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ECOGEOGRAPHICAL CLASSIFICATION OF ARCTIC VEGETATION

BASED ON SHOOTS DENSITY DETERMINATIONS

BY

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WITH 16 FIGURES AND 5 TABLES

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Abstract

A number of Greenland vegetation stands occurring on dry or mesic soils have been investigated according to shoots density. The objective density determination method is shortly described. The stands are arranged in a number of plant communities and each stand as well as the communities are characterized ecologically and by the percentage occurrence of ten ecogeographical distributional types. These "types" are treated like lifeforms, and their occurrences are based on density values (frequency sums). The main object of the paper, however, is not description of vegetation so much as by detailed analyses of selected habitats to contribute to an elucidation of the autecology of a number of species occurring in Greenland and arctic regions.

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Contents

1. Introduction

A number of shoots density determinations carried out in 1968, 1972 and 1974 in the southern part of Disko were thought to show interesting facts about the autecology of some of the species and to throw light upon the phytogeographical positions of the plant communities. The vegetation stands were analysed according to the method described by the author (Böcher, 1975b), and is revived shortly below. The majority of investigations including soil analyses (pH and conductivity, μs) were carried out in the vicinity of the Arctic Station of the Copenhagen University near the town of Godhavn, Disko.

The ecogeographical position of the vegetational units has been elucidated by calculating the percent occurrences of ecographical distributional types in the stands. A survey of the distributional types was recently published in Danish (Böcher, 1975a) and is repeated below with some few comments. The environmental tolerances of a number of species are discussed using the experiences from southern Disko and the continental areas at the head of Søndre Strømfjord (West Greenland mainland) as test areas. The vegetation at the head of Søndre Strømfjord has been studied at several occasions since the main investigation in 1946 (cp. Böcher, 1954, 1963).

I am greatly indebted to several colleagues for kind help with the determination of many mosses (Kjeld Holmen; Gert Steen Mogensen) and lichens (M. Skytte Christiansen and Eric Steen Hansen) and for undertaking the soil analyses (P. Milan Petersen).

2. The shoots density determination

The method used for the shoots density determinations has been described by Böcher & Weis Bentzon (1958) and (Böcher, 1975b). As some readers may have difficult access to the two cited papers it may here be appropriate to mention that the numbers in the analyses express densities of shoots, not coverage. Species with high coverage often reach high density values. But small plants, e.g. *Koenigia islandica*, may get very high density values but would hardly receive any coverage value or just be noted as present. The highest obtainable density value is 30. It means that the species in question has a shoot (bud) within the smallest, inmost circle in all ten sample plots. The smallest, inmost circle circumscribes an area of 1/1000 sqm (white part of horizontal leg in fig. 1).

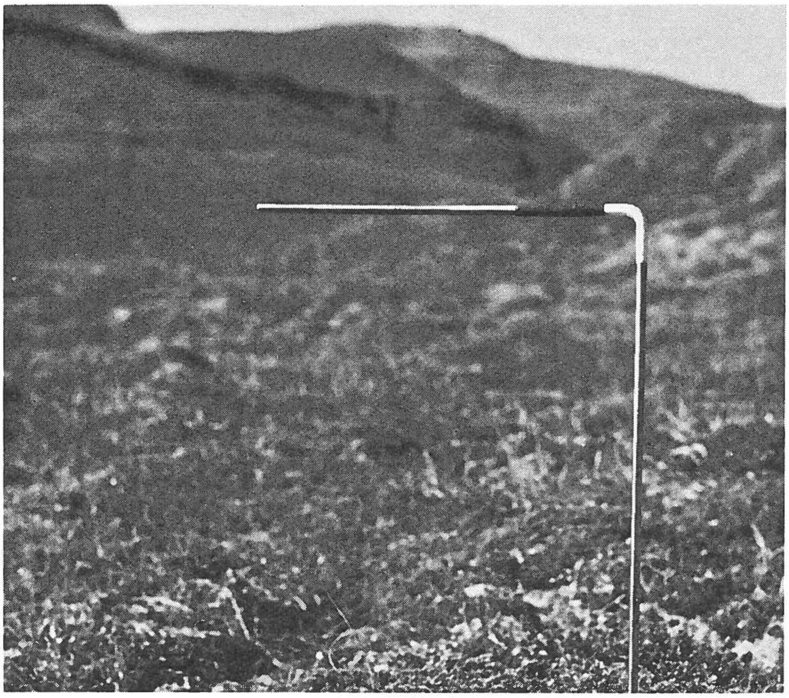

Fig. 1. Apparatus used during the field work with density determinations. The horizontal leg is 17,78 cm long (radius of the 0,1 sqm circle), the distance from the vertex to the outer edge of the dark area is 5,65 cm (radius of the 0,01 sqm circle) and to that from the vertex to the edge of the white area 1,78 cm (radius of the 0,001 sqm circle). During the analysis of each of the sample plots the horizontal leg is turned round in order to determine whether shoots of the various species issue inside the inmost (3) the next inmost (2) or the outer (1) of the three concentric circular areas. This procedure is repeated on ten different sample plots in the stand.

Species having shoots inside this small circle are designated with the number 3. Those which happen to get shoots (buds) inside the larger 1/100 sqm circle (black and white part of radius in fig. 1) are recorded with the number 2, while those which have shoots within the outermost circle only (circumscribing 1/10 sqm) get the value 1. All values (0, 1, 2 or 3) obtained in 10 sample plots (of 1/10 sqm) are added to express the density. A density value of 30 corresponds to 1000 or more shoots pr. square meter, see Table 2 p. 52 in Böcher & Weis Bentzon (1958).

2. Ecogeographical distributional types

Distinction should be made between area-types and ecogeographical distributional types (= biological distributional types of Böcher, 1938). Area-types simply express the geographical areas of the species. In Greenland there are four main area types: circumpolar, eastarctic, westarctic and endemic species. Together with the circumpolar species are usually such amphiatlantic species mentioned that are equally common on both sides of the Atlantic and have a gap in the Beeringian area. Area-types are not primarily resulting from ecological preferences of certain climatic combinations. The ecogeographical distributional types on the other hand try to express climatic preferences of the taxa and may be compared with other biological "types" such as xerophytes, mesophytes and hygrophytes. Of course demands with regard to climate can only be roughly estimated; still an ecogeographical classification in broad outlines may be relevant even if the determination of membership of a species to a "type" in certain cases is doubtful or troublesome. In connection with the present treatise it is impossible to estimate the ecogeographical affinity of a community without working out the percent occurrences of the different distributional types. These are shortly defined as follows:

A. *Arctic, wide ranging.* Mostly circum-greenlandic and circumpolar. Examples: *Saxifraga oppositifolia*, *Silene acaulis*, *Luzula confusa.*

AH. *High arctic.* Usually particularly common in mesic-humid soils in cold coastal areas. Very rare or missing in lowarctic areas (in Greenland roughly south of North Disko and the coastland at Scoresbysund). Examples: *Ranunculus sulphureus*, *Braya purpurascens*, *Minuartia rossii.*

AC. *Arctic-continental.* Northern Greenland, decreasing towards the outer coast, in lowarctic areas mostly inland and alpine. Usually missing in Iceland. Examples: *Lesquerella arctica*, *Cassiope tetragona*, *Calamagrostis purpurascens.*

AM. *Medium arctic.* With northern and southern limits in Greenland. Mostly missing in dry inland areas. Chionophilous. Outside Greenland in high mountains. Examples: *Ranunculus glacialis*, *Draba crassifolia*, *Campanula uniflora.*

L. *Lowarctic.* Mainly south of the real arctic in areas where the summer temperature enables growth of willow copses, not rarely also in subarctic (northern boreal) areas. Examples: *Diapensia lapponica*, *Carex bigelowii*, *Tofieldia pusilla.*

LO. *Lowarctic oceanic-montane.* Preferring towards the north coastal mountains rich in snow. Many are arctic-alpine. Examples: *Alchemilla alpina*, *Arabis alpina*, *Gnaphalium norvegicum*, *Veronica alpina.*

LC. *Lowarctic continental.* Missing in coastal mountains and mostly in Iceland. Preferably on dry localities. Examples: *Draba aurea*, *Artemisia borealis*, *Carex supina* ssp. *spaniocarpa.*

B. *Boreal.* Main distribution south of the Arctic area, but sometimes reaching far north into the lowarctic parts. The Bs-subtype shows connection with woodlands (e.g. *Coptis trifolia*, *Pyrola minor*), the Bv-subtype is connected with freshwater (e.g. *Epilobium palustre*, *Calamagrostis neglecta*), while the Bb-subtype has no specieal connections (e.g. *Botrychium lunaria*) or may be connected with saline localities (*Plantago maritima*).

BO. *Boreal-oceanic montane.* In Greenland in coastal mountains in the southernmost part. Examples: *Viola palustris*, *Cornus suecica*, *Juncus squarrosus*.

BC. *Boreal-continental.* Very few species in Greenland. Examples: *Diphasiastrum complanatum*, *Alnus crispa*, *Carex capitata*.

The percent occurrences of the distributional types (Dt) in the districts SWn (including south Disko), NWs (including north Disko), CWm (including Søndre Strømfjord) and CWn (including the Jakobshavn area) are added for comparisons with the Dt spectra of plant communities.

	A	AH	AC	AM	L	LO	LC	B	BO	BC	O	C	A	L	B
Coastal															
NWs	18	12	17	11	17	9	8	6	1	0	10	25	58	34	7
SWn	13	3	10	8	17	17	6	21	3	1	20	17	34	40	25
Inland															
CWm.........	15	4	13	4	17	11	14	18	1	2	12	29	36	42	21
CWn	15	10	13	8	17	10	12	13	1	1	11	26	46	39	15

4. Marginal habitats of Loiseleuria procumbens, Juncus trifidus, Diapensia lapponica and Arctostaphylos alpina

Ecologically these species may be related enough for a joint treatment. However, it is not easy to define their accordances. They are stated to prefer dry, acid or poor soils and are said often to be bare of snow in winter. This is particularly true in South Greenland with its high precipitation and higher degree of oceanity. At their northern limits all four species show deviating habitat preferences.

Loiseleuria procumbens.

In the archipelago (skerries) at Egedesminde south of Disko *Loiseleuria* prefers protected stands. A profile transect shows its type of occurrence at the foot of a dry rocky slope:

Fig. 2. Sloping hummocky area near projecting rocks. Vegetation rich in *Loiseleuria* in the foreground. In 1974 a patch of snow was still persisting in the middle of July off bracket on the right.

1. Upper part of slope *Saxifraga tricuspidata* and lichens on the rocks.
2. Middle part of slope *Empetrum* heath.
3. Lower part of slope *Salix herbacea*-soc. (with much *Ochrolechia frigida*).
4. Bottom of slope *Loiseleuria* – *Salix herbacea* – *Carex bigelowii*–soc. (scattered *Phyllodoce*, *Cassiope tetragona*, *Harrimanella hypnoides*).
5. Level area with low hummocks covered with *Salix herbacea* – *Carex bigelowii* and mosses.

At Godhavn on Disko *Loiseleuria* – sites were abundant between the ice – polished gneissic rocks and none of the accompanying species indicated strong wind exposure or lack of winter snow cover. In one locality the situation was particularly clear: A corner near steep rocks at the upper (northern) end of a gently sloping plain not far from the small river which runs down to the lagoon at the Arctic Station had often a prolonged snow cover and just here *Loiseleuria* was dominant. The zonation was studied and shoots density analyses undertaken in several belts:

1. Rock ledges and crevices in steep south exposed granite rocks. *Antennaria canescens* and *Luzula spicata* abundant.
2. Narrow strip along foot of rocks. *Phyllodoce, Diphasiastrum alpinum, Bartsia alpina, Poa alpina* etc.
3. Sunny gently sloping ground; some solifluction and small turf hummocks. *Loiseleuria* – soc. Analysis Table 1 No. 2. Fig. 2.
4. The same slope but distance from rocks greater. *Empetrum – Vaccinium – Phyllodoce* – soc. Table 1 No. 5.
5. On drier soil and shorter snow cover still further removed from the rocks. *Empetrum – Vaccinium – Betula nana* heath with *Pyrola grandiflora.*
6. On the driest part, slightly exposed near border of weakly developed ledge. *Vaccinium – Carex rupestris* – lichen – soc. Table 2 No. 8.

In the belts 3–5 scattered tufts of *Juncus trifidus* were present.

There are several indicators of lasting and constant snow cover in the *Loiseleuria* – soc., e.g. *Phyllodoce, Harrimanella, Salix herbacea, Pyrola minor* and *Cladonia ecmocyna.* The same was the case in the lower part of the valley Blæsedalen, where a similar *Loiseleuria* – soc. was analysed (Table 1 No. 1) also on gently sloping slightly hummocky ground; the latter stand was also sunny and was surrounded by *Cassiope tetragona* heath. *Salix herbacea* and *Harrimanella* are almost constantly present but not very dense. *Minuartia biflora* and *Bartsia* indicate protection, while the occurrence of *Carex nardina* shows that the site at least during summer dries up.

To sum up: *Loiseleuria procumbens* approching its northern limit in Greenland selects sites constantly protected by snow in winter, but the snow cover is not extremely long lasting. It prefers acid and poor rocks, but was found on moderately acid soil (pH 6,4) in the lower part of the valley Blæsedalen, where the substratum is tuff and volcanic agglomerates. In Disko Fjord it enters together with *Diapensia* a mixed dwarf shrub heath pattern (see Table 1 No. 9). It avoids the inland areas at Søndre Strømfjord and is very rare on basalt at least in West Greenland (cf. map fig. 88 in BÖCHER 1938). The species appears to be uniform genetically (2n = 24).

Juncus trifidus.

As the preceding this species is as far as we know missing at he head of Søndre Strømfjord. At Godhavn it never dominates in the vegetation. However, it was observed abundantly (as many scattered tussocks) in a belt along a small SW-facing slope, 200 m above sea level. The slope itself was covered with *Empetrum – Phyllodoce – Salix glauca* heath.

Juncus trifidus grew on slightly sloping, sometimes very wet soil. Between the tussocks the soil was blackish due to *Nostoc*. It was accompanied by *Diapensia*, *Tofieldia pusilla*, *Carex bigelowii*, *Harrimanella*, *Silene acaulis*, *Gnaphalium supinum* and *Sibbaldia*. Another *Juncus* site was found on a southexposed slope (incl. about 30°) near the river Røde Elv. It was here abundant as were *Phyllodoce coerulea*, *Bartsia alpina* and *Stereocanlon alpinum*. Less important, though frequent were *Salix herbacea*, *Silene acaulis* and *Vaccinium uliginosum*. Scattered occurrences of *Dryas* and *Carex rupestris* indicated moderate drying out.

In Disko Fjord a single *Juncus trifidus* occurrence was found at Eqalunguit along the margin of a south-exposed ledge on shallow soil over gneiss rocks. On deeper soil about 1 m from the margin there was *Vaccinium – Empetrum – Betula nana* heath rich in lichens. The margin had abundant *Stereocaulon alpinum* and *Cladonia mitis* together with the *Juncus*-tussocks. Below the uncovered rocks the heath continued but now with more mosses and *Phyllodoce*, *Cassiope*, *Equisetum arvense*, *Chamaenerion latifolium* and *Pedicularis lapponica*.

Thus, near its northern limit *Juncus trifidus* selects small niches characterized by sunny situation, some desiccation of the soil, some, not too long, snow cover in winter and acid soils. In all sites the competition from other vascular plants appeared to be low.

Ingram (1958) has studied the ecology of *Juncus trifidus* in the Cairngorms in Scotland. Here it forms closed and open communities. The closed ones are related to the *Rhacomitrium* heath. The open ones are widespread and occur on bare ground in acid gravel or between boulders. The snow cover is slight due to exposure to wind.

In Norway the ecology of *Juncus trifidus* is stated to be parodoxical (Nordhagen, 1943: 208). In the subalpine or lowalpine areas it grows excellently on wind exposed gravelly flats while in the medium alpine it becomes ± chionophilous. In Rondane Dahl (1956: 135–137) describes a *Chiono-Juncetum trifidi* with *Diphasiastrum alpinum* and *Salix herbacea*. This community is found on relatively dry soils below the *Myrtilletum* in snow-beds, usually in south exposures in the upper part of the low-alpine belt. This behaviour of *Juncus trifidus* in Norway is clearly closely related to that found in Greenland, where the Disko area is medium- to lowarctic.

Juncus trifidus seems to be represented in the north atlantic area, Scandinavia and Greenland by ecologically closely related populations. I have cultivated several strains of *Juncus trifidus* in pots filled with peat and those from Greenland, Iceland, the Faroes and Norway appeared to be almost identical. Morphologically deviating strains were obtained from the Pyrenees and the Tatra Mts. Plants from North and South Greenland, Iceland, Swedish Lapland and the Alps had all 2n = 30.

Diapensia lapponica.

Two of the analyses in Table 1 contain dominating *Diapensia* (No. 3–4). The two habitats are contrasting, but show two margins of the wide ecological amplitude of the species. Other habitats appear from a belt transect mentioned in BÖCHER, 1963: 145.

