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A Taxonomic Study on *Dermatocarpon* and Its Allied Genera (Lichenes, Verrucariaceae) in Japan*

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Abstract The genus *Dermatocarpon* and its allied genera of the lichen family Verrucariaceae in Japan are taxonomically revised. Eleven species belonging to the following five genera are recognized: *Catapyrenium* Flotow, *Dermatocarpella* Harada, *Dermatocarpon* Eschweiler, *Neocatapyrenium* Harada, and *Scleropyrenium* Harada. Of these genera, three are described as new, namely, *Dermatocarpella*, *Neocatapyrenium*, and *Scleropyrenium*. Three species are described as new to science: *Dermatocarpella yoshimurae*, *Scleropyrenium japonicum*, and *S. kurokawae*. Three new combinations are made: *Dermatocarpella kisovensis* (Zahlbr.) Harada, *D. squamulosa* (Ach.) Harada, and *Neocatapyrenium cladonioideum* (Vain.) Harada. Detailed description, illustration, habitat, and range are given for each species with taxonomic notes, and the keys to the genera and species are provided.

Key words: Lichenes, taxonomy, Verrucariaceae, *Catapyrenium*, *Dermatocarpella*, *Dermatocarpon*, *Neocatapyrenium*, *Scleropyrenium*.

The foliose and squamulose species with hyaline simple spores in the Verrucariaceae (or the Dermatocarpaceae by some authors) have been generally treated under the single genus *Dermatocarpon* by many lichenologists such as Zahlbruckner (1906, 1921, 1926) till recently. Most of these authors seemed to be aware of the heterogeneity of the genus and frequently recognized subgenera or sections in *Dermatocarpon*. Recently two generic names, *Catapyrenium* and *Placocarpus*, were resurrected to accommodate certain species or a species group of *Dermatocarpon* s. lat. However, the genus seems to have been still retained heterogeneous.

In Japan, species of *Dermatocarpon* and its allied genera have been studied only in a limited extent, and all the species have been treated under the genus *Dermatocarpon* following the generic concepts of Zahlbruckner (1906, 1921, 1926).

The present study aims at achieving clearer concepts of the genera segregated from *Dermatocarpon* (s. lat.) on the basis of the current knowledge of lichenology and to give description to each species found in Japan.

History

1. General history

A number of lichens referable to *Dermatocarpon* s. lat. were described in the 18th century under the classic genus *Lichen*, e.g. *Lichen miniatus* L. (1753), *Lichen luridus* With. (1776) *etc.* They were included in the genus *Endocarpon* (non Hedw.) by Acharius in his monumental works (Acharius, 1803, 1810, 1814).

Eschweiler (1824) described the genus *Dermatocarpon*, which was almost completely neglected for half a century till it was accepted by Th. Fries (1860). During this period, some generic names were proposed for certain species included in the circumscription of *Dermatocarpon* s. lat. These were *Sagedia* Fries (1825), *Catapyrenium* Flotow (1850), *Endopyrenium* Koerber (1855), *Placidium* Massalongo (1855), *Rhodocarpon* Loennroth (1858), and *Placocarpus* Trevisan (1860).

The genus *Dermatocarpon* was circum-

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scribed very broadly as were many other genera such as *Lecidea* or *Parmelia* by Zahlbruckner (1906, 1921, 1926). This concept had been followed by most lichenologists till recently. In the 1980's some authors revised *Dermatocarpon* s. lat. and recognized genera with more limited circumscriptions. Accordingly, the genus *Catapyrenium* Flotow (Hawksworth, James and Coppins, 1980; Thomson, 1987; Breuss, 1990) and *Placocarpus* Trev. (Breuss, 1985) were resurrected.

Dermatocarpon s. lat. of Japan was first studied by European lichenologists (Müller, 1892; Vainio, 1918), reporting *D. miniatum* and *D. fluviatile*. Since then, the following four species of this genus have been added mainly by Japanese lichenologists: *D. myogiense* Asahina (1933), *D. tuzibei* Sato (1939), *D. kisovense* Zahlbruckner (1931), and *D. moulinsii* Zsch. (Asahina, 1957). On the other hand, *D. fluviatile* was excluded from the Japanese lichen flora by Sato (1940) who considered the record was based on the misidentification of *D. miniatum*. Consequently five species of *Dermatocarpon* s. lat. have been known from Japan before the present study.

Materials and Methods

1. Materials

About 500 specimens were studied during the present study. I made field trips to various parts of Japan, from Hokkaido to Kyushu, mainly 1985 through 1987 to collect specimens and make ecological observations. The specimens are deposited in the herbarium of Hiroshima University (HIRO). Specimens from TNS, NICH, KYO, and CBM (Natural History Museum and Institute, Chiba) were also used for morphological and anatomical observations. In addition, material from the private herbarium of Dr. I. Yoshimura was also studied. For the present study, I have fortunately had the opportunity to study type specimens of the species of the Verrucariaceae and related families, loaned from the following herbaria: BM, FH, G, H, K, KYO, L, M, TNS, TUR, VER, and W.

2. Methods

Observations on external morphologies were made on air-dried materials, usually with a dissecting microscope (Olympus SZH 111). Some habit drawings were made with drawing equipment. Habit photographs were taken using this microscope with an Olympus PM10ADS camera.

For anatomical studies I made thin sections of the thallus, perithecia and pycnidia with a razor blade under the dissecting microscope. GAW preparations of these sections were usually used for observations and measurements of thallus, perithecia, pycnidia, *etc.* After the mounting medium was replaced by the lactophenol cotton-blue (abbreviated as LPCB), the same preparations were used for line-drawing and photographing various parts of thalli, perithecia and pycnidia, and for observations and measurements of spores and pycnoconidia. GAW was substituted by iodine (a diluted Lugol's solution) for observing iodine reactions of hymenium, asci, etc. Anatomical observations and measurements were made with a compound microscope in the magnifications of 40 to 1000. Line-drawings were made with the aid of drawing equipment. Photomicrographs were taken with this microscope equipped with an Olympus PM10ADS or an Olympus OM2N camera.

For chemical analysis, representative specimens of each species were tested by the TLC (thin-layer chromatography) method described by Culberson and Johnson (1982).

External Morphology and Anatomy

1. Thallus

1) External morphology of thallus

a) Habit. The thallus of the species treated are (1) foliose (umbilicate) or (2) squamulose, depending on genera.

(1) Foliose genus is represented only by *Dermatocarpon* s. str. among the genera treated. In *D. miniatum* and *D. vellereum* the foliose thallus is circular, frequently monolobed and has an umbilicus near the center on lower surface as in *Umbilicaria*. The thallus may be polylobed or seems to be composed of up to several individuals. In *D. tuzibei*, however, the thallus is almost squamulose and exclusively lobate with plural umb-

ilici scattered over the lower surface (see under lower surface of thallus).

The lobes vary greatly in size within a species, but is apparently different between species. Those are 1–5 cm in diameter in *D. miniatum* and 1–7 cm in *D. vellereum*, but up to 1 cm in diameter in *D. tuzibei*.

(2) The thallus is squamulose in the following four genera: *Catapyrenium*, *Dermatocarpella*, *Neocatapyrenium*, and *Scleropyrenium*.

The thallus is composed of loosely aggregated squamules which are easily separable from one another in species of *Dermatocarpella*, *Neocatapyrenium cladonioideum*, and *Scleropyrenium japonicum*. On the other hand, squamules are closely or tightly aggregated and are more or less difficult to separate into individual squamules in *Scleropyrenium kurokawae*, *Catapyrenium cinereum* and *C. psoromoides*.

The squamulose thallus is mono-lobed or lobate. In *Scleropyrenium japonicum* and *Dermatocarpella kisovensis* it is frequently mono-lobed, or dissected to weakly lobate. The thallus becomes more apparently dissected or lobate in *Dermatocarpella squamulosa* and *D. yoshimurae*. Only *Neocatapyrenium cladonioideum* has a exclusively and distinctly lobate thallus. The thallus is more or less lobate in *Catapyrenium cinereum*, *C. psoromoides* and *Scleropyrenium kurokawae*.

Squamules are apparently ascending in *Neocatapyrenium cladonioideum* which is attached to the substratum only at the basal ends. The thallus are attached to the substratum over the whole or most of the lower surface in the remaining species. Among them, *Catapyrenium cinereum* is most tightly attached to the substratum with the whole lower surface. The thalli of *Dermatocarpella yoshimurae* and *Scleropyrenium japonicum* are more or less loosely attached and are usually detached in some parts along the margin.

Lobes in the squamulose genera vary in shape from rotund to linear depending on the species. Only *Neocatapyrenium cladonioideum* has typically linear lobes. Rotund lobes are found in species of *Dermatocarpella*, *Catapyrenium cinereum* and *Scleropyrenium japonicum*. In *Catapyrenium cinereum* and *Scleropyrenium kurokawae*, the thallus consists of squamules with rotund to sublinear lobes which are very closely contiguous and very tightly attached to each other.

Among the species with rotund lobes, *Dermatocarpella yoshimurae* is somewhat different from the remainder in having frequently undulating lobe-margins.

Lobes of the squamulose thallus may be discrete, contiguous or overlapping. Lobes are more or less discrete to imbricate in *Neocatapyrenium cladonioideum*. Although the thallus is frequently imbricate in *Catapyrenium psoromoides*, the lobes are usually overlapping. Lobes of *Dermatocarpella yoshimurae* and *D. squamulosa* are discrete, contiguous to overlapping, and with more or less undulating margins, more apparently in the former species. They are exclusively contiguous and very tightly attached to adjacent ones in *Scleropyrenium kurokawae* and *Catapyrenium cinereum*.

b) Upper surface of thallus. Isidia, soredia and pustules are not found in the genera treated here nor in the whole Verrucariaceae, although they are very common in Lecanorales.

The upper surface of the thallus is scabrose or smooth, corresponding to the anatomy of the upper cortex (see 2. Anatomy of thallus). When smooth the upper surface is more or less shiny.

The color of the thallus does not vary much through the genera, since none of the species produces usnic or pulvinic acid derivatives or other pigments in the cortex. The thallus may be pale to dark gray or brown to almost black.

The variation of the color in each species seems to depend largely on ecological conditions. In *Dermatocarpon miniatum* in aqueous or amphibious habitats, the upper surface of a thallus grown in exposed condition is darker than one grown in mostly submerged condition. In terrestrial habitats, this species is darker in sunny conditions than in shaded conditions. Such darker surface is ascribed to the darkening of hyphal walls of the upper cortex. But in *Catapyrenium cinereum*, thalli

at sunny sites tend to be whitish. This discoloration results from disorganization of the upper cotext.

c) Lower surface of thallus. Various anchoring organs are formed on the lower surface, namely, (1) umbilicus, (2) rhizohyphae and/or (3) rhizines (the terminology fundamentally follows Hannemann, 1973). The anchoring organs are different among species and even among genera and are of great taxonomic value.

(1) An umbilicus is a kind of stipe, which is usually present near the center of the thallus on the lower surface. In Verrucariaceae, it is found only in species of *Dermatocarpon*. In Japan, a typical umbilicus is found at the center of the lower surface of thallus in *D. miniatum* and *D. vellereum*. *D. tuzibei* is unique among this genus in having plural umbilici scattered on the lower surface of thallus. They resemble sparse and short simple rhizines found in some genera of Parmeliaceae.

(2) Rhizohyphae are originated and elongated from the lower surface of the thallus, and they play the role of fastening the thallus to the substratum. They are characteristically found in species of *Catapyrenium*, *Dermatocarpella* and *Scleropyrenium*. The hyphae are usually sparse and almost hyaline to pale brown. In *Catapyrenium psoromoides*, however, the rhizohyphae form a dense mat on the lower surface and extend beyond the margin of the thallus, so that the thallus can be considered to form hypothallus.

(3) Rhizines are bundles of hyphae which run longitudinally and are more or less conglutinated to each other. They are found in species of *Scleropyrenium*. The rhizines are usually located near the center of the thallus on the lower surface and may be one to a few in number in one thallus.

Squamules of *Neocatapyrenium cladonioideum* attach to the substratum only at the basal end so that they appear almost stipitate just as *Sticta gracilis*. In *N. cladonioideum* the squamules are not distinctly spreading at the base. The squamules themselves are more or less penetrating into soft substratal rocks, and at the basalmost part there may be a few, somewhat fragile rhizines.

Rhizinomorphs are rhizine-like organs on the lower surface of the thallus but do not take part in attaching the thallus to the substratum (Hannemann, 1973). Among the species treated, only *Dermatocarpon vellereum* bears rhizinomorphs. They are repeatedly branched and the branchlets are more or less inflated and rounded at the apices, making the rhizinomorphs appear botryoid in shape (Poelt, 1977).

Although the color of the lower surface varies from white or pale to dark brown or almost black, it seems to be rather stable within a species. In *Dermatocarpon miniatum*, however, the color seems to largely vary according to the ecological conditions. It varies from very pale brown to dark brown, and in some cases almost black. Similar to the upper surface of the thallus, the lower surface tends to be darker in color in more exposed conditions. There may or may not be pink-pigmented regions on the lower side of the thalli of this species at aqueous or amphibious habitats.

2) Anatomy of thallus

The thallus of all genera treated is heteromerous and usually differentiated into four layers: upper cortex, algal layer, medulla and lower cortex. The constitution of the thallus and/or the tissue of each layer is constant in every genus and largely different among genera, and are, therefore, apparently of a great taxonomic value.

The thickness of the thallus varies largely in a species, especially in *Dermatocarpon miniatum* and *D. vellereum*, depending on the age or parts of the thallus and on ecological conditions. However, the thallus apparently differs in the range of thickness between species. It may be thickest in *Dermatocarpon miniatum* or *D. vellereum*, sometimes exceeding 1 mm, but is less than 200 μm thick in *Catapyrenium cinereum* in Japan.

a) Upper cortex. The upper cortex is anatomically rather uniform within one genus but differs in different genera. There are three types of this tissue in the genera treated: (1) pachydermatous, (2) scabrose, and (3)

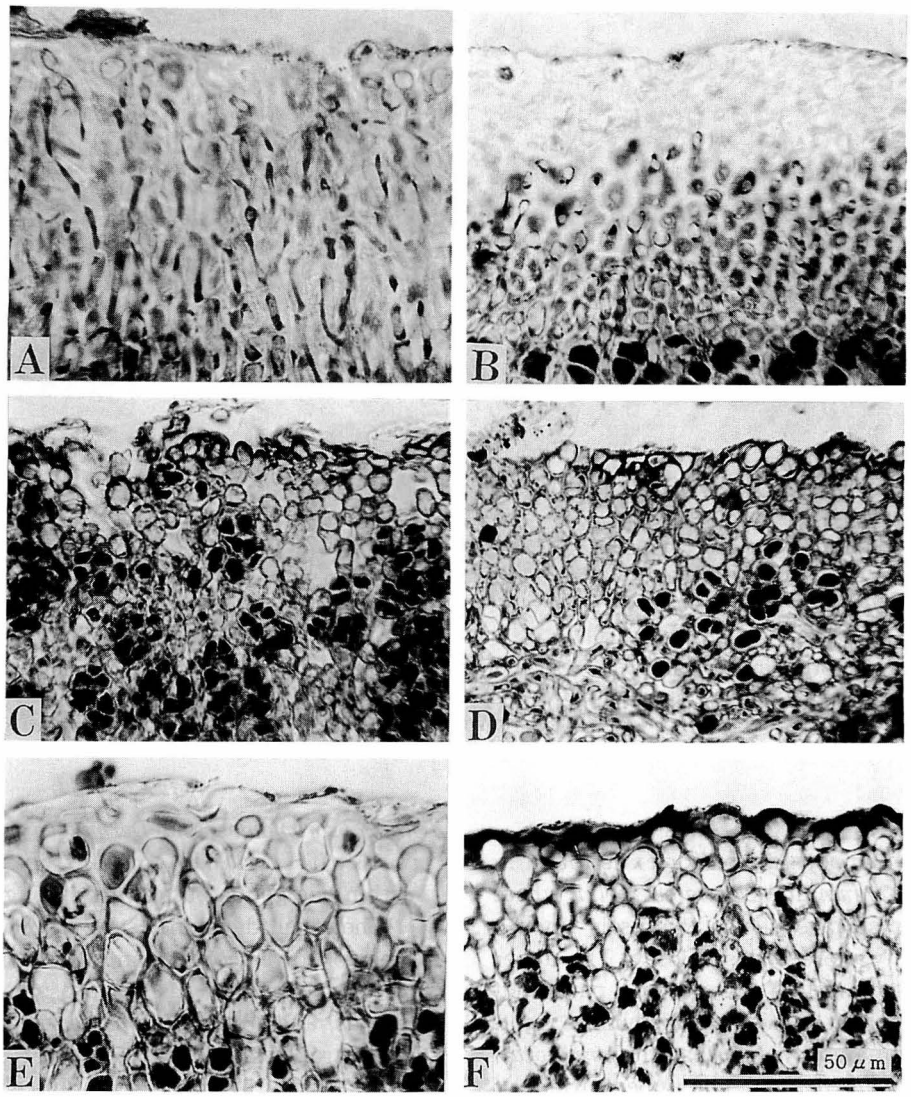

Fig. 1. Upper cortex in vertical section (LPCB preprations). A–B, pachydermatous upper cortex (A, *Scleropyrenium japonicum*, holotype; B, *S. kurokawae*, holotype). C–D, scabrose upper cortex (C, *Catapyrenium cinereum*, Harada 5013; D, *Dermatocarpon miniatum*, Harada 3090). E–F, smooth upper cortex (E, *Dermatocarpella squamulosa*, Harada 4727; F, *Neocatapyrenium cladonioideum*, Yoshimura 79452).

smooth.

(1) The pachydermatous upper cortex is restricted to *Scleropyrenium* among the genera treated. The upper cortex is apparently pachydermatous, being composed of thick-walled hyphae, and is relatively thick. The pachydermatous upper cortex of *S. kurokawae* is more or less subparaplectenchymatous, while that of *S. japonicum* tends to be prosoplectenchymatous. The upper surface of the thallus in this genus is smooth and more or less glossy.

(2) The scabrose upper cortex is characteristic of *Dermatocarpon* and *Catapyrenium* among the genera treated. In these genera, the upper cortex is a more or less loose and thin-walled paraplectonchyma which seems to degenerate primarily through losing parts of the uppermost layer. The upper surface of the thallus is more or less finely scabrose in

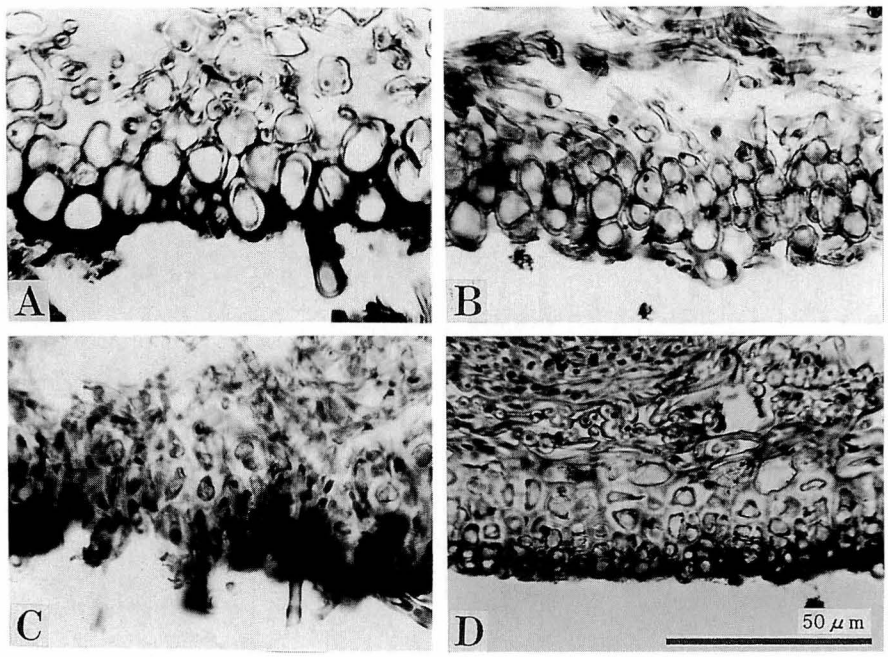

Fig. 2. Lower cortex in vertical section (LPCB preparations). A–B, paraplectenchymatous lower cortex (A, *Dermatocarpella squamulosa*, Harada 4727; B, *Neocatapyrenium cladonioideum*, Yoshimura 79452). C, prosoplectenchymatous lower cortex (C, *Scleropyrenium japonicum*, holotype). D, lower cortex of the *Dermatocarpon*-type (D, *Dermatocarpon miniatum*, Harada 3090).

these genera.

