

# SOME ECOLOGICAL AND TAXONOMIC OBSERVATIONS ON THE COLORED SNOW ALGAE FOUND IN RUMPA AND SKARVSNES, ANTARCTICA

Masaru AKIYAMA

*Laboratory of Biology, College of Education, Shimane University, Matsue 690*

**Abstract:** Some ecological and taxonomic observations were made on the algae of colored snow found in Rumpa and Skarvsnes, Antarctica. The red-colored snow resulted from the accumulation of a red pigment in algae which was identified as an astaxanthin-like substance. The biomass of colored snow algae revealed in the range of  $16-53 \times 10^4$  cells per ml of the melted water. The main components of colored snow algal flora were *Scotiella polyptera*, *Cryocystis brevispina*, *Chlamydomonas* sp. and *Stichococcus bacillaris*. It was recognized that the cells of *Scotiella* were frequently coated with thin membrane resembling the primary membrane in some Volvocalean zygospores.

## 1. Introduction

Although the Antarctic snow algae have been reported by FRITSCH (1912), GAIN (1911, 1912) and WILDEMANN (1935, cited from KOL, 1968), and recently by KOL and FLINT (1968), FOGG (1967) and SAMSEL and PARKER (1972), the most part of their works is geographically restricted to Antarctic islands and there is one report dealing with snow flora of the Antarctic Continent.

FRITSCH (1912) recorded twenty-eight taxa of snow algae from various kinds of colored snow found in the South Orkney Islands, and he established a new chlorococcalean genus *Scotiella*. Thereafter the genus has been known as one of the most common cryoalgae from alpine regions in Northern Hemisphere, and two species, viz. *S. antarctica* FRITSCH and *S. polyptera* FRITSCH, were described. Recently, FOGG (1967) reported *Chlamydomonas nivalis* FRITSCH, *Raphidonema nivale* LAGERH., *Ochromonas* sp., *Chlorosphaera antarcticus* FRITSCH and *Hormidium subtile* (KUETZ.) HEERING in the colored snow obtained from the same islands. In 1968, KOL and FLINT reported on the green snow found in Balleny Island, and described seven taxa including the following new five taxa; *Chlamydomonas ballenyana* KOL, *Bracteacoccus minor* (CHODAT) PTEROVA var. *glacialis* FLINT, *Ankistrodesmus antarcticus* KOL and FLINT, *Ellipsoidion perminium* PASCHER var. *cryophilia* KOL and *Chloridella glacialis* KOL.

As to the cryoflora of the vicinity of Syowa Station, FUKUSHIMA (1959) reported *Raphidonema tatrae* (KOL in GYORF.) KOL in the aquatic flora of a small pond in Ongul Island, and WATANABE *et al.* (1961) isolated *Chlamydomonas antarcticus* WILLE from the cultures of pond water of the same region, but colored snow has not been recognized in this region. FUKUSHIMA (1959) emphasized that the intense diurnal fluctuation of temperature would be unfavorable for the colored snow flora to develop in this region.

In the austral summer of 1972–1973, the author participated in the 14th Japanese Antarctic Research Expedition (JARE-14) and he obtained several samples of colored snow from Rumpa. In 1975, Dr. Mitsuo YAMANAKA, a member of JARE-15 found colored snow in the ice-free region of Skarvsnes of the Antarctic Continent.

Through the kindness of Dr. M. YAMANAKA, the author had an opportunity to study fresh materials of colored snow obtained from Skarvsnes. In the present paper, the author wishes to report some ecological and taxonomic notes on these colored snow algae.

## 2. Materials and Methods

The materials obtained from Rumpa were fixed with 10 per cent of formalin. In order to estimate biomass cell numbers of algae were counted. For counting cells fixed materials were made by the filtrating 1 ml of melted water of colored snow by means of Milipore membrane filter (filter pore size 0.45  $\mu\text{m}$ ) and then fixed with 1 per cent solution of erythrosine in 5 per cent of phenol aqueous solution. For scanning electron microscopic (SEM) examination, materials were prepared by the following procedure. The cells which were previously fixed with formalin were rinsed in 0.2 M sucrose-phosphate buffer after washing with distilled water and post-fixed with osmium tetroxide. Dehydration by ethanol and replacement by isoamile were made successively. After dried by critical point method, cells were coated with platinum.

