A C T A P A L A E O N T O L O G I C A P O L O N I C A

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ON TWO ORDOVICIAN CALCAREOUS ALGAE*

Abstract. — Organic thalli of Ordovician calcareous algae *Vermiporella fragilis* Stolley and *Palaeoporella variabilis* Stolley found for the first time are studied. The structure of *V. fragilis* is shown to be fundamentally different from that previously described by various authors. Its thallus consists of a central stem and lateral branches of three orders, arranged in regular whorls. Spores are preserved in stem segments, which are separated by septa. Morphologically they resemble the oospores of a Recent alga *Sphaeroplea* Fritsch. The structure of previously unknown filamentous central parts of thallus of *P. variabilis* is studied and their relation to subcortical and cortical threads penetrating the calcareous sheath are described. Revised diagnoses of *Vermiporella* Stolley and *Palaeoporella* Stolley and of their type species are given.

INTRODUCTION

Dissolving for many years Ordovician erratic boulders of the Baltic origin from the territory of Poland, the senior author (R. K.) came across a specimen (found in the locality Rewal, Baltic coast, Szczecin province), containing well preserved calcareous algae, whose tubes undervent a secondary silification (Pl. I, Figs. 1,2). After a close examination they turned out to be forms described in 1893 by Stolley, also coming from Ordovician erratic boulders of the Baltic coast and called by this author *Vermiporella fragilis* Stolley and *Palaeoporella variabilis* Stolley. These algae were subsequently described by several authors from Scandinavia and the U.S.S.R. Specimens of *Vermiporella* with silicified tubes which, like our ones, came from Ordovician erratic boulder of the Baltic Sea, were prepared with acid by Eisenack (1936) who, however, did not study them.

Dissolving the tubes of both algae referred to above in hydrofluoric acid, the senior author found, to his surprise, that they contained inside exceptionally well preserved organic parts of thallus (Pl. III, Fig. 3; Pl. X, Fig. 2). Since these parts have never before been separated from fossil calcareous algae, it was resolved, together with the junior author (J. K.), to make them the subject of detailed studies. The present paper is the result of these studies.

* Preliminary note — see *C. R. Acad. Sci. Paris*, **266**, 1968.

Considerable part of the research was done by the junior author who also took all photographs enclosed with the work, but both authors are responsible for its contents.

The boulder, from which the algae here described have been separated by means of hydrochloric acid, weighed about 580 g. It was a compact pelitic limestone of the type called by German authors „Ostseekalk". No graptolite indicating its accurate age were found in this boulder. In addition to algae, it contained the following fossils:

Chitinozoa:
Cyathochitina campanulaeformis Eisenack
Parachitina curvata Eisenack

Foraminifera:
Psammosphaera sp.

Annelida:
Mochtyella polonica Kielan-Jaworowska
Xanioprion borealis Kielan-Jaworowska

Brachiopoda:
Aulidospina cf. *trippi* Williams
Taphrorthis aff. *aspera* Williams
Hesperorthis sp.
Strophomena sp.

Ostracoda:
Pseudotallinella regalis (Neckaja).

None of the forms named above may be considered as an index fossil. They could indicate Caradocian, as well as Ashgillian stages. However, on the basis of the facts that other erratic boulders, lithologically identical with our boulder, frequently contain *Orthograptus gracilis* (Roemer), a graptolite found *in situ* on Oeland Island in Ashgillian stage, *Dicellograptus complanatus* Lapworth zone (oral communication of Dr. V. Jaanusson from Stockholm) and, in particular, that *Palaeoporella variabilis* Stolley has recently been described by Jux (1966) as abundantly occurring in Boda-Limestone (Dalarna Region, Central Sweden) which is of the Ashgillian age, our boulder may, in all likelihood, be of the same age.

An excellent preservation state of the organic parts of thallus of algae, described in the present paper, might cause the supposition that we had to do with quite an exceptional case. Considering, however, that all previous investigators of fossil calcareous algae employed in their studies only a traditional method of thin sections, in which organic parts of thallus are not easy to distinguish, we may believe that our specimens are not an exception and that, with the application of chemical methods, organic parts of thallus may be more than once found preserved in the tubes of calcareous algae. Thus, for instance, black coloured parts filling canals in the calcareous sheaths, shown in beautiful photographs of thin sections of *Palaeoporella variabilis*, recently published by

Jux (1966, Pls. 38, 39), seem to be nothing else but organic remains of thallus. Likewise, the possibility cannot be precluded that spores preserved in Permian algae, *Atractyliopsis carnica* Flügel (Flügel, 1966, Pl. 4), but presented only in thin sections, might be also chemically separated and studied in detail like spores contained in thalli of *Vermiporella fragilis* that we studied.

With a large scale application of chemical methods in separating fossil algae, one could undoubtedly obtained much more interesting results than those reached only by means of thin sections.

The described material is deposited at the Palaeozoological Institute of the Polish Academy of Sciences.

ACKNOWLEDGEMENTS

The present writers would like to express their thanks to the following persons who identified some fossils accompanying the algae described in their work: Prof. Z. Kielan-Jaworowska — jaw apparatuses of Polychaeta, Doc. Dr. G. Biernat — Brachiopoda, and Dr. V. Jaanusson from Stockholm — Ostracoda. They also feel indebted to Mrs. K. Budzyńska for drawing in ink the pencil sketches prepared by the junior author.

DESCRIPTIONS

Genus *Vermiporella* Stolley, 1893

The genus *Vermiporella* was erected by Stolley (1893) on the basis of a material contained in Ordovician erratic boulders of the Baltic origin, collected in the environs of Kiel, Germany. Of many specimens of the genus *Vermiporella* which, according to Stolley, probably belonged to a few species, only one was given the specific name *V. fragilis* Stolley and this was a type species.

In a very superficial description of this alga, it has been mentioned by Stolley that these are tortuous calcareous tubes, 0.5—1.0 mm in diameter, with walls variable in thickness and a very wide central canal. Walls of tubes are pierced by perpendicular canals which, according to Stolley, would correspond to lateral branches directly departing from the central stem of thallus.

Stolley's studies were based only on sections of branches embedded in the rock, surrounding them. They were illustrated by several schematic drawings.

Stolley's data served as a basis for Pia (1920) who presented a schematic reconstruction of a branch of *Vermiporella* (Text-fig. 1), in which the central stem of thallus occupies the entire width of the canal of tube, lateral branches irregularly disposed detach themselves directly from the central stem, are not branched and are completely contained in canals which pierce the walls of tube. This reconstruction was subsequently published in various palaeoalgological works and textbooks. On the basis of this interpretation, Johnson (1961*a*, p. 54) defines the genus *Vermiporella* as an alga consisting of "branches (no secondary branches exist) simple, anastomosing, of uniform width or slightly expanding toward the outside, perpendicular to central stalk". A similar diagnosis of the genus *Vermiporella* was given by Høeg (1961, pp. 108-109), who emphasized that lateral branches "are not arranged in verticils or any kind of regular order".

However, it has been previously correctly observed by Kamptner (1958, p. 103) that, when the central stem of the calcareous tube was very thin, only peripheral parts of lateral branches penetrated through the calcareous sheath and those, situated nearer the stem and not surrounded by the calcareous mass, left no traces at all. Such was the case of the specimens, described below, revealed after their examination. These specimens preserved cell-walls of the entire thallus from the stem up to the last row of lateral branches which penetrated the calcareous sheath.

As a result of our studies, the necessity arose of a radical change in the previous diagnosis of the genus *Vermiporella* Stolley, 1893.

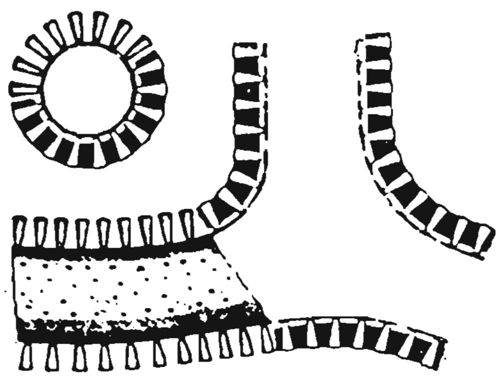

Fig. 1. — Reconstruction of *Vermiporella* Stolley made by Pia (1920), based on the sections of calcified parts of the thallus.

Revised diagnosis. — Calcified part of thallus consists of cylindrical, tortuous, calcareous tubes, dichotomously branching and anastomosing into an irregular network. Surface of tubes covered with densely distributed, rounded pores. Inside of tubes, the central stem of thallus occupies more or less $^1/_3$ of the diameter of canal. Over its entire length, this stem displays regular contractions. Four lateral branches of the I order are attached to the extended parts of the stem in the form of regular whorls. Three branches of the II order are attached on each branch of the I order, and 3 branches of the III order are in turn attached on the branches of the II order. The calcareous sheath of thallus is pierced only by the branches of the III order. Sporadic septae and spores of the type of oospores occur in the central stem of thallus.

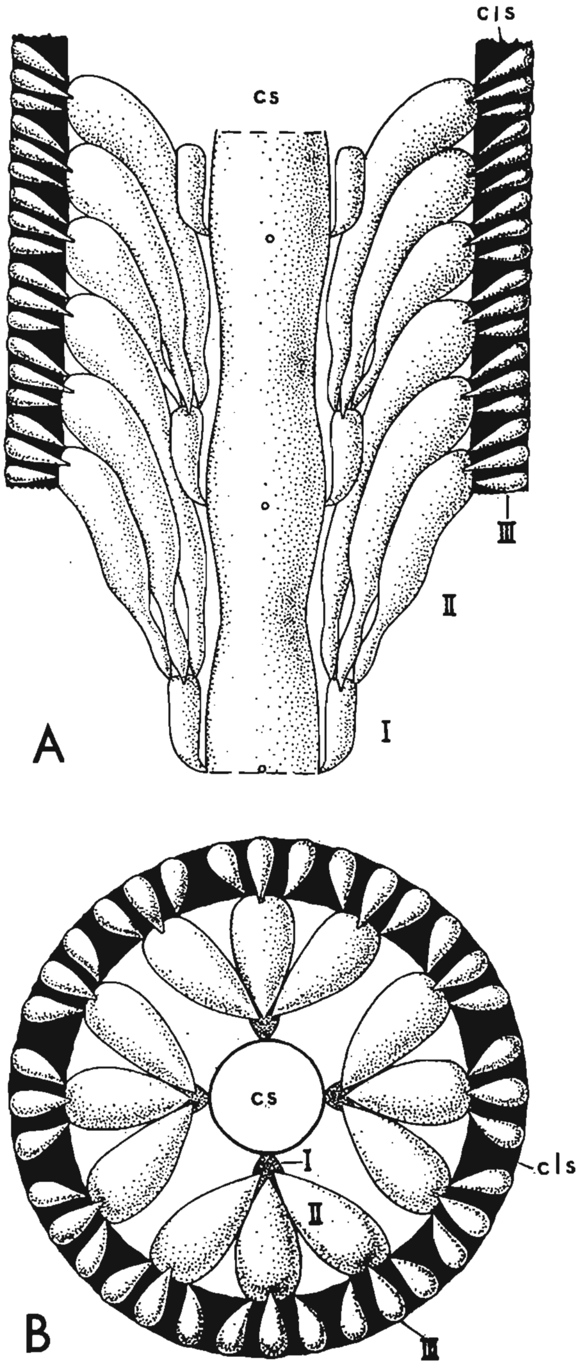

Fig. 2. — *Vermiporella fragilis* Stolley. Spatial reconstruction of a fragment of the thallus: *A* side view, *B* top view; *cs* central stem, *I*, *II*, *III* lateral branches, *cls* calcareous sheath; × 100.

