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OLAF I. RØNNING

STUDIES IN DRYADION OF SVALBARD

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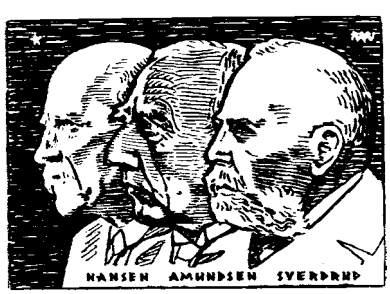

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Contents

Introduction

The purpose of this work is to give a survey of an important section of the plant communities that exist in Svalbard. The field-work for this investigation was carried out during the summers 1958, 1959 and 1960. In 1958 and 1960 I was a member of the land party in the Spitsbergen Biological Expedition from Tromsø Museum, while in 1959 I visited the groups of islands on my own, and among other things carried out research for "Expedition Svalbard-way".

Svalbard is so inaccessible that it is difficult to travel about the islands and visit just those localities one would most wish to see. The possibilities were greatly improved by the fact that the Tromsø Museum research vessel "Asterias" could be used for transport.

A review of these expeditions is to be found in Tromsø Museum's annual report for 1957-1958, where an account is given of the 1957 expedition to Bjørnøya and that of 1958 to Spitsbergen. This review includes lists of the participants, explanation of the methods used and a survey of the work carried out. In 1959 I worked in the areas around Kongsfjorden, especially the Lovénøyane at the inner end of the fjord, Ny-Ålesund and Brøggerhalvøya. Direct investigations of *Dryas* communities were on this occasion made only on a small scale and rather incidentally.

In 1960 the investigations were again carried out in cooperation with Tromsø Museum. An account of this, with details of the participants and the work carried out that year, is given in Tromsø Museum's annual report for 1960.

Practically speaking all the localities investigated are on the island of Vestspitsbergen, but from what is previously known it is believed that similar investigations on, for instance, the eastern side of Svalbard would scarcely have affected the results appreciably.

On the map, Fig. 1, are marked the localities where investigations have been made into the differentiation of *Dryas* communities, as well as those localities where the author has carried out botanical investigations over the years.

General description of the area

Geographical position and geology

Vestspitsbergen is situated between 76°60′ N and 80° N. It is a mountain area with deep fjords, and its interior is covered with large, more or less continuous glaciers. It comprises about 39,000 sq. km. Along the west coast especially there is a strand flat of considerable dimensions. Pre-Cambrian rocks, metamorphic

sediments and granites are found, especially in the north-western parts, the rest are covered by sediments of younger age. *Dryas octopetala* and species affiliated to plant communities dominated by this species occur mainly on basic or circumneutral subsoil. Except in the areas mentioned as having granitic rocks, all the other rocks provide good possibilities for the development of a *Dryas* community.

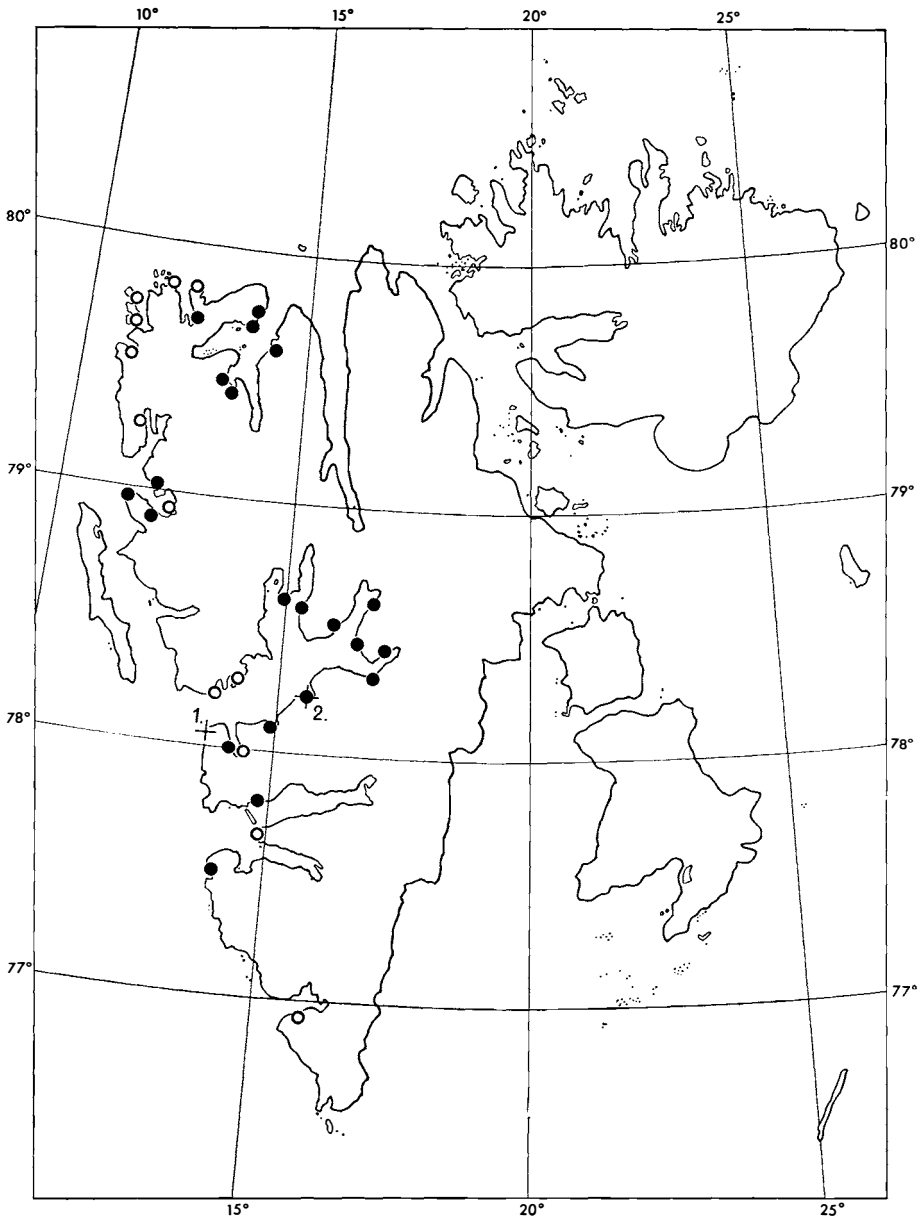

Fig. 1. *Map of Svalbard. Open and filled circles: visited localities. Filled circles: where Dryadion has been analysed. Crosses: the two meteorologicial stations: 1. Isfjord Radio. 2. Longyearbyen.*

Climate

Climatic conditions in Vestspitsbergen are distinctly favourable when the geographical latitude is taken into account. A branch of the Gulf Stream flows up the west coast, keeping it open and free of ice for a great part of the year. Cold arctic streams come down the east coast of Vestspitsbergen, swing round Sørkapp and then flow north again along the west coast between the land and the Gulf Stream.

There can be no doubt that the climate as a whole is influenced by atlantic air masses and by the Gulf Stream. In recent decades there has also been a marked improvement in the climate. As an example may be cited the fact that the annual mean for the meteorological station in Grønfjorden, in the outer part of Isfjorden, not far from Isfjord Radio, was –7.6° C for the period 1912 to 1930. For the period 1952–1961 the annual mean for Isfjord Radio was –3.7° C. The average temperature for Grønfjorden in the coldest winter month, March, in the period from 1912 to 1930 was –19.0° C, while Isfjord Radio for the period 1952–1961 had an average March temperature of –11.4° C.

These few data on temperature show a marked improvement in the climate primarily in the form of milder winters. It is probable that such a rise in the average annual temperature would improve the chances of introduced plants to survive the winter. The lack of summer warmth and duration of the winter are the most important limiting factors for the occurrence of these plants in Svalbard. Whether the improvement in the climate will have any influence on Svalbard's vegetation as such in the foreseeable future is an open question.

There are now four meteorological stations in Svalbard, viz. Bjørnøya, Hopen, Isfjord Radio and Longyearbyen, but only the last two of these are of interest and significance in this connection. Both are in Isfjorden, but Isfjord Radio at Kapp Linné is right out near the coast and is in fact a coastal station. Longyearbyen lies in the central part of Isfjorden, and must be regarded as an inland station, though not of the most pronounced kind. These two meteorological stations are shown on the map, Fig. 1. In Fig. 2 a comparison is made of the temperature data for

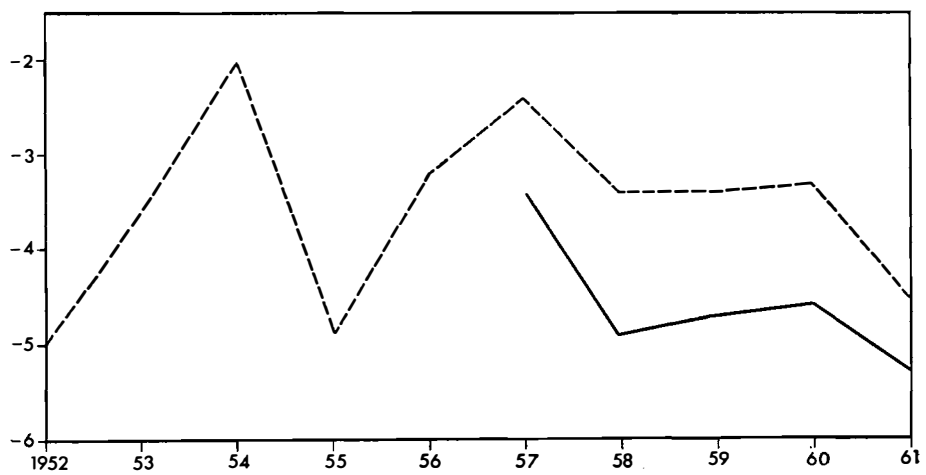

Fig. 2. *Yearly mean temperatures.* – – – *Isfjord Radio.* —— *Longyearbyen.*

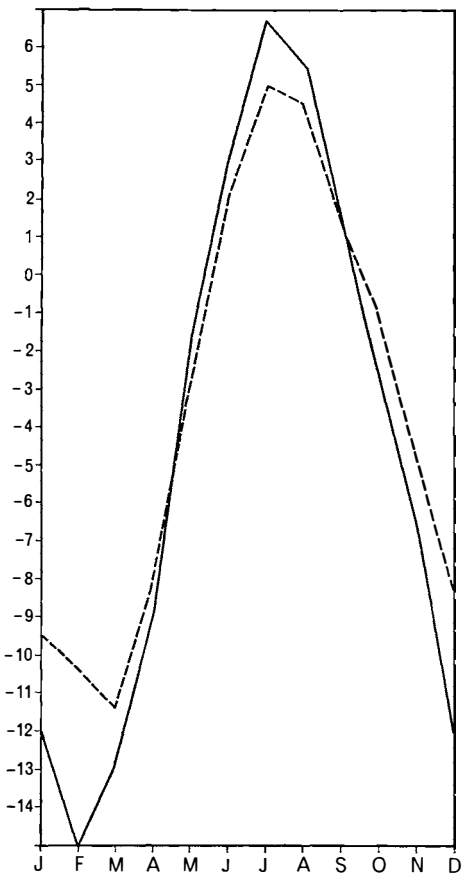

Fig. 3. *Monthly mean temperatures*
--- Isfjord Radio. Mean of the period 1952-61
—— Longyearbyen. Mean of the period 1957-61

the two stations. For Isfjord Radio I have chosen the period 1952–1961, while the station in Longyearbyen was not established until 1957, and therefore it has only been possible to include data for the last five years.

The diagram shows the annual average temperature for the two stations, and it will be seen that the annual mean at Longyearbyen is about one degree lower than at Isfjord Radio. Fig. 3 shows the average temperatures for each month of the year, and this reveals a similar state of affairs. First of all this diagram shows that the climate in Longyearbyen is rather more continental than at Isfjord Radio, i.e. the former has lower temperatures in winter and higher in summer. The difference can also be seen from Fig. 4, which shows the yearly precipitation, and it should be clear that there is considerably less precipitation in Longyearbyen than at Isfjord Radio. The annual difference between the two places ranges from 163 mm to 321 mm over the last five years.

The climatic data given here indicate an arctic climate.

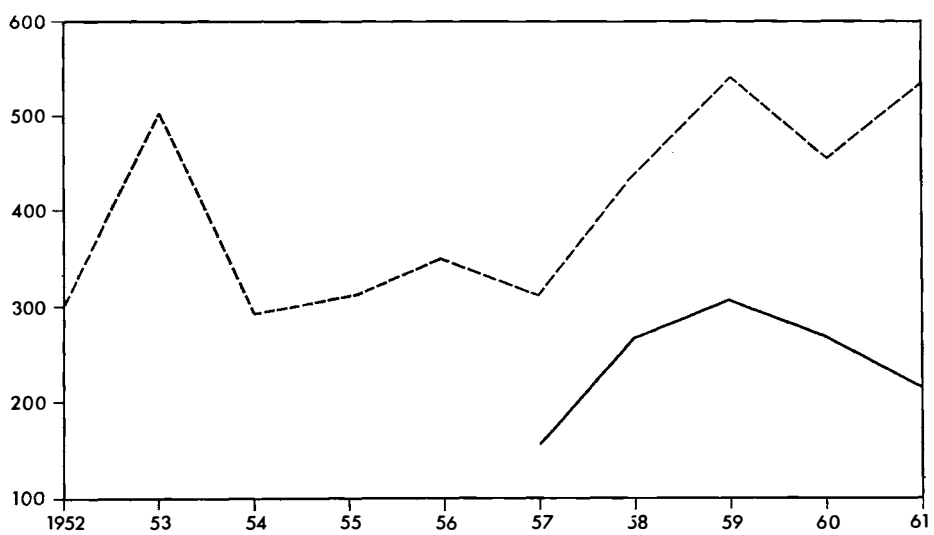

Fig. 4. *Total yearly precipitation. --- Isfjord Radio. —— Longyearbyen.*

Soils

It is not my purpose here to attempt a classification of the soils of Svalbard. This would be a difficult task, particularly as in general little has been done in the way of studies of arctic soils and their classification.

