Journ. Fac. Sci., Hokkaido Univ. Ser. V (Botany), 13 (1): 77-98 1983.

Morphological observations on *Porphyra occidentalis* SETCHELL et HUS (Rhodophyta, Bangiales) collected near Carmel, California

Tetsu SHIMIZU and Munenao KUROGI

Fresh material of a female plant and formalin-preserved female and male materials of a distromatic species, *Porphyra occidentalis* collected at the type locality, Carmel, California were observed morphologically. The morphology of fresh or preserved plants was carefully elucidated, and some features of vegetative and reproductive structures were newly added to the original description of HUS (1900, 1902). It was also made certain that *P. variegata* of HUS differs entirely from KJELLMAN's *P. variegata*, and is the female plant of *P. occidentalis*.

HUS (1900, 1902) identified a distromatic plant of *Porphyra* from Carmel on the Monterey Peninsula and San Pedro in California and Coupeville in Washington as *P. variegata* (*Diploderma variegata* KJELLMAN 1889) based on dried specimens. At the same time, he (1900) described a new distromatic species, *P. occidentalis* SETCHELL et HUS, based on dried specimens collected from Carmel Bay in the Monterey Peninsula. In the former species female plants only are known and in the latter male plants only. HOLLENBERG and ABBOTT (1966) considered HUS' *P. variegata* to be different from KJELLMAN's *P. variegata* and treated HUS' *P. variegata* as the female plant of *P. occidentalis*. After HUS, however, there are no detailed observations.

On the other hand, we have *P. occidentalis* identified by KAWABATA (1936) and NAGAI (1941) from Kurile Islands. KUROGI (1978, 1979) preliminarily reported that the plant is distributed also on the coast of eastern Hokkaido and it is dioecious with female and male plants. Comparison of the Japanese *P. occidentalis* with the *P. occidentalis* on the American Pacific coast was necessary in order to clarify the status. Fortunately, we had an opportunity to observe the fresh materials and formalin preserved ones of the female plant and male plant of *P. occidentalis* collected at the type locality of *P. occidentalis* in California. The type specimens of *P. occidentalis* and the original specimens of HUS' *P. variegata* were also observed. Here we describe the morphology of these as a part of our study on *P. occidentalis*.

Materials and Methods

Three plants were observed. One of them (Fig. 1 A) is a fully matured female plant collected cast ashore at Middle Reef of Moss Beach, Pacific Grove on August 22, 1980 by us. The second (Fig. 1 B) is a young female plant and the third (Fig. 1 C) is a fully matured male plant. Both the plants (B, C) were collected at Malpaso Creek, Monterey County, from a depth of 15 ft. on March 14, 1976 by R. SELLERS. The observation of the female

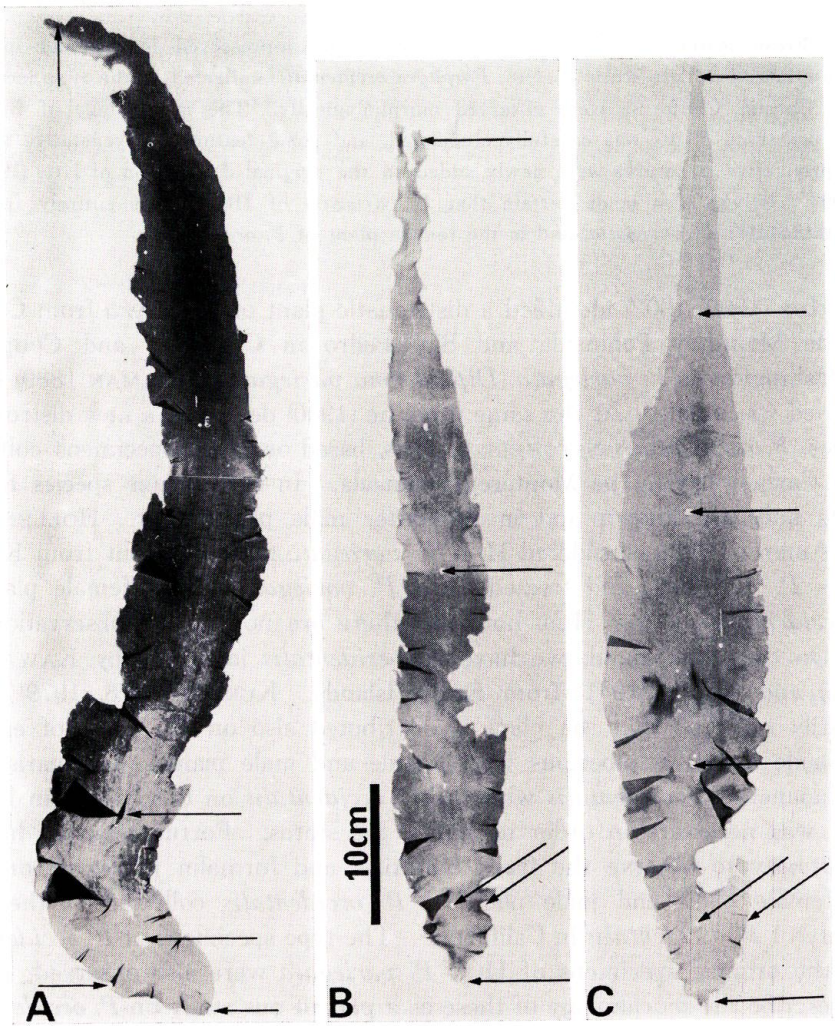


Fig. 1. *Porphyra occidentalis*, A: fully matured female, B: young female, C: fully matured male. Arrows showing the places examined.

plant A was done in living condition immediately after collection and supplementally eight months after it was dried on a sheet. The female B and male C observed were preserved in 5% formalin seawater.

Observations

1. Fully matured female plant (Fig. 1 A)

The plant observed is 78 cm long and 10 cm broad, linear lanceolate, round to somewhat cordate at the basal part, not stipitate, with a small discoid holdfast, brick red in color, forming cystocarps in the upper marginal part more than about 10 cm from the base and in the upper to middle central part, variegate in color in the cystocarpic portion owing to mixture of aborted and successful cystocarps, slightly undulate at the margin, showing an aureole near the base owing to rhizoids.