Vermiporella fragilis Stolley, 1893
(Pls. I-IX; Text-fig. 2)

1893. *Vermiporella fragilis* Stolley; E. Stolley, Ueber silurische Siphoneen, p. 142, Pl. 8, Fig. 7.

Neotypus: Thalli separated from the erratic boulder No. O.430.

Locus typicus: Rewal, Szczecin province, Poland, Baltic beach.

Stratum typicum: Ashgillian (Upper Ordovician) of the areas of the present Baltic Sea.

Taking into account the present methods of determining fossil calcareous algae, based on the analysis of the calcareous part of thallus, characters that may be easily traced on calcareous sheaths of thallus are emphasized in the diagnosis given below.

Revised diagnosis. — Traces of lateral branches of the III order preserved in the calcareous sheath, in the form of V-shaped canals, open on the surface as pores 0.042—0.056 mm in diameter, isolated from each other. Spaces between apertures: 0.12—0.15 mm. The thickness of calcareous wall is equal to the length of branches of the III order and amounts to 0.06—0.10 mm. Axial canal wide. Dimensions ratio d/D: 0.6—0.66.

Dimensions — see Table 1.

Table 1

Measurements of *Vermiporella fragilis* Stolley (in mm)

D	d	$\frac{d}{D}$	s	p		
				I	II	III
0.43—1.10	0.35—1.00	0.6—0.66	0.06—0.10	0.1—0.14	0.28—0.42	0.06—0.10
h	c	st	i	w		
				I	II	III
0.28—0.42	1.20—1.90	0.014—0.25	0.12—0.15	4	12	36

Most of symbols used in the table of measurements have been selected from those proposed by Johnson and Konishi (1959). The symbols are listed below:

D — Outer diameter of calcareous body
d — Inner diameter of calcareous body
d/D — Dimensions ratio
s — Thickness of calcareous wall
p — Diameter of branches I, II and III orders
h — Distance between centres of verticils
c — Distance between centres of central stem branches
st — Diameter of central stem
i — Distance between centre of branches on surface
w — Number of branches in a whorl, separately for I, II and III orders

Morphology of thallus. — External shape on the whole bushlike, formed as a result of repeated, dichotomous bifurcation of the central stem of thallus in many planes. Branchings are more or less regularly spaced, forming a sort of a tangled network or lattice (Pl. II). The present authors did not succeed in separating a complete thallus, the largest fragments preserved reaching 4 cm in size.

Central stem of thallus occupies about $^1/_3$ of the diameter of the axial canal of calcareous tube (Text-fig. 2). In older parts of the plant, it is conspicuously thicker and gradually becomes thinner and thinner towards the growth apex. In transverse section, stem is round and sometimes elliptically flattened in outline. Over its entire length, stem displays regularly repeated contractions and extensions in the form of nodes and internodes (Pl. IV, Figs. 4,5; Pl. V, Figs. 1,2). In younger parts of thallus, stem is divided by thick septa into segments varying in length. The septa are several times as thick as the walls of stem (Pl. VI, Figs. 6,7). Septa are built in principle of a uniform layer, some of them are, however, compound, particular layers being separated from each other by narrow spaces and situated obliquely to the stem axis (Pl. VI, Fig. 8). In its older parts, cell-wall of the central stem is strongly thickened and frequently wrinkled, the wrinkles running parallel to the growth axis; in younger parts it is thin, semi-transparent and smooth.

Lateral branches of the I order, situated at the base of each whorl, detach themselves from the central stem of thallus in the place of its maximum distension (Pl. V, Figs. 1, 2, 5). They always occur to the number of four and are uniformly distributed every 90° around the stem parallel to the growth axis of thallus (Text-fig. 2). Their length does not exceed $^1/_3$ of the distance between successive whorls. Lateral branches of the I order are on the whole macelike, uniformly contracting downwards, the surface of attachment to the stem is very small, almost punctual. Cell-wall of these branches, like that of the central stem, is frequently strongly thickened. Apical part of lateral branches of the I order makes up the base for branches of the II order detaching themselves from them.

Lateral branches of the II order are gathered in triads (Pl. VII, Figs. 4, 6), at first disposed almost parallel to the central stem and subsequently deviating from it towards the calcareous wall of thallus (Text-fig. 2). These branches mostly fill a space between stem and wall. Their length is not uniform and frequently a certain gradation may be observed in a single triad, or one of the branches happens to be slightly longer than the remaining two. Lateral branches of II order are on the whole 2.5 times and, in extreme cases, even 5 times as long as those of the I order. They are shaped like an elongate pear strongly narrowed at the base, with a characteristic neck-like contraction marked at $^1/_3$ of their length (Pl. VI, Figs. 1-3). The latter character allows one to identify the branches of the II order even when they are torn away from thallus. Each of the branches of the triad is separately attached to the apex of a branch of the I order. Apexes of the branches of the II order are somewhat flattened and directly contact the calcareous sheath of thallus. Cell-walls of those branches are usually very thin, transparent and, only in apical part, thickened and dark. Surface of cell-wall may be smooth or irregularly wrinkled.

Lateral branches of the III order, connected with thallus, have been preserved in a dozen or so specimens and, moreover, complete branches — in a few ones only. Like those of II order, they occur in triads but perpendicularly or slightly obliquely inclined to the axis of thallus (Pl. VI, Fig. 5; Pl. VII, Figs. 1—3; Text-fig. 2). Generally, they are conical, V-shaped and with a flattened apex, their length being more or less equal to the thickness of the calcareous sheath of thallus. Each branch of a triad is mounted separately on the apex of a branch of the II order. The tips of the branches of the III order do not contact each other and their openings on the surface of the calcareous sheath are visible in the form of small holes, separated from each other (Pl. III, Figs. 1, 2). The cell-wall of these branches is thin and usually torn in the apical part.

Characters and manner of developing of the calcareous sheath of thallus. — As mentioned above, thallus was to a considerable extent incrusted with calcium carbonate which — in the course of fossilization — was completely or partly replaced by silica (chalcedonite). Calcium carbonate was deposited only around the lateral branches of the III order. In Recent calcareous algae, the precipitation of $CaCO_3$ takes place by a special mucous substance (mucilage), secreted by the cell-wall of calcified parts of thallus. In *Vermiporella fragilis,* a similar function was most likely fulfilled by a gelatino-filamentous mat lining insides of the calcareous sheaths of thallus, particularly dense at the base of lateral branches of the III order. This substance was probably mostly secreted by the cell-wall of the branchings of the III order and maybe also by the apexes of the branches of the II order. Presumably, with the progressing calcification of thallus, it was gradually shifted outside. Judging from their apertures, now open to the surface of thallus, the ends of the branches of the III order were not covered with calcium carbonate. Taking into account an uncertain taxonomic position of the form here described, it is difficult to decide whether or not such a way of calcification of thallus may be considered as initial one for Dasycladaceae.

Remarks on the structure and composition of cell-wall. — The thalli of *Vermiporella fragilis* have been put to a control analysis to discover the presence of cellulosa, pectin and callose, three fundamental substances which make up cell-walls of Recent Green Algae. A negative result was obtained concerning cellulose, whereas traces of callose were discovered in the cell-wall of stem and lateral branches and of pectin in the filamentous, "feltlike" lining of the calcareous sheath of thallus. A very small amount (by weight) of the material available was an obstacle in making a complete biochemical analysis of cell-wall. Despite a very good state of preservation, most cell-walls were probably, to a greater or lesser degree, carbonized (primarily cellulose). The application of strong, hydrochloric and hydrofluoric acids, necessary for preparation of the specimens, must considerably contribute to the destruction of several components of cell-walls. In a large magnification, cell-walls display a certain type of microstructure, which is particularly distinct in the cell-wall of central stem. This microstructure is expressed in the presence of irregular, brighter or darker, densely distributed strands, parallel to the growth axis of thallus (Pl. VIII, Fig. 4). The lack of information on the microstructure of cell-walls of Recent Green Algae makes impossible any conclusions concerning its importance.

Spores. — Thalli of *Vermiporella fragilis* have not any individualized reproductive organs typical of Recent Dasycladaceae (gametangia). Likewise, they do not display the presence of other definite reproductive organs, known in Recent Green Algae such as sporangia, oogonia and antheridia. In the specimens examined, spores have been observed only within the range of central stem in parts, contained between septa. On the whole, they are distributed (Pl. VIII, Figs. 4-6) by ones or sometimes in larger groups. One may presume that during reproduction they were developed in larger amounts and almost completely filled parts of thallus separated from each other by septa. The occurrence of spores in the central stem of thallus in *Vermiporella* confirms the supposition of Pia (1920) who, not finding any traces of reproductive organs in the calcareous sheath of thallus, considered Palaeozoic Dasycladaceae to be an endosporate type.

Spores which occur in the thallus of *Vermiporella* are subroundly or ovally outlined bodies, usually slightly flattened on one side (Pl. IX, Figs. 1, 2). Their dimensions fluctuate within limits of 25 and 40 microns, mostly measuring on the average 35 microns. All of them are characteristically dark-red in colour, which is particularly well visible in a transmitted light and after a slight decolourization by means of potassium chlorate. The structure of well preserved spores is clearly bilayered (Pl. IX, Figs. 1—4, 6) i. e. an outer, thick cover, built of an irregularly cellular substance (synapsis) surrounds an individualized central part (nucleus). The whole is in turn tightly enveloped by a transparent hyaline, usually slightly folded membrane which, however, occurs only on some spores. The surface of spores is ornamented with many, irregular nodes and sometimes displays fissures (Pl. IX, Fig. 5).

An ascertainment, whether the described spores were developed as a result of the sexual or asexual reproduction, is a fundamental problem which should be resolved in the interpretation of the spores of *Vermiporella*. The structure of these spores is very similar to that of spores developed as a result of oogamy (oospores) observed in some representatives of Oedogoniales, primarily of Ulotrichales. Spores of *V. fragilis* display a striking similarity to oospores of *Sphaeroplea* Fritsch (Ulotrichales), considered to be one of the most primitively built oogamious Green Algae (Fritsch, 1961). Segments of thallus of *Sphaeroplea,* containing oogonia and antheridia, do not differ at all from vegetative segments, this being a character in which *Sphaeroplea* completely resembles isogamious Green Algae. Oospores, distributed in a chainlike manner, are developed after the fertilization of many ova with spermatozoids. A fertilized ovum is surrounded with a thin membrane, inside of which, as is observed in *V. fragilis,* a bilayered spore is contained. When oospores become mature, the membrane which envelops them dissolves, the undissolved fragments of it being often observed in oogonia close to oospores. The lack of the membranes on some spores of V. *fragilis* could be explained analogously. Like in *Sphaeroplea,* spores in *V. fragilis* were developed in vegetative threads of thallus, separated from each other by septa. Mature spores of *V. fragilis,* like those of *Sphaeroplea,* are mononuclear and have an ornamented surface. A peculiar red colouring (hematochrom) is also their common character.