One stand (Table 1 No. 3) was found on level gravelly ground on a low isthmus between two bays in the coastal rocks at Fortunebay, South Disko. The density of shoots of *Vaccinium* and *Diapensia* was high but *Dryas* was almost constantly present although clearly hampered by the two dominants. The soil was slightly acid and probably poor. The site was windy, no doubt with changing and shallow snow cover. This habitat resembles the open fell field habitats with abundant *Diapensia*, so common elsewhere in Greenland (cp. BÖCHER, 1954: 39: 1963: 202–203), but it also approaches the high alpine inland habitats described from Søndre Strømfjord where it dominates together with *Dryas* and *Rhododendron* (BÖCHER, 1954: 142–152) on soils which are moderately acid (pH 5,4–6,7). In the White Mountains in New Hampshire TIFFNEY (1972) found *Diapensia* habitats blown bare of snow throughout the winter. Increasing snow cover resulted in increasing dominance by other species.

The other stand (Table 1 No. 4) shows a characteristic and not uncommon type of habitat in the gneiss rocks near Godhavn. West of the Arctic Station in a small valley (Myggedal) between steep rocks the bottom of the valley contains shallow pools. Near such pools which often dry up during summer the flat rocks are sometimes covered by a vegetation of *Diapensia – Cetraria delisei – Andraea alpestris*. In rainy periods the vegetation may shortly be covered with water and during winter it is covered with thick masses of snow or ice and snow. This type of habitat of *Diapensia* is related to its occurrence in frost scars and small depressions in closed vegetation canopies on ± level areas. *Diapensia* occurs in such habitats on soils which mostly keep moist during the growing season e.g. depressions with *Pinguicula* (Table 4 No. 6) or *Arenaria humifusa* and *Sedum villosum* (Table 4 No. 7). At Arfersiorfik fiord (Sungaussup kangerdlua) *Diapensia* and *Loiseleuria* were exclusively found on bare soil patches in the heath (BÖCHER & LÆGAARD, 1962: 172). A habitat type blending the two contrasting ones described above is found in *Carex rupestris – Dryas –* communities with *Rhododendron*, *Tofieldia* and other species indicating moisture (Table 2).

Diapensia lapponica is in Greenland represented by ssp. *lapponica* which has a north-Atlantic range; however, like *Salix herbacea* it penetrates to areas west of Hudson Bay (PORSILD, 1955 fig. 16). In their habitat preferences near their northern limits *Loiseleuria*, *Juncus trifidus* and *Diapensia lapp.* ssp. *lapponica* show many similarities and all three have north-Atlantic distribution.

Arctostaphylos alpina.

In Scandinavia this species is classified as low-alpine, oligotrophic and chionophobous (see e.g. DAHL, 1956). In Greenland its ecological demands are so different that it deserves a short discussion. Its Greenland distribution was mapped by GELTING (1934: 263) who lists it among the bicentric species while his map clearly shows that it is tricentric with two small areas on the west coast and one large continuous area on the east coast (from 68°44′ to 74°30′). In East Greenland the species prefers warmer inland habitats and is mostly snow covered in winter (see e.g. HARTZ, 1895a). From the information given by HARTZ (1895b) about its ecology it is evident that it often occurs together with species which are ± eutrophic (e.g. *Dryas*, *Carex rupestris*, *C. supina*, *Erigeron compositus*, *Arabis holboellii*, *Kobresia myosuroides*). Similarly SCHWARZENBACH (1961) mentions *Arctostaphylos alpina* growing on dry calcareous ledges at Krumme Langsø together with *Dryas octopetala*, *Kobresia myosuroides*, *Carex nardina*, *Lesquerella arctica* and even *Braya purpurascens*. Also elsewhere its ecological behaviour deviates from that in Scandinavia. In the Canadian-eastern arctic POLUNIN (1948: 190) mentions it from half barrens e.g. open *Dryas*-heath with e.g. *Kobresia*, *Carex nardina*, *C. glacialis* and *Salix reticulata* (pH in the gravel 7,2), or in more protected sites together with *Vaccinium vitis-idaea* and *Salix herbacea* (l. c. p. 226) or *Ledum decumbens*, *Cassiope* and *Salix herbacea* (l. c. p. 271). In parts of Alaska *Arctostaphylos alpina* grows in "snow beds, depressions in *Dryas* fell-fields, ericaceous polygones, *Dryas* steps and stripes and gravel bars" (JOHNSON *et al.* 1966). In Kamchatka HULTÉN (1972) found it together with *Diapensia* but also in lowland dwarf shrub heath with mosses, *Empetrum*, *Ledum decumbens*, *Pedicularis labradorica* and even *Cornus suecica*. Thus there are many indications of a deviating behaviour of the populations occurring in America – Beringia. The best way of explaining the differential ecological behaviour is the assumption that the East Greenland populations originate from plants which immigrated long ago from North America and therefore show similar preferences as the American populations do now. But during migrations and persistence in glacial refugia in Greenland the populations there suffered from reductions in the gene pool and it became therefore impossible for them to migrate southwards to the southern areas where the rocky ground consists of precambian gneisses or granites and with experiences from Scandinavia ought to be particularly suitable for *Arctostaphylos alpina*.

Arctostaphylos alpina is absent from Iceland where the soil conditions probably are unfit for populations having "Scandinavian" ecological demands. On the other hand the species occurs in Scotland together with *Loiseleuria* just where a limestone ridge runs into a side of an acid hill and the vegetation changes abruptly and becomes dominated by heather and bilberry (RAVEN & WALTERS, 1956: 152). The Scottish population thus seems ecologically to correspond with the Scandinavian and may be of "eastern" origin.

Table 1.

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and exposure		10° S	5–10° S	–	–	10° S	40° W	10° SW	30° SE	5° S	15° E	5–10° S	5–10° N	–
pH		6.4	4.5	6.3	4.6	5.2	5.9	5.9	4.8	5.3	5.2	4.7	6.5	4.6
μs (conductivity)		52	202	363	78	248	700	94	240	371	112	–	45	226
DT (Ecogeographical distributional type) spectrum (percentages): Arctic	A	12	9	22	23	8	10	6	1	1	11	10	6	7
	AC	22	4	16		1	2	21	4	15	34	10	12	16
	AH													
	AM													
Low arctic	L	15	3	59	67	56	41	44	67	50	53	30	35	66
	LO	49	81	3	8	28	37			5	1	50	40	
	LC				2			29	28	29	2	1		
Boreal	B	2	2			7	10						9	11
	BO													
	BC													
Number of species..........		29	38	26	22	25	46	37	27	27	40	37	39	29
Freq. sums f. vasc. plants...		130	91	106	57	137	154	126	116	131	129	166	130	55
– – f. bryoph. + thalloph.		60	46	58	62	42	25	110	38	63	82	39	171	125
Points per sample plot (0.1 sq.m.)		19.0	13.7	16.4	11.9	17.9	17.9	23.6	15.4	19.4	21.1	20.5	30.1	18.0
I														
Betula nana	LC		+		1			9	10	**20**	2	1		+
Cassiope tetragona	AC	14	3			1	1	10		**20**	**28**	2	10	2
Diapensia lapponica	L			**22**	**25**					7				
Dryas integrifolia........	AC			15							1			
Empetrum hermaphroditum	L	18	2		1	**27**	**20**	**27**	**30**	**28**	17	11	**30**	4
Harrimanella hypnoides..	LO	12	6			+	+					**29**	**28**	
Ledum decumbens........	LC							**20**	**22**	15				
Loiseleuria procumbens...	LO	**29**	**30**							7				
Phyllodoce coerulea.......	LO	1	18			**22**	**23**					2		
Salix arctica............	A			3										
– *arctophila*	L				6									
– *glauca callicarpaea*..	L		+			4	**21**	+	15	2	15	19	+	4
– *herbacea*...........	LO	18	18	3	5	15	9				1	**27**	**22**	
Vaccinium ulig. microphyl.	L		+	**27**	1	**28**	14	**29**	**29**	**27**	**23**	1		**29**

Table 1. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and exposure		10° S	5–10° S	–	–	10° S	40° W	10° SW	30° SE	5° S	15° E	5–10° N	5–10° S	–
pH		6.4	4.5	6.3	4.6	5.2	5.9	5.9	4.8	5.3	5.2	4.7	6.5	4.6
μs (conductivity)		52	202	363	78	248	700	94	240	371	112	–	45	226
II														
Carex arctogena	L				1									
– *bigelowii*	L	1		12	4						+	2	9	
– *misandra*	AC										+			
– *nardina*	AC	7		+										
– *rupestris*	AC			2							11	3		
– *scirpoidea*	L		11			16		+			11	6		
Juncus trifidus	LO		1											
Luzula arctica	AC							+			+	1	2	
– *confusa*	A	2	1	2				3	+	1	2		+	3
– *frigida*	L		+				+							
– *parviflora*	Bs						6							
– *spicata*	LO		1											
Poa alpina	LO						4							
– *arctica* (– "*pratensis*")	AC						1	1	3			7	3	2
Trisetum spicatum	A	1					3							
III														
Antennaria canescens	LO						1							
Armeria scabra	AC									+				
Bartsia alpina	LO	2	+			1	11					6		
Cerastium alpinum	L						1				+			
Chamaenerion latifolium	A						1							
Erigeron humilis	AM						+							
Gnaphalium norvegicum	LO						3							
Leucorchis albida	BO						+							
Minuartia biflora	LO	2										2	2	
Pedicularis flammea	L		+	2		2					2	9	1	
– *hirsuta*	AC											+		
– *lanata*	AC			+							+			
– *lapponica*	LC		+			+		7		2	+			
Polygonum viviparum	A	12	7	11	13	11	12	5	1	+	6	15	8	1
Pyrola grandiflora	AC	7	1			1		15	2		4	3	+	4
– *minor*	Bs		2				3							
Sagina saginoides	LO						1							
Saxifraga oppositifolia	A			1										
Silene acaulis	A			6							2	1		
Stellaria longipes-monantha	L	1								2			3	
Thalictrum alpinum	LO										+	17		
Tofieldia pusilla	L		+	+			8		4		1	2	3	
Veronica alpina	LO						4							

(Continued)

Table 1. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and exposure		10° S	5–10° S	–	–	10° S	40° W	10° SW	30° SE	5° S	15° E	5–10° S	5–10° N	–
pH		6.4	4.5	6.3	4.6	5.2	5.9	5.9	4.8	5.3	5.2	4.7	6.5	4.6
μs (conductivity)		52	202	363	78	248	700	94	240	371	112	–	45	226
IV														
Equisetum arvense	B	3				2	6						9	6
Huperzia selago arctica	A	+	+								4		+	
Lycopodium annotinum alpinum	B		+			7	1							
V														
Andraea alpestris					**23**									
Aulacomnium palustre							1		2					
– *turgidum*				6	2			2		13				
Barbilophozia hatcheri						+			1		4	}3		
– *lycopodioides*						2								
Bartramia pomiformis							1							
Brachythecium salebrosum							2							
Bryum sp.							+							
Cephalozia pleniceps							1							
Cephaloziella arctica							1	1						
Desmatodon latifolius							+							
Dicranum acutifolium										10				
– *angustum*													7	
– *elongatum*			1											
– *fuscescens*						+	2							
– *majus*								**20**	4				11	
– *scoparium*		3		6		11			1			1		
– *spadiceum*											10			
– sp.					1							1		
Diplophyllum taxifolium			1		1									
Drepanocladus revolvens					1									
– *uncinatus*		3				1	7		1	2		9	5	
Hylocomium alaskanum								1		5	16	1		
Kiaeria glacialis					2									
Lophozia binsteadii								2						
– *excisa*							1							
– *kunzeana*													**20**	
– *wenzelii*							1					2		
– *ventricosa*							+						+	
Marchantia alpestre							3							
Oncophorus wahlenbergii				8			2							
Philonotis tomentella							1							
Pohlia cruda													5	
– *nutans*							1		1					
Polytrichum affine					2									
– *alpinum*				8			1				3	2	**22**	
– *hyperboreum*		1							1				3	
– *juniperinum*				8				7		2				
– *piliferum*			2											

Table 1. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and exposure		10° S	5–10° S	–	–	10° S	40° W	10° SW	30° SE	5° S	15° E	5–10° S	5–10° N	–
pH		6.4	4.5	6.3	4.6	5.2	5.9	5.9	4.8	5.3	5.2	4.7	6.5	4.6
us (conductivity)		52	202	363	78	248	700	94	240	371	112	–	45	226
– sp.												2		
Pottia obtusifolia											3			
Ptilidium ciliare				1		11		13		+	5		14	1
Rhacomitrium canescens											8		+	
– *lanuginosum*			3	4	1			1	1					27
Saelania glaucescens													1	
Schistidium apocarpum				10										
Rhytidium rugosum												3		
Tomenthypnum nitens											12			
Tortella fragilis														3
VI														
Alectoria nigricans								3						4
– *ochroleuca*								4						1
Cetraria delisei		3			26			2		+		1	10	8
– *islandica*		1	+		2			2		2	7		17	1
– *nivalis*					+			13		5				6
Cladonia bellidiflora			+									1		
– *coccifera*			+				+	6	3	3	2		5	1
– *ecmocyna*		1	2											
– *gracilis*			2			3		3	2		1		6	6
– *lepidota*											1			
– *mitis*		4	7			+		3	4	6	1		3	10
– *pleurota*		8	1											
– *pyxidata*				8	+								2	
– *rangiferina*								3	2					9
Cornicularia aculeata		10									1			
Crocynia neglecta			4									2	12	13
Nephroma expallidum								1						
Ochrolechia frigida		17						6		4	1	2	5	1
– *gemmipara*														1
Peltigera aphthosa									3					
– *canina*						3					1			
– *leucophlebia*									1					
– *malacea*		1	11					2	2				7	
– *polydactyla*									1					
– *rufescens*							+							
Pertussaria dactylina														1
– *oculata*			3									+		
Psoroma hypnorum				5				3					1	
Sphaerophorus globosus								4						18
Stereocaulon alpinum		8	9	4	1			7	8	7	6	}9	15	5
– *paschale*						11				4				
Thamnolia subuliformis								1						9
VII														
Mitrula gracilis (on *Philonotis*)							+							

5. Snow cover-dependent dwarf shrub heath pattern

The word acidophilous was omitted from this heading because of the behaviour of *Cassiope tetragona*, which according to previous investigations in Greenland and elsewhere (particularly in Norway by NORDHAGEN, 1936) in a number of stands occurs abundantly together with *Dryas*, *Rhododendron lapponicum* and other "calciphiles". The expression snowcover-dependent, however, deserves comments. Two of the dominant ericaceous species, *Empetrum hermaphroditum* and *Vaccinium ulig. microphyllum* (*V. gaultherioides*) are frequent where the protection by snow is scarce or intermittent. The latter species has such a wide ecological amplitude that it is able to occur in the majority of communities, see p. 55, except those in late snow beds or on ultrabasic soils rich in salts. *Empetrum* becomes selective in the continental inland areas, where it prefers wet soils, north exposure or shady sites with higher atmospheric humidity and more constant snow in winter. *Empetrum*-leaves resemble those of *Phyllodoce coerulea* which is almost exclusively connected with sites where snow gathers. The xeromorphic structure in both species is striking. Nevertheless this structure is probably a response to multifactorial long time selection (cp. discussion below regarding *Cassiope*). In connection with the preference of habitats with constant and thick winter snow cover we may point to the fact that the entrances to the furrows with the stomata on the leaf undersides are furnished with trichomes which probably impede melt water to enter the furrows and thereby block the stomatal apertures.

In Table 1 there are two stands with dominating *Phyllodoce* (No. 5–6). The belt occupied by No. 5 was already mentioned in connection with *Loiseleuria*. Among the dwarf shrubs *Empetrum* and *Vaccinium ulig. microphyllum* are even denser than *Phyllodoce*. Among the other species *Salix herbacea* and *Carex scirpoidea* are common.

The other stand (Table 1 No. 6) is from a fertile steep slope near the river which later passes the Arctic Station. Here *Vaccinium* is repressed while *Salix glauca* has reached a stage of co-dominans. The stand is characterized by very many herb-mat species e.g. *Bartsia*, *Gnaphalium norvegicum*, *Sagina saginoides*, *Pyrola minor*, *Leucorchis albida*, *Luzula parviflora* and many bryophytes. The local fertility is caused by soil water which occassionally oozes out. The conductivity value is particularly high (μs 700).

A characteristic species in many *Phyllodoce* – stands is *Lycopodium annotinum* ssp. *alpinum*. This taxon is equally characteristic in similar heaths in Southeast Greenland where it is regarded as having a high degree of fidelity (BÖCHER, 1933: 61). In Disko Fjord (Akuliaruseq) north of

Godhavn it is common but already somewhat selective occurring mainly in small heath covered gullies in the sunny slopes of the fiord. Here it prefers sites near the bottoms on east or west-exposures, growing in stripes together with *Phyllodoce*, *Arnica* and *Equisetum arvense*. In continental West Greenland *Lycopodium annotinum* ssp. *alpinum* is exclusively alpine and rare, selecting snow patch heath sites with *Timmia austriaca*, *Polytrichum hyperboreum*, *Cassiope* or matforming *Salix glauca* (Böcher, 1954: 181–182).

