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The genus *Polytretus* (Ectocarpaceae, brown algae) in Japan

Munenao KUROGI

The genus *Polytretus* SAUVAGEAU (1900), based on *Ectocarpus reinboldii* REINKE (1892), is characterized especially by the occurrence of hairs and the peculiar discharge of zoospores of plurilocular sporangia through an individual opening in each superficial loculus and not through a common apical opening in the sporangium as in *Ectocarpus*.

Morphological observations are described for a plant referable to *P. reinboldii* in Japan. Plurilocular sporangia of our plant are partitioned into a certain number of compartments containing a number of loculi. Zoospores of the sporangium are discharged through an opening formed in each compartment and not through an opening in each superficial loculus nor an apical opening in the sporangium. The differences in the structure of the sporangia and in the discharge of the zoospores in our plants and the descriptions of Reinke and others on European plants are also discussed.

Several Japanese taxa are placed in synonymy with *P. reinboldii*.

Introduction

The genus *Polytretus* was established by SAUVAGEAU (1900) in his paper on Sphacelariaceae based on *Ectocarpus reinboldii* REINKE (1892) from Helgoland. SAUVAGEAU placed *E. reinboldii* in *Polytretus* as *P. reinboldii* because of the occurence of hairs and because of the peculiar discharge of zoospores of plurilocular sporangia through an opening in each superficial loculus and not through an apical opening in the sporangium as in *Ectocarpus*. In addition, *P. reinboldii* is characterized by discoid chloroplasts, intercalary diffuse growth of erect filaments and angular shaped plurilocular sporangia. As far as the writer knows, the genus is monotypic and reported from only a few localities in Europe: Helgoland (REINKE 1892), Dorset in England (BATTERS 1902), northern and eastern parts of Kateggat in Denmark (ROSENVINGE & LUND 1941) and the west coast of Sweden (WAERN 1958). The genus name of *Polytretus* was not used by BATTERS, and ROSENVINGE & LUND.

The writer in 1950 reported briefly on the presence in Japan of *Polytretus* under the names of *P. sorocarpoides* (TAKAMATSU) KUROGI, *P. glo-*

bosoides (TAKAMATSU) KUROGI and *P. minutus* KUROGI. He mentioned that the plurilocular sporangia are partitioned into a certain number of compartments[1] containing a number of loculi and the zoospores are liberated through an opening in each compartment, and not through an opening in each superficial loculus nor a common apical opening in the sporangium.

In this paper new observations of the plant are described, and a variety of taxa, some previously published (*nomina nuda*) or announced in Japan, are placed in *P. reinboldii*. A possible hibernal form. f. *minutus* forma nova is proposed.

Polytretus reinboldii (**REINKE**) **SAUVAGEAU**

1900, p. 6; HAMEL 1931, p. 62; WAERN 1958, p. 324, Pl. 3.

Basionym: *Ectocarpus reinboldii* REINKE 1892, p. 61, Taf. 41-figs. 1-12; BATTERS 1902, p. 33; NEWTON 1931, p. 122; ROSENVINGE & LUND 1941, p. 56.

Thalli epiphytic or saxicolous, forming entangled tufts, 0.5-4 cm high, yellowish brown in color, attached by numerous rhizoids issuing from the basal part of erect filaments; erect filaments laterally or subdichotomously much branched 3-5 times at comparatively equal intervals, often not showing distinct axes, frequently provided with branchlets here and there; branches given off at somewhat closer intervals in the upper part of erect filaments, but not forming dense apical clusters, and terminating in hairs; growth of erect filament diffuse; cells quadrate to cylindrical, often slightly constricted at the septum, narrowed near the base of erect filaments and again attenuated toward the apex, variable in size, (25)-27.5-50-(60) μm broad in the largest part, and 1-3-(4) times as long as broad; cell walls comparatively thick; chloroplasts numerous, small, discoid or elliptical; hairs terminal or occasionally lateral on erect filaments, with a short meristematic zone at the base, deciduous; plurilocular sporangia abundant in the upper part of erect filaments, sessile or stalked, frequently seriate on ultimate branches and lateral branchlets or grouped on stalks, irregular in shape and variable in size, ovate, globose-quadrate or elliptical-rectangular, undulate at the margin, broadly obtuse or truncate at the apex, (20)-25-60-(80) μm in length, (17.5)-20-35-(50) μm in breadth, (0.8)-1-2-(3) times as long as broad, divided into a certain number of compartments consisting of a number of loculi, discharging zoospores through an opening in each compartment; unilocular sporangia (?) having pale and homogenous contents, on separate filaments from those with

1) In this paper, "compartment" means a group of loculi surrounded by a common wall, and "loculus" the smallest chamber in the sporangium (cf. Fig. 2).

plurilocular sporangia, disposed in the same manner as plurilocular sporangia, obovate, 17.5–27.5 μm long and 15–25 μm broad.

Locality: Oshoro (March 19, 1947; May 11, 1948; May 26, 1950) and Ranshima (June 13, 1946; July 8, 1950), Shiribeshi Prov. in Hokkaido, Asamushi (April 16, 1950) in Pref. Aomori, and Maizuru (April 24, 1950) in Pref. Kyoto.

Observation

The results of observations are mainly based on the materials from Oshoro and Ranshima.

The plants (Pl. I A, B) were collected at Oshoro and Ransihima on the Japan Sea coast of Hokkaido in spring to early summer (March to early July). They are abundant on upper branches of *Sargassum confusum* C. Agradh at all times floating near the surface in calm water and on branchlets and air bladders of *S. thunbergii* (MERTENS) O. KUNTZE growing in the intertidal zone.