Despite such considerable similarity to oospores, the possibility cannot be excluded that spores are developed in *V. fragilis* as a result of isogamy (zygospores) and even parthenogenesis, particularly so if we take into account the fact that thallus is closely covered with calcium carbonate which hinders the migration of spermatozoids to oogonia. Likewise, it is difficult to determine a manner in which the mature spores were liberated from thallus. Open also remains the problem whether or not, in addition to the sexual, *Vermiporella* had also a possibility of an asexual and vegetative manners of reproduction.

To sum up, the phases of developing spores in *Vermiporella fragilis* might be reconstructed as follows: after developing septa in the central stem, either oogenesis (oogamy) or gametogenesis (isogamy) took place in this part of thallus and afterwards, following the copulation, there were formed oospores (or zygotes) which might be liberated shortly after reaching maturity or they remained in thalli for a longer time as resting forms (zygospores).

Taxonomic position and phylogenetic importance. — According to a unanimous opinion of all previous authors, *Vermiporella* was considered one of the most primitive representatives of Dasycladaceae which was placed at the beginning of the evolution line of this group of calcareous algae. Pia's (1920) reconstruction of *Vermiporella* (here reproduced in Text-fig. 1), based only on the traces of branches of the III order, preserved as canals in the calcareous sheath, became — among other factors — a basis for considerations of the phylogeny and evolution of Dasycladaceae. The primitive type of structure of *Vermiporella*, expressed in the presence of lateral branches of the I order and their irregular distribution on the central stem of thallus, was more than once emphasized in these considerations (Pia, 1920, 1927; Kamptner, 1958; Rezak, 1959; Johnson, 1961 *a,b*). In the light of these studies, an increase in the number of orders of lateral branches and their arrangement in regular whorls, was a principal trend in the evolution of Dasycladaceae. According to Emberger (1944), forms with such a type of structure appeared as late as the beginning of Mesozoic. However, there are forms, known even from Lower Palaeozoic (*Primicorallina* Whitefield, *Verticillopora* Rezak, *Phragmoporella* (Rezak)), in which these characters are distinct (Ruedemann, 1909; Rezak, 1959).

The structure of thallus in *Vermiporella*, described in our paper, indicates a high degree of its morphological organization which — in its fundamental features — does not differ from that in the Recent genus *Dasycladus* Agardh. Some morphological characters of *Vermiporella* cause, however, the arisal of serious doubts concerning whether or not it should be continuously assigned to the family Dasycladaceae.

The lack of septa in the central stem of thallus and, consequently, Dasycladaceae being typically coenocytic, is one of the most important diagnostic characters of this family. Thick, closed septa segmenting the thallus of *Vermiporella*, glaringly contradict the above statement and seem to disqualify *Vermiporella* as representative of Dasycladaceae. Moreover, *Vermiporella* has not separate gametangia, typical of Recent Dasycladaceae and also known in Mesozoic and Cenozoic forms. Even if we assumed that septa were related to the reproduction process, the hypothesis that they were only a prototype of the septa which, in Recent Dasycladaceae, separate gametangia from thallus and, consequently, considering parts of thallus separated from each other by septa to be gametangia, seem to be highly improbable. The structure of spores of *Vermiporella* displaying a considerable similarity to oospores of some primitive Green Algae of the order Ulotrichales (cf. the previous chapter), testifies against such an interpretation. This similarity seems to indicate a probably oogamious manner of reproduction never recorded in Dasycladaceae. Thus understood segments of thallus, contained between septa, should rather be interpreted as oogonia and antheridia. A dichotomous branching of the central stem in many planes, so characteristic of *Vermiporella*, also is not typical of Dasycladaceae.

Thus, on the one hand, *Vermiporella* has characters typical of Dasycladaceae, which are expressed in three orders of lateral branches verticilately arranged around the central stem, as well as a calcareous incrustation of thallus characteristic of this family, but, on the other, the presence of septa and spores, with characters of oospores, situated inside the stem, make it similar to Recent Green Algae of the order Ulotrichales. *Vermiporella* is, therefore, an example of a form having characters of a few Recent groups of algae and, in the present stage of knowledge of fossil algae, it is impossible to establish its accurate taxonomic position. A possibility of an extensive discussion, devoted to the taxonomic position of *Vermiporella*, will arise only when a more abundant new material will be available, concerning forms similar to *Vermiporella* with preservation state resembling that here described, in particular forms coming from Lower Palaeozoic sediments. The observations on *Vermiporella*, presented in our paper, seem to make up a sufficient basis for excluding it from a key position it took at the beginning of the phylogenetic line of Dasycladaceae. The instance of an erroneous reconstruction of *Vermiporella*, made only on the basis of the sections of the calcified part of thallus, causes the suspicion as to the adequacy of several other reconstructions of fossil calcareous algae, made according to this same method.

Family **Codiaceae** (Trevisan) Zanardini, 1843
Genus *Palaeoporella* Stolley, 1893

The genus *Palaeoporella* has, like that described above, been erected by Stolley on the basis of the specimens found in Ordovician erratic boulders from the environs of Kiel, North Germany. *P. variabilis* Stolley whose fragments, examined in the form of thin sections and presented by Stolley (1893, Pl. 7, Figs. 1—5) as schematic drawings, was considered by this author to be a type species (monotype). In addition, Stolley superficially described this alga and assigned it to the Dasycladaceae. This view was subsequently rectified by Pia (1926, 1927) who assigned *Palaeoporella* to the Codiaceae. Further information on the structure of *Palaeoporella*, based only on the sections of the calcified part of thallus, is supplied by, among other authors, Johnson (1961 *a*, *b*), Johnson & Konishi (1959) and Høeg (1961). Recently, more detailed studies on *Palaeoporella* based on an abundant material, collected from Boda-Limestone (Ashgillian) at Dalarna, Central Sweden, where this alga occurs as a rock--building fossil, have been made by Jux (1966). On the basis of a considerable number of thin sections, the last-named author presents a fairly accurate picture of the morphology of outer threads of thallus in *Palaeoporella* ("Zellschlauch"), whose traces are preserved in calcified parts of thallus. Organic parts of *Palaeoporella*, separated by the authors of the present paper from the silicified thalli, allow them to elucidate the structure of central threads of thallus unknown so far and their relation to the threads which penetrate the calcareous sheath.

Revised diagnosis. Thallus strongly calcified, non-articulated, in the form of an elongated mace, bifurcated in the upper part and broadened at the base. Inside, there is a bundle of closely arranged, parallel, non--septate threads. A main thread, frequently with contractions and swellings, from which deviate thinner threads of the I order, whose apexes make up a base of great number of very thin threads of the II order, occurs in the central bundle. The main thread and the thread of the I order display a sporadic dichotomy, whereas the threads of the II order bifurcate dichotomously very densely, forming a tightly packed network. The threads of the II order send out subcortical branches, dichotomously ramified by ones. Pairs of cortical utricles with flat terminations, closely adhering to each other, are situated on forked terminations of subcortical branches. The subcortical and cortical zones are calcified.

Palaeoporella variabilis Stolley, 1893

(Pls. I, X, XI; Text-fig. 3)

1893. *Palaeoporella variabilis* Stolley; E. Stolley, Ueber silurische Siphoneen, pp. 137—138, Pl. 7, Figs. 1—5.

1966. *Palaeoporella variabilis* Stolley; U. Jux, Palaeoporella in Boda-Kalk..., pp. 156—158, Pl. 38, Figs. 1—5; Pl. 39, Figs. 1—7 (*with earlier synonymy*).

Diagnosis. — Calcified part of thallus in the form of a forked tube with a narrow axial canal. Central bundle consisting of the main thread 0.2 mm in maximum diameter, longitudinal threads of the I order 0.035—0.045 mm in diameter, and longitudinal threads of the II order 0.012—0.015 mm in diameter. Subcortical branches 0.52—0.60 mm and cortical utricles 0.085 mm long. The diameter of flat terminations of cortical utricles amounts to about 0.04 mm.

Material. — A dozen or so incomplete thalli, chemically separated from a calcareous erratic boulder No. O.430 from the environs of Rewal, Szczecin province.

Description. — *External morphology of thallus.* Calcified part of thallus in the form of a mace forked at the end and bulbously broadened at the base (Pl. X, Figs. 1, 5). The longest preserved fragment of thallus reach 3 cm in length. Diameter of the cross section through thallus variable: from about 2.5 mm at the base, gradually decreasing upwards and amounting to about 1 mm at the top. An outlet of axial canal, through which the rhizoids of thallus were probably let out, is situated in the base of calcareous sheath of thallus (Pl. X, Fig. 3).

Internal morphology of thallus. Central threads of thallus in the form of a tightly interlaced bundle are arranged, on the whole, parallel to the growth axis. The following three types of threads make up the entire bundle:

The *main thread,* the thickest of all of them, rarely dichotomously ramified, with a strongly thickened cell-wall, here and there displays the presence of deep contractions and bulbous swellings (Pl. XI, Figs. 2, 3).

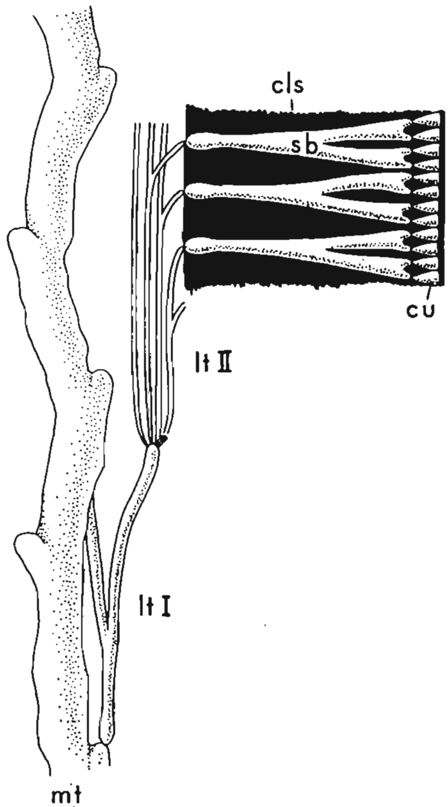

Fig. 3. — *Palaeoporella variabilis* Stolley. Diagrammatic spatial reconstruction of the thallus, in side view; *mt* main thread, *lt I, II* longitudinal threads of I and II order, *sb* subcortical branches, *cu* cortical utricles, *cls* calcareous sheath; × 50.

