

A Phytosociological Study of the Vegetation in the Ny-Ålesund Area, Spitsbergen

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スピッツベルゲンの Ny-Ålesund 地域における植生の植物社会学的研究

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要旨：スピッツベルゲンの Ny-Ålesund 地域において、維管束植物と蘚苔地衣類から構成された植生を植物社会学的に解明した。特に、これまで優占種に主体をおいた植生単位の抽出がなされていたが、本研究では種の結びつきと適合度に基づき、さらに表操作ではコンピューターを使用することによって、興味ある植生単位を識別することができた。識別した植生単位は、1. *Saxifragetum cernuae* KOBAYASHI 1994 prov. : a. Subass. of *typicum*, b. Subass. of *Orthothecium chryseum*, c. Subass. of *Leptobryum pyriforme*, d. Subass. of *Cetraria delisei*. 2. *Dryadetum minoris* HADAČ 1946 em. KOBAYASHI 1994 : a. Subass. of *Racomitrium lanuginosum*, b. Subass. of *Lecanora epibryon*. 3. *Xanthoria elegans* community の 2 群集と 6 亜群集、および 1 群落である。これら植生単位について、種組成、生態、分布などの記載を行った。さらに、これら植生単位については、類似度の指数から相互関係を分析して、植生単位と種組成および立地の関係を明らかにした。

Abstract: This paper was undertaken to classify and describe the vegetation of the Ny-Ålesund area in Spitsbergen using the method of the Z-M school of phytosociology. The investigations were carried out at 55 stands which were located in an area ranging from the coast to the mountain regions in and around Ny-Ålesund. The vegetation investigated was classified according to the fidelity of species and the species combination. The term "association" was adopted as the fundamental unit of the vegetation with the exception of the provisional vegetation unit treated as the community. Moreover, associations were subdivided into subassociations according to the scale of the floristic variation.

On the basis of the data obtained from 55 stands in the Ny-Ålesund area, the following vegetation units were classified: 1. *Saxifragetum cernuae* KOBAYASHI 1994 prov.: a. Subass. of *typicum*, b. Subass. of *Orthothecium chryseum*, c. Subass. of *Leptobryum pyriforme*, d. Subass. of *Cetraria delisei*. 2. *Dryadetum minoris* HADAČ 1946 em. KOBAYASHI 1994: a. Subass. of *Racomitrium lanuginosum*, b. Subass. of *Lecanora epibryon*. 3. *Xanthoria elegans* community. They belong to some higher units left to be investigated in the future. Each of the vegetation units classified is described with an association table showing the floristic composition and data about growing habitats. Their distribution is made clear by showing the actual localities of each association

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on the map.

The interrelations among six associations and one community classified were examined on the basis of the similarity index (P. JACCARD, Bull. Soc. Vaudoise Sci. Nat., **37**, 547,1901).

1. Introduction

Early botanical visitors to Spitsbergen who described the vegetation were NATHORST (1883) and RESVOLL-HOLMSEN (1920). HADAČ (1946) was the first to perform a classification of the vegetation of Spitsbergen according to the phytosociological nomenclature system. On the basis of information obtained in July and September 1939 from the Sassen Quarter, situated in the inner part of Isfjord, he attempted to prove that the principles and methods of Central European phytosociology were applicable to the vegetation of the high arctic. The vegetation units that he recognized were 17 associations, six alliances, seven orders, and five classes. However, though his classification was worthy of close attention in his day, it appears unsatisfactory today because his units are constructed without considering the fidelity concept, which demands an intensive accumulation of monographic research concerning the floristic composition of local communities.

Recently, KOBAYASHI *et al.* (1990) reported four associations, 11 subassociations, and one community on the basis of data obtained from 52 of 56 stands in the Bohemanflya area, Spitsbergen, with association tables describing floristic composition, community structure, and habitat of vegetation. When a new association is recognized, it must be placed in the system of higher units. However, the vegetation units classified in the Bohemanflya area were not assigned to an alliance or other higher unit. The principle aim of our study was to classify and describe the vegetation from a phytosociological point of view in the strict sense. In this study, it was the author's aim to complete the floristic composition and classification of the vegetation of the Ny-Ålesund area using the Z-M school of phytosociology.

2. Area Investigated

Spitsbergen is the largest island of Svalbard, composed of a group of islands situated between 74°N and 81°N latitudes and 10°E and 35°E longitudes (Fig.1). The main area of investigation was the strandflat of the Ny-Ålesund area, situated in the inner and southern part of Kongsfjorden, about 78°35'N and 78°48'N latitudes and 11°30'E and 12°10'E longitudes.

The area is remarkably rich in topographic variation, comprising the well-developed strandflat of Stuphallet, mountains, and glaciers. The area is based upon rocks of the Carboniferous and Permian age. The climate of Spitsbergen is more favorable than one would anticipate for such an arctic region. On the west coast of Spitsbergen, the average temperature during the year is -4.7°C . In June and September, it is above zero; in July and August it is $+4.5^{\circ}\text{C}$. On the other hand, the average of the coldest months, January and March, is -11.9°C . The amount of precipitation