Cultures of fresh materials were maintained in BBM (BOLD, 1970), and incubated at 10°C and 20°C in a 12–12 hours light-dark cycle at *ca.* 800–1000 lx intensity provided by “day-light” fluorescence lights.

## 3. Results and Discussion

In Rumpa, five patches of colored snow were found on the surface of snow drifts developed around an unnamed small pond near a rookery of Adélie penguin. The patches were colored green, orange and reddish orange, and covered a space of one to several square meters with about 1 cm depth of penetration.

The colored snow found in Skarvsnes also developed on the surface of snow

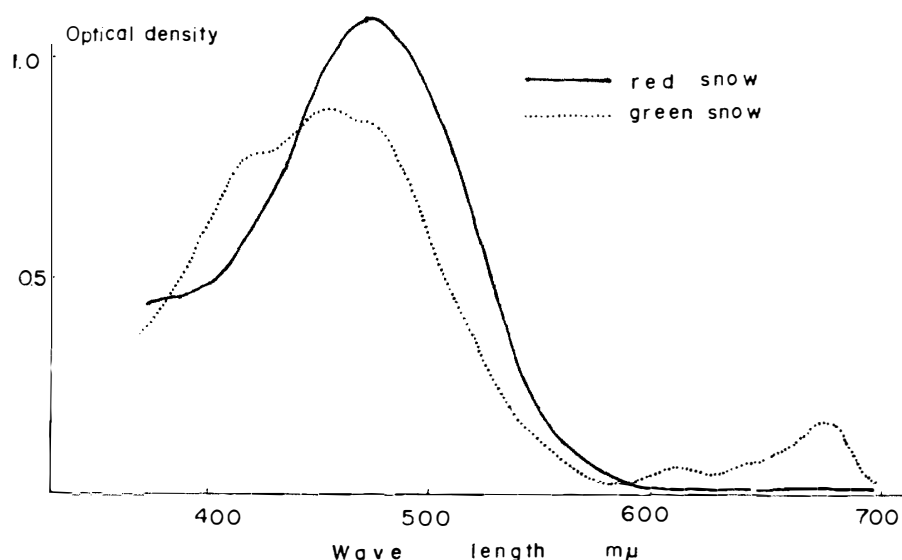


Fig. 1. Absorption spectra of acetone extracts of pigments obtained from red and green snow in Antarctica.

drifts near a rookery of snow petrel. The colors of those fresh materials were green and red.

The absorption spectra of acetone extract of pigments from fresh materials obtained in Skarvsnes are demonstrated in Fig. 1. The absorption spectrum of extract of green snow shows a typical spectral pattern of the mixture of carotenes and chlorophyll derivatives which are regularly recognized in green algal extracts. However, in the reddish orange snow, the absorption spectrum of acetone extract shows a unique pattern of monomodal spectrum ( $\lambda_{max}$  ca. 475 nm) which coincides with that of astaxanthin-like substance (GOODWIN and SRISUKH, 1949; GOODWIN and JAMIKORN, 1954; BROWN *et al.*, 1967).

Although there are a great variety of pigmentation of colored snow found in Rumpa and Skarvsnes, the pigmentation is supposed to be unrelated to the species components.

On the biomass of snow algae, we have some information. According to FOGG (1967), in the case of green snow found in Signy Island (South Orkney Islands), the dominant species were *Chlamydomonas nivalis*, *Phaphidonema nivale* and *Ochromonas* sp., and the total biomass was about  $40 \times 10^4$  cells per ml. KOL and EUROLA (1973) reported that  $1.0-1.7 \times 10^4$  cells of the red snow algae per ml were found in North Finland.