(3) The smooth upper cortex is found in *Neocatapyrenium* and *Dermatocarpella*, where the upper surface of the thallus is smooth and usually more or less glossy. The upper cortex is thin-walled and a typical paraplectenchyma which consists of much more tightly conglutinated hyphae than in *Dermatocarpon* and *Catapyrenium*. The upper surface of this type is prominently smooth when the vertical section of thallus is observed with an optical microscope. Dead hyphae on the uppermost layer of the cortex seem to become horizontally flattened, before they slough off from the upper surface of thallus.

The upper cortex is more or less even in thickness in most species treated. In *Scleropyrenium japonicum*, in contrast, the upper cortex is extended downward between masses of phycobiont cells and is, therefore, quite uneven in thickness.

b) Lower cortex. The lower cortex is well developed in the Japanese species of the squamulose and foliose genera, except *Catapyrenium psoromoides* and *Dermatocarpella kisovensis*. It is rather constant in anatomy within one genus but differs among genera.

When well developed, the following three types of lower cortex can be recognized: (1) paraplectenchymatous, (2) prosoplectenchymatous, and (3) the *Dermatocarpon*-type. (1) The paraplectenchymatous lower cortex is characterized by single to multi-cell-layered and thin-walled hyphae with almost isodiametric lumina. It is characteristic of species of *Dermatocarpella* (Fig. 2A), *Neocatapyrenium* (Fig. 2B), and *Catapyrenium cinereum*. (2) The prosoplectenchymatous lower cortex is composed of vertically running hyphae with more or less thickened walls. It is found in *Scleropyrenium* (Fig. 2C). (3) The lower cortex of the *Dermatocarpon*-type may be considered to be paraplectenchymatous but is composed of thick-walled hyphae with more or less irregularly shaped lumina. The lumina are usually smaller in the outer part of the lower cortex. This type of lower cortex is quite unique and found only in *Dermatocarpon* (Fig.

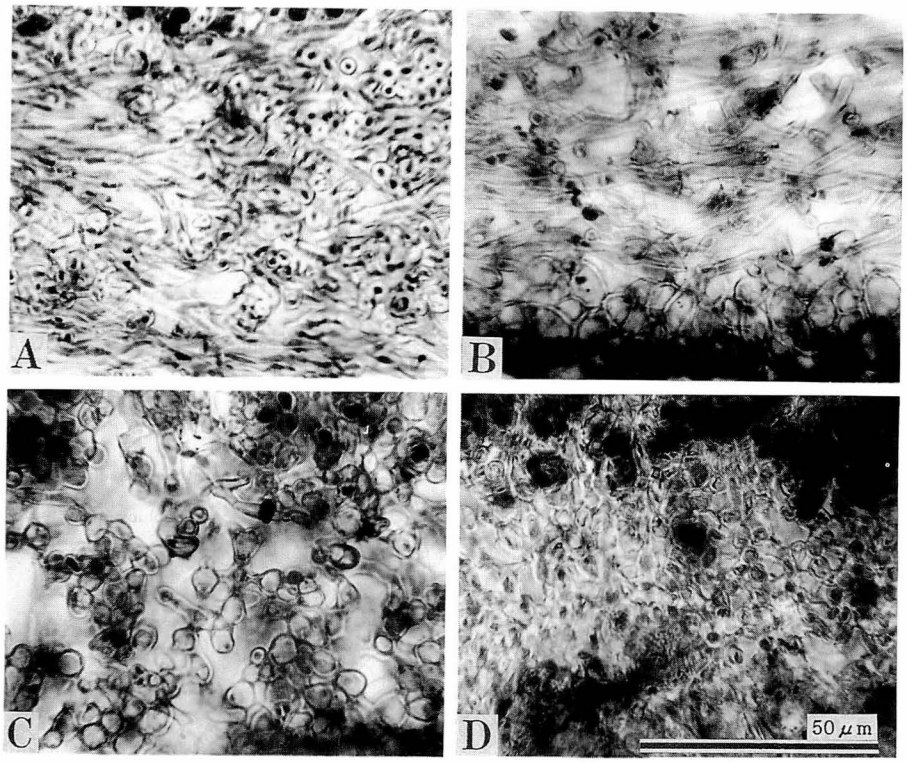

Fig. 3. Medulla in vertical section (LPCB preparations). A–B, medulla composed of filamentous hyphae (A, *Dermatocarpon miniatum*, Harada 3090; B, *Neocatapyrenium cladonioideum*, Yoshimura 79452). C–D, medulla composed of spheric hyphae (C, *Catapyrenium cinereum*, Harada 5013; D, *Scleropyrenium kurokawae*, Harada 4284).

2D), so that it is here named for that genus.

c) Medulla. The medulla consists of (1) filamentous and/or (2) spheric hyphae. (1) The filamentous hyphae are hyaline, uniform in thickness, running in horizontal directions, and sparsely branched and anastomosing. The whole medulla consists of hyphae of this type in species of *Dermatocarpon* (Fig. 3 A), *Neocatapyrenium* (Fig. 3 B), *Dermatocarpella squamulosa*, and *Scleropyrenium japonicum*. The hyphae are constantly thin-walled in most genera, whereas they are frequently thick-walled and tightly conglutinating in some parts in *Dermatocarpon*. In the latter genus, the thickness of medullary hyphae seems to be related to the ecological conditions and the age of the thallus. (2) The spheric hyphae are more or less inflated with constrictions at the septa. Usually these hyphae are thin-walled and repeatedly branched. This type of hyphae predominates in the medulla of the following genera and species: *Catapyrenium* (Fig. 3C), *Scleropyrenium kurokawae* (Fig. 3D), and *Dermatocarpella yoshimurae*. The individual cells tend to be more or less elongated in *S. kurokawae* and *Catapyrenium*.

The thickness of the medulla varies greatly, largely depending on the age of thallus and the ecological conditions.

d) Algal layer. A more or less distinct algal layer is formed in all the species of the squamulose and umbilicate genera of the Verrucariaceae. Phycobiont cells are more dense in the upper part of the algal layer than in the lower part. Thus, the algal layer is more sharply delimited in the upper limit than in the lower one. In *Scleropyrenium japonicum*, on the other hand, the phycobiont cells appear to be arranged more or less in vertical rows in the thallus and tend to form masses rather than a horizontally continuous

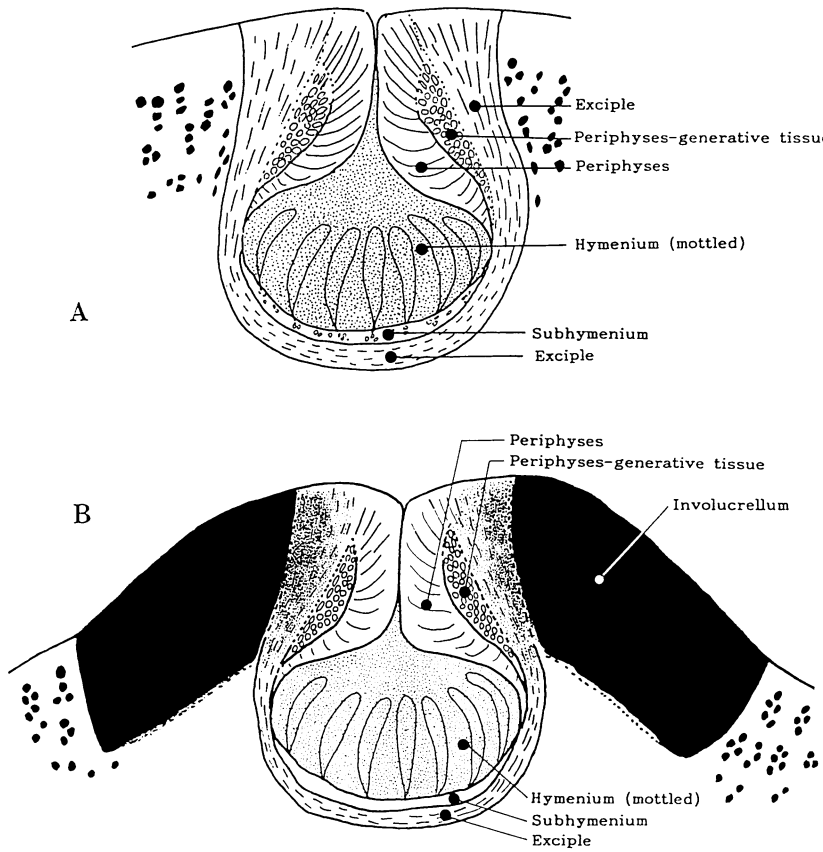

Fig. 4. Ascomata of Verrucariaceae in vertical section (schematic). A, ascoma without involucrellum. B, ascoma with involucrellum.

layer.

2. Perithecia

Ascomata of the Verrucariaceae are perithecia. They are laminal, usually scattered over the thallus, and are almost completely immersed in the thallus in the species treated. Each of the perithecia is simple with an apical ostiole. Perithecia are globose to pyriform and characterized by the lack of hamathecium other than periphyses, as defined by Henssen and Jahns (1973) for the Verrucariaceae. The hymenium is enclosed by the exciple, a sac-like structure, which also encloses subhymenium at the bottom and sides and periphyses-generative tissue in the upper parts. The exciple is surrounded by involucrellum (Fig. 4B) in the crustose genera of the family, but is directly surrounded by the thallus in the genera treated in the present study.

1) Two types of exciple

The exciple is (1) hyaline or (2) brown, depending on genera.

(1) The hyaline exciple (Fig. 5 A–C) remains largely colorless even (Fig. 5A) at the maturity of the ascoma but frequently becomes pale brown only in the upper parts (Fig. 5B). Or, less frequently, only the outermost layer of the exciple may be pale brown (Fig. 5C). This type of exciple is found in *Dermatocarpon*, *Dermatocarpella*, and *Neocatapyrenium*.

(2) The brown exciple (Fig. 5D, E) is pigmented even in juvenile stages of the ascoma. This type is presented by *Catapyrenium* and *Scleropyrenium*. The exciple is more or less dark brown in *Catapyrenium* (Fig. 5D), very dark brown to almost black in *Scleropyre-*

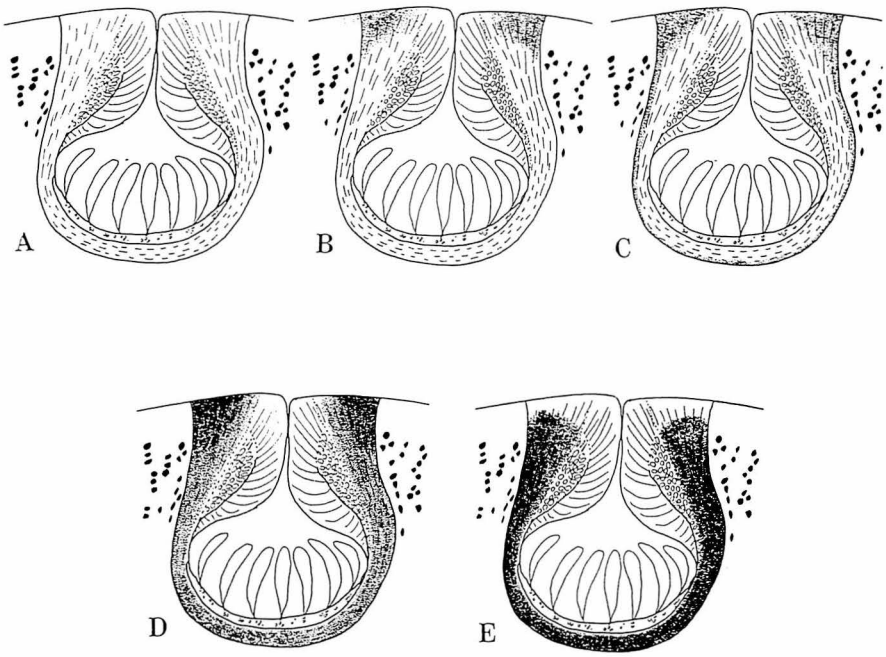

Fig. 5. Exciples in vertical sections (schematic). A–C, hyaline exciples (A, hyaline throughout; B, brown only at the uppermost; C, brown at the uppermost and the outermost). D, E, brown exciples (D, brown; E, very dark brown to almost black, or carbonized).

nium (Fig. 5E).

Although the thickness of exciple varies greatly in a species, depending on the age of ascomata or the ecological conditions, the range is different among species or genera. The exciple becomes very thick, sometimes exceeding 100μm, in *Dermatocarpon*, *Dermatocarpella*, *Neocatapyrenium*, and *Scleropyrenium*. In *Catapyrenium*, however, it is only 20 to 40μm thick.

2) Periphyses

Periphyses are elongated from periphyses-generative tissue which usually lines the upper and middle part of the exciple. In vertical section of the perithecium, the layer of periphyses is largely seen as a pair of triangles (Fig. 4). Those in the upper and middle parts of the layer are relatively long and become shorter in the lower part. The length of periphyses is rather stable in the middle part within a given species, and the periphyses in this part are, therefore, measured as the length of periphyses in this study. They are usually 20–30μm in most species, but very short in *Catapyrenium* (usually about 10μm long).

Periphyses are septate, very sparsely branched and anastomosing in the genera treated.

3) Asci and spores

Asci are, according to the definition of the family Verrucariaceae, bitunicate, usually clavate, more or less thick-walled, especially near the apices, and non-amyloid without exception.

Ascospores are simple, smooth-surfaced, non-amyloid and lack a halo in all the genera treated. They are usually 15 to 20μm long and about 10 μm wide, as frequently encountered in many species of other groups of lichens. However, the size and shapes are more or less different between species.

3. Pycnidia and pycnoconidia

Pycnidia and pycnoconidia of lichenized Ascomycetes have been thought to be a kind of spermogonia and spermatia of the mycobionts, respectively. They have been consid-

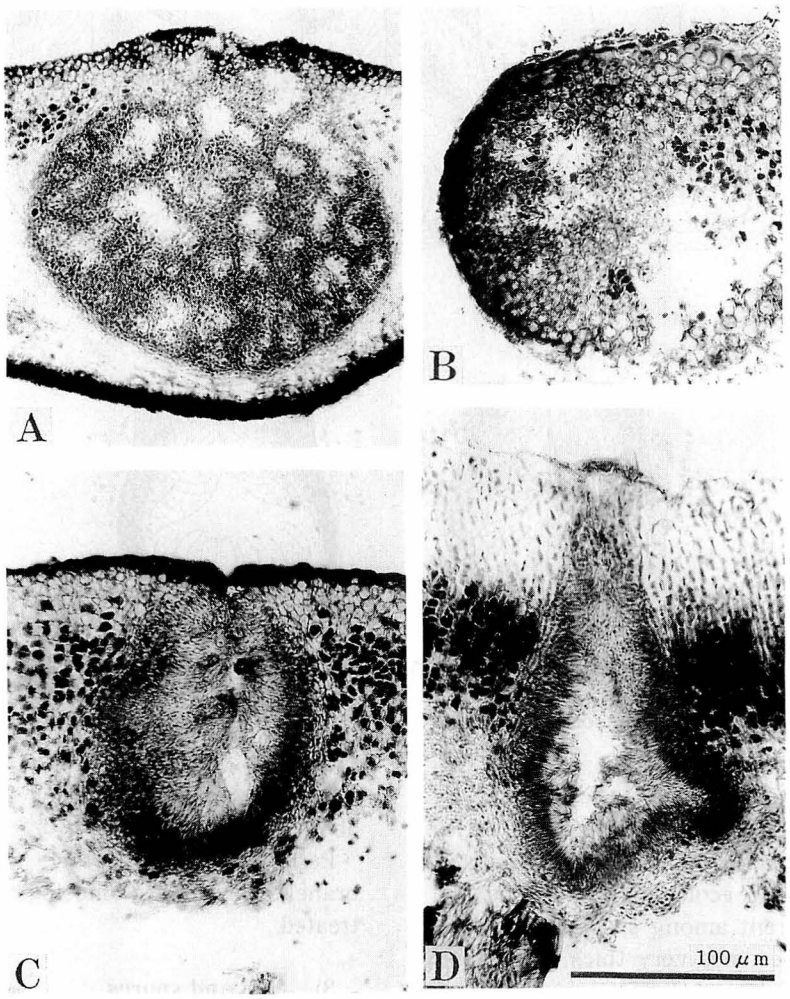

Fig. 6. Pycnidia in vertical section (LPCB preparations). A–B, *Xanthoria*-type (A, *Dermatocarpon miniatum*, Harada 3090; B, *Dermatocarpella yoshimurae*, Harada 1083); C–D, *Staurothele*-type (C, *Neocatapyrenium cladonioideum*, Yoshimura 79452; D, *Scleropyrenium japonicum*, holotype).

ered as important features in the classification of fungi as well as lichens. In the Verrucariaceae, however, they have been studied only in some species by Glück (1899), Vobis (1980), and Wagner and Janex-Favre (1986). Breuss (1990) has been the only lichenologist who evaluated the position of pycnidia on thallus and the shape of pycnoconidia as important features in separating species in *Catapyrenium* (s. lat.).

Pycnidia are very common in the species treated except *Catapyrenium cinereum* and *C. psoromoides*. In these two species pycnidia have not been found through this study nor have they been reported before.

1) Two types of pycnidia

Two types of Pycnidia are found in the genera treated: the *Xanthoria*-type and *Staurothele*-type. The difference between these two types is very significant and is used for the definition of genera in this family for the first time in the present work.

a) Xanthoria-type. This type of pycnidium is characterized by the plurilocular cavity and the wall composed of almost isodiametric cells (Fig. 6A, B). Pycnidia of this type originate from a small mass of spherical

cells in the algal layer, which grows in three dimensions. They are almost spheric when mature (Glück, 1889; Vobis, 1980; Wagner and Janex-Favre, 1986). These pycnidia continue to grow in three dimensions keeping a spheric shape, until they contact the lower cortex. They sometimes push the lower cortex downward, and may be recognized as round verrucae on the lower surface.

Pycnidia of this type are characteristic of species of *Dermatocarpon* and *Dermatocarpella* among the genera treated. They are also found in the monotypic genus *Placocarpus* among exotic genera in the family Verrucariaceae, with the type species *P. schaereri* (formerly known as *Dermatocarpon monstrosum*).

b) Staurothele-type. This type of pycnidium is characterized by the single (but rarely semi-plural) cavity enclosed by more or less elongated hyphae (Fig. 10C–E). It was named and illustrated for *Staurothele iwatsukii* Harada (1991) and was also observed and illustrated in detail for *Endocarpon pusillum* by Wagner and Janex-Favre (1986). Pycnidia of this type seem to be originated in the algal layer as in the *Xanthoria*-type. They grow mainly in a vertical direction and less extensively in a horizontal direction, and are vertically slender as compared with the *Xanthoria*-type.

Staurothele-type is found in *Neocatapyrenium* and *Scleropyrenium* among the genera treated, and also in *Staurothele*, *Endocarpon*, and *Verrucaria* within the Verrucariaceae.

2) Position of pycnidia

Pycnidia, when present, are usually laminal in most Japanese species examined. Marginal ones are very rare in the Verrucariaceae, being found only in species of *Dermatocarpella*, which have laminal or marginal pycnidia, or either, depending on species or thallus.

In the species examined, pycnidia are found usually on sterile thalli, but rarely on the fertile (with ascomata) ones. Pycnidia on the fertile thalli are more difficult to detect since they are easily confused with ascomata in appearance.