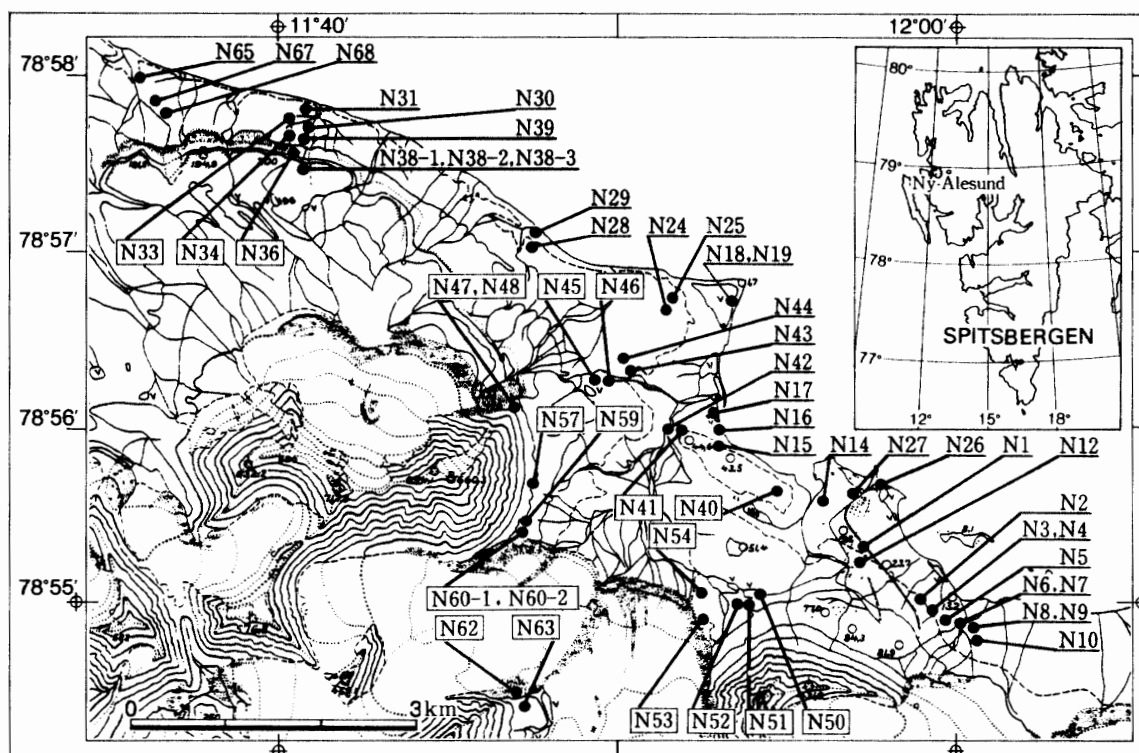


Fig. 1. Map showing the location of the study stands, which are indicated by a dot. The numerals in the map correspond to the stand numbers in Tables 2 and 3.

in Spitsbergen is small, normally less than 400 mm per year. The highest concentration of precipitation occurs in autumn in the west coast of this region (HISDAL, 1985).

3. Methods

The present investigation follows the general vegetation concept and methodology of the Z-M school of phytosociology (BRAUN-BLANQUET, 1932, 1964; TÜXEN, 1950; ELLENBERG, 1956; BECKING, 1957; SZAFER, 1966; KOBAYASHI, 1971). The field work was carried out from the middle of July to the middle of August in 1985.

In the field, a stand including only the most typical segment of a homogeneous community was chosen. Most of the stands were a square, but some were rectangular, depending on the condition of the community. The usual size of the stand employed was 1 m × 1 m, but in some cases larger sizes were employed in consideration of the heterogeneity of communities. The investigated stand was first carefully delimited, and then a note was made of all the details including locality, exposure, inclination of the slope, altitude, situation of the stand on the slope (near the top: t, upper: u, middle: m, or lower: l; or bottom of the valley: v, etc.). Data pertaining to the soil and the soil moisture (dry: d, medium: m, wet: w, and swamp: s) were also collected on the stand.

Next, observations were made of the properties of the vegetation in the given stand. Total coverage for the herb and the moss layer, and the total coverage of

Table 1. Differential table of vegetation units in the Ny-Ålesund area.

Vegetation unit	1				2		3
	a	b	c	d	a	b	
Number of stand	7	6	5	9	10	13	5
Average no. of species	9	18	12	22	29	27	8
<u>Character and differential species of association</u>							
<i>Saxifraga cernua</i>	H	III 1-2	III 1	IV + -1	IV + -1	.	I + .
<i>Poa alpina</i>	H	III 1-3	I 1	III 1-3	IV + -2	.	. .
<i>Cochlearia officinalis</i>	H	III + -1	II +	I 1	II +	.	. I +
<i>Deschampsia alpina</i>	H	I 2	II 2-4	III 4-5	II + -2	.	. .
<i>Philonotis tomentella</i>	M	I 3	V + -2	.	II + -5	.	. .
<i>Bryum pseudotriquetrum</i>	M	I 4	IV + -3	.	II + -2	.	I 1 .
<i>Drepanocladus fluitans</i>	M	II 2-5	I 2	I 3	II 2-4	.	. .
<i>Drepanocladus revolvens</i>	M	I +	II 3-4	.	II 1-2	.	. .
<u>Differential species of subassociation</u>							
<i>Orthothecium chryseum</i>	M	.	V 2-4	.	.	.	. .
<i>Cinclidium arcticum</i>	M	.	V 2-3	.	.	.	I + .
<u>Differential species of subassociation</u>							
<i>Leptobryum pyriforme</i>	M	.	.	V + -3	.	.	. .
<i>Bryum arcticum</i>	M	.	.	III 3	.	.	II + .
<u>Differential species of subassociation</u>							
<i>Cladonia pocillum</i>	M	.	.	.	III +	III +	III + .
<i>Blepharostoma trichophyllum</i>	M	.	I +	.	III + -2	I + -1	III + -1 .
<i>Lecidea sp.</i>	M	.	.	.	III + -4	III + -2	III + -2 .
<i>Pohlia sp.</i>	M	.	.	.	III + -1	.	I + .
<u>Character and differential species of association</u>							
<i>Pedicularis dasyantha</i>	H	.	.	.	.	III + -1	III + .
<i>Silene acaulis</i>	H	.	.	.	.	III + -1	III + -2 .
<i>Cetraria nivalis</i>	M	.	.	.	I +	IV + -3	II + -1 .
<i>Coelocaulon aculeatum</i>	M	.	.	.	I +	III + -4	II + -1 .
<i>Rhizocarpon geographicum</i>	M	.	.	.	.	III + -1	II + -2 .
<i>Alectoria nigricans</i>	M	.	.	.	.	IV + -2	I + -2 .
<i>Dryas octopetala</i>	H	.	.	.	.	II + -4	II 3-5 .
<i>Hypnum revolutum</i>	M	.	.	.	.	II + -2	II + -3 .
<u>Differential species of subassociation</u>							
<i>Racomitrium lanuginosum</i>	M	.	.	.	.	IV 1-4	. .
<i>Gymnomitrium corallioides</i>	M	.	.	.	.	III + -3	. .
<i>Polytrichum juniperinum</i>	M	.	.	.	.	II + -3	. .
<i>Huilia sp.</i>	M	.	.	.	.	II + -2	. .
<i>Pseudephebe pubescens</i>	M	.	.	.	.	II + -1	. .
<i>Cnestrum alpestre</i>	M	.	.	.	.	II +	. .
<i>Umbilicaria arctica</i>	M	.	.	.	.	II + -2	. .
<i>Dicranum sp.</i>	M	.	.	.	.	II + -1	. .
<u>Differential species of subassociation</u>							
<i>Lecanora epibryon</i>	M	.	.	.	I 2	.	V + -2 .
<i>Placynthium asperellum</i>	M	.	.	.	.	.	IV + -1 .
<i>Carex misandra</i>	H	.	.	.	.	.	III + -2 .
<i>Tortella fragilis</i>	M	.	.	.	.	.	II + .
<i>Equisetum scirpoides</i>	H	.	.	.	.	I +	II + -1 .
<u>Differential species of subassociation</u>							
<i>Physcia caesia</i>	M	.	.	.	.	.	V 1-3
<i>Phaeophyscia sciastra</i>	M	.	.	.	.	.	I + V 1-2

Table 1. (continued)