Below are mentioned only some general features, and in particular the soil sections and the problems that are of interest in connection with these investigations.

The formation of soil in arctic regions and the development of soil sections is dependent on topography, origin, materials, climate and time. Drainage conditions play a particularly important part. Everywhere in high-arctic regions such as Svalbard there will be found, at varying depths, a layer of permafrost which prevents natural drainage downwards. The water follows the frozen layer, and the drainage of the upper active layer (i.e. that which thaws each year) is greatly reduced.

Typical tundra, i.e. the grass-sedge-moss tundra, is produced under these conditions of poor drainage, and it always rests on a layer of permafrost. Uppermost is a layer of organic materials, usually only slightly decomposed. Below this comes a layer of mineral soil which may have a strong admixture of clay particles. This typical tundra profile is the most common in arctic regions, and occurs in various forms over large areas.

The vegetation is dominated by species of grasses and sedges. *Dupontia fisheri*, *Arctophila fulva*, *Eriophorum triste*, together with species of *Drepanocladus* and *Calliergon*, and to some extent *Sphagnum*, characterize the vegetation to be found in the wettest tundra localities. Genuine bogs hardly occur in Svalbard.

The contrast to this typical arctic tundra is found in places with good drainage. The soil here is almost pure mineral (lithosol), often with a thin covering of humus on top. Soil of this type is not widely distributed, being limited to moraine ridges, the edges of beach ridges and terraces. This type of earth is an arctic variant of the common podsol, formed in more southerly regions under free drainage, but certain horizons are so little developed that they may be discernible only in quite special cases, or possible to demonstrate only by chemical or mineralogical methods. For this type of soil the term "Arctic brown" is now commonly employed. (See, for instance, TEDROW and CANTLON 1958, BLISS 1956.) In localities with "Arctic brown" soil types the typical *Dryas* communities occur. As soon as the subsoil begins to be better drained, i.e. where the permafrost is situated at such a considerable depth that we may talk about free drainage, *Dryas octopetala* will make its appearance, together with *Silene acaulis*, species of *Potentilla*, *Carex nardina*, *C. rupestris*, etc. In *Tetragono-Dryadetum*, there is usually a much thicker layer of but slightly decomposed plant remains on top, but in this community, too, drainage is good. It should be emphasized, though, that the development of the plant community is not to be ascribed to drainage conditions alone; the other ecological factors, such as depth of snow and exposure to wind, etc., are also of considerable significance.

Below are given a few examples of soil profiles that are found among *Dryadion* in Svalbard (See also Fig. 5):

I. Profile from Bockfjorden on the north coast of Vestspitsbergen (locality No. 19) in a *Nardino-Dryadetum* community. Uppermost a very thin layer of plant

remains, which may sometimes be absent. Below this 15 cm of a mixture of humus and wind-blown sand. This rests directly on rock.

II. Profile from Isfjorden, Kapp Wijk in a *Rupestri-Dryadetum* community (locality No. 3). On top a very thin layer of slightly decomposed plant remains. Below this about 12 cm of a mixture of sand and humus. The whole rests on beach gravel.

III. Profile from Isfjorden, Colesbukta (locality No. 6) in a *Tetragono-Dryadetum* community. The topmost layer of plant remains, either not at all decomposed or only very slightly, is relatively thick here, about 8 cm. Below this is found an 11 cm thick layer of a mixture of sand and humus. This rests on an old beach in which gravel and sand are mixed. At the time when the test was taken, 19/7 1958, the permafrost lay at a depth of about 28 cm.

In these and similar soil profiles the layer which is accessible for the plant roots is the upper active layer. The depth of this will in turn depend on the topographic conditions, exposure, composition of the soil, content of humus and not least the density of the plant cover.

In this respect it is typical that the only place where it was possible in summer to get down to the permafrost with an ordinary field spade in a community belonging to *Dryadion* was in *Tetragono-Dryadetum*. This must be because of the dense vegetation on the surface and a relatively thick layer of plant remains which acts as an insulator against the conduction of heat and because the duration of snow cover is longer. Because of the greater content of organic matter the pH value is also on the average lowest in this community (6.6). Generally speaking it is to be supposed that the development of arctic soil profile is a considerably slower process than in other climatic regions.

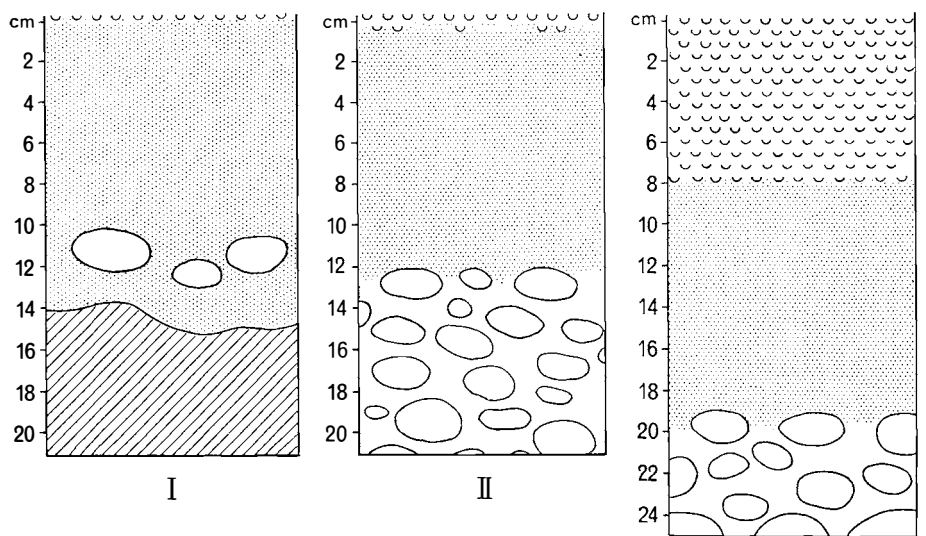

Fig. 5. *Soil profiles from Dryas communities.*

I. Nardino-Dryadetum. *II. Rupestri-Dryadetum.* *III. Tetragono Dryadetum.*

Methods

In these sociological analyses squares of the size of 1 sq. metre have been used, this being the size most commonly employed by Scandinavian phytosociologists. When applied to arctic plant communities, which often occur in larger or smaller patches or strips, such a square may often be on the large side. The use of squares of this size will also faciliate the comparison of my analysis results with those obtained by Scandinavian phytosociologists.

In each stand a series of either 5 or 10 square analyses was taken (in one case 8). At the same time this shows that the stands analysed must have been of a certain minimum size. Altogether analyses were carried out of 193 squares from 35 stands. In addition a number of notes were made on smaller stands, though these have not been included in the tables.

In each square the degree of cover of the various species was noted, HULT-SERNANDER's scale being used as it is the most common among Scandinavian botanists. A scale of 10 degrees, for instance, would in my opinion be more difficult to operate at all objectively, even though HULT-SERNANDER's scale, too, has definite weaknesses. The degree of cover is given also for bare earth and stone in order to present a more complete picture of the plant community. In the work here presented I have preferred to give the analysis results in full.

In the analysis of the various stands, samples of the bottom cryptogams were always collected, since in many cases microscopic examination is necessary for definite determination. I have, however, refrained from estimating any degree of cover for the cryptogams, firstly because it is always difficult to gauge a degree of cover of small mosses and lichens on the basis of a cryptogam identification long after it is taken, secondly because I doubt the rightness of doing so for all the species whose existence is entirely dependent on the presence of mats of *Dryas*. Even in those cases where a degree of cover was actually observed in the field, I have refrained from including it in the tables for the sake of consistency.

The tables have been arranged in four categories, first the dwarf-shrubs, then herbs and graminoid species arranged alphabetically, then mosses and liverworts and at last the lichens. Together with the analysis of each stand a soil pit was dug in a representative square, usually the first, and soil sample was taken. The soils were described and a soil sample from the upper root zone collected for later chemical analysis. In this work only data on pH and humus content are included. These measurements were made by the Ecological section of the Botanical Laboratory, Copenhagen, under the direction of Dr. M. KØIE, to whom I owe thanks for his valuable assistance.

The soil samples were air-dried as quickly as possible. The pH value was determined by the usual method with a glass electrode, and the humus content by "wet burning" (sulphuric-acid-chromic acid and titration with "Mohr's salt" by WALKLEY-BLACK's method).

The nomenclature of species follows in the main the modern handbooks that are normally used in Scandinavia. The vascular plants, as far as possible, follow LID (1952), and for newer taxonomic results in Svalbard also RØNNING (1961). Mosses and liverworts in the main follow ARNELL and MÅRTENSSON (1959) and

MÅRTENSSON (1955–1956), and lichens MAGNUSSON (1952). Certain species, e.g. *Festuca rubra, Cerastium arcticum, Poa arctica, Stereocaulon alpinum*, etc., are treated as collective species without any attempt to divide them into sub-species or varieties. Specimens that are difficult to determine, are usually referred to by the generic name alone. This applies, for instance, among *Bryum* sp. and *Lecidea* sp.

Studies in the Spitsbergen Dryadion

These investigations into the differentiation and ecology of the *Dryas* communities in Spitsbergen are intended as an effort at making a contribution to the sociology and ecology of the plant-life of Svalbard. Whereas in Scandinavia generally there exists a fairly comprehensive amount of literature on this subject, relatively little information is available about the corresponding problems in Arctic regions.

Suffice is here to recall that the name "*Dryas*-formation" was introduced by BLYTT in his classical essay of 1876 (p. 6). Later the concept was adopted by a number of investigators, but the difference between dwarf shrub communities on acid and calcareous subsoils was not always clearly expressed. It was not until 1928 that a firm distinction in this respect was made by NORDHAGEN in his great monograph of the Sylene mountains. In this the xerophilous dwarf shrub communities, dominated by *Dryas*, were placed in sharp contrast to those found on acid subsoils, dominated by *Ericaceae* and *Empetrum*-species.

In accordance with the accepted international recommendations for plant sociology, the "Amsterdam Convention", the higher units (alliances: association) are classified according to the qualitative species composition of the community, while the lower units (sociation) are classified according to the quantitative composition, i.e. dominance relationships.

Consequently the alpine *Dryas* communities in Scandinavia have been placed together in a natural unit (alliance), clearly demarcated from other alpine dwarf shrub communities by their profusion of species, some of which are exclusive or nearly so. This alliance was given the name "*Caricion nardinae*" by NORDHAGEN (1935), but *Carex nardina* in Scandinavia is a northern unicentric species with limited distribution in the north. As a result of this, NORDHAGEN in 1936 changed the name to "*Elynion Bellardii*", but this likewise proved unsuitable, one reason being that *Elyna bellardii*, because of taxonomic considerations, had to be renamed *Kobresia myosuroides*. Meanwhile KALLIOLA (1939) had introduced the name "*Dryadion octopetalae*" for the same alliance. Because *Dryas octopetala* is incomparably the most important dominant and distinctive species as against other alliances, I find this name more characteristic and logical. A further nomenclatorial reform was effected by DU RIETZ (1942), who simply abbreviated the name of the alliance to "*Dryadion*", which I find very suitable, and it is this name I shall be using in what follows.

The classification of the dwarf shrub communities of Svalbard is, however, somewhat simpler than in Scandinavia. The other two alliances within the Scandinavian alpine dwarf shrub communities, *Myrtillion* (*Phyllodoce-Myrtillion*) and

Empetrion (*Loiseleurieto-Archtostaphylion*) do not occur in Svalbard. The dominant and characteristic species of *Empetrion*, *Empetrum hermaphroditum, Loiseleuria procumbens, Vaccinium vitis-idaea, V. uliginosum, Diapensia lapponica*, either do not occur or have a very limited distribution in Svalbard.

Similar conditions prevail among the *Myrtillion* species, of which the typical ones *Phyllodoce coerulea, Vaccinium myrtillus,* and *Deschampsia flexuosa* are not represented in Svalbard. The fact remains that the only dwarf shrub alliance found in Svalbard is *Dryadion*, with the species *Dryas octopetala, Cassiope tetragona* and *Salix polaris* predominating.

In Svalbard the *Dryas*-communities occur on ridges and places exposed to the wind, while communities dominated by *Cassiope* are found in more sheltered places. Generally it is believed that *Dryas* is a strongly chionophobous species, while *Cassiope* can stand some snow cover. In localities with some snow cover *Dryas* cannot stand the competition with *Cassiope tetragona* and a dwarf shrub community is found with *Cassiope tetragona* virtually exclusive. On acid soil both *Dryas octopetala* and *Cassiope tetragona* disappear, and there remains only a community very poor in species and very open, where *Salix polaris* still holds out, supplemented by *Juncus biglumis, Luzula confusa, Ranunculus sulphureus, R. pygmaeus, Oxyria digyna, Saxifraga cernua, S. caespitosa, S. nivalis,* and *S. rivularis*. This plant community is found developed over large areas of Svalbard, especially in the granite areas along the coast west and north-west.