Other parts of the main thread have fairly uniformly distributed swellings of cell-wall, occurring in the form of little knots which make up a base for the longitudinal threads of the I order (Pl. XI, Figs. 1, 4, 5; Text-fig. 3).

Longitudinal threads of the I order (Pl. XI, Figs. 1,4; Text-fig. 3) are attached by ones, with a very small attachment area, to the knots of the main thread from which they are considerably thinner. They are marked by a straight trace and may be once or several times dichotomously ramified. Cell-walls of these threads, like those of the main threads, are thickened. The terminations of the threads of the I order make up bases for the longitudinal threads of the II order.

Longitudinal threads of the II order (Pl. XI, Figs. 1,4; Text-fig. 3) make up the main bulk of the central bundle of thallus, which fills the canal of calcareous sheath. They are attached to the apexes of the threads of the I order by separate, small bunches, each of them containing at least a dozen or so threads, which subsequently ramify dichotomously many times. The threads of the II order are the thinnest in the central bundle and their cell-walls are also very thin.

Subcortical branches (Pl. XI, Figs. 6—9; Text-fig. 3) detach themselves from longitudinal threads of the II order, a strong contraction of cell-walls occurring in the points, where they are connected with these threads. Subcortical branches are more or less uniform in length, narrowly ramified dichotomously at 2/3 of their length, and their terminations are shallowly forked. These branches are arranged close to each other, often interlaced and together form a conspicuous subcortical zone, easily distinguishable from the rest of thallus.

Cortical utricles (Text-fig. 3) shaped like truncate cones, detach themselves by pairs from forked ends of subcortical branches. Their ends closely adhere to each other, as a result of which a cortical layer (cortex) is formed, which resembles in outline a honeycomb (Pl. X, Fig. 4). Cortical layer is covered with a thin calcareous lamina.

Like in *Vermiporella fragilis* described above, the walls of the axial canal of the calcified part of thallus in *Palaeoporella variabilis* are lined with a gelatino-filamentous substance (Pl. X, Fig. 6), which is particularly dense at the base of subcortical branches. Furthermore, it is also in the case of *Palaeoporella variabilis* that this substance was a precipitator of calcium carbonate which formed a fabric of the calcareous sheath of thallus. A further precipitation of calcium carbonate probably took place on a mucous secretion of the cell-wall of subcortical branches and cortical utricles, as is the case in Recent *Halimeda* Lamx.

Traces of callose in cell-walls of thallus and of pectin in the lining have been discovered by a colour analysis, made on the cell-walls and mucous lining of *Palaeoporella variabilis*.

Discussion. — The assignment of *Palaeoporella variabilis* Stolley to the Codiaceae seems to be quite justified. It is emphasized by the presence of a markedly separated bundle of central threads and zone of subcortical branches and cortical utricles, as is recorded in Recent genera *Halimeda* Lamx. and *Udotea* Lamx. In its general morphology of thallus and calcareous incrustation, *P. variabilis* is most similar to *Halimeda,* as it has already been stressed by Pia (1926, 1927) and Jux (1966). Like in *P. variabilis,* in *Halimeda* and other Codiaceae, cortical utricles form, on the surface of thallus, a layer consisting of polygonal fields (facets). Strong contractions and swellings characteristic of the main threads of the central bundle in *P. variabilis* are also known in many Recent Codiaceae (cf.

Halimeda Lamx., *Udotea* Lamx., *Avrainvillea* Boerg). They might be an initial stage which, in extreme cases, led to the development of annular thickenings in the threads of thallus in some Recent forms (cf. *Codium* Stackh.). A distinct morphological differentiation of particular threads in the central bundle which, in *Halimeda,* are to a considerable extent isomorphous, makes up a primitive character of *P. variabilis,* as compared with the representatives of *Halimeda.* Likewise, in *P. variabilis* no tendency is observed to the integration of the threads of thallus into a pseudoparenchyma and to the articulation which occurs in thalli of *Halimeda.*

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ROMAN KOZŁOWSKI & JÓZEF KAŹMIERCZAK

O DWÓCH ORDOWICKICH ALGACH WAPIENNYCH

Streszczenie

W wyniku chemicznego rozpuszczenia wapiennego głazu narzutowego, znalezionego na wybrzeżu Bałtyku (Rewal, woj. szczecińskie), pierwszy z autorów uzyskał ciekawą kolekcję alg wapiennych z zachowanymi częściami organicznymi plechy. Wapienne rurki tych alg uległy wtórnemu skrzemionkowaniu. Po rozpuszczeniu tych rurek w kwasie fluorowodorowym okazało się, że wewnątrz nich zawarte były świetnie zachowane części organiczne plechy. Plechy organiczne kopalnych alg wapiennych nie były dotychczas opisywane.

W zbadanym materiale znajdują się przedstawiciele dwóch rodzajów: *Vermiporella* Stolley i *Palaeoporella* Stolley, opisane po raz pierwszy z ordowickich głazów narzutowych Niemiec północnych (Stolley, 1893). Dotychczasowe opisy tych form oparte były wyłącznie na morfologii wapiennej osłony plechy, na podstawie której wykonane zostały rekonstrukcje organicznej plechy (Pia, 1920, 1927; Jux, 1966). Unikalny stan zachowania opisanego materiału zmienia radykalnie przyjętą dotychczas interpretację budowy *Vermiporella* oraz wnosi szereg nowych szczegółów do poznania budowy *Palaeoporella* (Codiaceae).

Wiek opisanych alg określony został, na podstawie towarzyszących im skamieniałości, na górny ordowik, najprawdopodobniej aszgil.

Budowa plechy *Vermiporella* Stolley, oparta na gatunku typowym *V. fragilis* Stolley, 1893, którego zbadany okaz autorzy proponują jako neotyp, jest następująca:

Zwapniała część plechy złożona jest z powyginanych, cylindrycznych rurek wapiennych, o szerokim kanale osiowym, rozgałęziających się dychotomicznie i anastomozujących w nieregularną siatkę. Wewnątrz każdej z rurek wapiennych znajduje się pień centralny, zajmujący około $^1/_3$ kanału osiowego. W swym przebiegu pień centralny wykazuje regularnie powtarzające się przewężenia. Do rozszerzonych odcinków pnia przyczepione są regularne okółki, złożone każdy z 4 odgałęzień bocznych I rzędu. Od odgałęzień bocznych I rzędu odchodzą następnie po 3 odgałęzienia II rzędu, znacznie dłuższe od poprzednich, o charakterystycznym, gruszkowatym kształcie. Do wierzchołków odgałęzień II rzędu przyczepione są wreszcie po 3 krótkie, banieczkowate odgałęzienia boczne III rzędu, wnikające w wapienną osłonę plechy i wychodzące na jej powierzchnię w postaci odizolowanych od siebie otworków.

W centralnym pniu plechy występują sporadycznie przegrody poprzeczne oraz spory, których budowa wykazuje znaczne podobieństwo do oospor niektórych dzisiejszych zielenic z rzędu Ulotrichales, jak np. *Sphaeroplea* Fritsch.

U podstawy odgałęzień bocznych III rzędu występuje warstwa fibrylno-śluzowatej substancji, wyścielająca od wewnątrz osłonkę wapienną plechy. Substancja ta pełniła przypuszczalnie rolę precypitatora węglanu wapnia, otaczającego plechę.

W błonie komórkowej *Vermiporella fragilis* stwierdzono ślady kallozy, zaś śluzowata substancja wyścielająca kanał osiowy wykazała śladową obecność pektyny.

Przedstawiona wyżej budowa *V. fragilis* nasuwa autorom szereg zastrzeżeń odnośnie przyjmowanej dotychczas pozycji systematycznej tej algi w obrębie Dasycladaceae (Pia, 1920; Johnson, 1959, 1961, i inni). *V. fragilis* posiada, z jednej strony, typowe cechy Dasycladaceae, wyrażone trzema rzędami okółkowo rozmieszczonych odgałęzień bocznych, i charakterystyczną dla tej rodziny alg inkrustację wapienną plechy, z drugiej jednak, obecność przegród poprzecznych i spor o cechach oospor w centralnym pniu zbliża ją do niektórych dzisiejszych zielenic oogamicznych (por. Ulotrichales). W tej sytuacji *Vermiporella* nie może być nadal uważana za prymitywnego przodka Dasycladaceae, umieszczanego przez paleoalgologów na początku linii filogenetycznej tej grupy zielenic (Pia, 1920; Kamptner, 1958).

Obserwacje autorów nad drugą formą — *Palaeoporella* Stolley — są poniekąd uzupełnieniem badań Juxa (1966), przeprowadzonych na bogatym materiale zebranym z górnego ordowiku centralnej Szwecji. Badacz ten daje dość dokładny opis morfologii zewnętrznych nici plechy *Palaeoporella*, obserwowanych w różnych przekrojach w płytkach cienkich i zachowanych w postaci śladów w zwapniałej części plechy. Wypreparowane przez autorów ze skrzemionkowanych plech części organiczne *Palaeoporella* pozwalają wyjaśnić budowę nieznanych dotychczas nici centralnych plechy i ich stosunek do nici wnikających w osłonę wapienną.

Uzupełniona w ten sposób charakterystyka *Palaeoporella* Stolley, oparta na gatunku typowym (monotypie) *P. variabilis* Stolley, 1893, wygląda następująco:

Plecha silnie zwapniała, w kształcie maczugi zwężonej i rozwidlonej w górnej części, nieczłonowana. Centralna część plechy złożona jest z wiązki równolegle biegnących nici, bez przegród poprzecznych. Na wiązkę nici centralnych składają się grube nici główne, pojedyncze lub dychotomicznie rozgałęzione, często z wąskimi przewężeniami i banieczkowatymi rozdęciami, od których odchodzą cieńsze nici podłużne I rzędu, również sporadycznie dychotomicznie rozgałęzione. Główną masę centralnej wiązki stanowią nici podłużne II rzędu, najcieńsze i gęsto dychotomicznie rozgałęzione, przyczepione pęczkami do zakończeń nici I rzędu. Od nici podłużnych II rzędu odchodzą odgałęzienia subkortykalne dychotomicznie rozgałęzione, na których lekko rozwidlonych końcach umieszczone są parami odgałęzienia kortykalne. Płaskie zakończenia odgałęzień kortykalnych przylegają ściśle do siebie i tworzą warstwę kortykalną. Kalcyfikacją objęta jest strefa subkortykalna i kortykalna.

Wytrącanie węglanu wapnia na plechach *P. variabilis* odbywało się, podobnie jak u *V. fragilis*, na powierzchni fibrylno-śluzowatej substancji, która u *P. variabilis* rozmieszczona jest zwartą warstwą u podstawy odgałęzień subkortykalnych.