In Finnish Lapland it occurs according to Kalliola (1939) frequently in the *Phyllodoceto – Vaccinion myrtilli*. It is strikingly less important in corresponding Norwegian communities (Nordhagen, 1943; Dahl, 1956). This is difficult to explain, but according to Kallio, Laine and Mäkinen (1969: 56) there are in Finnish Lapland numerous intergradations between the silvine ssp. *annotinum* and the low-alpine ssp. *alpinum*. In Greenland ssp. *annotinum* is absent. Hence the Greenland population of ssp. *alpinum* has probably not like many Scandinavian populations suffered from introgression of silvine genes.

Ssp. *alpinum* is not restricted to the *Phyllodoce* – heath. At Godhavn it is abundant in margins of willowmats or low scrubs. Near the belt transect with *Loiseleuria* (p. 10) another transect was studied which unveiled an ecotone from herb mat conditions to heath and willow mat.

(1) Along foot of sunny rock, on slightly towards west inclining ground: Narrow belt of *Phyllodoce* - heath with *Diphasiastrum alpinum*, *Sibbaldia* and some *Alchemilla glomerulans*.

(2) Almost level area *Salix herbacea – Polygonum* – soc. rich in mosses (Table 3 No. 11). The vegetation had character of a meadow.

(3) *Salix herbacea* – soc. rich in mosses and lichens. *Lycopodium annotinum* ssp. *alpinum* physiognomically dominating (Table 3 No. 12).

(4) *Salix glauca* – mat (heath).

(5) *Salix glauca* – mat (heath) with *Pyrola grandiflora* (Table 3 No. 10).

The character of the vegetation stands on level areas dominated by low *Salix glauca* varies greatly. The soil is mostly dry and the vegetation contains much *Vaccinium* so that it deserves to be grouped with heath vegetations. In other cases *Salix* communities are clearly members of the herb mat series, as are the low willow stands on sunny slopes (e.g. Table 3 No. 8). On the almost flat area in front of Østerlien (see Fig. 5) such willow-stands had very much *Vaccinium*, *Salix herbacea* and *Polygonum*, further *Equisetum arvense*, *Pedicularis hirsuta*, *P. flammea*, *Poa* cfr. *arctica* and *Aulacomnium turgidum* and very scattered *Polytrichum juniperinum* and *Bryum curvatum* (pH 6,6, μs 88).

In the valley Brededal east of the Godhavn area on Disko *Aulacomnium turgidum* is very abundant in a low *Salix glauca* - vegetation extending over wide level areas. Two examples were studied in detail, characterized by two species of horsetail. One is characterized by *Equisetum arvense* and much *Empetrum* and *Vaccinium*. Scattered in the moss carpet which further contains *Dicranum* ssp., *Stereocaulon alpinum*, *Cladonia mitis*, *C. gracilis* and *Cetraria islandica* shoots of *Alopecurus alpinus*, *Stellaria monantha* and *Salix herbacea* are found. *Pedicularis hirsuta*, *Tofieldia pusilla* and *Polygonum viviparum* occur as single specimens or in small groups.

The other vegetation is dominated by *Vaccinium ulig. microphyllum*, *Salix glauca* and very dense *Aulacomnium turgidum*. Here *Equisetum scirpoides* was abundant while *E. arvense*, *Empetrum*, *Pyrola grandiflora*, *Draba glabella*, *Luzula confusa* and *Pedicularis flammea* were scattered. The moss-lichen layer had *Drepanocladus uncinatus*, *Hylocomium alascanum*, *Dicranum spadiceum*, *Oncophorus wahlenbergii*, *Polytrichum affine*, *Stereocaulon alpinum*, *Peltigera scabrosa*, *Cladonia cyanipes* and *chlorophaea*.

Equisetum scirpoides is common in dry willow copses, particularly in continental tracts. The vegetation in question was clearly related to such copses, but entirely heathlike reaching 10–20 cm above the ground. Other vegetations with abundant *E. scirpoides* have been described from the slopes of Præstefjældet at Holsteinsborg (HARTZ, 1894) and in BÖCHER, 1963: 183.

The lowarctic *Ledum decumbens* occurs in Disko together with the likewise lowarctic *Phyllodoce* and the higharctic *Cassiope tetragona*. However, *Ledum* and *Phyllodoce* belong plantgeographically to widely different types. *Phyllodoce* is more depending on snow and atmospheric moisture and disappears in the driest inland areas, while *Ledum decumbens*, like its close relative *L. palustre*, becomes more and more abundant with increasing climatic continentality. In Disko it is interesting to observe how the two species are distributed. They almost never enter the same community in spite of the fact that they occur in the same gully or belt transect. In Disko Fjord (east of Akuliaruseq) *Ledum* was abundant in small gullies on eastexposures, while *Phyllodoce* was observed on westfacing slopes. The heath stand Table 1 No. 8 is from such a small gully. *Ledum* disappeared on the upper drier part of the slope. At the same time the density of *Betula* and lichens increased. Near the top of the slope *Salix glauca* became important followed by scattered *Saxifraga tricuspidata*, *Festuca brachyphylla*, *Poa glauca*, *Campanula gieseckiana* and *Dryas*.

In the lower part of the valley Blæsedalen east of Godhavn the two dwarf shrubs occurred in adjacent belts. Below a steep rock, there was a gently towards S-SW sloping area (Fig. 3) with abundant *Ledum* (Table 1 No. 7). Just above this area along the steep rock on its southern

Fig. 3. Gently sloping area near protruding rock covered with *Empetrum – Vaccinium – Ledum* heath. *Ledum* flowering abundantly. Blæsedalen near Godhavn, 1974.

and western side there was a narrow belt with very much *Phyllodoce*, *Lycopodium annotinum* ssp. *alpinum* and *Bartsia.* All three were absent from the heath below, the reason probably being found in less favourable microclimatic conditions in the heath with *Ledum.* The sunny rock presumably creates early thawing of thick snow that gathers around the rock. The *Ledum*-site, on the other hand, had clearly a constant and longer but not thick snow cover. The frequency of species like *Cassiope tetragona* and *Pyrola grandiflora* was high and *Dicranum majus* was constant and reached a high density. The latter seems to belong to a "hygric oceanic" distributional type.

Pyrola grandiflora shows greater affinity to heath communities than to those of the herb mat series. Near Godhavn it hybridizes with *P. minor* and the hybrids grow in sites with intermediate ecological conditions.

Ledum palustre occurs in Disko Island often together with *Cassiope tetragona.* Also in the inland areas at the head of Søndre Strømfjord transitions between *Ledum*- and *Cassiope* - heath are common in higher elevated areas (Böcher, 1954: 174).

In spite of related snow cover tolerance it is not common to find *Phyllodoce* in *Cassiope* heaths. It happens e.g. in the coastal mountains north of Søndre Strømfjord (Böcher, 1963: 186). At Godhavn there are also sites which contain both but usually as subordinate members of other heath types (e.g. Table 1).

Table 1 No. 9–10 shows two stands with abundant *Cassiope.* They are both from Disko but different in many respects. Stand No. 9 in Table 1 is from a gently sloping area near the beach in Kangerdluarssuk

Fig. 4. Kangerdluarssuk in Diskofjord. Gently sloping area at the head of the creek. Mosaic of heath covered and small clayey – silty patches with *Pinguicula*. Incipient turf hummock formation, 1972.

Disko Fjord (Fig. 4). This heath was interrupted by many shallow clayey—silty tongue—shaped depressions which were slowly percolated. The vegetation in these depressions was analysed separately and is commented on later p. 46. In the surrounding heath a number of species were present also in the depressions, thus *Equisetum arvense*, *Tofieldia*, *Diapensia*, *Salix glauca*, *Vaccinium* and *Empetrum*. The latter three were able to enter the clayey – silty spaces but they were clearly not vigorous here owing to unfavourable soil conditions. The surrounding heath had pH 5,3 and the clayey spaces 5,9. The heath contained *Betula*, *Cassiope* and *Ledum* in 9 out of 10 0.1 m^2 circles and *Diapensia* and *Loiseleuria* in 4, while *Vaccinium* and *Empetrum* were constantly present and very dense.

The other stand is from the eastfacing slopes at the valley Blæsedalen. It is a very vigorous *Cassiope* heath with subordinate *Vaccinium* and *Empetrum*. Other dwarf shrubs are suppressed but the moss-layer is well developed and the vegetation contains some of the typical *Cassiope*

– companions, viz. *Carex misandra* and *Luzula arctica*, but also some less typical species: *Carex rupestris* the dominating species on the drier soils in the area was present with small weak shoots in 8 out of 10 0.1 m^2 circles. *Thalictrum alpinum* occurred in great quantities in small interspaces in the dwarf shrub canopy evidently where slow percolating took place.

Both stands are clearly protected by thick snow during winter and during summer there are no signs of exsiccation or strong wind exposure. Any explanation of the ericaceous leaf structure in *Cassiope* as an adaptation towards dry conditions needs to be augmented and further commented. In the case of *Cassiope* the only possible environmental factor involving water shortage is prolonged soil frost inhibiting root activity at a time when photosynthesis and transpiration have started in the light-exposed shoots. But the *Cassiope* leaf is certainly not a structural response to one factor. The dense cover of glandular trichomes on the adaxial sides of the leaves must have some adaptive value. In wet periods e.g. during snow melting the shoots are often submerged. Water can probably penetrate between the leaves but will rarely be able to fill the stomatal furrows; presumably the epistomatal chambers contain airbubbles behind the trichomes which prevent water infiltration, and water on the dorsal sides might perhaps be taken up by the glands. This was first suggested but later abandoned by WARMING (1856: 177 and 204).

Harrimanella hypnoides is frequently found together with *Cassiope*. *Harrimanella* is a very important element in the coastal mountains in late thawing sites. *Harrimanella* dominated stands are described in detail in BÖCHER, 1959: 21 and BÖCHER, 1963: 137–141. They may be rich in lichens (e.g. *Cladonia ecmocyna* Table 1 in BÖCHER, 1959) or mosses and lichens but dense *Harrimanella* carpets may often be mixed with *Salix herbacea* and contain several forbs like *Thalictrum alpinum*, *Polygonum viviparum*, *Minuartia biflora*, or even *Bartsia* and *Pedicularis flammea*. The latter occurred regularly scattered in a stand above the steep part of the Østerlien slope (Table 1 No. 11).

Table 1 No. 12 also contains an example with *Empetrum* as co-dominant. It was found along the upper margin of a snow bed area ("Gryden" at Godhavn) and was downwards succeeded by a *Salix herbacea* – *Harrimanella* – belt rich in lichens.

A snow bed with two large *Harrimanella* patches was charted at an earlier occasion and the chart is published in BÖCHER, 1963. In 1968 the place where the two patches occur was covered by late snow (Fig. 5). In the strip between the two snow gatherings the soil was percolated with melt water which came from a small gully behind. The seepage strip had much *Minuartia biflora*, *Oxyria* and *Arabis alpina* and a few specimens of *Arenaria humifusa*.

Fig. 5. Østerlien at Godhavn as viewed from SE July 1968. The snow has disappeared from the steep sunny slopes with its luxuriant vegetation (low willow copses, bright green *Alchemilla glomerulans* stands and many herb mat sociations, e.g. those in Table 3 No. 3–4). The snow in the picture is situated exactly where snow was supposed to gather (BÖCHER, 1963 Fig. 63). Under the snow there are two large patches covered with *Harrimanella.* They are separated by a narrow strip without *Harrimanella* situated off and below a small gully in the slope behind. In the foreground the vegetion is dominated by *Vaccinium ulig. microphyllum* and *Carex rupestris.*

6. Snow cover-independent dwarf shrub-heath pattern

The designation chionophobous is as well as its counterpart chionophilous not used because these two words cover the two extreme situations while the ecological conditions caused by an intermediate duration or an intermittent snow cover are better expressed through the word snow-cover-independent.

Dryas integrifolia and *Rhododendron lapponicum* are among the dwarf shrubs both calciphilous and not dependent on snow protection, but they are markedly different in other respects. An ecological distinction, however, is difficult. In the humidity scale both species have a wide range but *Dryas* is able to grow more abundantly on wind-exposed gravelly areas while *Rhododendron* is better adapted to humid and fertile peaty areas, but both species are not rarely seen side by side in both types of habitats. In a few cases *Dryas* disappears from sites dominated by *Rhododendron.* It happens in the almost scrub-like tall *Rhododendron*-heaths without moss-lichen layer found on sunny slopes at the Søndre Strømfjord airbase (BÖCHER, 1954: 223). In other cases *Rhododendron* is absent from *Dryas*-heath sites e.g. in areas beside salt lakes

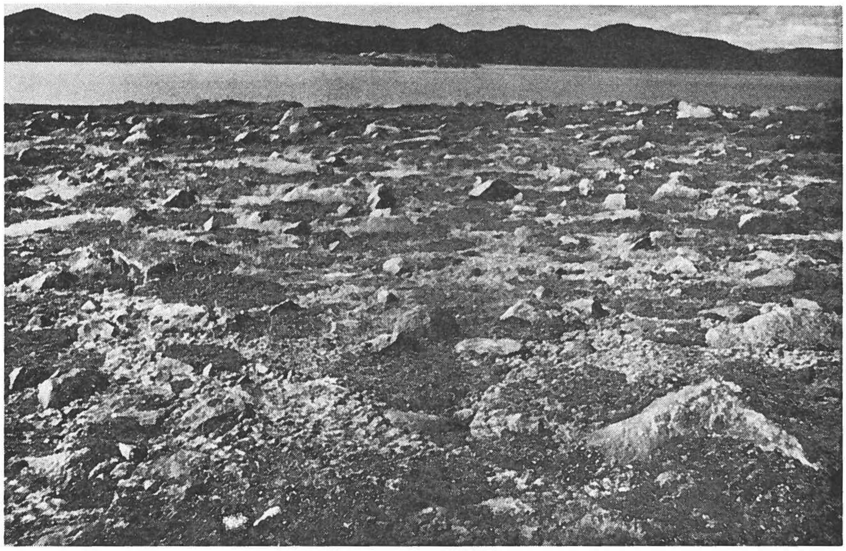

Fig. 6. Lake Hundesø near the head of Søndre Strømfjord. Level area with *Dryas*-carpets and cracked bare-soil areas interspaced with big stones. The soil is alkaline and the lake is salt. Photo July 1974.

(Böcher, 1954: 153, 209, 214). A similar vegetation was found 1974 near the lake Hundesø (Fig. 6). An extensive almost level area was here covered with a mosaic of naked islands of cracked dry soil and small pure *Dryas integrifolia*-carpets. pH was 8.0, and the conductivity very high (μs 445). A few species were able to grow together with *Dryas* or even sometimes in the bare-soil islands: *Artemisia borealis*, *Calamagrostis purpurascens*, *Kobresia simpliciuscula* and *myosuroides*, *Carex glacialis*, *boecheriana* and *scirpoidea*. Lichens were also very scattered: *Cetraria nivalis*, *Cladonia pocillum*, *Cornicularia muricata*, *Dermatocarpon rufescens*, *Physcia endococcina* and *Fulgencia bracteata*.

On Disko *Rhododendron* and *Dryas* are present in the majority of dry and exposed vegetations which here further mostly contain much *Carex rupestris*.

The sunny basalt scree of the hill "Katrinehöj" near the Arctic Station at Godhavn was investigated in 1968, 1972 and 1974. Three stands with vigorous specimens of *Rhododendron* were analysed (Table 2 No: 1–3). The scree was not stabilized and had many open stony spaces (Fig. 7). *Dryas* – *Rhododendron* obtained shoots densities between 10 and 16 in the stands from the middle part of the scree but near its lower margin *Carex rupestris* became denser, while *Dryas* decreased considerably in density (No. 3). All three stands had abundant *Vaccinium* and lichens, but *Empetrum* avoids the area. In one of the stands single small specimens

Fig. 7. Scree of the hill "Katrinehöj" near the Arctic Static Station at Godhavn. The vegetation is rich in *Dryas* and *Rhododendron lapponicum*. Table 2. Nos. 1–3.

of *Woodsia glabella* occurred. Of other species from open rocks or gravel flats there were *Saxifraga tricuspitata*, *S. caespitosa*, *S. nivalis*, *Draba nivalis*, *Potentilla vahliana* and *Minuartia rubella*.

The density (expressed in points per sample plot) is low in all three stands. The vegetation is a successional stage and exposed to occasional sliding down of stones detached from the steep rocks above the scree (Fig. 7).