In Scandinavian plant sociology it is often a problem to find species with a sufficiently narrow ecological amplitude to constitute the characterizing species desirable for a classification into associations and alliances. Attention has therefore been paid to those species which appear as dominants, but these species cannot always be used as criteria in classifying the associations.

In Svalbard this presents less difficulty. The characteristic species for the various associations are also the actual dominants. At the same time it may be said that the ecological amplitude of these species in Svalbard is far narrower than of the same species in Scandinavia. In order to understand this, one must clearly realise that in Svalbard these species are found near the limit of their area of distribution. Any little change in the external ecological conditions may be a catastrophe for a certain species.

The consequence of this is that in Svalbard there may be found, within a very limited area, a vegetation that is varied not only in associations, but also physiognomically. In exposed localities with a split-up vegetation it is not difficult to find open spots where one square metre could easily be placed without having a single plant inside it. Whereas the limits of *Dryadion* in Svalbard do not present any great problems, there is on the other hand the question as to whether the vegetation there can really be called a plant community.

In Scandinavia, of course, similar problems arise, but not so prominently, and they occur either high up near the upper limits of vegetation, or on unstable scree.

Scandinavian alpine scree vegetation has been specially dealt with by NORDHAGEN (1935, 1943). Of the alliances he proposes (1943, p. 544) there is only one which can be compared physiognomically with the open type of *Dryadion* in Svalbard, i.e. *Arenarion norvegicae*. NORDHAGEN gives a detailed description of this plant

community (1935, pp. 70-77). Here, too, is emphasized the doubt that surrounds calling such vegetation a community. The Scandinavian screes of the *Arenarion norvegicae* alliance are admittedly characterised by such species as *Arenaria norvegica, Braya linearis* and *Dryas octopetala*, but a great number of occasional species may occur, so that the actual composition varies widely. No such variation in the grouping of species is found in Svalbard. The objection which ought to be possible on account of the relatively large open spaces between patches of vegetation can therefore be discounted.

In order to bring out the differentiation within the Svalbard *Dryadion* it is necessary to classify it at a lower level than the alliance. Chief stress is laid on a classification at the association level. For this attention is paid to the qualitative distribution in the various strata. But in classifying in the Arctic, where the number of species is very limited, attention must be paid not only to a certain minority of characteristic and differential species, but one must equally try to form a picture of the entire plant community viewed as a whole, and pay special attention to the distribution, frequency and dominance of the species. The individual species have their quite definite pattern of distribution, with a preference for certain quite definite ecological conditions. It is therefore important in classifying by associations, or in any form of sociological classification, to make use of all the species that are represented, and from the available knowledge of their requirements to try to form a picture of where they find their normal environment. This means that not only must stress be laid on the characteristic and differential species, but it is equally important to try to make use of the indicators for classification that are to be found in the occurrence of the so-called "preference-species". This was also strongly emphasized by Sjörs (1954, p. 35) and Bringer (1961, p. 353). I regarded the use of the information provided by the preference-species as specially valuable and important in arctic regions where the number of species is relatively limited. But this presupposes, too, that these species are known from field study, and that both their relative frequency and the degree of vitality they exhibit can be judged.

For the ordinary classification by associations, though, qualitative grouping is highly important, with the so-called characteristic and differential species being especially important. By a differential species is meant one which is found in one community but is lacking in the other. A differential species will be more valuable diagnostically if it occurs as the characteristic species in its community. (Du Rietz 1942, Nordhagen 1943, Bringer 1961.) In Svalbard the classification into associations is made on the basis of species of the latter category.

This does not do away the need, already emphasized, to attach great importance to the so-called preference species, i.e. those which have a wide ecological amplitude and occur in several associations, but obviously prefer, or have their optimum, in a specific association or alliance.

If we follow these principles the below mentioned species can be regarded as characteristic species for the *Dryadion* of Svalbard:

Carex nardina	*Cassiope tetragona*
Carex rupestris	*Dryas octopetala*

Of these four species *Carex nardina* represents the extreme wind-exposed communities, while *Cassiope tetragona* represents those in sheltered places. In Svalbard the species which appear most commonly and appear to attain their optimal environment in *Dryadion*, but which are also found in other plant communities, i.e. the preferential species of *Dryadion*, are the following:

Carex misandra
Draba alpina coll.
Draba subcapitata
Equisetum variegatum
Luzula nivalis
Minuartia biflora
Minuartia rubella
Papaver dahlianum
Pedicularis dasyantha
Pedicularis hirsuta
Poa arctica coll.
Polygonum viviparum
Saxifraga oppositifolia
Silene acaulis
Stellaria crassipes

In the compilation of this list of preferential species only little attention has been paid to the cryptogams which are found in certain associations. For instance, our knowledge of the ecology and distribution of mosses in arctic regions is very scant, so that I have not ventured to classify them neither as characteristic nor as differential species. On the other hand it is quite obvious that several species of moss display affinity with *Dryadion*. Examples of this are *Aulacomnium turgidum, Hypnum bambergeri, Oncophorus wahlenbergii, Timmia austriaca* and *Tomentypnum nitens* as well as the liverwort *Ptilidium ciliare*.

Similar considerations also apply to lichens, but here information as to their ecology is even more scant. The majority of the lichens that are represented are small epiphytic crustaceous species whose significance in the associations factor is very difficult to assess.

Order: *Seslerietalia* (Braun-Blanquet 1951).
Alliance: *Dryadion* (Du Rietz 1942).

Dryadion is associated with the central European alliance *Seslerion* (Braun-Blanquet 1951) which is also a calcicolous community.

The alliance occurs chiefly, and in its most highly developed form, on windswept ridges with little or no snow cover in winter. The subsoil is calcareous sand and gravel or projecting rocks and stones. Wind erosion is very pronounced, and its intensity is crucial for the number of species that make up the associations. On the most eroded gravel ridges there occurs no vegetation at all, or at most mats of *Dryas octopetala* alone. As the amount of protection is increased the number of species also increases gradually. On the other hand, communities in localities with good snow cover may be strongly dominated by *Cassiope tetragona*. Those localities near cliffs and slopes which are most affected by snow patches are dominated by communities in which *Cassiope tetragona* may be virtually supreme. The typical species of the alliance in Svalbard are: *Carex nardina, C. rupestris, Cassiope tetragona* and *Dryas octopetala*. The last three are quite common in Svalbard, but *Carex nardina* is much rarer and occurs only occasionally. In Svalbard calcareous

and basic rocks are very common, and it is just these rocks which provide the best conditions for the development of *Dryadion*.

Most of the Svalbard plant communities which are now embraced by *Dryadion* were included under the term "Fjældmark" (mountain soil) by WARMING (1888). Later RESVOLL-HOLMSEN (1913) divided the vegetation into five groups, "une végétation littorale", "sols marécageux", "campagne rocheuse", "la végétation d'un sol bien fumé" and "la lande". Of these groups it is the last-named which exhibits the greatest floristic relationship to the alliance *Dryadion*, if any such comparison is at all possible.

SUMMERHAYES and ELTON (1923) make contribution to the ecology of Spitsbergen, and give a certain amount of phytosociological information, but the classifications made by RESVOLL-HOLMSEN and by SUMMERHAYES and ELTON are purely ecological without laying any stress on the phytosociological conditions.

Similar ecological classifications were made by SCHOLANDER (1934) in his work on the flora of Nordaustlandet (North Eastland), but here again no use was made of phytosociological principles, so that the results arrived at cannot be directly compared with the sociological classification which is made below.

Very little has been done in the way of real phytosociological research. Only HADAČ (1946) can be said to have concerned himself with the phytosociological problems of Svalbard.

HADAČ (1946) made a survey of some plant communities in the Sassen area of Isfjorden. He divided the communities belonging to *Dryadion* (or *Caricion nardinae* according to HADAČ) into three associations: *Tomentohypnetum involuti*, *Dryadetum minoris* and *Cassiopetum tetragonae spitsbergense*. He states (p. 156) that the association *Tomentohypnetum involuti* is dominated by *Salix polaris*, *Pedicularis hirsuta*, *Polygonum viviparum*, *Saxifraga oppositifolia*, *Stellaria longipes*, *Tomentypnum nitens*, *Drepanocladus uncinatus*, *Distichum capillaceum*, and *Stereocaulon alpinum*, and particularly the mosses.

The association *Dryadetum minoris* (HADAČ 1946) is dominated by *Dryas octopetala* (var. *minor* according to HADAČ), *Salix polaris*, *Saxifraga oppositifolia*, *Polygonum viviparum*, *Drepanocladus uncinatus* etc. Mosses are rather less common in this case.

In my opinion it is not right to separate these two communities as distinct associations; they can hardly be regarded as more than variants of one and the same association. If the two associations are considered together they correspond with the association *Polari-Dryadetum* described below.

The third association mentioned by HADAČ, *Cassiopetum tetragonae spitsbergense*, is dominated by *Cassiope tetragona*, *Saxifraga oppositifolia*, *Dryas octopetala*, *Salix polaris*, *Luzula nivalis* etc., and the cryptogams *Tomentypnum nitens*, *Drepanocladus uncinatus* etc. This association corresponds in all respects to *Tetragono-Dryadetum*, described below, and can be indentified with it.

I find it natural to distinguish the following associations of *Dryadion* in Svalbard:

Nardino-Dryadetum

This association is very limited and rarely occurs over large areas. It is found on wind-exposed ridges or surfaces, and has little or no snow protection in winter.

The subsoil is well drained, dry and stony, with a shallow layer of earth. The association is relatively poor in *species*, and apart from *Dryas octopetala* it is characterised by *Carex nardina*.

Rupestri-Dryadetum

This association, too, is distributed in exposed places, especially terraces and beach ridges where the subsoil is affected by frost, and the sides of valleys where there is movement of the subsoil. Here too the subsoil must be well drained and dry. The dominant species, apart from *Dryas octopetala,* are primarily *Carex rupestris, Saxifraga oppositifolia,* and *Polygonum viviparum.*

Polari-Dryadetum

This association occurs in places with better snow protection than the two already discussed. It, too, occurs on ridges and terraces, but usually so that stones and projecting rocks accumulate enough snow to provide a certain shelter in winter. It melts later in the spring. The subsoil is well drained, but the late thaw makes it moister in spring, yet drier in summer when the permafrost is lower. The dominant species here, apart from *Dryas octopetala,* is *Salix polaris*. This association is the richest in species in Svalbard, and is for one thing characterised by the fact that the number of species of grass is greater than in other associations.

Tetragono-Dryadetum

This association is chiefly developed on the sides of valleys and the lee side of protruding ridges, cliffs and the like. It is dependent on a comparatively small but steady supply of moisture during the whole period of growth, and a good snow cover in winter. With the dark hue of *Cassiope tetragona* the association makes a prominent feature in the landscape.

Other differences which are found within the various associations are likewise scarcely so marked that they can justify any further classification into sociations or facies. But it is possible that certain of the communities that have been analysed must be regarded as variants within the association, or transitions between the various associations. I have arranged my associations in a series believed to correspond to an increase in soil moisture and snow protection in winter. This is also in accordance with previous investigations, especially in Scandinavia (Du Rietz 1950, Hedberg 1952, Nordhagen 1955, and Bringer 1961). It would not, however, be realistic to expect complete agreement at the association level.

It is possible that the associations described are so narrow that in Scandinavia, for instance, they would hardly be considered as separate associations. It may be, for example, that the first two would have been grouped together as one association. Nevertheless I have found that in high arctic regions they are quite typical and peculiar both physiognomically and ecologically, so that they fully deserve the rank of separate associations.

Description of the analysed stands

Association: *Nardino-Dryadetum*

This association has a limited distribution in Svalbard. Of the four associations discussed in this paper, this is the most exclusive. It is entirely restricted to very exposed ridges or beach ridges with little or no snow cover in winter. The vegetation is scattered and usually very much split up. *Carex nardina* occurs most frequently in isolated tussocks. *Dryas octopetala* may also extend over considerable areas, but may at the same time be near its tolerance limit. This applies especially where the wear and tear of the wind on the plants is excessive. It is strongly attacked here by crustaceous lichens. If *Dryas octopetala* is damaged, or if it gets split up in the vegetative system, it will fall an easy prey to wind erosion. Besides the two dominant species, *Carex nardina* and *Dryas octopetala*, the following may display quite high frequency: *Salix polaris*, *Carex rupestris*, *Saxifraga oppositifolia*, *Silene acaulis*, and *Polygonum viviparum*. This association does not afford very much scope for mosses. Of those with relatively high frequency may be mentioned: *Hypnum bambergeri*, *Oncophorus wahlenbergii* and *Tomentypnum nitens*.

Lichens, on the other hand, are of rather greater importance. A considerable proportion of them are crustaceous lichens, e.g. *Ochrolechia frigida* and *Lecanora epibryon*, both of which occur with high frequency. They live especially on *Dryas octopetala* and the base-tufts of *Carex nardina* and *C. rupestris*, and contribute most probably to the breakdown of these species. Of fruticose lichens *Cetraria islandica*, *C. nivalis* and *Stereocaulon alpinum* show high frequency.

On the whole lichens in this association have a greater frequency and are of greater importance for the development of the association than in the other associations.

Within the association analyses have been made of 20 quadrates of 1 sq. metre from four different stands. In three of these *Carex rupestris* also occurs to a greater or lesser degree, sometimes with a degree of cover between 2 and 3. This makes it clear that there exists a possibility for ranking *Nardino-Dryadetum* as a unit (sociation, facies, etc.) under *Rupestri-Dryadetum*. Yet the association shows so many special features in its floristic composition, ecological requirements, extreme habitat and physiognomic development that I find it reasonable to list it as a separate independent association. The pH measurements show very little variation, as three of them show pH–7.8 (stand 2, 5 and 19) and one pH–7.4 (stand 22).

