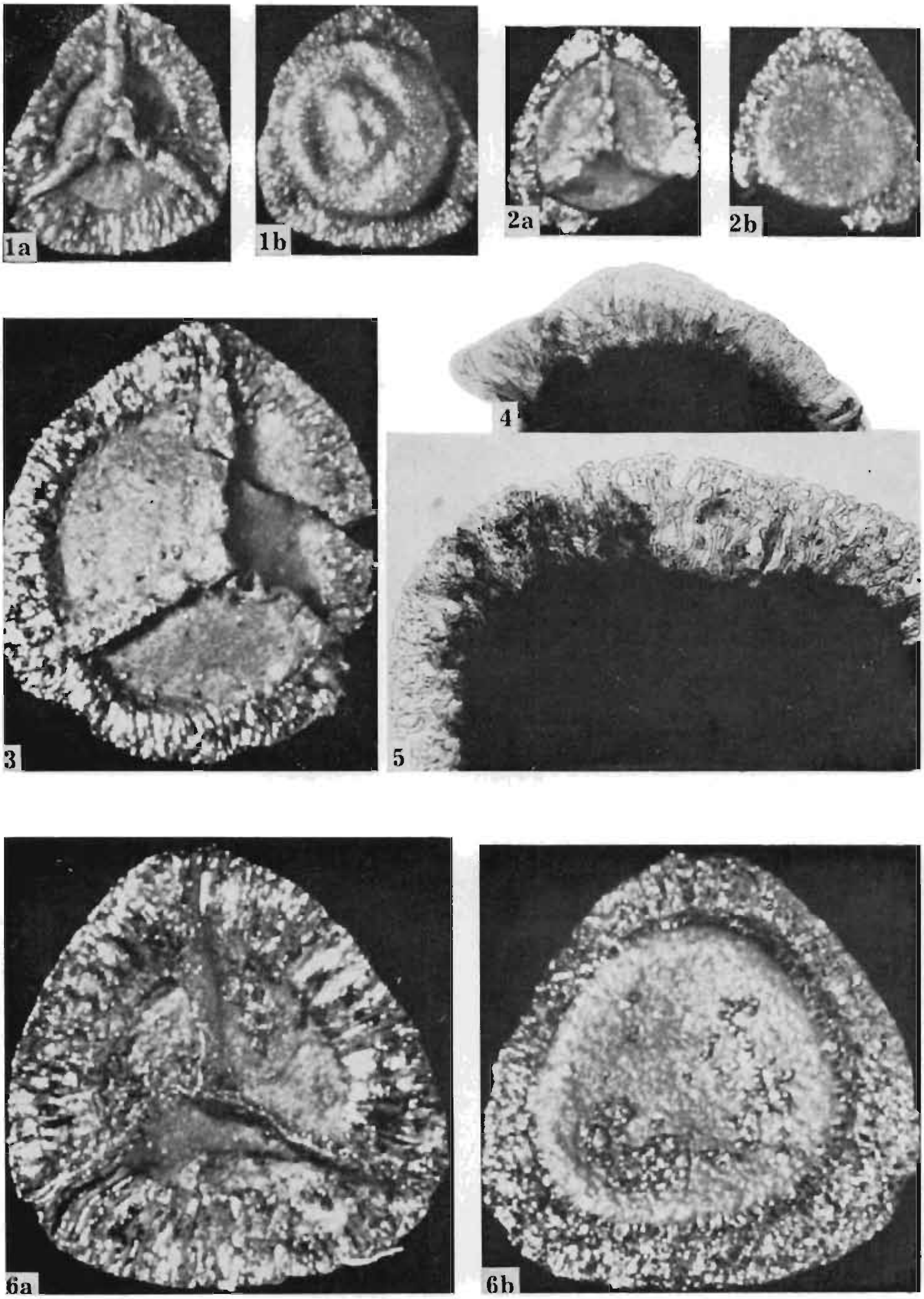

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