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BLUE-GREEN ALGAE FROM THE TREMADOCIAN OF THE HOLY CROSS MOUNTAINS (POLAND)

Abstract. — *Schizothrichites ordoviciensis* n. gen., n. sp., a Tremadocian blue-green alga, with exceptionally well preserved microscopical structure is described. It was etched from the chalcedony of the Holy Cross Mountains. Its close similarity to recent genus *Schizothrix* (Cyanophyceae) is shown.

INTRODUCTION

In Ordovician sandstones of the Holy Cross Mountains (Góry Świętokrzyskie), assigned by Samsonowicz (1916) to the Tremadocian, there are intercalations and lenses of the chalcedony. In this rock Kozłowski (1948) discovered excellently preserved faunal remains, those of graptolites in the first place. Dark-brown agglomerations of filamentous blue-green algae were also encountered in the same material which Professor R. Kozłowski kindly put at my disposal for investigation. My sincere thanks are due to Professor Kozłowski for this material.

After splitting up the sub-transparent siliceous rock, dark stains can be seen up to 3 cm in diameter. Under a strongly magnifying binocular lens separate filaments are distinguishable in those agglomerations (pl. I, fig. 1). After dissolving the rock in hydrofluoric acid, the residuum yields balls of tangled filaments, convenient for further study. Thus, by means of Kozłowski's (1948) method of etching the fossil remains in the chalcedony, perfectly preserved material may be secured. It is considerably elastic and suitable for preparations which can then be conveniently investigated at a chosen magnitude under the microscope.

The blue-green algae etched from the rock have the appearance of brown, coiled up and tangled filaments of a rather band-like shape, more rarely in the shape of a tube. During careful preparation separate fragments of filaments, well fit for a more detailed description of morphological features for determining the genus and species, can be extracted by means of thin needles. The shape of the filaments and their

structure show that the Ordovician blue-green algae closely resemble the recent genus *Schizothrix*. In view of the age of material, however, I consider these blue-green algae as belonging to the new genus *Schizothrichites*. By means of that name I wish to stress the strong similarity of morphological features with the recent blue-green algae of the genus *Schizothrix*.

SYSTEMATIC DESCRIPTION

Type **Cyanophyta**
Class **Hormogoniophyceae**
Order **Oscillatoriales**
Family **Oscillatoriaceae**
Genus *Schizothrichites* n. gen.
(text-fig. 1; pl. I, II)

Diagnosis. — Thalli dark-brown, composed of loosely coiled and tangled filaments. Filaments long, repeatedly branched, composed of 1-4 trichomes situated in a common sheath (pl. I, fig. 2-4; text-fig. 1, *1*, *2*).

Brown or black-brown sheaths, stratified, with undulating strata, externally uneven and rough, sometimes fimbriated, have the appearance of an irregular net on the surface, closed at the apex, narrowed, sometimes sharpened (pl. I, fig. 3-5; pl. II, fig. 1-6).

The trichomes are composed of cells, mostly shorter than broad, less frequently nearly square. Granular formations arranged on the circumference of the central body (centroplasm) are preserved in the cells. They correspond to the cyanophycin granules, perhaps also to volution and the so-called metachromatic bodies in the cells of the present blue-green algae. Transversal walls of the cells are not visible, however, and the peripheral part of the protoplasm of cells, the chromatoplasm, is not preserved. The young and growing apical cells of trichomes are not preserved.

In the older parts of the filaments 2-4 trichomes are usually enclosed in the sheath, but only one trichome can be seen in the apical branches. The trichomes are twisted loosely, cord-like, sometimes divided into segments.

Type species: *Schizothrichites ordoviciensis* n. sp.

Schizotrichites ordoviciensis n. sp.
(pl.II, fig. 2, 3)

Description. — Thalli composed of tangled filaments, branched according to the *Schizothrix* type. Filaments consisting of 1-4 trichomes, surrounded by a common, distinctly parallelly stratified sheath. External parts of the sheath are sometimes fimbriated and have an irregular net on the surface.