Ze współczesnych Codiaceae, *Palaeoporella variabilis* ogólną morfologią i wapienną inkrustacją plechy zbliżona jest najbardziej do *Halimeda* Lamx. Podkreślone to jest obecnością wydzielonej strefy nici centralnych i strefy odgałęzień subkortykalnych i kortykalnych, z których te ostatnie, podobnie jak u *Halimeda*, tworzą na powierzchni plechy warstwę kortykalną, złożoną z wielokątnych pólek. Zwężanie i rozszerzanie nici głównej plechy u *Palaeoporella variabilis* jest także cechą charakterystyczną dla wielu współczesnych Codiaceae. Prymitywną cechą *P. variabilis* w stosunku do *Halimeda* jest wyraźne zróżnicowanie morfologiczne nici centralnych, które u tej ostatniej są w wysokim stopniu izomorficzne, oraz brak członowania plechy.

Wypreparowanie przez autorów niniejszej pracy organicznych plech pozwala przypuszczać, że zastosowanie na dużą skalę metod chemicznych do badań nad kopalnymi algami wapiennymi może umożliwić uzyskiwanie ciekawszych rezultatów, niż przy wyłącznym stosowaniu metody szlifów cienkich. Przykład błędnej rekonstrukcji *Vermiporella*, wykonanej wyłącznie na podstawie przekrojów zwapniałej części plechy, stawia pod znakiem zapytania poprawność szeregu innych rekonstrukcji kopalnych alg wapiennych, wykonanych na tych samych zasadach.

РОМАН КОЗЛОВСКИ & ЮЗЕФ КАЗЬМЕРЧАК

О ДВУХ ИЗВЕСТКОВЫХ ВОДОРОСЛЯХ ИЗ ОРДОВИКА

Резюме

В результате химического растворения известкового эрратического валуна, найденного на побережьи Балтийского моря (Реваль, Щецинское воеводство), первый из авторов получил интересную коллекцию известковых водорослей с захороненными органическими частями слоевища. Известковые трубки этих водорослей подвергнуты были вторичному окремнению. После растворения этих трубок в плавиковой кислоте оказалось, что внутри их находились очень хорошей сохранности органические части слоевища. Органические слоевища ископаемых известковых водорослей до сих пор не были описаны.

В изученном материале находятся представители двух родов: *Vermiporella* Stolley и *Palaeoporella* Stolley, впервые описанные из эрратических валунов ордовика Северной Германии (Stolley, 1893). Существовавшие до сих пор описания этих форм основывались исключительно на морфологии известковой

оболочки слоевища, на основании которой изготовлено реконструкции органического слоевища (Pia, 1920, 1927; Jux, 1966). Чрезвычайно хорошая сохранность описанного материала радикально меняет принимаемую до сих пор интерпретацию строения *Vermiporella* и вносит ряд новых деталей к изучению строения *Palaeoporella* (Codiaceae).

На основании сопровождающих окаменелостей, возраст описанных водорослей определено как верхний ордовик, наиболее вероятно ашгильский ярус.

Основываясь на строении слоевища *Vermiporella* Stolley, у типичного вида *V. fragilis* Stolley, 1893, которого исследованный образец авторы предлагают принять как неотип, можно дать следующий диагноз рода:

Кальцифицированная часть слоевища состоит из изогнутых, цилиндрических, известковых трубок, с широким осевым каналом, дихотомирующих и анастомизирующих в нерегулярную сетку. Внутри каждой известковой трубки находится центральная трубка слоевища, которая занимает около $^1/_3$ осевого канала. Эта центральная трубка характеризуется регулярно повторяющимися сужениями и расширенными отрезками. На ней прикреплены регулярные мутовки, состоящие из 4 боковых ответвлений I порядка. От боковых ответвлений I порядка отходят по 3 грушевидные ответвления II порядка, значительно длиннее от предыдущих. К верхушкам ответвлений II порядка прикреплены наконец по 3 короткие, пузырчатые ответвления III порядка, проникающие в каналы известковой оболочки. Эти каналы открываются на поверхности трубки в виде отизолированных от себя отверстий.

В центральной трубке слоевища спорадически находятся поперечные септы и связанные с ними споры. Строение этих спор обнаруживает значительное сходство с ооспорами некоторых современных зеленых водорослей из отряда Ulotrichales, как например *Sphaeroplea* Fritsch.

У основания боковых ответвлений III порядка находится фибрильно-слизистый слой, выстилающий от внутренней стороны известковую оболочку слоевища. Субстанция эта вероятно исполняла роль преципитатора карбоната кальция, окружающего слоевище.

В клеточной оболочке *V. fragilis* констатировано следы каллуса, а слизистая субстанция, выстелающая осевой канал, обнаружила признаки присутствия пектин.

Выше представленное строение *V. fragilis* приводит авторам ряд сомнений относительно принимаемой до сих пор систематической позиции этого рода в пределах Dasycladaceae (Pia, 1920; Johnson, 1959, 1961, и ин.). *V. fragilis*, с одной стороны, имеет типичные черты Dasycladaceae, выраженные тремя рядами мутовчато распределенных боковых ответвлений, и характеристическую для этого семейства известковую инкрустацию слоевища, с другой однако стороны, присутствие поперечных септ и спор с признаками ооспор в центральной трубке приближает ее к некоторым современным оогамическим зеленым водорослям (см. Ulotrichales). В такой обстановке род *Vermiporella* нельзя в дальнейшем считать примитивным предком Dasycladaceae, помещаемого палеоалгологами вначале филогенетической линии этой группы зеленых водорослей (Pia, 1920; Kamptner, 1958).

Наблюдения авторов над второй известковой водорослей *Palaeoporella* Stolley являются отчасти дополнением исследований Юкса (Jux, 1966), проведенных на богатом материале, собранном из верхнего ордовика центральной Швеции. Этот автор приводит подробное описание морфологии внешних трубок слоевища *Palaeoporella*, наблюдаемых в разных сечениях в тонких пластинках и сохраненных в виде следов в кальцифицированной части слоевища. Выпрепарированные авторами органические части *Palaeoporella* из окременелых слоевищ разрешают выяснить строение неизвестных до сих пор центральных трубок слоевища и их соотношение к трубкам проникающим в известковую оболочку.

Дополненная характеристика рода *Palaeoporella* Stolley, основанная на типичном виде (монотип) *P. variabilis* Stolley, 1893, есть следующая:

Слоевище сильно кальцифицированное, нечленистое, в виде палицы суженной и раздвоенной в верхней части. Центральная часть слоевища состоит из пучка параллельных трубок, без поперечных септ. Пучок центральных трубок состоит из толстых главных трубок, единочных или же дихотомирующих, часто с узкими сужениями и пузырными вздутиями, от которых отходят более тонкие продольные трубки I порядка, тоже спорадически дихотомирующие. Главная масса центрального пучка состоит из продольных трубок II порядка, нитевидных, густо дихотомически разветвляющихся, прикрепленных пучками к окончанию трубок I порядка. От продольных трубок II порядка отходят дихотомирующие, субкорковые ответвления; на их легко раздвоенных концах размещены попарно корковые ответвления. Их плоские концы плотно прилегают к себе и образуют корковый слой.

Зоны субкорковая и корковая кальцифицированы.

Осаждение карбоната кальция на слоевищах *P. variabilis* проходило так же, как и у *V. fragilis* на поверхности фибрильно-слизистой субстанции, которая у *P. variabilis* расположена плотным слоем у основания субкорковых ответвлений.

Из современных Codiaceae, *Palaeoporella variabilis* общей морфологией и известковой инкрустацией слоевища наиболее сходна с *Halimeda* Lamx. Подчеркнуто это присутствием выделенной зоны центральных трубок и полосы субкорковых и корковых ответвлений, из которых эти последние, так как у *Halimeda*, образуют на поверхности слоевища корковый слой, сложенный из многоугольных площадок. Сужение и расширение трубок главного слоевища у *P. variabilis* тоже является характерной чертой для многих современных Codiaceae. Примитивной чертой *P. variabilis* по отношению к *Halimeda* является четкая морфологическая дифференциация центральных трубок, которые у этой последней в большой степени изоморфные, а также отсутствие членения слоевища.

Выделение авторами настоящей работы органических слоевищ позволяет предполагать, что применение химических методов в большом масштабе для изучения ископаемых известковых водорослей, может сделать возможным получить более интересные результаты, чем при исключительном применении метода микрошлифов.

Пример ошибочной реконструкции *Vermiporella,* изготовленной только на основании разрезов кальцифицированной части слоевища, приходит к сомнению правильность ряда иных реконструкций ископаемых известковых водорослей, изготовленных таким же методом.

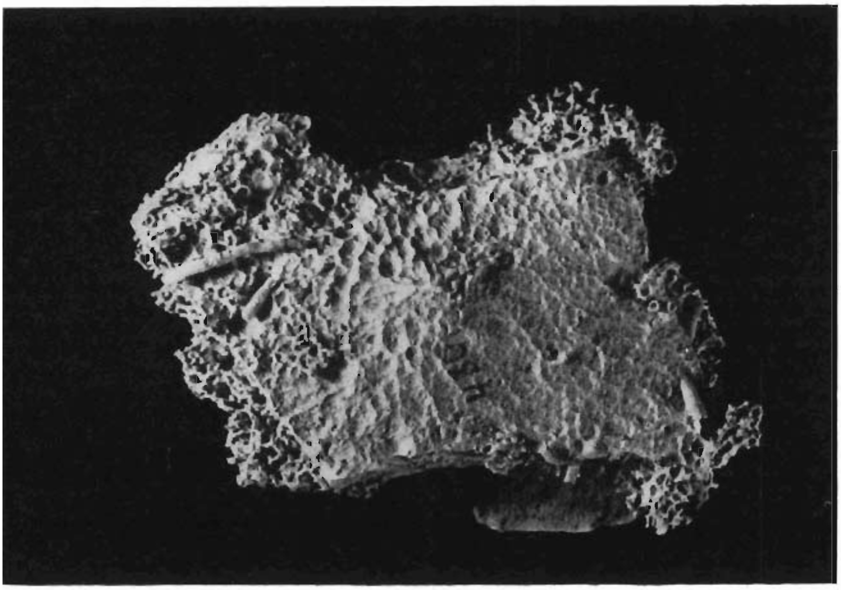
PLATES

All specimens illustrated in Plates come from the erratic boulder No. O.430, found on the Baltic coast, Szczecin province, presumably of Ashgillian age.

Plate I

Fig. 1. Fragment of erratic boulder, slightly etched with hydrochloric acid. Partly separated, tangled, silicified thalli of *Vermiporella fragilis* Stolley and rod-like *Palaeoporella variabilis* Stolley are visible; nat. size.

Fig. 2. Fragments of the same thalli; $\times$ 2.5.