The laminal pycnidia are completely immersed in the thallus ("vollständig eingesenkt" in the sense of Vobis 1981). When marginal, the pycnidia are half-immersed ("halb eingesenkt" by Vobis 1981).

3) Pycnoconidia

Pycnoconidia are relatively constant in color and form, namely, hyaline, simple, thin-walled, bacillar, about 1 μm wide and 5 μm long. However, they apparently differ in subtle morphologies among species and genera, and are of taxonomic value, as shown for the species of *Catapyrenium* s. lat. by Breuss (1990).

Phycobiont

Phycobionts of the Verrucariaceae are assigned to the green algae invariably. Even though phycobionts have never been isolated and observed in any Japanese species of Verrucariaceae, they have been often investigated in exotic species of the family. Recently Tschermak-Woess (1988) summarized previous reports on phycobiont species of lichens, in which many species of green algae of the Chlorococcales were listed as the phycobionts of Verrucariaceae.

Chemistry

Although some primary metabolic substances have been reported (summarized in Culberson, 1969, 1970; Culberson, Culberson and Johnson, 1977), no "lichen substance" has ever been recorded in *Dermatocarpon* s. lat. nor in the whole Verrucariaceae. No lichen substance has been detected among the species treated in this study.

Habitat and Ecology

Similar to other genera of the Verrucariaceae, the species treated are usually saxicolous or terricolous with only exceptional corticolous species. Species of *Dermatocarpon* and *Neocatapyrenium* are exclusively saxicolous; species of *Dermatocarpella* are terricolous, muscicolous or saxicolous, more or less depending on species; species of *Scleropyrenium* are terricolous or saxicolous; *Catapyrenium psoromoides* is the only corticolous species, but *C. cinereum* is terricolous.

As to the saxicolous species, the substrata

are usually limited to certain kinds of rocks. Calcareous rocks are inhabited by *Dermatocarpon miniatum*, species of *Scleropyrenium* and *Dermatocarpella*. In Japan, *Dermatocarpon vellereum* and *D. tuzibei* are found only on serpentine or ryolite. *Neocatapyrenium cladonioideum* grows on volcanic rocks such as andesite.

Some saxicolous species seem to prefer certain ecological conditions rather than the substratum. *Dermatocarpon miniatum* is found not only on limestone at non-aqueous habitats but also on other rocks at amphibious habitats.

Taxonomy

The family Verrucariaceae has been treated as the sole family of the order Verrucariales (Henssen and Jahns, 1973; Poelt 1974, etc.). Although the circumscription of the order was fundamentally the same, there were some differences in the definition of Verrucariales among authors. Henssen and Jahns (1973) defined the order as having (1) perithecia of ascohymenial development, (2) periphyses as the only hamathecium, (3) bitunicate asci, (4) plurilocular pycnidia composed with short-celled conidiophores, and (5) green algae as phycobionts. Poelt (1974) described it as characterized by (1) perithecia structurally similar to apothecia of Lecanorales, (2) persistent periphyses, (3) paraphyses very soon gelatinizing and deliquescing, (4) asci nonfissitunicate and I− or I+ blue, (5) immersed pycnidia, (6) fulcra with long cells, (7) thread-like pycnospores, (8) protococcoid algae. Hale (1983) described it as having "(1) pseudothecia resembling perithecia; (2) paraphyses often gelatinizing or lacking at maturity."

These definitions look rather different from each other, but the disagreements are mainly caused by different usages of the technical terms. Pycnidia were described in quite different ways in Henssen and Jahns (1973) and in Poelt (1974) as noted above. As pointed out above there are two types of pycnidia in this family, and their descriptions were apparently based on different species. There are much differences also in describing hamathecium between these authors. Henssen and Jahns (1973) excluded the presence of paraphyses. In contrast, Poelt (1974) indicated as "paraphyses very soon gelatinizing and deliquescing" and Hale (1983) similarly as "paraphyses often gelatinizing..." "Paraphyses" reported by Poelt and Hale might be degenerating asci after ejection of spores.

In this study I basically follow Henssen and Jahns (1973) in the definitions of the order Verrucariales as well as the family Verrucariaceae. The order is defined here to be characterized by (1) perithecia, (2) bitunicate asci and (3) the lack of hamathecium other than periphyses.

The genus *Dermatocarpon* s. lat. is characterized by foliose to squamulose thallus and simple spores within the family Verrucariaceae. In the present study, the following five genera are recognized within *Dermatocarpon* s. lat. in Japan: *Catapyrenium*, *Dermatocarpon*, *Dermatocarpella*, *Neocatapyrenium*, and *Scleropyrenium*.

Key to the genera

1a. Thallus foliose (or almost squamulose), umbilicate, large, frequently exceeding 1 cm in diameter, lacking rhizohyphae; lower cortex of the *Dermatocarpon*-type ..... 5. *Dermatocarpon*

1b. Thallus squamulose, lacking umbilicus, usually less than 1 cm in diameter, frequently with rhizohyphae on the lower surface; lower cortex paraplectenchymatous or prosoplectenchymatous, or lacking 2

2a. Exciple hyaline 3

2b. Exciple brown to almost black 4

3a. Pycnidia of the *Xanthoria*-type; lobes rotund, attached to the substratum by rhizohyphae over almost the whole lower surface ..... 4. *Dermatocarpella*

3b. Pycnidia of the *Staurothele*-type; lobes linear, canaliculate below, attached to the substratum by the basal ends, almost stipitate; lower surface naked ..... 2. *Neocatapyrenium*

4a. Pycnidia of the *Staurothele*-type; the exciple almost black; upper surface of thal-

lus smooth, more or less glossy; upper cortex pachydermatous; terricolous or saxicolous·····3. *Scleropyrenium*

4b. Pycnidia unknown; exciple brown; upper surface more or less scabrose, dull; upper cortex paraplectenchymatous; terricolous or corticolous ····· 1. *Catapyrenium*

1. *Catapyrenium* Flotow

Bot. Zeit. 8: 361 (1850). Type species: *Catapyrenium cinereum* (Pers.) Körb.

Description. Thallus squamulose, with rhizohyphae, lacking rhizines and umbilicus; upper surface scabrose, dull; medulla composed of spheric hyphae; lower cortex parenchymatous or lacking. Perithecia laminal, almost completely immersed in the thallus, almost globose, lacking involucrellum; exciple brown; ascus bitunicate; spores 8 in each ascus, simple, hyaline. Pycnidia unknown.

Remarks. *Catapyrenium* s. lat. has been distinguished from *Dermatocarpon* s. str. by the squamulose rather than umbilicate thallus by Hawksworth, James and Coppins (1980), Thomson (1987), Breuss (1990), *etc.* However, *Catapyrenium* in the sense of these authors is still heterogeneous in some important anatomical characters, namely, in (1) pycnidia, (2) exciple, (3) upper cortex, *etc.* Based on differences of these characters, *Catapyrenium* (s. lat.) is divided into the following four genera in the present study: *Catapyrenium* (s. str.), *Dermatocarpella*, *Neocatapyrenium* and *Scleropyrenium.*

The exciples of these genera are either hyaline or brown (Fig. 5). A hyaline exciple is found in *Dermatocarpella* and *Neocatapyrenium*, and the brown type is characteristic of *Catapyrenium* and *Scleropyrenium.* The exciple of *Scleropyrenium* becomes highly carbonized at maturity of the perithecia. In *Catapyrenium* it becomes brown but not so dark nor carbonized.

Pycnidia are not known in species of *Catapyrenium* s. str., whilst they are very common in the remaining genera, *e.g. Dermatocarpella*, *Neocatapyrenium* and *Scleropyrenium.* Pycnidia of the *Xanthoria*-type are found in the genus *Dermatocarpella*, and those of the *Staurothele*-type are in *Neocatapyrenium* and *Scleropyrenium.*

The upper surface of the present genus is scabrose, while in *Dermatocarpella*, *Neocatapyrenium* and *Scleropyrenium* the surface is smooth and may be shiny or dull.

Key to species of *Catapyrenium*

1a. Lobes contiguous; lower cortex present, paraplectenchymatous; growing on soil or humus ····· 1) *C. cinereum*

1b. Lobes more or less overlapping; lower cortex lacking; corticolous ····· 2) *C. psoromoides*

1) *Catapyrenium cinereum* (Pers.) Koerb. (Figs. 7A and B, 8)

Syst. Lich. Germ.: 325 (1855) = *Endocarpon cinereum* Pers., Neue Annal. Bot. 1: 28 (1794). Type: Provenit ad terram in locis montosis muscosis, reperi hane speciem prope Schanzfeld: circa die alte Kirche & prope montem Meisner (L ?, not seen). For further synonyms, see Breuss (1990).

External morphology. Thallus squamulose, composed of tightly contiguous and hardly separable squamules, tightly adnate, lobate, usually up to 10 cm in diameter. Lobes rotund, 0.15–0.3 mm wide, contiguous; upper surface pale gray, more or less greenish particularly in shaded condition, more greenish towards the margin, dull, more or less finely scabrose, epruinose, almost flat or slightly convex; lower surface almost completely covered with dense rhizohyphae; rhizohyphae forming inconspicuous black hypothallus. Perithecia laminal, common, scattered, immersed in the thallus, seen as black points (ca. 0.1 mm across, prominent), slightly elevated. Pycnidia unknown.

Anatomy. Thallus 150–250 μm thick. Upper cortex 20–40 μm thick, a little brown in the uppermost parts, hyaline in the remainder, more or less loose and eu- to subparaplectenchymatous, weakly differentiated from algal layer, with or without epinecral layer (ca. 10 μm thick, hyaline at the uppermost, brownish in the lower); lumina of hyphae 5–8 μm high and 4–7 μm wide; walls of hyphae usually thin, 0.5–1 μm thick. Algal

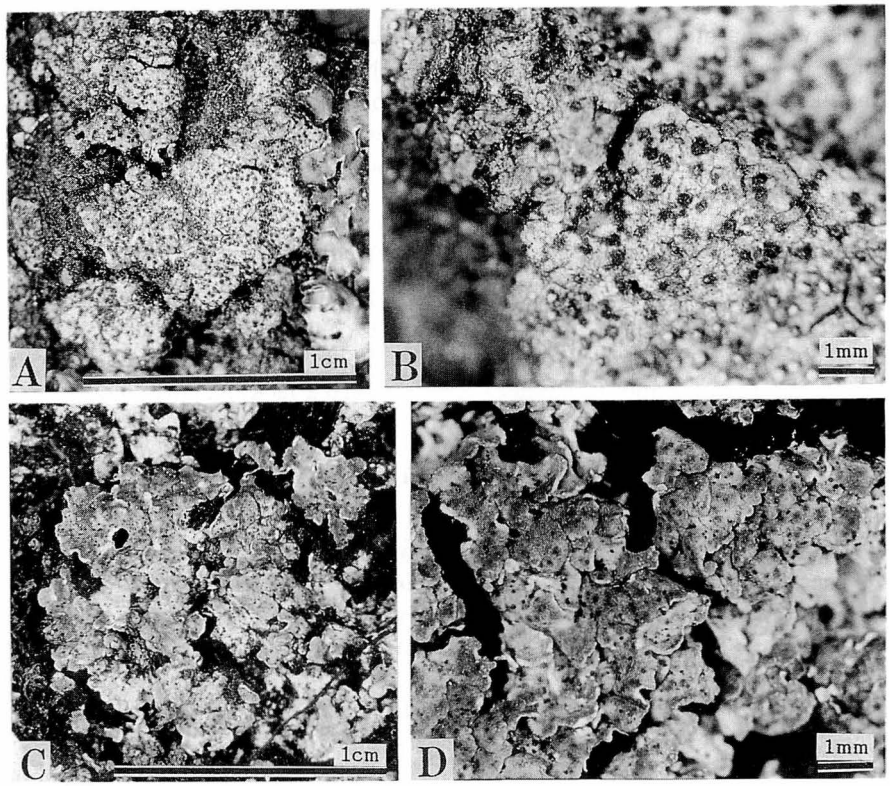

Fig. 7. Habit of *Catapyrenium*. A–B, *Catapyrenium cinereum* (Harada 5013); C–D, *Catapyrenium psoromoides* (Asahina s. n.).

layer 60–140 μm thick; phycobiont cells scattered or in clusters. Medulla up to 100 μm thick, composed of spheric hyphae (slightly elongate, 4–7 μm in diameter, with ca. 0.5 μm thick walls). Lower cortex 10–25 μm thick, very dark brown to almost black, eu- to subparaplectenchymatous, 1–3 cell-layered; lumina of hyphae isodiametric, 7–10 μm wide in the lowermost ones. Rhizohyphae dark brown, uniform in thickness, ca. 4 μm in diameter. Perithecia pyriform, 180–220 μm high and 150–190 μm wide; exciple brown, 15–20 μm thick; periphyses 15–20 μm long, ca. 2 μm in diameter; subhymenium ca. 20 μm thick in the bottom; hymenium 140–180 μm high and 110–150 μm wide; asci clavate, ca. 70×10 μm; spores 8 in each ascus, hyaline, simple (2-celled when overmatured), oval to almost fusiform, 20–25×5–7 μm.

Habitat. On soil or humus, with or without litters, between or on rocks, at more or less exposed sites, sometimes around snow beds in alpine or subalpine zones.

Range. Japan, Europe, North America, New Zealand.

Specimens examined. HOKKAIDO. Rishiri Isl., 1400–1500 m alt., H. Harada 5007, 5009 and 5013 (HIRO); Mt. Ashibetsu, ca. 1600 m alt., H. Harada 5944, 5946 and 5947 (HIRO).

Remarks. This species is characterized by (1) the thallus composed of repeatedly branched, very tightly contiguous squamules, (2) brown exciple, and (3) rather large simple spores.

This is the first record of *Catapyrenium cinereum* in Japan.

2) *Catapyrenium psoromoides* (Borr.) Sant. in Hawksw., P. James and Coppins

(Figs. 7C and D, 9)

Lichenologist 12: 106 (1980) = *Verrucaria psoromoides* Borr. in Hooker and Sowerby, English Botany, Suppl. 1: pl. 2612, fig. 1 (1831). Type: England, 'On elm at Hurstpier-

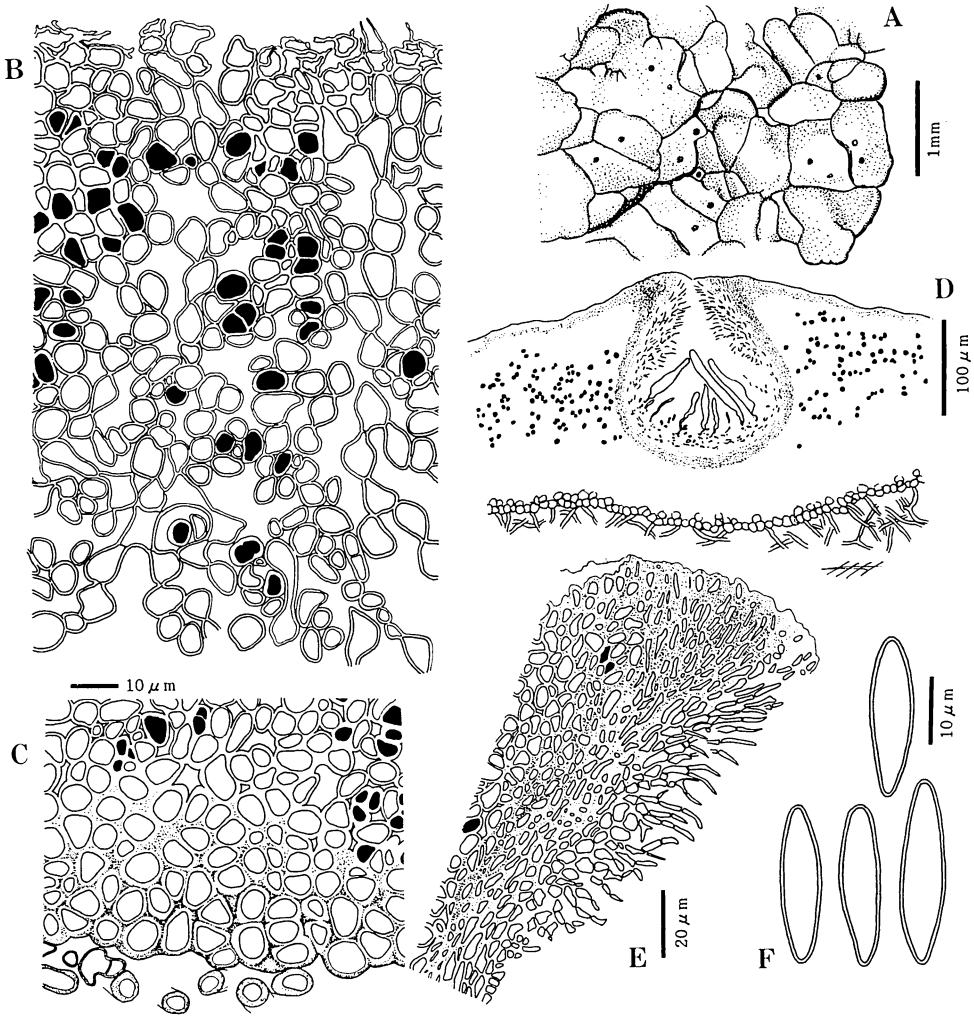

Fig. 8. *Catapyrenium cinereum* (Pers.) Koerb. A, habit. B, upper part of thallus in vertical section. C, lower part of thallus in vertical section. D, vertical section of perithecium. E, part of perithecium in vertical section. F, spores. (A, air-dried material; B–F, LPCB preparations. A–F, Harada 5009).

point and on ash at Beeding, Sussex,' Borrer, s. n. et d. (BM—not seen). For further synonymy, see under *Dermatocarpon psoromoides* in Swinscow and Krog (1975).

External morphology. Thallus squamulose, composed of overlapping and hardly separable squamules, tightly adnate, shallowly to deeply lobate, ca. 2 cm in diameter. Lobes more or less rotund, 0.5–0.8 mm wide, contiguous or slightly overlapping to imbricate, more or less ascending towards the apices; upper surface more or less grayish, pale brown, dull, slightly and very finely scabrose, pruinose or epruinose, concave to convex; lower surface with rhizohyphae, but naked and almost white or very pale brown near the margin; rhizohyphae forming a prominent hypothallus (very dark brown to almost black). Perithecia laminal, common, scattered, immersed in the thallus, dark brown (ca. 0.1 mm across). Pycnidia unknown.