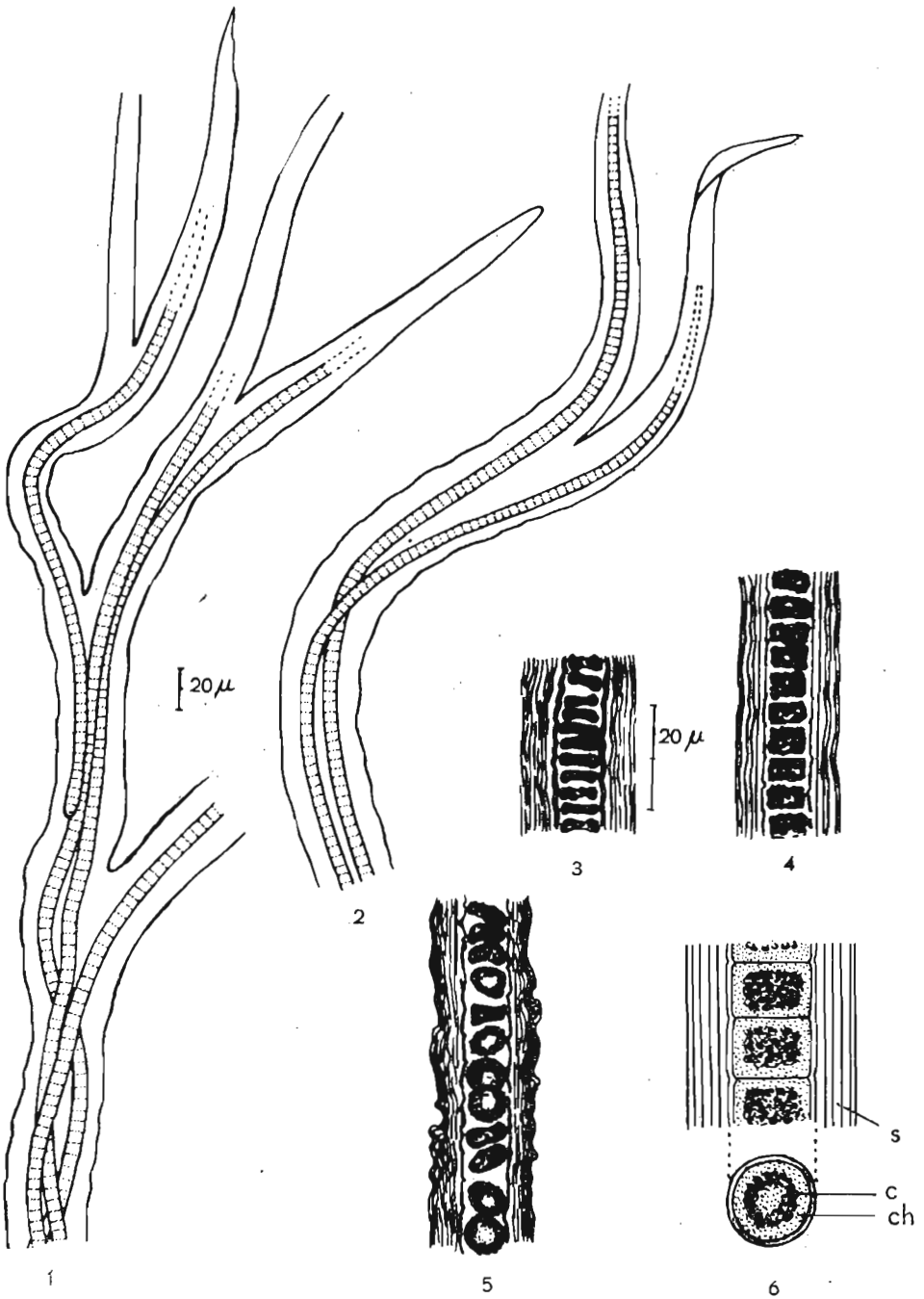

Fig. 1. — *1,2* Typical shape of branched filaments; *3,4* fragments of filaments more strongly magnified, showing cells of various length; *5* fragment of filaments with loosely disposed and partly overturned cells; *6* diagrammatic restoration of filament and cells structure.
s sheath, *c* centroplasm, *ch* chromatoplasm (reconstructed).