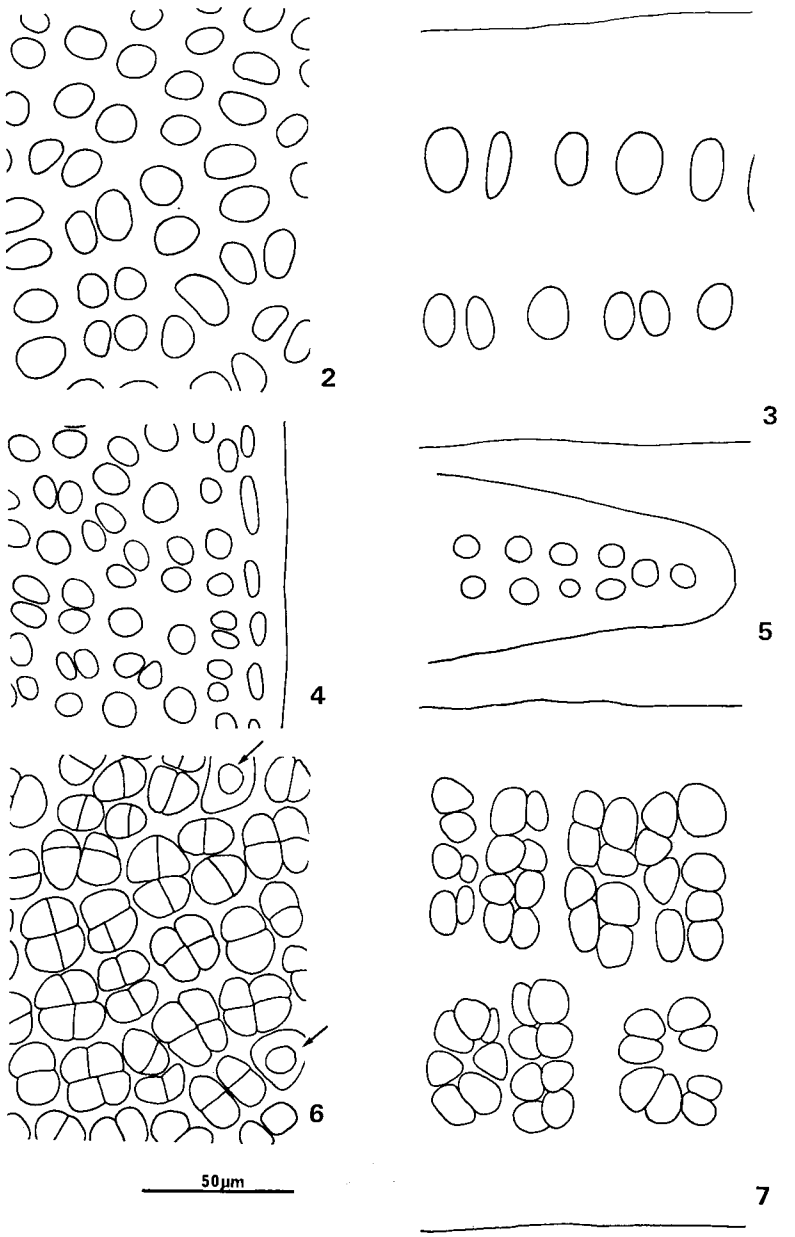
The margin of the vegetative part is entire and without microscopic dentation. The thickness of thallus and the sizes of vegetative cells and of cystocarps at different parts are shown in Table 1.

The thickness is about 150–160 μm throughout longitudinal central part from the lower vegetative part to the upper cystocarpic part. It is thinner down to about 50 μm toward the margin in the lower vegetative part.

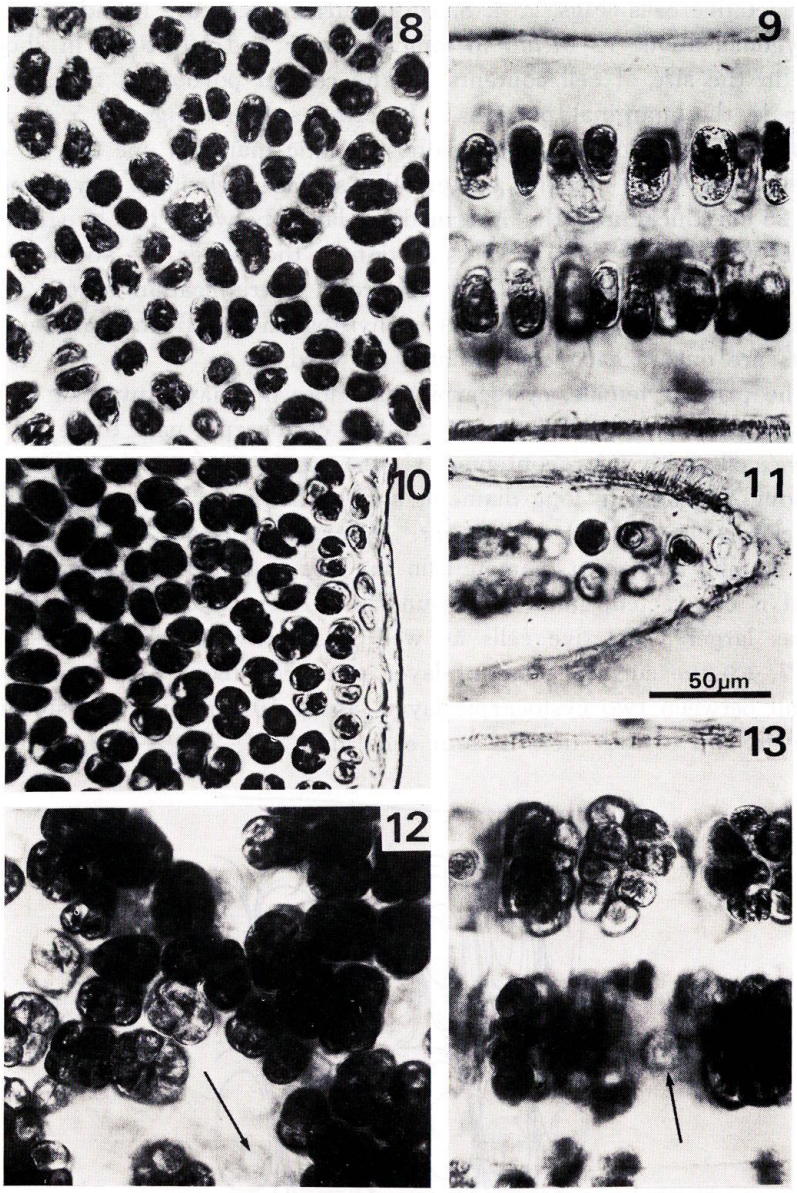
TABLE 1. Thickness of thallus, size of vegetative cell and cystocarp of a fully matured female plant (Fig. 1 A) (μm)

place of thallus measured (cf. Fig. 1)	thickness of thallus	cell layer	size of veget. cell and cystocarp[1] surface view: long diam.× short diam.	cross section: height×breadth	h/b
			cystocarp		
apical part	150–175	2	22.0–27.5×17.6–22.0	41.0–49.5×17.7–25.1	2.0–3.7
			veget. cell		
16 cm from base					
center	150–155	2	14.3–26.4×11.0–16.5	28.5–31.0×10.1–21.0	1.5–3.0
7 cm from base					
margin	50	1 or 2			
inner 0.5 mm	100	2	12.1–15.4×11.0–13.2	13.2–16.5× 9.9–11.0	1.2–1.6
inner 1.5 mm	125	2	12.1–22.0×11.0–16.5	20.9–26.4×13.2–19.8	1.3–1.7
center	150–160	2	12.1–27.5× 8.8–17.6	27.5–37.4×11.0–22.0	1.5–3.2

1) showing the size of cell content and cystocarp content measured in living condition.



Figs. 2–7. Fully matured female (Fig. 1 A), anatomical drawings from the preparation of fresh material placed in 50% Karo syrup; 2, 4, 6 surface view, 3, 5, 7 cross section. 2, 3 vegetative cells in the lower central part; 4, 5 vegetative cells in the marginal part; 6, 7 cystocarps and abortive cells (arrows) in the upper fertile part.



Figs. 8–13. Fully matured female (Fig. 1 A), anatomical microphotographs taken in living condition; 8, 10, 12 surface view, 9, 11, 13 cross section. 8, 9 vegetative cells in the lower central part; 10, 11 vegetative cells in the marginal part: 12, 13 cystocarps and abortive cells (arrows) in the upper fertile part.