The plants are tufted, mostly entangled, resembling *Sorocarpus* plants in appearance. The tufts are 0.5–4 cm high and generally higher on *Sargassum confusum* than on *S. thunbergii*, and yellowish brown in color.

The plants are attached by means of numerous rhizoidal filaments issuing from the basal part of erect filaments (Pls. II C, V C). Rhizoidal filaments often issue from the more distal parts of erect filaments. Cells of them are nearly colorless, elongated, 5–15 μm broad and 2–10 times as long as broad. Creeping filaments are not detected.

Erect filaments are much branched laterally or subdichotomously 3–5 times at comparatively equal intervals, and frequently provided with lateral branchlets here and there (Pls. II–VI). The axes are often indistinct. Branches are given off at somewhat closer intervals in the upper part of erect filaments, but do not form dense apical clusters. They are terminated in hairs. Branchlets and ultimate branches are frequently widely spread out or recurved especially in mature old plants. Growth of erect filaments is diffuse, with intercalary cell division widespread, and a special growing zone is absent.

Cells of erect filaments are quadrate to cylindrical, often slightly constricted at the joint, narrowed near the base of erect filaments and again gradually attenuated toward the apex, 1–3–(4) times as long as broad, generally shorter in the upper part than in the lower part, variable in breadth, (25)–27.5–50–(60) μm (occasionally up to 80 μm) broad in the lower largest part, and generally slender in young filaments. Some measurements of erect fila-

ments are shown. Erect filaments of the plant on *S. confusum* collected on May 11, 1948 at Oshoro are 20-32.5 μm broad near the base, 25-50 μm broad in the lower part and 7.5-12.5 μm broad in the apical part. Those of the plant on *S. thunbergii* collected on March 19, 1947 at Oshoro are 22.5-52.5 μm broad near the base, 42.5-80 μm in the lower part and 10-17.5 μm in the apical part. Filaments on *S. thungbergii* collected on May 11, 1948 at the same place are 32.5-50 μm broad in the largest lower part.

Cell walls are comparatively thick and 4-7 μm in thickness in the lower part of erect filaments. Chloroplasts (Pls. II D, IV B) are numerous in each cell, small, discoid or elliptical and 2.5-5 μm in diameter.

Hairs are terminal or occasionally lateral on erect filaments, having a short meristematic zone consisting of 2 to 4 short cells (Pls. III, V, VI). Cells of hairs are cylindrical, elongated, nearly colorless, 7.5-17.5 μm broad and up to 13 times as long as broad. Hairs are deciduous and they are hardly seen in mature old plants. With age, the apical cells of erect filaments with hairs become broader and rounded at the apex, whereas hairs are not so broadened. Thus, hairs appear to fall off so spontaneously that the apex of erect filaments do not show any traces of hairs. Old plants without hairs are more rigid and entangled than young plants with hairs.

Plurilocular sporangia are abundant in the upper part of erect filaments and disposed on branches, ultimate branches and branchlets (Pls. II-V). They are sessile or stalked, and frequently seriate on ultimate branches and branchlets and grouped on 1-5 celled stalks. Sporangia on ultimate branches and branchlets are mostly sessile and sometimes issue side by side from the same articulation. Grouped sporangia on stalks are issued 2 or more (up to 5) from the apical cell and often additionally from other cells of stalks. Plurilocular sporangia are occasionally terminal on branchlets and rarely intercalary in the apical part of branches. Sporangia issuing from rhizoidal filaments are rarely found.

Plurilocular sporangia are irregular in shape and variable in size (Fig. 1). The shape is ovate, globose-quadrate or elliptical-rectangular, frequently undulate at the margin, and broadly obtuse or truncate at the apex. The size is (20)-25-60-(80) μm in length, (17.5)-20-35-(50) μm in breadth, and (0.8)-1-2-(3) times as long as broad. Sporangia on ultimate branches and branchlets are mostly small and ovate or globose-quadrate, while scattered ones on branches are mostly large and elliptical-rectangular.

The plurilocular sporangia are partitioned into a certain number of compartments containing a number of loculi by 1 or (more) longitudinal walls and by 1 or more (up to 7) transverse walls. Occasionally some of the com-

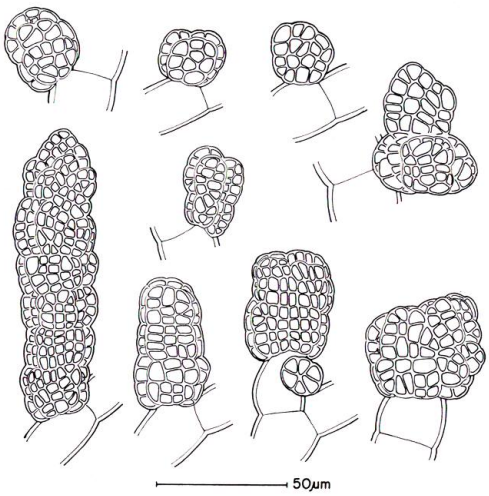

Fig. 1. *Polytretus reinboldii*, various shapes of plurilocular sporangia.