The breadth of the filaments ranges from 13 to 35 μ, but filaments 16-26 μ broad with one or two trichomes are the most common. Older segments of the filaments may, however, exceed 35 μ in breadth. The trichomes are usually 8-10 μ broad. These dimensions are repeated regularly in nearly all investigated specimens. The cells are mostly 3-4 μ long, occasionally nearly square. These dimensions are only approximate, since the transversal walls of the cells are not preserved. The central body, determined by an agglomeration of granules, probably cyanophycin and perhaps also volutine, is readily visible in the cells, but the chromatoplasm cannot be distinguished. Cells, loosely disposed in the sheath or overturned, can be seen in some of the filaments (pl. II, fig. 2, 3). As can be clearly observed from this arrangement, the granular agglomeration are mostly situated on the periphery of the central body, in a similar manner as the metachromation bodies and the cyanophycin granules in the cells of recent blue-green algae. No apical cells of trichomes were found which, in recent blue-green algae, always have a definite shape and are an important taxonomic character. They are growing cells containing a small amount of resistant reserve material and presumably that is why they were entirely destroyed, similarly as the chromatoplasm. Parts of cells containing agglomerations of resistant reserve material are the only ones that remained.

Locality and horizon. — Wysoczki near Bogoria in the Holy Cross Mountains (Góry Świętokrzyskie) in central Poland. Tremadocian.

Holotype. — Typical specimens are kept in the Institute of Palaeozoology of the Polish Academy of Sciences. Warszawa, Żwirki i Wigury, 6.

Paratype. — Preparations of the same material are also kept in the Department of Hydrobiology of the Jagellonian University, Kraków, Oleandry 2a.

DISCUSSION

The material, excellently preserved in siliceous rocks and prepared after dissolving the rock in hydrofluoric acid, allowed the present author to clearly enough determine all the basic details of the structure of filaments and cells of the blue-green algae. A simplified reconstruction of the investigated blue-green alga is presented on text-fig. 1, 6. In the blue-green algae of the recent order Oscillatoriales the filament (*filamentum*) is composed of trichome (*trichom*) and a sheath (*vagina*). The trichomes are composed of a system of cells disposed in one row and having durable cellulose membranes. The lateral membranes are thicker, the transversal ones delicate; they adhere closely to the protoplasm and are of a pellicular character. The protoplasm is differentiated into a peripheral part in which pigments active in photosynthesis are dissolved (chlorophyll, carotenoids, phycocyan and phycocoerithrin) and which is therefore called

the chromatoplasm, and a medial part, usually colourless, called the central body or centroplasm. In this part the chromatin substance is present, as is shown by the presence of ribo- and desribonucleic acid. On the circumference of the central body are concentrated granular metachromatin bodies, as well as reserve material in the shape of blue-green algae starch, volutin and cyanophycin granules. As compared with starch, cyanophycin granules and volutin represent a substance singularly resistant to the action of strong acids and alkalies. There is no cell nucleus in blue-green algae and no sexual reproduction. The recent blue-green algae of the genus *Schizothrix* occur as a rule in the shape of smaller or larger turfy, bushy or tuft-like concentrations of filaments. They occur all over the globe, in fresh waters, seas, as well as on land, soil and damp rocks.

The Ordovician blue-green algae have the same structure as the recent ones. Sheaths with their chracteristic stratification, partly also lateral cellular membranes and granular agglomerations, probably cyanophycins, perhaps even volutines concentrated on the circumference of the central body, are perfectly preserved in the investigated material. The delicate transversal walls separating the cells in the trichomes, the chromatoplasm and other plasmatic parts have disappeared. No apical cells of trichomes were found. As growing cells, they were decomposed like chromatin. The granular concentrations still existing in the cells are situated on the circumference of the central body. This can be seen on pl. II, fig. 2 which presents loosened and overturned cells. In flat-lying cells granulosity surrounding an interior of a lighter colour can be noticed. Even these details correspond to the cell morphology of blue-green algae, in which granular elements (reserve material) are assembled, in the first place, on the circumference of the central body, in the adhering chromatoplasm.

It must be stressed that all the morphological details mentioned above were clearly visible in the material etched from chalcedony. This can be seen on microphotographs (pl. II, fig. 2) taken by means of oil immersion 60 × and a compensating ocular 10 ×.

Schizothrichites ordoviciensis n. sp. shows close similarities with the recent blue-green algae of the genus *Schizothrix* in the following characters:

1) The thalli are turf-like, composed of tangled filaments.