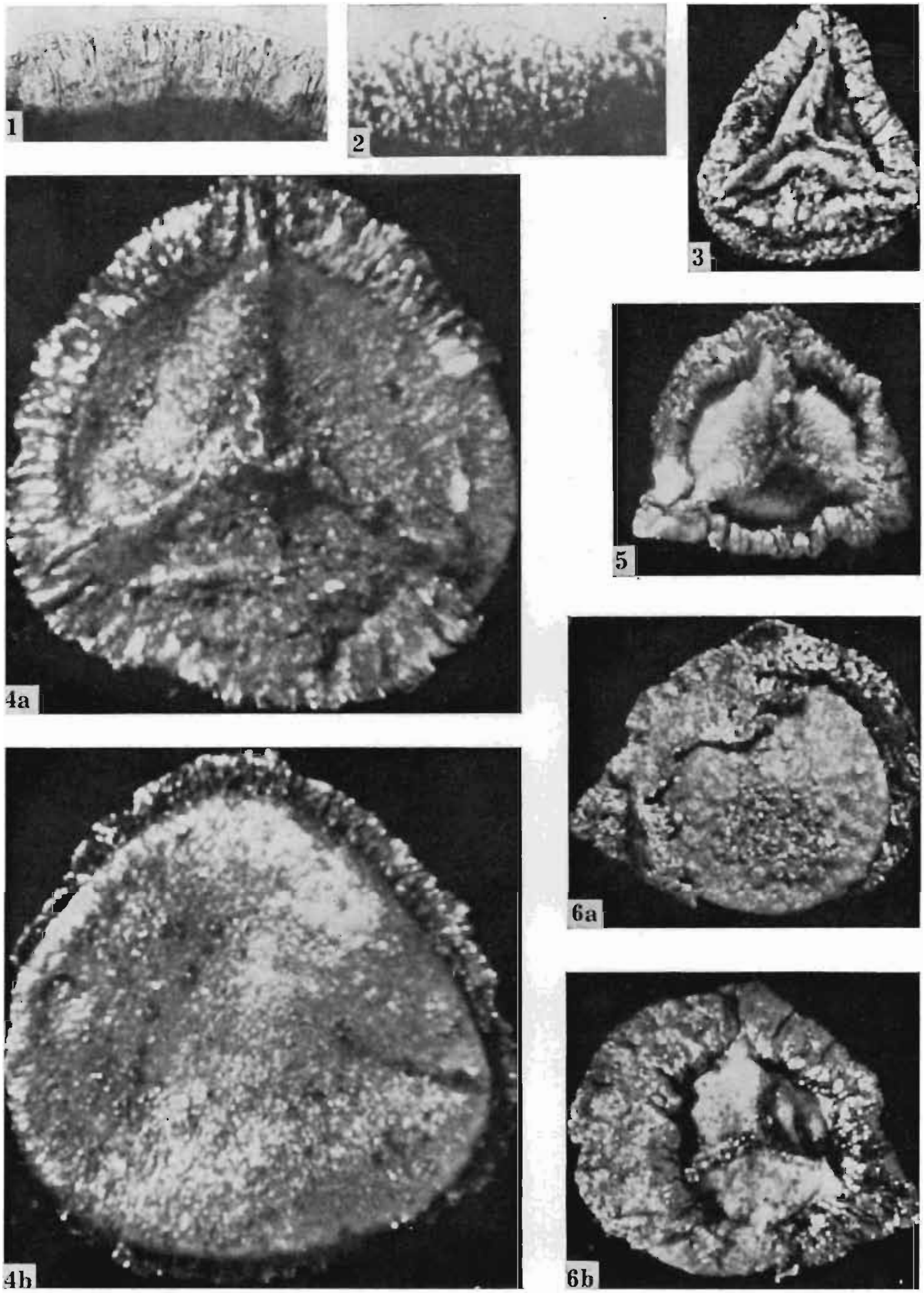

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