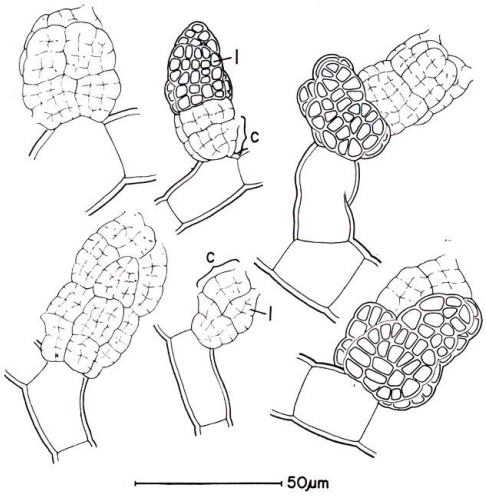

Fig. 2. *Polytretus reinboldii*, wholly or partly emptied plurilocular sporangia, showing structure of sporangia and openings of zoospore discharge. l: loculus, c: compartment.

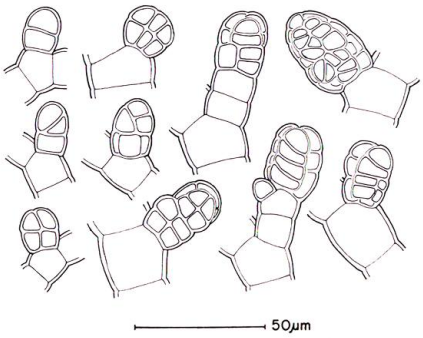

Fig. 3. *Polytretus reinboldii*, developmental stages of plurilocular sporangia.

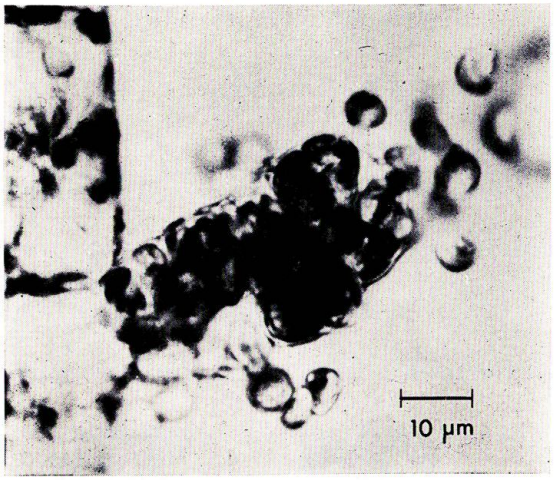

Fig. 4. *Polytretus reinboldii*, discharge of zoospores of a plurilocular sporangium through two or more openings.

partments are protruded laterally. In other words, the plurilocular sporangia are considered as a mass of a certain number of "small sporangia" stuck to each other. The walls of compartments are thin and not always easily detected, but comparatively clear in empty sporangia. The structure, moreover, is demonstrated by partly emptied plurilocular sporangia (Fig. 2), by

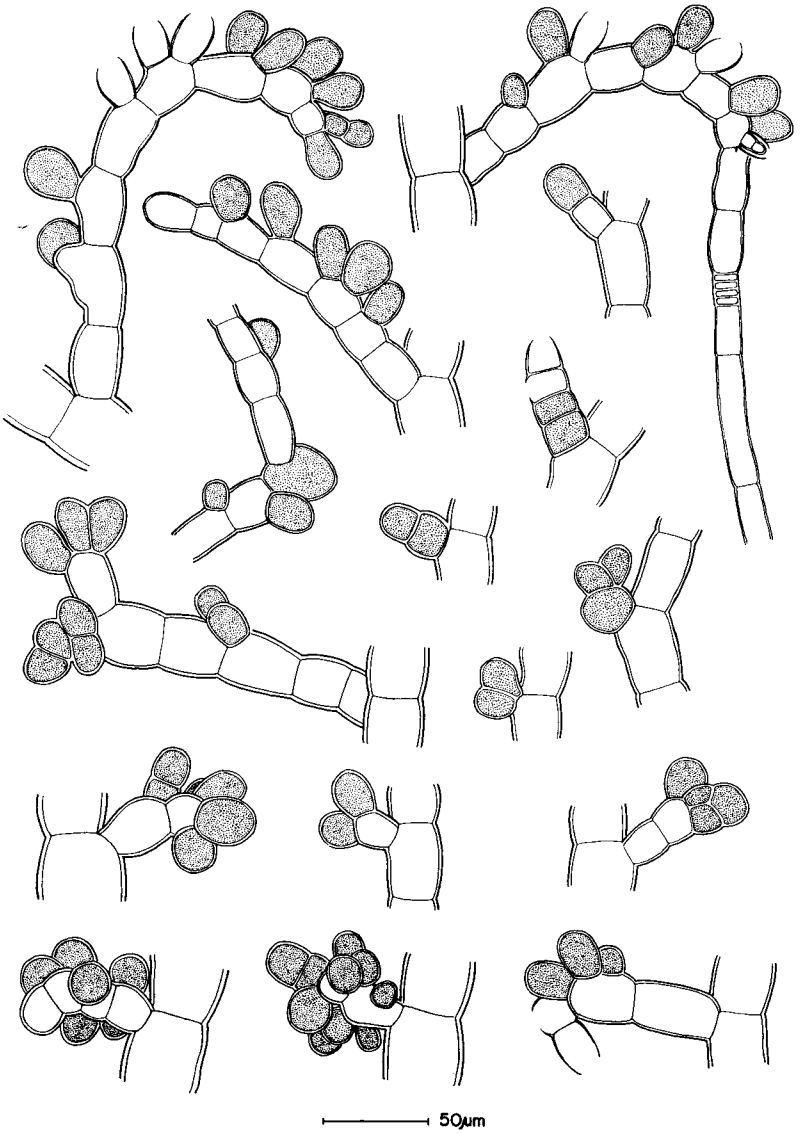

Fig. 5. *Polytretus reinboldii*, variously disposed unilocular sporangia (?).

tracing the developmental stages (Fig. 3) and by observing the discharge of zoospores (Fig. 4). It is not so easy to observe the opening of the discharge in fixed materials. The writer made an observation of the discharge of zoospores in living materials at the Seaside Laboratory at Oshoro. Zoospores of plulilocular sporangia are discharged through an opening in each compartment, but not through an opening in each sporangium nor an opening in each loculus. When the sporangia are ripened, an opening is formed in each compartment and elongate zoospores are pushed out through the opening. On the outside the zoospores become globular and stand still for several seconds before they begin to move quickly. Which compartment of a plucilocular sporangium at first discharges zoospores is not clear.

