Chinese Journal of Polar Science, Vol. 11, No. 2, 141 - 146, December 2000

Determination of element composition of three lichens and their distribution in King George Island, Antarctica

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Received May 16, 2000

Abstract Cross-section slices of *Usnea antarctica* Du Rietz, *Usnea aurantiaco-atra* (Jacq.) Bory. and *Cladonia* sp. at upper, middle and basal positions were prepared, respectively. The element composition and relative content were determined by SEM and EDS at the surface, intermediate and inner layers in each slice, respectively. The result indicated that the composition of element is mostly same in these lichens. The relative content of Al, Si, K and Ca elements is high, and P is close at each position. The result is of benefit to study the structure and physiological characteristics of lichens, and to analyze geological environment in Antarctica.

Key words Antarctica, lichen, element composition, distribution.

1 Introduction

The vegetation growing in Antarctica plays an important role on the ecological environment there. King George Island is the nearest and biggest island apart from the South American continent. The distance is 1100 km from King George Island to the South American continent, but only 140 km to the Antarctica Peninsula. The Fildes Peninsula is in the southwest part of King George Island, which is located at latitude 62°10′ - 62°13′S, longitude 58°30′ - 62°10′W. Its width is 2 - 5 km from east to west, and the length is about 10 km. The area is about 36 km^2. The whole peninsula is almost composed of the laminar basaltic lava, volcaniclastic rock and volcanic sedimentary rock of Tertiary system. The climate of the Fildes Peninsula belongs to the subantarctic oceanic type. Annual average temperature is about - 2.1℃, precipitation is about 630 mm, and relative humidity is about 90%. The vegetation is flourishing in the summer of each year at the Fildes Peninsula, dominant species are cryptogamic bryophyta, lichens and algae. The bryophyta occur extensively in the wet habitat on flat or gently sloping ground where the freezing-thaw disturbance is relative weak. The groundmasses are gravelly or sandy-skeletal accumulation materials. The algal communities are abundantly scattered on the surface of firn snow or in the depression. In later summer, the surface of firn snow is red, green or yellow in color caused by the algal communities. The lichens occur extensively on the surface of bedrock and gravel. The epilithic crustose lichens are predominant in the maritime regions of Antarctica. The foliose lichens occur only on the

bedrock in the coast area. *Usnea* and *usnea antarctica* are dominant species of fruticose lichens, and widely developed in some places of the Fildes Peninsula (Friedmann 1982; Zheng and Birkenmajer 1996; Zhu and Wang 1995; Zhao and Li 1995; Chen 1996). The growth of lichens is closely related to the environment of Antarctica. By studying the element composition and distribution in lichens, we could understand the relationship between lichens and the environment in Antarctica.

2 Material and method

The West Lake (62°12′59″S, 58°57′56″W) is near the east shore of Fildes Peninsula. The length of lake is about 130 m, and the width is about 90 m (Zhu and Wang 1995). The lichens for studying were collected at north hillside of the West Lake by Zhang Zhengwang in January 1994. The sampling site was less than 500 m apart from the sea. The rock of this region is composed of laminar basalt. It is 43 m above the sea level. The earth´s surface is rather flat or gently sloping. The earth surface covered the vegetation (lichens and bryophyta) accounts for more than 40% of the total region. All lichens collected were developed on the surface of weathering rock and gravel. They were fruticose lichens. The highness was about 20 – 150 mm. They were *Usnea antarcica* Du Rietz, *Usnea aurantiaco-atra* (Jacq.) Bory and *Cladonia* sp., respectively. Naturally dry after washing, the cross-section slices were prepared at upper, middle and basal positions, respectively. Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray Spectrometer (EDS) were used to observe the morphology and to determine the relative content of element at the surface, intermediate and inner layers on each slice, respectively. The type of SEM used is HITACHI X-650, and the accelerating voltage was 20 kV. The type of EDS is EDAX-9100, and the resolution is about 150 eV.