Vegetation unit		1				2		3
		a	b	c	d	a	b	
Number of stand		7	6	5	9	10	13	5
Average no. of species		9	18	12	22	29	27	8
Xanthoria elegans	M	.	.	.	.	.	I +	V 2-5
Physcia dubia	M	.	.	.	.	.	.	III +
<u>Character and differential species of higher units</u>								
Saxifraga oppositifolia	H	III +2	V +2	.	III +3	III +3	V +4	.
Salix polaris	H	I 1	II 1-2	II +2	III +3	V +3	V 1-4	.
Saxifraga cespitosa	H	III 1-3	III +1	II +2	III +1	I 1	.	I 1
Oxyria digyna	H	IV +3	.	I 1	IV +2	II +1	II +1	.
Luzula confusa	H	II +	I +	I 1	III +2	V +2	II +1	.
Cerastium regelii	H	III +1	.	II +1	III +2	III +	II +	.
Distichium hagenii	M	.	I +	I 1	III +1	II +1	IV +1	.
Cetraria delisei	M	I +	.	.	V +4	V +5	V +5	.
Ochrolechia frigida	M	.	.	.	IV +3	V +3	V +4	.
Campylopusium stellatum	M	.	V +4	II +3	II +1	.	II +1	.
Tomentohypnum nitens	M	.	IV +3	.	I 2	I +	III +4	.
Ditrichum flexicaule	M	.	I +	II +2	I +	I +	IV +3	.
Cetraria ericetorum	M	.	.	.	II +2	V 1-3	II +3	.
Draba alpina	H	III +1	I +	.	II +2	.	I +1	.
Dicranum spadiceum	M	.	.	.	II 1-2	III +2	I +1	.
Polygonum viviparum	H	I 1	I 1	I 1	.	I +	V +2	.
Equisetum arvense	H	.	III +2	.	.	.	I +1	.
Draba fladnizensis	H	I 1	II +	II +	I +	.	I +	.
Polytrichum sexangulare	M	.	.	.	II 2-4	II +1	I +	.
Verrucaria aethiobola	M	.	.	I +	II +1	.	II +1	.
Tortula ruralis	M	II 2	.	.	.	.	I +	II +1
Saxifraga rivularis	H	I 2	II +1	.	.	I +	.	.
Poa arctica	H	II 3	II 1	.	.	.	.	.
Encalypta alpina	M	.	.	I +	.	.	II +1	I +
Candelariella vitellina	M	.	.	.	.	.	I +	II 1
Cardamine bellidifolia	H	.	.	I +	.	.	.	I +
Candelariella aurella	M	.	.	.	I +	.	.	II +2
<u>Companions</u>								
Drepanocladus uncinatus	M	II 2-3	I 4	I 3	III +3	II +2	III 1-3	.
Oncophorus wahlenbergii	M	I 1	I 3	I +	II 1-3	III +3	III +3	.
Bryum sp.	M	V +5	I +	II +2	II +	II +	II +	I +
Pohlia cruda	M	I 2	.	I +	III +	II +	II +1	.
Buellia sp.	M	.	.	.	II +3	III +3	II +2	II 1
Stereocaulon alpinum	M	.	.	.	II +1	V +2	III +2	.
Schistidium apocarpum	M	.	.	.	.	II +2	I 1	III +1
Psoroma hypnorum	M	.	.	.	II +	III +1	I +	.
Polytrichum alpinum	M	.	I +	.	I 1	II 1-3	II +1	.
Timmia sp.	M	.	II +	.	I 4	.	II +	.
Lophozia sp.	M	.	.	I +	II +2	I +	I +	.
Lecanora sp.	M	.	.	.	II 1-2	I +	I +2	.
Rinodina turfacea	M	.	.	.	I +	I +1	II +2	.
Cetraria islandica	M	.	.	.	I +	I +	II +2	.
Caloplaca tetraspora	M	.	.	.	I 2	I +	II 1-2	.
Ptilidium ciliare	M	I +	.	.	I 1	I +	I 2	.
Didymodon sp.	M	I +	.	I +	.	I +	I +	.
Rhizocarpon sp.	M	.	.	.	I +	I +3	I +	.
Isopterygium pulchellum	M	.	.	.	I +	I +	I +	.
Caloplaca cerina	M	.	.	.	I +	I +	I +	.
Buellia insignis	M	.	.	.	I +	I 2	I 2	.

vegetation were determined by viewing each stand from above. Moreover, the maximum height of vascular plants in the given stand was noted. A separate list was then made for each layer of the stand, noting as accurately as possible all the species growing in the stand. When the list was completed, the degree of cover-abundance and sociability of each species was determined and recorded.

In the present study, the vegetation units were classified on the basis of the fidelity and combination of species in accordance with the Z-M school's table manipulation principle. The table manipulation was done with a computer, using VEGET software written by HADA and TOYOHARA (1990). Thus, the records with definite character species and homogeneous floristic composition were synthesized into an association, the abstract unit that is the fundamental unit of vegetation systematics (Table 1). The association was further subdivided into lower units, subassociations, according to differential species.

4. Classification of Vegetation

In the present study, the vegetation units identified on the basis of the data obtained from 55 stands (Fig. 1) in the Ny-Ålesund area are: two associations, including six subassociations, and one community. As the relationship and affinity of the character species of the relevant higher units were not strictly observed—either on a presence-absence or quantitative basis—it could not be concluded to which units (alliances, orders, or classes) the vegetation units at the association level belong. Moreover, the classified associations were subdivided into subassociations according to the scale of the floristic variation.

Floristic composition, community structure, habitat, and distribution of those vegetation units classified were described with an association table showing the floristic composition and a brief topographic-ecological characterization of each stand.

4.1. *Saxifragetum cernuae* KOBAYASHI 1994 prov. (Table 2, Fig. 2)

Character species: *Saxifraga cernua*, *Poa alpina*, *Cochlearia officinalis*, *Deschampsia alpina*, *Philonotis tomentella*, *Bryum pseudotriquetrum*, *Drepanocladus fluitans*, and *Drepanocladus revolvens*.

This association is, with respect to floristic composition, characterized by the high fidelity and the strong combination of the following species: vascular plants such as *Saxifraga cernua*, *Poa alpina*, *Cochlearia officinalis*, and *Deschampsia alpina* and mosses such as *Philonotis tomentella*, *Bryum pseudotriquetrum*, *Drepanocladus fluitans*, and *Drepanocladus revolvens*. There are great variations in the moss layer, and even more so in the herb layer. As is often the case in irrigated areas, the ground is uneven. Flat areas, tussocks and furrows alternate. The author has tried to differentiate some associations based upon the predominating species of the herb and moss layers. This task proved completely impracticable, resulting in numerous microassociations scattered about the herb and moss layers. Furthermore, when he tried to classify this association on the basis of the fidelity and combination of species

in accordance with the Z-M school's principle, it became apparent that such a classification would be an artificial puzzle. The species of the herb and moss layers are mosaic, a fact which we have to accept.