Uniloclar sporangia (?) were found on the plants collected at Oshoro (May 11, 1948 on *Sargassum confusum*) and Ranshima (July 8, 1950 on *S. confusum*). The sporangia are on separate filaments from those with plurilocular sporangia and disposed in the same manner as plurilocular sporangia (Fig. 5, Pl. VI). They are sometimes in chains longitudinally or laterally. The chains are similar to the structure of plurilocular sporangia. The sporangia are commonly obovate in shape, or doliiform in chained ones, 17.5–27.5 μm long and 15–25 μm broad, pale and homogenous in contents. In spite of the occurrence of many empty sporangia, any differentiation into zoospores in them could not be found. The sporangia seem to agree with "ovate cells resembling ascocyst" which are described by ROSENVINGE & LUND (1941).

As mentioned before, the plant is variable in the breadth of erect filaments, the shape and size of plurilocular sporangia and the disposition of them. There are seen some morphological differences between plants on *Sargassum confusum* (Pls. I A, II, III) and those on *S. thunbergii* (Pls. I B, C, IV, V). In the former, the tufts are 1–4 cm high and erect filaments are much branched up to 5 times and at comparatively distant intervals. Plurilocular sporangia are frequently closely seriate on branchlets and ultimate branches and densely grouped up to 5 on stalks, and many of them ovate, globose-quadrate in shape. On the other hand, in the latter the tufts are 0.5–1.5 cm high and erect filaments are branched 3–4 times at closer intervals. Plurilocular sporangia are not frequently seriate on branchlets and ultimate branches and not densely grouped on stalks and many of them are larger and rather elliptical-rectangular in shape. Erect filaments are also broader. Nevertheless, there are intermediate forms of the two on *S. confusum* as well as *S. thunbergii*.

The plants referable to this species were also collected from Asamushi

in Mutsu Bay in northern part of Honshu and from Maizuru on the Japan Sea coast of Honshu. The former grew on rocks and the latter on *S. thunbergii*.

Discussion

The plant found on our coast agrees with *Polytretus reinboldii* (REINKE) SAUVAGEAU in showing diffuse growth of erect filaments and in possessing discoid chloroplasts, hairs and ovate to elliptical angular plurilocular sporangia with undulate margin. But the occurences of grouped plurilocular sporangia on stalks and the deciduous nature of hairs as seen in our plant are not described by REINKE (1892). Moreover, he described that zoospores of plurilocular sporangia are discharged through an opening of each superficial loculus. The peculiar discharge of zoospores is a main character by which SAUVAGEAU (1900) established the genus *Polytretus*. The method of zoospore discharge differs from that of our plant. Nevertheless, our plant seems to be referred to *Polytretus reinboldii* (REINKE) SAUVAGEAU. The reasons are as follows.

Plurilocular sporangia of our plant are not always grouped on stalks as mentioned before. Concerning the disposition of plurilocular sporangia of *Ectocarpus reinboldii* from Denmark, ROSENVINGE & LUND (1941) mentioned "In both cases (sessible or shortly stalked) very frequently more than one sporangium issue from the same cell. If a stalk of sporangium consists of more than one cell, sporangia may issue from each cell. The position of the sporangia is generally quite irregular." The description shows a quite similarity of our plant to European one.

As to the discharge of zoospores, when zoospores of plurilocular sporangia are discharged through openings of superficial loculi as mentioned by REINKE (1892) and ROSENVINGE & LUND (1941), there is a question through which openings zoospores of inner loculi are discharged. REINKE's figures of *Ectocarpus reinboldii* (Taf. 41-figs. 6, 7, 11) show partly emptied plurilocular sporangia, which suggest the partitioning of sporangia into compartments as seen in our plant. Moreover, ROSENVINGE & LUND (1941) remarked on the sporangia of the plant from Denmark, "Actually, several of the sporangia are certainly to be considered sori of sporangia formed by sporangia in chains. At any rate some of the transverse walls of the sporangia occasionally are so marked that certain of the compartments seem to be sporangia of the own. Some sporangia (or sori) project a little or more from longitudinal direction of the sporangium (the sorus)". These facts suggest the possibility that plurilocular sporangia of *Polytretus reinboldii* reported

from Europe also may be partitioned into a certain number of compartments, in other words the so called pluriocular sporangia may be a mass of a certain number of plurilocular sporangia as in our plant. This makes it reasonable to suppose that the openings of plurilocular sporangia of *P. reinboldii* are not formed in each superficial loculus as described by REINKE, but in each compartment as seen in our plant. Reexamination of the plant from Europe especially on the structure of plurilocular sporangia and the discharge of zoospores is needed.