Anatomy. Thallus 110–200 μm thick. Upper cortex 15–30 μm thick, more or less brown in the uppermost part, hyaline in the remainder, more or less loose and eu- to subparaplectenchymatous, with epinecral layer (up to 10 μm thick); lumina of hyphae rather small, 4–9 μm high, 4–6 μm wide; walls of

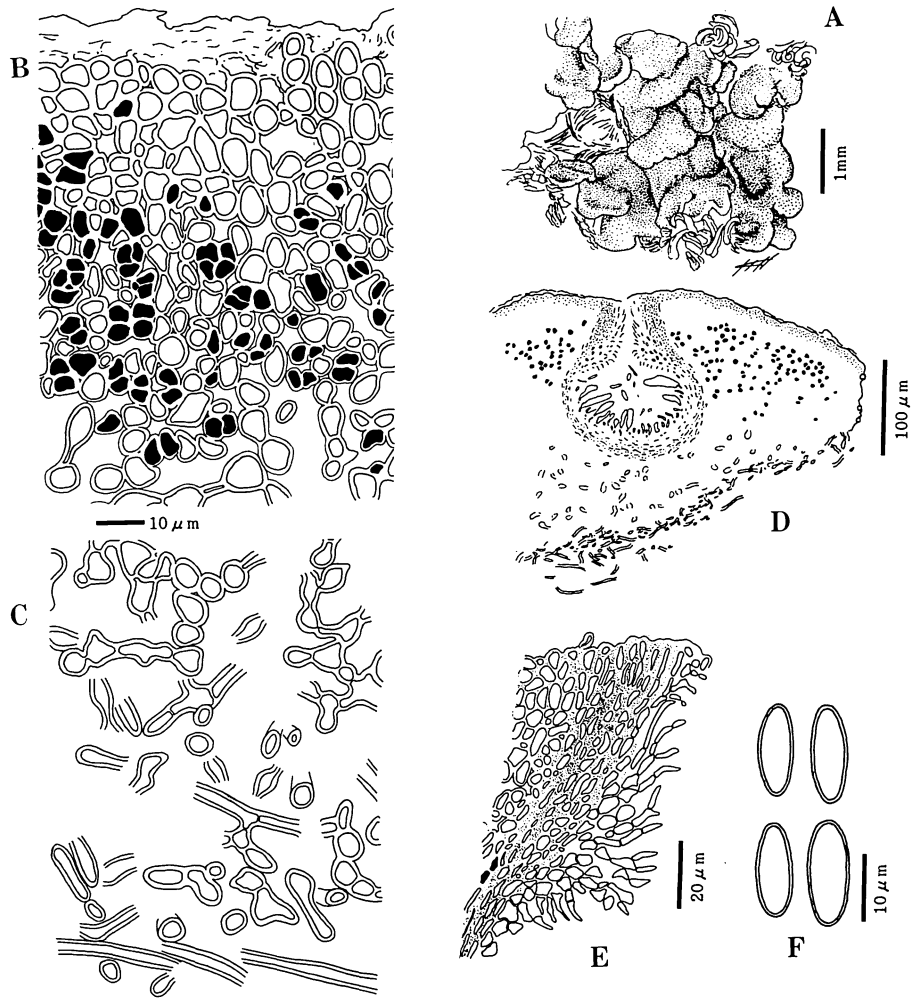

Fig. 9. *Catapyrenium psoromoides* (Borr.) Sant. A, habit. B, upper part of thallus in vertical section. C, lower part of thallus in vertical section. D, vertical section of perithecium. E, part of perithecium in vertical section. F, spores. (A, air-dried material; B–F, LPCB preparations. A–F, Asahina s. n.).

hyphae ca. 1 μm thick. Algal layer 40–60 μm thick. Medulla 30–80 μm thick, composed of more or less spheric hyphae (5–9 μm thick, ca. 2.5 μm thick at septa, with ca. 0.5 μm thick walls). Lower cortex undifferentiated. Rhizohyphae brown, linear, rather uniform in thickness, 2.5–3.5 μm thick. Perithecia pyriform, 170–190 μm high, 130–170 μm wide; exciple brown, darker at the bottom and uppermost, ca. 10 μm thick in the sides and bottom; subhymenium 10–20 μm thick in the bottom, thinner in the upper; hymenium 130–150 μm high, 110–140 μm wide; periphyses 5–10 μm long, ca. 3 μm in diameter; asci clavate, 45–50×10 μm; spores 8 in each ascus, hyaline, simple, oval, 13.5–14.5×5–5.5 μm.

Habitat. On bark. The only specimen from Japan (coll. Y. Asahina s. n.) was collected probably on bark of *Quercus crispula.*

Range. Japan, Europe, Africa, New Zealand.

Specimen examined. HONSHU. Shizuoka-ken: Mt. Echizen, 25 Aug. 1933, Y. Asahina s. n. (TNS-22173).

Remarks. This species is characterized by a rather dense mat of hypothallus and the lack of lower cortex.

Ecologically this species is unique in the

Verrucariaceae because of the corticolous habit as pointed out by Swinscow and Krog (1975). *Polyblastia japonica* was the only corticolous species of Verrucariaceae reported for Japan, but that species was excluded from the family by Harada (1989). At present, consequently, *Catapyrenium psoromoides* is the only corticolous species of Verrucariaceae in Japan.

This is the first record of *Catapyrenium psoromoides* in Japan.

2. *Neocatapyrenium* Harada, gen. nov.

Similis Dermatocarpellae sed pycnidiis typo Staurothele.

Typus generis: *Neocatapyrenium cladonioideum* (Vain.) Harada.

Description. Thallus squamulose; squamules attached to the substratum only at the basal ends; lobes linear, branched, imbricate, apparently ascending; upper surface smooth, a little glossy or dull; lower surface lacking umbilicus, rhizohyphae and rhizines; medulla of filamentous hyphae; lower cortex paraplectenchymatous. Perithecia laminal, almost completely immersed in the thallus, lacking involucrellum; exciple hyaline; ascus bitunicate; spores 8 in each ascus, simple, hyaline. Pycnidia laminal, completely immersed in the thallus, of the *Staurothele*-type.

Remarks. This new genus is characterized by (1) squamules attached to the substratum only at the basal ends (2) with naked lower surface and (3) smooth upper surface, paraplectenchymatous upper cortex, (4) hyaline exciple, (5) pycnidia of the *Staurothele*-type, and (6) medulla composed of filamentous hyphae. It resembles *Dermatocarpella* in having squamulose thallus, smooth upper surface, paraplectenchymatous lower cortex, and hyaline exciple. However, they apparently differ in pycnidia: the *Staurothele*-type in *Neocatapyrenium*, but the *Xanthoria*-type in *Dermatocarpella.*

At present, this genus is monotypic.

1) *Neocatapyrenium cladonioideum* (Vain.) Harada, comb. nov.

(Figs. 10, 11)

Siphula cladonioidea Vain., Bot. Mag. Tokyo 35: 47 (1921) = *Dermatocarpon cladonioideum* (as "*cladonioidea*") (Vain.) Sato, Bull. Fac. Arts Sci., Ibaraki Univ., Nat. Sci., no. 12: 44 (1961). Type: Japan, Honshu, Gunma-ken (as Prov. Kozuke), Mt. Myôgi, on rock, 19 April 1916, A. Yasuda 142 (TUR-VAIN 32944—holotype).

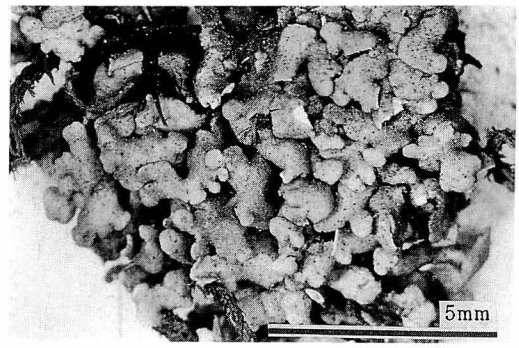

Fig. 10. Habit of *Neocatapyrenium cladonioideum* (holotype of *Dermatocarpon myogiense*).

Dermatocarpon myogiense Asah., J. Jpn. Bot. 9: 64 (1933). Type: Japan, Honshu, Gunma-ken, Mt. Myôgi, on the earth, Aug. 1930, K. Hisauchi s. n. (TNS—holotype).

External morphology. Thallus squamulose, composed of loosely aggregated squamules. Squamules lobate, attached to the substratum only at the basal ends, usually up to 1.5 cm across. Lobes sublinear, 1–2.5 mm wide, sparsely, almost pinnately or irregularly branched, incurved at the apices, imbricate; upper surface flesh-colored, dull or a little glossy, smooth, epruinose, convex; lower surface pale brown, concolorous with the dorsal surface, dull, smooth, canaliculate, lacking rhizines and rhizohyphae. Perithecia laminal, rather common, usually sparse, immersed in the thallus. Pycnidia laminal, common, immersed in the thallus, indistinct.

Anatomy. Thallus 300–400 μm thick. Upper cortex 40–80 μm thick, hyaline, but frequently pale brown in the uppermost parts, euparaplectenchymatous, lacking epinecral layer; lumina of hyphae more or less isodiametric, polygonal, 5–9 μm across; walls of hyphae 1–2 μm thick, but 2–3 μm thick in the upper part. Algal layer 50–130 μm thick. Medulla 100–200 μm thick, composed of filamentous hyphae (4–5 μm in diameter), fre-

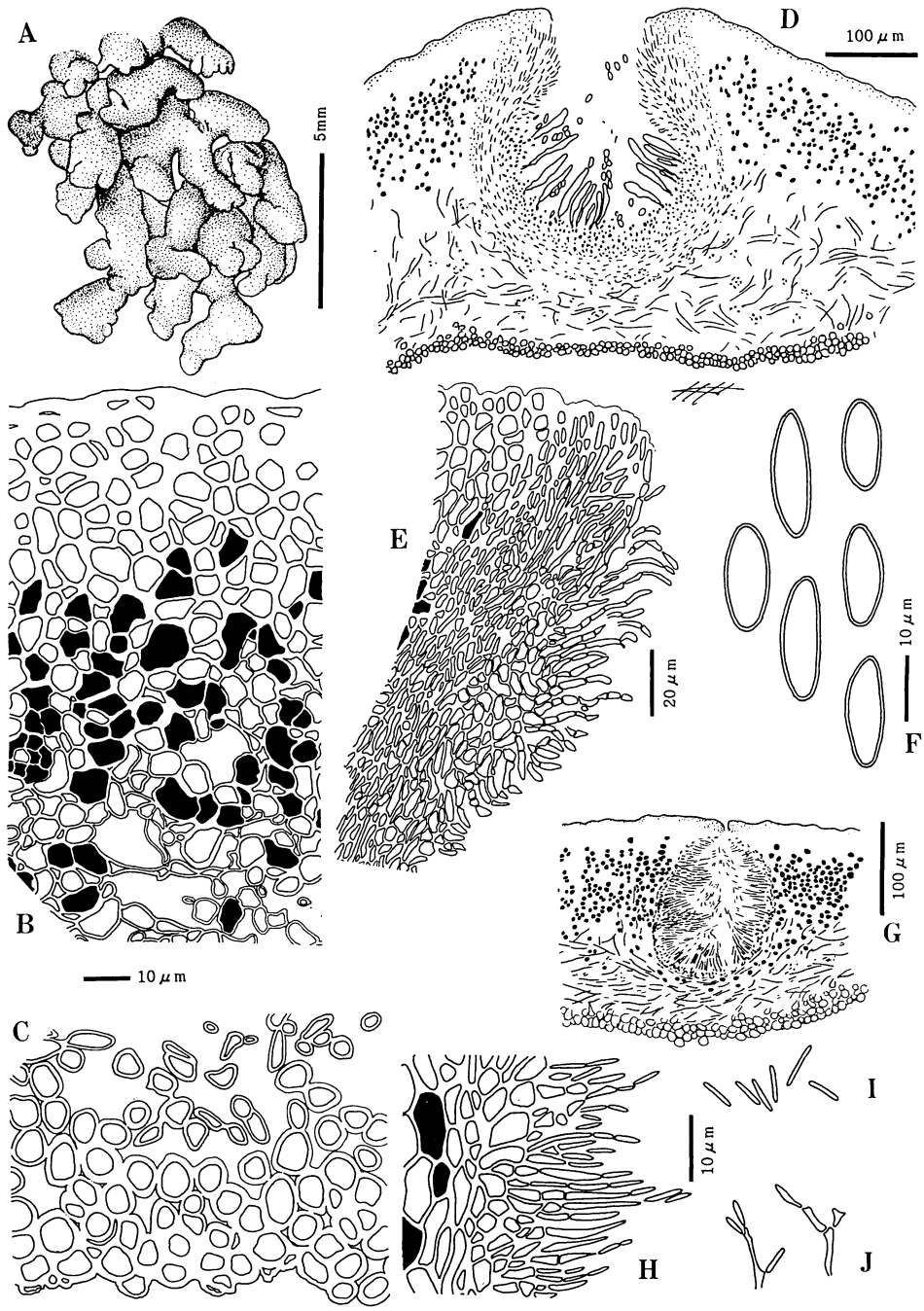

Fig. 11. *Neocatapyrenium cladonioideum* (Vain.) Harada. A, habit. B, upper part of thallus in vertical section. C, lower part of thallus in vertical section. D, vertical section of perithecium. E, part of perithecium in vertical section. F, spores. G, vertical section of pycnidium. H, part of pycnidium in vertical section. I, pycnoconidia. J, pycnoconidiophores. (A, air-dried material; B–J, LPCB preparations. A, holotype of *Dermatocarpon myogiense*; B, C, Nuno and Izumi s. n., NICH-509601; D, Kashiwadani 15372; E, G–J, Yoshimura 79452; F, Sato s. n., TNS-22190).

quently with spheric ones only in the uppermost and lowermost parts. Lower cortex 30–90 μm thick, hyaline throughout, or brownish in the lowermost part, euparaplectenchymatous; lumina of hyphae 5–12 μm high, 5–8 μm wide; walls of hyphae usually 1–2 μm thick. Perithecia pyriform to almost spheric (but almost campanulate in largest ones), up to 400 μm high and 420 μm wide (but 450 μm across at the uppermost in largest ones); exciple hyaline (or pale brown at the uppermost), up to 100 μm thick in the sides and bottom; subhymenium ca. 30 μm thick; periphyses 20–35 μm long, ca. 3 μm in diameter; hymenium up to 300 μm high and 190 μm wide; asci clavate, ca. 60×15 μm; spores 8 in each ascus, hyaline, simple, oval, 15–17×7–8 μm. Pycnidia of the *Staurothele*-type; pycnoconidia bacilliform, 5–7×ca. 1 μm.

Habitat. On rocks, particularly rather fragile volcanic ones.

Range. Japan, Korea.

Representative specimens examined. HONSHU. Fukushima-ken: Date-gun, Ryôzen-chô, ca. 200 m alt., H. Kashiwadani 15372 (NICH, TNS). Ibaraki-ken: Kuzi-gun, Suifu-mura, Ryûjin-kyô, M. Sato s. n. (NICH). Gunma-ken: Mt. Myôgi, ca. 850 m alt., on rocks, M. Nuno and H. Izumi s. n. (TNS), A. Yasuda 142 (TUR-Vainio 32944—holotype), K. Hisauchi (TNS—holotype of *Dermatocarpon myogiense*). Nagano-ken: Wada-mura, M. Togashi s. n. (TNS 22192). Shizuoka-ken: Ôhito-chô, S. Kurokawa 58016 (TNS). Hiroshima-ken: Asa-gun, Minochi, H. Kashiwadani 14566 (TNS).

Remarks. In Japan, the present species has been known as *Dermatocarpon myogiense* Asah., which is reduced as a synonym of *Siphula cladonioidea* Vain. in the present paper.

Vainio (1921a) described the present species as a member of *Siphula*, which was considered an imperfect lichen by him (Vainio, 1921b), probably because he did not find ascomata in the holotype. The holotype specimen of *Siphula cladonioidea* contains fractured squamules of lichen thalli, and most of these are actually sterile. Fortunately, I found overmatured perithecium in one of the fragments. Even though the perithecial cavity has been disorganized, the perithecium agrees well with those of *Dermatocarpon myogiense*. Furthermore, the fragmented thalli are typical of *Dermatocarpon myogiense* in habit and anatomical characters: (1) thallus convex on the upper surface, concave on the lower surface (2) lacking rhizohyphae and rhizines for the most parts, (3) pale brown on the upper surface, (4) pale brown and somewhat paler on the lower surface, (5) eu- to subparaplectenchymatous upper and lower cortex composed of thin-walled hyphae, (6) and medulla composed of filamentous hyphae. *Siphula cladonioidea* and *Dermatocarpon myogiense* are apparently conspecific and *Dermatocarpon myogiense* can be simply reduced as a synonym of *Siphula cladonioidea*.

Sato was the first lichenologist who noticed *Siphula cladonioidea* Vain. might be identical with *Dermatocarpon myogiense* Asah. After he examined a specimen collected on Mt. Myôgi by A. Tsunoda and annotated as "*Siphula cladonioidea* Wain.", Sato (1939) suggested that "*Dermatocarpon cladonioidea* might be used for *D. myogiense* Asah. if the specimen examined by me was the isotype of *Siphula cladonioidea*" in Japanese. The combination "*Dermatocarpon cladonioideum*" was not validly published at that time (ICBN Art. 34.2) but was validated later by him (Sato, 1961).

The present species has been only once reported from Shikoku as *Dermatocarpon myogiense* Asah. (Yoshimura, 1962). However, the specimen is now identified as *Dermatocarpella squamulosa* (Ach.) Harada.

3. *Scleropyrenium* Harada, gen. nov.

Thallus squamulosus, subtus rhizinatus; cortex superior pachydermatus. Perithecia immersa; exciplum fuscum vel nigricans; asci clavati, bitunicati, octospori; sporae simplices, hyalinae. Pycnidia typo Staurothele, immersa. Cortex superior pachydermatus.

Typus generis: *Scleropyrenium japonicum* Harada.

Description. Thallus squamulose; lobes with rhizohyphae and rhizines, lacking umbilicus; upper surface smooth and glossy; upper cortex pachydermatous; medulla com-

posed of filamentous or more or less inflated hyphae; lower cortex prosoplectenchymatous. Perithecia laminal, almost completely immersed in thallus, lacking involucrellum; exciple brown (very dark brown to almost black); ascus bitunicate; spores 8 in each ascus, simple, hyaline. Pycnidia laminal, completely immersed in thallus, of the *Staurothele*-type.

Remarks. This genus is characterized by (1) brown (very dark brown to almost black) exciple, (2) pycnidia of the *Staurothele*-type, (3) pachydermatous upper cortex.

This genus resembles *Involucrocarpon* Servit in having a dark brown to almost black exciple. *Involucrocarpon* was described by Servit (1953) on the basis of three new species from Italy: *Involucrocarpon framurense* Servit, *I. licentosum* Servit, and *I. margheritae* Servit. Although type specimens of *I. licentosum* and *I. margheritae* were not available for the present study, I fortunately had a chance to examine the type material of *I. framurense* preserved in the herbarium of Museo Civico di Storia Naturale, Genova. In *I. framurense*, (1) hyphal walls of the upper cortex are thin or weakly thickened as in *Dermatocarpella squamulosa* or *Neocatapyrenium cladonioideum*, and (2) the thallus is attached to the substratum only by almost hyaline rhizohyphae on the lower surface. In contrast, in species of *Scleropyrenium*, the upper cortex is composed of highly thick-walled hyphae, and true rhizines in addition to rhizohyphae are formed on the lower surface. The rhizines are apparently strongly conglutinated bundles of hyphae running longitudinally.

Key to the species of *Scleropyrenium*

1a. Thallus usually mono-lobed, solitary or aggregating to form a loose mat; upper surface flesh-colored or pale brown, distinctly black-margined; upper cortex strongly pachydermatous, with narrow and elongated lumina; medulla composed of filamentous hyphae ..... 1) *S. japonicum*

1b. Thallus lobate, composed of tightly contiguous and hardly separable squamules; upper surface pale yellowish brown, margin not distinct; upper cortex pachydermatous, with more or less roundish lumina; medulla composed of slightly inflated hyphae ..... 2) *S. kurokawae*

1) *Scleropyrenium japonicum* Harada, sp. nov.

(Figs. 12A–D, 13)

Thallus carneus, squamulosus, monophyllus, lobis ad marginem nigrescentibus. Cortex superior pachydermatus, prosoplectenchymatus, cellulis linearibus, angustus.

Typus. Japan, Shikoku, Kôchi-ken, Befukyô, on thin soil on limestone, 27 May 1982, H. Harada 1045 (CBM—holotypus).

External morphology. Thallus squamulose, composed of more or less loosely aggregated squamules. Squamules usually mono-lobed, frequently dissected, or branched irregularly, somewhat loosely attached to the substratum, slightly ascending at the margin, usually up to 5 mm in diameter; lobes rotund, ca. 1 mm wide, ± overlapping, ± undulating; upper surface flesh-colored or pale brown, more or less glossy, semipellucid, smooth, almost flat; lower surface black, more or less rough (due to the occurrence of rhizohyphae), with rhizohyphae and rhizines; rhizohyphae very sparse, usually lacking near the margin; rhizines very sparse, black, extended into substratal soil. Perithecia laminal, rather common, scattered, immersed in the thallus, distinctly black around ostioles (usually up to 0.3 mm across). Pycnidia laminal, common, immersed in the thallus, indistinct, recognizable only by the ostioles.