Table 1 shows some biomass of colored snow of Rumpa and Signy Island compared with records of the Northern Hemisphere. It should be noticed that the values of biomass obtained from Antarctic snow approximately coincide with those of FOGG (1967) and HOHAM (1975) but differ from the value obtained by

Table 1. Biomass of snow algal population.

Station	R-1	R-2	R-3	R-4	R-5	Mean
Biomass $\times 10^4$ cell/ml	53	23	35	21	16	29.6
Author	Locality	Biomass	Dominant species			
KOL and EUROLA, 1973	Finland	1.0-1.7	<i>Scotiella</i> sp. etc.			
FOGG, 1967	S. Orkney	40	<i>Chlamydomonas</i> sp. etc.			
HOHAM, 1975	USA	40	<i>Chloromonas</i> sp.			
MOSSER <i>et al.</i> , 1977	USA	0.8-14	<i>Chlamydomonas</i> sp.			

Table 2. Species composition of Antarctic colored snow flora.

Locality Coloration	Green	Rumpa Orange	Red	Skarvsnes	
				Green	Red
Algae					
Chlorophyceae					
<i>Scotiella polyptera</i>	d(34.1)	d(3.7)(7.5)			
<i>Cryocystis brevispina</i>	d(10.8)	d(37.7)(68.7)			
<i>Chlamydomonas</i> sp.	d(55.1)	d(58.6)(23.9)	d(99.9)		d(99.9)
<i>Stichococcus bacillaris</i>				d(99.9)	
<i>Koliella helvetica</i>				+	
<i>Chlorella</i> sp.				+	
<i>Cosmarium</i> sp.			+		
<i>Prasiola</i> (fragments)	+	+			
Cyanophyceae					
<i>Oscillatoria</i> sp.	+				
<i>Nostoc</i> sp.			+		
Bacillariophyceae					
<i>Navicula muticopsis</i>	+	+	+		
<i>Navicula</i> sp.			+		
Protozoa					
Ciliata	+				
Total taxa	7	5	5	3	1

d: dominant species, ( ): frequency (%)

KOL and EUROLA (1973, 1974), which seems to depend upon the immaturity of development of algae population.

The species composition of colored snow algae from Rumpa and Skarvsnes is given in Table 2.

As previously noted, there is poor relation between the appearance of coloration of snow and the species constitution of the snow algal population. The main components of the green snow found in Rumpa are *Scotiella polyptera*-

Table 3. Comparison of taxonomic constitution of Antarctic snow flora.

Algal class	AKIYAMA 1973, 1975	KOL & FLINT 1968	FOGG 1967	FRITSCH 1912	Summerized data by KOL, 1968
Chlorophyceae	8	3	4	18	32
Cyanophyceae	2	1		1	2
Xanthophyceae		2			2
Bacillariophyceae	2	1		4	6
Chrysophyceae			1		
Total taxa	12	7	5	23	42

like alga (pl. 1, f. 2) and *Cryocystis brevispina* (pl. 1, f. 1), but in the green snow of Skarvsnes, *Stichococcus bacillaris* and *Chlorella* sp. are dominant. On the other hand, *Scotiella* and *Cryocystis* are frequently dominant in both green and orange snows. It is conceivable that the appearance of coloration in snow flora is related to the physiological condition of algae concerning the results of production by secondary carotenogenesis which is frequently affected by the nutrient condition and the aging of these algae.

From the taxonomic data given in Tables 2 and 3, it will be seen that the species composition of the colored snow algal flora in Rumpa and Skarvsnes corresponded quantitatively to those of the results by KOL and FLINT (1968) and FOGG (1967). In contrast, there are some differences in quality, especially on the dominant species. The green snow reported by KOL and FLINT (1968) was dominated by *Chlamydomonas ballenyana* KOL and FOGG (1967) pointed out that *Chlamydomonas nivalis* and *Raphidonema nivale* are dominated in both green and red snows found in Signy Island. In the present materials, it is apparent that there are three types of snow algal community represented by the following dominant species, 1) *Cryocystis* sp., 2) *Stichococcus* sp. and 3) *Chlamydomonas* sp.