Du Rietz (1942) found (p. 131) in some exposed places in the Torneträsk area a pH value around 7. It is to be supposed that the reason for this value lies in increasing humification with a corresponding increase in the degree of acidity. In the extreme localities in Svalbard the subsoil was practically pure mineral soil, strongly reminiscent of typical lithosol, with a humus content ranging from 1 % in No. 19 to 3.7 % in No. 22.

Among the associations or sociations within Scandinavian phytosociology more or less comparable to *Nardino-Dryadetum* in Svalbard, may be mentioned: Hedberg's (1952) *Nardino-Dryadetum*, Bringer's (1961) *Epibryo-Dryadetum*,

Table 1. Nardino-Dryadetum

Stand No.:	19					2					15					22				
Quadrate No.:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Cassiope tetragona	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.
Dryas octopetala	5	2	1	4	4	5	5	5	5	5	3	2	2	2	4	5	5	5	5	5
Salix polaris	2	.	1	.	1	1	.	.	1	1	3	.	1	2	2	.	.	.	.	.
Carex misandra	.	.	.	1	.	.	.	.	1	1	.	.	.	.	.	1	.	.	.	.
» *nardina*	1	1	1	1	1	1	1	2	2	2	1	1	1	1	1	1	1	1	1	1
» *rupestris*	2	2	1	.	1	2	2	.	1	1	.	.	.	.	.	3	1	.	1	1
Cerastium arcticum	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.	1	.	1	.
Luzula confusa	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
» *nivalis*	.	.	.	.	.	1	1	.	1	1	.	.	.	.	.	.	.	.	.	.
Minuartia rubella	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Pedicularis dasyantha	.	.	.	.	.	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.
» *hirsuta*	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Poa alpigena	.	1	1	.	3	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
» *alpina*	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.	.
» *arctica vivipara*	2	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Polygonum viviparum	2	1	1	.	1	.	.	.	1	1	2	2	1	.	1	.	.	.	.	.
Potentilla hyparctica	.	.	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Saxifraga oppositifolia	.	.	.	1	.	1	1	1	1	1	2	2	1	.	1	1	1	1	1	1
» *rivularis*	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Silene acaulis	.	.	.	.	.	1	.	1	1	1	.	.	.	.	.	1	.	.	1	1
Aulacomnium turgidum	1	.	.	.	1	.	.	.	.	.	.	.	1	1	1	.	.	.	.	.
Bryum sp.	1	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Dicranum majus	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Distichium capillaceum	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.	.
Drepanocladus uncinatus	.	.	.	.	.	.	.	.	.	.	1	.	.	1	1	.	.	.	.	.
Hylocomium splendens	.	.	.	.	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.
Hypnum bambergeri	.	1	.	.	1	1	1	1	1	1	1	1	1	1	1	1	1	1	.	1
» *revolutum*	1	1	1	1	.	.	.	.	.	.	.	.	.	1	1	.	.	.	.	.
Mnium orthorrhynchum	.	.	.	.	.	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Oncophorus wahlenbergii	1	1	.	.	1	1	1	1	.	1	.	1	1	1	1	1	1	.	1	1
Rhacomitrium lanuginosum	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Timmia austriaca	.	.	.	.	.	.	.	1	1	.	1	.	.	1	1	.	.	.	.	.
Tomentypnum nitens	1	.	.	1	1	1	.	1	1	1	1	.	1	1	1	.	.	.	.	.
Tortula ruralis	.	1	1	1	1	.	.	.	.	.	1	.	1	.	1	1	1	1	1	.
Blepharostoma tricophyllum	1	.	1	.	1	1	.	.	1	.	.	.	.	.	.	.	.	.	.	.
Cetraria islandica	1	1	.	.	1	.	.	.	.	.	1	1	.	.	.	1	1	.	1	1
» *nivalis*	1	1	.	.	1	.	.	.	.	.	1	1	1	1	1	1	1	.	1	.
Cladonia pyxidata	.	1	1	1	.	.	.	1	1	.	.	.	.	.	.	.	.	.	.	.
Cornicularia divergens	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.	.	.	.	.
Lecanora epibryon	1	1	.	1	1	.	.	.	.	.	1	.	.	1	1	.	1	1	.	.
Lecidea sp.	1	1	1	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Ochrolechia frigida	1	1	1	1	.	.	1	.	1	1	1	1	.	1	1	1	1	.	1	1
Peltigera erumpens	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.	.	.	.
Stereocaulon alpinum	1	1	.	1	1	1	1	1	1	1	1	.	1	.	.	.	.	.	.	.
Thamnolia vermicularis	1	.	1	.	1	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
Open soil and stones	1	1	1	1	1	2	1	2	2	2	2	2	2	3	2	3	3	3	3	4
Number of vasculars	7	5	7	5	9	8	6	5	10	9	6	4	6	4	5	6	6	3	6	5
Number of cryptogams	14	12	8	10	13	6	4	6	8	5	11	7	7	11	12	7	7	3	5	4

both fram Northern Sweden, and NORDHAGEN's *Caricetum nardinae* from Norway (1955).

In Table 1 is given a survey of the *Nardino-Dryadetum* of Svalbard.

Description of the analysed stands in Table 1.

Stand 19, 1–5. North coast, Woodfjorden, Bockfjorden, east of Jotunkjeldane, 13/8 1958.

The locality lies to the east of the warm springs. The community occurs on very eroded gravel ridges, with coarse gravel and stone, and practically no visible effect of humus. Snow protection in winter is in all probability very slight.

Tufts of *Carex nardina* are scattered, while *Dryas octopetala* has a greater degree of cover. The cryptogams are found between twigs and leaves of *Dryas octopetala*. The pH value is relatively high, 7.8, and the humus content is low, about 1 %.

Stand 2, 6–10. Isfjorden, Kapp Wijk, 7/7 1958.

The locality lies to the north of Kapp Wijk on a very exposed terrace. The vegetation is dotted about on a subsoil badly broken up by frost. Snow protection in winter is probably meagre and the effect of the frost considerable. The soil section shows neither humus effect nor stratification. The subsoil consists of stone, gravel and sand without any demonstrable order.

Tufts of *Carex nardina* are scattered, in some cases with several together covering the greater part of the square. The community itself is less marked by deflation, and has a considerably lower content of crustaceous lichens than No. 19. Because of the severe drought there is very little moss. The pH value is 7.8, while the humus content is 2.9 %.

Stand 15, 11–15. North coast, Raudfjorden, Alicehamna, 9/8 1958.

The locality is on the slope of Solanderfjellet towards the western end of Richardvatnet, about 130 m above sea level.

The community appears on ridges of sand and gravel with projecting crags. Wind erosion is severe, and windblown sand collects between and around the crags.

The vegetation is scattered, with open spaces between. The situation, combined with the height above sea level, reduces the number of species, of which not more than 4 to 6 are found.

The pH value of the soil is 7.8, the humus content being 3.1 %.

Stand 22, 16–20. Kongsfjorden, London, 28/8 1958.

The locality lies on the north side of the fjord, on Blomstrandhalvøya.

The community is found developed on dry dolomite ridges north of the bay leading in to London. The vegetation is very scattered, sometimes with large openings between. The subsoil is calcareous sand (dolomite gravel) and the soil section revealed no sign of stratification. The locality is very exposed to the wind, and the snow cover in winter is minimal. The number of species in the community is small, ranging from 6 to 13 per m^2. *Carex rupestris* may occur quite thickly in certain squares.

As for cryptogams, it is difficult to point to any direct dominants. The number of mosses and lichens is very small. Of the four stands analysed within *Nardino-Dryadetum* this one shows the lowest pH value, 7.4, and the highest humus content, 3.7 %.

Association: *Rupestri-Dryadetum*

In Svalbard this association is comparatively widely distributed and is much more common than *Nardino-Dryadetum.* It differs from this, in the first place, in the absence of *Carex nardina,* while *Carex rupestris* is clearly dominant. Apparently *Carex misandra* can be regarded as a differential species as compared with the other associations.

This association, too, occurs in localities with thin snow cover, but hardly so exposed to wind as *Nardino-Dryadetum.* It is particularly well developed on beach ridges and terraces, where it is dry and the effect of frost on the subsoil is great. It may likewise occur on dry slopes on the sides of valleys, etc., where there is some movement in the subsoil, at any rate in spring.

The number of species per sq. m is usually greater than in the case of *Nardino-Dryadetum,* varying from 9 to 18. The presence of *Cassiope tetragona* in certain stands shows that the community can vary greatly in its requirements of snow protection in winter. It can obviously develop both in dry exposed localities and in more sheltered ones.

Among the cryptogams are the mosses *Oncophorus wahlenbergii, Tomentypnum nitens* and *Hypnum bambergeri* common, all of which may occur in thick tufts between the twigs of *Dryas octopetala* and *Salix polaris,* and between the tussocks of *Carex rupestris.*

The crustaceous lichens can be quite common on twigs and leaves of *Dryas octopetala,* and at the base of the tufts of *Carex rupestris.*

In this association 53 quadrates of 1 sq. metre from 9 different stands have been analysed. The association in itself constitutes a distinctive feature of the landscape. The grey hue of *Carex rupestris* combined with the grey leaves of *Dryas octopetala* give the association an appearance of its own.

In Table 2 is given a survey of the analysed stands.

Descriptions of the analysed stands in Table 2.

Stand 3, 1–5. Isfjorden, Kapp Wijk, 8/7 1958.

The community is found distributed on the old beach ridges. It occurs on dry and frost-broken ground, sometimes with coarse gravel. The vegetation may be quite continuous, but there may also be relatively large patches of bare gravel. In small depressions, crags and sheltered spots the moss vegetation can be comparatively thick between the twigs of *Dryas octopetala* and *Salix polaris.* The soil profile shows an upper layer of humus which is very thin, less than 1 cm. Below this comes 12 cm of fine sand slightly tinged by humic acids, and below this again coarse sand or gravel.

In more sheltered places such as small depressions *Cassiope tetragona* may be found. The moss vegetation is little developed. Of the lichens the crustaceous are again the commonest.

The pH value of the soil is 6.7 and the humus content 18.9 %.

Stand 9, 6–10. Isfjorden, Gipsvika. East side of the bay, 29/7 1958.

The community occurs on an old beach ridge of dolomite gravel. The vegetation is patchy and *Rupestri-Dryadetum* is particularly well developed in exposed places

Where there are depressions or other places with a high degree of snow protection *Cassiope tetragona* is so common that the community must be assigned to *Tetragono-Dryadetum.*

An interesting feature of these communities from the inner fjord regions is that *Pedicularis dasyantha* may be fairly regularly distributed.

As for cryptogams, mosses are sometimes well developed, and particularly the larger species.

Lichens are very little in evidence.

The pH value is 7.9, which is very high, while the content of humus is low, 2.2%.

Stand 21, 11–18. Kongsfjorden, Ny-Ålesund, south-west of the village.

The analyses were taken on dry ridges extending from east to west. The vegetation occurs in patches and strips, with open parts between. The locality is exposed to the wind, but where there are depressions or sheltered places *Cassiope tetragona* appears. The subsoil is clayey or very finely powdered without stratification.

Besides the dominant species *Salix polaris* and *Saxifraga oppositifolia* occur quite profusely, and in well-drained places also *Silene acaulis.* The community is rich in mosses and lichens. The pH value here is 7.8 and the humus content 4.3 %.

Stand 11, 19–23. Isfjorden, Tempelfjorden. An unnamed promontory on the east side of the fjord.

The community occurs on clayey solifluction soil. The vegetation appears in patches with open spaces between. The soil section shows no stratification, and there is no visible effect of humic acids.

Apart from the species that dominate the association it may be observed that *Polygonum viviparum* occurs in all squares.

Cryptogams are little in evidence. The mosses *Hypnum bambergeri, Oncophorus wahlenbergii* and *Tomentypnum nitens* occur in all squares, while not a single fruticose lichen could be demonstrated. The pH value is 8.4. There is no demonstrable humus content.

Stand 12, 24–28. Isfjorden, Tempelfjorden.

This analysis was taken in the same locality as No. 11, but the vegetation is more continuous. Among other things this has resulted in a far stronger development of the top layer of humus. The soil section reveals, uppermost, 10–12 cm of dark raw humus, and beneath this coarse gravel. The soil analysis shows a very high humus content, 52 %. The transition from the layer of humus to that of gravel is very sharply defined. The effect of the high humus content is a lower pH value than in No. 11.

The community does not display any floristic peculiarities. It is noteworthy that *Carex misandra* and *Polygonum viviparum* occur in all squares, and in one case *P. viviparum* attains a degree of cover of 3.

The pH value here is 6.5, and the content of humus as high as 52 %.

Stand 16, 29–33. North coast, Raudfjorden, Alicehamna, 9/8 1958.

The locality is about 70 m above sea level. It is exposed to the wind, but not extremely so. The vegetation is open and scattered. The subsoil is mostly conglomerate gravel. Besides the dominant species *Poa alpina, Silene acaulis* and *Saxifraga oppositifolia* occur commonly in this community.

The pH value is 6.2 and the content of humus 7.8 %.

Stand 28, 34–38. North coast, Woodfjorden, Reinsdyrflya, 6/8 1960.