Vegetative cells (Figs. 2, 4, 8, 10) in surface view are rounded triangular to polygonal, about 12–27 μm in long diameter and 10–18 μm in short diameter (in the size of cell contents) in the central portion of the blade, and smaller in the marginal portions. In cross section (Figs. 3, 5, 9, 11) the thallus is distromatic, remaining monostromatic marginal one or two cells in the vegetative part. In the center, the surface gelationus layer measures about 25 μm thick, and the intermediate layer between the two cell layers about 10 μm thick. Cells in cross section of the center are about 27–37 μm high, being 1.5–3.2 times as high as broad. Stratification of cell wall described in "*P. variegata*" by Hus is invisible in the fresh material. Chloroplasts are one in each cell, situated outward.

The plant is female, cystocarpic, and does not have any male reproductive structures nor their remnant. In the cystocarpic part there are mixed abortive cells with poor contents. Cystocarps in surface view (Figs. 6, 12) are about 22–27 μm in long diameter and 17–22 μm in short diameter, sometimes closely attached to each other. Abortive cells are 22–26 μm and 20–22 μm in long and short diameters in the size of inner cell cavity. The cell content is contracted, small and roundish. The size of cystocarps is nearly same as larger vegetative cells as well as abortive cells. In corss section (Figs. 7, 13) the surface gelatious layer measures about 11–16 μm thick and the wall between two cystocarpic layers about 10 μm thick. Cystocarps are divided in two to four tiers of four each (a/2, b/(1)–2, c/2–4 in the formula),

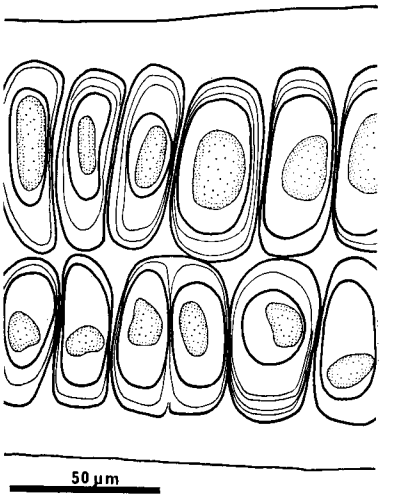


Fig. 14. Fully matured female (Fig. 1 A), stratification of cell walls in the plant after dried, dotted space showing contracted cell content and inner thick line cell cavity.

containing 8 to 16 carpospores.

Supplemental observation of the same plant that was observed in living condition eight months later after being dried on a sheet revealed some different details of cell wall structure and the structure of basal part of thallus. In the dried plant cell walls are clear, thick and stratified in several layers

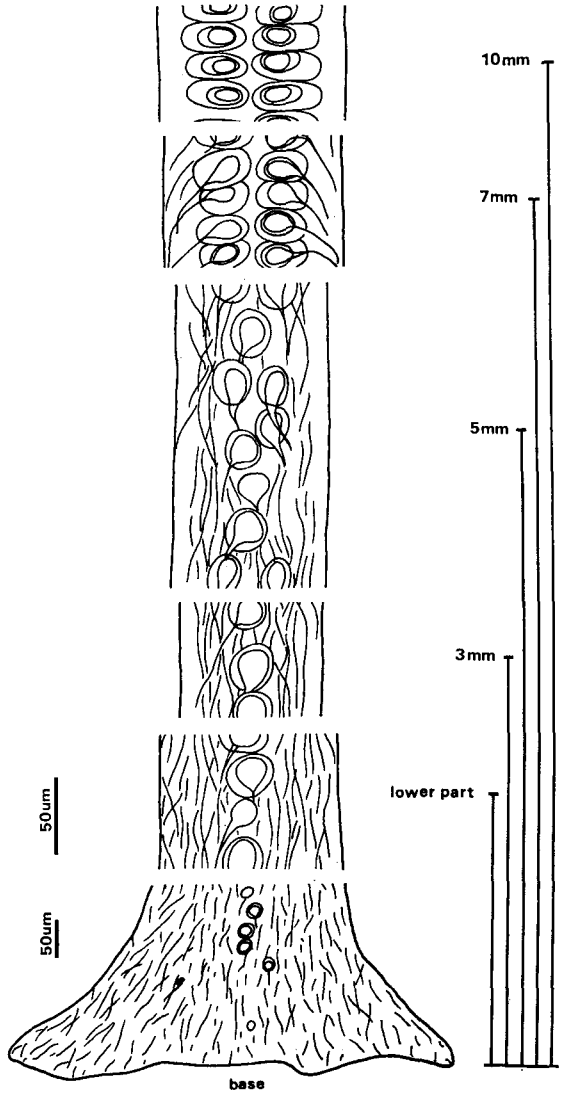
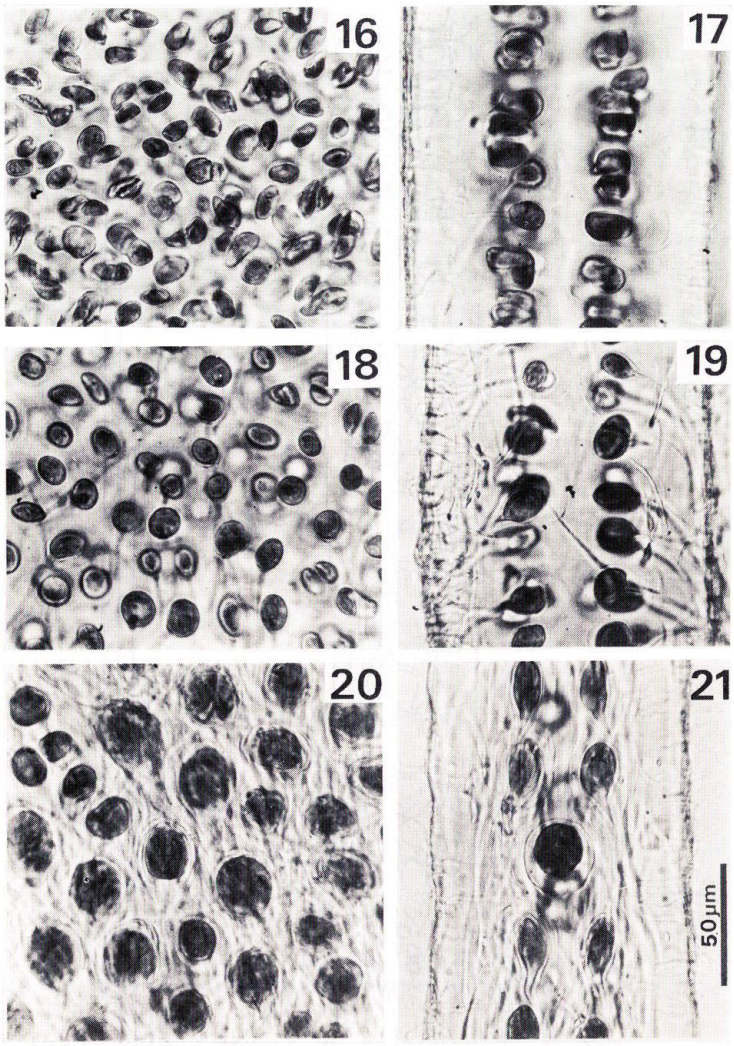


Fig. 15. Fully matured female (Fig. 1 A), schematic drawing of longitudinal section of the basal part of thallus.

especially in the outer and inner sides (Fig. 14). The thicknesses of outer side, inner side and lateral side in the vegetative central part of thallus are 7-20 μm, 3-12 μm and 2-6 μm respectively. The thickness of the surface gelatinous layer is 14-20 μm, somewhat smaller than measured in living condition. When soaked with water, the cystocarpic part disintegrates and



Figs. 16-21. Fully matured female (Fig. 1 A), anatomical microphotographs of the basal part examined after dried; 16, 18, 20 surface view, 17, 19, 21 longitudinal section (cf. Fig. 15). 16, 17 lower 10 mm, without rhizoids; 18, 19 lower 7 mm, with rhizoids; 20, 21 lower 5 mm, with rhizoids.

carpospores are liberated as described in "*P. variegata*" by HUS.