A stabilized heath patch with abundant *Rhododendron* was analysed at the crest of the sunny slope above the snow bed with *Harrimanella* discussed above (Table 2 No. 4). The peaty soil was shallow and was clearly periodically percolated by water gathering on the hummocky plane above the slope. pH was 6,3 and the conductivity high (μs 409) probably due to ions contained in the evaporating soil water. The vegetation was developed as a narrow belt near the corner in the slope where the small gully cuts the lowermost part of Østerlien. The heath was dominated by *Vaccinium* but contained also *Empetrum*, *Betula* and *Dryas*. Among the mosses *Tetraplodon mnioides* indicates a high content of nutritive substances. Also in other localities on southern Disko *Rhododendron* was observed in similar sites along the crests of rocky slopes where slow water percolating takes place. One site of this type had a dense heath canopy of *Vaccinium*, *Rhododendron*, *Salix glauca* and *Dryas*. Among the graminoid species *Carex rupestris* was common, while *C. capillaris*, *C. scirpoidea* were scarce; the forbs were mainly represented by *Polygonum viviparum*, *Campanula uniflora* and *Thalictrum alpinum*.

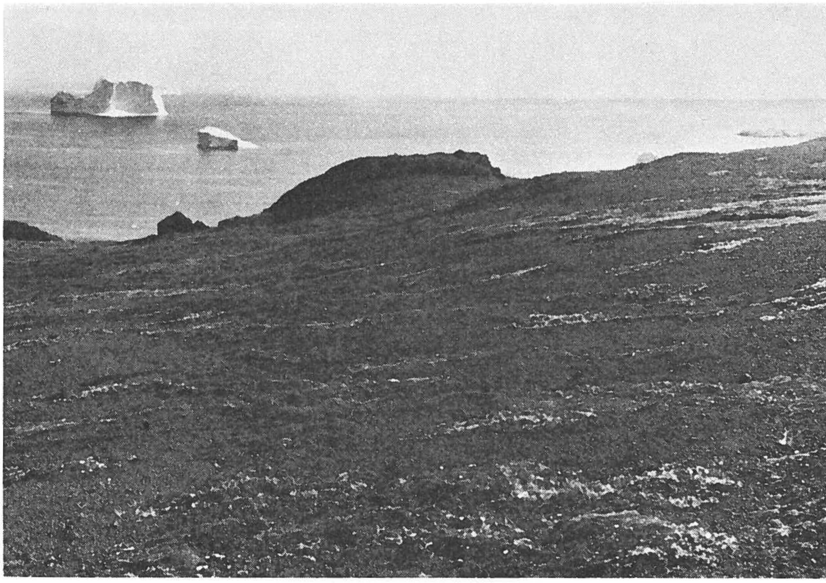

Fig. 8. Barren landscape on the mountain plateau just above Østerlien near the Arctic Station. Basalt gravel and *Dryas-Carex rupestris* – lichen – heath carpets.

Among the bryophytes there were *Isopterygium pulchellum*, *Myurella tenerrima*, *Plagiobryum demissum* and *Pohlia cruda*. *Myurella tenerrima* is mentioned from Norway (Dovre) in *Carex microglochin-maritima* marshes (Nordhagen, 1943: 456).

Calcareous water oozing out where rocks approach the surface, e.g. near the foot of a hill slope, created in the inland areas at Søndre Strømfjord small ecological niches inhabited by the rare *Amerorchis rotundifolia*. It occurred at one place near Strømfjordshavn and near the fiord often together with *Dryas* – *Rhododendron* thus in the following vegetations: *Dryas* – *Rhododendron* heath with *Vaccinium*, *Salix*, *Pinguicula*, *Equisetum arvense*, *E. variegatum*, *Tofieldia pusilla*, *Carex scirpoidea* and *Euphrasia frigida*. This heath type showed great stand to stand diversity and had in other places also *Empetrum*, *Betula nana*, *Kobresia simpliciuscula*, *Carex boecheriana*, *C. norvegica* ssp. *inserrulata* and even the rare *C. capitata* ssp. *capitata*. Another site with *Amerorchis* in *Dryas* – *Rhododendron* vegetation was described in Böcher, 1953: 230.

The mountain plateau above Østerlien on Disko is gently sloping towards east and towards the valley Blæsedalen. The area is exposed to a strong wind pressure and to solifluction. The vegetation is a mosaic of east–west orientated elongate dense vegetation "islands" and elongate areas of sorted material consisting of east–west running stripes of small stones alternating with gravel (Fig. 8). In the open spaces *Potentilla vahliana* is common; the other species here occur very scattered (e.g.

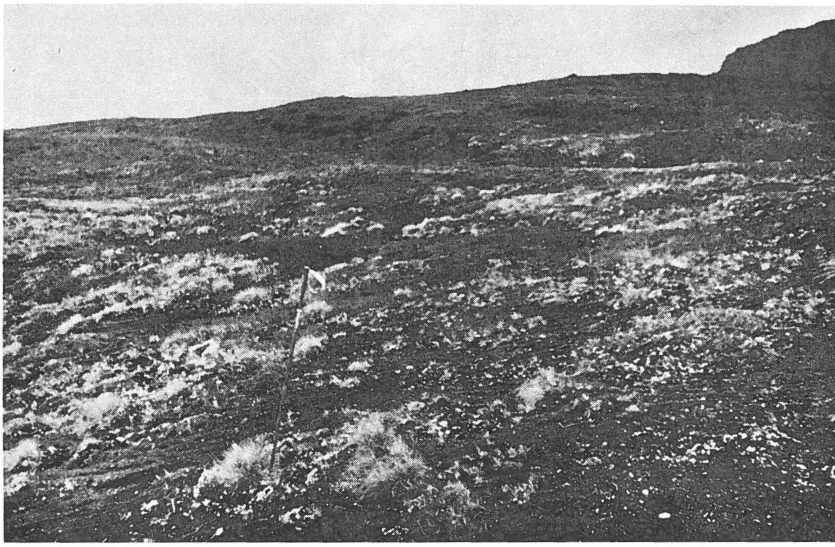

Fig. 9. Fell field with small solifluction lobes bordered by tufts of *Carex nardina* on the plateau above Østerlien.

Saxifraga tricuspidata, *S. oppositifolia*, *Campanula uniflora*, *Silene acaulis* and *Draba nivalis*). The islands are dominated by *Vaccinium*, *Salix*, *Dryas* and lichens (Table 2 No. 5) or *Vaccinium* – *Carex rupestris* and lichens (Table 2 No. 9). Similar communities of *Dryas*, *Carex rupestris* and many lichens occur elsewhere on Disko and were thoroughly analysed by GELTING (1955).

The sloping area becomes more sheltered and the soil less dry and more stabilized near the Ionospheric Station at the entrance to Blæsedalen. The vegetation islands fuse to larger expanses and the soil becomes richer (μs 571). An analysis from a stand here (Table 2 No. 10) has the same dominants with densities approaching 30 but several scattered species indicating moister conditions (*Carex misandra*, *Draba crassifolia*, *Equisetum arvense*).

A still moister and level area with much solifluction interspaced with lengthy frost hummocks (BÖCHER, 1963 Fig. 92 off asterisk) was analysed 1972. It is situated above the crest with *Rhododendron* just mentioned. *Vaccinium* – *Carex rupestris* – *Cetraria nivalis* are still able to hold their position as dominants (Table 2 No. 6) but on moister areas between the heath islands there are few specimens of species like *Pinguicula*, *Arenaria humifusa*, *Salix arctophila* and *Carex misandra* and on dry gravelly interspaces *Papaver radicatum* and *Potentilla vahliana*.

The most wind exposed areas on the mountain plateau are characterized by *Carex nardina*, which here occupies margins of solifluction lobes (Fig. 9). It is accompanied by some *Cetraria nivalis*, *Dryas*, *Carex rupe-*

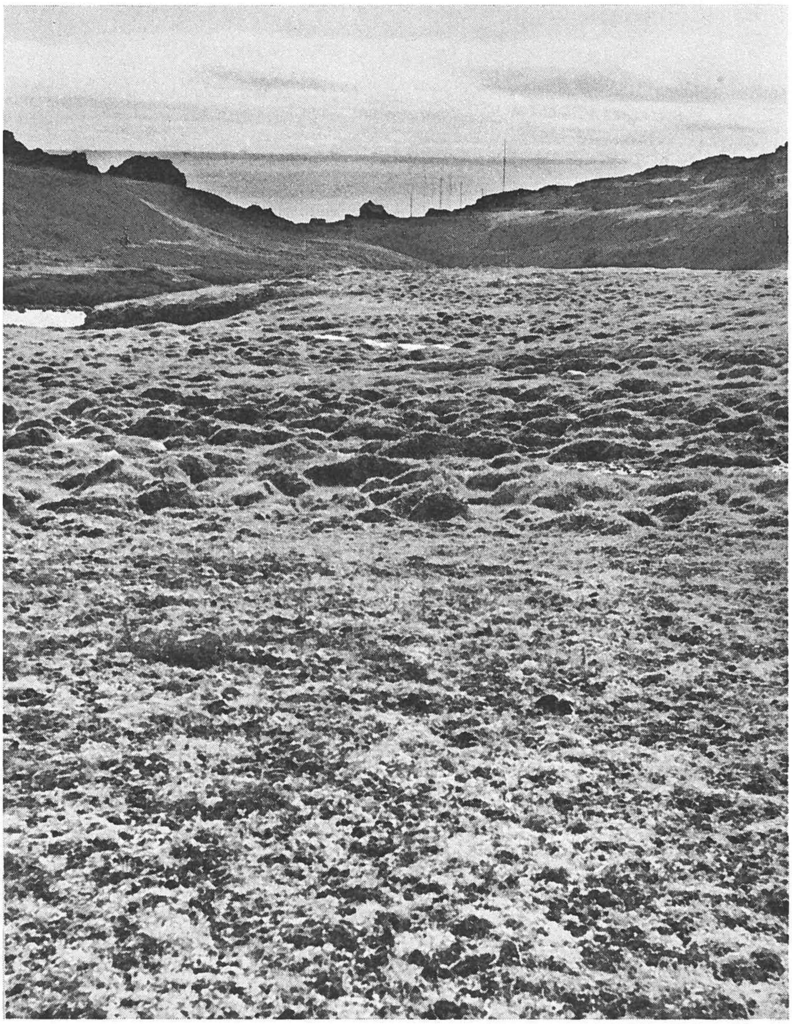

Fig. 10. Dense lichen heath on level area in the lower southern part of the valley Blæsedalen (Table 2 No. 12). In the background the Ionospheric Station and the sea.

stris, *Saxifraga tricuspidata* and *Potentilla vahliana*. Even *Silene acaulis* occurs very scattered, in one place as a hemispherical cushion 10 cm high and 16 cm in diameter. The center of this cushion was occupied by gravel penetrated by a strong taproot which near the branching part was 1,8 cm in diameter. Obviously gravel in the surrounding area had been removed by the wind and the margin of the *Silene* cushion had been able to grow obliquely downwards hiding and protecting a central cone of gravel.

Wind exposed stands often has very much *Carex nardina* as a member of a *Carex rupestris – Dryas* – heath (Böcher, 1975: 85) or even dense lichen heath in the valley Blæsedalen. The latter type was analysed carefully according to shoots density (Table 2 No. 12) and its position in the valley appears from Fig. 10. It was developed on an almost level terrace surface. In a southerly direction it was replaced by frost turf hummocks on slightly sloping ground and finally by a less hummocky moister community dominated by *Carex stans*, *Equisetum arvense* and bryophytes. The number of vascular and non-vascular species is almost the same but the densities are very different. Expressed in the number of 3-values obtained in 10 circles of 1/10 m^2 the vascular plants get 3 such values while the non-vascular plants obtain 17.

Another dense lichen heath was studied at Kangerdluarssuk in Disko Fjord. It covered sunny granite rocks (Table 2 No. 13). Here *Vaccinium* is the only constantly occurring vascular plant. The soil is poor; *Dryas* and *Carex rupestris* therefore are very scarce. The number of 3-values obtained by vascular and non-vascular species is here 3 and 30 respectively.

In the belt series mentioned above (pp. 10) a *Vaccinium – Carex rupestris – lichen* heath occurred on the driest part (Table 2 No. 8). *Dryas* was also scarce here and the occurrence of *Empetrum*, *Carex bigelowii*, *Minuartia biflora* and several bryophytes indicated greater moisture and longer snow cover than in the preceding stands. The 11 vascular species obtained 15 values indicating high density (3-values) and the 22 non-vascular species 17 such values.

A similar though not so dense *Vaccinium – Carex rupestris* stand occurred on flat dry ground on the lower outer raised beach in front of the southernmost parts of Østerlien (Table 2 No. 7) Fig. 5. Here *Dryas* grew in isolated flat cushions and this type of growth is expressed in the number of 3-values. It was found within 5 of the 10 0,1 m^2 circles and in four of these also within the 0,001 m^2 circles, thus getting four 3-values.

Towards west there is another more elevated raised beach terrace. It is mainly covered by dwarf shrub heath but part of it has an interesting vegetation in which dwarf specimens of *Kobresia myosuroides* are constantly present though not dense (Table 2 No. 11). The soil is rich (μs 424) and lichens are remarkably rare. Perhaps the soil gets some water oozing out from the fertile slope of Østerlien (see Table 3) which is close behind the stand. The occurrence of *Carex norvegica* ssp. *inserrulata*, *C. capillaris*, *Pedicularis flammea*, *Encalypta rhabdocarpa* and abundant *Polygonum* may result from these relatively fertile soil conditions. NORDHAGEN (1943: 578) mentions *Encalypta rhabdocarpa* as a constant species in Norwegian *Carex rupestris* sociations rich in species occurring in areas with seep water.

Considering the abundance of *Kobresia myosuroides* in Iceland it is astonishing to observe how rare it is in the basaltic areas in South Disko. The Greenland population may belong to another ecological race which is particularly favoured by the conditions in the Strømfjord inland, see

BÖCHER, 1954 and 1963. In Southern Disko *Kobresia myosuroides* was observed in a community resembling those at the head of the Strømfjord. The site in question was at Fortunebay near a sunny rocky wall and had *Kobresia* and *Cladonia mitis* as dominants intermixed with *Cetraria nivalis*, *Carex scirpoidea*, *Polygonum*, *Campanula gieseckiana*, *Saxifraga paniculata*, *Dryas* and *Potentilla chamissonis*. One stand was more carefully investigated. It was a more extended area with SSE exposure and shallow soil over the rocks. During springtime some seeping probably took place. pH was measured to 6,1 and the conductivity to µs 187. High density was obtained by *Kobresia*, *Vaccinium* and *Polygonum viviparum* as well as *Cladonia mitis* and *Stereocaulon alpinum* while *Cetraria nivalis*, *C. cucullata* and *Cornicularia* were more scattered. Flowering plants occurring scarcely were *Carex glacialis*, *Saxifraga paniculata* and *oppositifolia* and of lichens *Cetraria islandica* (*ericetorum*), *Alectoria ochroleuca*, *Ochrolechia upsaliensis*, *Cladonia rangiferina*, *C. uncialis*, *Thamnolia vermicularis* and among the mosses *Grimmia alpestris*, *Rhytidium rugosum* and *Rhacomitrium lanuginosum*.

The Greenland steppe communities so profusely developed at the heads of the long West Greenland fjords occur very sporadically on Disko. A single site was found on a steep southern slope at the head of Disko Fjord (Kuánerssuit). It was dominated by *Carex supina* ssp. *spaniocarpa* and contained *Campanula gieseckiana*, *Dryas* and *Cladonia pyxidata* as subdominants and further *Arabis holboellii*, *Draba lanceolata*, *Melandrium triflorum*, *Viscaria*, *Cerastium alpinum*, *Potentilla chamissonis* and *Festuca rubra* ssp. *cryophila*, *Stereocaulon alpinum* and *Cetraria nivalis*. Other similar sites would contain *Kobresia myosuroides*, *Calamagrostis purpurascens*, both sometimes forming small stands, furthermore *Euphrasia frigida*, *Draba aurea*, *D. glabella*, *Poa glauca*, *Potentilla nivea*, *Artemisia borealis* and *Antennaria affinis*.

Before leaving the snow-independent communities a short discussion of *Rhacomitrium lanuginosum*-dominated spots. This species is the dominant on the top of the Faroe mountains and the old lava fields in Iceland (e.g. the "mosathembur" vegetation described by MØLHOLM HANSEN (1930: 40–43). While the Iceland vegetation has constant occurrence of *Salix herbacea*, this being the only conspicuous phanerogam in the moss carpet, this species is hardly present in *Rhacomitrium* carpets in Disko. In Iceland the "mosathembur" at its lower limit passes over into the "Elyna-mo", i.e. *Kobresia myosuroides* community rich in *Carex bigelowii*, *Agrostis canina*, *Salix herbacea*, *Empetrum*, *Thymus*, sometimes even *Thalictrum alpinum* and *Selaginella selaginoides*. In Greenland on Disko island the best developed *Rhacomitrium* stands occur on old morainic boulder fields. The most important pioneer in the succession on such boulder fields is *Rhacomitrium* and it holds its dominating position also in later stages, where lichens contribute to the cover of the boulders.