The locality is about 4 km north of Worsleyhamna. The vegetation is relatively continuous. The community is found on exposed ridges. In similar localities in the immediate neighbourhood *Polari-Dryadetum* occurs profusely, but it is difficult to demonstrate any clear ecological difference to account for this difference in the plant communities. In addition to the dominant species *Saxifraga oppositifolia* also occurs with a degree of cover from 1 to 3 in this community.

The moss-flora is quite well developed here.

Soil sample for this community is lacking.

Stand 29, 39–43. North coast, Woodfjorden, Bockfjorden, 7/8 1960.

The locality is right in at the head of the fjord, on the mountain slope. The vegetation is relatively continuous, which suggests that here the wind erosion is not very pronounced. The soil section shows an upper layer, 15 cm thick, a mixture of humus and sand. Below this is a thick layer of sand and gravel tinged by humic acids. Apart from the two dominant species there must be remarked the frequent occurrence of *Saxifraga oppositifolia.*

The pH value is 7.1 and the humus content 19.7 %.

Stand 30, 44–53. North coast, Woodfjorden, Bockfjorden, 7/8 1960.

The locality is situated between the head of the fjord and the warm springs (Jotunkjeldane) on the valley slopes. The vegetation is, on the whole, continuous, but extremely hummocky. Down in the depressions, and therefore sheltered, *Cassiope tetragona* is found growing. On the top and sides of the hillocks *Carex rupestris* dominates. The soil section shows 4 or 5 cm of tightly packed tomentum, with remains of dead plants and mosses. Below this come 20–25 cm of a dark, brown mixture of humus and sand, and below this again the humus content decreases till finally there is pure sand.

The community is difficult to classify and tends towards *Tetragono-Dryadetum.* Of the 10 quadrates analysed, *Cassiope tetragona* occurs in 8, with a degree of cover 1–2. Nevertheless the community most probable belongs to *Rupestri-Dryadetum,* because *Carex rupestris* is clearly the most important and dominant species. The presence of *Pedicularis hirsuta* and *Eutrema edwardsii* indicates some moisture throughout the summer.

The pH value is 7.1 and the content of humus 18.6 %.

Association: *Polari-Dryadetum*

This association differs from *Nardino-Dryadetum* and *Rupestri-Dryadetum* by the fact that *Carex nardina* and *C. rupestris* do not occur or are only sparingly represented. It is distinguished from *Tetragono-Dryadetum* by the absence of *Cassiope tetragona.* To a certain extent, therefore, it may be said that the association is united by negative qualities. Thus the absolute dominants in this association are, first, *Salix polaris* and *Dryas octopetala,* and then *Saxifraga oppositifolia.* This association is certainly the richest in species of those considered here. The number of species varies widely, from 10 (quadrate 52) to 25 (quadrate 11). The total number of species represented in the published analyses is 72. Of those that

show a marked preference for this association may be mentioned the following: *Cerastium arcticum, Oxyria digyna, Papaver dahlianum, Pedicularis hirsuta, Saxifraga caespitosa* and *S. cernua.*

Among the mosses it is mainly the larger species that are common, e.g. *Dicranum majus, Drepanocladus uncinatus, Hylocomium splendens, Hypnum bambergeri, Timmia austriaca, Tomentypnum nitens* and *Ptilidium ciliare.*

Lichens also show certain peculiar features here, particularly that the fruticose lichens *Cetraria islandica, C. nivalis* and *Stereocaulon alpinum* are common and evenly distributed. The relatively large number of species, together with the species of higher plants that were mentioned above, show that the localities where the association is found have a fairly good supply of moisture, especially during the first part of the summer, without thereby diminishing the need for good drainage. They are also covered by a protective blanket of snow in winter. The community is particularly common in places where there is polygon soil and frost action, especially where these occur on elevated ground or ridges. In very exposed places the association is found best developed down the slopes, while up towards the exposed ridges it may tend to become a practically pure *Dryas* vegetation. The polygon soil and the frost phenomena that are found in this association must primarily be due to stagnant water in the subsoil in the early spring months, but when the permafrost thaws to a certain depth necessary drainage conditions will be achieved.

In this association 75 quadrates from 13 different stands have been analysed. All the stands show a distinct dominance of *Salix polaris* and *Dryas octopetala,* but have also in other respects great similarity in their floristic composition. Only No. 13 deviates with regard to *Carex rupestris.* This is the only place where this species is represented in a community which, in my opinion, must be assigned to *Polari-Dryadetum.* It occurs in three out of five quadrates, with a degree of cover from 1 to 2. This stand represents a transition to the *Rupestri-Dryadetum.* In the other stands *Rhacomitrium lanuginosum* is common on elevated ground.

It is not altogether easy to understand the ecological differences between this community and the *Tetragono-Dryadetum.* In areas where *Cassiope tetragona* is absent, e.g. on the outer coastal streches of the north coast, *Polari-Dryadetum* will appear instead. But this is not sufficient explanation, inasmuch as in some places such as the inner parts of the fjords on the west coast, where *Cassiope tetragona* also is plentiful, this association is nevertheless found well developed. Apparently the prerequisite conditions must be an interplay between a well-drained subsoil with a steady supply of moisture, and a certain minimum of snow cover in winter. It is therefore to be supposed that communities with a large number of species, e.g. Nos. 5, 8 and 23, must have a certain covering of snow in winter, which also is suggested by their topographical location. Communities that are poor in species, e.g. Nos. 7 and 31, apparently have less snow cover in winter. It is also possible that the degree of oceanity makes itself felt here, but about this it is difficult to say anything with certainty.

The pH values of the soils ranges from 5.5 to 7.7 with a mean of 6.8, which indicates approximately neutral soil.

The humus content varies among the 12 stands from 2.3 % to 36 %, with a mean of 17.6 %.

It is difficult to find parallels to this association in Scandinavian phytosociological literature. BRINGER (1961) refers to *Bifloro-Dryadetum* from Torneträsk a *Dryas* community bordering on the snow-patch communities. It shows relationship to *Polari-Dryadetum,* but differs unmistakably in its lack of dominant dwarf shrubs other than *Dryas*. It is highly probable that of all the associations I have come across this is the most arctic in its composition.

Descriptions of the analysed stands in Table 3.

Stand 5, 1–5. Isfjorden, Ymerbukta, near Morenekilen, 15/7 1958.

The locality faces south on the slope of a little crag near the bottom of Morenekilen. The subsoil is a relatively unstable scree with vegetation dotted here and there. The soil section shows 14 cm of loose gravel partly mixed with humus, but without stratification, down to the underlying rock or stone.

Between the twigs of *Dryas octopetala* and *Salix polaris* is found quite a large number of mosses, especially the somewhat larger species such as *Aulacomnium turgidum, Dicranum majus, Drepanocladus uncinatus* and *Rhacomitrium lanuginosum.* The liverwort *Ptilidium ciliare* also occurs frequently. Lichens display little dominance.

The pH is 6.6 and the humus content is quite high, 33 %.

Stand 7, 6–10. Van Mijenfjorden, Camp Morton, 24/7 1958.

The locality is situated on the western slope of Kolfjellet. The subsoil is scree, and the vegetation is interspersed with open patches of sand and stone. There is no stratification of the gravel.

The dominants are the usual ones for the association while the frequency of certain species, e.g. *Saxifraga oppositifolia*, is somewhat less. The mosses show approximately their usual distribution in the association. More remarkable is the low content of lichens.

The pH value of the subsoil in this community is the lowest that has been measured for *Dryadion* anywhere in Svalbard, i.e. pH 5.5. The humus content is also very low, 2.3 %, which is the lowest that has been found in this association.

Stand 8, 11–15. Isfjorden, Grønfjorden, Kongressdalen, 26/7 1958.

The locality is on an old beach ridge of open gravel very much exposed to the wind. The gravel is very dry, hard dolomite. Here, too, the vegetation occurs in patches and is held together by *Dryas octopetala* and *Salix polaris*. The soil section shows no stratification, but only an irregular mixture of sand and stone.

From the floristic point of view the occurrence of *Equisetum variegatum* is interesting.

Cryptogams are little in evidence. The pH value is 6.5. The humus content of the subsoil 13.6 %.

Stand 20, 16–25. North coast, Woodfjorden, Reinsdyrflya, 14/8 1958.

The locality lies on the mainland inside the Stasjonsøyane I's. The community was analysed on gravel running from north to south and on sandstone ridges north of Worsleyhamna. The subsoil is strongly affected by frost. The vegetation occurs here in strips and patches, and this splitting up must be regarded as the result of the spring thaw.

The substance of the subsoil is very finely powdered, especially in the bare

open patches, and the soil section shows no stratification. But within the vegetation-patches we find a distinct upper layer of humus or slightly decomposed plant remains.

It must be said that floristically the community is poor i higher plants. One remarkable feature is the presence of *Pedicularis hirsuta* in 9 out of 10 quadrates.

The pH is 6.4 and the humus content is 14.3 %.

Stand 23, 26–30. West coast, Dunderbukta, south of Bellsund, 18/7 1960.

The locality lies on the north side of the bay near the bird cliff Dundrabeisen. Here the *Dryas* community has a very limited distribution, but is found on certain knolls south-east of Dundrabeisen. Compared with most of the analyses that have been made of *Dryadion* in Svalbard, the vegetation here is relatively dense. The subsoil is brown, a mixture containing humus and sand, but without stratification. It covers stone and rock, and is from 15 to 20 cm thick.

The community is comparatively rich in mosses and lichens. Of the mosses it is the larger species which predominate, particularly *Drepanocladus uncinatus*, *Rhacomitrium lanuginosum* and *Ptilidium ciliare*. The number of species of lichens are also quite large, especially crustose and fruticose lichens. It is possible that this community with its profusion of moss and lichen may be partly oceanic. It is, moreover, the most southerly locality in which a *Dryadion* community has been analysed.

The pH of the subsoil is 7.4 and the humus content is relatively small, i.e. 7 %.

Stand 24, 31–35. Van Mijenfjorden, Berzeliusdalen, 22/7 1960.

The locality lies on the west side of the bay, at the crossing to Fridtjovhamna. The subsoil here is sandstone, badly broken up by frost, partly covered with powdered sand which has presumably been brought by the wind. The community is found only on the western side of the north-south ridge, which ensures the best possible insolation, as protection is thereby afforded against the eastern winds. The soil section shows a top layer, from 15 to 20 cm thick, of sandy soil mixed and tinged with humus. The consistency was very even, presumably because of the wind-borne sand.

From the floristic viewpoint it may be noted that *Salix polaris* is rather more weakly represented than usual, and that *Silene acaulis* is a common species in this community. This species would seem to suggest a well-drained subsoil. As for cryptogams, here again the larger mosses are well represented. The fruticose lichens also appear regularly.

The pH is 7.3 and the humus content is 15.4 %.

Stand 25, 36–40. North coast, Woodfjorden, Reinsdyrflya, 1/8 1960.

The locality is on the south side of Reinsdyrflya, a little way up Liefdefjorden. The analysis was made on a windswept ridge with protruding rocks which presumably accumulate a good deal of snow during the winter. The community is found best developed some way below the actual ridge, or in between stones etc. A special feature is the relatively powerful influence of *Festuca rubra* in quadrates 4 and 5. Otherwise cryptogams occur more or less as in the previous stands, with the exception of *Oncophorus wahlenbergii* which comes in here with a high frequency.

The pH is relatively high, 7.7 and humus content is low, 7.3 %.

Stand 26, 41–45. North coast, Woodfjorden, Reinsdyrflya, 6/8 1960. The locality lies about 5 km inland on the peninsula north of Worsleyhamna. The analyses were made on windexposed ridges. *Dryas octopetala* occurs alone, particularly near the top of the ridge, but at the bottom of the slopes, near lower and damper ground it disappears. The vegetation occurs in large and small patches with relatively large deflation surfaces between.

Some of the larger mosses, *Drepanocladus uncinatus, Oncophorus wahlenbergii* and *Tomentypnum nitens* also occur regularly, as does the lichen *Cetraria islandica.*

The pH value is 6.6 and the content of humus is 12.2 %.

Stand 27, 46–50. North coast, Woodfjorden, Reinsdyrflya, 6/8 1960. The locality lies about 3 km north of Worsleyhamna, and in its main features resembles No. 26. The analysis was made on an old beach ridge of gravel and stone. It is probable that the snow protection is rather better than in No. 26, but here too the community is found best developed near the top of the ridge. The soil section shows a thin upper layer of slightly decomposed leaf and moss remains, and below this about 5 cm of sand with a strong admixture of particles of humus.

The community diverges floristically in that *Carex misandra* is much in evidence in quadrates 2 and 3, and that *Saxifraga oppositifolia* has regularly a degree of cover from 1 to 3. There is also a relatively strong element of lichens, particularly *Cetraria islandica* and *C. nivalis.*

The pH value is 7.1 and the humus content is relatively high, 24 %.

Stand 31, 51–55. North coast, Woodfjorden, Reinsdyrflya, 8/8 1960. The locality lies on the ridges above Worsleyhamna. The analyses were taken from a wind-exposed slope of coarse gravel strongly affected by frost. The vegetation is very scattered with large open spaces between. The soil section shows about 10 cm of black soil mixed with humus, and below this stone and gravel, presumably rock sandstone broken up by frost. Floristically the community shows only slight differences from the others. The moss flora shows a marked divergence in the comparatively small number of species that occur. The lichen flora shows a regular occurrence of *Cetraria islandica* and *C. delisei.* This indicates a small but adequate layer of snow in winter.

The pH is 6.7 and the content of humus is very high, 36 %, which is the greatest found in any soil test in this association.