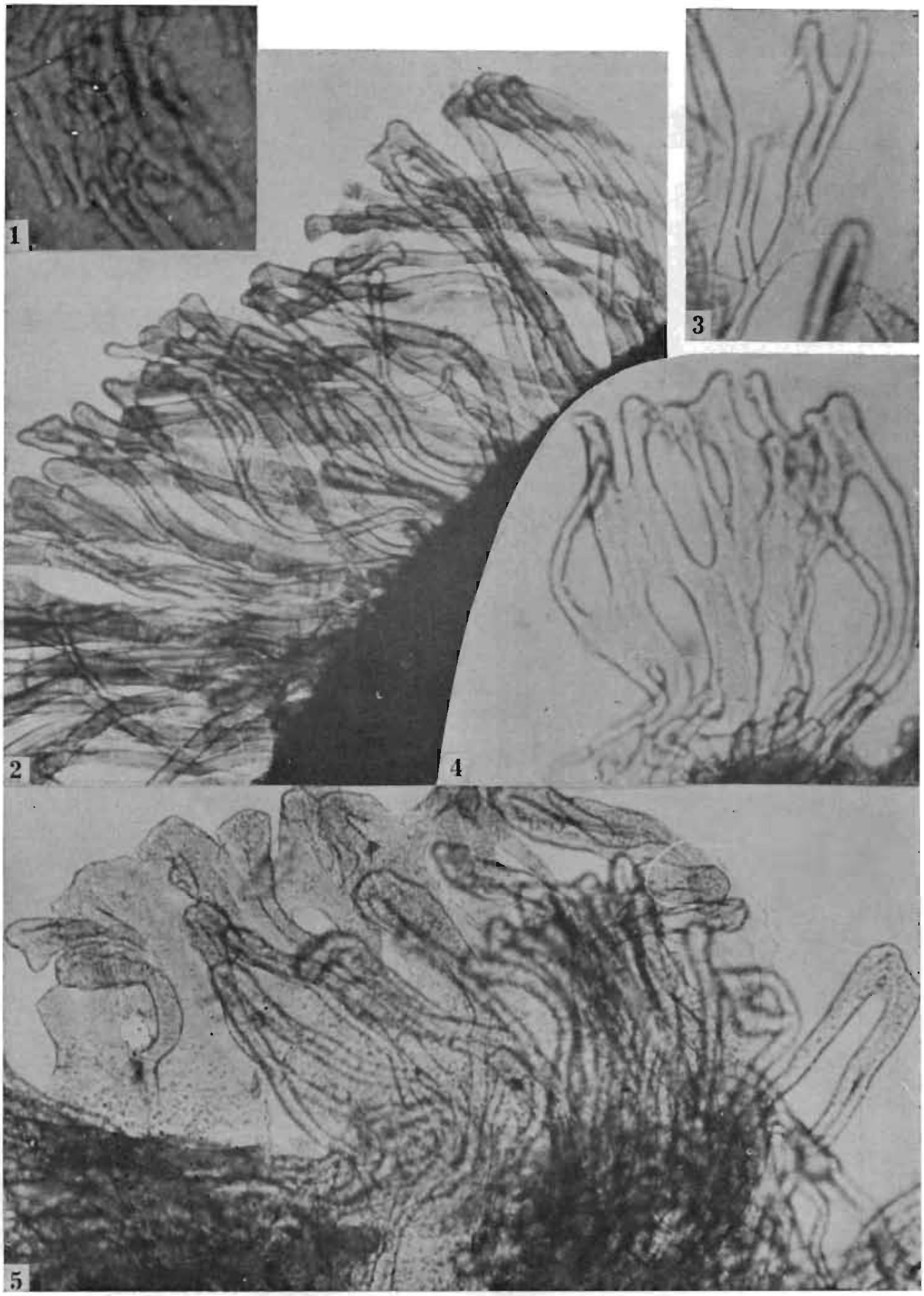
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