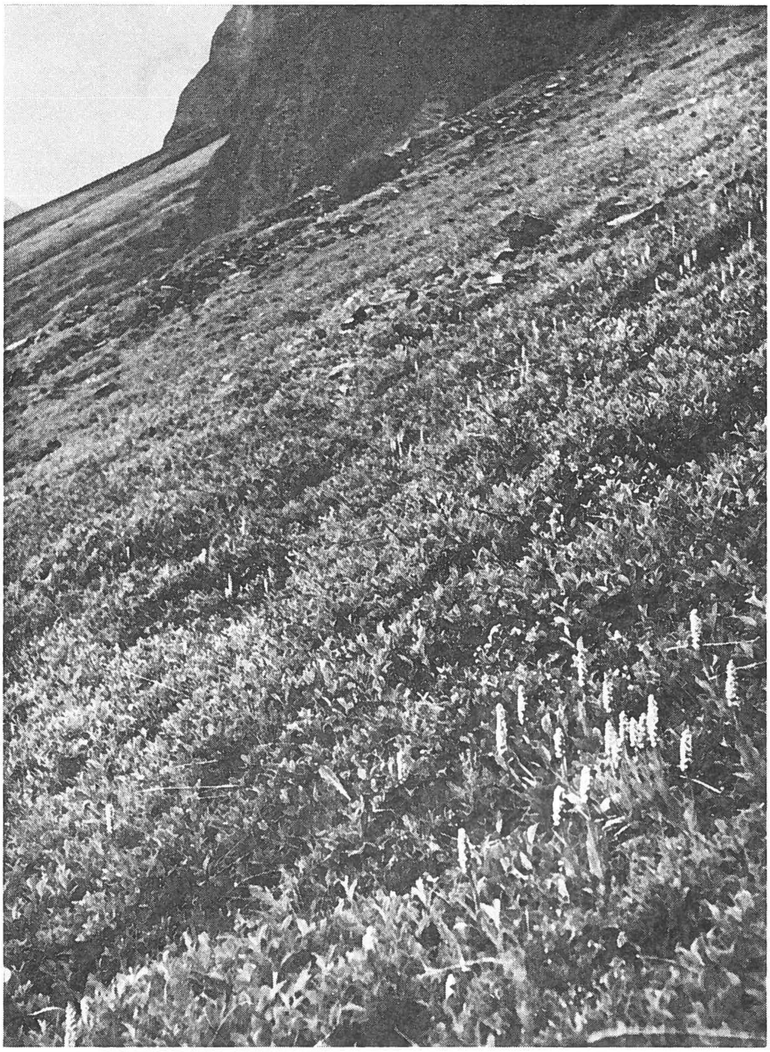

Fig. 11. Fertile herb mat and willow mat on talus slope below the steep bird cliff at Igpik west of Godhavn. White inflorescences in the foreground and further behind belong to *Leucorchis albida*. The herb mat contains much *Poa alpina*, *Polygonum viviparum* and on open spaces with boulders *Viscaria*, *Veronica fruticans* and *Draba aurea*. In the willow mats there are *Orthilia secunda* ssp. *obtusata* and *Pyrola grandiflora*. Along the steep rocks in the background on wet places *Equisetum arvense*, *Taraxacum croceum*, *Arabis alpina* and *Oxyria*, while on drier gravel there are *Arabis holboellii*, *Roegneria borealis*, *Elymus mollis*, *Poa glauca* and *Chamaenerion angustifolium*.

As it appears from the analysis Table 1 No. 13 *Vaccinium* is able to dominate together with *Rhacomitrium* and among the lichens *Sphaerophorus globosus* is constant but scattered. A similar boulder field covered with *Rhacomitrium* occurs on the northern slope of the ridge south of the lake in the valley Blæsedalen.

Table 2

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and		30°	30°	30°	5°	15°	–	–	–	10°	10°	5°	–	15°
exposure		SW	SW	SW	S	SE				SE	SSE	S		S
pH		5.6	6.2	5.8	6.3	6.6	6.2	6.2	–	–	6.1	5.8	5.8	4.9
μs (conductivity)		384	228	235	409	293	150	89	–	–	571	424	89	322
DT (Ecogeographical distributional type) spectrum (percentages) — Arctic	A	19	7	23	18	7	21	30	9	19	11	24	34	
	AC	51	50	43	31	43	41	49	38	35	56	44	55	7
	AH													
	AM													
Low arctic	L	27	44	34	45	49	37	21	50	46	29	31	10	75
	LO								1					
	LC	3			8	1					3	1		18
Boreal	B									1	2			
	BO													
	BC													
Number of species		38	39	30	38	46	43	32	32	33	40	23	41	26
Frequency sums f. vasc. plants		87	76	74	143	85	99	88	94	103	109	101	66	28
– – f. bryoph. + thalloph.		90	62	82	49	113	100	84	130	126	115	30	125	129
Points per sample plot (0.1. sq.m.)		17.7	13.8	15.6	19.2	19.8	19.9	17.2	22.4	22.9	22.4	13.1	19.1	15.7
I														
Betula nana	LC	3			12	1	+				3		+	5
Cassiope tetragona	AC					+	+			2			+	+
Diapensia lapponica	L	+	3	1	+	1	13			11				
Dryas integrifolia	AC	10	12	1	11	**21**	14	13	3	12	15	5	10	1
Empetrum hermaphroditum	L				15		1	+	11			1		+
Rhododendron lapponicum	AC	16	11	11	17	9	1			1	5		+	
Salix glauca callicarpaea	L	4	5	4	11	12	1	2	1	5	1		+	2
Vaccinium ulig. microphyl.	L	18	**25**	13	**28**	**27**	**21**	17	**26**	**27**	**26**	**26**	4	19
II														
Carex bigelowii	L								9			1		+
– *capillaris*	L				1							2		
– *misandra*	AC				1		+				7			
– *nardina*	AC							1					9	
– *norvegica inserrulata*	LC											1		
– *rupestris*	AC	11	8	19	8	2	**24**	**23**	**23**	**21**	**25**	**20**	14	1
– *scirpoidea*	L	2		6			1	+				1		
Festuca brachyphylla	A		+											
Hierochloe alpina	AC			1			+							
Kobresia myusuroides	AC											19		
Lusula arctica	AC					+	2				7		4	
– *confusa*	A	2	1	1	7				2	3		+		+
– *spicata*	LO	+												
Poa arctica	AC	1			1	+	+				2			
– *glauca*	A		+							1				

(Continued)

Table 2. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and		30°	30°	30°	5°	15°	–	–	–	10°	10°	5°	–	15°
exposure		SW	SW	SW	S	SE				SE	SSE	S		S
pH		5.6	6.2	5.8	6.3	6.6	6.2	6.2	–	–	6.1	5.8	5.8	4.9
μs (conductivity)		384	228	235	409	293	150	89	–	–	571	424	89	322
III														
Arenaria humifusa	AM						+							
Armeria scabra	AC										+			
Campanula gieseckiana	L	+												
– *uniflora*	AM					+	+				+			
Cerastium alpinum	L	+	+		2						2		1	
Chamaenerion latifolium	A						4						4	
Draba crassifolia	AM										+			
– *glabella*	AC							1						
– *nivalis*	A	3		+		+								
Minuartia biflora	LO							1						
– *rubella*	A	1							1			+	1	
Papaver radicatum coll.	A						+						5	
Pedicularis flammea	L			1	1		+							
– *hirsuta*	AC					+						+	1	
– *lanata*	AC					+	+	+	+		2	1	2	
Polygonum viviparum	A	10	4	15	14	6	16	15	7	15	10	**24**	6	
Potentilla vahliana	AC		+			+	+			+				
Pyrola grandiflora	AC	2	5		7			4	11					
Saxifraga caespitosa	A		+										1	
– *nivalis*	A	+	+											
– *oppositifolia*	A					+	+						1	
– *paniculata*	L												1	
– *tricuspidata*	AC	4	2	1		5	+							
Silene acaulis	A				6	+	1	12			2	+	2	
Stellaria longipes coll.	L(A)				1									
Tofieldia pusilla	L				+	1				4	+			+
IV														
Equisetum arvense	B									1	2			
Huperzia selago arctica	A										+			
Woodsia glabella	A		+											
V														
Andraea rupestris								1						
Anastrophyllum minutum						1								
Aulacomnium turgidum					+	+	+		+			5		+
Bartramia ityphylla													2	
Bryoerythrophyllum recurvirostre			+	+										
Bryum archangelicum												3		
– sp.					+	+	1				+			
Ceratodon purpureus					1	+	+	+						
Cnestrum alpestre														2

Table 2. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and		30°	30°	30°	5°	15°	–	–	–	10°	10°	5°	–	15°
exposure		SW	SW	SW	S	SE				SE	SSE	S		S
pH		5.6	6.2	5.8	6.3	6.6	6.2	6.2	–	–	6.1	5.8	5.8	4.9
μs (conductivity)		384	228	235	409	293	150	89	–	–	571	424	89	322
Desmatodon latifolius			+											
Dicranum acutifolium		1	+	+										
– *elongatum*				1										
– *fuscescens*													1	
– *majus*							+							
– *scoparium*			+		3	+		1	14	2				
– *spadiceum*											5	1		
Distichium capillaceum					2		1				+			
Drepanocladus revolvens						1								
– *uncinatus*						1								
Encalypta rhabdocarpa		3	+					4			1	+		
Gymnomitrium sp.										2		5		
Hylocomium alaskanum										3				
Hypnum revolutum			+							3				
Oncophorus wahlenbergii					1	2					1	1		
Pohlia cruda			1										2	
– *longicollis*			2											
– *nutans*		1			1?					1				
Polytrichum alpinum			+	1										
– *juniperinum*		1						1	6	10		7	13	
– *piliferum*							7	12						5
Ptilidium ciliare									1					
Rhacomitrium canescens							1							
– *lanuginosum*		1	1				1		3	3	1		3	
Rhytidium rugosum						+				+				
Tetraplodon mnioides					1									
Tomenthypnum nitens					2	+								
Tortella fragilis				1							14	10		
Tortula ruralis		1	1			+								
VI														
Alectoria nigricans		7	5	13	2	18	18		1	13	1		12	
– *nitidula*													2	
– *ochroleuca*		9	6	3	12	**26**	4		5	**21**	18		8	3
Artroraphis alpina								1						
Bacidia cfr. *alpina*		+												
Caloplaca cinnamoena		+									1			
Candelaria canadensis								6						
Candelariella placodizans													1	
Cetraria cucullata		11	10	10	9	16	4	1	3	5	15			18
– *delisei*					1									
– *islandica* coll.		4	2		3	6	11	10	6	15	3		12	5
– *nivalis*		13	9	15	7	16	**22**	19	**23**	**26**	**28**		**30**	17

Table 2. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and		30°	30°	30°	5°	15°	–	–	–	10°	10°	5°	–	15°
exposure		SW	SW	SW	S	SE				SE	SSE	S		S
pH		5.6	6.2	5.8	6.3	6.6	6.2	6.2	–	–	6.1	5.8	5.8	4.9
μs (conductivity)		384	228	235	409	293	150	89	–	–	571	424	89	322
Cladonia coccifera						1		1	1		+		1	1
– *gracilis*									2					1
– *mitis*		7		9					**20**	1	1		1	**24**
– *pleurota*									2		1	3		
– *pyxidata*		1	3	3										6
– *rangiferina*									4		+			17
Cornicularia aculeata				3				3		2	10		1	
– *muricata*					1			3						
Lecidea wulfenianum						4								
Lepadium pezizoideum ...						3								
Ochrolechia frigida			2	12		1	14	12	**20**	17	13		**23**	4
– *geminifera*				2										
– *upsaliensis* ...					1	1								
Pertussaria dactylina									+					
– *oculata*								1						1
Physcia muscigena		5	1											
Psoroma hypnorum						1	8		3	1				
Rinodina mniaraea						1								
Solorina bispora							6						2	
Sphaerophorus globosus ...			+	+		2	1	2	10	+	1		2	+
Stereocaulon alpinum		2	+	2	1	12		1	5	1				
– *paschale*		**20**	19	7									1	**27**
– *vesuvianum* ..								1					1	
Thamnolia subuliformis ..		3			1	1	1	4	1	+	1			

7. Snow cover-dependent willow-forb vegetation complex

The famous "herb mat" (Danish: urteli) was described already by WARMING (1888) and all later botanical visitors in Greenland have considered this type of vegetation to be the culmination with regard to luxuriance, number of flowering herbs and even primary production rates. However, the typical herb mat has no limits towards late herb-snow beds and is difficult to separate from certain luxuriant heaths (the *Phyllodoce*-type) and from *Salix glauca* – mats or low willow copses. Their may even be transitions to *Mniobryum* – *Epilobium hernemannii* – or *Archangelica* vegetations in springs or along running water. In Scandinavia there are similar vegetations. The most luxuriant herb mats are by NORDHAGEN (1935) and DAHL (1956) placed in the group "Adenostyletalia".

A very striking feature in the majority of Greenland herb mats is their paucity in mosses and lichens and the high number of vascular species. This clearly is connected with the fact that herb mats often are developed in talus slopes and in many cases should be looked upon as stages in a succession from open scree to closed plant canopy. In a talus there will be many small differences with regard to degree of disintegration, size of boulders, thickness of soil over rocks etc. Thus, the scree is a mosaic of many small ecological niches and is therefore the home of so many species. The scarcity in mosses and lichens is due to competition from the vascular plants and to the unstable soil conditions. Rooting plants are much better adapted to withstand sliding down of gravel or rocks or temporary streaming of melt water.

The central latest thawing part of the Østerlien – slope at Godhavn was investigated in 1956 as were the surrounding low *Salix glauca* scrubs and the dry rock and talus – slide vegetation on the top of the talus slope (Böcher, 1959 Table 2–4). The late thawing vegetation appears in the summer as a large bright green area due to the dominance of *Alchemilla glomerulans – Taraxacum croceum.* The willow scrubs appear greyish green but they are in many places interspaced or interrupted by green herb mats without or with scattered *Alchemilla.* A number of such herb mats was analysed in 1968–74 using the shoots density technique and the results are summarized in Table 3. In the same table are further a few examples of related willow mats or low willow scrubs and a few analyses from the upper talus slopes at Lyngmarksbugt west of Østerlien. Three analyses (Table 3 No. 10–12) are from an almost level area below the corner in the rocks with *Loiseleuria* as a dominant, mentioned above, see p. 19.

The analyses from the Lyngmarksbugt talus slope (Table 3 No. 5 and 11) were undertaken near the steep rocks as seen on Fig. 12. The fertility of the soil appears to be great (μs 728–792) and this undoubtedly influences the flora which contains locally rare species as *Draba aurea, Leucorchis albida* and a bryophyte like *Encalypta rhabdocarpa.* The latter is not uncommon in dry heath areas with *Dryas* and *Carex rupestris* (e.g. Table 2 No. 1 and 7) and is mentioned by Nordhagen (1943) as a character species on dry rock ledges in Sikkilsdal.

Analyses No. 9 and 13 in Table 3 are from the upper margin of the talus on disintegrating rocks or loose gravel. They are characterized by species like *Arabis holboellii* and *Veronica fruticans.* The conductivity values are low (56 and 44) due to the low content of humus.

Marginal areas of the *Alchemilla – Taraxacum* mat are occupied by communities richer in species thus e.g. the *Potentilla crantzii* – sociation (Table 3 No. 1), the *Sibbaldia*-sociations (Table 3 No. 2–3) and *Salix herbacea* – sociations in which *Antennaria canescens, Cerastium alpinum* and *Polygonum* are conspicuous or glaring. These communities

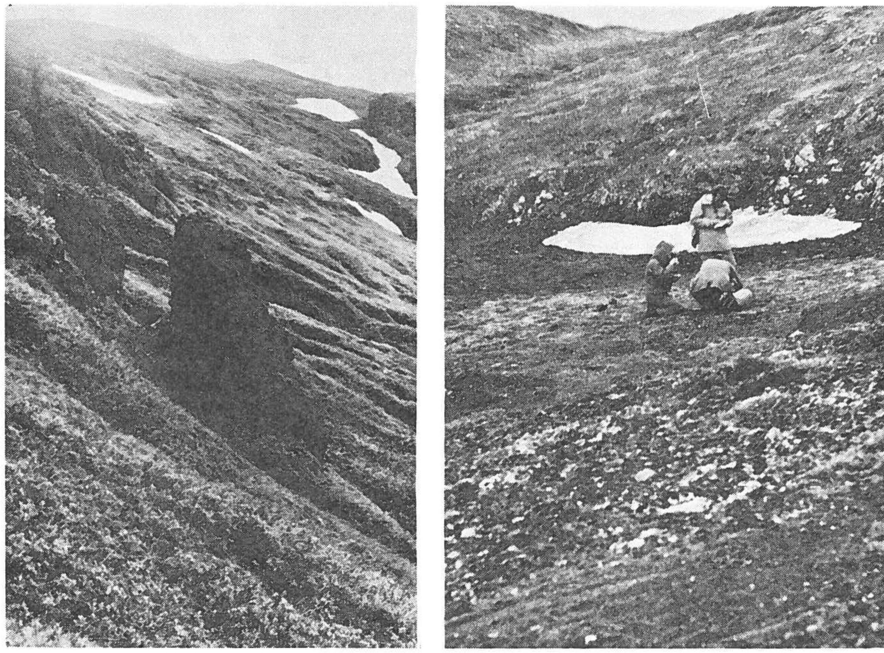

Fig. 12. On the left fertile talus slope near Lyngmarksbugt, Godhavn. The vegetation near the rocks is analysed and shown in Table 3 No. 11, the *Sibbaldia* – sociation in Table 3 No. 5 is situated on the slope behind the isolated rock pillar. On the right the snow bed vegetation in "gryden" near the Arctic Station. Behind the three students are the last snow remains in the middle of July 1974. The students are analysing a *Ranunculus pygmaeus* – *Carex lachenalii* – *Salix herbacea* – *Oxyria* vegetation, see Table 4 No. 12. In the foreground sorted stripes in the gravel due to solifluction.

correspond to Nos. 19–20 described from the northern part of the Blosseville Coast in East Greenland (BÖCHER, 1933: 41). They are on one side bordering the *Alchemilla* – *Taraxacum* – sociation on moister areas with longer snow cover and on the other side *Salix glauca* mats or low copses (e.g. Table 3 No. 10) on drier soils and with shorter or equally long snow cover.

