A CONTRIBUTION TO THE PHYTOGEOGRAPHY OF THE ANGMAGSSALIK AREA, EAST GREENLAND, WITH SPECIAL REFERENCE TO CHIONOPHILY

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1. INTRODUCTION

As delimited by POLUNIN (1951), the Arctic is situated on the Northern hemisphere North of (1) a line 50 miles North of the coniferous forest line, (2) the Northern limit of microphanerophytic growth, or (3) the Nordenskjöld line, according to the formula $V = 9–0,1K$. According to this delimination the whole of Greenland belongs to the arctic region. Within the Arctic a subdivision in low- and high-arctic regions is usually recognized. LARSEN (1960) marks this transition on the East coast of Greenland near Cape Dalton.

Low-arctic East Greenland thus stretches from 60° to 69°30′ N. lat. The Angmagssalik area in Southeast Greenland ranges from circa 65° to 67°20′ N. lat. Between the Sermilik and the Kangerdlugssuatsiak fjords to the West and East, Denmark Strait to the South and the extensive nunatak area Schweitzerland, merging into the central Greenland ice-cap to the North, the Angmagssalik area in stricter sense (35°45′ – 38° W. long., 65°30′–66°20′ N. lat.) is the largest ice-free region of low-arctic East Greenland and must therefore, and for its isolated and central situation, be regarded as highly representative.

Being the most mountainous coastal region of the island, it is deeply cut by several branched fjord systems. The outlets of the central Greenland ice-cap evade this rugged, deglaciated area and reach the coast to the North and the South of it. The area itself bears a glacier system of its own, in addition to numerous local firn fields with glacier-like outlets. Numerous authors have drawn attention to the topographic peculiarities and the glacial history which, in relation to the present day flora, strongly suggest the former existence of both high- and lowland, coastal and inland perglacial plant refugia. For this reason, from a phytogeographical point of view, the region is highly interesting, not in the least with regard to its highly isolated inland part.

2. CLIMATE AND SUBSTRATUM

The climate of Southeast Greenland is characterized by HASTINGS (1960) as "harsh, disagreeable most of the year". Coastal areas have a rather extreme oceanic local climate, which becomes increasingly continental more inland under the rapidly increasing influence of the ice-cap and because of the decreasing influence of the cold East Greenland Current. The inner fjords, consequently,

have a warmer, drier local climate in the summertime than the littoral zone (HASTINGS 1960, HALLIDAY 1967).

The substratum in the Angmagssalik area consists mainly of (Pre-?) Cambrian granites, schists and gneisses. Locally, however, amphibolith and feldspars may be very abundant. Soils are shallow, hardly differentiated and occur only locally. Under alpine conditions, as in this area, intense frost action (congeliturbation, cryoturbation, cryopedologic processes) operates to a much smaller extent than in true arctic regions. In such areas where these phenomena are less intensive due to soil conditions, it seems unrealistic to separate frost action from the other environmental factors that are acting and interacting upon the vegetation. The effects of the snow cover will be dealt with later on.

3. FLORA

The Greenland vascular flora consists of 590 species, about 490 of which are indigenous (BÖCHER *c.s.* 1957). Several phytogeographic-ecological elements may be distinguished, but in general two of them, viz. a neoarctic, usually high-arctic-alpine, rather continental element and a palaeoarctic, boreal-low-arctic and rather oceanic one are most characteristic. The former mainly dominates in the West, North and Northeast, the latter in the Southwest, South and East. This pattern shows a marked relation to both historical migration routes and present day occurrence and ecology of the different species. Endemics hardly occur, save a few species belonging to such apomictic genera as *Taraxacum* and *Hieracium*.

The vascular flora of the Angmagssalik area amounts to circ. 170 species (Hooft, unpublished). The bryophyte flora is not very characteristic either, it chiefly consists of circumpolar-holarctic, low-arctic-boreal species and totals about 170 species as well (DE MOLENAAR 1968). The lichen flora counts ca. 70 species (DANIËLS 1968). This short survey already gives an impression of the importance of the cryptogams in the vegetation. Their relative importance increases with increasing altitude and latitude, as the climate becomes more severe.

4. PLANT COMMUNITIES

The plant communities of Southeast Greenland can be classified in three major physiognomical units.

1. The principal type of vegetation is the low-arctic shrub heath, communities that are composed predominantly of arctic-alpine dwarf shrubs, mainly *Empetrum hermaphroditum* and *Vaccinium uliginosum*. Beneath the shrub layer is an undergrowth of mosses, fruticose and foliose lichens and occasionally *Salix herbacea* and *Cassiope hypnoides*, or grasses, sedges and other herbs. The heath prefers mineral, sometimes peaty substrata, gravel soils with usually good drainage and favours lower latitudes and elevation. The heath is highly characteristic for mountain talusses along fjords.