2) The filaments are branched in a manner typical of the genus *Schizothrix*.

3) The sheaths are strong, durable, longitudinally stratified, closed at the apex, often ending sharply.

4) The trichomes are placed in the sheaths in a manner typical of the genus *Schizothrix*.

The agreement of the structure of filaments and cells and, lastly, that of the whole association of features pertaining to the genus *Schizothrix* with the Ordovician material is astonishing. This material dates back to about 500 million years ago. We have here a very ancient group of plants which in very distant geological epochs had attained a high degree of morphological differentiation and preserved it till now. The preservation of the details of cellular structure is probably due, on the one hand, to a rapid and compact impregnation of the blue-green algae growing at the bottom of the Ordovician sea with siliceous gel, in which the plants were enclosed and only partly decomposed; on the other hand, to the skilfull preparation of remains found in the rock by means of Professor Kozłowski's chemical method.

Nearly all the descriptions of fossil blue-green algae from old geological periods were based on macroscopic specimens or on slides, on which a resemblance to colonies and thalli of recent blue-green algae could be observed, but details of the structure of thalli and cells could not be accurately distinguished. None of the previous lists of fossil blue-green algae, those of Pia (1927), Němejc (1959) and others, also the last list of algae remains found in U.S.S.R., elaborated by Vologdin (1962), and a special list of Ordovician algae from calcareous rocks worked out by Johnson and Hoeg (1961) — have supplied any new details concerning the morphology and structure of these plants. All the authors, while stressing the fact of a very ancient appearance of blue-green algae, at the same time state that the knowledge of their morphology and systematics is inadequate. On the base of their purely external features, fossil blue-green algae are comparable with such recent families as the Chroococcaceae, Nostocaceae, Oscillatoriaceae, and Rivulariaceae, but the details remain unknown. It appears that material obtained from limestone is preserved only in its external outline, without any details of internal structure. Material enclosed in a siliceous mass is much better preserved. This is also postulated by Croft and George (1959) in a paper concerning blue-green algae from the Middle Devonian in England. These authors publish good microphotographs and figures illustrating many details of the structure of filaments and cells of blue-green algae of the order Stigonematales. The outlines of the central body in the cells, those of the membrane and sheath of filaments, are visible on the photographs, similarly as in our Tremadocian blue-green algae. It is interesting to note that these investigations were carried out on small fragments of rock examined under a microscope in cedar ail, and not on material isolated from the rock. The work of Croft and George is probably the only one that contains more accurate morphological details concerning old fossil blue-green algae. The material etched from the Tremadocian rocks of Poland furnish, however, considerable more details and permit, in the first place, to distinguish with sufficient accuracy parts of the cells.

This confirms the supposition, already expressed by many scientists, that fossil blue-green algae do not differ greatly from the living forms.

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Kraków, May 1963

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SINICA Z TREMADOKU GÓR ŚWIĘTOKRZYSKICH

Streszczenie

Opisano nowy rodzaj i gatunek sinicy kopalnej na podstawie okazów, wytrawionych za pomocą kwasu fluorowodorowego z chalcedonu, występującego wśród piaskowców tremadockich w Wysoczkach koło Bogorii w Górach Świętokrzyskich.

Sinice te tworzą w skale ciemne skupienia, złożone ze skłębionych nici, które po rozpuszczeniu skały są na tyle elastyczne, że można je częściowo rozplątać i sporządzić preparaty mikroskopowe. Na podstawie szeregu preparatów podano charakterystykę rodzaju i gatunku, który dzięki daleko idącej zgodności z dziś żyjącymi sinicami z rodzaju *Schizothrix* nazwano *Schizothrichites ordoviciensis* n. gen. n. sp.

Typ **Cyanophyta**
Rodzina **Oscillatoriaceae**
Rodzaj *Schizothrichites* n. gen.

Diagnoza. — W skale zawarte są bezkształtne, darniste skupienia nici wielokrotnie rozgałęzionych, luźno pozwijanych i splątanych ze sobą. Nici złożone są z 1-4 trychomów umieszczonych we wspólnej pochwie. Pochwy są brunatne lub

czarno-brunatne, warstwowane, o warstwach przebiegających falisto, na zewnątrz nierówne, niekiedy postrzępione, na szczycie zamknięte, zwężone i czasem zaostrzone. Powierzchnia pochwy ma często wygląd siatki o nieregularnych oczkach. Trychomy złożone są z komórek przeważnie krótszych od szerokości, rzadziej prawie kwadratowych.