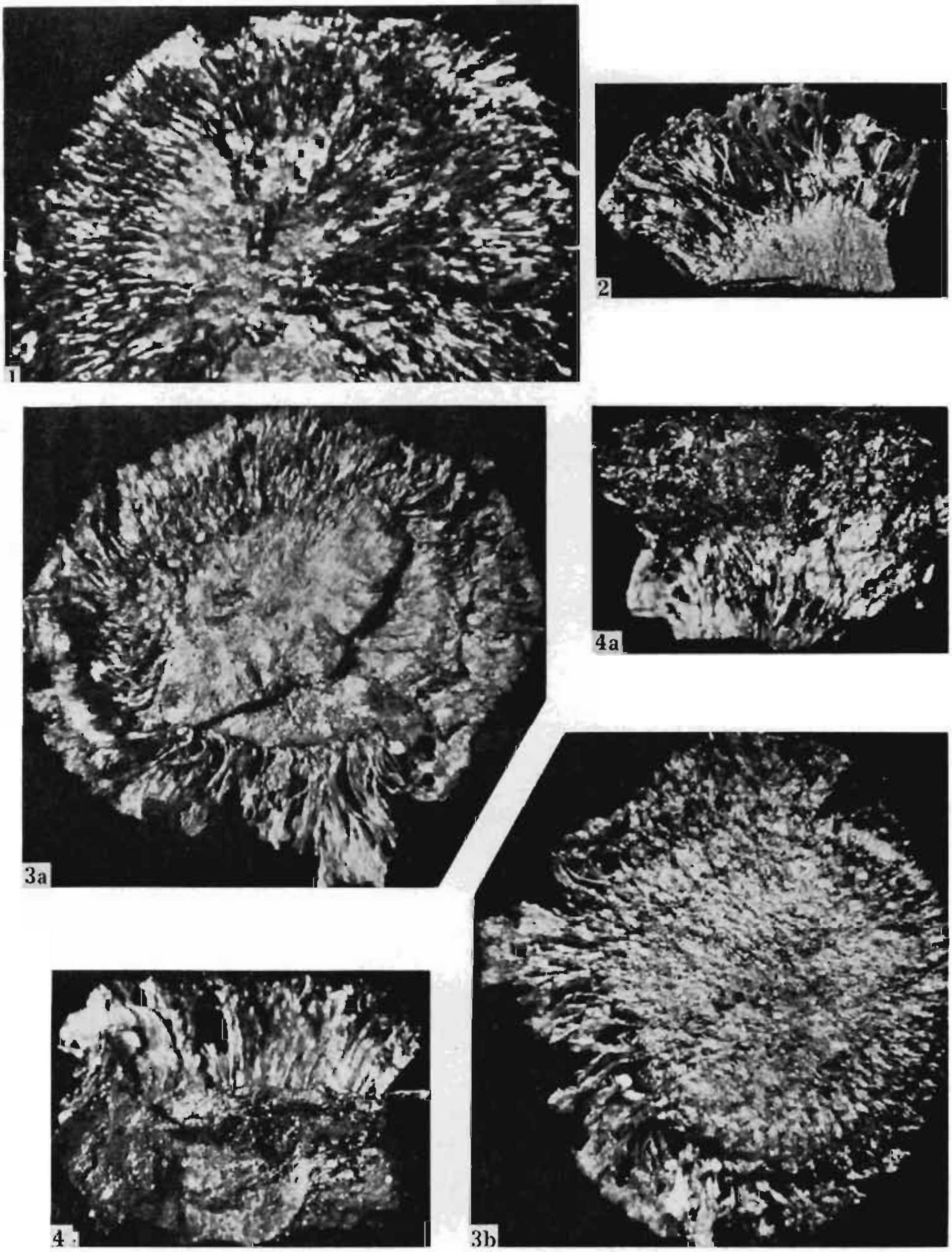

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