2. Communities of herbaceous vegetations and alpine sedge meadows occur usually associated with heath. These communities prefer South-facing gravel slopes in more sheltered habitats than shrub heath. This group will be dealt with in more detail further on in this paper.
3. The third type of communities is that of the so-called fell fields (WARMING 1902: fjaeldmark, HARTZ & KRUUSE 1911 and OSTENFELD 1923: rocky-flat formation, RUEBEL 1930: frigorideserta or arctische Schuttflur, BÖCHER 1933: fell field, POLUNIN 1948: barrens, and ALEKSANDROVA 1960: polar desert, all seem to cover the same concept), i.e. poorly developed, open, scanty and scattered vegetations of high altitudes and latitudes. To this group belong epilithic microcommunities composed of crustaceous lichens and of patches of musci, and communities of widely scattered individuals of many of the commonest, though hardier species of often procumbent or cushion-like growth also occurring in the first two physiognomical groups. This third group is, therefore, floristically less sharply defined. It occurs under unfavourable conditions in upland areas, either in wind-swept areas with a very thin or even absent snow cover in wintertime, or at high altitudes in the mountains.

In addition more locally restricted, rare types of vegetation do occur. Near the settlement of Angmagssalik a type occurs that closely resembles a *Sphagnum* bog of more temperate regions. On stream- and pondbanks, as well as on river deltas in lakes and fjords marshes or marsh-like vegetations may develop on wet substratum. On sandy beaches, protected from drift ice by shallow coast water, sparse herbaceous halophytic vegetations may be observed.

The tundra, in its strict sense (cf. ALEKSANDROVA 1960, TEDROW & CANTLON 1958), which is characteristic for the Arctic, does in all probability not occur in this mountainous area. Soils, when present, are usually very shallow, on inclined mountain slopes and well drained and because of this apparently free of permafrost or 'tjäle'.

5. SNOW EFFECT

Bot depth and persistence of the snow cover are two of the most decisive factors determining the distribution of plant species and communities in the mountains and the Arctic.

In areas of very changeable physiography snow is even less evenly distributed than rain as it is transported from exposed ridges and wind-swept plains and accumulates in depressions and other sheltered sites.

This irregular distribution of the snow cover is repeated every year. The quantity of the snow may vary considerably from year to year, but the pattern of distribution remains practically the same (Nordhagen's 'conservative distribution'). Exposed sites are only irregularly covered by a shallow snow layer that melts early if it has not disappeared even shortly after snowfall. Plant life is exposed in wintertime under these conditions to very low temperatures, to extreme changes in temperature, to strong desiccation and often to strong wind erosion. Soil material is also strongly eroded under these conditions.

In more sheltered sites and depressions the snow is not swept away by the wind but in the contrary may drift deeply, and plant life here is in a different way also strongly subject to the regimen of the snow cover. A constant, constantly thick snow cover during the wintertime provides a very efficient protection against low temperatures (BRAUN-BLANQUET 1948), extreme changes in temperature, as well as desiccation and wind erosion. The persistence of the snow cover depends partly on its depth. Snow accumulation may therefore on the other hand greatly reduce the growing season by its late disappearance every summer.

Depending on both the persistence of the local snow cover, the local physiography, the soil conditions and the snow cover in the surrounding area, the soil will remain moist during a longer or shorter time after the snow has disappeared, and may receive melt water during some time from nearby snow drifts or be irrigated from higher mountain slopes.

The chionophobous fell field vegetation is characteristic for the exposed, mostly snow-free sites. The chionophilous heath and herbaceous vegetations prefer more sheltered conditions with a constant snow cover in winter time. The habitat in which chionophilous communities occur is usually referred to as 'snowbed'. However, a further division in 'snowpatch' and 'snowbed' proper must be preferred.

Thus a general division of the ecosystem in three types of habitats is possible.

1. Fell field, an arctic-alpine habitat of exposed situations characterized by very scanty, scattered chionophilous vegetations.
2. Snowpatch, a more arctic habitat of more or less sheltered depressions or gentle leeward slopes. The snow hardly drifts and a constant snow cover of medium depth protects the vegetation until the start of the growing season. The length of this growing season is not reduced and the soil is irrigated by melt water only during spring or early summer. Medium chionophilous vegetations are characteristic (cf. PORSILD 1957).
3. Snowbed, an arctic-alpine habitat in which, due to very variable physiographic conditions, the snow in the winter accumulates so deeply that, apart from its protective effect, the growing season is much reduced by its late disappearence or even, partly, its persistence. True and extreme chionophilous vegetations correspond to this type of habitat of late snow.