W komórkach zachowały się ziarniste utwory ułożone na obwodzie ciała centralnego (pl. I, fig. 2), odpowiadające widocznym w komórkach dzisiejszych sinic ziarnom cyanoficyny (może również wolutyny?) oraz tak zwanym ciałom metachromatynowym. Nie są widoczne delikatne ścianki poprzeczne komórek, nie zachowała się też chromatoplazma oraz szczytowe komórki trychomów.

Schizothrichites ordoviciensis n. sp.

Diagnoza. — Nici 15-35 μ szerokości, najczęściej spotyka się jednak nici 1-2 trychomowe, szerokości 16-26 μ. Trychomy szerokości 8-10 μ, komórki przeważnie 3-4 μ długości, rzadziej prawie kwadratowe. Inne cechy podobne jak w diagnozie rodzaju.

Występuje w chalcedonie z dolnego ordowiku (tremadok) w Wysoczkach koło Bogorii w Górach Świętokrzyskich.

Opisane sinice mają budowę plech i komórek podobną jak sinice dzisiejsze. Zachowane szczegóły w komórkach dowodzą, że miały one taki sam schemat budowy, jak sinice żyjące dzisiaj, co przedstawiono na fig. 1, rys. 6. Komórki miały więc obwodową część, czyli chromatoplazmę (nie zachowaną) oraz ciało centralne, na obwodzie którego gromadziły się ziarniste skupienia materiałów zapasowych, które się w materiale ordowickim doskonale zachowały (pl. II, fig.2). Schemat budowy trychomów, plech, nici i rozgałęzienia nici odpowiadają w zupełności żyjącym dziś sinicom z rodzaju *Schizothrix*.

Dowodzi to, że sinice już w odległych epokach geologicznych uzyskały wysoki stopień zróżnicowania morfologicznego, który zachował się do dziś.

OBJASNIENIA DO ILUSTRACJI

Fig. 1 (p. 453)

1,2 Typowy pokrój rozgałęzionych nici; *3,4* fragmenty nici przy silniejszym powiększeniu (widać komórki różnej długości); 5 fragment nici z luźno ułożonymi i częściowo poprzewracanymi komórkami; *6* schemat budowy nici i komórek; *s* pochwa, *c* centroplazma, *ch* chromatoplazma (rekonstrukcja).

Pl. I

Fig. 1. Szlif tremadockiego chalcedonu z nagromadzonymi nićmi sinicy. Ciemne kulki — konkrecje opalu; × 35.

Fig. 2,3. Rozgałęzione nici × 112; *3* rozgałęzienie typowe dla sinic z rodzaju *Schizothrix*.

Fig. 4,5. Szczyty rozgałęzionych nici, ×320.

Pl. II

Fig. 1,4,5. Najczęściej spotykane fragmenty nici o komórkach różnej długości i pochwach warstwowanych, na zewnątrz nierównych lub postrzępionych.

Fig. 2,3. Trychomy z rozluźnionymi i częściowo poprzewracanymi komórkami; *2* skupianie się ziarn cyanoficyny na obwodzie ciała centralnego.

Fig. 6. Powierzchnia pochwy tej samej nici, którą przedstawia fig. 5.

Wszystkie zdjęcia pl. II × 1200

КАРОЛЬ СТАРМАХ

СИНЕ-ЗЕЛЕНАЯ ВОДОРОСЛЬ ИЗ ТРЕМАДОКА СВЕНТОКРЖИСКИХ ГОР (ПОЛЬША)

Резюме

Описан новый вид и род сине-зеленой водоросли на основании образцов извлеченных плавиковой кислотой из халцедона. Халцедоны выступают среди тремадокских песчаников в Высочках около Богории в Свентокржиских Горах.

Водоросли эти выступают в халцедоне в виде спутанных нитей, которые после растворения породы сохраняют в такой степени свою первичную эластичность, что их можно частично размотать и приготовить микроскопические препараты. Базируясь на многих препаратах автор характеризует вид и род, который ввиду значительного сходства с современной сине-зеленой водорослью, принадлежащей роду *Schizothrix*, назван *Schizothrichites ordoviciensis* n. gen. n. sp.