Stand 32, 56–65. North coast, Woodfjorden, Reinsdyrflya, 8/8 1960. The locality lies about 2 km east of Worsleyhamna on a ridge running from north to south. Here, too, the vegetation is split up, with fairly large patches devoid of vegetation, especially where there has been frost action. The community shows a relatively high content of hygrophilous plants, such as *Cerastium arcticum, Oxyria digyna, Saxifraga cernua* and *S. oppositifolia.* Square No. 61 must also be noticed, as *Papaver dahlianum* occurs there with a degree of cover of 4. The hygrophilous plants together with the comparatively high content of mosses and lichens indicate the locality has quite a good supply of moisture during the summer, while the snow cover in winter is enough to afford some protection.

The soil section shows, uppermost, 10 to 12 cm of relatively tightly-packed and slightly decomposed humus, below with some sand, gravel and stone without any stratification.

The pH value is 7.4 and the content of humus is 18 %.

Stand 35, 66–70. North coast, Reinsdyrflya, south-eastern headland, 9/8 1960.

The locality lies 1 km east of Worsleyhamna, out on the headland. The plant community is found on the highest parts of the ridges. The subsoil is a relatively coarse gravel strongly affected by the action of frost and thaw. Where the terrain drops a little, *Dryas octopetala* rapidly vanishes and we get a community dominated mainly by *Salix polaris* and *Saxifraga oppositifolia* alone. There is distinctly more moisture here, probably because the drainage is so poor that water stands in the subsoil almost up to the surface. The result is that the effects of thaw and frost are powerful.

The vegetation is very much split up with large open spaces between. *Dryas octopetala* in particular is thickly covered with crustaceous lichens such as *Ochrolechia frigida* and *Lecanora epibryon*. The many crustaceous lichens can give the community a typical grey colour.

The pH is 6.7, very near the mean for the association, and the humus content is 28.0 %.

Stand 13, 71–75. Isfjorden, Billefjorden, Brucebyen, 2/8 1958.

The analysis was taken along the edge of the beach ridge east of the old houses. The vegetation here is very scattered. On the upper ridges, very exposed to the wind, are to be found places where *Dryas octopetala* is the only higher plant. It is the only one which manages to resist the powerful wind. The tussocks lie as far as possible in the lee of the strong katabatic winds which must be assumed to come from the nearby glaciers. Further down the slope this plant community changes to another in which *Cassiope tetragona* dominates (stand 14) and here it is mainly the thickness of the snow cover which is decisive. From a floristic point of view this plant community shows a transition from *Rupestri-Dryadetum* to *Polari-Dryadetum*.

No soil sample is available from this stand.

Association: *Tetragono-Dryadetum*

In the foregoing discussion of the various associations an attempt has been made to arrange them in ascending order of their requirements of moisture in the subsoil and thickness of snow cover in winter. The *Dryadion* association which of them all has the highest requirement of these ecological factors is *Tetragono-Dryadetum*.

This differs from the other associations in the first place in that *Cassiope tetragona* ranks with *Dryas octopetala* as the absolute dominant species. The association diverges floristically in the relatively frequent occurrence of such species as *Equisetum variegatum, Pedicularis dasyantha, Poa arctica* and *Stellaria crassipes*. These species may also be regarded as differential species with respect to the other associations. Altogether 33 species of higher plants are found represented in this association. The number of species in the various quadrates varies greatly, from 7 to 23.

Other special features which result from the more even supply of moisture are,

first, the relatively rich moss flora, and second, the far more modest lichen flora. Althogether in these analyses there have been found 23 species of mosses, while lichens are represented only by 13. For *Polari-Dryadetum* the corresponding figures are 21 and 18, and for *Rupestri-Dryadetum* 17 and 11. With regard to the dominant species of mosses, however, there is little difference, inasmuch as *Hylocomium splendens, Dicranum majus, Oncophorus wahlenbergii, Tomentypnum nitens,* etc., occur quite commonly here too. A minor but characteristic feature is the appearance of some species of liverworts, of which *Blepharostoma trichophyllum* and *Ptilidium ciliare* are commonest.

The total number of species in this association is on the whole less than in *Polari-Dryadetum.* The association therefore shows a rather more uniform composition than the other associations.

Altogether 45 quadrates from 9 different stands have been analysed in this association. All the stands show a marked dominance of *Dryas octopetala* and *Cassiope tetragona,* but in seven of them *Salix polaris* is also constant. The last three stands, Nos. 4, 14 and 18 also show a noticeable occurrence of *Carex rupestris,* sometimes with a regular degree of cover from 1 to 3. These three analyses show that there are to be found sociological transitions between *Rupestri-Dryadetum* and *Tetragono-Dryadetum,* and that these two associations may merge directly into each other, without having *Polari-Dryadetum* as an intermediate stage. My reason for assigning these three stands (4, 14 and 18) to *Tetragono-Dryadetum* is the very powerful dominance of *Cassiope tetragona.*

Tetragono-Dryadetum is dependent on an even supply of moisture throughout the greater part of the period of growth. The effect of wind erosion seems to be a particularly important factor in the development of stands of *Cassiope tetragona.* Because of its ecological requirements this community is never found developed on the top of ridges, old moraines, beaches, etc., but usually down the slopes in the lee of the prevailing wind. The greatest distribution of the community is to be found in the inner fjord areas. It is never found, for instance, in such an extremely wind-exposed area as Reinsdyrflya on the north coast, but is quite common not far away in the more sheltered fjords.

Where there is too much moisture in the soil, and where the spring thaw comes too late, this community can show transitional stages to those in which *Dryas* occurs either sparsely or not at all. Such localities are to be found near steep slopes or on the lee side of a mountain precipice. It must be presumed that the deciding factors are the length of the growing period of *Dryas octopetala.* Another special feature of *Tetragono-Dryadetum* is that the community grows so thickly that, in comparison with the other associations, insignificantly little bare ground is to be seen. In this respect it differs distinctly from the other associations considered here. Another consequence is that the community as a whole is strongly tinged by the dark green and brown colours of *Cassiope tetragona,* and is easily distinguished in the landscape, where it forms characteristic brown belts on the slopes.

The degree of acidity of the subsoil varies among the eight measured stands from 5.4 to 7.3, with a mean of 6.6, which is the lowest pH value of these four associations. The humus content also varies widely, from 1.2 % in No. 18 to 53 % in No. 34, with a mean of 23.1 %. This shows that it is primarily in *Tetra-*

gono-Dryadetum that a significant stratum of humus is formed, but further that the rich supply of humus is a secondary phenomenon which does not condition the development of the community, but results from it.

Of all the associations in Svalbard, *Tetragono-Dryadetum* is the one which shows closest agreement with the corresponding associations in Scandinavia, Greenland and other arctic and alpine regions.

Description of the analysed stands in Table 4.

Stand 1, 1–5. Isfjorden, Kapp Wijk, 17/7 1958.

The locality lies on the south side of the headland, near the lagoon. The vegetation here is relatively continuous, very hummocky, but with depressions between. *Cassiope tetragona* and *Dryas octopetala* occur especially on the top and side of these tussocks. The locality itself is fairly sheltered on a slope where there is presumably considerable snow cover in winter. It should be noticed that such a moisture-loving species as *Juncus biglumis* occurs in four of the five quadrates, but always down in the hollows where ground water has more influence than in the tussocks. The pronounced unevenness of the ground is presumably brought about by the effect of the thaw combined with the surface water remains standing during the melting of the snow in spring.

Taken on the whole the cryptogam vegetation shows a distinctly greater occurrence of mosses. All the larger mosses are quite common here. Lichens, however, are far more limited.

The soil section shows 3 cm of dense raw humus on top, then 10 cm of a dark mixture of sand and humus, and then 13 cm of beach gravel, below which is frozen earth. The digging was carried out along the edge of a hillock, in a relatively flat place with average conditions.

The pH value of the soil is 7.0, while the humus content is 13.4 %.

Stand 6, 6–10. Isfjorden, Colesbukta, 19/7 1958.

This locality lies on the west side of the bay, near the edge of an old beach about 10 metres above sea level. The vegetation on the beach itself is fairly continuous, but near the edge and on the slope down to the present beach it is broken up and appears in patches.

Floristically this community shows certain divergent features from the others in the association. The fact that *Alopecurus alpinus* is evenly distributed would seem to indicate a quite moist subsoil, as do also *Pedicularis hirsuta*, *Polygonum viviparum* and *Ranunculus sulphureus*. The absence of *Saxifraga oppositifolia* from this company is more difficult to understand. The moss flora, too, has certain peculiarities, in particular the occurrence of *Aulacomnium turgidum*.

In typical places the soil section shows about 8 cm of densely matted roots on top, then 11 cm of a humus-coloured mixture of sand and humus, below is old beach gravel in which stone and sand are mixed. Permafrost was found at a depth of 25 cm.

The soil test shows a pH value of 5.4, the lowest value for *Dryadion* that has been found in Svalbard. The content of humus is rather below average, 12.4 %.

Stand 10, 11–15. Isfjorden, Gipsvika, 29/7 1958.

This locality is near the head of the fjord on the north side. The vegetation is

quite dense and occurs on the lee side of a projecting crag, where the snow protection is good. The community has the floristic peculiarity that *Salix polaris* is completely lacking whereas *Carex misandra* is well represented.

The cryptogam flora also shows close similarity to the other analyses.

The small number of species is a special feature of this community. Unfortunately no soil sample is available.

Stand 17, 16–20. North coast, Woodfjorden, Jakobsenbukta, 12/8 1958.

This locality lies at the innermost end of the bay on the north side of the valley. The vegetation appears on slopes facing south, and here too it grows in patches and strips with bare scree gravel between. The subsoil is fine gravel and sand, and is to some extent unstable.

Besides the two dominant species, both *Salix polaris* and *Minuartia biflora* occur regularly. The presence of *Trisetum spicatum* is remarkable.

The moss flora is quite plentiful.

The soil test shows a pH value of 6.5. The humus content is only 15 %.

Stand 33, 21–25. Isfjorden, Skansbukta, 16/8 1960.

This locality is on the east side of the bay above the old mines. The vegetation is relatively dense and well developed. Mentioned must be the plentiful occurrence of *Poa arctica* and *Polygonum viviparum*. These species, together with *Pedicularis dasyantha*, *Ranunculus sulphureus* and *Saxifraga oppositifolia* indicate a fairly moist subsoil throughout the summer.

The moss vegetation here is very strongly developed. The lichen flora, on the other hand, is little developed. The soil section shows a top layer of about 15 cm of humus and slightly decomposed plant remains, then 8 to 10 cm of a mixture of humus and sand, and below this the underlying old beach gravel. The soil was very wet at the lowest level, and it may be that there is a slight trickle of water along the layer of frozen earth.

The pH value of the subsoil is 7.1, which is relatively high for the association. The humus content is 40 %.

Stand 34, 26–30. Isfjorden, Skansbukta, 16/8 1960.

The locality lies on the south-west side of the bay. Here, too, the vegetation is dense and continuous without open spaces, and relatively rich in mosses.

Besides the dominant species, *Saxifraga nivalis*, *Pedicularis dasyantha* and *Stellaria crassipes* occur more or less regularly.

The moss flora is abundant and particularly *Hylocomium splendens* and *Tomentypnum nitens* are common.

The lichen flora is also relatively rich.

The soil section shows close similarity to No. 33 above, with an upper layer of slightly decomposed plant remains, and then a layer of humus extending down to the underlying old beach gravel. The soil test shows a pH value of 6.6, which is the same as the mean for the association. The humus content is very high, 53 %, the highest that has been found in *Dryadion* in Svalbard.

Stand 4, 31–35. Isfjorden, Kapp Wærn, 12/7 1958.

The locality lies on the west and north-west side of the peninsula. The vegetation is on the whole continuous and covers the ground completely.

A special feature is the relatively rich occurrence of *Carex rupestris*. It shows

that this community, together with the following two stands, Nos. 14 and 18, occupies a transitional place between *Tetragono-Dryadetum* and *Rupestri-Dryadetum*.

Here again the moss vegetation is rich, and *Drepanocladus uncinatus*, *Hypnum bambergeri*, *Oncophorus wahlenbergii* and *Tomentypnum nitens* are regularly present.

There are many fruticose lichens represented.

The soil section shows about 5 cm of tomentum at the top, then a layer of 15 cm of humus down to coarse stone and gravel. The pH value of the soil is 6.7 and the content of humus is 34 %.

Stand 14, 36–40. Isfjorden, Billefjorden, Brucebyen, 1/8 1958.

This locality is situated near No. 13, which belongs to *Polari-Dryadetum*, buth rather lower and better protected by snow.

The same dwarf shrub species are dominant, and *Carex rupestris* here shows an even greater degree of dominance than in No. 4. A special feature here is the occurrence of *Equisetum variegatum*.

The moss vegetation here is on the whole less well developed than usual.

The lichen flora is also very meagre.

The soil section shows a top layer of about 7 cm of dead plants slightly decomposed, then 11 cm of a mixture of fine sand and humus, and below this the old beach ridge.

The soil sample shows that the pH value is 7.3 and the content of humus 15.9 %.

Stand 18, 41–45. North coast, Woodfjorden, Bockfjorden, near Jotunkjeldane, 13/8 1958.

The analysed community is found on a slope facing north-east, 20 to 30 metres above sea level. The vegetation is on the whole continuous, although some open spaces are to be found. Not far from this locality are the warm springs, Jotunkjeldane, where in the course of time great quantities of lime and silicates have been precipitated.