Its physiognomy is characterized by the relatively high growth of moss layer, but the dominant species of moss layer are not uniform. The total coverage of the moss layer varies from 16 % to 100 %, with an average of 77 % per stand. The dominant species in the moss layer are mainly bryophytes, such as *Bryum* sp., *Drepanocladus revolvens*, *Drepanocladus uncinatus*, *Orthothecium chryseum*, *Cinclidium arcticum*, and *Campylium stellatum*. The herb layer shows variation from 1 cm to 20 cm in height and from 1 % to 90 % in coverage. Its physiognomy is characterized by vascular plants such as *Poa alpina*, *Poa arctica*, *Deschampsia alpina*, *Saxifraga cespitosa*, and *Saxifraga oppositifolia*, but the dominant species of herb layer are not always the same.

The distribution of its stands is, with a single exception (Stand No.N62), limited to the well-developed strandflat ranging from 1 m to 48 m above sea level. Its habitat is mostly a lowland plain along the coast, so this association has severe conditions caused by intense human impact. On the other hand, the soil condition is not uniform; stands are to be found on soil ranging from dry to swamp.

This association is further subdivided into four subassociations as a result of its combination of species.

4.1.a. Subassociation of *typicum*

This subassociation is composed of only the substantial components of the association and lacks differential species. It is physiognomically characterized by its remarkably luxuriant growth of cryptogams, such as *Bryum* sp., *Bryum pseudotriquetrum*, or *Drepanocladus uncinatus*. Therefore, the moss layer is relatively rich both in the number of species and in coverage when compared to the herb layer. The height of the herb layer varies from 1 cm to 20 cm, with coverage ranging from 15 % to 80 %. The total coverage of the moss layer is quite variable, from 16 % to 98 %, with an average of 63 % per stand. Also, the total number of species is smaller, from 4 to 13, with an average of 9 per stand.

The distribution of the subassociation is restricted to the lower areas along the coast at an altitude from 1 m to 31 m, with an average of 10 m above sea level, which is lower than that of the other vegetation units. Also, its habitat is not uniform; the slope degree varies from 0° to 38°, the soil moisture ranges from swamp to dry, and the slope aspect also varies. In respect to its floristic composition and ecological condition, this subassociation reflects intense human impact and is a somewhat open community with a labile floristic composition, and therefore quite variable. Accordingly, the subassociation may contain a few vegetation units.

4.1.b. Subassociation of *Orthothecium chryseum*

Differential species: *Orthothecium chryseum* and *Cinclidium arcticum*.

This subassociation is physiognomically characterized by the remarkably luxuriant growth of the mosses such as *Drepanocladus revolvens*, *Orthothecium chryseum*, *Cinclidium arcticum*, *Campylium stellatum*, and *Tomentohypnum nitens*, but the dominant species in the moss layer is not always the same. The total coverage of

Table 2. Association table (1).

		1																											
		a							b							c							d						
Vegetation unit		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	
Running number		N41	N17	N16	N12	N19	N18	N1	N25	N33	N39	N67	N68	N34	N62	N27	N26	N50	N2	N14	N51	N52	N45	N53	N46	N36	N7	N6	
Altitude (m)		15	1	1	31	1	1	19	25	25	45	35	45	25	95	8	5	30	25	5	45	35	25	48	25	70	13	13	
Slope aspect		NW	-	-	N	NW	NW	NE	-	SE	NE	-	NW	-	NE	-	SW	-	-	N	NW	NW	-	NW	-	NE	SE	SE	
		80			0	43	40	40		70	25		28		25		10			0	28	35		45		15	38	40	
Slope degree (°)		5	0	0	7	5	5	38	0	8	10	0	5	0	25	0	8	0	0	7	8	15	0	5	0	38	50	45	
Microtopography		f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	f	m	f	f	
Soil condition		s	d	d	m	w	s	m	s	s	s	s	s	s	s	m	m	m	w	m	w	m	s	m	m	d	d	d	m
Quadrat size (m ²)		1	1	1	1	1	1	1	1	1	1	1	1	1	1	0.3	1	1	1	1	1	1	1	2	2	1	2	1	1
Total coverage (%)		100	80	70	80	100	100	90	100	100	100	100	100	100	70	95	90	95	90	95	90	90	80	85	95	100	80	90	
Herb layer (cm)		3	10	10	5	1	2	20	5	4	4	10	4	1	10	20	10	10	20	5	4	3	3	15	3	4	5	3	
(%)		18	70	60	15	45	30	80	20	20	45	70	7	15	50	80	80	30	90	50	30	1	20	30	1	30	10	5	
Moss layer (%)		98	40	20	75	95	95	16	90	90	100	100	100	100	60	60	65	90	18	80	90	90	80	80	95	100	70	90	
Number of species		12	10	11	11	4	4	13	11	20	21	27	13	15	7	10	12	14	18	24	25	10	28	33	16	33	24	9	
<u>Character and differential species of association</u>																													
<i>Saxifraga cernua</i>	H	.	1.2	2.2	.	.	.	1.2	.	.	1.2	1.2	1.2	.	.	+	+	1.2	+	.	+	+	1.2	+	+	+	+	.	
<i>Poa alpina</i>	H	1.2	3.2	3.3	.	.	.	3.3	.	1.2	.	.	.	.	3.4	1.2	.	3.2	.	+	+	+	1.2	1.2	.	2.3	.	.
<i>Cochlearia officinalis</i>	H	+	.	1.2	+	+	.	.	.	+	.	+	.	.	1.2	+	.	.	+	.	.
<i>Deschampsia alpina</i>	H	.	.	.	2.2	.	.	.	2.2	.	.	4.4	.	.	.	5.5	4.4	.	5.5	+	.	.	+	2.2	.	.	.	.
<i>Philonotis tomentella</i>	M	3.3	.	.	.	.	.	.	.	+	1.2	2.2	+	2.2	.	.	.	.	.	+	2	.	5.5	.	.	.	.	.
<i>Bryum pseudotriquetrum</i>	M	4.4	.	.	.	.	.	.	1.2	.	.	+	2.2	3.3	.	.	.	.	.	.	.	.	.	.	.	+	.	.
<i>Drepanocladus fluitans</i>	M	.	.	.	.	2.3	5.4	.	.	.	.	.	2.2	.	.	.	.	3.3	.	.	.	.	.	.	.	.	2.3	4.4
<i>Drepanocladus revolvens</i>	M	.	+	.	.	.	.	.	.	.	3.3	4.5	.	.	.	.	.	.	.	1.2	.	2.2	.	.	.	.	.	.
<u>Differential species of subassociation</u>																													
<i>Orthothecium chryseum</i>	M	.	.	.	.	.	.	.	3.3	2.3	4.4	2.3	2.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Cinclidium arcticum</i>	M	.	.	.	.	.	.	.	3.3	3.3	3.3	2.2	.	3.3	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Differential species of subassociation</u>																													
<i>Leptobryum pyriforme</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	+	1.2	+	3.3	2.3	.	.	.	.	.	.	.	.	.
<i>Bryum arcticum</i>	M	3.3	3.3	3.3
<u>Differential species of subassociation</u>																													
<i>Cetraria delisei</i>	M	.	.	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4.4	2.3	+	3.3	3.3	3.2	.	1.2	+
<i>Ochrolechia frigida</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2.2	.	+	2.2	3.2	+	+	.
<i>Lecidea sp.</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	3.2	.	.	4.4	.	2.2	+	+	.
<i>Cladonia pocillum</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	+	+	.
<i>Blepharostoma trichophyllum</i>	M	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	2.2	.	1.2	1.2	.	+	.	.
<i>Pohlia sp.</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2	.	1.2	.	.	.	1.2	1.2