Род *Schizothrichites* n. gen.

Диагноз. — Нити многократно разветвленные, свободно спутанные, в виде бесформенных, дернистых скоплений. Нить сложена из 1—4 трихомов, содержимых в общем влагалище. Влагалища коричневые или черно-коричневые, слоистые, со слоями волнистыми, неровными снаружи, иногда обтрепанные, замкнутые на верхушке, суженные и иногда заостренные. Поверхность влагалища имеет часто вид сеточки с нерегулярными ячейками. Трихомы сложены из клеток, преимущественно более коротких чем их ширина, реже — почти квадратных.

В клетках сохранились зернистые включения вокруг центрального тела (пл. II, фиг. 2). Эти включения соответствуют присутствующим у современных сине-зеленых водорослей зернам фикоциана (может быть также волютина?), и так называемым метахроматиновым телам. Тонкие поперечные стенки клеток невидимы, хроматоплазма и вершинные клетки трихом не сохранились.

Schizothrichites ordoviciensis n. sp.

Диагноз. — Нити 15—35 μ шириной, но чаще всего выступают 1—2 трихомовые нити шириной 16—26 μ. Трихомы 8—10 μ шириной, клетки преимущественно 3—4 μ длиной, реже почти квадратные. Остальные признаки как в диагнозе рода.

Выступает в халцедоне нижнего ордовика (тремадока) в Высочках около Богории в Свентокржиских Горах.

Описанные водоросли строением своего слоевища и клеток похожи на современные сине-зеленые формы. Сохраненные в клетках подробности доказывают, что их микроструктура прдставляла такой же план как у современных сине-зеленых водорослей (фиг. 1, рис. 6). В клетках имелась обводная часть или хроматоплазма (не сохранившаяся) и центральное тело, вокруг которого сосредотачивались зернистые отложения запасных материалов, хорошо сохранившихся в ископаемых образцах. Схема строения трихом, слоевища, нитей и разветвления нитей соответствует севременным сине-зеленым водорослям рода *Schizothrix*. Это доказывает, что уже в очень отдаленных геологических периодах сине-зеленые водоросли осуществили высокую степень морфологической дифференциации, которая сохранилась до нашего времени.

PLATES

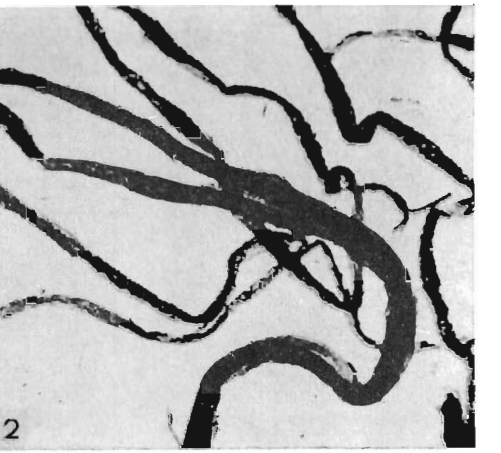
Pl. I

Fig. 1. Thin section of Tremadocian chalcedony with blue-green algae filaments. Dark spheres — opal concretions; × 35.

Fig. 2,3. Branched filaments, × 112; *3* branches typical for blue-green algae of the genus *Schizothrix*.

Fig. 4,5. Tips of branched filaments; × 320.