One of the stands (Table 3 No. 8) is from a small slope about 200 m. above sea level. It occurred beneath a steep rock and along the foot of the slope the vegetation borders a *Phyllodoce* – *Empetrum* heath with abundant *Bartsia*. *Alchemilla* has already disappeared in this altitude. Thus the moister parts of the small slope with longer snow cover had no *Alchemilla* but were dominated by *Taraxacum croceum*, *Oxyria*, *Veronica alpina* and *Sibbaldia*.

At an elevation of 4–500 m. the herb mats are replaced by snow bed vegetations rich in species. Two examples a and b may be mentioned. They were not analysed according to the shoots density method. Both stands had *Salix herbacea* as a dominant and as important members *Equisetum arvense*, *Oxyria*, *Polygonum viviparum* and *Stereocaulon alpinum*. Subordinate species in both were *Draba glabella*, *D. crassifolia*, *Silene acaulis* and *Peltigera canina*. Stand (a) had much *Poa arctica* and furthermore *Potentilla hyparctica*, *Minuartia biflora* and *Luzula frigida*. Stand (b) contained many bryophytes, the most important being *Tortula norvegica*, *Brachythecium salebrosum*, *Dicranum fuscescens* and *Aulacomnium palustre*.

Potentilla hyparctica clearly increases in frequency and ecological amplitude with increasing altitude. Already at an elevation of 200 m. it may be found in gravelly, though generally in winter snow protected slopes but furthermore in snow beds dominated by *Harrimanella – Salix herbacea – Cladonia ecmocyna* together with *Taraxacum croceum*, *Poa alpina*, *Polygonum*, *Arnica*, *Minuartia biflora*, *Erigeron humilis*, *Antennaria angustata*, *A. canescens* and *Gnaphalium supinum*.

Accumulation of loose wind blown material near top of talus slope. In the northern parts of Østerlien the steep rocks above the talus become low and the talus slope itself is less steep. Here the upper part just below the rocky wall is a pronounced lee side. During winter heavy winds remove loose gravel, sand, dust, leaves and stalkes from the fell fields or open heath areas on the mountain plateau above and a deposit is formed as a low lengthy brownish mound. In the beginning such a mound is almost without plants but after 2–3 years the herb mat species recolonize the loose soil. The most important species were noticed to be *Polygonum viviparum*, *Carex bigelowii*, *C. scirpoidea*, *Poa alpina*, and *Taraxacum*. Less important were *Salix glauca*, *S. herbacea*, *Trisetum spicatum*, *Sibbaldia* and *Antennaria canescens*. There were very few indications of immigration of species from the top plateau (e.g. no *Potentilla vahliana*, *Papaver* or *Dryas*), but some fragments of wind blown lichens were believed to be able to grow further and a few specimens of *Silene acaulis* were supposed to be juvenile.

Transitions between herb mats and herb snow beds are numerous. They have usually mat forming *Salix herbacea* and much *Sibbaldia*, *Veronica alpina*, *Erigeron humilis* and *Minuartia biflora* and comparatively few mosses and lichens. As soon as mosses become dense the vegetation turns over to snow bed. A vegetation of this type is shown in Table 3 No. 1, where *Carex lachenalii*, *Oxyria digyna*, *Cerastium cerastoides*, *Ranunculus pygmaeus* are found in a carpet of *Drepanocladus aduncus* and *Salix herbacea*. The vegetation covered the margin of a large depression ("gryden") which was analysed very thoroughly by a number of students taking part in a course in Arctic Botany arranged at the Arctic Station in 1974 (see Lauridsen & Thostrup, 1975). A number of the density determinations from "gryden" is included in

Table 4 No. 10–14. *Carex lachenalii*, *Cerastium cerastoides*, *Oxyria*, *Ranunculus pygmaeus*, *Saxifraga cernua* and *Polytrichum norvegicum* are constantly present, the latter reaching the highest densities (27–30) in sites with the longest lasting snow cover. Very similar snow bed communities are thoroughly studied in Scandinavia e.g. by GJÆREVOLL (1956).

Comparing the DT-spectra of the herb mats (Table 3) and the herb snow beds (Table 4 No. 10–14) the predominance in the herb mats of lowarctic-oceanic and a constant and sometimes significant occurrence of boreal species is conspicuous. The snow beds also have a large contingent of lowarctic-oceanic species (37 percent) but this type of vegetation has 25 percent arctic and 17,8 percent medium arctic species. The number of species in the stands varies between 12 and 26 (mean 20) while in the herb mats the numbers are between 17 and 38 (mean 31). The mean densities (points per sample plot) are 12 (snow beds) against 17 (herb mats).

Table 3

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and exposure		(N)	–	5° W	30° SW	40° SW	40° SE	30° SW	35° SW	40° SW	40° SW	40° SW	5° S	10° SW
pH		6.4	5.5	5.6	5.0	6.0	5.1	5.2	4.9	6.1	4.7	6.5	5.0	6.9
μs (conductivity)		34	202	235	276	728	376	151	455	44	380	792	339	56
DT (Ecogeographical distributional type) spectrum. Percentages: Arctic	A	24	23	19	6	12	3	4	15	18	1	7	19	6
	AC	7	3			7	7	1	11			7		4
	AH													
	AM	10	1	1	1	2	1		3	(1)		2	1	
Low arctic	L	29	14	29	25	16	18	33	19	40	34	53	29	34
	LO	24	44	48	47	57	59	54	49	32	34	17	48	31
	LC													14
Boreal	B	5	15	4	21	6	13	9	5	10	32	15	4	12
	BO													
	BC													
Number of species...........		38	37	32	25	28	26	31	37	27	19	32	28	17
Frequency sums f. vasc. plants		161	111	145	173	132	134	138	147	153	101	123	97	66
– – f. bryoph. + thalloph		143	81	56	3	11	13	33	77	22	0	16	29	0
Points per sample plot (0.1 sq.m.)		30.4	19.2	20.1	17.6	14.3	14.7	17.1	22.4	17.5	10.1	13.9	12.6	6.6
I														
Betula nana	LC													1
Dryas integrifolia........	AC												+	1
Empetrum hermaphrodit...	L			3		3		1		3		**26**	4	
Phyllodoce coerulea.......	LO		+											
Salix glauca callicarpaea..	L	10					5		2	**23**	**25**	**25**	**23**	8
– *herbacea*...........	LO	**27**	**30**	**26**	**26**	**29**	18	**26**	**28**	+				
Vaccinium ulig. microphyl.	L			**22**									**28**	

Table 3. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and			–	5°	30°	40°	40°	30°	35°	40°	40°	40.	5°	10°
exposure		(N)		W	SW	SW	SE	SW	SW	SW	SW	SW	S	SW
pH		6.4	5.5	5.6	5.0	6.0	5.1	5.2	4.9	6.1	4.7	6.5	5.0	6.9
μs (conductivity)		34	202	235	276	728	376	151	455	44	380	792	339	56
II														
Carex bigelowii	L		2	7					14					
– *lachenalii*	L	16												
– *macloviana*	LO				+		1	5			+			
– *scirpoidea*	L		8	3										
Festuca brachyphylla	A												+	
– *rubra cryophila*	L				10	3	1	**21**		13		3		1
Juncus trifidus	LO								+					
Luzula confusa	A	2	1										+	
– *spicata*	LO					+		4	4					
Poa alpina	LO		+	1	8	4	9	7	6	9	+	3		12
– *arctica*	AC	12							8				4	
– *glauca*	A													2
– *pratensis* coll.	B	3	3	4	19		6	+		1	7			
Trisetum spicatum	A		7	4	2	3	2	+	7	11	+	4		
III														
Alchemilla glomerulans	LO			3			+							
Antennaria angustata	AM								2					
– *canescens*	LO		3	3	3		1	17	12	14	1			
– *glabrata*	AM			1										
– *intermedia*	AM					1						1		
Arabis alpina	LO	2					+							+
– *holboellii*	LC											+		8
Arnica alpina	AC					9	9		9		+	8		
Bartsia alpina	LO			+										
Campanula gieseckiana	L		1		10	13	10	11	2	1	4	8		7
Cardamine nymanii	L	3												
Cerastium alpinum	L	2	4	3	10	2	8	12	6	8	5	3	+	6
– *cerastoides*	LO	3												
Chamaenerion angustifol.	Bs					7	4			2	17	10		5
Draba aurea	LC											+		
– *crassifolia*	AM						1							
– *glabella*	AC						+	1		+			+	
– *lactea*	A				+			1	1					
– *nivalis*	A													1
– *norvegica*	LO								1					
Erigoron humilis	AM	12	1	+	2	2		+	3	1	+	1		
Euphrasia frigida	L				11					12				
Gentiana nivalis	LO											1		
Gnaphalium norvegicum	LO										+	2		
Leucorchis albida	BO											5		
Minuartia biflora	LO	7	6	2	+	1		7	2					
– *rubella*	A													1

Table 3. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and			–	5°	30°	40°	40°	30°	35°	40°	40°	40°	5°	10°
exposure		(N)		W	SW	SW	SE	SW	SW	SW	SW	SW	S	SW
pH		6.4	5.5	5.6	5.0	6.0	5.1	5.2	4.9	6.1	4.7	6.5	5.0	6.9
μs (conductivity)		34	202	235	276	728	376	151	455	44	380	792	339	56
Oxyria digyna	A	10												
Pedicularis flammea	L	1	1	1				+					+	
– *hirsuta*	AC		+										+	
Polygonum viviparum	A	**20**	15	**23**	8	13	2	4	11	17	1	4	3	
Potentilla crantzii	LO			+	**21**						11			
Pyrola grandiflora	AC		3										**21**	
– *minor*	Bs			1		1			2			1		
Ranunculus pygmaeus	AM	5												
Saxifraga cernua	A	6												
– *tricuspidata*	AC												+	2
Sibbaldia procumbens	LO			3	11	**24**	**25**	+	4	5	2	+		
Silene acaulis	A	1	2	3				1	3					
Stellaria longipes-monantha	L	15			1						+		4	
Taraxacum croceum	LO		2	4	8	13	16	3	5	3	17	9		5
Thalictrum alpinum	LO		5	19										
Tofieldia pusilla	L												+	
Veronica alpina	LO			8	4	2	9	5	6		3			
– *fruticans*	LO									17		4		3
Viscaria alpina	LO					2				1		2		
IV														
Cystopteris fragilis	B									1				
Equisetum arvense	B	4			15	+	7	12	5	11	8	3	10	3
Diphasiastrum alpinum	LO		3	1					4					
Lycopodium annot. alpinum	B		14		2					+				
V														
Barbilophozia hatcheri				3										
Brachythecium groenlandic.		4	5	**21**										
Bryum sp.		18				1		+	15			1		
Cynodontium strumiferum													2	
Desmatodon latifolius		5			2	1	1	3				7		
Distichium sp.		9												
Dicranum acutifolium													6	
– *majus*		7												
– *scoparium*			2	1										
Drepanocladus uncinatus		**29**	1	2										
Encalypta rhabdocarpa						1						1		
Hylocomium alascanum													1	
Hypnum revolutum													2	
Lophozia ventricosa		1												
Myurella tenerrina												+		
Oncophorus wahlenbergii		14												
Polytrichum alpinum		14	3											
– *juniperinum*			2					7		8			2	

Table 3. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13
Slope and			–	5°	30°	40°	40°	30°	35°	40°	40°	40°	5°	10°
exposure		(N)		W	SW	SW	SE	SW	SW	SW	SW	SW	S	SW
pH		6.4	5.5	5.6	5.0	6.0	5.1	5.2	4.9	6.1	4.7	6.5	5.0	6.9
µs (conductivity)		34	202	235	276	728	376	151	455	44	380	792	339	56
Polytrichum norvegicum . .		9												
– *piliferum*									12					
Pohlia cruda										1				
– *nutans*								1						
Ptilidium ciliare			5											
Tortella fragilis			3											
Tortula norvegica			14	19		2	10							
– *ruralis*		4			1		2					1	1	
VI														
Caloplaca cinnamoena		2												
– *leucocraea*												1		
Cetraria cucullata													5	
– *delisei*		4	1					1	1					
– *islandica*									2				4	
– *nivalis*													4	
Cladonia cariosa									+					
– *chlorophaea*			5							1				
– *ecmocyna*			1						1					
– *macrophyllodes* . .							+							
– *mitis*									+				1	
– *pyxidata*		6	5		+	2		10	12			1		
Crocynia neglecta									1					
Lecidea sp.		2												
– *vernalis*			3											
Ochrolechia frigida			3							1				
Peltigera macrophyllodes . .						1	+							
– *malacea*								3						
– *rufescens*			13			2			11	11		4		
– *scabrosa occident.*				2										
– *spuria erumpens.*													1	
Psoroma hypnorum			1						2					
Rinodina mniaraea												+		
Stereocaulon alpinum		5	19	8		1		8	**20**					
VII														
Nostoc sp.		9												
Cortinarius minutulus		1												
Lycoperdon sp.								+						

Fig. 13. *Arenaria humifusa* (flowering) and *Carex scirpoidea* in depression in the heath near the Arctic Station, see Table 4 No. 3.

8. Analyses of small ecologically specialized stands

The majority of communities are not homogeneous but are mosaics. This was pointed out in the description of the *Carex rupestris* dominated relatively stable patches which are divided up by heavily frost-influenced open gravel areas. (Fig. 8). One of the small specialized habitats was already mentioned. A flat shallow depression in the rocks dominated by *Diapensia – Andraea alpestris* (Table 1 No. 4). In Table 4 there are a number of similar analyses of small patches where one or a few species are particularly common or show a characteristic type of occurrence. It seems most adequate to describe each of them separately.

Table 4 No. 3. Vegetation dominated by *Polygonum viviparum – Carex scirpoidea – Nostoc* in small shallow depressions in flat heath covered area in front of Østerlien at Godhavn (Fig. 13). The depressions have irregular outlines and the soil between the shoots of vascular plants is almost covered by *Nostoc*, lichens and mosses. The depressions may represent remains of frost scars. In winter they are covered by ice and snow. The surrounding heath is composed of *Betula nana*, *Empetrum*, *Vaccinium* and *Salix glauca* and contains much *Pedicularis lapponica*, *hirsuta* and *lanata*. A very characteristic species is *Arenaria humifusa* occurring in 6 out of 10 sample plots of 0.1 m^2. Almost constantly present in all ten plots but never dense were apart from the dominants *Tofieldia pusilla*, *Juncus biglumis*, *Dryas*, *Pedicularis flammea* and *Drepanocladus revolvens*. A comparison of this site for *Arenaria humifusa* with five Norwegian sites with very scattered specimens of *Arenaria* (NORDHAGEN, 1935: 81) shows that there are certain ecological and floristical similarities. Also in N-Norway (Duken, Mageröya) *Arenaria* grows in spots

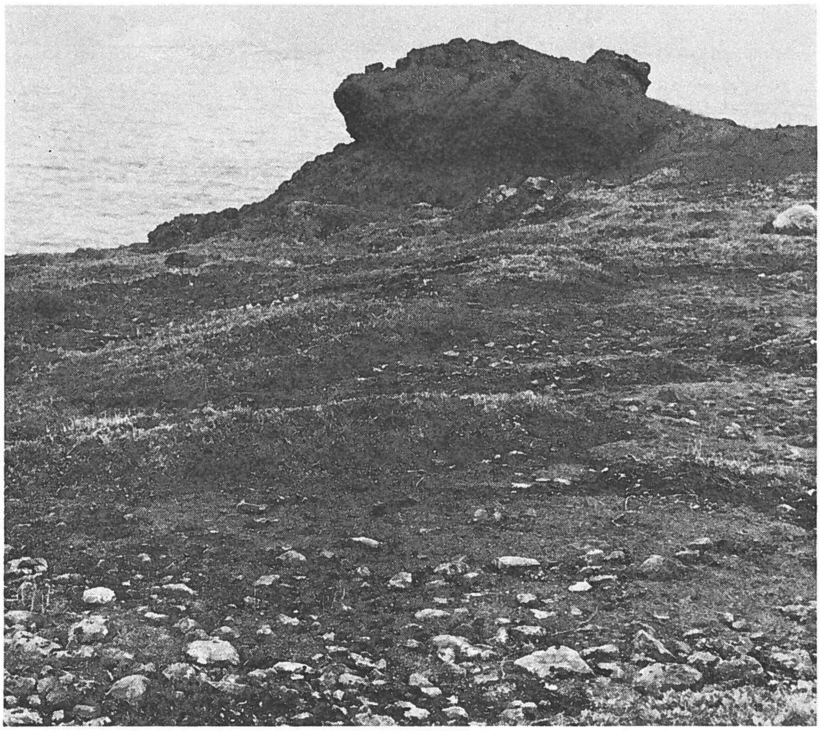

Fig. 14. Solifluction lobes near the coast in southern part of the valley Blæsedalen, Disko. Open vegetation rich in *Koenigia*, *Polygonum viviparum* and *Nostoc*. Scattered *Arenaria humifusa*, *Juncus biglumis*, *Sagina intermedia*, *Sedum villosum*, see Table 4 No. 7.

much influenced by frost action and some deflation. Important species common to *Arenaria*-sites in Disko and Mageröya are *Polygonum viviparum*, *Tofieldia pusilla*, *Silene acaulis*, *Carex bigelowii*, *Dryas* (although represented in Norway by *D. octopetala*). Important differences are frequent occurrence in Greenland by *Pedicularis flammea* and *Carex scirpoidea* and in Norway by *Arenaria ciliata*, *Pinguicula alpina*, *Thalictrum alpinum* and *Salix reticulata*.