Character and differential species of higher units

<i>Saxifraga cespitosa</i>	H	.	3·3	2·2	1·1	.	.	.	.	+	1·2	+	.	.	.	+	2·3	.	.	.	+	1·2	+	+	2	.	.	
<i>Saxifraga oppositifolia</i>	H	+	2·3	.	+	.	.	.	.	+	2·2	+	+	2·3	.	.	.	.	.	.	.	+	1·2	1·2	.	2·3	.	.
<i>Oxyria digyna</i>	H	+	+	2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1·2	+
<i>Cerastium regelii</i>	H	.	+	2	1·2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Campylium stellatum</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Luzula confusa</i>	H	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Salix polaris</i>	H	.	.	.	.	.	1·3	1·2	.	.	.	.	.	2·3	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Draba fladnizensis</i>	H	.	.	.	.	.	1·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Distichium hagenii</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Draba alpina</i>	H	.	.	1·2	+	.	1·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Tomentohypnum nitens</i>	M	.	.	.	.	.	.	1·2	3·3	.	3·4	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2·3	.
<i>Ditrichum flexicaule</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Poa arctica</i>	H	.	.	.	.	3·2	3·5	.	.	.	.	1·2	.	1·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Cetraria ericetorum</i>	M	2·2	+	
<i>Polygonum viviparum</i>	H	.	.	.	.	.	1·2	.	.	.	1·2	.	.	.	.	.	.	1·3	.	.	.	.	.	.	.	.	.	.
<i>Saxifraga rivularis</i>	H	2·2	.	.	.	.	.	1·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Verrucaria aethiobola</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Equisetum arvense</i>	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Dicranum spadiceum</i>	M	2·2	1·2	
<i>Polytrichum sexangulare</i>	M	2·3	4·4	
<i>Tortula ruralis</i>	M	.	2·2	2·3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Cardamine bellidifolia</i>	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Coelocaulon aculeatum</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Encalypta alpina</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Candelariella aurella</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<u>Companions</u>																														
<i>Bryum</i> sp.	M	.	3·3	2·2	4·4	5·5	4·4	+	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Drepanocladus uncinatus</i>	M	3·3	.	.	.	.	.	2·3	.	.	.	.	4·4	.	3·3	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Pohlia cruda</i>	M	.	.	.	.	.	.	2·3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Oncophorus wahlenbergii</i>	M	1·2	.	.	.	.	.	.	3·3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Oreas martiana</i>	M	.	.	.	.	.	.	2·3	+	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Lophozia</i> sp.	M	2·2	+	
<i>Encalypta</i> sp.	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Scorpidium turgescens</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Arenaria pseudofrigida</i>	H	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Stereocaulon alpinum</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1·2
<i>Buellia</i> sp.	M	2·2	3·2	+
<i>Timmia</i> sp.	M	4·4	.	
<i>Plagiomnium ellipticum</i>	M	2·3	+	1·2	.	
<i>Saxifraga hieracifolia</i>	H	.	.	.	.	.	.	.	2·2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Calliargon cordifolium</i>	M	.	.	.	.	.	.	.	2·2	.	1·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Saxifraga hirculus</i>	H	.	.	.	.	.	.	.	+	2·2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Ranunculus sulphureus</i>	H	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Table 2. (continued)

Vegetation unit	Running number Stand number	1																											
		a							b							c							d						
		1 N41	2 N17	3 N16	4 N12	5 N19	6 N18	7 N1	8 N25	9 N33	10 N39	11 N67	12 N68	13 N34	14 N62	15 N27	16 N26	17 N50	18 N2	19 N14	20 N51	21 N52	22 N45	23 N53	24 N46	25 N36	26 N7	27 N6	
<i>Cardamine nymani</i>	H	.	.	.	.	.	.	.	.	.	.	1-2	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Psoroma hypnorum</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.	.
<i>Lecanora</i> sp.	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2-2	.	1-3	.
<i>Drepanocladus vernicosus</i>	M	.	.	.	.	.	.	4-4	3-3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Cratoneuron filicinum</i>	M	.	.	.	.	.	.	2-3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Polytrichum alpinum</i>	M	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	1-3	.	.	.	.	.
<i>Lecidea ementiense</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.	.	.	.	.
<i>Ptilidium ciliare</i>	M	+2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1-2	.	.	.	.
<i>Didymodon</i> sp.	M	.	.	+2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.
<i>Buellia geophila</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2-2	.	.	.
<i>Pogonatum urnigerum</i>	M	.	.	.	.	.	.	.	.	.	1-2	.	.	.	.	.	.	.	.	.	.	.	.	2-3	.	.	.	.
<i>Lopadium pezizoideum</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4-4	.	2-3	.	.	.
<i>Saxifraga nivalis</i>	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	+	.	.	.
<i>Cladonia coccifera</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	+
<i>Calliargon richardsonii</i>	M	.	1-2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	2-2	.	.	.	.
<i>Distichium inclinatum</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Pleurozium schreberi</i>	M	.	.	.	.	.	.	.	.	.	.	2-3	3-3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Kiaeria blyttii</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	+	.
<i>Ceratodon</i> sp.	M	.	.	.	.	.	.	1-2	.	.	.	.	.	.	.	2-3	.	.	.	.	.	.	.	.	.	.	.	.
<i>Paludella squarrosa</i>	M	.	.	.	.	.	.	.	1-2	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Aneura pinguis</i>	M	.	.	.	.	.	.	.	.	1-2	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.
<i>Alopecurus alpinus</i>	H	.	.	.	.	.	.	.	.	3-4	2-3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Sagina caespitosa</i>	H	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.
<i>Cladonia lepidota</i>	M	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	+	2	.	.	+
<i>Ranunculus pygmaeus</i>	H	+	1-2