The structure and thickness of rhizoidiferous basal part and the sizes of rhizoidiferous cells are shown in Figs. 15, 16–21 and Table 2. They are compared with measurements in the upper vegetative part. The basal part is mostly distromatic, but monostromatic near the discoid holdfast. Cells with rhizoid are round to obovate longitudinally. Rhizoids are mostly issued outside (abaxially). The thickness of rhizoidiferous basal part except for near the discoid holdfast is thinner than in the upper vegetative part.

TABLE 2. Thickness of thallus and size of vegetative cell in the lowest part of a fully matured female plant (Fig. 1 A) (μm)

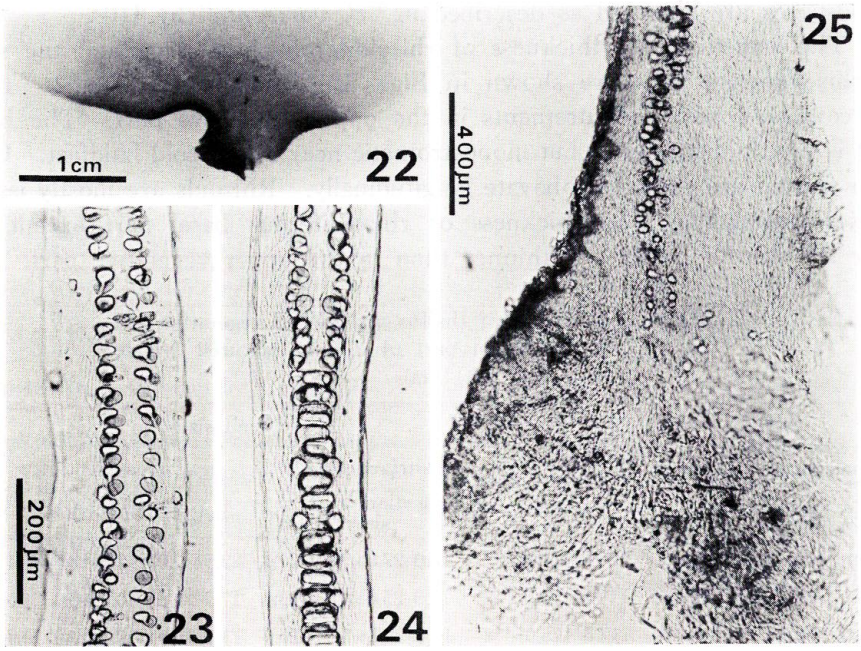
place of thallus measured (cf. Fig. 1)	rhizoid	thickness of thallus	cell layer	cell size[1] surface view: long diam.× short diam.	cell size[1] cross section: height×breadth	h/b
7 cm from base	absent	145.0–150.0	2	15.0–27.5×10.0–20.0	22.5–30.0× 7.5–12.5	1.4–2.5
1 cm from base	absent	117.5–125.0	2	17.5–25.0×15.0–20.0	17.5–22.5×10.0–15.0	1.0–1.8
7 mm from base	absent	117.5–125.0	2	12.5–22.5×12.5–20.0	12.5–15.0×10.0–15.0	0.9–1.5
5 mm from base	present	105.0–112.5	1 or 2	22.5–32.5×20.0–27.5	20.0–30.0×22.5–30.0	0.8–1.0
3 mm from base	present	92.5–102.5	1	20.0–32.5×20.0–30.0	20.0–27.5×22.5–32.5	0.8–1.0
lower part	present	122.5–140.0	1	20.0–35.0×20.0–30.0	25.0–27.5×25.0–35.0	0.6–1.0
base	present	610	1	not clear	not clear	

1) showing the size of inner cell cavity, which is equal to cell content in living condition, measured eight months after being dried as a herbarium sheet, with sections embedded in 20% glycerine.

2. Young female plant (Fig. 1 B)

The plant is 61 cm long, 8 cm broad, linear lanceolate, slightly undulate at margin, round at basal part, and with a very shortly stipitate holdfast (Fig. 22). The color is faded because of the long time preservation in formalin seawater. The upper marginal part above about 10 cm from the base is matured, forming cystocarps, but does not show any trace of the liberation of carpospores. The microscopical observations of vegetative and reproductive structures are shown in Table 3 and Figs. 22–25.

The thallus is distromatic except for the margin of 1 to 2 cells. The thickness is about 130 μm in the lower center of thallus and gradually thinner down to about 50 μm toward the margin. The thickness of longitudinal central part is thinner upward and thicker near the base. It is about 95 μm



Figs. 22–25. Young female (Fig. 1 B). 22 basal part of thallus; 23–25 longitudinal section of the basal part with rhizoids; 23 upper 2 layered part, 24 middle 1–2 layered part, 25 lowest 1–2 layered (not arranged in line) part.

TABLE 3. Thickness of thallus, size of vegetative cell and cystocarp of a young female plant (Fig. 1 B) (μm)

place of thallus measured (cf. Fig. 1)	thickness of thallus	cell layer	size of veget. cell and cystocarp[1)] surface view: long diam.× short diam.	cross section: height×breadth	h/b
			cystocarp		
apical part	95– 98	2	18–26×13–19	30–35×18–23	1.8–2.3
			veget. cell		
middle central part	99–105	2	13–26×10–20	20–26×12–23	1.0–1.8
6 cm from base					
margin	48	1 or 2	7–16× 6–14	12–15× 7–13	1.5–2.0
inner 2 mm	71 –75	2	14–27×10–19	15–19× 9–20	1.1–1.7
center	127–136	2	16–30×11–21	26–30×13–22	1.3–2.9
lowest part					
without rhizoid	168–175	2	15–34×14–20	27–39×11–22	1.4–3.5

basal part with rhizoid					
uppermost	186–195	2	16–33×16–27	25–32×19–27	1.0–1.8
intermediate	165	1			
middle	188–195	1	26–38×24–33	28–37×15–32	1.1–2.1
lowermost	525–925	1 (or 2)	not clear	13–17×11–14	0.9–1.3

1) showing the size of cell content measured in formalin preserved specimen.

in the apical cystocarpic part, about 170 μm immediately above the rhizoidiferous basal part and more than 185 μm in the rhizoidiferous basal part. The rhizoidiferous part (Figs. 23, 24, 25) is distromatic in the upper, and distromatic or monostromatic and then monostromatic downward. The intermediate monostromatic part (Fig. 24) is slightly thinner, down to about 165 μm, than above or below it.