Anatomy. Thallus 210–280 μm thick. Upper cortex 50–100 μm thick, with extension of vertical strands into algal layer, usually hyaline throughout, subparaplectenchymatous and slightly pachydermatous in the lowermost part, prosoplectenchymatous and strongly pachydermatous in the remainder; hyphae running in vertical directions; lumina of hyphae 2–5 μm wide, 3–20 μm long; walls of hyphae usually very thick, 2–5 μm thick, but thinner near algal layer. Algal layer 50–120 μm thick; phycobiont cells in clusters and more or less in vertical rows.

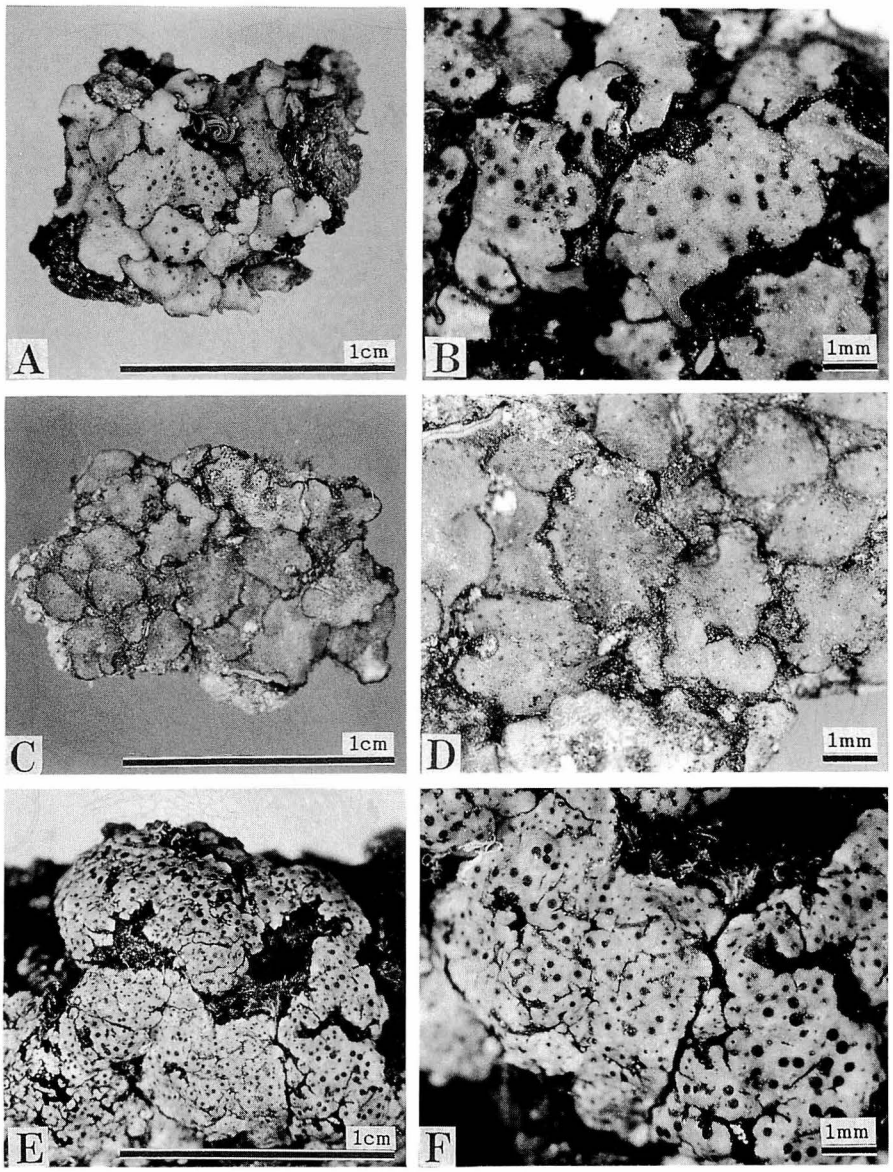

Fig. 12. Habit of *Scleropyrenium*. A–D, *S. japonicum* (A–B, thalli with perithecia, holotype; C–D, thalli lacking perithecia, Harada 8868); E–F, *S. kurokawae* (holotype).

Medulla 30–100 μm thick, hyaline, composed of filamentous hyphae (lumina of hyphae usually 1–2 μm wide, with ca. 1 μm thick walls). Lower cortex 20–50 μm thick, brown to almost black, prosoplectenchymatous, rarely almost subparaplectenchymatous in some part; hyphae running in various directions but mainly vertical; walls of hyphae ca. 2 μm thick. Perithecia pyriform to almost spheric, 350–410 μm high, 270–410 μm wide; exciple brown (almost black), 20–50 μm thick; subhymenium 20–30 μm thick; periphyses 25–40 μm long, usually up to 3 μm in diameter; hymenium 250–340 μm high, 200–260 μm wide; asci clavate, 70–80 × ca. 15 μm; spores 8 in each ascus, hyaline, simple, ellipsoidal to oval, 14–18 × 7–7.5 μm. Pycnidia of the *Staurothele*-type, longitudinally elongated, narrower in the upper part; pycnoconidia clavate, 5–9 × ca. 1 μm.

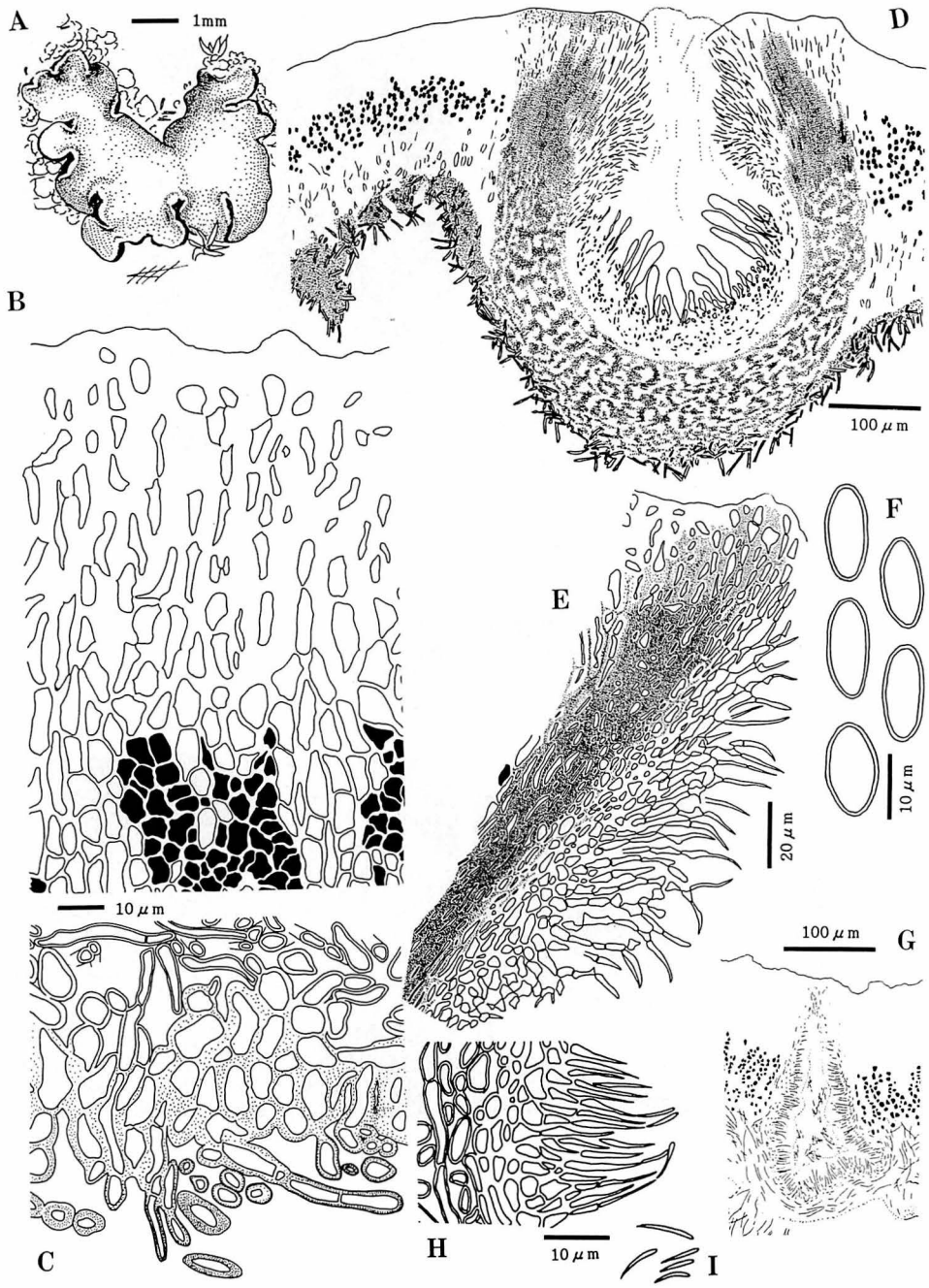

Fig. 13. *Scleropyrenium japonicum* Harada. A, habit. B, upper part of thallus in vertical section. C, lower part of thallus in vertical section. D, vertical section of perithecium. E, part of perithecium in vertical section. F, spores. G, vertical section of pycnidium. H, part of pycnidium in vertical section. I, pycnoconidia. (A, air-dried material; B–I, LPCB preparations. A, Harada 8868; B–C, E–I, holotype; D, Harada 3992).

Habitat. On soil on or between limestones, at sunny to a little shades sites.

Range. Only known from Japan.

Representative specimens examined. HONSHU. Niigata-ken: Nishi-kubiki-gun, Mt. Kurohime, ca. 700 m alt., H. Harada 3992 (HIRO). Hiroshima-ken: Taishaku-kyô, 400 m alt., H. Harada 8868 (HIRO). SHIKOKU. Kochi-ken: Kami-gun, Monobe-mura, Behu-kyô, H. Harada 1045 (CBM—holotype), H. Kashiwadani 14930 (TNS).

Remarks. This species is characterized by the highly pachydermatous and prosoplectenchymatous upper cortex, and the black-margined upper surface of lobes.

2) *Scleropyrenium kurokawae* Harada, sp. nov.

(Figs. 12E and F, 14)

Scleropyrenium japonicum affinis sed cortices superioribus subparaplectenchymatis vel sclerenchymatis differto.

Typus: Japan, Shikoku, Kôchi-ken, Nagaoka-gun, Ochi-chô, Mt. Yokogura, 700 m alt., on limestone with or without soil, 8 June 1986, H. Harada 4355 (HIRO—holotypus).

External morphology. Thallus squamulose, composed of tightly contiguous and hardly separable squamules, adnate, lobate, frequently becoming hemispheric to almost spheric, up to 2 cm in diameter; lobes sublinear to rotund, ca. 0.5 mm wide, irregularly branched, contiguous; upper surface pale yellowish brown, a little glossy, smooth, epruinose, almost flat; lower surface black, with rhizohyphae and rhizines; rhizohyphae black, prominent; rhizines black, single to several for each thallus, prominent. Perithecia laminal, common, scattered or more or less crowded, immersed in the thallus, distinctly black around ostioles (0.1–0.3 mm across). Pycnidia laminal, not so common, immersed in the thallus.

Anatomy. Thallus 90–230 μm thick. Upper cortex 30–100 μm thick, hyaline throughout, pachydermatous, subparaplectenchymatous in the lower part, but more or less prosoplectenchymatous in the upper part; lumina of hyphae polygonal or roundish, 3–5 μm across in the uppermost ones, 5–10 μm high and 3–7 μm wide in the lower ones; walls of hyphae thicker in the upper part of the layer, 0.5–1 μm thick in the lower, ca. 2 μm thick or thicker in the upper. Algal layer 40–120 μm thick; phycobiont cells more or less scattered, but frequently in small clusters. Medulla up to 70 μm thick, composed of spheric hyphae (more or less elongate, 3–4 μm in diameter, with ca. 1 μm thick walls). Lower cortex up to 25 μm thick, well developed or sometimes disorganizing, very dark brown, prosoplectenchymatous, more or less thick-walled. Perithecia pyriform to almost spheric, 210–320 μm high, 180–380 μm wide; exciple brown (very dark brown to almost black), 20–90 μm thick; subhymenium 20–40 μm thick; periphyses 20–40 μm long, ca. 2.5 μm in diameter; hymenium 160–230 μm high, 140–200 μm wide; asci clavate, ca. 50 × 15 μm; spores 8 in each ascus, hyaline, simple, oval, 16–17 × 7–7.5 μm. Pycnidia of the *Staurothele*-type; pycnoconidia bacilliform, ca. 5 × 1 μm.

Habitat. Growing directly on limestone, or soil on or between limestone, at sunny to moderately shaded sites.

Range. Only known from Japan.

Specimens examined. HONSHU. Hiroshima-ken: Taishaku-kyô, 400 m alt., H. Harada 8871 (HIRO). SHIKOKU. Tokushima-ken: Mt. Tsurugi, 1800 m alt., H. Harada 4284 (HIRO). Kôchi-ken, Tosa-gun, Tosayama-mura, Mt. Kuishi, 100 m alt., H. Harada 3449 B (HIRO); Nagaoka-gun, Ochi-chô, Mt. Yokogura, 700 m alt., H. Harada 4348 (HIRO) and 4355 (HIRO—holotype).

Remarks. Scleropyrenium kurokawae differs from *S. japonicum* in the color of the thallus, and in the anatomies of the upper cortex and medulla. The thallus of *S. kurokawae* is constantly pale brown with a shade of yellow ocher. The thallus of *S. japonicum* is usually flesh-colored, although infrequently almost same in color as the former species at the exposed habitats. The upper cortex is pachydermatous, and the lumina of the hyphae are more or less vertically elongated in these species. The lumina are apparently much more slender in *S. japonicum* (Figs. 1A and 13B); however, they tend to be more isodiametric and the cortex is almost sub-

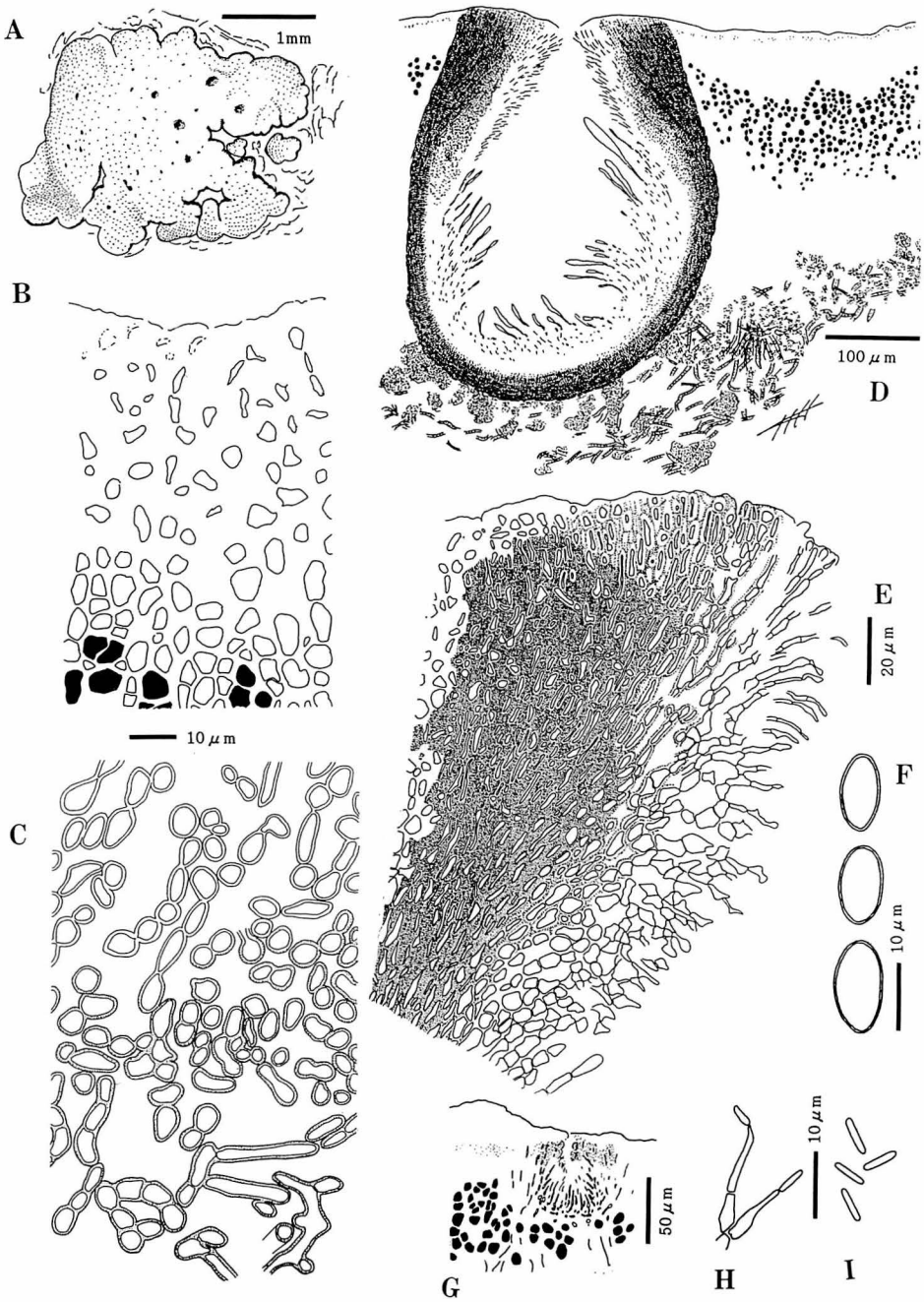

Fig. 14. *Scleropyrenium kurokawae* Harada. A, habit. B, upper part of thallus in vertical section. C, lower part of thallus in vertical section. D, vertical section of perithecium. E, part of perithecium in vertical section. F, spores. G, vertical section of pycnidium. H, pycnoconidiophore. I, pycnoconidia. (A, air-dried material; B–I, LPCB preparations. A, Harada 8871; B–I, holotype).

paraplectenchymatous in *S. kurokawae* (Figs. 1B and 14B). Medullary hyphae are exclusively linear in *S. japonicum* (upper part in Fig. 13C) but are more or less spheric in *S. kurokawae* (Figs. 3D, 14C).

The thallus of this species varies from

monolobed to polylobed. Thalli growing directly on limestone tend to be solitary and do not become large and polylobed. On the other hand, polylobed thalli are common when this species grows on soil. Polylobed thalli may sometimes form a hemispheric to almost spheric mass.

Scleropyrenium kurokawae and *S. japonicum* seem to be different in subtle habitat selection. Frequently *S. kurokawae* grows directly on limestone and also on soil between the rock, whereas *S. japonicum* seems to prefer calciferous soil rather than limestone itself as the substratum.

4. *Dermatocarpella* Harada, gen. nov.

Thallus squamulosus, umbilico et rhizinis destituto, cum rhizohyphas; cortex superior eu-vel subparaplectenchymatus, parietum tenuium; hyphae medullae linear vel spherici; cortex inferior paraplectenchymatus. Perithecia immersa; exciplum hyalinum sed plerumque fuscus summus; algae hymenii nullae; asci clavati, bitunicati, octospori; sporae simplices, hyalinae. Pycnidia typo Xanthoriae.

Typus generis: *Dermatocarpella yoshimurae* Harada.

Description. Thallus squamulose, lacking umbilicus and rhizines, with rhizohyphae; upper surface smooth; medulla composed of spheric and/or filamentous hyphae; lower cortex parenchymatous. Perithecia laminal, almost completely immersed in the thallus, lacking involucrellum; exciple hyaline; ascus bitunicate; spores 8 in each ascus, simple, hyaline. Pycnidia of the *Xanthoria*-type, laminal or marginal.

Remarks. This genus is characterized by (1) squamulose thallus with rhizohyphae and without umbilicus, (2) paraplectenchymatous upper cortex, (3) perithecia with hyaline exciple but lacking involucrellum, (4) pycnidia of the *Xanthoria*-type.