6. CHIONOSERE

Fell field – dwarf shrub heath – arctic-alpine meadows and herb fields – *Salix herbacea* and *Gnaphalium supinum* vegetations – cryptogam vegetations give in this order a sere from extreme chionophobous to extreme chionophilous vegetations, on acid soils and in low-arctic – low-alpine areas. Where to draw the line between true chionophobe and chionophil offers a problem which is discussed in detail by numerous authors. DU RIETZ (1942) in Scandinavia, BÖCHER (1933 and later) in Greenland, GUINOCHET (1938) in the Alps and BRAUN-BLANQUET (1948) in the Pyrenees fixed this borderline between the gram-

inaceous vegetations and the *Gnaphalium* and *Salix herbacea* communities. NORDHAGEN (1943) on the other hand, and also DAHL (1956) and GJAEREVOLL (1949, 1956), all in Scandinavia, do so already between the *Vaccinium* heath and the graminaceous vegetations.

For practical reasons, Nordhagen's delimination is followed in this study. The borderline between the Southeast Greenland *Empetrum-Vaccinium-Salix glauca* heath and the *Carex bigelowii* and herbaceous meadows is much more pronounced than the gradual transition of these meadows to the *Salix herbacea* and *Gnaphalium* vegetations: indeed a *Salix herbacea* variant of the *Carex bigelowii* community was to be recognized. Even this gave no clear solution as the heath offers a complication by its vertical structure. In favourable sites the undergrowth may be strongly chionophilous and closely related to several variants of the *Salix herbacea* community, while the dwarf shrub layer is usually only slightly chionophilous to chionophobous.

The Southeast Greenland low-arctic chionophilous vegetations may thus be defined as vegetations constantly covered during the winter period by a more or less thick snow layer, that does not disappear until the start of the growing season or (much) later, and in which vegetation, apart from the procumbent *Salix herbacea* and *Cassiope hypnoides*, no woody species occur.

7. SNOWBED AND SNOWPATCH VEGETATIONS

As a result of the 1966 investigations the following division and subdivision of the Angmagssalik chionophilous vegetations is given.

	number of sub-units	coast exp.	coast alt. limit	inland exp.	inland alt. limit
I. Carex bigelowii community					
I.1 Carex bigelowii variant	3	S	200	–	–
I.2 Salix herbacea variant	3	–	480	–	700
II. Salix herbacea community					
II.1 Hieracium alpinum variant	1	W	240	W	500
II.2 Juncus trifidus variant	1	S	200	–	–
II.3 Chamaenerion latifolium variant	1	–	–	W	350
II.4 Equisetum arvense variant	2	S	200	W	130
II.5 Sibbaldia procumbens variant	2	SE	230	SW	670
II.6 Cassiope hypnoides variant	2	N	380	–	640
II.7 Lichens variant	2	N	570	S	760
II.8 Musci variant	1	S	200	–	–
II.9 Anthelia juratzkana variant	1	E-W	330	–	–
III. Herbaceous communities					
III.a Alchemilla alpina sociation	2	S	200	–	–
III.b Carex scirpoides sociation	1	–	–	S	540
III.c Taraxacum croceum sociation	6	S	200	–	80
III.d Gnaphalium supinum sociation	1	–	–	S	500
III.e Alchemilla vulgaris s.l. sociation	4	S	350	W	470
III.f Oxyria digyna sociation	1(5)	–	370	SW	390

This survey needs comment. It shows three groups that are unequal with respect to each other. I and II are two clearly defined communities that might be called associations, III is a rest group of six local and more or less fragmentary miscellaneous herbaceous communities that might be termed sociations, strongly determined by the predominance of a single species. Within each community or group of communities the variants or sociations are arranged to increasing chionophily. Among themselves, I.1, together with III. a might be placed between II.3 and 4. I.2, together with III.b and c between II.4 and 5. III.d and e between II.5 and 6, and III.f between II.8 and 9. For each unit the number of sub-units that could be distinguished is given in order to give an impression of the heterogenity. Furthermore is indicated, separately for the two investigated areas, the vicinity of the Angmagssalik settlement ('coast') and the inner Tasilaq fjord ('inland'), the possible preference in exposition and the recorded altitudinal limit.

To some degree this survey shows a differentation between the two areas. The altitudinal limit of most variants and sociations occurs at a higher elevation in the inland than near the coast. At least two factors are important in this respect. The local climate in the inner fjords is in summer warmer and in summer and winter drier, and in extremely oceanic areas a slight rise in altitude is sufficient to give rise to a considerable decrease in temperature and an increase in precipitation, aerial moisture and wind force (DE SMIDT 1967) which rise has less pronounced effects on the micro-climate in more continental regions. Secondly, the physiography in the inland area provides up to higher elevations more possibilities to both soil accumulation and development of a plant cover than near the coast. In many cases preference to a certain exposition, though an important factor, is due to orographic and resulting hydrologic conditions. However, within the not listed sub-units a distinct preference to certain expositions is often very clear and apparently related to micro-climatological conditions.