Species occurring in one plot in 1: *Bryum lisae* var. *cuspidatum* M+, in 4: *Dicranella* sp. M-1-2, *Psilopilum* sp. M+, in 5: *Saxifraga hyperborea* H-3-5, in 7: *Bryoerythrophyllum* sp. M+, in 8: *Juncus arcticus* H+, in 9: *Calliargon stramineum* M-1-2, *Barbilophozia hatcheri* M-1-3, *Calliargon obtusifolium* M+, in 11: *Tritomaria quinqueidentata* M+, *Calliargon giganteum* M-1-2, *Distichium capillaceum* M+, *Aplodon wormskioldii* M+, in 12: *Brachythecium* sp. M+, in 13: *Meesia triquetra* M-2-2, in 14: *Pyrenastrum asperellum* M+, *Bryum uliginosum* M-1-2, in 15: *Campyllum* sp. M-1-2, in 17: *Bryum algovicum* M-4-4, *Juncus biglumis* H+, *Marchantia polymorpha* M+, in 18: *Aongstroemia longipes* M+, *Cephalozia pleniceps* M+, in 19: *Cynodontium strumiferum* M-1-2, *Huillia macrocarpa* M+, in 20: *Athalamia hyalina* M-2-2, *Orthothecium intricatum* M+, *Polyblastia* sp. M+, *Dicranella grevilleana* M+, *Phippsia concinna* H+, in 22: *Lecanora epibryon* M-2-2, *Caloplaca tetraspora* M-2-2, *Cladonia chlorophaea* M+, in 23: *Buellia insignis* M+, *Anthelia juratzkana* M-3-3, *Tritomaria scitula* M+, in 24: *Rhizocarpon* sp. M+, *Tortula* sp. M+, *Minuartia rubella* H+, in 25: *Cetraria nivalis* M+, *Rinodina turfacea* M+, *Isopterygium pulchellum* M+, *Caloplaca cerina* M+, *Hylocomium splendens* M-5-5, *Cladonia macroceras* M+, *Caloplaca tirolensis* M+, *Peltigera rufescens* M-1-2, *Aulacomnium palustre* M+, in 26: *Cetraria islandica* M+, *Cladonia ecmocyna* M+, *Peltigera polydactyla* M-1-2, in 27: *Solorina crocea* M+.

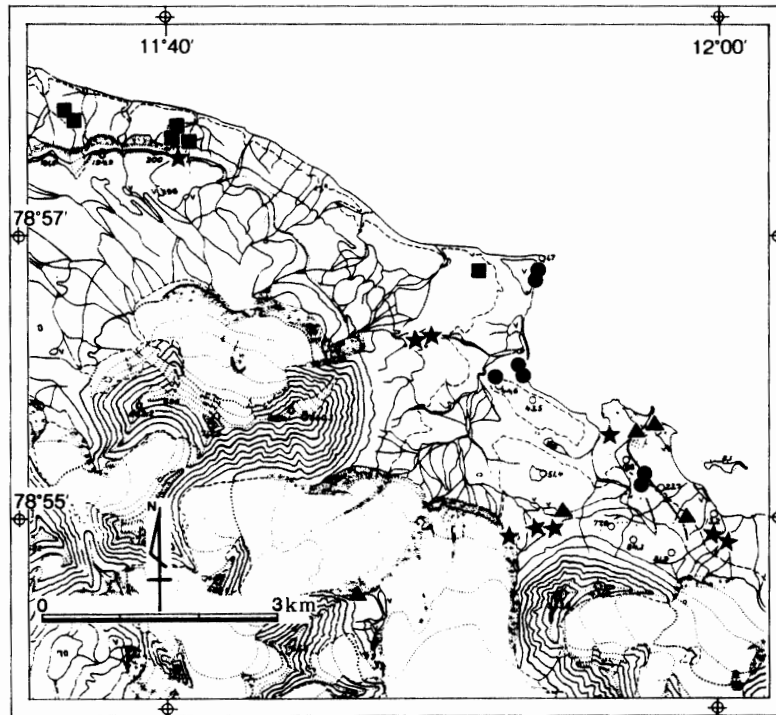


Fig. 2. Distribution of vegetation units (1). ● *Saxifragetum cernuae* subass. of *typicum*; ■ *Saxifragetum cernuae* subass. of *Orthothecium chryseum*; ▲ *Saxifragetum cernuae* subass. of *Leptobryum pyriforme*; ★ *Saxifragetum cernuae* subass. of *Cetraria delisei*.

vegetation is 100 % in all the stands, the total coverage of the moss layer is between 90 % to 100 %, and the total coverage of the herb layer varies from 7 % and 70 %. Also, the total number of species is from 11 to 27, with an average of 18.

The subassociation is only found on flat expanses of terrain at the base of Stein Flaen terrace, with a single exception (Stand No. N25). Its habitat is restricted to the swamps of flat terrain with an altitude mostly restricted to 25 m to 45 m above sea level. In respect to its floristic composition, human impact, and ecological aspect, this subassociation is the most hygrophilous and stable subassociation among the vegetation units observed in this study.

4.1.c. Subassociation of *Leptobryum pyriforme*

Differential species: *Leptobryum pyriforme* and *Bryum arcticum*.

The present subassociation is differentiated by the presence of the mosses, *Leptobryum pyriforme* and *Bryum arcticum*. But its physiognomy is mostly characterized by the remarkably luxuriant growth of such Gramineae species as *Poa alpina* and *Deschampsia alpina*. Therefore, the herb layer is relatively remarkable both in coverage and in height when compared to the herb layer of the other subassociations. The herb layer is from 10 cm to 20 cm in height, with coverage ranging from 30 % to 90 %. The total coverage of the moss layer is quite variable, from 18 % to 90 %, with an average of 59 % per stand. On the other hand, the total number of species is small, from 7 to 18 with an average of 12 per stand.

This subassociation is distributed on a soccer ground, the site where a pile of coal once lay, a swamp, a roadside, and a moraine. Accordingly, its habitat is not uniform; the distribution of stands extends from 8 m to 95 m above sea level, the slope degree varies from 0° to 25°, the soil moisture ranges from swamp to relative dry, and the slope aspect also varies.

4.1.d. Subassociation of *Cetraria delisei*

Differential species: *Cetraria delisei*, *Ochrolechia frigida*, *Lecidea* sp., *Cladonia pocillum*, *Blepharostoma trichophyllum*, and *Pohlia* sp.

This subassociation is distinguishable from the others by the presence of cryptogams such as *Cetraria delisei*, *Ochrolechia frigida*, *Lecidea* sp., *Cladonia pocillum*, *Blepharostoma trichophyllum*, and *Pohlia* sp. These species occur so widely throughout the subassociations of the next association that they cannot be designated as the character species of an association. The physiognomical appearance is rather heterogeneous. Therefore, the herb layer is usually poor in coverage, while the moss layer is characterized by the remarkably luxuriant growth of such cryptogams as *Philonotis tomentella*, *Drepanocladus fuitans*, *Cetraria delisei*, *Lecidea* sp., *Polytrichum sexangulare*, *Timmia* sp., and *Hylocomium splendens*, though they are not frequent. The total coverage of its herb layer varies from 1 % to 50 %, but the total coverage of its moss layer is between 70 % and 100 %, with an average of 86 % per stand.