As mentioned before, one of the main characters of *Polytretus* by which SAUVAGEAU separated the genus from *Ectocarpus* is the discharge of zoospores of plurilocular sporangia through an opening in each superficial loculus. If my supposition about the structure of plurilocular sporangia and the discharge of zoospores in *Polytretus reinboldii* in Europe will be proved right, the character of the genus mentioned by SAUVAGEAU should be emended in respect to the structure of plurilocular sporangia and the discharge of zoospores. Nevertheless, the genus *Polytretus* is clearly separated from other genera of Ectocarpaceae by its vegetative and reproductive structures. The most closely related genus is *Sorocarpus*. The genus *Polytretus* shows a close similarity to the genus *Sorocarpus* in the occurrence of haris, discoid chloroplasts and grouped sporangia. The latter genus, however, is distinguished from the former in respect to grouped plurilocular sporangia and each sporangium is not partitioned into compartments, and the zoospores are discharged through an apical opening in each plurilocular sporangium.

On the other hand, the plant referable to *P. reinboldii* from Japan was first found and described by Dr. Masahiko TAKAMATSU in his doctoral thesis submitted to Hokkaido University in 1948, "Ectocarpales Oltm. aus dem nordöstlichen Honshu, Japan". This paper is deposited in Hokkaido University, but not published. He described *Ectocarpus reinboldii* and six other new species of *Ectocarpus*, *E. sorocarpoides*, *E. firmus*, *E. diffusus*, *E. furcatus*, *E. globosoides* and *E. quadratus*, which are considered to belong to *Polytretus* judging from the angular shape of plurilocular sporangia and other features. They are mainly separated from each other by the presence or absence of hairs, branching of filaments especially in the upper part, and shape of plurilocular sporangia. The limits among the species are difficult to be fixed. He did not describe the structure of plurilocular sporangia, the discharge of zoospores and the deciduousness of hairs. Among them *E. sorocarpoides* and *E. firmus* resemble the plant on *Sargassum confusum* mentioned by the writer here and *E. globosoides* and *E. quadratus* resemble that on *Sargassum thunbergii*. The writer in 1950 proposed provisionally

the combination of the four species to the genus *Polytretus* as *P. sorocarpoides* (TAKAMATSU) KUROGI including *E. firmus* and *P. globosoides* (TAKAMATSU) KUROGI including *E. quadratus*, when TAKAMATSU's paper was not published. The proposal was done by oral lecture in the annual meeting of the Botanical Society of Japan. The summary was published, but the full descriptions of the species were omitted there. NODA (1969) described *E. sorocarpoides* TAKAMATSU which was not accompanied by latin description, when the TAKAMATSU paper was not published also. At any rate, TAKAMATSU's species names concerned have not been published validly. The writer concluded that "*P. sorocarpoides*" and "*P. globosoides*" are not separable from *P. reinboldii* as mentioned above.

As other related species to this plant there are found *Ectocarpus iwadatensis* NODA (NODA 1971, KONNO & NODA 1974), *E. intricatus* KONNO (KONNO & NODA 1974) and *E. recurvatus* KONNO (KONNO & NODA 1974). Although the presence of hairs in them are not described, they seems to be closely related to the present old plant without hairs, judging from the shape of plurilocular sporangia and other features.

***Polytretus reinboldii* f. *minutus* KUROGI f. nov.**

Frondibus floccos parvos formantibus, 0.5-1.5 mm altis, filamentis repentibus saepe distinctis; filamentis rhizoideis parcis; filamentis erectis simplicibus aut parce ramosis, ad apices piliferis; cellulis filamentorum erectorum quadratis aut cylindricis, 1-2-(3) plo longioribus quam latis, in partibus inferioribus (17.5)-20-27.5-(30) μm latis; sporangiis plurilocularibus in filamentis erectis dispositis, frequenter terminalibus in pedicellis emissis ex filamentis repentibus, interdum duplicatis in pedicellis, elliptico-rectangularibus, interdum globoso-quadratis, (25)-35-60-(75) μm longis, (20)-22.5-30-(35) μm latis, (1)-1.5-2.3-(2.7) plo longioribus quam latis.

Fronds forming a small tuft, 0.5-1.5 mm high; creeping filaments visible; rhizoidal filaments scanty; erect filaments issued from creeping filaments, unbranched or sparingly branched, ending in hairs; cells of erect filaments quadrate or cylindrical, 1-2-(3) times as long as broad, in the lower largest part (17.5)-20-27.5-(30) μm broad; plurilocular sporangia scattered on erect filaments, frequently terminal on stalks arising from creeping filaments, sometimes double on stalks, elliptical-rectangular, sometimes globose-quadrate, (25)-35-60-(75) μm long, (20)-22.5-30-(35) μm broad, (1)-1.5-2.3-(2.7) times as long as broad.

Locality: Muroran (Sept. 12, 1946), Iburi Prov., Hokkaido.

This plant occurred mingled with the small plants of *Compsonema*

sp. densely covering the old thallus of *Sargassum thunbergii* (MERT.) O. KUNTZE growing in the tide pool, and slightly projected above them.

This forma is distinguishable from *f. reinboldii* by the small size of plant and simple or sparingly branched erect filaments issued from creeping filaments (Pl. VII). Moreover, erect filaments are slender. Plurilocular sporangia are scattered on erect filaments and not seriate nor densely grouped, and frequently terminal on stalks from creeping filaments.

This forma was provisionally reported as "*P. minutus* KUROGI" by the writer in 1950, and it may be a hibernal form of this species.

Acknowledgement

The writer wishes to express his hearty thanks to the late Professor Yukio YAMADA and Professor Yositeru NAKAMURA for their kind guidance in course of the investigation made in 1947-1951. The writer wishes to thank Professor Isabella A. Abbott, Hopkins Marine Station of Stanford University for her critical reading and English correction.