Table 4 No. 4. Salix herbacea – Polygonum viviparum – sociation rich in *Silene acaulis*. An area along the foot of the Østerlien talus slope. *Silene* was forming flat extensive cushions. The conductivity value is high. The soil is undoubtedly rich, constantly snow covered in winter and in spring receiving melt water from the talus slope. *Polygonum*, *Carex bigelowii* and *rupestris* send up shoots between the *Silene* cushions. Several mosses indicate high fertility (*Tetraplodon*, *Encalypta*, *Distichium*). There is locally abundance of very small specimens of *Euphrasia*. *Carex capillaris* and *C. norvegica* ssp. *inserrulata* are local but characteristic as indicators of higher soil fertility.

Table 4 No. 5. The community is a vigorous *Salix glauca* mat with scattered *Salix arctophila*, *Equisetum arvense* and *Carex rariflora* indicating higher moisture while *C. maritima*, *C. norvegica* and *Tomenthypnum* point to higher soil fertility. In fact the conductivity value (1065) is high and small open spots between the higher plants were covered with *Nostoc* sp. Physiognomically this willow mat, however, was stamped by very tall specimens of *Pedicularis hirsuta* which was constant in the sample plots but scattered (getting 17 points only). *Pedicularis* probably exploits *Salix glauca* or *arctophila* which again profit from the fertility of the soil which perhaps is partly derived from nitrogene collected by *Nostoc.* The vegetation occurs in a spot near the preceding.

Table 4 No. 6. Shows the vegetation on small solifluction lobes in the *Cassiope* heath mentioned in Table 1 No. 9. The soil was almost naked or covered with a blackish layer of bluegreen algae and *Cephaloziella.* The most important phanerogame on the clay lobes was *Pinguicula vulgaris.* Wet soil indicators were numerous (*Tofieldia*, *Sagina intermedia*, *Juncus biglumis*, *J. triglumis*, *Saxifraga foliolosa*, *Marchantia*).

Table 4 No. 7. Another site with scattered *Arenaria humifusa*, here together with *Koenigia*, *Sagina intermedia* and *caespitosa* as well as *Sedum villosum*, *Campanula uniflora* and *Carex maritima*, Fig. 14. The plant cover was not closed and the plants grew in large solifluction lobes in a gently sloping heath near the sea in the valley Blæsedalen at Godhavn. The heath on the elevated margin of the next lobe consisted of *Salix glauca*, *Empetrum*, *Vaccinium*, *Betula nana*, *Rhododendron*, *Carex rupestris*, *Luzula arctica* and *Pedicularis lapponica.* Again here *Nostoc* sp. almost covered the surface between the dwarfish vascular plants. In other similar lobes *Scirpus caespitosus* was more abundant than in the present site. *Arenaria* was not confined to the solifluction lobes but entered in a few places moss cushions along the heath covered lobe margins. The cushions might be composed of *Tomenthypnum nitens* and *Hylocomium alaskanum.* Even *Dryas* mats or cushions may contain small specimens of *Arenaria* as well as *Tofieldia pusilla* and single shoots of *Chamaenerion latifolium.*

Table 7 No. 8. Small south exposed depressions between gneiss rocks. Vegetation dominated by *Scirpus caespitosus.* Slowly seeping water in shallow soil over rock. The surrounding heath with much *Phyllodoce*, *Cassiope*, *Ledum decumbens* and *Pedicularis lapponica.*

Table 4 No. 9. An almost closed moss cover with densely spaced *Koenigia* plants and scattered *Montia fontana. Stellaria humifusa* and *Carex glareosa* common. The vegetation is developed at the shore of a lagoon near the Arctic Station. The occurrence of *Koenigia* and *Montia* in salt marshes on Disko Island was already mentioned by Porsild (1902: 151).

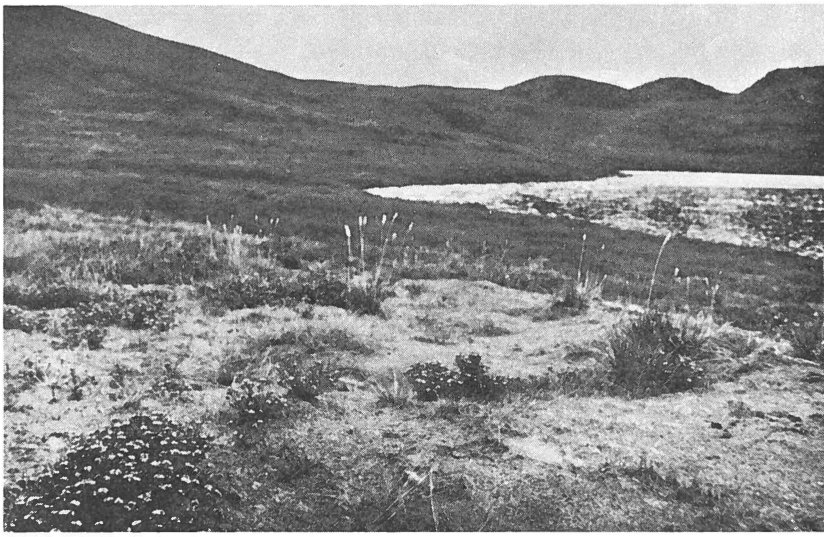

Fig. 15. Brayasø. Cracks in deposit near the lake bank. The cracks are filled with loess and have a vegetation of *Braya novae-angliae*, *Calamagrostis purpurascens*, *Carex boecheriana* and more scattered *Primula stricta* and *Gentiana detonsa*. TWB. photo 25 July 1974.

Table 4 No. 1–2. The two analyses were undertaken near the salt lake Hundesø which is situated near the head of Søndre Strømfjord not far from Strømfjordshavn at the air field. The lake has been mentioned in previous papers (Böcher, 1959: 49–50) and also some vegetation analyses from its surroundings, but no density determinations.
No. 1. Saxifraga aizoides – Juncus triglumis – sociation with constant occurring *Dryas*, *Pinguicula*, *Polygonum viviparum* and very much *Primula stricta*, *Kobresia simpliciuscula* as well as small and poor *Salix glauca*. The vegetation was found on level areas at some distance from the shore. Unfortunately no soil sample was collected but similar vegetations in the area show very high conductivity values and pH about 8. Working out the analysis it was possible to lie down on the soil surface which was completely dried up and cracked late in July. There were salt crusts on the soil surface. The *Primula* had been profusely flowering.
No. 2. Braya – sociation with much *Primula stricta* and *Distichium capillaceum*. *Carex boecheriana* and the two species of *Kobresia* are common. Both *Braya*-species are almost equally common. The soil is drier than in No. 1 pH 7,8 and conductivity 1650. On moister soil closer to the lake *Triglochin palustre* becomes abundant. The vegetation No. 2 may be characterized as a lowarctic continental salt steppe. In this case where the two *Braya* species grew intermixed and almost with the same density it was not possible to see any ecological difference between them. However, *B. linearis* grew closer to the lake, thus perhaps it is able

to tolerate the most saline or ultrabasic soil conditions. *B. novae-angliae* on the other hand came closer to *Betula nana* forming the lower margin of the surrounding heath and perhaps it preferred sites where soil water oozed out. It had late in July still flowers while *B. linearis* was ripening its pods. The vegetation belts at the lake Hundesø were difficult to characterize because all communities blend with each other at their margins or constitute mosaics. However, the belt formations are sometimes clear: The heath vegetation at some distance from the lake is a *Betula nana – Ledum decumbens* community with much *Aulacomnium turgidum*, *Peltigera aphtosa*, *Calamagrostis lapponica*, *Pedicularis labradorica* and *Vaccinium vitis-idaea* ssp. *minus*. *Ledum*, *Empetrum* and *Vaccinium uliginosum* ssp. *microphyllum* decrease as soon as one approaches the lake and the soil becomes less acid. At the same time *Rhododendron*, *Salix glauca* and *Dryas* increase. They form together with *Betula nana* the border towards the steppe-communities and the *Dryas*-barrens near the lake (Fig. 6).

In the first belt outside the closed shrub or heath (1) there are patches with *Saxifraga aizoides – Primula stricta – Pinguicula* or abundant *Euphrasia frigida*, *Carex boecheriana*, *Primula stricta* sometimes also *Equisetum variegatum*.

A next belt (2) corresponds to the *Braya* community (No. 2) but the composition varies greatly; *Kobresia simpliciuscula* is sometimes more abundant and *Carex maritima*, *Calamagrostis purpurascens*, *Tofieldia* and *Saxifraga aizoides* locally increase their share. *Puccinellia deschampsioides* may enter this belt but occurs also in the third belt.

The outermost belt (3) is dominated by *Juncus arcticus* and *Triglochin palustre* and contains several of the above mentioned species but further many scattered specimens of *Taraxacum lacerum*. However, the belt is not uniform sometimes being interrupted by deposits of snail shells etc. washed up from the lake and mixed with reindeer excrements. In some places the belt was on its off-shore side (toward (2)) followed by a manured strip dominated by *Tetraplodon*, sometimes together with *Euphrasia*, *Carex boecheriana*, *Polygonum viviparum*, *Salix glauca* and even *Pedicularis flammea*.

Table 4

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13	14
pH		–	7.8	5.5	6.3	5.7	5.9	5.6	5.4	–	5.5	5.2	–	–	–
*μ*s (conductivity)		–	1650	242	765	1065	66	335	281	–	42	42	–	–	–
DT (Ecogeographical distributional type) spectrum. Percentages.															
Arctic	A	28		31	46	24	22	70	2	52	32	30	34	14	15
	AC	24	15	13	9	17	3	1							
	AH							3		13					
	AM			6				15		1	24	14	25	11	15
Low arctic	L	23	14	49	26	40	42	2	58	16	13	18	15	22	18
	LO				18	4		5			24	36	26	48	52
	LC	17	66	1	1	3	6	1	7						
Boreal	B	8	5			11	26	1	4	4	7	3		5	
	BO							2	29	13					
	BC														
Number of species		23	23	35	47	34	30	30	19	17	12	18	22	27	21
Frequency sums f. vasc. plants		173	99	144	129	151	89	82	90	75	109	59	103	97	57
– – f. bryoph. + thalloph.		13	26	69	68	51	88	47	44	51	22	11	17	176	79
Points per sample plot (0.1 sq.m.)		18.6	12.5	21.3	19.7	20.2	17.7	12.9	13.4	12.6	13.1	7.0	12.0	27.3	13.6
I															
Betula nana	LC	2	2	2	+	+	6		6				+		
Diapensia lapponica	L						4	1							
Dryas integrifolia	AC	16	+	14				1							
Empetrum hermaphroditum	L			10			3		4					+	
Harrimanella hypnoides	LO														
Rhododendron lapponicum	AC	3	+	+		+									
Salix arctica	A			1	5			3							
– *arctophila*	L					14			16						
– *glauca callicarpaea*	L	13	11		4	**23**	5								
– *herbacea*	LO				**20**	6					4	18	19	**23**	12
Vaccinium ulig. microphyl.	L			9	3	5	8		11						
II															
Calamagrostis purpurasc.	AC		6												
Carex bigelowii	L			6	16	8			19						
– *capill. boecheriana*	AC	6	10												
– *capillaris*	L				1	2	3								
– *glareosa*	L									12					
– *lachenalii*	L			1							8	18	14	**21**	10
– *maritima*	A					3		3							
– *misandra*	AC			1											
– *norvegica inserrulata*	AC				1	5									
– *rariflora*	L					4			+						
– *rupestris*	AC			2	9										
– *scirpoidea*	L	4	+	**21**	1			+							
Eriophorum angustifolium	B								4						

Table 4. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13	14
pH		–	7.8	5.5	6.3	5.7	5.9	5.6	5.4	–	5.5	5.2	–	–	–
μs (conductivity)		–	1650	242	765	1065	66	335	281	–	42	42	–	–	–
Juncus arcticus	L	5													
– *biglumis*	A			11			5	6							
– *castaneus*	AM							1		1					
– *triglumis*	A	**24**					1								
Kobresia myosuroides	AC	5	9												
– *simpliciuscula* ...	LC	12	10												
Luzula arctica	AC			2		7									
– *confusa*	A				4	2								+	
Poa alpina	LO				3							5	3	6	4
– *arctica*	AC				2	2	3								
– *pratensis* coll.	B											3			
Scirpus (Baeothryon) caespitosus	BO							2	**26**						
III															
Arabis alpina	LO											+			
Arenaria humifusa	AM			9				4							
Armeria scabra	AC	+		+											
Artemisia borealis	LC	6													
Braya linearis	LC		15												
– *novae angliae*	LC		16												
Campanula uniflora	AM							4							
Cardamine nymanii	L											+			
Cerastium arcticum	A			+	3										
– *cerastoides*	LO										10	17	1	10	4
Chamaenerion latifolium ..	A			+											
Draba alpina	AM							1							
– *nivalis*	A				1										
– *norvegica*	LO				1										
Erigeron humilis	AM											3	4		
Euphrasia frigida	L	3	2		6										
Gentiana detonsa	B		2												
– *tenella*	L		1												
Gnaphalium supinum	LO												3	3	9
Koenigia islandica	A							15		**29**					
Minuartia biflora	LO														
Montia fontana	BO									10					
Oxyria digyna	A										17	17	15	8	8
Pedicularis flammea	L	4		12	2	5		1	1						
– *hirsuta*	AC				+	17									
Pinguicula vulgaris	B	13					17	1							
Primula stricta	LC	12	12												
Polygonum viviparum	A	19	+	**22**	**26**	**25**	10	**24**	2			7	3		
Ranunculus hyperboreus ..	A									+					9
– *pygmaeus*	AM										14	12	**21**	11	

Table 4. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13	14
pH		–	7.8	5.5	6.3	5.7	5.9	5.6	5.4	–	5.5	5.2	–	–	–
μs (conductivity)		–	1650	242	765	1065	66	335	281	–	42	42	–	–	–
Sagina caespitosa	AM							2							
– *intermedia*	A						4	5		6					
Saxifraga aizoides	L	**24**													
– *caespitosa*	A				1			+		+					
– *cernua*	A										1	8	14	10	1
– *foliolosa*	AH						+	3							
– *hyperborea*	AH									10			+		
– *oppositifolia*	A			+											
– *rivularis*	L										1	1	1		
– *tenuis*	A												+		
Sedum villosum	LO							4							
Sibbaldia procumbens	LO													3	
Silene acaulis	A			10	**20**	6		1					+	6	+
Stellaria humifusa	A									4					
– *longipes-monantha*	L			+			2								
Tofieldia pusilla	L	2		11		+	12		1					1	
Triglochin palustre	B		3												
IV															
Equisetum arvense	B				+	17	6			3	4	+		5	
Huperzia selago arctica	A			+											
V															
Anthelia juratzcana										3			1	**23**	7
Aulacomnium palustre						1			**20**						
– *turgidum*						2			5						
Bartramia pomiformis					1										
Blepharostoma trichophylla					2									18	
Bryoerythrophyllum recurvirostre					4										
Bryum sp.					6	+					4	11	2	18	13
Calliergon sarmentosum						2			2						
Campylium stellatum		+	2												
Catascopium nigritum										3					
Cephaloziella sp.							**20**								
Ceratodon purpureus							12								
Dicranoweisia crispula										11	+				
Dicranum fuscescens								2							
– *scoparium*					6	3									
Distichium capillaceum		10	18		+									17	
– *inclinatum*				6											
Ditrichum flexicaule				3	3										
Drepanocladus badius						2			2						
– *revolvens*				15		5		3	5						
– *uncinatus*					5	15	8		2	**29**		5	1	9	

Table 4. Continued

Analysis No.	DT	1	2	3	4	5	6	7	8	9	10	11	12	13	14
pH		–	7.8	5.5	6.3	5.7	5.9	5.6	5.4	–	5.5	5.2	–	–	–
μs (conductivity)		–	1650	242	765	1065	66	335	281	–	42	42	–	–	–
Encalypta rhabdocarpa . . .					4					1					
Fissidens osmundioides . . .				1											
Hydrogrimmia mollis													5		
Hypnum sp.		1													
Leiocolea heterocolpos						1									
Leptobryum pyriforme							5								
Lophozia quadriloba														12	
Marchantia polymorpha . .							3								
Meesia uliginosa				2											
Mniobryum albicans															2
Myurella julacea						1									
Oncophorus wahlenbergii . .						1						3	2	**26**	
– *virens*															12
Philonotis tomentella						1							1		
Pleuroclada albescens								1		1					3
Pohlia longicollis					1	1									
Polytrichum alpinum				3	1	4	4	6		2					
– *juniperinum* .					10										
– *norvegicum* . .											1	3	15	**27**	**30**
Ptilidium ciliare									8						
Tetraplodon mnioides					1										
Tomenthypum nitens					9	14									
Tortula ruralis					1										
VI															
Buellia disciformis			6												
Caloplaca leucocraea					5										
Cetraria cucullata					1										
– *delisei*				1	2		1	+		2					
– *islandica*				1	1		1								
– *nivalis*			+		+										
Cladonia pocillum		2	+												
– *pyxidata*				4	4		1	1						10	1
Crocynia neglecta			+												1
Lecanora polytropa														8	1
Ochrolechia frigida				12	+			7							
Peltigera malacea							1								
Pertussaria oculata				+											
Psorona hypnorum							1							7	6
Stereocaulon alpinum							1								
– *vesuvianum* . .					1		10	1						3	1
VII															
Nostoc and other bluegreen algae				**21**	+	**!**	**20**	**26**	**!**		6				

Fig. 16. Shore of lake Hundesø. A low wet path (probably used by reindeer) leads to the shore. The zonation along the path shows three belts: a lower (darker) with much *Juncus arcticus* (sometimes *Triglochin*), a middle belt (greyish) dominated by *Braya – Kobresia* etc. (cp. Table 4 No. 2) and the upper which shows the shrub margin with *Salix glauca* ssp. *callicarpaea* and *Betula nana*. TWB. photo 25 July 1974.