1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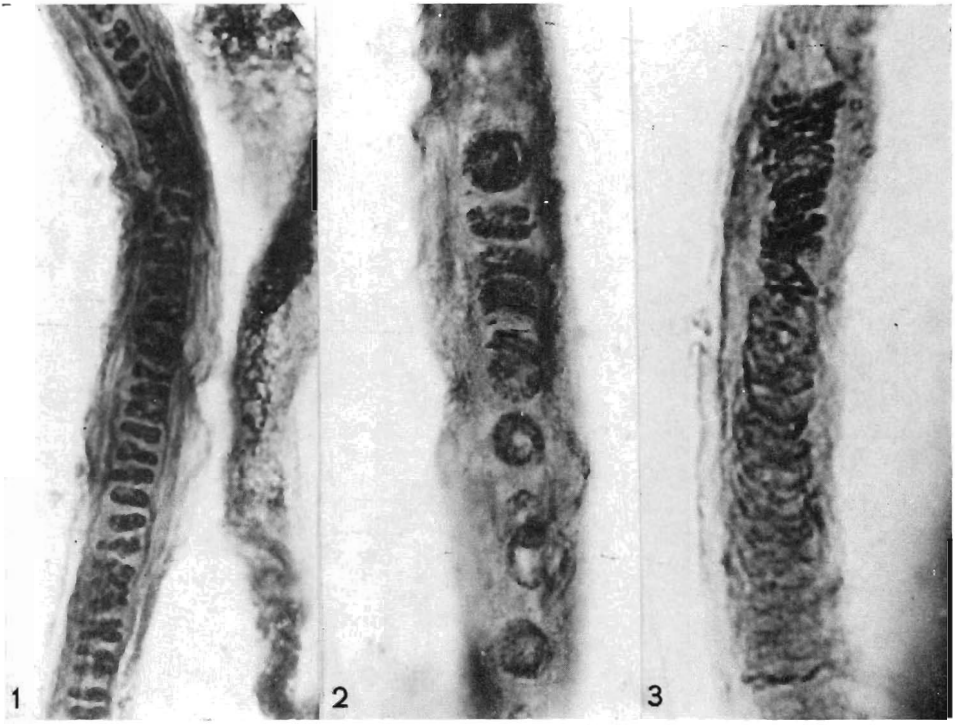
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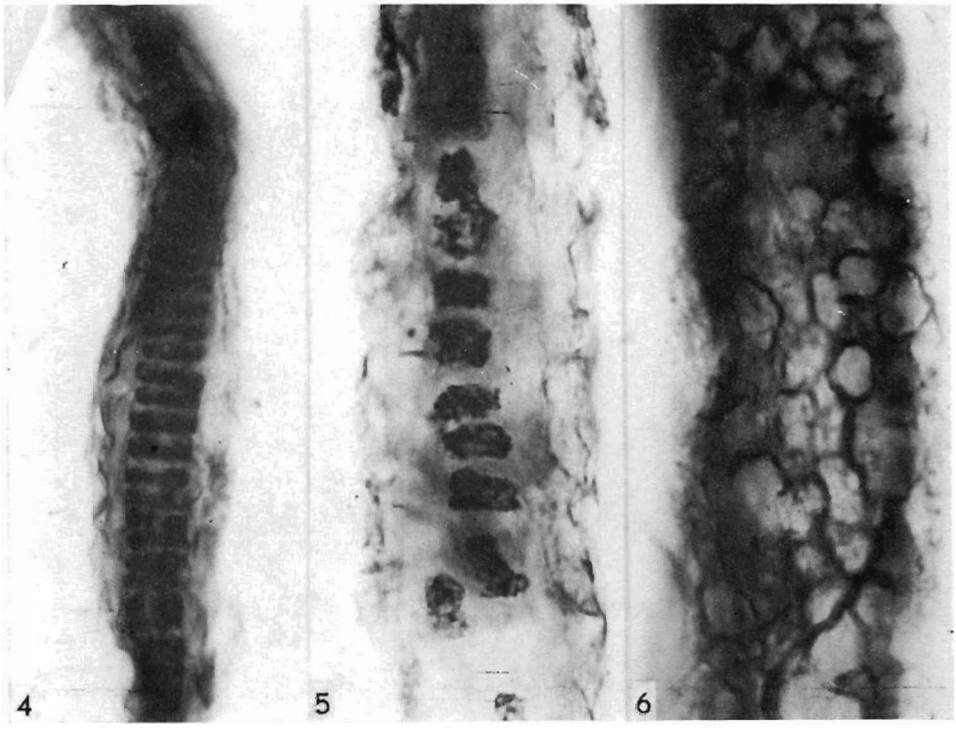
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Pl. II

Fig. 1,4,5. Most common fragments of filaments, with cells of various length and stratified sheaths, externally irregular or fimbriated.

Fig. 2,3. Trichomes with loosened and partly overturned cells; *2* cyanophycin granules concentrated on the circumference of the central body.

Fig. 6. Surface of the sheath of the filament shown on fig. 5.

All figures × 1200.