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Supplement

After completion of this manuscript, I have received a copy of Dr. PEDERSEN's paper* on the culture study of *Polytretus reinboldii*. As to the structure of plurilocular sporangia and liberation of zoospores in Danish material, he mentioned in his paper "there is not an opening at each loculus along the surface of the plurilocular sporangia as previously assumed, REINKE's sporangium must be considered a sorus of sporangia". This quite agrees with the result of my observation mentioned before. Thus I cannot separate the Japanese plant from the European plant in this respect also.

PEDERSEN proposed a new family Sorocarpaceae including *Polytretus*, *Hummia* and *Sorocarpus* which are characterized by hairs and sympodial branching. The writer could not ascertain the sympodial branching of erect filaments. The branching should be surveyed minutely in our plant.

* PEDERSEN, P. M. 1977. *Polytretus reinboldii*, a rare brown alga in culture (Ectocarpales, Sorocarpaceae fam. nov.). Bot. Not. **130**: 35–40.

Plate I *Polytretus reinboldii*, habit. A plants on *Sargassum confusum* (Oshoro, May 11, 1948); B, C plants on *Sargassum thunbergii* (Oshoro, May 11, 1948).

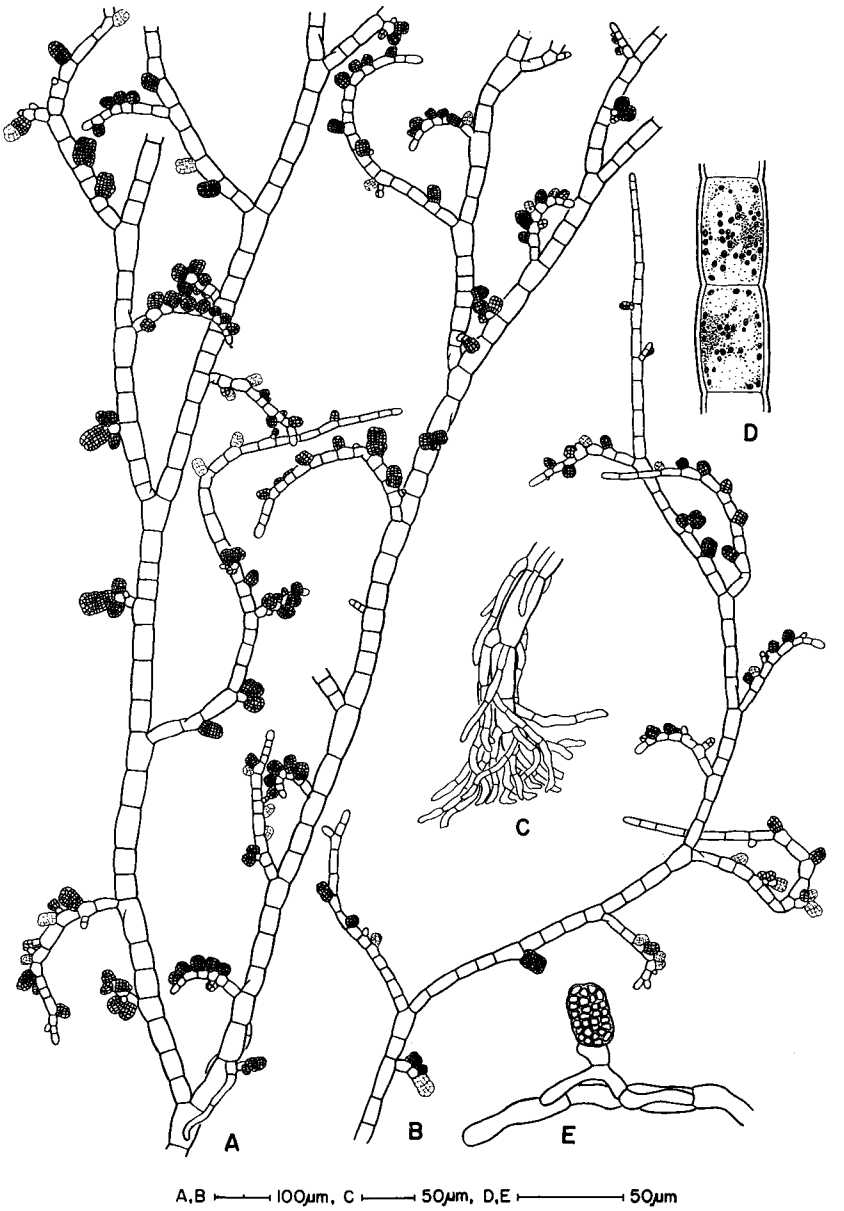

Plate II *Polytretus reinboldii.* A, B old erect filaments without hairs of the plant on *Sargassum confusum,* A middle part and B apical part; C rhizoidal filaments issued from basal part of erect filament; D showing discoid chloroplasts; E plurilocular sporangium on rhizoidal filament. (Oshoro, May 11, 1948).