Some units are restricted to one of the two areas. It is possible, however, that this is partly a result of logistic-financial circumstances, because of which only limited areas could be investigated. A further and more extensive research is desired, also in many other respects. The absence in the Tasilaq area of *Carex bigelowii* meadows (I.1) and the most chionophilous *Salix herbacea* variants, however, should be considered significant (cf. KRUUSE 1912, BÖCHER 1933). They all seem to be very oceanic in distribution, but different in degree of chionophily.

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REFERENCES

ALEKSANDROVA, V. D. (1960): Some regularities in the distribution of the vegetation in the arctic tundra. *Arctic* **13**, 3:147–162.

BÖCHER, T. W. (1933): Studies on the vegetation of the East coast of Greenland between Scoresby Sound and Angmagssalik. *Medd. om Grønl.* **104**, 4.

BÖCHER, T. W., K. HOLMEN & K. JAKOBSEN (1959): A synoptical study of the Greenland flora. *Medd. om Grøn.* **163**, 1.

BRAUN-BLANQUET, J. (1948): La végétation alpine des Pyrénées orientales. *S.I.G.M.A.* 98.

DAHL, E. (1956): Rondane. Mountain vegetations in South Norway and its relation to the environment. *Vid. Akad. Skr. I.M.N.K.* **1956**, 3.

DANIËLS, F. J. A. (1968): Lichens collected during the first Dutch botanical East Greenland expedition to the Angmagssalik area in 1966. *Acta Bot. Neerl.* **17**: 345-348.

DU RIETZ, G. E. (1942): *De svenska fjällens växtvärld-Norrland.* Natur, befolkning og näringar Stockholm.

GJAEREVOLL, O. (1949): Snøleievegetasjonen i Oviksfjellene. *Acta Phytogeogr. Suecica* **25**.

— (1956): The plant communities of the Scandinavian alpine snow-beds. *Kgl. Norske Vid. Skr.* **1956**, 1.

GUINOCHET, M. (1938): Etudes sur la végétation de l'étage alpine dans le bassin supérieur de la Tinée (Alpes-Maritimes). *S.I.G.M.A.* **59**.

HALLIDAY, G. (1967): Appendix V from the Report on the Royal Naval East Greenland Expedition, 1966. 9 p. Place of publication not specified.

HARTZ, N. & C. KRUUSE, (1911): The vegetation of Northeast Greenland. *Medd. om Grønl.* **30**:335–431.

HASTINGS, A. D. (1960): Environment of Southeast Greenland. U.S. Army, Environmental Protection Research Division. *Technical Report E.P.* **140**. Natick.

KRUUSE, C. (1912): Rejser og botaniske undersøgelser i Øst Grønland mellem 65° 30' og 67° 20' i aarene 1898–1902, samt Angmagssalik egnens vegetation. *Medd. om Grønl.* **49**.

LARSEN, S. (1960): On the influence of the arctic fox Alopex lagopus on the distribution of arctic birds. *Oikos* **11**, 2:276–305.

MOLENAAR, J. G. DE (1968): Bryophytes collected during the first Dutch botanical East Greenland expedition to the Angmagssalik district 1966. *Acta Bot. Neerl.* **17**: 340-344.

NORDHAGEN, R. (1943): Sikilsdalen og Norges fellbeiter. *Bergens Museums Skrifter* **22**.

OSTENFELD, C. H. (1923): The vegetation of the North coast of Greenland. *Medd. om Grønl.* **64**.

POLUNIN, N. (1948): Botany of the Canadian Eastern Arctic III, vegetation and ecology. *Nat. Mus. Canada Bull.* **104**.

— (1951): The real arctic; suggestions for its delimination, subdivision and characterization. *J. Ecol.* **39**:308–315.

PORSILD, A. E. (1957): Illustrated Flora of the Canadian Arctic Archipelago. *Nat. Mus. Canada Bull.* **146**.

RUEBEL, E. (1930): *Pflanzengesellschaften der Erde.* Berlin.

SMIDT, J. T. DE (1967): Phytogeographical relations in the North West European heath. *Acta Bot. Neerl.* **15**, 3:630–647.

TEDROW, J. C. F. & CANTLON, J. E. (1958): Concepts of soil formation and classification in arctic regions. *Arctic* **11**: 166–179.

WARMING, E. (1902): *Lehrbuch der ökologischen Pflanzengeographie.* Berlin.