9. Ecological specialization and degrees of exclusiveness in relation to ecogeographical distributional types

Among the Greenland species a few are circumgreenlandic and common from Kap Farewell to Peary Land. Many are widely distributed arctic species, ubiquitous or omnipresent in mesic-dry habitats. However, going through the four tables it is striking to see how few species of the A-type (arctic wide ranging) that are omnipresent in the stands.

Polygonum viviparum is present in 47 of 53 stands and it is almost constant in the heath and herb mat stands (Tables 1–3), but with high density only in one heath (Table 2 No. 11) and two herb mats (Table 3 No. 1 and 3). It acquires high densities in four of the specialized stands (Table 4 No. 3–5, 7), but is scarce in the herb snow beds. The only Greenland community in which this species virtually seems to be absent is the continental *Carex supina* steppes and related communities (Böcher, 1954 Tables 17, 20) and the *Puccinellia deschampsioides* salt steppes (Böcher, 1954 Table 24) in the Strømfjord inland. However, as soon as the water content in the soil in this region increases and *Kobresia myusuroides* becomes dominant, *Polygonum viviparum* is present or becomes even common (Böcher, 1954 Table 2 No. 11). Other A-type species which in Disko are present in many different stands are *Luzula confusa*, although scarce in herb mats, *Silene acaulis* which is abundant in Table 4 No. 4 only, *Saxifraga caespitosa* which, however, never reaches high density.

Among the A-species *Trisetum spicatum* shows preference for herb mats, *Saxifraga cernua* and *Oxyria digyna* are almost confined to snow beds, while *Juncus biglumis*, *Koenigia islandica* prefer special wet habitats and *Papaver radicatum*, *Draba nivalis*, *Minuartia rubella*, *Festuca brachyphylla* and *Poa glauca* are all restricted to dry more or less exposed often gravelly or open areas. *Chamaenerion latifolium* is poorly represented in the stands but it prefers margins of snow beds (BÖCHER, 1963: 140–141) gravelly river banks and certain types of non stabilized talus slopes.

The *high arctic element* (AH) is at lower elevations on Disko very poorly represented. *Potentilla hyparctica* occurs on rocks in the lowland, but becomes more abundant in snow beds at higher altitudes. *Salix arctica*, *Saxifraga foliolosa* and *hyperborea* occur only in few specialized stands (Table 4) and *Ranunculus sulphureus* was only seen in a dense moss cover near the lake in the valley Blæsedal (the cover consisting of *Tomenthypnum nitens*, *Aulacomnium palustre*, *Sphagnum warnstorfii*, *S. teres*, *Hylocomium alascanum*, *Timmia austriaca*, *Isopterygium pulchellum*, etc.).

The arctic continental element (AC) on the other hand is important. It is represented by *Dryas integrifolia*, *Potentilla vahliana*, *Saxifraga triscuspidata*, *Armeria scabra*, *Pyrola grandiflora*, *Cassiope tetragona*, *Rhododendron lapponicum*, *Pedicularis lanata*, *P. hirsuta*, *Arnica alpina*, *Luzula arctica*, *Carex nardina*, *C. rupestris*, *C. glacialis*, *C. misandra* and *Hierochloe alpina*. Among these species *Dryas*, *Rhododendron* and *Carex rupestris* occur in 21, 14 and 18 stands respectively out of 53. However, very few are present in many ecologically different types of stands. The AC-species with the widest ecological amplitude are perhaps *Pedicularis hirsuta*, *P. lanata* and *Carex rupestris*. The latter has in Greenland a southern limit already at 66° n. lat. and seems in its genepool not to include lowarctic biotypes. It is the most important species in sites with *Dryas*, *Rhododendron* and lichens (Table 2) but is absent from herb mats or fertile talus slopes (Table 3). One group, viz. *Carex misandra*, *Luzula arctica* are particularly common together with *Cassiope*; *Pyrola grandiflora* is also here, but is almost ubiquitous in the dwarf shrub heaths or willow mats. *Carex nardina*, *C. glacialis*, *Potentilla vahliana* are clearly connected with gravel open to the wind, the latter as well as *Saxifraga tricuspidata* also with rocks. *Arnica* may be the only AC-species which prefers the herb mat situation (Table 3) and it is able to grow in sites which approach herb snow beds (cp. BÖCHER, 1963: 224–226). *Armeria* occurs scattered in specialized habitats (Table 4). In the Blæsedalen valley it was abundant in shallow wet depressions with much *Saxifraga foliolosa* and *Nostoc* covering the bottom.

The *medium arctic element* (AM) is well represented in ecologically specialized stands: Solifluction terraces, late herb snow beds and the transitional habitats between snow beds and herb mats. This element is very characteristic for these habitats. In South Disko there are the following: *Ranunculus pygmaeus*, *Draba crassifolia*, *D. alpina*, *Sagina caespitosa*, *Arenaria humifusa*, *Campanula uniflora*, *Erigeron humilis*, *Antennaria glabrata*, *A. angustata*, *A. intermedia*, see Tables 3 No. 1, 4 Nos. 7, 10–14. *Campanula uniflora* also enters alpine herb mats as *Melandrium affine* does, while *Ranunculus nivalis* is most abundant in wet snow beds (Böcher, 1963: 243) and in mossy stream banks.

Draba crassifolia is difficult to place ecologically. It occurs in many unexpected habitats (Table 2 No. 10), but is most characteristic in sites together with *Sibbaldia* (Table 3 No. 6 and Böcher, 1933 Tables 10 and 26).

Southern Disko is situated within the lowarctic part of Greenland. Hence, its vegetation is stamped by the lowarctic element. Among the lowarctic widely distributed species which neither show oceanic – montane nor continental distributional tendencies there are several important species.

Vaccinium uliginosum ssp. *microphyllum* Lge. (*V. gaultherioides* Bigel.) is present in 32 out of 53 stands and was recorded with densities above 19 in 17 of the stands. Going through the tables it appears that it is absent from late herb snow beds, many herb mats and from salt lake shores. This picture is maintained when going through the analyses in Böcher, 1954 and 1963 but from these papers it becomes evident that *Vaccinium* is totally missing in the *Carex supina* or *Calamagrostis purpurascens* steppes on neutral-basic loess soils. In the southern part of Greenland *Vaccinium* exhibits its ecological versatility by occurring in dry barrens, fertile heath and bogs. At the northern limit (Astrup Fjord, 81°55′) it seems to prefer mesic to humid habitats rich in mosses which, however, get partly free of snow in early June (Holmen, 1957: 104).

Empetrum hermaphroditum is another wide ranging lowarctic species reaching Germania Land in East Greenland and Etah (78°25′) in West Greenland. It occurs in 27 out of 53 stands in Southern Disko and is a frequent dominant in heath vegetation with snow protection. In continental West Greenland it becomes more selective (Böcher, 1954: 276) preferring *Sphagnum* rich banks of lakes and shady places or north facing heath slopes protected by snow in the winter. It becomes the most important heath plant in the oceanic parts of Southern Greenland. *Salix glauca* ssp. *callicarpaea* represents at present an unsufficiently understood complex which probably has suffered from introgression from *S. arctica*. It seems to reach the Melville Bugt and Scoresbysund. In South Disko it was found in 36 out of 53 stands and several times abundant (Table 3). It forms extensive copses in the interior of Disko Fjord but in South Disko the copses are low (Böcher, 1959: 27) with e.g. *Orthilia secunda* ssp. *obtusata* (Boreal – continental, BC) and *Chamaenerion angustifolium* (Bs).

Salix arctophila is ecologically more selective being confined to level or tussocky areas on wet not particularly acid ground often with seeping soil water (Table 4 No. 5 and 8).

Carex bigelowii and *C. scirpoidea* are the most prominent sedges in Southern Disko and most parts of lowarctic Greenland. They are noticed in 18 and 17 stands out of 53. They occur not rarely in the same habitat, but ecologically they are obviously different although it is difficult to establish their peculiarities. *Carex bigelowii* reaches its greatest densities in tussocky snow beds (BÖCHER, 1954: 124) and many kinds of coastland heaths but is more poorly represented in the continental areas at Søndre Strømfjord and mostly represented here by ssp. *hyperborea*. It is clearly oligotrophic while *C. scirpoidea* is mesotrophic – eutrophic occurring e.g. abundantly in hollows with *Arenaria humifusa* (pp. 44). In the continental areas also in habitats with seep water together with e.g. *Sisyrinchium groenlandicum* and *Gentiana aurea* (BÖCHER, 1954: 215–262) and even scattered in salt steppe (the present paper Table 4 No. 1–2; BÖCHER, 1954: 209, 244, 245).

Cerastium alpinum belongs to a polymorphic complex but in most of the stands it is represented by typical *C. alpinum* thus in the herb mats where the species is constant (Table 3). From the same table it appears that *Campanula gieseckiana* occurs in 10 of the 13 examples. It clearly prefers fertile talus slopes, but is able to ascend to dry gravelly places even at high altitudes (BÖCHER, 1954: 155). It is most abundant in dry gravelly spots with slight competition from other species, thus e.g. together with true oreophytes. In the Strømfjord area it grows abundantly together with *Dryopteris fragrans* and *Saxifraga tricuspidata* (BÖCHER, 1954: 157), and it also enters the *Calamagrostis purpurascens* and the *Kobresia myosuroides* steppes (BÖCHER, 1954: 193–198, 201).

Pedicularis flammea occurs in 20 of the investigated stands. It is able to grow in widely different types of habitats except on the driest ones. According to WARMING it is parasitically on *Vaccinium uliginosum* and *Salix herbacea*, but it probably also attacks *S. glauca* (cp. Table 4 No. 1). The species is westarctic (cp. NORDHAGEN, 1935: 144) reaching Norway where it is surprisingly rare considering its ecological amplitude in Greenland. It cannot be the total gene pool which is present in the restricted Norwegian populations.

As it appears from the spectra in the four tables the low arctic element is dominating in the majority of stands but only if it is made to include the LO- and LC-types. These elements, on the other hand, are characterizing some of the natural groups of stands (major vegetational units) thus the oceanic-montane plants are most prominent in certain snow protected heath stands (Table 1 No. 1–2, 5–6, 11–12) as well as most herb mats (Table 3) and snow beds (Table 4 No. 10–14). They are completely suppressed or absent from the vegetations rich in *Dryas* – *Carex rupestris* (Table 2). The low arctic continental element is able to characterize heath vegetations dominated by *Betula nana* – *Ledum decumbens* (Table 1) or salt steppes (Table 4 No. 2) and of course the *Carex supina* steppes (cp. Böcher, 1954). Among the many oceanic-montane chionophilous species it is obviously *Salix herbacea* which is most important in South Disko occurring in 24 of the stands and very often acquiring high densities. However, it is locally absent from the stands in Table 2.

Among the LO-species mentioned in the tables *Salix herbacea*, *Poa alpina*, *Luzula spicata*, *Bartsia alpina* and *Potentilla crantzii* occasionally reach the continental area at Søndre Strømfjord. *Salix herbacea* is exclusively alpine there and the other species selective and rare.

The boreal element is always modestly represented in Disko and not rarely by northern races of boreal species (*Equisetum arvense*, *Lycopodium annotinum*). The most conspicuous boreal sylvicolous species in South Disko are *Luzula parviflora* (dominant in fertile meadows along streams) and *Chamaenerion angustifolium* (in warm talus slopes). *Gymnocarpium dryopteris*, *Listera cordata*, *Platanthera hyperborea* and *Pyrola minor* occur in fertile humid copses, but only the latter species is among the species found in the stands (Tables 1–2). Widely distributed boreal species found in the analysed stands are few: *Pinguicula vulgaris* and *Poa pratensis* only.

A survey of the average percentage distribution of the DT-types in five major communities (Table 5) summarizes the above mentioned results. It is obvious from the tables that the percentages would have been conspicuously different if density values had been replaced by values based solely upon presence.

The average number of species in the stands (in all cases within 10 samples of 0,1 sq. m) is 30 and ranges from 12 to 47. The lowest numbers are found in late snow beds, the highest in one of the specialized stands with much *Silene acaulis* and high conductivity (Table 4 No. 4). There are 46 species in the likewise fertile steep slope with *Phyllodoce* and *Leucorchis* (Table 1 No. 6). Otherwise the number of species is surprisingly constant but the share of mosses and lichens varies greatly. This appears also from the frequency sums. The average frequency sum (for 10 samples of 0,1 m^2) is 101 for vascular plants and 63 for mosses and lichens. In the stands collected in Table 2 which comprises vegetations with *Dryas* – *Carex rupestris* and often interspaced with open areas due to solifluction, strong wind etc. the average frequency sum for mosses and lichens exceeds that of vascular plants while in the herb mats which mostly are developed in talus slopes the average frequency sum for vascular plants is 129 while that of the mosses and lichens is 37. The average

Table 5

Average percentages of distributionel types in five plant communities (groups of related stands) based upon density values.

		Six snow protected dwarf shrub heath stands (Table 1, Nos.1–2,5–6, 11–12)	Seven other dwarf shrub heath stands (Table 1, Nos. 3–4, 7–10,13)	13 stands with Dryas, Carex rupestris (Table 2)	13 herb mat willow stands (Table 3)	Five herb snow bed stands (Table 4 No. 10–14)
Arctic	A	9	10	17	12	**25**
	AC	9	15	**42**	4	
	AH					
	AM				2	**18**
Low arctic	L	30	**58**	38	29	17
	LO	**48**	2	1	**42**	**37**
	LC		**13**	3	1	
Boreal	B	5	2		**12**	3

density expressed through the number of points obtained by all species per sample plot (of 0,1 sq. m) is 17 and varies from 12,4 in snow beds (Table 4 No. 10–14) to 18,8 and 18,4 in the vegetations in Table 1–2. It falls to 16,7 in the herb mats (Table 3) but this is because the moss-lichen layer is so incomplete in many of the herb mat stands. Of course the analysed stands are selected and no typical fell fields or barrens have been included. One such stand mentioned in (BÖCHER, 1975b: 85) had 4 points per sample plot while the lichen heath close by had 17. In many fell fields there are desert like conditions. In the valley Blæsedalen a typical fell field is developed in a dry gravelly plane area exposed to strong winds. The vegetation was analysed along a line 25 m long. 25 equidistant sample areas of 0,1 sq. m contained *Papaver radicatum* (4 points), *Dryas integrifolia* (4), *Salix arctica* and *glauca* (2), *Silene acaulis* and *Chamaenerion latifolium* (1), while *Vaccinium uliginosum*, *Luzula confusa*, *Carex nardina* and *rupestris* were noted as present outside the line. Lichens on stones and gravel were numerous (e.g. *Umbilicaria*, *Alectoria pubescens*, *Cetraria hepatizon*, *C. nivalis*, *Stereocaulon cf. vesuvianum*). pH in the gravel was 6,3 and the μs 39.

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Index to vascular species mentioned in some detail