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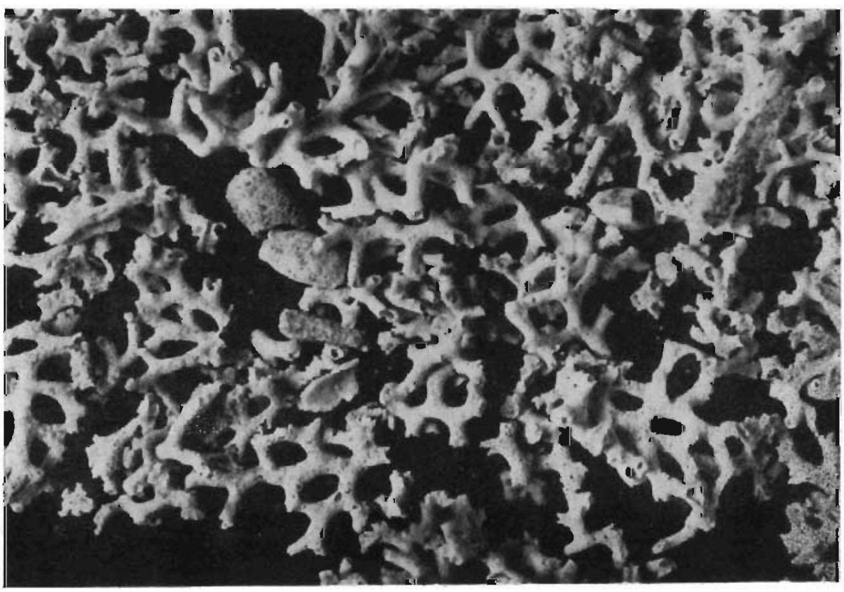

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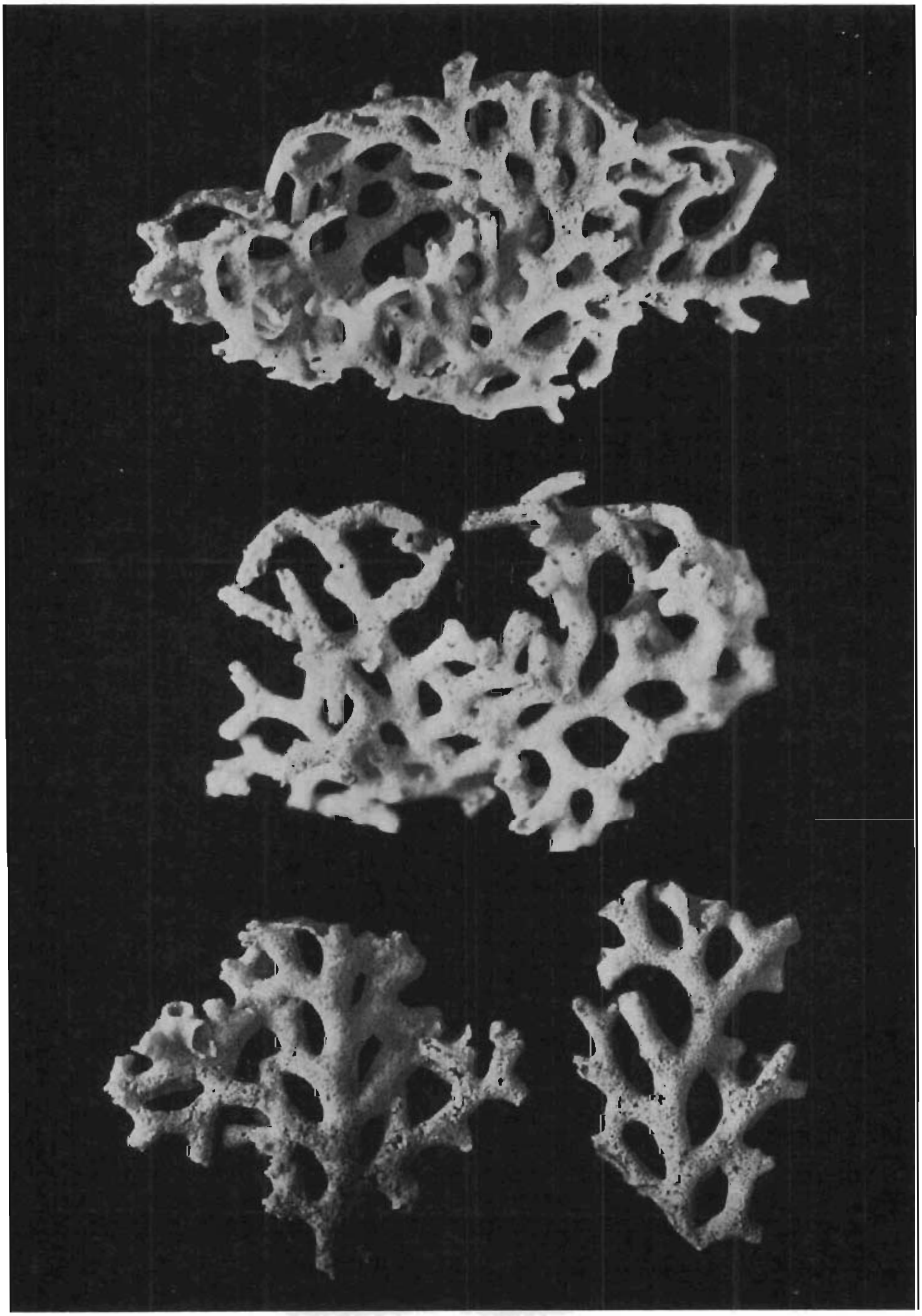


Plate II

Vermiporella fragilis Stolley

Four fragments of silicified thalli chemically prepared from limestone. Dichotomously ramifying and anastomosing branches with fine pores on their surface are visible; × 5.

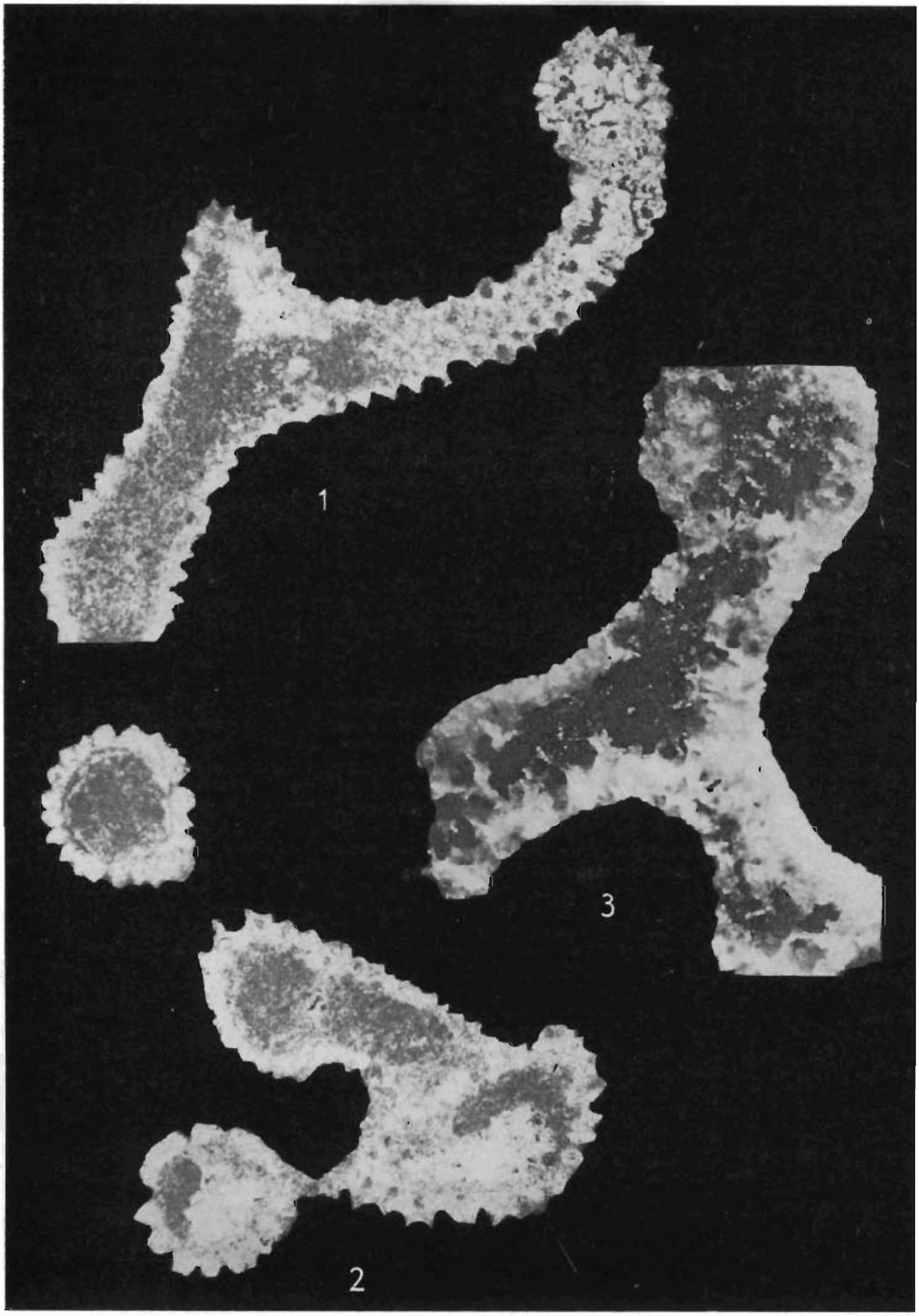
Plate III

Vermiporella fragilis Stolley

Fig. 1. Thin section through a fragment of a silicified sheath of thallus. In the bottom part of the photograph, a longitudinal section passing upwards into a tangential and then transverse; × 30 (thin section No. 1).

Fig. 2. Thin sections through another fragment of a silicified sheath of thallus. Two transverse (at the top and in the left bottom corner of the photograph) and an oblique (on the right) section; × 30 (thin section No. 4).