The composition of the vegetation indicates a sheltered and not particularly moist locality. The moss flora is quite plentiful, including *Aulacomnium turgidum*.

The community is relatively poor in lichens.

The soil section shows a top layer, 2 or 3 cm thick, of dead plant remains, etc. Below this come about 16 cm of fine sand and then rock or stone. It is probable that this sand is at least partly brought by the wind.

The soil sample shows pH 6.4. The content of humus is very low, 1.2 %. This low humus content may be due to the fact that organic ingredients are blown away by the wind, and the strikingly high degree of sand drift would seem to confirm this.

In Table 5 a survey is given for the associations within the alliance Dryadion.

Dryas communities in other arctic or sub-arctic regions

The material available for comparing the *Dryas* communities of Svalbard with those of other arctic regions is very heterogeneous. There are several reasons for this. In the first place, not all the areas round the pole are equally well-known from a botanical viewpoint. Secondly, the methods normally used by Scandinavian and Central European phytosociologists have not been adopted in certain areas, e.g. in Canada and to some extent in Russia. The consequence is that the available information on *Dryas* vegetation does not permit direct comparison. It must also be born in mind that the species which forms the principal component of *Dryas* communities is not the same all over the vast arctic and sub-arctic area.

The two species which, independently of each other, constitute the main association-forming factor in *Dryadion* are *Dryas integrifolia* and *D. octopetala* s.l., and these two are also the indispensable basis of the development of the communities, and there seems to be no great differences in their ecology.

Historically, both species are very old and can probably be traced back to a tertiary origin, and both, from a systematic viewpoint, are quite difficult to deal with, as they consist of a series of subspecies, varieties and forms. Several of these have been regarded as distinct species (JUZEPCZUK 1929, PORSILD 1947).

My own experience of *Dryas* is limited to Scandinavia, Iceland and Svalbard, where the common species *Dryas octopetala* is well known to be extremely variable. Even so, it is difficult to follow the wide-ranging division made, for instance by JUZEPCZUK (l.c.) and PORSILD (l.c.), and extremely difficult to understand the reason for this division. A rather more lucid and, in my opinion, better system is found in HULTÉN's work (1959). The genus *Dryas* is here regarded as consisting of four species, viz. *Dryas octopetala*, *D. integrifolia*, *D. drummondii* and *D. grandis*.

Of these accepted species it is *Dryas octopetala* and *D. integrifolia* that are of significance for the work presented here. Both are very variable and occur in several forms. *D. octopetala* in particular has in the course of time caused many taxonomic difficulties. In fact, what is here regarded as one species has been subdivided into more than 20 (HULTÉN 1959). In HULTÉN's work *D. octopetala* is mentioned as having 6 subspecies and 4 varieties, which jointly occupy a large circumpolar area. This extends over East Greenland, Scandinavia and Arctic Russia to the eastern parts of Alaska. The form which occurs in Svalbard is regarded as *D. octopetala* subsp. *octopetala* HULT., which is the same form as in Scandinavia, Iceland and eastern Greenland.

Dryas integrifolia is divided by HULTÉN into two subspecies and one variety. This species is distributed over the greater part of northern Canada and Alaska, and in western Greenland. In eastern Greenland both species occur, and hybrids between them are also found.

One of the first to appreciate the phytosociological position of the arctic *Dryas* communities was STEFFEN (1928) who, in his paper on the flora and phytogeography of Novaya Zemlja and Kolguyev, wrote as follows: "Der durch die folgende Zusammenstellung dargestellten Pflanzengesellschaften kommt, soweit ich es

nach meinen Beobachtungen beurteilen kann, der Rang einen Formation zu, innerhalb deren bei näherem Studium wohl mehrere Assoziationen unterscheiden lassen."

Thus STEFFEN has clearly seen the unity of the arctic *Dryas* communities and the justification for separating out units with the rank of association. His use of the word "Formation" also appears to approximate closely to what is here referred to as "Alliance".

It must be emphasized that STEFFEN was thinking primarily of what he calls "Steinige Tundra", but the description of the localities and the table which he publishes (l.c. p. 353) prove to agree closely with the plant communities here brought together under the designation *"Dryadion"*.

Scandinavia

In Scandinavia, as already mentioned, efforts have been going on for a long time to reach a more detailed subdivision of the alpine plant communities. In 1928 NORDHAGEN separated out a series of floristic alliances (floristische Verbände) in which the *Dryas* communities were clearly distinguished from the more commonplace *Empetrum-Ericaceae-Betula nana* dwarf shrub communities. The more precise division into sociological units of lower rank than alliances may be said to begin in 1936 with NORDHAGEN's paper "Versuch einer neuen Einteilung der subalpinen-alpinen Vegetation Norwegens".

Here NORDHAGEN lists 10 sociations which are dominated by the species *Dryas octopetala*, *Carex nardina*, *C. rupestris*, *Cassiope tetragona*, *Kobresia myosuroides* and *Rhododendron lapponicum*. Besides these, one species, *Arctostaphylos uva-ursi* is dominant in one sociation together with *Carex rupestris* and *Dryas octopetala*. These ten sociations may be naturally grouped into four units of higher order (associations).

Of NORDHAGEN's sociations, No. I is dominated by *Carex nardina*, and must be assigned to what NORDHAGEN (1955) calls the *Caricetum nardinae* association. Nos. II and VII are partly dominated by *Kobresia myosuroides* and must be assigned to *Kobresietum myosuroides*, Nos. III, IV a and b, V, VI, IX and X to *Dryadetum octopetalae*, and sociation No. VIII to *Cassiopetum tetragonae dryadetosum*. This grouping corresponds to that made later by NORDHAGEN (1955) in his treatment of the northern Scandinavian associations in the alliance *Dryadion* (*Kobresieto-Dryadion* according to NORDHAGEN).

In the *Caricetum nardinae* of NORDHAGEN, *Carex nardina* and *C. rupestris* dominate together with *Dryas octopetala*, *Oxytropis lapponica*, *Saxifraga oppositifolia* and others. The community is open and occurs especially on ridges exposed to the wind with little or no snow cover in winter.

In Scandinavia *Kobresietum myosuroides* is more widespread than *Caricetum nardinae*. It is dominated mainly by *Kobresia myosuroides*, *Festuca ovina* and *Salix reticulata* together with *Dryas octopetala*, though the latter may, in some localities, be quite rare or completely absent. In Scandinavian phytosociology the placing of this association seems to be a vexed question (HEDBERG 1952, NORDHAGEN 1955,

BRINGER 1961), but it would nevertheless appear to be correct to preserve it as a separate association.

Cassiopetum tetragonae dryadetosum is dominated by species of dwarf bushes, *Dryas octopetala*, *Cassiope tetragona* and also *Empetrum hermaphroditum*, *Salix polaris* and *Vaccinium uliginosum*. The community requires snow cover in winter and forms humus.

Dryadetum octopetala is distinguished by the absence of *Kobresia myosuroides* and *Cassiope tetragona*. The chief dominant species, apart from *Dryas octopetala*, are *Carex rupestris*, *Salix reticulata*, *Vaccinium uliginosum* etc. But the association includes a number of phytosociological units (sociations) of lower order, and embraces communities both in dry wind-swept places and more sheltered localities.

DU RIETZ (1942, 1950) divides the alliance into two sub-alliances, viz. *Nardino-Dryadion* and *Tetragono-Dryadion*. HEDBERG (1952) carries this classification a stage further by rating DU RIETZ's two sub-alliances as associations, together with a new third one, *Tomentypno-Dryadetum*.

KALLIOLA (1939) mentions the northern Finnish *Dryadion* (*Dryadion octopetalae* according to KALLIOLA) and divides the north Finnish *Dryas* communities into three sociations, viz. the *Dryas* sociation rich in species (Artenreiche *Dryas*-Soz.), *Carex rupestris* sociation rich in lichens (Flechtenreiche *Carex rupestris*-Soz.) and the *Dryas-Alectoria-Cetraria nivalis* sociation. This classification seems suitable for the continental parts of northern Scandinavia.

A detailed investigation of the differentiation of *Dryadion* in the Torneträsk area has recently been carried out by BRINGER (1961). He distinguishes the following five associations:

Epibryo-Dryadetum has as its principal dominants *Dryas octopetala* and *Carex rupestris* together with *Carex nardina*, *C. glacialis*, *Festuca ovina* and others. This association is found especially on wind-swept ridges.

Tetragono-Dryadetum is dominated by *Dryas octopetala*, *Vaccinium uliginosum*, *Empetrum hermaphroditum*, *Cassiope tetragona* and *Rhododendron lapponicum*. This association requires a certain degree of snow protection.

Tomentypno-Dryadetum is dominated mainly by *Dryas octopetala* together with a number of mosses. The chief difference from *Tetragono-Dryadetum* is that the dominant heather species disappear. This association is prevalent on permanently moist ground.

Bifloro-Dryadetum occurs in damp localities that border on the pure snowpatch communities. This association is dominated by *Dryas octopetala* and *Viola biflora* together with *Selaginella selaginoides*, *Parnassia palustris* a.o.

Arctostaphyleto-Dryadetum is a very open community on scree slopes. *Dryas octopetala* dominates, together with *Carex rupestris* and *Arctostaphylos uva-ursi* in some stands.

Of the works that have been mentioned here, two are of special importance, viz. NORDHAGEN (1955) and BRINGER (1961). Both make classifications of the alliance in northern Scandinavian regions, and both pay attention to the prevailing ecological conditions such as the thickness of snow cover, dampness of the subsoil, and the exposure of the locality to wind. An attempt to correlate

NORDHAGEN's classification with BRINGER's reveals the following points of agreement: BRINGER's *Epibryo-Dryadetum* may be compared to two of NORDHAGEN's associations, *Caricetum nardinae* and *Kobresietum myosuroidis*. BRINGER here appears to interpret the concept of an association rather more widely than NORDHAGEN does. He appears to pay more attention to species of lichen, especially micro-lichens, than NORDHAGEN does. This, together with the fact that *Kobresia* appears to be rare in the area investigated by BRINGER, leads one to support NORDHAGEN's classification. In that case, BRINGER's *Epibryo-Dryadetum* must be divided into NORDHAGEN's *Caricetum nardinae* and *Kobresietum myosuroidis*. Between the associations *Tetragono-Dryadetum* (BRINGER) and *Cassiopetum tetragonae dryadetum* (NORDHAGEN) there appears to be good agreement.

Likewise between the two associations *Tomentypno-Dryadetum typicum* (BRINGER) and *Dryadetum octopetalae* (NORDHAGEN) there exists quite a high degree of agreement.

It is more difficult to place the moisture-loving community *Bifloro-Dryadetum* (BRINGER). At least in the Torneträsk area it must be regarded as a transitional stage between *Dryadion* and the snow patch community *Reticulato-Poion alpinae* (GJÆREVOLL 1956).

It is my opinion after studying also the North-Norwegian *Dryas* communities that the classification which comes nearest to the truth is NORDHAGEN's. At the same time it is the easiest to compare with the *Dryas* communities found in Svalbard.

In making such a comparison it is quite essential to bear in mind the difference in latitude and the number of species in Scandinavia and Svalbard, and also that common species in Svalbard may be among the rarest in Scandinavia.

Caricetum nardinae (NORDHAGEN 1955) can be compared directly with the Svalbard community which I have described as *Nardino-Dryadetum*.

If these two *Dryas* communities are compared, it is seen that the dominant species in Scandinavia are *Dryas octopetala*, *Carex nardina*, *C. rupestris*, *Kobresia myosuroides*, *Festuca ovina*, *Saxifraga oppositifolia*, *Silene acaulis*, and *Salix reticulata*. In Svalbard the chief dominants are *Dryas octopetala*, *Carex nardina*, *Saxifraga oppositifolia* and *Salix polaris*.

It will be observed that there is a high degree of agreement here both floristically and ecologically.

Kobresietum myosuroidis (NORDHAGEN 1955) cannot be directly compared with any plant community in Svalbard. It displays certain floristic similarities to *Rupestri-Dryadetum*. Even if these are not very pronounced, it is still possible that *Rupestri-Dryadetum* can be interpreted as an arctic formation of *Kobresietum myosuroidis*.

Cassiopetum tetragonae dryadetosum (NORDHAGEN 1955) is a parallel to the *Tetragono-Dryadetum* of Svalbard. But in fact the dominance of *Dryas octopetala* and *Cassiope tetragona* is so strong that the selection of accompanying species is relatively accidental.

The last association, *Dryadetum octopetalae* (NORDHAGEN 1955), consists of several sociations or facies of lower rank. At the association level it is natural to compare it with *Polari-Dryadetum*. In *Dryadetum octopetalae* the dominant

species are *Dryas octopetala*, *Salix reticulata*, *Vaccinium uliginosum*, *Carex rupestris*, *Festuca ovina*, *Polygonum viviparum*, *Saxifraga oppositifolia*, and *Silene acaulis*. In *Polari-Dryadetum*, *Dryas octopetala* and *Salix polaris* dominate, and other important species are *Cerastium arcticum*, *Oxyria digyna*, *Papaver dahlianum*, *Polygonum viviparum*, *Saxifraga oppositifolia*, and *Silene acaulis*. These species show that the community has many features in common with *Dryadion octopetalae* in Scandinavia.

The similarity between the two communities is further emphasized if one thinks that *Salix reticulata* in *Dryadetum octopetalae* physiognomically replaces *Salix polaris*.