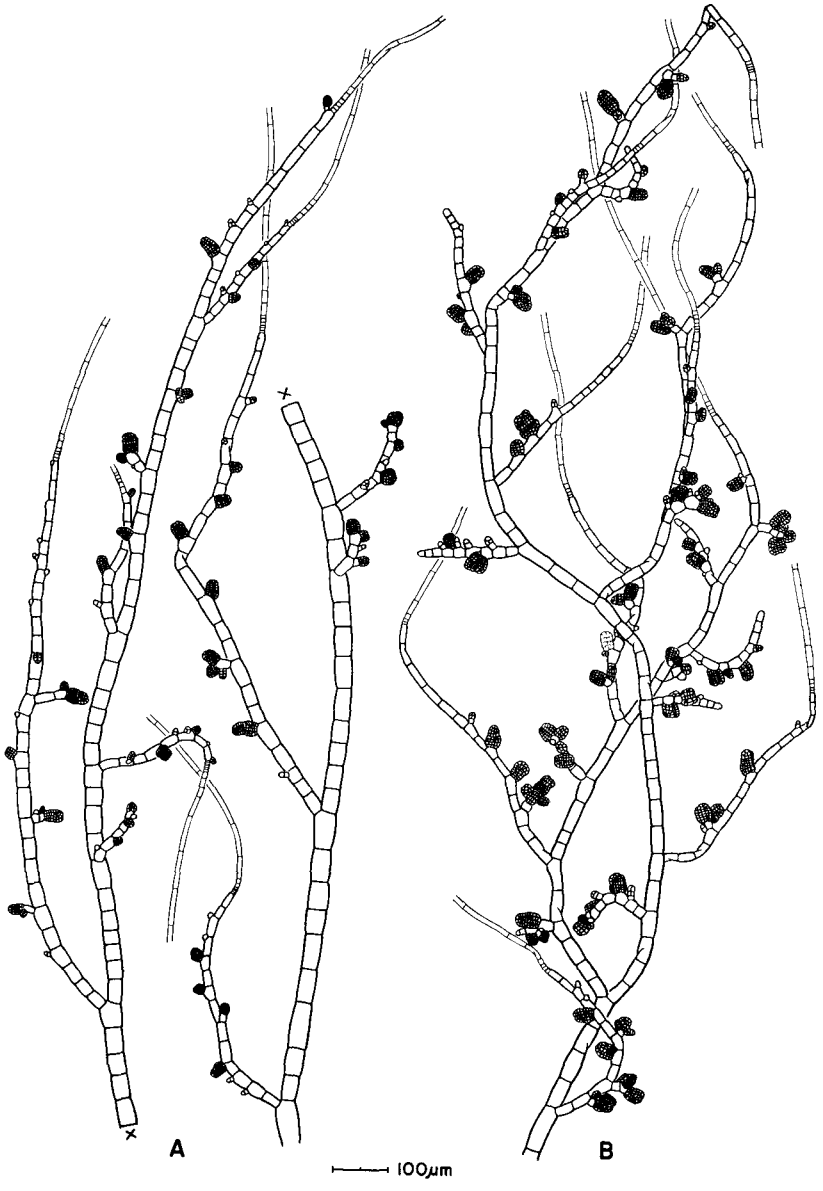

Plate III *Polytretus reinboldii.* Young erect filaments with hairs of the plant on *Sargassum confusum* (Ranshima, June 13, 1946).

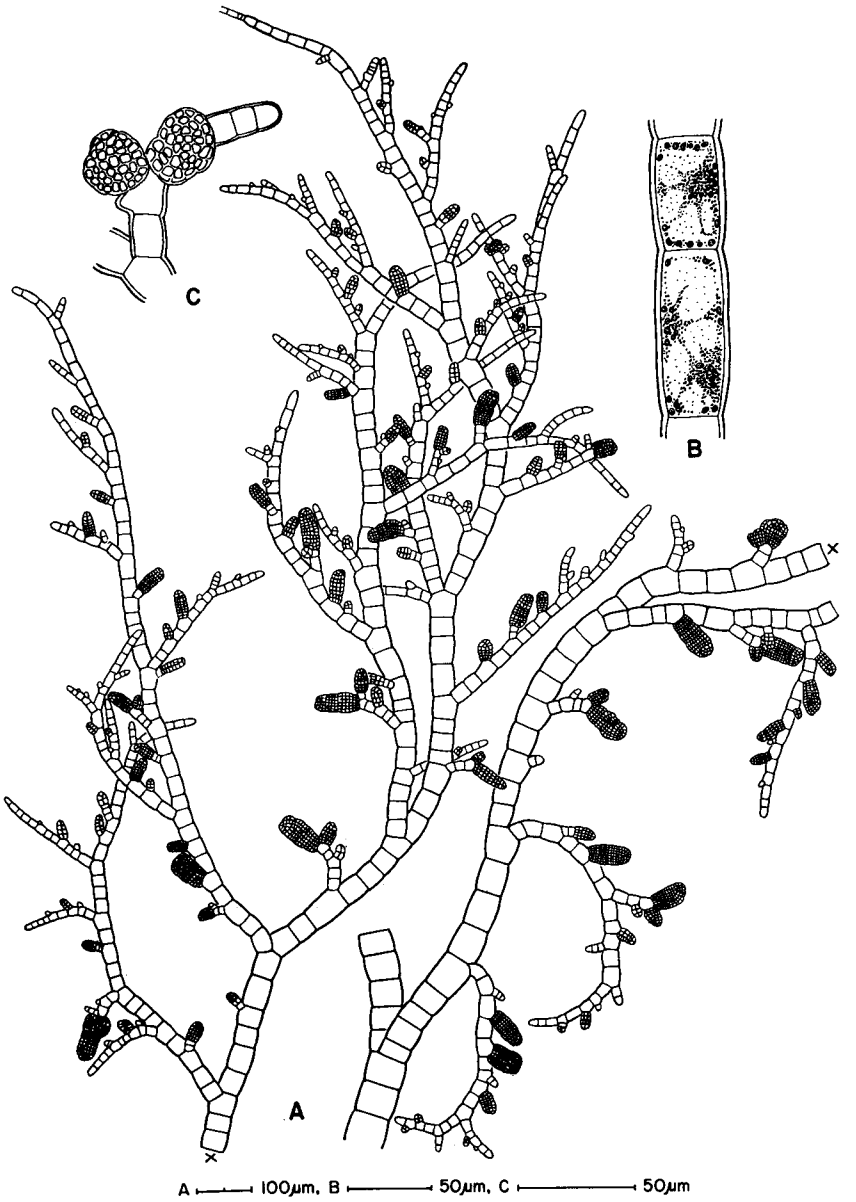

Plate IV *Polytretus reinboldii.* A old filament without hairs of the plant on *Sargassum thunbergii*; B showing discoid chloroplasts. (Oshoro, March 19, 1947).