Fig. 3. Fragment of a silicified sheath of thallus with organic parts preserved inside the axial canal; × 40.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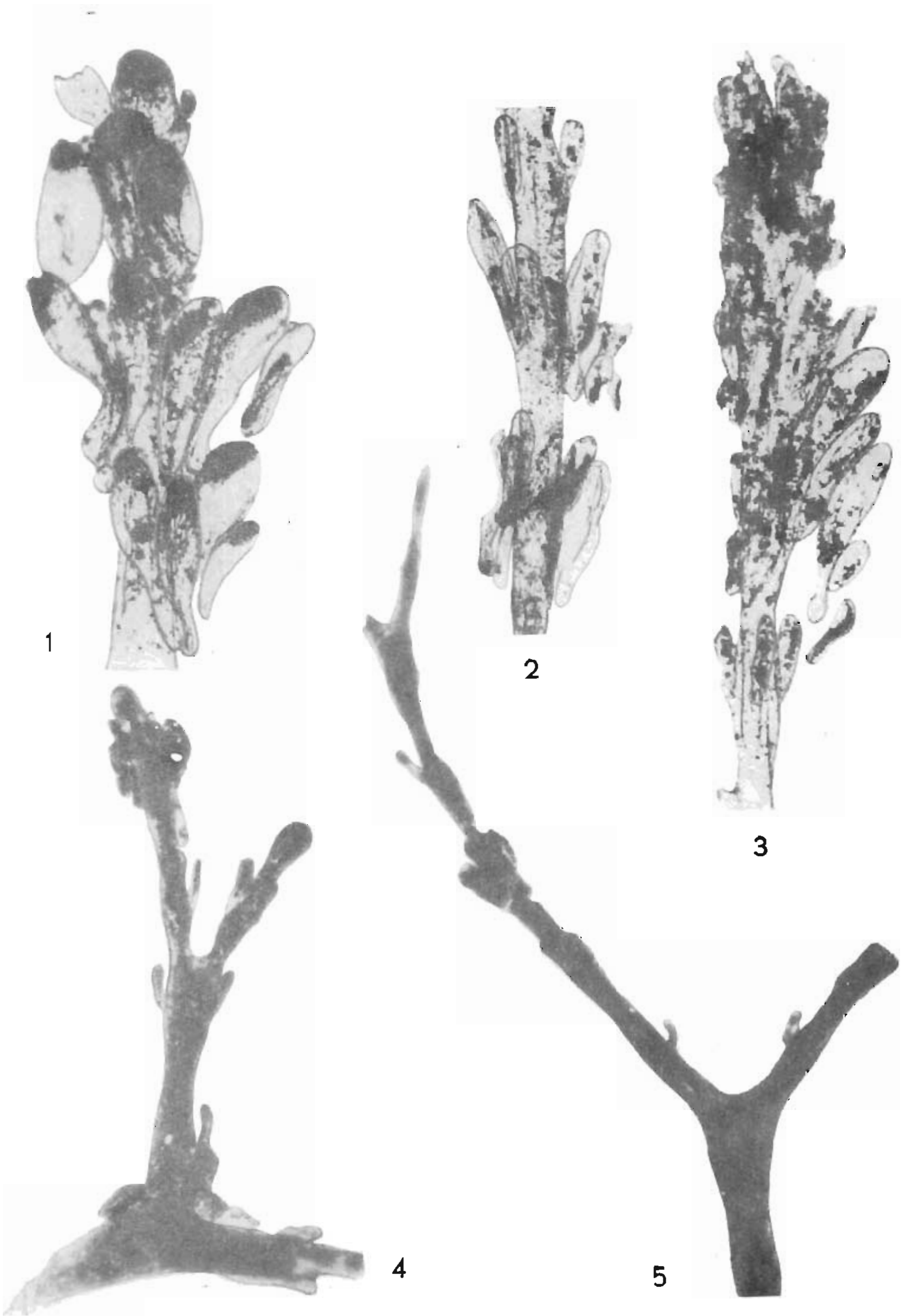

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Plate IV

Vermiporella fragilis Stolley

Figs. 1-3. Three different fragments of thallus with central stem and lateral branches of the I and II order in a verticillate arrangement; × 75.

Figs. 4, 5. Two other fragments of thallus illustrating a dichotomous bifurcation of the central stem and its successive contractions and distensions. Verticillate lateral branches of the I order and a few loose branches of the II order are visible in the places where the stem is extended. Bulbous terminations of the apical part of the stem of thallus are also visible in Fig. 4; × 50.

Plate V

Vermiporella fragilis Stolley

Figs. 1-5. Five different fragments of thallus with whorls of lateral branches of the I and II order attached on the central stem. Cell-wall of the stem and lateral branches of the I order is markedly thicker, than that of the branches of the II order, which is transparent. Some branches of the II order are torn away from their whorls and stuck to the stem. Figs. 1, 3, 5 × 150; Figs. 2, 4 — × 100.

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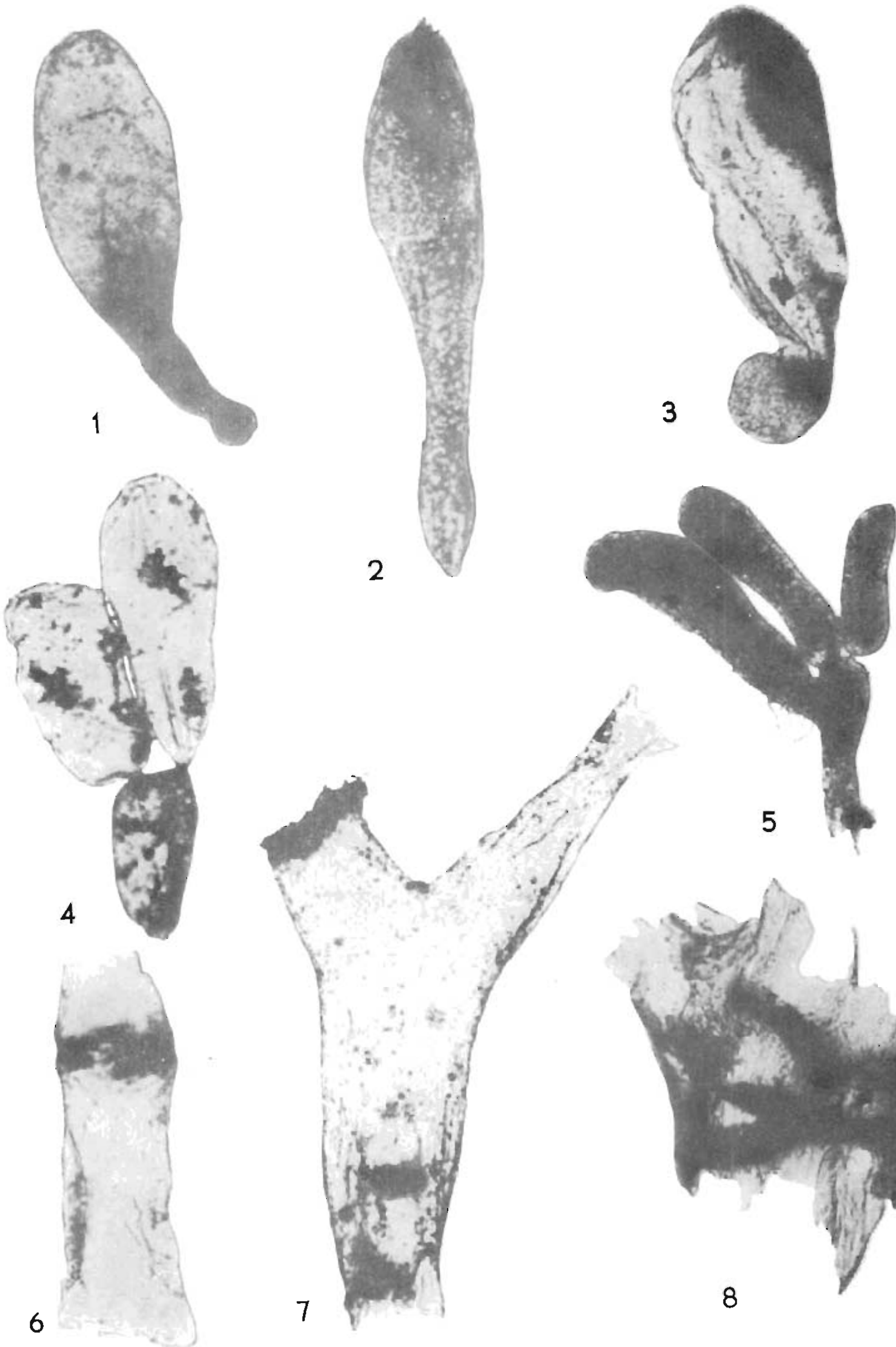
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Plate VI

'ermiporella fragilis Stolley

Figs. 1-3. Three different lateral branches of the II order with a characteristic, necklike contraction in the lower part; × 200.

Fig. 4. A lateral branch of the I order with two branches of the II order, attached to its apex. Very small attachment surfaces of branches and differences in the thickness of cell-wall of the branches of the I and II order are visible; × 150.

Fig. 5. A triad of lateral branches of the III order, deviating from the apical part of the lateral branch of the II order; × 400.

Figs. 6, 7. Fragments of the central stem with septa many times thicker than a transparent cell-wall of stem. A dark, oval spore is visible in the lower part of stem in Fig. 7; × 150.

Fig. 8. A septum with a laminar structure in the central stem. Particular layers are arranged obliquely to each other; × 150.

Plate VII

Vermiporella fragilis Stolley

Figs. 1-3. Three lateral branches of the II order with branches of the III order, deviating from its apical part. Differences in size and shape between both types of the branches are clearly visible. Figs. 1 and 3 — × 180; Fig. 2 — × 360.

Fig. 4. A triad of lateral branches of the II order, attached to the branch of the I order; × 180.

Fig. 5. Lateral branches of the I, II and III order, attached to the central stem. Diameter proportions between several types of branches are visible; × 180.

Fig. 6. A triad of lateral branches of the II order, detached from the whorl. Cell--wall of the apical part of the branches is clearly thickened; × 180.


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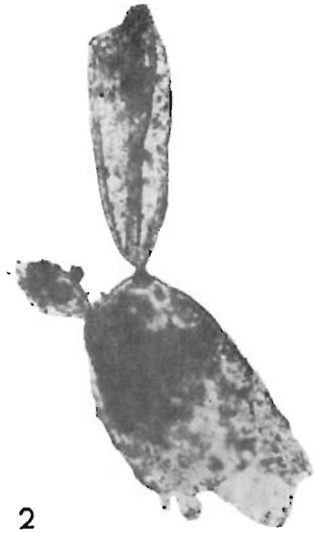
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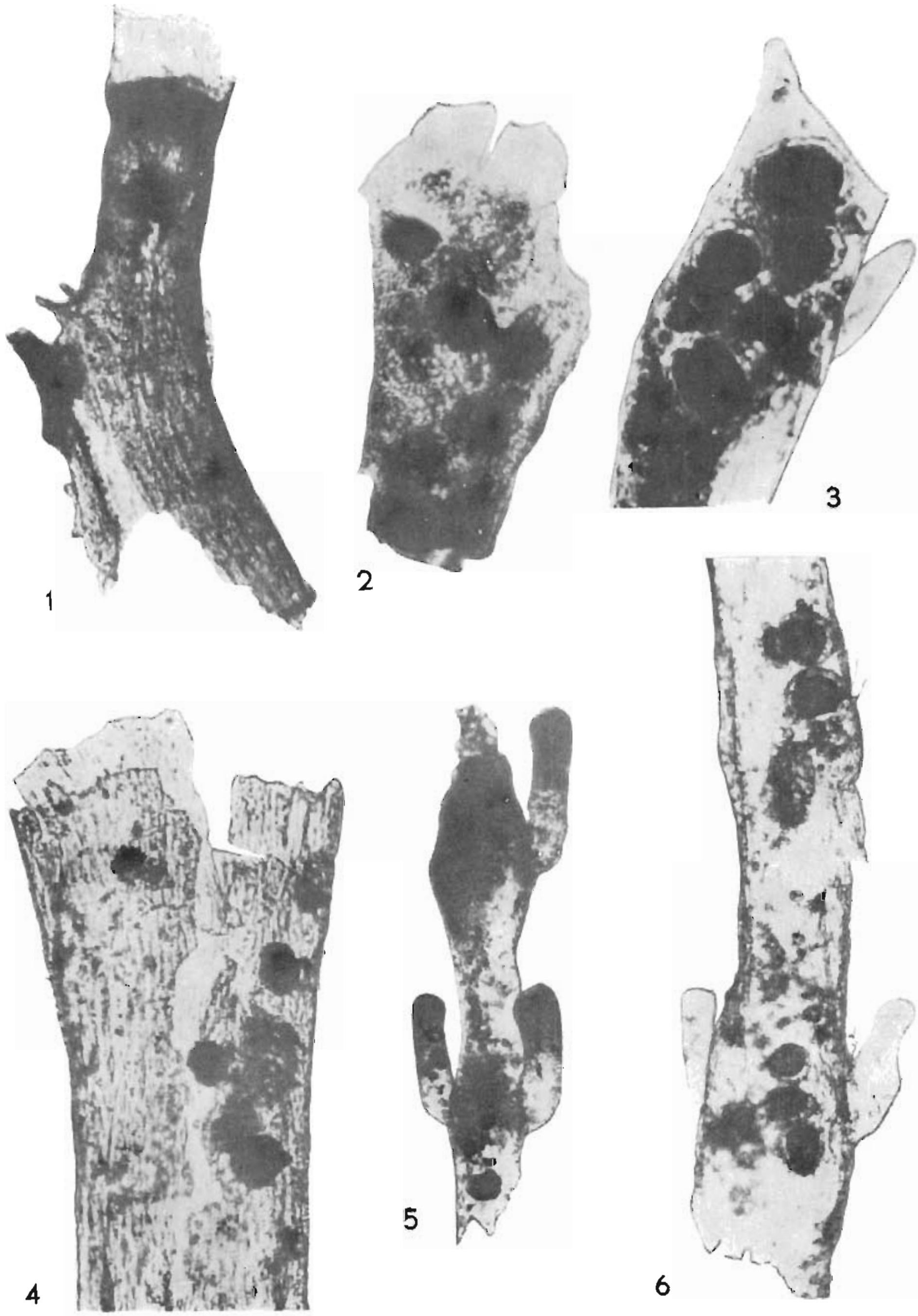