Dermatocarpella is distinguished from *Catapyrenium* s. str. by the hyaline exciple and the smooth upper surface.

Dermatocarpella resembles *Dermatocarpon* in having pycnidia of the *Xanthoria*-type and hyaline exciple. However, it apparently differs from the latter by having rhizohyphae rather than umbilici on the lower surface.

Pycnidia of the *Xanthoria*-type are also found in *Placocarpus schaereri*, an exotic species of the family Verrucariaceae. The two genera are apparently different in habit, namely squamulose with rhizohyphae in *Dermatocarpella* and placoid in *Placocarpus schaereri*.

This genus also resembles *Neocatapyrenium* in having hyaline exciple. But they apparently differ from each other in having different type of pycnidia: *Xanthoria*-type in *Dermatocarpella*, but the *Staurothele*-type in *Neocatapyrenium*.

Key to the species of *Dermatocarpella*

1a. Pycnidia marginal ····· 3) *D. yoshimurae*
1b. Pycnidia laminal ····· 2
2a. Lower cortex loose; spores larger, 14–19 × 9–11 μm; growing on riverside rocks ····· 1) *D. kisovensis*
2b. Lower cortex compact; spores smaller, 11–14 × 5–6 μm; growing on calcareous soil ····· 2) *D. squamulosa*

1) *Dermatocarpella kisovensis* (Zahlbr.) Harada, comb. nov.

(Figs. 15A, 16)

Dermatocarpon kisovense Zahlbr., Annal. Mycol. 29: 75 (1931). Type: Japan, Honshu, Nagano-ken (=Shinano, as 'Shinauo'), secus flumen Kiso, ad terram humosam, Y. Asahina 534 (W—holotype; TNS—isotype).

External Morphology. Thallus squamulose, composed of loosely aggregated squamules. Squamules mono-lobed or dissected to weakly lobate, tightly attaching to the substratum with whole lower surface or ascending at the margin, contiguous, ±weakly undulate, usually 2–3 μm in diameter; upper surface more or less dark brown, dull, smooth, epruinose, almost flat; lower surface blackish, with rhizohyphae; rhizohyphae sparse, very pale brown. Perithecia laminal, common, immersed in the thallus, black or very dark brown around ostioles (0.1–0.2 mm across), slightly elevated. Pycnidia laminal, common, immersed in the thallus.

Anatomy. Thallus 200–310 μm thick. Upper cortex 30–40 μm thick, brown in the

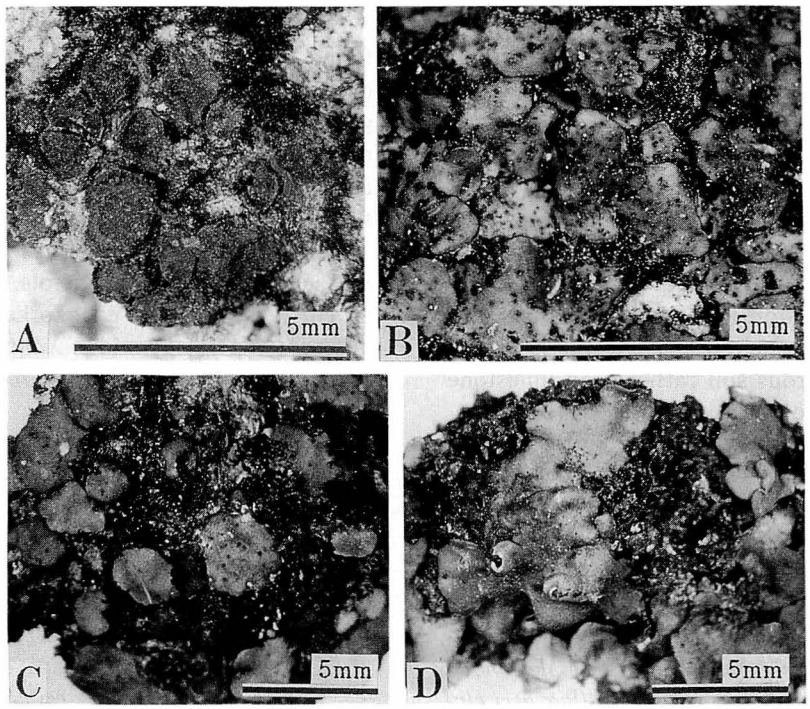

Fig. 15. Habit of *Dermatocarpella*. A, *D. kisovensis* (isotype in TNS); B, *D. squamulosa* (Harada 4727); C–D, *D. yoshimurae* (holotype).

upper part (darkest at the uppermost), hyaline in the lower part, euparaplectenchymatous, with or without hyaline, amorphous layer; lumina of hyphae 3–7 μm high, 3–6 μm wide; walls of hyphae 2–3 μm thick in the upper ones, 0.5–1 μm thick in the lower ones. Algal layer 80–110 μm thick; phycobiont cells more or less scattered. Medulla ca. 100 μm thick, composed of spheric hyphae (more or less inflated, 6–8 μm in diameter, with ca. 1 μm thick walls). Lower cortex weakly differentiated, composed of spheric hyphae similar to those of the medulla; walls of hyphae ca. 2 μm thick. Rhizohyphae 3–4 μm thick, pale; walls of hyphae ca. 1 μm thick. Perithecia pyriform to almost spheric, 290–350 μm high, 230–310 μm wide; exciple hyaline (pale to dark brown at the uppermost, ca. 20 μm thick; subhymenium ca. 20 μm thick; periphyses 20–30 μm long, ca. 3 μm in diameter; hymenium 240–260 μm high, 200–210 μm wide; asci clavate, ca. 50×10 μm; spores 8 in each ascus, hyaline, simple, ellipsoidal, 14–19 ×9–11 μm (walls 0.5–1 μm thick). Pycnidia of the *Xanthoria*-type; pycnoconidia bacilliform, 4–5×ca. 1 μm.

Habitat. On riverside rocks, with or without soil or mosses.

Range. Only known from Japan.

Specimens examined. HONSHU. Nagano-ken: Agematsu, Y. Asahina 129 (TNS) and 534 (W—holotype; TNS—isotype).

Remarks. This species resembles *Dermatocarpella squamulosa* in having laminal pycnidia and almost flat to concave thallus. They apparently differ from each other in size of spores: 14–19×9–11 μm in *D. kisovensis*, but 11–14×5–6 μm in *D. squamulosa*.

This species was reported from Kochi-ken, Shikoku by Yoshimura (1963, as *Dermatocarpon kisovense*). The specimen for this record (coll. Yoshimura no. 3830) does not include the *Dermatocarpella* but two other species of pyrenocarpous lichens (*Endocarpon* and probably *Peltula*).

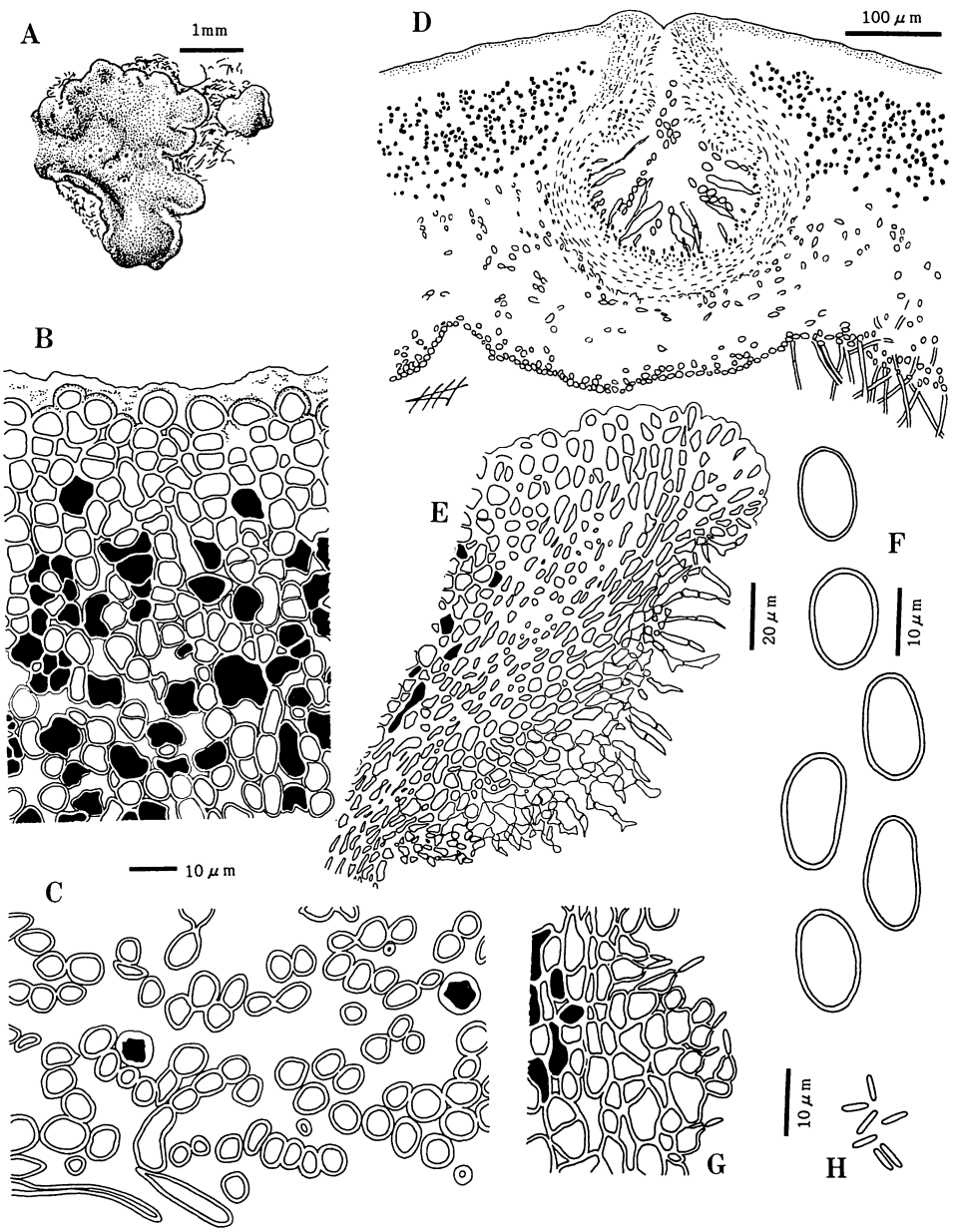

Fig. 16. *Dermatocarpella kisovensis* (Zahlbr.) Harada. A, habit. B, upper part of thallus in vertical section. C, lower part of thallus in vertical section. D, vertical section of perithecium. E, part of perithecium in vertical section. F, spores. G, part of pycnidium in vertical section. H, pycnoconidia. (A, air-dried material; B–H, LPCB preparations. A, isotype in TNS; B–H, Asahina 129).

2) *Dermatocarpella squamulosa* (Ach.) Harada, comb. nov.

(Figs. 15B, 17)

Endocarpon squamulosum Ach., Method. Lich.: 126 (1803) = *Catapyrenium squamulosum* (Ach.) Breuss, Ber. Deutsch. Bot. Ges. 98: 389 (1985). Type: Germania, Sprengel (H-Ach 855, left upper—lectotype, not seen).

External Morphology. Thallus squamulose, composed of loosely or tightly aggregated but easily separable squamules, usually

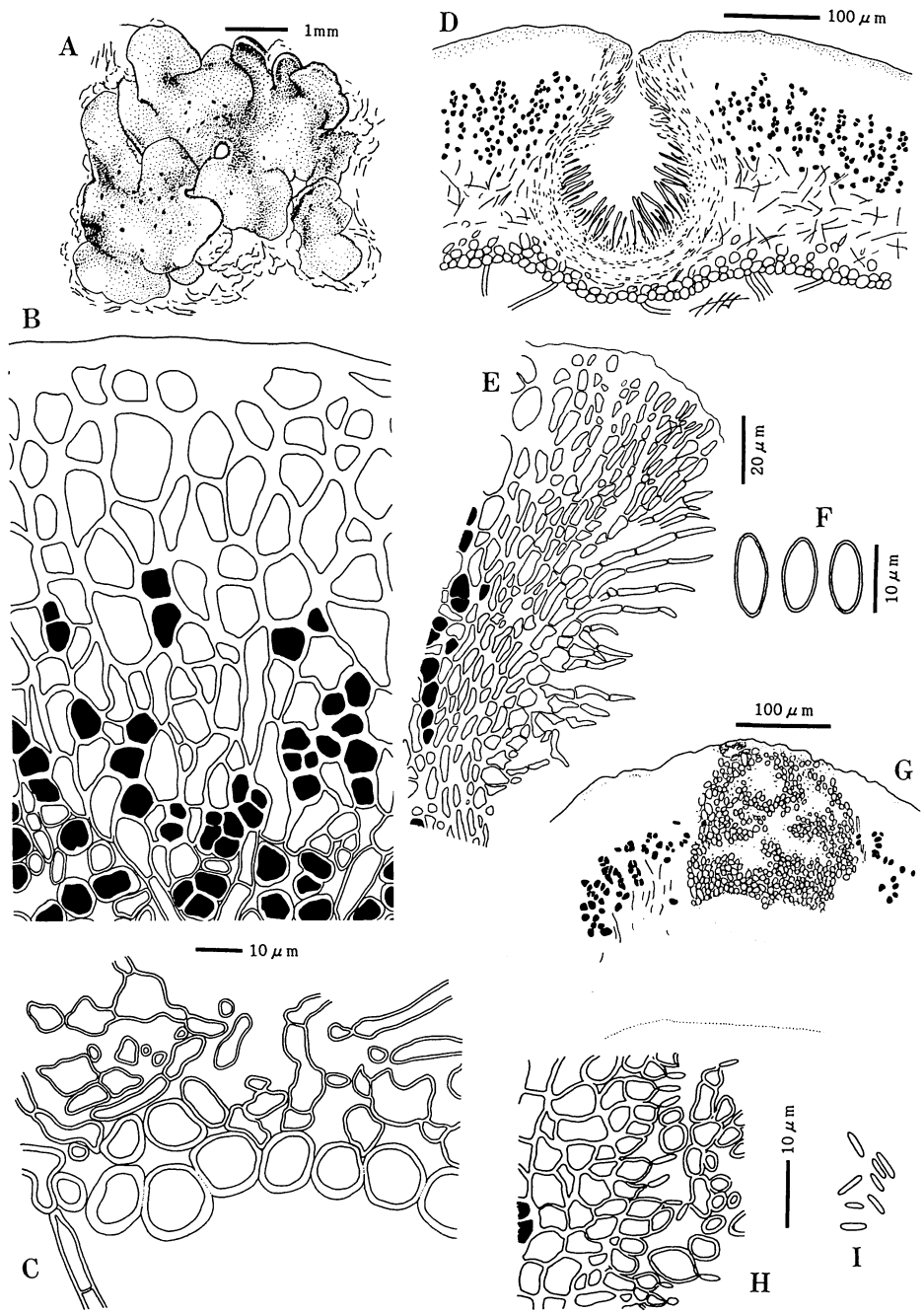

Fig. 17. *Dermatocarpella squamulosa* (Ach.) Harada. A, habit. B, upper part of thallus in vertical section. C, lower part of thallus in vertical section. D, vertical section of perithecium. E, part of perithecium in vertical section. F, spores. G, vertical section of pycnidium. H, part of pycnidium in vertical section. I, pycnoconidia. (A, air-dried material; B–I, LPCB preparations. A–F, H, I, Harada 4727; G, Harada 4499).

up to 10 cm in diameter. Squamules monolobed, or more or less lobate, usually adnate, or a little ascending near the margin, contiguous, 1–8 mm in diameter; upper surface pale to dark brown, ochraceous or castanean, dull to a little glossy, smooth, weakly concave to

almost flat; lower surface brown to black, with sparse to dense rhizohyphae. Perithecia laminal, common, scattered, immersed in the thallus, very dark brown to black around ostioles, slightly elevated or almost plane. Pycnidia laminal (but exceptionally marginal), rather common, immersed in the thallus, almost plane to slightly elevated and very dark brown or almost black around ostioles.

Anatomy. Thallus 120–330 μm thick. Upper cortex 30–70 μm thick, brown in the upper part, hyaline in the remainder, eu- to subparaplectenchymatous, lacking epinecral layer; lumina of hyphae 6–15 μm high, 6–12 μm wide in the middle ones; walls of hyphae thicker in the upper part, 0.5–1(–2) μm thick in the lower part, 2–5 μm thick in the upper part. Algal layer 40–120 μm thick; phycobiont cells scattered or in clusters. Medulla up to 180 μm thick, composed of spheric (8–10 μm thick, with ca. 0.5 μm thick walls) and filamentous hyphae (2.5–4 μm thick, with ca. 0.5 μm thick walls). Lower cortex 10–30 μm thick, paraplectenchymatous, 1–3 cell-layered; lumina of hyphae spheric, 7–15 μm across. Rhizohyphae 4–6 μm thick; walls of hyphae ca. 1.5 μm thick, very dark brown to almost hyaline. Perithecia pyriform to almost spheric, 130–320 μm high, 110–340 μm high; exciple hyaline (brown at the uppermost), 10–25 μm thick; subhymenium 10–20 μm thick; periphyses prominent, 30–35 μm long, ca. 3 μm in diameter; hymenium 150–240 μm high, 130–260 μm wide; asci clavate to almost cylindric, 45–55×ca. 10 μm; spores 8 in each ascus, hyaline, simple, oval, 11–14×5–6 μm. Pycnidia of the *Xanthoria*-type; pycnoconidia bacilliform, 2.5–4.5×1.5–2 μm.

Habitat. On calcareous soil.

Range. Japan, Nepal, Turkmenskaja S. S. R., Iran, Irak, Algeria, Tunisia, Europe, North America.

Specimens examined. HOKKAIDO. Shimamaki-gun, Mt. Ôbira, 900–950 m alt., H. Harada 4713 (HIRO); 1000 m alt., H. Harada 4727 (HIRO). HONSHU. Iwate-ken: Shimohei-gun, Iwaizumi, 200 m alt., S. Kurokawa 67191 (TNS). Niigata-ken: Itoigawa-shi, Mt. Myôjô, 1100–1188 m alt., H. Harada 4499 (HIRO). SHIKOKU. Tokushima-ken: Miyoshi-gun, Mt. Tenguzuka, 1750 m alt., I. Yoshimura 3349 (herb. Yoshimura).

Remarks. This species is characterized by laminal pycnidia and small spores (11–14×5–6 μm).

This is the first record of *Dermatocarpella squamulosa* in Japan.

3) *Dermatocarpella yoshimurae* Harada, sp. nov.

(Figs. 15C and D, 18)

Thallus squamulosus, lobatus, ad marginem undulatus; hyphae medullae filamentae. Sporae simplices, ovales, 13.5–18×7–8.5 μm. Pycnidia marginalia; pycnoconidia bacilliformis, 5–7×ca. 1 μm.

Typus: Japan, Shikoku, Tokushima-ken, Mt. Tsurugi, 1800 m alt., on mosses on limestone outcrop, 5 June 1986, H. Harada 4276 (HIRO—holotypus; CBM—isotypus).

External morphology. Thallus squamulose, composed of loosely aggregated squamules. Squamules round when young, entire to dissected, or lobate in older ones, 1–8 mm across, usually ascending near the margin; lobes rotund, usually 2–3 mm wide, slightly overlapping, undulating on the margin; upper surface pale to dark brown, ochraceous or castanean, moderately glossy to dull, smooth, slightly convex; lower surface brown to black, with sparse to dense rhizohyphae. Perithecia laminal, common, scattered, very dark brown to black around ostioles, slightly elevated or almost plane. Pycnidia marginal, common, black or very dark brown.