The gelatinous surface layer in the lower central part is 14–18 μm and the intermediate layer is 2–4 μm.

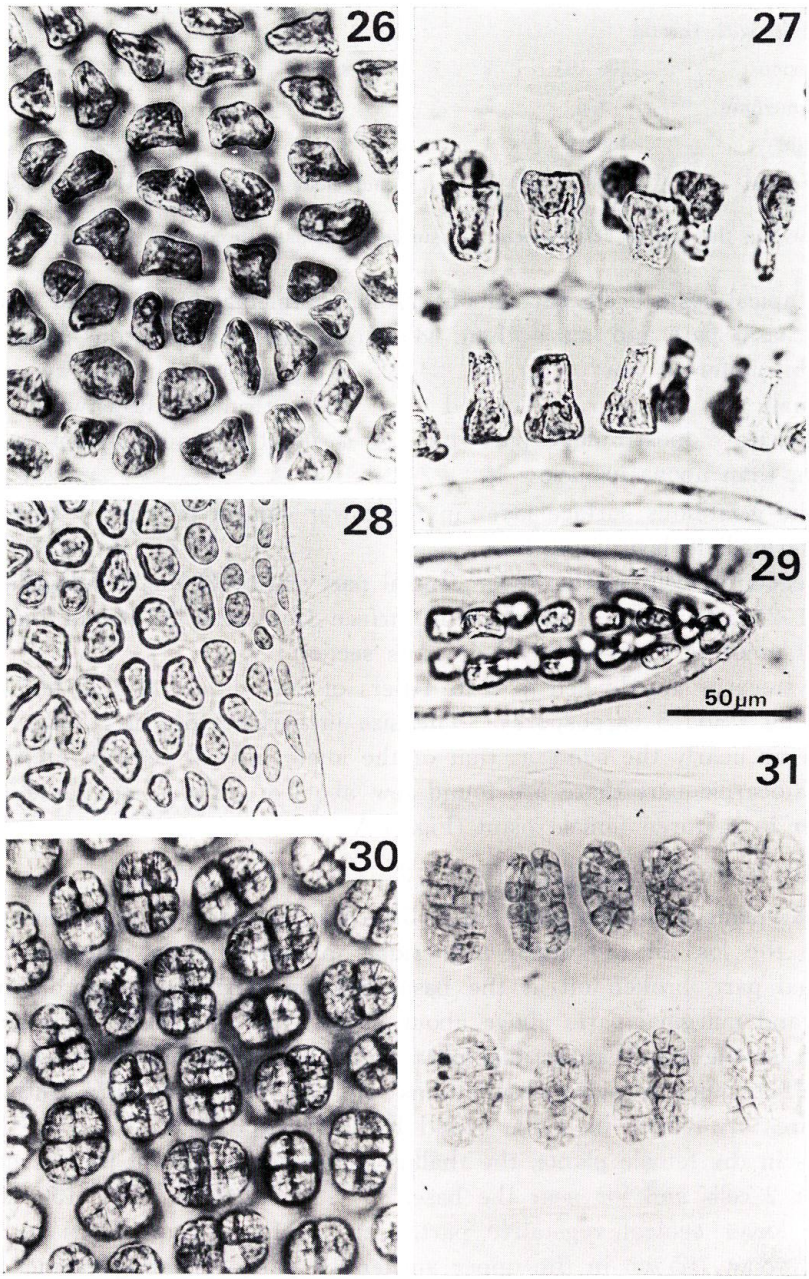
Vegetative cells in the lower central part are 16–30 μm in long diameter and 11–21 μm in short diameter in surface view, and 26–30 μm high and 1.3–2.9 times as high as broad in cross section.

Cystocarps are divided in 2 to 4 tiers of 2 to 4 each (a/1–2, b/2, c/2–4) producing 4 to 16 carpospores. The size in surface view is 18–26×13–19 μm, being nearly the same as that of the lower central vegetative cells. In the cystocarpic part there are found few abortive cells as compared to the number in matured female plant (Fig. 1 A).

3. Fully matured male plant (Fig. 1 C)

The plant is 66.5 cm long and 11.5 cm broad, lanceolate, tapering upward due to the loss of the upper antheridial margin, slightly undulate in the marginal part, broken off at the basal holdfast, forming antheridia in the upper and marginal parts above about 20 cm from the base. The color is whitish in the upper antheridial part, faded purple in the lower vegetative part. The microscopical observations on the vegetative and antheridial structures are shown in Table 4 and Figs. 26–31, 32.

As in the female plants, the thallus is distromatic except for the margin of 1 or 2 cells and for near the base. The thickness is about 150–160 μm in the lower central vegetative part, thin toward margin down to about 50 μm, about 165 μm in the upper antheridial part, becoming thinner down to about 115–120 μm in the upper and middle rhizoidiferous di- or monostromatic basal part and again perhaps thicker near the basal holdfast which is lost in this plant. The gelationous surface layer in the lower central



Figs. 26–31. Fully matured male (Fig. 1 C), anatomical microphotographs taken from formalin-preserved material; 26, 28, 30 surface view, 27, 29, 31 cross section. 26, 27 vegetative cells in the lower central part; 28, 29 vegetative cells in the marginal part; 30, 31 antheridia in the upper fertile part.

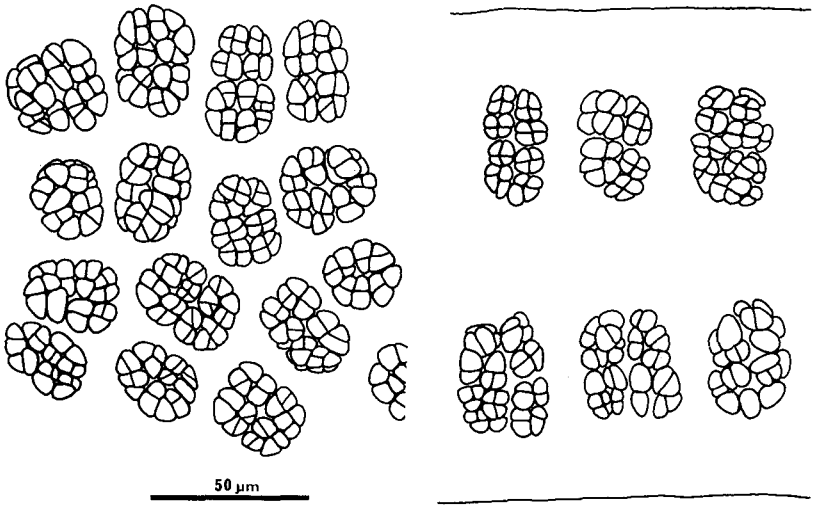


Fig. 32. Fully matured male (Fig. 1 C), antheridia in surface view (left) and in cross section (right).