Determination of lichen substances was performed by using thin layer chromatography (TLC) according to standardized methods (Chen 1996). *Usnea antarcica* Du Rietz and *Usnea aurantiaco-atra* (Jacq.) Bory belong to *Usnea*, and *Cladonia* sp. belongs to *Cladonia*.

3 Experiment result

3.1 Element composition and relative content for the lichens

Thirteen elements were determined in *Usnea antarcica* Du Rietz and *Cladonia* sp. by EDS. These elements are Na, Mg, Al, Si, P, S, Cl, K, Ca, Ti, Mn, Fe, and Cu, respectively, according to *K* line position. Cu was not detected in *Usnea aurantiaco-atra* (Jacq.) Bory. The element composition and the relative content of the three lichers are shown in Table 1.

Table 1. Element composition and content of these three lichens(%)

Lichen name	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu
Usnea antarcica	4.08	2.31	13.92	11.80	8.29	8.91	4.07	15.86	24.34	0.57	0.10	2.19	1.52
Usnea aurantiaco-atra	5.28	0.77	11.13	16.33	8.21	14.07	12.92	21.01	5.90	0.02	0.34	1.31	0.0
Cladonia	3.33	2.10	16.57	4.40	8.54	5.24	3.64	25.83	15.06	3.50	3.70	2.85	5.18

From Table 1, the average relative content is different for these three lichens. The content of Al, Si, K and Ca elements is rather high, more than 10% for the *Usnea antarcica* Du Rietz. Ca is 24.34%, the most in all elements determined. For the *Usnea aurantiaco-atra* (Jacq.) Bory, the content of Al, Si, S, Cl and K elements is more than 10%, and K is the most, reaching to 21.01%. For the *Cladonia* sp., the relative content of Al, K and Ca is more than 10%, and K is 25.83%, the most in all elements. It is clear that the content of Al and K is high, P is close, and Ti, Mn, Fe, and Cu is relatively low. Especially, in *Usnea aurantiaco-atra* (Jacq.) Bory the content of Ca is 5.90%, lower than the other two lichens, and in contrast, the content of Cl is 12.92%, more than the other two lichens.

3.2 Distribution of elements in the surface, intermediate and inner layers for these three lichens

The relative content and distribution of all elements are different in the surface, intermediate and inner layers for these lichens, respectively. See Table 2. The relative content of Al and Si is high in the surface layer for these lichens. The content of Al and Si is 40.51% and 27.98% for the *Usnea antarcica* Du Rietz, 25.83% and 22.52% for the *Usnea aurantiaco-atra* (Jacq.) Bory, 47.90% and 8.40% for the *Cladonia* sp., respectively. The content of Al and Si drops obviously from surface to inner layer. For example, the content of Al drops from 40.51% to 0.99%, and Si drops from 27.98% to 2.56% for the *Usnea antarcica* Du Rietz. The content of P is close in each layer. There are more K and Ca contents in the intermediate and inner layers. But the Ca element cannot be detected in the inner layer, and only seven elements (Na, Al, Si, P, S, Cl and K) can be detected for the *Usnea aurantiaco-atra* (Jacq.) Bory. It can be seen that the distribution of element for the *Usnea aurantiaco-atra* (Jacq.) Bory is quite different from that of other two lichens.

Table 2. Element distribution in the surface, intermediate and inner layers of these three lichens(%)

Lichen name	Layer	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu
Usnea	Surface	3.95	4.81	40.51	27.98	3.09	1.86	0.17	3.46	0.66	1.72	0.27	7.86	2.16
Antarcica	Inter-mediate	5.08	2.36	7.92	9.41	9.91	10.76	3.71	16.54	32.60	0.14	0.0	0.08	0.63
	Inner	4.03	1.30	0.99	2.56	9.6	12.42	7.56	22.68	37.76	0.09	0.0	0.0	0.97
Usnea	Surface	0.60	1.16	25.83	22.52	7.04	10.78	5.73	11.38	1.63	0.10	0.53	4.50	0.0
aurantiaco-	Inter-mediate	7.19	0.96	6.07	14.79	7.60	16.46	13.56	20.48	10.49	0.0	0.42	1.31	0.0
Atra	Inner	6.13	0.0	6.74	13.2	10.59	12.88	18.87	31.73	0.0	0.0	0.0	0.0	0.0
	Surface	0.0	0.25	47.90	8.40	8.92	4.65	1.94	13.78	10.39	0.11	0.80	0.56	2.25
Cladonia	Inter-mediate	3.63	1.33	7.17	3.04	10.36	6.98	5.13	33.73	17.35	3.37	2.77	1.59	3.49
	inner	6.06	5.51	3.83	3.13	4.51	2.35	2.543	22.06	15.14	7.24	8.46	7.67	8.43