According to KOL (1968), *Stichococcus bacillaris* NAEG. is one of the most common cryosectonic algae especially in green snow of Antarctica, whereas *Koliella* spp. (= *Raphidonema*) and certain species of Volvocalean alga are frequently dominated in green snow of the alpine region of the Northern Hemisphere. And such species of *Chlamydomonas* as *C. nivalis* (VAUCH.) WILLE, *C. sanguinea* LAGERH. and *C. Boryaiana* KOL are commonly known as the typical cryosectonic algae in red snow widely distributed in the world (KOL, 1968, 1969; FUKUSHIMA, 1963; GARRIC, 1965; LIGHT and BELCHER, 1968). The so-called *Scotiella* species are frequently recognized in both red and green snow, and according to KOL (1958, 1968, 1969), the frequency of this alga in colored snow varies widely from 2 to 95 per cent in each population, and occasionally the snow-blooms caused by this alga have been reported. In the case of our materials, *Scotiella polyptera*-like alga occupied about 3.7–34.1 per cent of the snow population.

On the taxonomy of *Scotiella*, STEIN and AMUNDSEN (1967), and HOHAM (1975) suggested that certain species of *Scotiella* are probably resting spores of some Volvocalean algae. In the studies on life history and ecology of a Volvocalean alga *Chloromonas pichincae* (LAGERH.) WILLE by unialgal culture, HOHAM (1975) recognized that the biflagellated vegetative cells of that alga produced two or four gametes in each cell and successively four-flagellated planozygotes were produced anisogamously. Then the zygotes lost their flagella and subsequently a distinct morphological change, that is, the development of ridges or flanges, occurred on the wall surface of zygote. The mature aplanozygote morphologically resembled the vegetative cells of the so-called *Scotiella tatrae* KOL. Moreover, in 1977 HOHAM and MULLET obtained the same result that the gametes of *Chloromonas cryophila* HOHAM developed into the aplanozygotes, which resembled the vegetative cells of *Scotiella nivalis* (SCHUTT.) FRITSCH.

The morphological features of materials from Rumpa coincide with the original description of *Scotiella polyptera* FRITSCH, namely, the cells are 26.8  $\mu\text{m}$  (mean) in length and 19.7  $\mu\text{m}$  (mean) in width, 18 to 23 ridges are developed on the surface of cell wall, and the ridges are transversal, and slightly spiraled longitudinally (pl. 1, f. 2). The ridges are slightly waved and sometimes ramified once or twice. Several ridges usually join at the apex of a cell.

A detailed observation of the structure of cell wall surface by SEM revealed an interesting fact that the vegetative cells are frequently coated with thin and smooth membrane in part (pl. 1, f. 4). In general, such an outer membrane covering the cell wall has not been observed in Chlorococcalean algae excluding the old cell wall in Oocystacean algae and the gelatinous common sheath in certain genera. On the contrary, in such Volvocalean genera as *Chlamydomonas*, *Chlorogonium*, *Coccomonas* and *Shaeropsis*, the zygosporangium walls of these algae usually have multilayered structures composed of at least two distinguishable elements, namely, a thick, cellulosic cell wall occasionally ornamented and a thin and smooth outer membrane or the so-called primary membrane (FRITSCH, 1956; BOURRELLY, 1966; BROWN *et al.*, 1968). The membrane found in our materials resembles the primary membrane of some Volvocalean zygosporangia.

It is probable that the presence of such an outer membrane in *Scotiella polyptera* FRITSCH supports an evidence of the alga corresponding to the resting stage of certain Volvocalean alga (probably a species of *Chloromonas*) as suggested by STEIN and AMUNDSEN (1967), HOHAM (1975) and HOHAM and MULLET (1977).