Anatomy. Thallus 170–400 μm thick. Upper cortex 40–50 μm thick, brown in the upper part, hyaline in the remainder, euparaplectenchymatous; lumina of hyphae 7–12 μm across; walls of hyphae 0.5–1(–2) μm thick in the lower part, 2–5 μm thick in the upper part. Algal layer 30–80 μm thick; phycobiont cells scattered or in clusters. Medulla 50–100 μm thick, composed of filamentous hyphae (ca. 4 μm in diameter, with ca. 0.5 μm thick walls). Lower cortex 20–60 μm thick, paraplectenchymatous, (1–)3–10 cell-layered; lumina of hyphae spheric, 7–11 μm across. Rhizohyphae 5–7 μm thick, very pale brown to almost hyaline; walls of hyphae 1–1.5 μm thick. Peri-

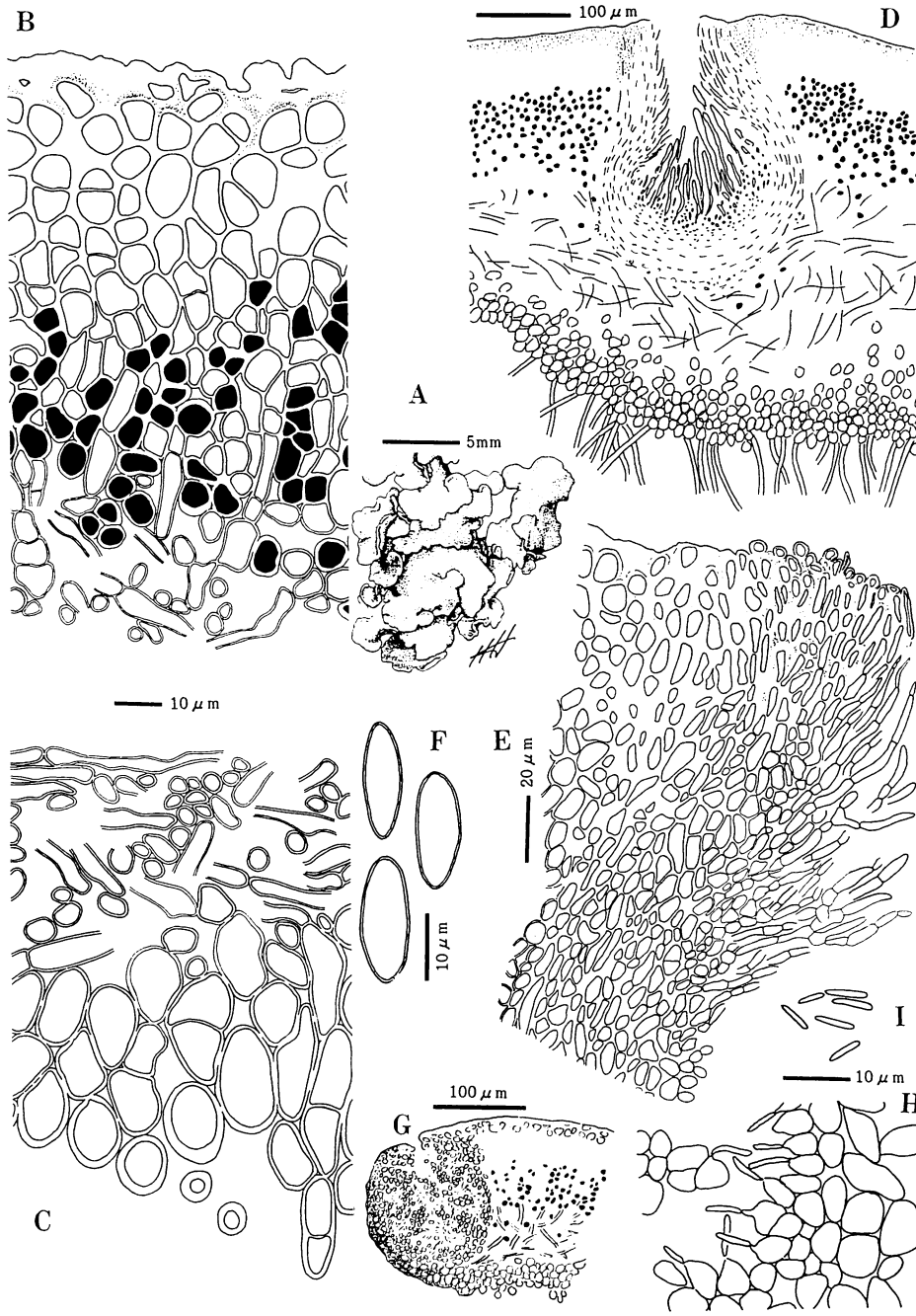

Fig. 18. *Dermatocarpella yoshimurae* Harada. A, habit. B, upper part of thallus in vertical section. C, lower part of thallus in vertical section. D, vertical section of perithecium. E, part of perithecium in vertical section. F, spores. G, vertical section of pycnidium. H, part of pycnidium in vertical section. I, pycnoconidia. (A, air-dried material; B–I, LPCB preparations. A, Harada 1083; B–I, holotype).

thecia pyriform to almost spheric, 200–250 μm high, 140–150μm wide; exciple hyaline (brown at the uppermost), 20–25μm thick; subhymenium 10–15 μm thick; periphyses 35–50μm long, ca. 3μm in diameter; hymenium 170–210 μm high, 110–210 μm wide;

Asci cylindric, 60–80×ca. 10μm; spores 8 in each ascus, hyaline, simple, oval, 13.5–18×7–8.5μm. Pycnidia of the *Xanthoria*-type; pycnoconidia bacilliform, 5–7×ca. 1μm.

Habitat. On mosses on limestone.

Range. Only known from Japan.

Specimens examined. SHIKOKU. Tokushima-ken: Mt. Tsurugi, 1800 m alt., H. Harada 4276 (HIRO—holotype; CBM—isotype) and 4314 (HIRO); Mt. Tsurugi, F. Fujikawa, s. n. (TNS 22186). Kôchi-ken: Kami-gun, Monobemura, Mt. Ishidate, I. Yoshimura 4534 (herb. Yoshimura).

Dermatocarpella yoshimurae is characterized by having marginal pycnidia, bacilliform pycnoconidia (5–7μm long), and more or less convex thallus.

All three species of *Dermatocarpella* in Japan are ecologically distinguished. *D. kisovensis* is known only from soil on riverside granite. *D. squamulosa* is found on calcareous soil, and *D. yoshimurae* grows on mosses on limestone.

5. *Dermatocarpon* Eschweiler

Syst. Lich.: 21 (1824): Type species: *Dermatocarpon miniatum* (L.) Mann.

Description. Thallus foliose, umbilicate, lacking rhizohyphae and rhizines; upper surface more or less very finely scabrose, or nearly scabrose, dull; medulla composed of filamentous hyphae; lower cortex prominent, pachydermatous, of the *Dermatocarpon*-type. Perithecia laminal, completely immersed in the thallus, lacking involucrellum; exciple hyaline; ascus bitunicate; spores simple, hyaline, 8 in each ascus. Pycnidia laminal, almost completely immersed in the thallus, of the *Xanthoria*-type.

Remarks. The genus *Dermatocarpon* is characterized by umbilicate thallus, hyaline exciple, hyaline simple spores, pycnidia of the *Xanthoria*-type, and lower cortex of the *Dermatocarpon*-type.

Three species of *Dermatocarpon* are recognized in Japan. Two other species formerly included in *Dermatocarpon*, *D. kisovense* Zahlbr. (1931) and *D. myogiense* Asah. (1933), are now circumscribed in the genera *Dermatocarpella* and *Neocatapyrenium* respectively.

Key to the species of *Dermatocarpon*

1a. Thallus with rhizinomorphs ····· 3) *D. vellereum*
1b. Thallus lacking rhizinomorphs ····· 2
2a. Thallus with an umbilicus at the center of the lower surface ····· 1) *D. miniatum*
2b. Thallus with several umbilici scattered over the lower surface ····· 2) *D. tuzibei*

1) *Dermatocarpon miniatum* (L.) Mann
(Figs. 19A and B, 20)

Lich. Bohem. Observ. Dispos.: 66 (1825) = *Lichen miniatus* L., Sp. Pl.: 1149 (1753). Type: Dillenius, Historia Muscorum, 223, t. 30, f. 127 (1741) (not seen); Hall., helv. 75, t. 2, f. 2 (not seen).

Dermatocarpon fluviatile auct. non Th. Fr.: Müller Arg., Nuovo Giorn. Bot. Ital. 24(3): 845 (1892).

External morphology. Thallus foliose, umbilicate, usually mono-lobed, but frequently composed of up to several lobes, 1–5 cm in diameter. Lobes more or less orbicular, shallowly to deeply and irregularly dissected, more or less concave in the central part (with a umbilicus); upper surface pale grayish brown, dull, smooth or slightly and very finely scabrose, with white powder in the herbarium, more or less concave in the central part; lower surface more or less dark brown, very pale brown, or almost black, rarely with red tint, dull to a little glossy, usually smooth, sometimes wrinkled or veined, with a central umbilicus. Perithecia laminal, very common, abundantly scattered on the upper surface of thallus, completely immersed in the thallus, dark brown around ostioles. Pycnidia laminal, common, scattered, immersed in the thallus, dark brown to almost black around ostioles.

Anatomy. Thallus 100–500 μm thick (or thicker). Upper cortex 20–50μm thick, more or less brown in the uppermost part, hyaline in the remainder, a little loose eu- to subparaplectenchymatous; lumina of hyphae isodiametric, 3–6μm across, more or less in vertical rows; walls of hyphae ca. 1μm thick. Algal layer 20–100μm thick; phycobiont cells solitary or in clusters. Medulla 50–320

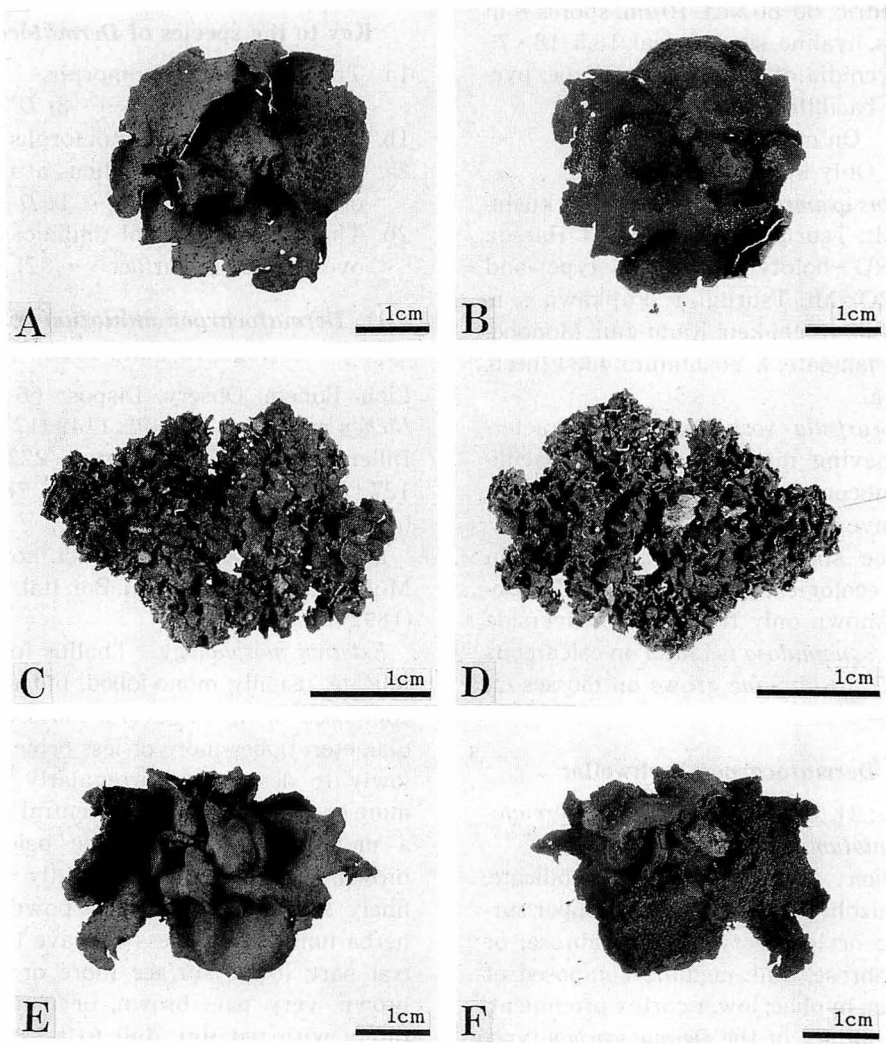

Fig. 19. Habit of *Dermatocarpon*. A–B, *D. miniatum* (Harada 4359); C–D, *D. tuzibei* (Harada 7866); E–F, *D. vellereum* (Harada 7767). A, C, E, thalli seen from above; B, D, F, thalli seen from below.

μm thick (or thicker), composed of filamentous hyphae (quite uniform in thickness, 3–5 μm in diameter, with ca. 1 μm thick walls). Lower cortex 20–70 μm thick, of the *Dermatocarpon*-type; lumina of hyphae larger and more or less anticlinally elongate in upper part (3–5 μm wide, 3–10 μm long), almost isodiametric in lower part (ca. 3 μm across); walls of hyphae thicker in upper part (1–3 μm thick), ca. 1 μm thick in outer part. Perithecia spheric, completely immersed in the thallus, 210–470 μm wide, 200–470 μm high; exciple hyaline, up to 80 μm thick; subhymenium 20–50 μm thick; periphyses ca. 20 μm long, ca. 3 μm in diameter; hymenium 150–340 μm high, 90–230 μm wide; asci clavate, 60–70 × 10–15 μm; spores 8 in each ascus, hyaline, simple, oval, 11–19.5 × 4.5–7.5 μm. Pycnidia of the *Xanthoria*-type; pycnoconidia bacilliform, 4–7 × ca. 1 μm.

Habitat. On rocks at the edge of streams, also on limestones.

Range. Japan, Korea, Taiwan, China, Mongolia, Western Asia, Europe, Africa, North America.

Representative specimens examined. HOKKAIDO. Rebun Isl., Wennai, D. Shimizu s. n. (NICH-501124); Asahikawa-shi, Kamui-kotan,

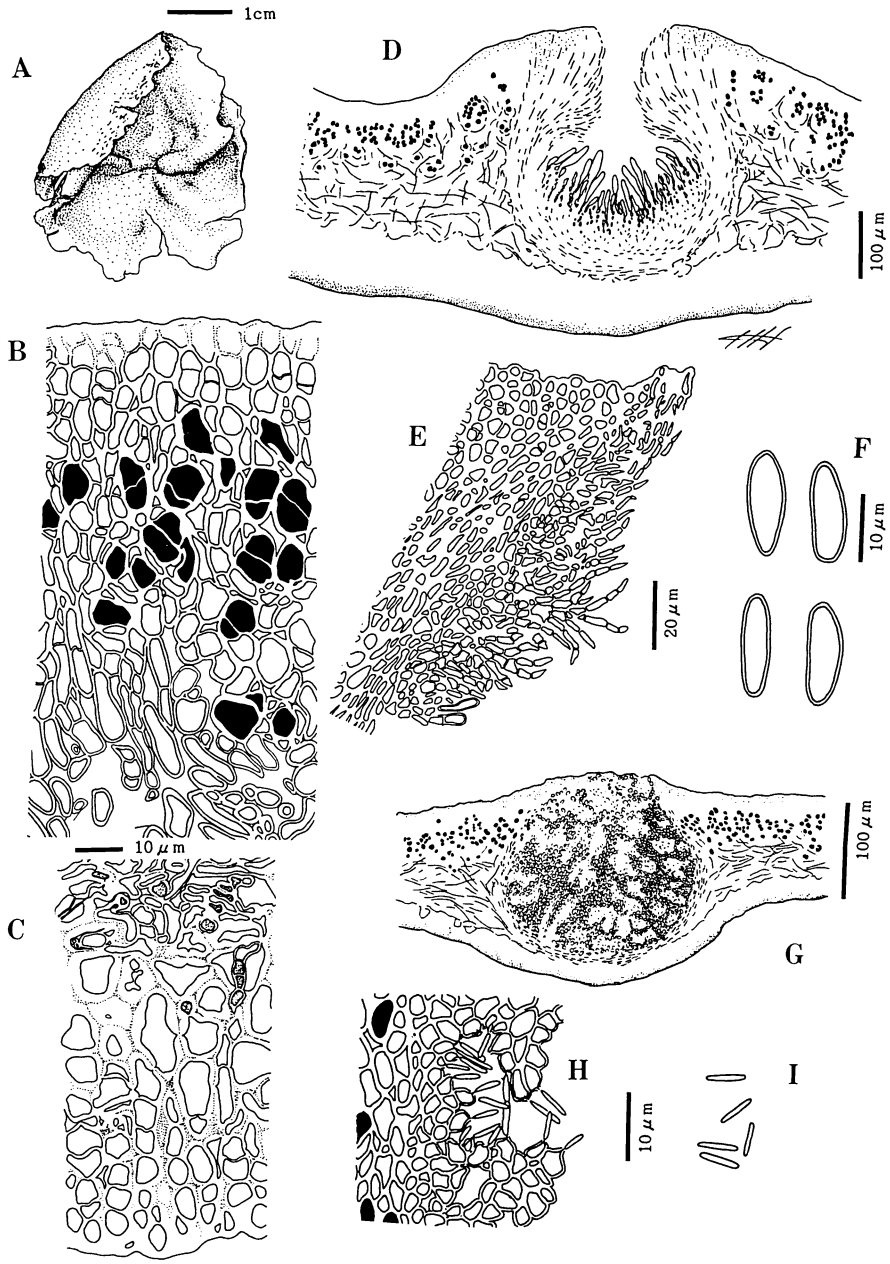

Fig. 20. *Dermatocarpon miniatum* (L.) Mann. A, habit. B, upper part of thallus in vertical section. C, vertical section of lower cortex. D, vertical section of thallus with perithecium. E, part of perithecium in vertical section. F, spores. G, vertical section of pycnidium. H, a part of pycnidium in vertical section. I, pycnoconidia. (A, air-dried material; B–I, LPCB preparations. A–C, F, Harada 71; D, Harada 1671; E, G–I, Harada 3090).

80 m alt., U. Faurie 6241 (KYO). HONSHU. Iwate-ken: Morioka, U. Faurie 1337 (KYO). Gunma-ken: Ozegahara, Y. Asahina s. n. (TNS-22178). Saitama-ken: Mt. Bukô, Y. Asahina s. n. (TNS-1866). Tôkyô-to: Nishi-tama-gun, Mt. Mitô, 1200 m alt., H. Harada 10250 (CBM). Toyama-ken: Tateyama, Kuranosuke-daira, K. Honda s. n. (TNS). Nagano-ken: Mina-

mi-saku-gun, Minami-maki-mura, K. Ohwi s. n. (TNS-25172). Yamanashi-ken: Kita-tsuru-gun, 1000 m alt., T. Osada and K. Osada s. n. (NICH-509573). Shizuoka-ken: Haibara-gun, Hon-kawane-chô, 360 m alt., H. Harada 3476 (HIRO). Aichi-ken: Kita-shitara-gun, Tôei-chô, 200 m alt., H. Harada 3494 (HIRO). Gifu-ken: Gujô-gun, Minami-mura, 150 m alt., H. Harada 3512 (HIRO). Kyoto-fu: Ayabe-shi, 50 m alt., H. Harada 3462 (HIRO). Mie-ken: Taki-gun, Ôsugi-dani, M. Togashi s. n., Lichenes japoniae exsiccati no. 123 (NICH). Wakayama-ken: Akitsu-gawa, Y. Asahina s. n. (TNS-1870). Tottori-ken: Yazu-gun, Kawabara-chô, 630 m alt., H. Miyawaki 6842 (HIRO). Okayama-ken: Maniwa-gun, Katsuyama-cho, 500 m alt., H. Kashiwadani 13078, Lichenes rariores et critici exsiccati no. 220 (TNS, NICH). Shimane-ken: Mino-gun, Hikimi-chô, 500 m alt., H. Harada 4174 (HIRO); Oki Isl., Chibu-gun, Kuniga, 40 m alt., H. Kashiwadani 5732 (TNS); Kanoashi-gun, Muikaichi-chô , Mt. Jakuji, 600 m alt., H. Harada 3090 (HIRO). Hiroshima-ken: Saiki-gun, Yoshiwa-mura, Mt. Kanmuri, 850–900 m alt., H. Harada 2657 (HIRO). SHIKOKU. Tokushima-ken: Mt. Tsurugi, 1800–1850 m alt., H. Harada 2266 (HIRO). Kochi-ken: Kami-gun, Monobe-mura, 1430 m alt., H. Harada 71 (CBM); Hata-gun, Taishô-chô, 150 m alt., H. Harada 1671 (HIRO); saxicola in rivulis montium Tosa, T. Yatabe 216 (G), det. by Müller Arg. as *Dermatocarpon fluviatile* Th.Fr. Ehime-ken: Kami-ukena-gun, Yanadani-mura, 600 m alt., H. Harada 3330 (HIRO). KYUSHU. Fukuoka-ken: Mt. Hiko-san, S. Komura s. n. (TNS-22189). Nagasaki-ken: Nagasaki, U. Faurie 1789 (KYO). Kumamoto-ken: Kuma-gun, Isshô-chi, F. Fujikawa s. n., Lichenes japoniae exsiccati no. 75 (NICH). Miyazaki-ken: Koyu-gun, Nishimera, 300 m alt., Z. Iwatsuki s. n. (NICH-509576).