3.3 Distribution of elements at the upper, middle and basal sections for these three lichens

The relative content and distribution of elements are different at the upper, middle and basal sections for these lichens (see Table 3). For the *Usnea antarcica* Du Rietz Mg cannot be detected. The content of Al, K and Ca at the upper section, Al, Si and Ca at the middle section, Si, P, S, K and Ca at the basal section are more than 10%,

respectively. For the *Usnea aurantiaco-atra* (Jacq.), the content of Na, Al, Si and Cl at the upper section, Si, P, S, K and Ca at the middle section, and Si, S and K at the basal section are more than 10%, respectively. For the *Cladonia* sp., the content of Al, P, K and Ca at the upper section, Al, K, Ca and Cu at the middle section, and Al, K and Ca at the basal section are more than 10%, respectively. So it is shown that the content of Al, Si, K and Ca is higher at each section of lichens.

Table 3. Element composition and relative content at the upper, middle and basal sections of these three lichens(%)

Lichen name	Section	Na	Mg	Al	Si	P	S	Cl	K	Ca	Ti	Mn	Fe	Cu
Usnea antarcica	Upper	1.91	0.0	27.59	3.71	7.33	9.14	7.86	22.73	11.65	1.17	0.27	2.90	3.09
	Middle	8.93	6.92	12.97	17.78	3.92	2.62	0.33	5.27	39.71	0.26	0.0	1.43	0.41
	Base	2.23	2.17	8.87	18.46	11.34	12.24	3.25	16.68	19.66	0.53	0.11	3.61	0.26
Usnea Aurantiaco-atra	Upper	10.91	0.96	21.6	10.84	3.64	9.35	24.44	5.29	1.19	0.0	0.53	0.94	0.0
	Middle	2.41	0.0	7.47	21.75	18.44	18.72	6.99	12.52	10.49	0.0	0.42	0.42	0.0
	Base	0.61	1.16	9.42	17.93	3.15	11.92	6.72	45.78	0.44	0.10	0.0	2.57	0.0
Cladonia	Upper	1.92	0.25	11.57	6.54	11.61	6.69	0.81	31.03	13.93	2.82	3.74	3.43	5.61
	Middle	0.0	0.0	29.87	0.49	0.47	0.05	0.0	22.20	13.14	7.80	8.29	6.40	11.23
	Base	3.47	6.84	17.47	7.54	11.77	7.24	8.62	16.35	15.81	0.0	0.0	0.0	0.40

4 Discussion

4.1 The characteristics of structure and distribution of element for lichens

Lichens are perennial plant, commensal of alga and fungus. SEM indicated that these lichens for studying are heteromerous. The surface and inner layers are composed of fungal mycelium. The cells of alga are arranged at inner side of epidermal layer. EDS indicated that the composition of element is mostly same for these lichens. The relative contents of Al and Si are high in the surface layer, K and Ca in the intermediate and inner layers. There are distinct difference comparing these lichens with seed-bearing plant, and it reflects the characteristics of their physiological action.