TABLE 4. Thickness of thallus, size of vegetative cell and antheridium of a fully matured male plant (Fig. 1 C) (μm)

place of thallus measured (cf. Fig. 1)	thickness of thallus	cell layer	size of veget. cell and antheridium[1] surface view: long diam.× short diam.	cross section: height×breadth	h/b
			antheridium		
apical part	166–168	2	24–37×20–26	36–47×20–29	1.1–1.8
50 cm from base	162–168	2	27–35×18–30	35–43×21–36	1.0–1.6
			veget. cell		
30 cm from base	140–144	2	22–39×15–25	36–42×18–33	1.1–2.3
16 cm from base	153–159	2	18–34×14–24	24–36×18–36	0.8–2.1
6 cm from base					
margin	43– 48	1	8–17× 3– 6	6–15× 6–18	1.1–1.6
inner 0.5 mm	69– 72	2	14–28×12–18	14–18×12–20	0.7–1.4
inner 1.0 mm	78– 79	2	14–28×11–22	18–23×12–25	0.6–1.4
inner 2.0 mm	78– 84	2	15–33×12–24	18–22×12–25	0.6–1.4
center	150–156	2	15–32×12–20	35–39×11–23	1.4–3.1
lowest part	119–129	1	17–29×14–19	36–42×13–20	1.8–3.3
without rhizoid		or 2		15–29×14–25	0.6–1.8
basal part with rhizoid					
upper most	114–120	1	13–23×14–26	33–45×17–19	1.4–2.8
		or 2		14–18×31–34	0.4–0.6
middle	114–121	1	16–24×18–23	30–44×15–25	1.6–1.9
lowermost[2]	129–132	1	not clear	20–22×16–21	1.1–1.4

1) showing the size of cell content measured in formalin preserved specimen.
2) this plant lacks basal holdfast.

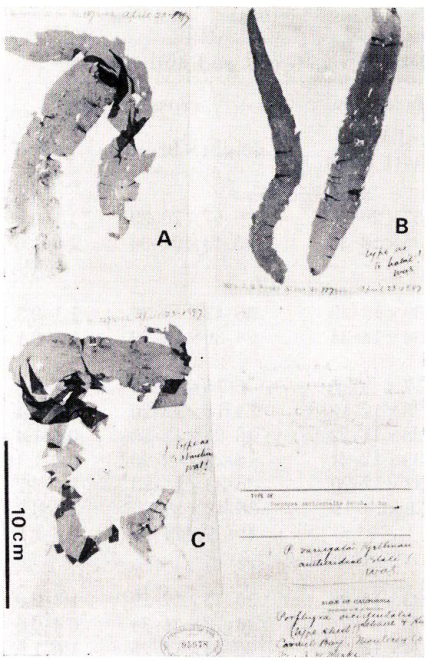
part is 9–19 μm thick and the intermediate layer between the two cell layers is 2–6 μm thick.

Vegetative cells in the lower central part is 15–32 μm in long diameter and 12–20 μm in short diameter in surface view, and 1.4–3.1 times as high as broad in cross section. In the middle central part there are found some slightly larger cells in the surface view. After being dried, the specimen showed the stratification of cell wall as seen in the female thallus (Fig. 1 A).

Antheridia divide in eight tiers of 16 to 32 each (a/4, b/4–8, c/8 in formula), producing 128 to 256 spermatia. The size is 24–37 × 20–26 μm in surface view, and 36–47 μm high and 1.1–1.8 times as high as broad in cross section. The size is somewhat larger than that of the lower central vegetative cells.

4. Type specimens of *Porphyra occidentalis*

The type specimens are deposited in the Herbarium of Department of Botany, University of California, Barkeley (UC). They are composed of four plants collected by Mrs. J. M. WEEKS, on April 23, 1897 and placed on a sheet with the accession number of 95678 (Fig. 33). The sheet has hand-



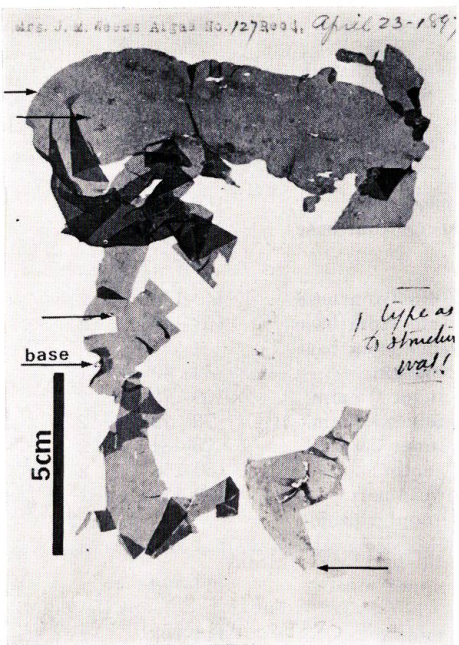
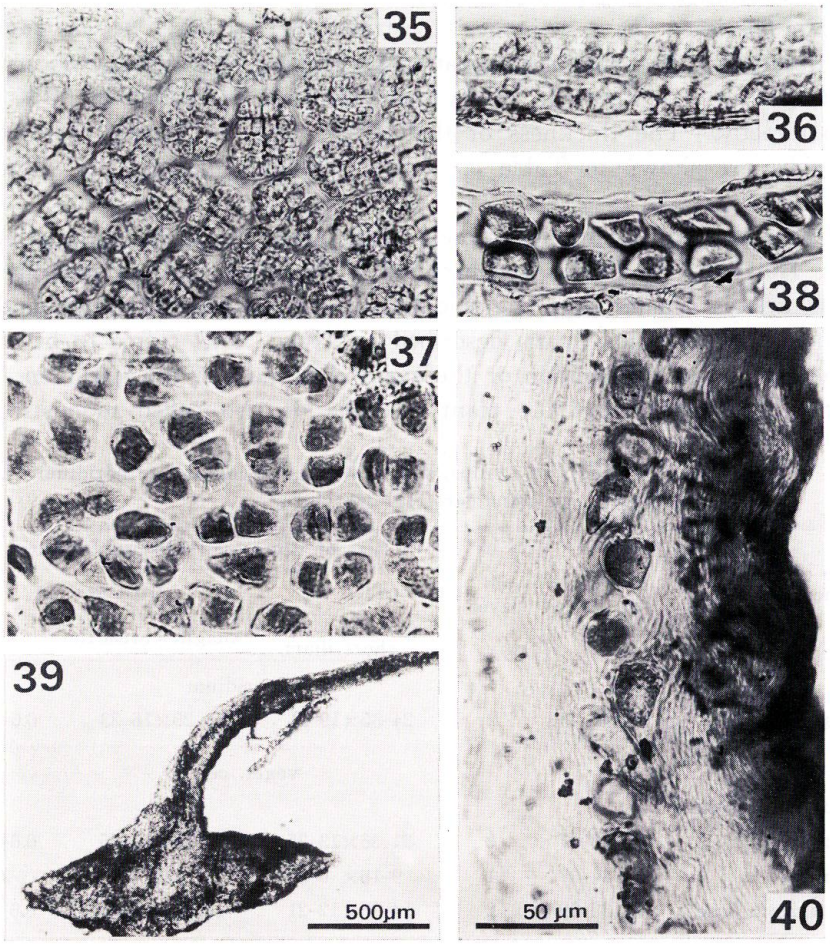


Fig. 33 (left). Type specimens of *P. occidentalis* SETCHELL et HUS.

Fig. 34 (right). Lectotype ("type as to structure") of *P. occidentalis* SETCHELL et HUS, arrows showing the places examined.

written notes by W. A. SETCHELL as "*Porphyra occidentalis* SETCHELL and HUS (type sheet !), Carmel Bay, Monterey Co., Mrs. J. M. WEEKS" and "*P. variegata* KJELLMAN, antheridial state !, W. A. S."