This is a somewhat open community with a labile floristic composition and therefore fairly variable. The total number of species varies from 9 to 33, with an average of 22 per stand. Also, its habitat is not uniform; stands are to be found on a swamp, a ploygon, a stony slope, the middle part of a depression, and a flat and a slope where rocks of various sizes protrude everywhere and the soil layer is very shallow. The ecological amplitude seems to be very large, namely, the humidity of its preferred soil ranges from swamp to dry, the slope degree varies from 0° to 50°, and the slope aspect also varies.

With respect to the floristic composition and the ecological condition, this subassociation is considered to be further subdivided into some lower units. In this paper, however, it was not subdivided because the investigation stands were too few, making classification difficult.

4.2. *Dryadetum minoris* HADAČ 1946 em. KOBAYASHI 1994 (Table 3, Fig. 3)

Character species: *Pedicularis dasyantha*, *Cetraria nivalis*, *Silene acaulis*, *Coelocaulon aculeatum*, *Rhizocarpon geographicum*, *Alectoria nigricans*, *Dryas octopetala*, and *Hypnum revolutum*.

Perhaps more extensive stands will justify a division into associations but, from a practical point of view, it is inappropriate to divide a homogeneous-looking community too much, and the combination of *Dryas octopetala* and *Hypnum revolutum* gives a very strong impression of homogeneity. An attempt was made to differentiate an association based upon the predominating species of the herb and moss layers, but it proved to be completely impracticable, resulting in numerous microassociations scattered about the herb and moss layers. Therefore, this associa-

tion was classified on the basis of the fidelity and combination of species, accepting the fact that those species of the herb and moss layers are mosaic.

HADAČ (1946) reported the *Dryadetum minoris* without due consideration to the concept of fidelity and the combination of species, which are of prime importance for the character species of an association. This association is most closely related to the *Dryadetum minoris* described by HADAČ. In respect to the floristic composition, HADAČ's association seems to be differentiated on the basis of the dominant species such as *Dryas octopetala* var. *minor*, *Salix polaris*, *Saxifraga oppositifolia*, *Polygonum viviparum*, and *Drepanocladus uncinatus*, which do not show a definite preference for this association without *Dryas octopetala*. It is, therefore, impossible to discuss in detail the relationship between HADAČ's association and the present association.

This association is characterized by the high presence and remarkably luxuriant growth of the character species of higher units, such as *Salix polaris*, *Cetraria delisei*, *Ochrolechia frigida*, and *Saxifraga oppositifolia*, but the dominant species is not always the same. The stands are rich in species; the total number of species is from 19 to 45, with an average of 28 per stand, and the total coverage of vegetation is between 75 % and 100 %, with an average of 93 % per stand.

The association is well developed from the slopes of the mountains to the strandflat along the coast, where the soil humidity ranges from medium to dry and is somewhat xerophilous.

This association is further subdivided into two subassociations on the basis of its combination of species.

4.2.a. Subassociation of *Racomitrium lanuginosum*

Differential species: *Racomitrium lanuginosum*, *Gymnomitrium corallioides*, *Polytrichum juniperinum*, *Huilia* sp., *Pseudephebe pubescens*, *Cnestrum alpestre*, *Umbilicaria arctica*, and *Dicranum* sp.

In floristic composition, this subassociation is differentiated by the presence of somewhat xerophilous species, such as *Racomitrium lanuginosum*, *Gymnomitrium corallioides*, *Polytrichum juniperinum*, *Huilia* sp., *Pseudephebe pubescens*, *Cnestrum alpestre*, *Umbilicaria arctica*, and *Dicranum* sp. Physiognomically, the stands show that the herb layer is characterized by the remarkably luxuriant growth of either *Dryas octopetala* or *Cassiope tetragona*, and that the moss layer is dominated by *Racomitrium lanuginosum* and *Cetraria delisei*. There are great variations in the herb layer, namely, from 2 cm to 5 cm in height, with coverage ranging from 5 % to 100 %. The total coverage of the moss layer is very luxuriant, with a single exception (Stand No. N42), and varies between 65% to 100%, with an average of 81% per stand.

The ecological amplitude seems to be very narrow; its distribution is restricted to the strandflat, from 12 m to 38 m above sea level, and its habitat is rather xerophilous owing to the stony substratum with poor soil.

With respect to the floristic composition, this subassociation is considered to be further subdivided into variants on the basis of the combination of species such as *Pseudephebe pubescens*, *Umbilicaria arctica*, and *Dicranum* sp., or such as *Cassiope tetragona*, *Cladonia mitis*, and *Cladonia gracilis*. In this paper, however, this subas-

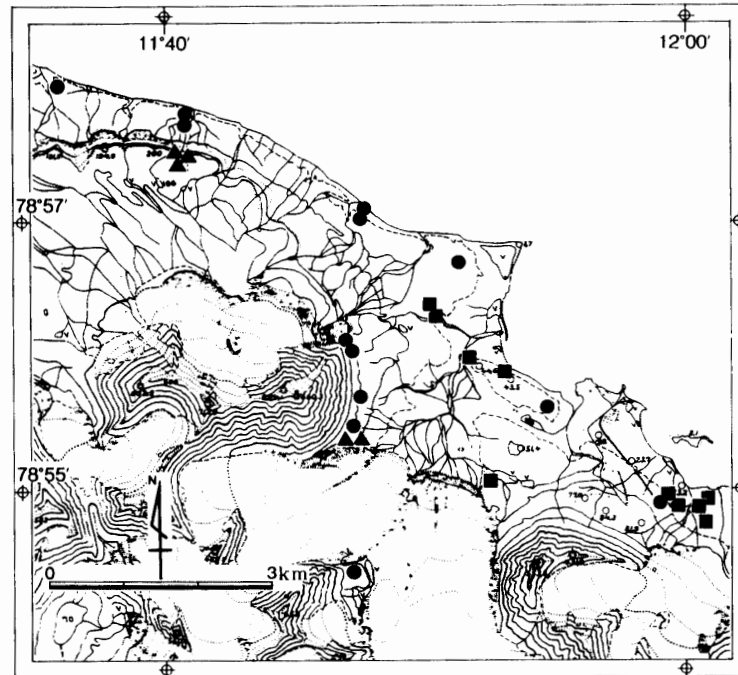


Fig. 3. Distribution of vegetation units (2). ■ *Dryadetum minoris* subass. of *Racomitrium lanuginosum*; ● *Dryadetum minoris* subass. of *Lecanora epibryon*; ▲ *Xanthoria elegans* community.

sociation was not subdivided because the investigation stands were too few, making classification difficult.