Table 4. Comparison between seed-bearing plants and Antarctica lichens

	P	K	S	Ca
Seed-bearing plants	Growth point of rhizoma, tender leaf and fruit	Growth point, young leaf and forming layer	Uniform distribution in all organ	Leaf and old organ
Usnea antarcica	Basal section, intermediate and inner layers	Upper and basal sections, intermediate and inner layers	Upper and basal sections, intermediate and inner layers	Each layer at each section
Usnea aurantiaco-atra	Middle section, inner layer	Each layer at middle and basal sections	Each layer at middle section	Middle section, intermediate layer
Cladonia	Upper and basal sections, surface and intermediate layers	Each layer at each section	Upper and basal sections, intermediate layer	Each layer at each section

4.2 *The relative content and distribution of elements for the three lichens*

From Tables 1, 2 and 3, it is clear that the distribution of some elements is relatively close for these three lichens, such as Al, Si, K and Ca. There are higher Al and Si contents in the surface layer, K and Ca in the intermediate and inner layers, and P is close in each layer. But the distribution of other elements is rather different, Cl and Cu for example. This difference is related to physiological metabolism of lichen itself.

4.3 *Relationship between the element content of lichens and the environment in Antarctica*

The growth of every plant is related to its environment. These lichens were developed on the surface of rock in Antarctica. By using EDS, the analysis of the average oxide component of laminar basalt indicated the results shows in Table 5. The elements of these oxides are necessary to the growth of lichens, and influence the element composition and content. Lichen-acid that lichen excretes would corrode surface of rock, causing rock weathering. Lichens grow at weathering surface of rock. Fungus cells absorb water and inorganic salt from the air or the adhesion that lichens grow on. Alga cells obtain water, inorganic salt and carbon dioxide to produce organic substances. It constitutes a coexisting system. So the surface layer of lichens is affected by rock component, and the content of Si and Al is high in this layer. Whereas the element contents of the intermediate and inner layers are influenced by absorption of fungus cells, so that the contents of Si and Al are low, and Ca and K are high. Moreover for the *Usnea aurantiaco-atra* (Jacq.), the content of Cl element is quite high (average relative content is 12.92%), Na is higher than that of the other two lichens. Cl and Na come from the sea. Wind blows the seawater to the lichens leaf, absorbed by lichens, due to strong windstorms in this region. It is revealed that the *Usnea aurantiaco-atra* (Jacq.) is salt-like (Chen 1996). Determination of relative content and element distribution for lichens in different region and habitats where the lichens grow would benefit to investigate the rule of absorption and transportation of elements.

Table 5. The chemical composition of the basalt on the Fildes Peninsula, Antarctica(%)

	SiO_2	Al_2O_3	Fe_2O_3(FeO)	CaO	MgO	Na_2O	K_2O	TiO_2	P_2O_5
EDS	44.53	18.63	17.44	4.98	7.22	3.27	1.13	1.68	1.04

There are many advantages to analyze element distribution at different section and layer for lichens by using EDS. But some shortages are:

(1) The contents of C, H, O and N cannot be detected by EDS, and their total contents exceed 90% of weight of lichens.

(2) The relative element content suitable for EDS is around $(100 - 1000) \times 10^{-6}$, therefore some elements cannot be detected if their relative content is less than the critical level of determination of EDS, that influenced the category of detected elements.

Acknowledgment We are grateful to Professor Chen Jianbin and Zhao Ye for their help.

References

Chen JB (1996): Lichens from Fildes Peninsula of King George Island, Antarctica. Acta Mycologica Sinica, 15(1): 21-25 (in chinese).

Friedmann EI (1982): Endolithic Microorganisms in the Antarctic Cold Desert. Science, 215 (26): 1045-1052.

Zhao Y, Li TJ (1995): Analysis of the chemical weathering characteristics of soil-minerals on Fildes Peninsula of King George Island, Antarctica. Antarctic Research (Chinese Edition), 7(2), 18-24.

Zheng XS, Birkenmaier K (1996): Petrochemistry and geochemistry of tertiary volcanics, northern coast of King George Island, West Antarctica. Antarctic Research(Chinese Edition), 8(2): 1-15.

Zhu GH, Wang M (1995): Studies on nano- and microalgae in the adjacent waters of Antarctica •. Distribution of freshwater algae in different habitats around Great Wall Station. Antarctic Research (Chinese Edition), 7 (1): 67-74.