One of the four plants (Fig. 33 C, Fig. 34) is annotated "type as to structure, W. A. S" by SETCHELL, other two on the same paper (Fig. 33 B) "type as to habit, W. A. S.". The remaining specimen (Fig. 33 A) has no annotation. The specimen (Fig. 33 C) "as to structure" is divided, cut off numer-



Figs. 35–40. Anatomical microphotographs of the lectotype specimen of *P. occidentalis* SETCHELL et HUS. 35, 36 antheridia in surface view (35) and in cross section (36); 37, 38 vegetative cells in surface view (37) and in cross section (38); 39–40 longitudinal section of base, 40 showing monostromatic part. 35–38 transferred to 50% Karo syrup, 39–40 placed in 20% glycerin after treatment with saturated $HgCl_2$ and heated. Figs. 35–38: same magnification as Fig. 40.

ously in the marginal part for observation. It is difficult to describe its original shape, but a cordate base with a short stipe, and antheridia in the upper margin are present. The specimens "as to habit" (Fig. 33 B) are linear lanceolate, one (left) of which is 17 cm long and 1.7 cm broad, without base, sterile, and the other (right) is 17 cm long and 2.5 cm broad, forming antheridia only in the apical part. The specimen with no annotation is divided, 23.2 cm long and 3.4 cm broad, forming antheridia in the upper part. All the specimens appear to be young.

The specimen "as to structure" illustrated in Figs. 33 C, 34 was anatomically observed. To avoid disintegration by soaking in water the observation was made with sections cut in dry condition and embedded in 50% Karo syrup directly. The thickness of thallus, the sizes of vegetative cells and antheridia are shown in Table 5. Some anatomical figures are shown in Figs. 35–40.

Generally, our anatomical observations agree with the description by Hus. However, the thallus is contracted in thickness, and our measurement of thickness is smaller than the thickness (45 μm in vegetative part and 65–75 μm in the antheridial part) described by Hus. This seems to be caused by the method of observation or the age and dryness of the specimen. Our observation revealed that the plant has one or two celled monostromatic

TABLE 5. Thickness of thallus, size of vegetative cell and antheridium of the type specimen (Fig. 34) (μm)[1]

place of thallus measured (cf. Fig. 34)	thickness of thallus	cell layer	size of veget. cell and antheridium[2] surface view: long diam.×short diam.	cross section: height×breadth	cross section: h/b
			antheridium		
apical part	38–43	2	24–35×19–26	16–20×16–23	0.6–1.6
			veget. cell		
67 mm from base					
center	43–47	2	21–36×13–25	14–18×13–25	0.8–1.2
margin	34–37	1	9–18× 6–12	13× 6	2.1
14 mm from base	33–39	2	14–28×12–21	12–14×11–24	0.6–1.2
			cells with rhizoid		
a part of base[3]	75–84	2	not clear	16–27×12–34	0.7–1.2

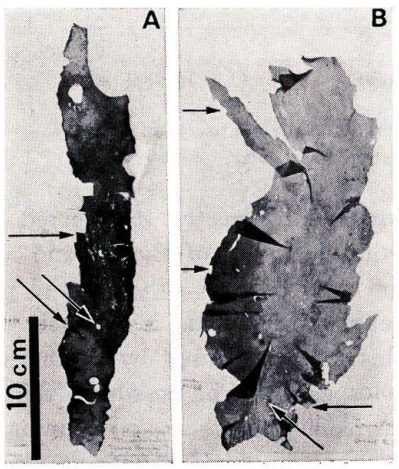
1) sections were transferred to 50% Karo syrup directly.
2) showing the size of cell content and antheridium content.
3) sections were treated with saturated $HgCl_2$, heated, and placed in 20% glycerine.

margin and 1-2 cell layered basal rhizoidiferous part. Antheridia are divided in 2-4 tiers of 16-32 each (a/4, b/4-8, c/2-4 in formula)[1], producing 32 to 128 spermatia.

5. Two female specimens identified by HUS as "*P. variegata*"

Among the specimens used for observation by HUS (1902) as "*P. variegata*", two specimens are deposited in the Herbarium, Department of Botany, University of California, Berkeley (UC). They are a part of the phycological collection of the Missouri Botanical Garden Herbarium and transferred to UC. One of the two (MO 24365 in UC) was collected at Moss Beach, Monterey Peninsula in California on July 22, 1898 by C. P. NOTT (Fig. 41 A), the other (MO 24342 in UC) was collected at San Pedro in California in August, 1896 by de Alton SAUNDERS (Fig. 41 B).

Both the specimens are not perfect in habit, having lost their bases. Cystocarps are formed to show variegate appearance in almost all of the thallus. The Nott specimen is linear, 30.7 cm long and 5.0 cm broad. The Saunders specimen is lanceolate, 29.0 cm long and 12.3 cm broad. The



MO 24365 MO 24342

Fig. 41. Two female specimens identified by HUS as "*P. variegata*", arrows showing the places examined.

1) According to the formula defined by HUS (1902) the division may be 16-64 (1/2 a/4, 1/2 b/2-4, c/2-4). He considered that each vegetative cell gives rise to a single cystocarp (sporocarp), while in the formation of antheridium each vegetative cell gives rise to four antheridia by the first cruciate division perpendicular to the surface of frond. We regarded the four antheridia derived from a vegetative cell as one antheridium.

TABLE 6. Thickness of thallus, size of vegetative cell and cystocarp of two specimens of HUS' "*Porphyra variegata*" (Fig. 41) (μm)[1]

place of thallus measured (cf. Fig. 41)	thickness of thallus	cell layer	size of vegetative cell and cystocarp[2] surface view: long diam.× short diam.	cross section: height×breadth	cross section: h/b
			cystocarp		
MO in UC 24365					
15 cm from base					
margin	87– 95	2	23–27×17–20	20–35×19–24	0.6–1.3
9 cm from base					
near margin	78– 97	2	22–30×18–26	27–30×20–26	1.0–1.5
center	88– 92	2	27–32×23–28	34–39×23–28	1.3–1.6
			cystocarp		
MO in UC 24342					
apical part	75– 89	2	21–30×19–27	29–32×22–28	1.1–1.5
9 cm from base	100–110	2	24–30×17–27	28–45×18–30	1.2–1.8
3 cm from base					
margin	75– 88	2	21–30×18–23	24–35×22–27	1.2–1.7
			veget. cell		
center	65–68	2	10–28× 8–25	10–19×13–18	0.7–1.2

1) sections were transferred to 50% Karo syrup direclty.
2) showing the size of inner cell cavity.

sections for observation were directly transferred to 50% Karo syrup. The measurement of the thickness of thallus and sizes of vegetative cells and cystocarps are shown in Table 6 although the preparations were poor.

The observed thickness of thallus is thinner than that (100–220 μm) described by HUS. This may be caused by a different method of observation, age and dryness of specimens, or possibly a different plant. The treatment of sections with a boiling concentrated solution of corrosive sublimate and mounting in 20% glycerine, which was described by HUS, was not successful for these plants to be restored to natural position and size except for the vegetative part. Cystocarps are mixed with abortive cells, divided in four or more tiers of four each (a/2, b/2, c/4–8), and often two or more cystocarps are closely stuck to each other.