Plate V *Polytretus reinboldii.* A, B young erect filaments with hairs of the plant on *Sargassum thunbergii*; C rhizoidal filaments from basal part of erect filament (A, B Oshoro, May 11, 1948; C Oshoro, March 19, 1947).

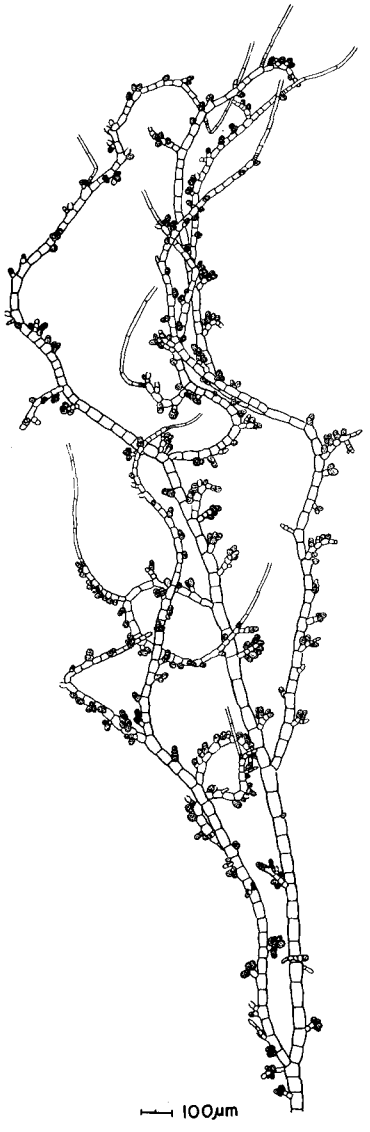

Plate VI *Polytretus reinboldii.* Filament with unilocular sporangia (?) on *Sargassum confusum* (Oshoro, May 11, 1948).

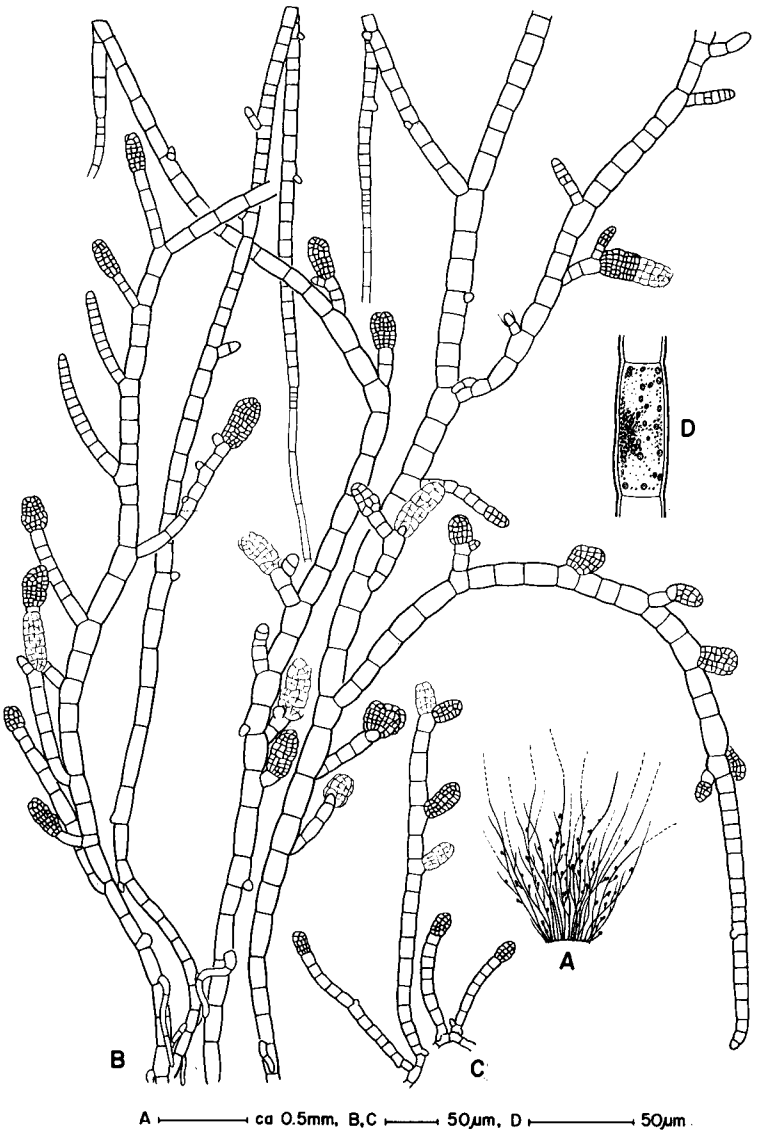

Plate VII *Polytretus reinboldii* f. *minutus*. A habit; B erect filaments; C terminal plurilocular sporangia on erect filaments issued from creeping filaments; D showing discoid chloroplasts. (On *Sargassum thunbergii*, Muroran, September 12, 1946).