Remarks. This species is characterized by large (usually exceeding 1 cm in diameter) and fundamentally mono-lobed thallus with an umbilicus at the center of the lower surface.

This species shows a rather wide range of variation in the color of lower surface of thallus. Some individuals grown on riverside rocks are reddish on the whole or part of lower surface. In addition, frequently submerged thallus tends to be very pale brown on the lower surface in contrast to more exposed ones which are usually very darker. The texture of the lower surface also varies smooth to wrinkled to veined. Periodically submerged thallus growing by the stream tends to have dense and conspicuous veins or wrinkles on lower surface.

2) *Dermatocarpon tuzibei* Sato
(Figs. 19C and D, 21)

J. Jpn. Bot. 15: 572 (1939). Type: Japan, Honshu, Iwate-ken, ad saxa non calcarea in cacumine montis Hayachine, 22 July 1936, M. Tuzibe & M. Sato s. n. (TNS—holotype).

External morphology. Thallus foliose to squamulose, usually composed of several squamules, up to 6 cm in diameter. Squamules lobate, with several umbilici scattered on the lower surface. Lobes rotund, up to 1 cm wide, almost entire on the margin, ascending, overlapping, imbricate; upper surface grayish brown, blackish brown along the margin (darker towards the margin), dull, slightly and finely scabrose, or nearly smooth, pruinose or epruinose, concave in the central part of squamules, infrequently convex particularly when imbricate; lower surface dark brown, a little glossy, with laminal or submarginal umbilici, smooth, or with ridges in the concaved parts. Perithecia laminal, rather common, scattered but rather crowded when fertile, immersed in the thallus, almost even, almost black around ostioles. Pycnidia laminal, common, immersed in the thallus, dark brown around ostioles.

Anatomy. Thallus 110–230 μm thick. Upper cortex 10–25 μm thick, brown in the uppermost part (ca. 5 μm thick), hyaline in the remainder, a little loose eu- to subparaplectenchymatous; lumina of hyphae 5–9 μm high, 4–5 μm wide; walls of hyphae ca. 0.5(–1) μm thick. Algal layer 20–80 μm thick; phycobiont cells solitary or in clusters. Medulla 40–80 μm thick, composed of filamentous hyphae (uniform in thickness, ca. 5 μm thick, with ca. 1 μm thick walls). Lower cortex 20–30 μm thick, of the *Dermatocarpon-*

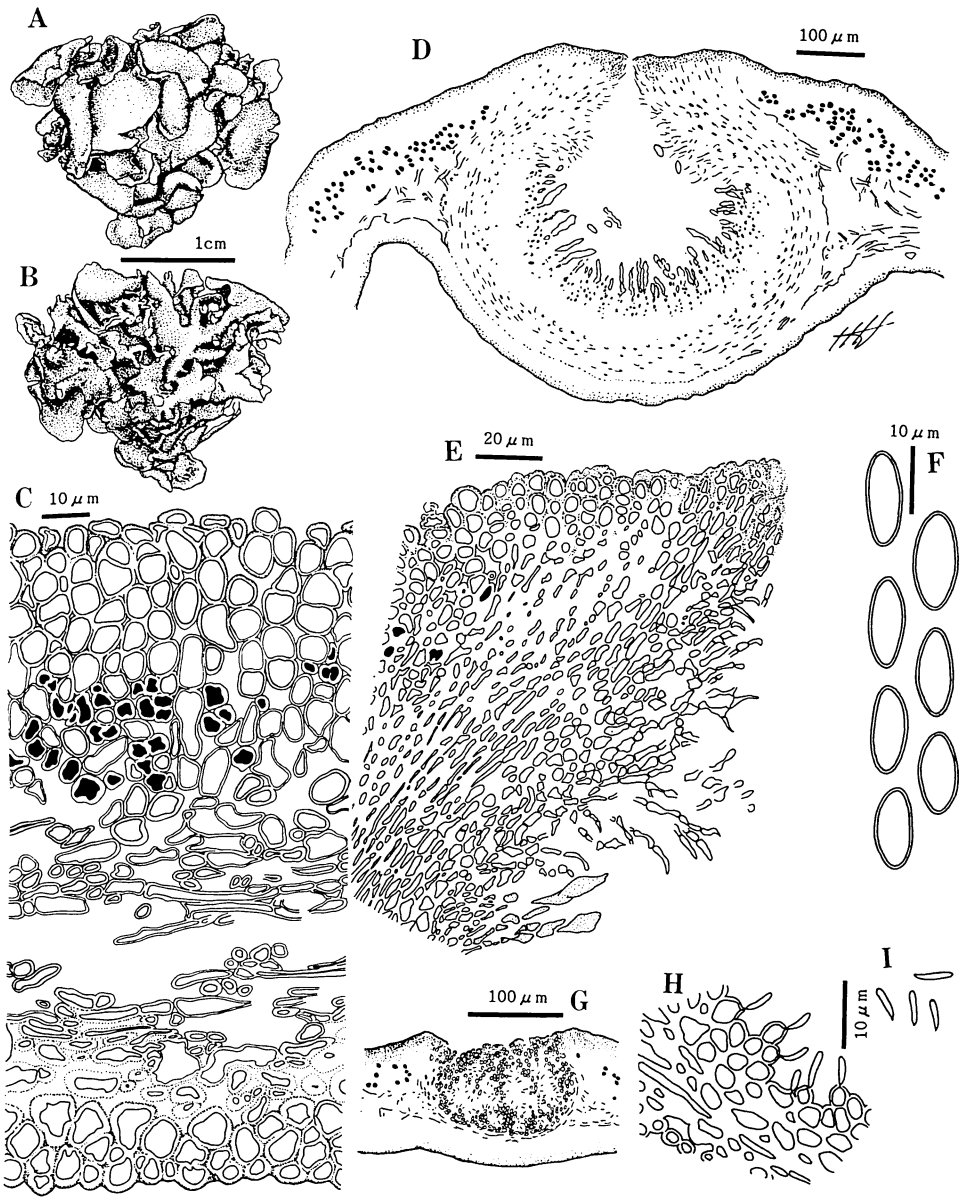

Fig. 21. *Dermatocarpon tuzibei* Sato. A, thallus in upper view. B, thallus in lower view. C, vertical section of thallus. D, vertical section of perithecium. E, part of perithecium in vertical section. F, spores. G, vertical section of pycnidium. H, part of pycnidium in vertical section. I, pycnoconidia. (A, B, air-dried material; C–I, LPCB preparations. A–B, Harada 7887; C–F, Kashiwadani 9015; G–I, Hisauchi s. n.).

type, 3–5 cell-layered; lumina of hyphae larger in the upper ones, almost isodiametric, 5–7 μm across in the lowermost ones, 7–10 μm across in the uppermost ones; walls of hyphae rather even in thickness in the lower part (ca. 1 μm thick), thicker in the upper part. Perithecia almost spheric, 220–320 μm high, 190–310 μm wide; exciple hyaline (hyaline throughout or brown at the uppermost), 25–50 μm thick; subhymenium 20–50 μm thick; periphyses 20–40 μm long, ca. 3 μm in diameter; asci clavate, 40–60 × ca. 15 μm; spores 8 in each ascus, hyaline, simple, oval, ca. 12×7–7.5 μm. Pycnidia of the *Xanthoria-*

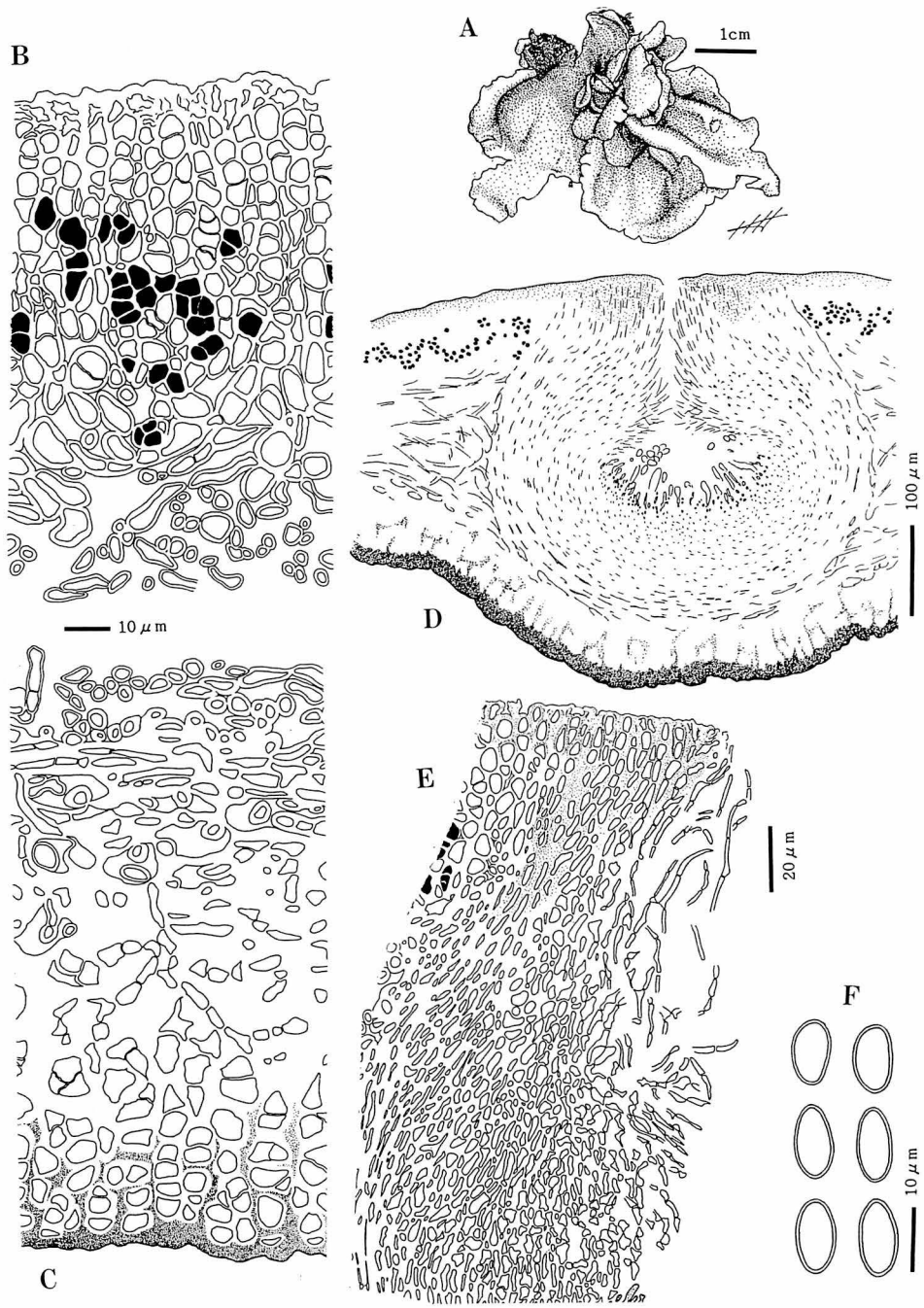

Fig. 22. *Dermatocarpon vellereum* Zsch. A, habit. B, upper part of thallus in vertical section. C, vertical section of lower cortex. D, vertical section of perithecium. E, part of perithecium in vertical section. F, spores. (A, air-dried material; B–F, LPCB preparations. A–C, Harada 7767; D, Koizumi s. n.; E, F, Kurokawa 72132).

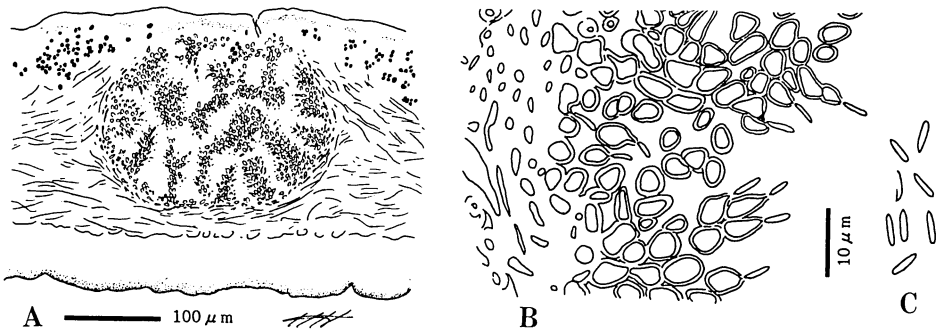

Fig. 23. *Dermatocarpon vellereum* Zsch. A, vertical section of pycnidium. B, part of pycnidium in vertical section. C, pycnoconidia. (A–C, LPCB preparations; A–C, Harada 7767).

type; pycnoconidia bacilliform, 4–6 × ca. 1 μm.

Habitat. On rocks, especially serpentine, at more or less exposed sites on mountains.

Range. Only known from Japan.

Representative specimens examined. HONSHU. Iwate-ken: Mt. Hayachine, 1900–1913 m alt., H. Harada 7887 (HIRO), M. Tuzibe & M. Sato s. n. (TNS—holotype); 1700 m alt., H. Kashiwadani 9015 (TNS); Hisauchi s. n. (TNS). Gunma-ken: Mt. Tanigawa, Y. Asahina s. n. (TNS-22181).

Remarks. This species is characterized by (1) small lobate thallus (2) with plural umbilici scattered over the lower surface.

3) *Dermatocarpon vellereum* Zschacke
(Figs. 19E and F, 22, 23)

Rabenh. Kryptog.-flora 9, Abt. 1, Teil 1: 638 (1934). Type: Kaukasus (Elenkin, Lichenes Florae Rossiae 49, as *Dermatocarpon moulinsii*; M—isotype).

Dermatocarpon moulinsii auct. non (Mont.) Zahlbr.: Asahina, J. Jpn. Bot. 32: 132 (1957).

External morphology. Thallus foliose, umbilicate, usually mono-lobed, but frequently composed of up to several lobes, 1–7 cm in diameter. Lobes almost entire to irregularly and sparsely dissected; upper surface brownish or grayish, dull, slightly and finely scabrose, or nearly smooth, epruinose, concave in the central part; lower surface black or dark brown, dull, with or without ridges, with a central umbilicus, with rhizinomorphs. Rhizinomorphs dense, completely or partly covering the lower surface of thallus, repeatedly branched, more or less swollen at tips of branchlets, almost botryoid, usually 1–2 mm long, up to 0.15 mm thick at the base, black to dark brown, concolorous with the lower surface of thallus. Perithecia laminal, common, scattered, completely immersed in the thallus, almost plane, dark brown around ostioles. Pycnidia laminal, common, scattered, immersed in the thallus, dark brown around the ostioles.

Anatomy. Thallus 130–660 μm thick (or thicker). Upper cortex 5–50 μm thick, brown in the uppermost part, hyaline in the remainder, a little loose eu- to subparaplectenchymatous; lumina of hyphae larger and more or less vertically elongated in the inner part, isodiametric and 3–5 μm across in the outer ones; walls of hyphae ca. 1 μm thick in the upper ones. Algal layer 30–180 μm thick. Medulla 40–350 μm thick, composed of filamentous hyphae (uniform in thickness, ca. 4 μm in diameter, with ca. 1 μm thick walls). Lower cortex (25–)50–110 μm thick, of the *Dermatocarpon*-type; lumina of hyphae 4–7 μm across in the lower part, up to 15 μm high and 10 μm wide in the upper part, more or less polygonal; walls of hyphae variable in thickness, 0.5–5 μm thick, generally thicker in the upper part, ca. 3 μm thick in the lowermost. Rhizinomorphs I−. Perithecia pyriform to almost spheric, 280–510 μm high, 200–550 μm wide; exciple hyaline (brown at the outermost), 20–110 μm thick; periphyses 30–50 μm long, ca. 3 μm in diameter; subhymenium 40–50 μm thick; hymenium 200–320 μm high, 120–200 μm wide; asci clavate, 55–80×12–15 μm;

spores 8 in each ascus, hyaline, simple, ellipsoidal, 10.5–17.5×5–7 μm. Pycnidia of the *Xanthoria*-type; pycnoconidia 4–5×ca. 1 μm.

Habitat. On rocks, especially serpentine and rhyolite, at more or less exposed sites in northern Japan.

Range. Japan, China, Siberia, Himalaya, India, Afghanistan, Caucasus.

Representative specimens examined. HOKKAIDO. Rebun Isl., U. Faurie 5261 (KYO); Mt. Yûbari, H. Koidzumi 72048 (TNS), S. Kurokawa 72132, Lich. Rariores et Critici Exsiccati 272, as *Dermatocarpon moulinsii* (TNS, NICH). HONSHU. Akita-ken: Oga-shi, Mt. Shinzan, ca. 500 m alt., K. Sasaki s. n. (TNS). Iwate-ken: Mt. Hayachine, 1400–1500 m alt., H. Harada 7767 (HIRO).

Remarks. This species is characterized by (1) fundamentally mono-lobed large thallus (usually exceeding 1 cm in diameter) and (2) dendroid rhizinomorphs on lower surface.

This species had been known as *Dermatocarpon moulinsii* (Mont.) Zahlbr. in Japan (Asahina, 1957). It resembles *D. moulinsii* (Mont.) Zahlbr. in having rhizinomorphs. However, these two species are apparently different in morphology of rhizinomorphs and color of lower surface, as shown in the original description of *D. vellereum* given by Zschacke (1934) and also by Poelt (1977). The rhizinomorphs are dendroid in *D. vellereum* but simple in *D. moulinsii*. The lower surface of the thallus is almost black in the former but brown in the latter.

The thallus is mono-lobed to lobate in this species as in *D. miniatum*. Even though various degrees of lobation are found for this lichen on Mt. Yûbari in Hokkaido and on Mt. Hayachine in Honshu, they can not be distinguished by other morphological or anatomical characters.

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日本産カワイワタケ属および近縁属（地衣類，アナイボゴケ科）の分類学的研究

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アナイボゴケ科地衣類のうち葉状ないし鱗片状の地衣体を持ち単室の胞子を生ずるものは従来はカワイワタケ属 (*Dermatocarpon*) にまとめられていた．日本産のこれらの地衣類について分類学的検討を行ない，5属11種を認めた．5属の中には，最近認められている2属 (*Dermatocarpon* Eschw., *Catapyrenium* Flotow) に加え，次の3新属が含まれる：*Dermatocarpella* Harada, *Neocatapyrenium* Harada, *Scleropyrenium* Harada．また11種のうち，3種を新種として記載したものである：*Dermatocarpella yoshimurae* Harada, *Scleropyrenium japonicum* Harada, *Scleropyrenium kurokawae* Harada．また，次の新組合せを作った：*Dermatocarponella kisovensis* (Zahlbr.) Harada, *D. squamulosa* (Ach.) Harada, *Neocatapyrenium cladonioideum* (Vain.) Harada.