4.2.b. Subassociation of *Lecanora epibryon*

Differential species: *Lecanora epibryon*, *Placynthium asperellum*, *Carex misandra*, *Equisetum scirpoides*, and *Tortella fragilis*.

This subassociation is differentiated by the high fidelity of *Lecanora epibryon*, *Placynthium asperellum*, *Carex misandra*, *Equisetum scirpoides*, and *Tortella fragilis*. As a whole, the floristic composition and physiognomy of this subassociation are similar to the preceding subassociation, but distinguished from it by the fact that the growth of character species of this association seems to be poor and constant in most of its stands. Physiognomically, the dominant species of this subassociation is not always the same. Sometimes, such vascular plants as *Dryas octopetala*, *Salix polaris*, or *Saxifraga oppositifolia* are dominant, but at other times the dominant species are cryptogams, such as *Hypnum revolutum*, *Cetraria delisei*, *Ditrichum flexicaule*, *Tomentohypnum nitens*, or *Drepanocladus uncinatus*.

Its distribution and its habitat are not uniform: The distribution of stands extends from 5 m to 150 m above sea level; the slope degree varies from 0° to 30°; stands are to be found on the flat site of strandflat, the lower parts of slopes, and the upper parts of slopes; and the slope aspect is also very different.

With respect to the floristic composition and the ecological condition, the subassociation seems to contain some lower units. Therefore, if further investigation

of this subassociation is carried out, they may be differentiated.

4.3. *Xanthoria elegans* community (Table 3, Fig. 3)

Differential species: *Xanthoria elegans*, *Physcia caesia*, *Phaeophyscia sciastra*, and *Physcia dubia*.

The composition and physiognomy of this community are characterized by the high fidelity of lichens such as *Xanthoria elegans*, *Physcia caesia*, *Phaeophyscia sciastra*, and *Physcia dubia*, and by the luxuriant growth of *Xanthoria elegans*. An herb layer is usually absent, with a single exception (Stand No.N38). On the other hand, the moss layer is relatively rich, with coverage from 75 % to 95 %, with an average of 84 % per stand. The total number of species is between 8 and 10, and the number of component species in this community is fewer than in the other vegetation units.

It is found only on steep surfaces of rock walls under nests of birds and has a very restricted distribution in the middle and lower parts of slopes. Ecologically, the community is more photophilous, xerophilous and ornithocoprophilous than the other vegetation units. The habitat is rather sheltered from the wind and dry.

DANIËLS (1975) reported "Community of *Xanthoria elegans*" differentiated by *Xanthoria elegans* and *Physcia dubia* from Southeast Greenland. With regard to the floristic composition and the ecological aspect, the present community is closely related to the community described by DANIËLS. Especially, *Xanthoria elegans* plays a role as the differential species in DANIËLS's community as well as in the present community. In this paper, this community is provisionally treated as the *Xanthoria elegans* community because there are only five stands in this community and the present investigation has not clarified the higher unit of this community.

5. Relationship of Vegetation Units to Similarity Indices

The mutual relationship of the vegetation of the Ny-Ålesund area was examined among six subassociations and one community classified in the present study. The similarity indices (JACCARD, 1901) were calculated on the basis of the species with a presence in either of the two vegetation units to be compared. The formula used in the calculations is $100w/a+b-w$, where a is the sum of the presence class of all species present in one subassociation (or community), b is the sum of the presence class in the other subassociation, and w is the sum of the lower presence class of species common to both subassociations. The value is considered to be useful in expressing the correlations of floristic composition among the subassociations to be compared (Table 4).

Generally speaking, the *Xanthoria elegans* community differs from the others, showing low values of similarity indices, ranging from 2.1 to 5.3 for all the other vegetation units. As far as the data obtained in the present study are concerned, this difference may be because there are few species in the floristic composition and it is a strongly photophytic, xerophytic, and ornithocoprophytic community occurring on steep surfaces of rock walls under the nests of birds.

Table 4. Matrix of similarity indices of vegetation units classified in the Ny-Ålesund area.

	1.						
1. Saxifragetum cernuae subass. of typicum	100.0	2.					
2. Saxifragetum cernuae subass. of <i>Orthothecium chryseum</i>	20.0	100.0	3.				
3. Saxifragetum cernuae subass. of <i>Leptobryum pyriforme</i>	25.8	17.5	100.0	4.			
4. Saxifragetum cernuae subass. of <i>Cetraria delisei</i>	24.6	19.0	18.6	100.0	5.		
5. Dryadetum minoris subass. of <i>Racomitrium lanuginosum</i>	10.7	6.8	7.7	29.0	100.0	6.	
6. Dryadetum minoris subass. of <i>Lecanora epibryon</i>	10.8	11.5	12.3	32.4	36.2	100.0	7.
7. <i>Xanthoria elegans</i> community	5.3	2.1	5.3	2.6	2.9	4.2	100.0

In contrast, the *Saxifragetum cernuae* subass. of typicum and the *Dryadetum minoris* subass. of *Lecanora epibryon* are closely related to all other subassociations except the *Xanthoria elegans* community as seen from Table 4, with high similarity indices with values of more than 10.7. Especially, the *Saxifragetum cernuae* subass. of typicum shows a very close resemblance to both the *Saxifragetum cernuae* subass. of *Leptobryum pyriforme* and the *Saxifragetum cernuae* subass. of *Cetraria delisei*, as indicated by their respective large values, 25.8 and 24.6. Also, the *Dryadetum minoris* subass. of *Lecanora epibryon* and the *Dryadetum minoris* subass. of *Racomitrium lanuginosum* show the largest value of 36.2. It may be because each subassociation is composed of a large number of species common to each subassociation.

On the other hand, the *Saxifragetum cernuae* subass. of *Cetraria delisei* shows a very close resemblance to both the subassociation of *Racomitrium lanuginosum* and the subassociation of *Lecanora epibryon* belonging to the *Dryadetum minoris*, as shown by their respective large values, 29.0 and 32.4. Such values are considered to reflect the fact that these three subassociations comprise the differential species of the subassociation of *Cetraria delisei*, the character species of the same higher vegetation units, and a large number of companions which occur with high presence and dominance.

As far as the data obtained in the present study are concerned, both the *Saxifragetum cernuae* subass. of *Orthothecium chryseum* and the *Xanthoria elegans* community are different from the other subassociations, showing low values for all other subassociations. This is attributed to the fact that both vegetation units are different ecologically from all other subassociations; the subassociation of *Orthothecium chryseum* prefers the most hygrophilous habitat, and the *Xanthoria elegans* community, by contrast, prefers the most xerophilous.

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