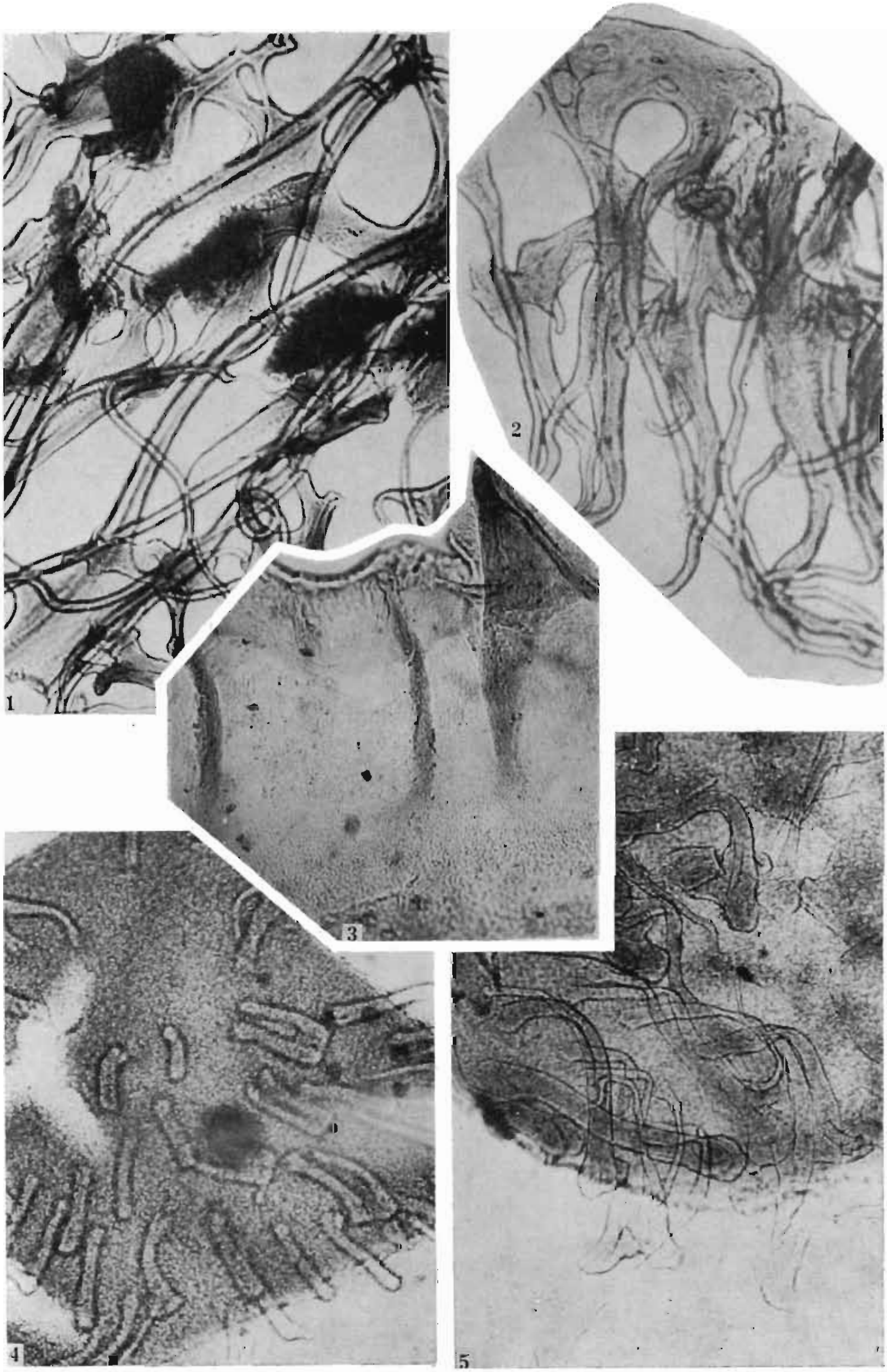
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