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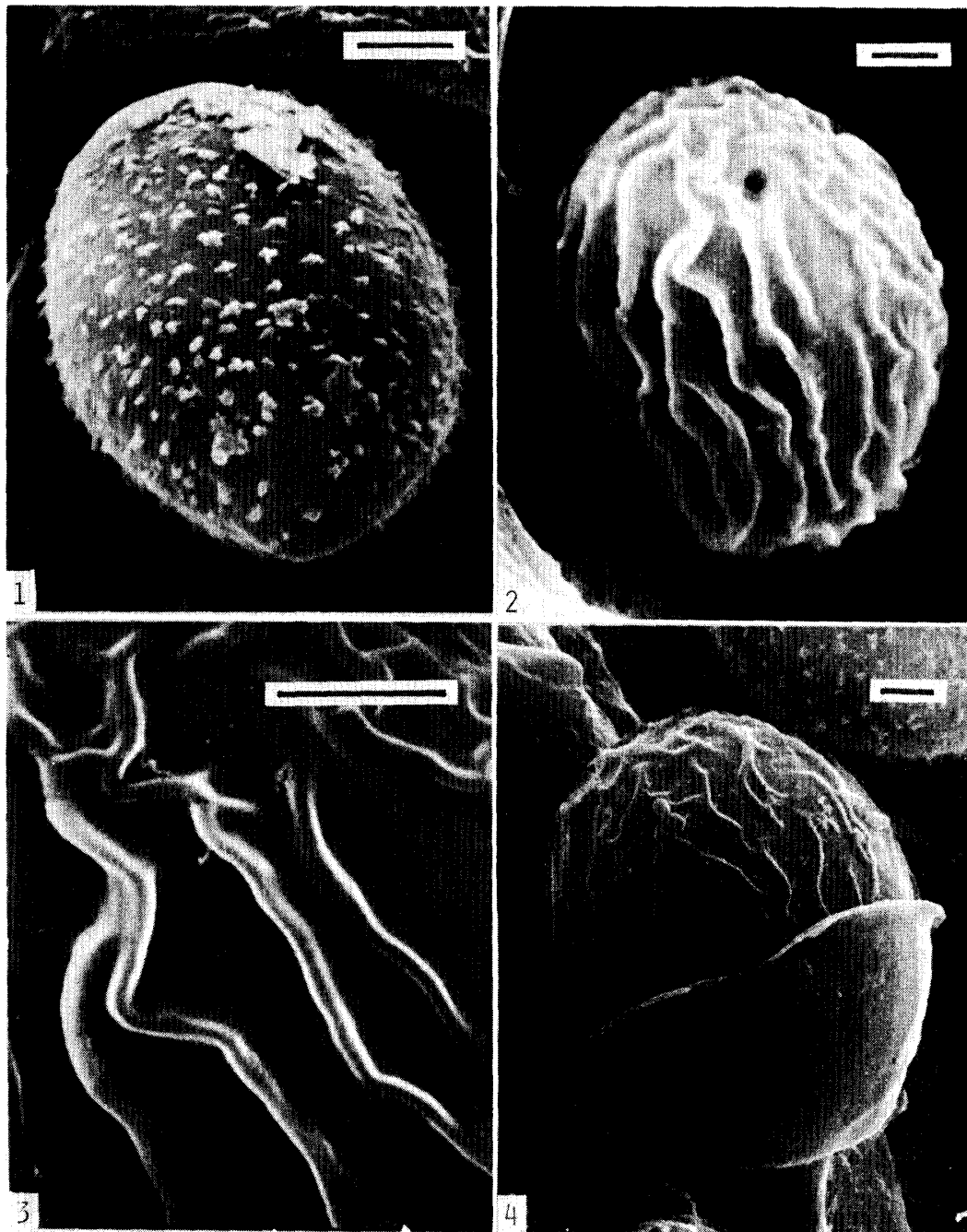
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(scale=2  $\mu$ m)

Plate 1

- Fig. 1. *Cryocystis brevispina* (FRITSCH) KOL shown in a scanning electron micrograph.  
Fig. 2. *Scotiella polyptera* FRITSCH shown in a scanning electron micrograph.  
Fig. 3. Surface structure of wall of *Scotiella polyptera* FRITSCH in a scanning electron micrograph.  
Fig. 4. *Scotiella polyptera* FRITSCH showing a vegetative cell partially coated with a thin and smooth membrane.