Discussion

Both the fully matured female (Fig. 1 A) and male (Fig. 1 C) plants agree well morphologically in shape, structure and thickness of thallus and

size of vegetative cells except that one is female and the other male, in spite of different collecting date and locality. The plants are considered to represent a female plant and a male plant of the same species.

Thus, this species, *P. occidentalis*, is characterized as follows.

Plant is lanceolate to linear lanceolate, slightly undulate in the marginal part, rounded in the basal part, with a very shortly stipitate holdfast, showing an aureole near the base. Thallus is distromatic except at the margin and in rhizoidiferous lowest basal part. Marginal 1 or 2 cells are monostromatic, and rhizoidiferous basal aureole part is distromatic, becoming monostromatic downward. Thickness of thallus is about 150–160 μm in the lower central vegetative part, nearly equal throughout from lower to upper central part, thinner toward vegetative margin and in the rhizoidiferous 1–2, or 1 cell layered basal part. When young, thallus is thin, becoming thinner upward as well as toward the margins. Vegetative cells are rounded triangullar to polygonal in shape, about 12–32 × 10–20 μm in surface view, 26–39 μm high and 1.4–3.2 times as high as broad in cross section. Cell walls are thick. Cells near the margin are somewhat smaller and the ratio of height to breadth becomes smaller down to 1.0 or 0.6. Chloroplasts are one in each cell, situated near the surface. Plant is dioecious. Female and male plants mature from the upper margin to the lower and inner part. Female plant is brick red when matured. Cystocarps are 18–27 × 13–22 μm in surface view, of nearly the same size as that of vegetative cells, divided in four tiers of four each (a/2, b/2, c/4) and producing 16 carpospores. In fully matured plant there are mixed abortive cells with cystocarps and are found closely attached cystocarps to each other. Male plant is pale. Antheridia are 24–37 × 18–30 μm in surface view, somewhat larger than vegetative cells, divided in eight tiers of 16 to 32 each (a/4, b/4–8, c/8) and producing 128 to 256 spermatia.

The female plant (Fig. 1 A) observed agrees with the description of "*P. variegata*" in Hus (1900, 1902), in which female plants only are known, in almost all respects of morphological features. However, among the numerous dried specimens investigated by Hus there seem to be thicker or thinner individuals than our plant. Hus (1902) described the thallus as 100–220 μm thick and vegetative cells as 30–60 μm high and 3–5 times as high as broad in cross section. Hus described the thick cell wall composed of several layers of jelly. We could not observe such layers in living condition. However, it was clarified that such thick and stratified walls are clearly visible after drying. As to the thickness of thallus he described that it is constant throughout, but our observations show that only the longitudinal center of

thallus is constantly thick. According to our observation the thallus is thinner toward the margin of the vegetative part, and the one or two marginal cells are one-layered. The rhizoidiferous basal part is also somewhat thinner and monostromatic near the basal holdfast. According to HUS cystocarps are divided in two tiers of four each (in formula a/2, b/2, c/2), often in two tiers of 16 each (in formula a/4, b/4, c/2) and produce 8-32 carpospores in each cystocarp. Nevertheless, he showed the division of c/4 in Pl. 21-Fig. 18. According to our observation cystocarps are divided in two to four tiers of four each (in formula a/2, b/2, c/2-4) and produce 8-16 carpospores. The boundaries between cystocarps are often difficult to detect. However, we believe that cystocarps do not become larger than carpogonia which are equal to vegetative cells in size. The division, a/4, b/4 by HUS, seems to be in cystocarps closely attached to each other as observed sometimes in our plant or to be a mistake in description. The examination of the two specimens cited by HUS showed also that our plant agreed morphologically with HUS' *P. variegata*. These plants differ entirely from KJELLMAN's *P. variegata* (*Diploderma variegata* KJELLMAN) which is monoecious, protandrous and later falcate in shape as investigated by KUROGI (1977).

The female plant (Fig. 1 B) is young one in which thallus is generally thin and thinner toward margin and upward. There is also no variegate appearance caused by the mixture of abortive cells in the cystocarpic part. However, there is no essential difference between the female plant (Fig. 1 A) and HUS' "*P. variegata*".

The male plant observed agrees with the female plant (Fig. 1 A) in vegetative portions. Compared with the description of *P. occidentalis* by HUS, our plant is thicker and has more divided antheridia. HUS described that the vegetative part of *P. occidentalis* is 45-75 μm thick, vegetative cells are square or 1.5-2 times as broad as high (0.5-1 times as high as broad), and antheridia are divided in four tiers of 16 each (1/2a/4, 1/2b/4, c/4)[2] and produce 64 spermatia. However, Pl. 21-Fig. 17 b by HUS (1902) shows that the division of antheridia in c is 4 or more. The examination of the type specimens showed us that they are young plants and in early stage of maturation, their marginal 1 to 2 cells are monostromatic, and the lowest basal rhizoidiferous part is monostromatic. It seems that the thin thallus and fewer divisions of antheridia are a result of the youth of the plant which is seen in almost all species of *Porphyra*.

We are deeply indebted to Professor Isabella A. ABBOTT, Hopkins Marine Station of Stanford University, for her kindest help in collecting

2) see footnote 1) in page 93.

the materials at Pacific Grove, for providing laboratory facilities, and for her critical reading of this paper, and to Dr. Paul C. SILVA, University of California, Berkeley, for the loan of specimens investigated by HUS.

References

HOLLENBERG, G. J. and ABBOTT, I. A. (1966). Supplement to Smith's Marine algae of the Monterey Peninsula. Stanford Univ. Press, Stanford, California. xii-130 pp.

HUS, H. T. A. (1900). Preliminary notes on West Coast *Porphyras*. Zoe **5** (4-5): 61-70.

HUS, H. T. A. (1902). An account of the species of *Porphyra* found on the Pacific coast of North America. Proc. Calif. Acad. Sci., 3 Ser., Bot. **2** (6): 173-239.

KAWABATA, S. (1936). A list of marine algae from the Island of Shikotan. Sci. Pap. Inst. Algol. Res., Fac. Sci., Hokkaido Imp. Univ. **1** (2): 199-212.

KJELLMAN, F. R. (1889). Om Beringhafvets Algflora. Kongl. Sv. Vet.-Akad. Handl. **23** (8): 1-58, Taf. 1-7.

KUROGI, M. (1977). Observations on the type specimen of *Porphyra variegata* (KJELLMAN) HUS and its comparison with Japanese "*P. variegata*". Bull. Jap. Soc. Phycol. **25**, Suppl.: 101-112.

KUROGI, M. (1978). On the red algae Benitasa (*Porphyra amplissima*) and Kiirotasa (*P. occidentalis*) (in Japanese). Proc. 43rd Ann. Meet. Jap. Soc. Bot.: 90.

KUROGI, M. (1979). Systematic comparison between two red algae, Benitasa (*Porphyra amplissima*) and Kiirotasa (*P. occidentalis*) in Japan (in Japanese). *In*: Report of "Biosystematic study of the benthic marine algae on the northern coast of Japan" supported by Grant-in-Aid for Scientific Research No. 254229 from the Ministry of Education (ed. by M. KUROGI): 18-23.

NAGAI, M. (1941). Marine algae of the Kurile Islands II. J. Fac. Agr., Hokkaido Imp. Univ. **46** (2): 139-310, pls. 4-6.