Plate VIII

Vermiporella fragilis Stolley

Fig. 1. A fragment of the central stem with a septum in its upper part. Below septum, an outline of a spore is visible inside of stem. Cell-wall of older part of stem is strongly thickened and longitudinally wrinkled, that of the younger part — above septum, very thin, transparent; × 150.

Fig. 2. A fragment of the central stem with spores inside. A thick septum visible at the bottom; × 300.

Fig. 3. Another fragment of the central stem filled with spores. Transparent membranes visible around spores; × 300.

Fig. 4. A fragment of central stem with widely scattered spores inside. An irregularly strandlike microstructure of cell-wall of stem is clearly visible; × 150.

Figs. 5, 6. Two fragments of central stem with single spores inside. Outer membranes visible on some spores; × 150.

Plate IX

Vermiporella fragilis Stolley

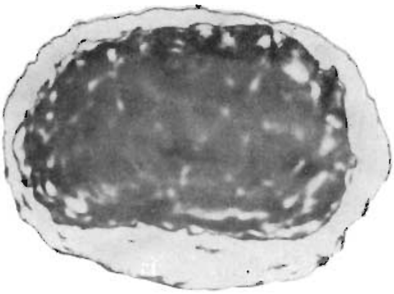
Figs. 1-3. Three spores (of the oospore type) with distinctly visible bilaminar structure (synapsis and nucleus), enveloped by a thin, transparent membrane.

Fig. 4. A spore (oospore) with a structure similar to those in Figs. 1-3 and traces of membrane enveloping it.

Fig. 5. A spore (oospore) photographed without decolouration, with a split surface (early stage of germination?), without a membraneous sheath.

Fig. 6. A spore (oospore) with a less distinct bilaminar structure without a surrounding membrane.

All × 1000



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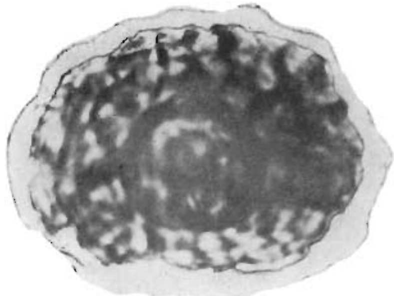

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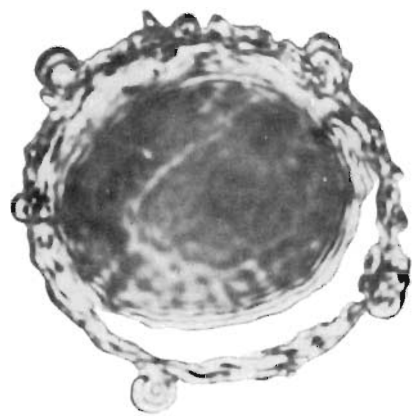

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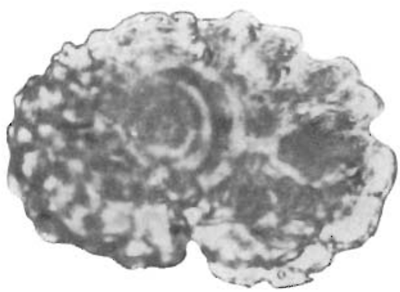

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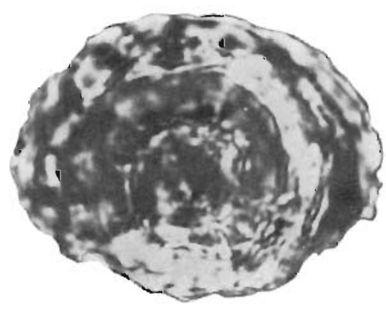

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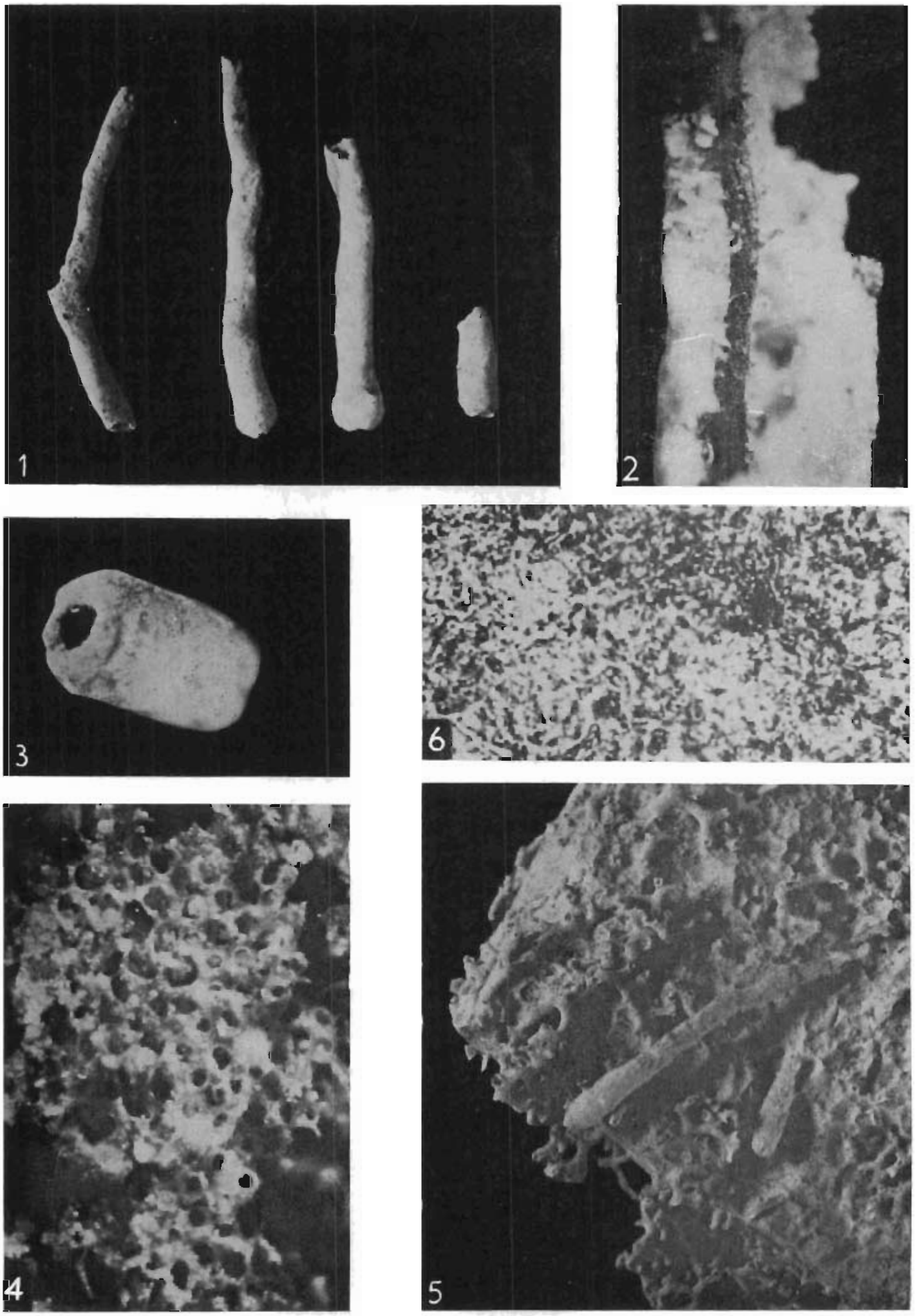
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Plate X

Palaeoporella variabilis Stolley

Fig. 1. Four fragments of silicified thalli chemically prepared from limestone; × 2.5.

Fig. 2. A fragment of a silicified sheath of thallus with organic parts (mostly threads of the central bundle), preserved inside the axial canal; × 20.

Fig. 3. A fragment of the basal part of a silicified thallus. An outlet of axial canal visible; × 7.

Fig. 4. A fragment of a separated cortical layer of thallus. The ends of cortical utricles adhering to each other in the form of a honeycomb are visible; × × 75.

Fig. 5. A fragment of a calcareous erratic boulder, slightly etched with hydrochloric acid, with silicified thalli of *Palaeoporella variabilis* and *Vermiporella fragilis;* × 2.

Fig. 6. A fragment of the gelatino-filamentous substance lining the axial canal of thallus; × 400.

Plate XI

Palaeoporella variabilis Stolley

Fig. 1. A fragment of the central bundle of threads which consists of a thick main thread, a fragment of the longitudinal thread of the I order, attached to the knot of the main thread, and a great number of the longitudinal threads of the II order; × 50.

Figs. 2, 3. Two dichotomously ramifying fragments of the main thread with characteristic bulbous swellings: Fig. 2 — × 50; Fig. 3 — × 80.

Fig. 4. A fragment of the main thread with a longitudinal thread of the I order, detaching itself from it, and many longitudinal threads of the II order; ×50.

Fig. 5. A fragment of the main thread with uniformly distributed knots; × 50.

Fig. 6. Subcortical branches of thallus with one arm broken off. A split end of this branch constituted a base for a pair of cortical utricles; × 150.

Figs. 7-9. Apical parts of a few other subcortical branches with forked ends are visible; × 200.