There is nevertheless a tendency for *Polari-Dryadetum* to require more moisture in the soil than does *Dryadetum octopetalae* in Scandinavia. Species such as *Oxyria digyna*, *Pedicularis hirsuta* and *Cerastium arcticum* suggest this. It is probably most correct to place *Polari-Dryadetum* as an arctic equivalent of *Dryadetum octopetalae* as described from Scandinavia.

The great similarities to be found between Scandinavian mountain flora and the flora of Svalbard, make the likeness that can be demonstrated between the various associations of the alliance *Dryadion*, not unexpected.

Novaya Zemlya, Arctic Russia and Arctic Siberia

In many ways it is difficult to compare the vegetation of Svalbard with that farther east in Novaya Zemlya, Arctic Russia and Siberia. This is both because of the lack of directly comparable investigations and because a great part of the literature on the subject is little accessible on account of the language barrier.

A survey of the distribution of the vegetation in the arctic tundra was made by ALEXANDROVA (1960). This deals principally with conditions in Novaya Zemlya. What ALEXANDROVA (l.c.) calls *Dryas*-tundra with *Dryas octopetala* is presumably a special form of "the polar desert". The *Dryas* communities are also markedly confined to dry localities, and with the relatively large distribution which *Dryas octopetala* has in Novaya Zemlya (LYNGE 1928) there seems good reason to suppose that *Dryadion* likewise is widespread. One gets the same impression from studying TIKHOMIROV (1957) whose ecological investigations of "spotted tundras" in arctic regions reveal *Dryas* communities of the same type as in Svalbard. These investigations further suggest that this type of vegetation is spread throughout the arctic regions of Russia and Siberia. The plants that are mentioned as typical of dry localities include *Dryas octopetala* (*D. punctata* according to TIKHOMIROV), *Potentilla emarginata*, *Saxifraga oppositifolia*, *Papaver radicatum* and several species of *Draba*.

STEFFEN (1928) gives a survey of some aspects of the flora of Novaya Zemlya, Vaigach and Kolguyev, mentioning *Dryas octopetala* as the only species whose mats cover relatively large areas. He also points out (p. 313) that *Carex rupestris* is commonly found together with *Dryas octopetala*.

The type of vegetation which is easiest to compare with conditions in Svalbard is what STEFFEN calls "Die steinige Tundra". The vegetation cover is not closed, but has large open spaces between. It occurs in wind-swept places. STEFFEN

compiles lists of plants (p. 350) showing the species on the stony tundra from 10 different localities, and on the basis of these lists the following species can be regarded as constant for this community: *Dryas octopetala*, *Draba alpina*, *Luzula confusa*, *Papaver radicatum*, *Poa arctica*, *Saxifraga caespitosa*, *S. oppositifolia*, *Salix arctica*, and *Artemisia borealis*. The last two are not found in Svalbard, but all the others are common species there and important plants in *Dryadion*. Besides these, mention must be made of the following species which in STEFFEN's tables occur in half the localities: *Carex rupestris*, *Cerastium regelii* and *Potentilla emarginata* (= *P. hyparctica*). It is probable that from the tables published by STEFFEN it would be possible to pick out the two associations presumably corresponding to *Rupestri-Dryadetum* and *Polari-Dryadetum* in Svalbard. Neither *Carex nardina* nor *Cassiope tetragona* is found in Novaya Zemlya.

KOROTKEVICH (1958), in his description of the vegetation of Severnaya Zemlya, characterizes it as belonging to the "arctic deserts". No continuous plant cover is found, the vegetation being in strips, and if we take the term "arctic (or polar) desert" in the sense in which it is normally employed by Russian botanists this would seem to mean that communities including *Dryas octopetala* are found also in Severnaya Zemlya.

A more general description of the flora of the north coast of Siberia is given by KJELLMAN (1882 a and b). He refers to *Dryas octopetala* as common in "blomstermark" (flower fields) and mentions as typical species for this type of vegetation: *Dryas octopetala*, *Salix polaris*, *S. reticulata*, *S. arctica*, etc. and *Poa cenisea* (= *P. arctica*). Here again the vegetation is not continuous, but split up by larger or smaller patches of bare soil.

POLUNIN (1960) also emphasizes the wide distribution of these arctic heathlands.

On the whole it must be regarded as certain that *Dryas* communities corresponding to those in Svalbard are also found on the arctic islands and in the arctic areas of Russia and Siberia. Communities which resemble *Rupestri-Dryadetum* and *Polari-Dryadetum* appear to be most widely spread.

Arctic North America

Alaska. A number of plant communities from Alaska are described in the works of HANSON (1951, 1953). It is difficult to obtain a clear impression of these communities from these investigations. Both *Dryas octopetala* and *D. integrifolia* occur in the Alaskan *Dryas* communities. A community which appears to show some similarity to Scandinavian *Dryas* communities is *Dryas octopetala-Kobresia myosuroides-Hedysarum alpinum americanum* – community of HANSEN (1951).

Better comparisons are however afforded by HANSON (1953). He mentions three *Dryas* communities. The first, "Four-angled heather-blueberry type", is dominated by the species *Dryas octopetala* and *Cassiope tetragona*, together with *Vaccinium uliginosum*, *Empetrum nigrum*, *Salix reticulata*, and others. The resemblance to *Tetragono-Dryadetum* in Svalbard is great.

An interesting feature is the occurrence of *Salix reticulata* in the "Four-angled heather-blueberry type" community. It occurs with a frequency of 90 %. This species is not very common in Svalbard and appears only rarely in *Dryadion*.

In Scandinavia, on the other hand, it shows quite a wide ecological amplitude. It occurs both in *"Kobresieto-Dryadion"* (NORDHAGEN 1943) and in very wind-swept places in the association *"Caricetum nardinae"*. Further, it is also found in wet snow patches on calciferous ground in the alliance *"Reticulato-Poion alpinae"* in the association *Salicetum reticulatae* (GJÆREVOLL 1956).

The other species in the two communities from Alaska and Svalbard are quite different, which is only to be expected.

The other two *Dryas* communities mentioned by HANSON (1953), "Alpine *Dryas* type" and "Alpine sedge-alpine *Dryas* type", are in my opinion so much alike in their composition that they can be taken under one heading here. They are mainly dominated by *Dryas octopetala*, *Salix chamissonis*, *Ledum decumbens*, *Agrostis borealis*, *Hierochloë alpina*, *Luzula confusa*, and *Poa arctica*. The last two occur especially at higher levels. This community bears some resemblance to *Polari-Dryadetum* in Svalbard, even though it contains rather fewer grasses and sedges. In the "Alpine *Dryas* type" the occurrence of *Salix chamissonis* does not seem to match those of *Salix polaris* in Svalbard.

SPETZMAN (1959) makes a survey of certain important plant communities in the arctic of Alaska. The classification is based on ecological principles and named according to the topographical conditions where the association chiefly occurs.

Plant communities that can be assigned to the alliance *Dryadion* are found here on high ridges with a thin layer of topsoil and well drained subsoil, e.g. on sand dunes and dry terraces.

The number of species that are represented in *Dryadion* in North Alaska appears much larger than in corresponding localities in Svalbard, but species as *Carex misandra*, *C. rupestris*, *Salix reticulata*, *Pedicularis lanata*, *Polygonum viviparum*, *Saxifraga oppositifolia*, *Silene acaulis*, etc. show clearly the kinship of the communities.

A rather more detailed survey is found in GJÆREVOLL's work *"Kobresieto-Dryadion* in Alaska" (GJÆREVOLL 1954). The analyses were carried out by the methods used in Scandinavia, which were also applied in the present work, so that the results are easier to compare.

GJÆREVOLL distinguished four separate sociations in the alliance *Kobresieto-Dryadion*, viz. *Dryas punctata*-soc., *Carex glacialis*-soc., *Kobresia simpliciuscula*-soc. and *Carex franklinii*-soc. GJÆREVOLL's sociations as they are arranged in his table (p. 54) are immediately comparable with the associations that are set up for the *Dryadion* of Svalbard. Of these sociations there is one, maybe two, that can be likened to associations from Svalbard.

Dryas punctata-soc. shows agreement with *Polari-Dryadetum*, but the rather great occurrence of *Carex rupestris* is a striking difference.

It is more difficult to compare *Rupestri-Dryadetum* with any of the sociations in *Dryadion* described from Alaska. *Carex rupestris* occurs there, too, but does not dominate any *Dryas* community as it does in Svalbard. On the other hand, several species of *Carex*, especially *C. glacialis* and *C. scirpoidea*, seem able to form with *Dryas punctata* communities physiognomically similar to *Rupestri-Dryadetum*. In Alaska *C. rupestris* occurs in *Carex glacialis*-soc. in four quadrates in one of the analysed stands, and in *Kobresia simpliciuscula*-soc. it occurs in from

2 to 4 quadrates in three of the four analysed stands. Were we to base our comparison only on *C. rupestris*, *Rupestri-Dryadetum* would most nearly resemble *Kobresia simpliciuscula*-soc. But the content of *Carex* species in *Carex glacialis*-soc. appears to be rather more prominent, so that when these species are viewed collectively this sociation seems to stand closer to *Rupestri-Dryadetum*. I would suppose, however, that neither of these sociations can be directly equated with *Rupestri-Dryadetum*.

To the other two sociations described by GJÆREVOLL no parallels can be found in Svalbard. Of the dominant species here, *Kobresia simpliciuscula* and *Carex franklinii*, the former is very rare in Svalbard, while the other is a North American species which is not found anywhere in Europe.

GJÆREVOLL's investigations (1954) show that there is a certain connection between the *Dryas* communities of Alaska and those of Svalbard. There are, of course, considerable differences because of the species that are represented. The number of species in the central regions of Alaska is, moreover, much greater than in Svalbard.

Canadian Arctic. POLUNIN (1948), in his paper on the vegetation and ecology of the eastern arctic part of Canada, makes some valuable contributions to the understanding of the vegetation of this area. No detailed analysis results are presented in his work, but there are lists of plants showing the frequency of each species. In the northernmost district, Ellesmere Island, Devon Island, Baffin Island, etc., communities with *Dryas integrifolia*, *Cassiope tetragona*, *Carex nardina*, *C. rupestris*, *Saxifraga oppositifolia* and *Salix arctica* are not uncommon. POLUNIN states that the localities are chiefly wind-swept ridges and beach ridges with stone and gravel. If the snow cover is rather greater, communities dominated by *Cassiope tetragona* and *Dryas integrifolia* occur instead.

In several places, e.g. on Devon Island (Dundas Harbour), northern Baffin (Arctic Bay), southern Baffin (Lake Harbour), there are found communities having *Dryas integrifolia*, *Carex rupestris* and *C. nardina* together with several other species, which show a strong affinity to the Svalbard communities. Whether the similarity is greatest to *Nardino-Dryadetum* or to *Rupestri-Dryadetum* in Svalbard is difficult to decide. However, judging from POLUNIN's plant lists several communities must be compared with *Nardino-Dryadetum*, e.g. those described from Ellesmere Island (Craig Harbour), northern Baffin (Arctic Bay), southern Baffin (Cape Dorset), northernmost Labrador (Port Burwell).

Similarly is found for *Rupestri-Dryadetum*. These communities will be very much like *Nardino-Dryadetum* floristically, but with the notable absence of *Carex nardina*. Communities comparable to *Rupestri-Dryadetum* have been described by POLUNIN from southern Baffin (Lake Harbour), and northern Quebec (Wakeham Bay). Important species in such communities are *Dryas integrifolia*, *Carex rupestris*, *Salix reticulata Oxytropis maydelliana*, *Rhododendron lapponicum*, *Hierochloë alpina*, and *Luzula confusa*. A number of mosses are also common to the two communities in Canada and Svalbard. The content of dwarf shrubs, however, appears to be rather larger in Canada than in Svalbard.

The community *Tetragono-Dryadetum* in Svalbard appears to have its parallels in the Canadian Eastern Arctic. Quite often it is not always clear how the *Dryas*

communities with *Cassiope tetragona* are made up, but, for instance in southern Baffin (Lake Harbour and Cape Dorset) and northern Quebec (Wakeham Bay), communities are found which may be classed as *Tetragono-Dryadetum*. On the other hand the content of dwarf shrubs is considerably greater in these localities, such species as *Ledum palustre*, *Vaccinium vitis idaea*, *Empetrum hermaphroditum*, etc. POLUNIN also emphasizes that communities containing *Cassiope tetragona* occur in depressions or on slopes with adequate snow protection in winter. It is also clear that where the snow cover lies too late in spring, and where drainage conditions may be rather more unfavourable, there may develop dwarf shrub communities without *Dryas integrifolia*. This corresponds exactly to what happens in Svalbard, the only difference being that the number of species of dwarf shrubs is considerably greater in Canada.

The similarity between the communities mentioned above also applies to the mosses and lichens. Such species as *Cetraria nivalis*, *C. islandica*, *Cornicularia divergens*, *Cladonia rangiferina*, *Ochrolechia frigida*, *Lecanora epibryon*, etc., with the mosses *Ditrichum flexicaule*, *Distichium capillaceum*, *Hylocomium splendens*, *Hypnum bambergeri*, and *Tomentypnum nitens* are also of great importance in the Canadian *Dryas* communities.

It is more difficult to compare *Polari-Dryadetum* with communities in Arctic Canada. On screes and slopes, communities with *Dryas integrifolia*, species of *Salix* and *Saxifraga oppositifolia* are mentioned by POLUNIN (l. c. p. 242). Possibly these communities could be compared with *Polari-Dryadetum* but the information available is to small.

DRURY (1962), writing about Bylot Island (north of Baffin), mentions the interplay between vegetation and certain frost phenomena. Vegetation with well-developed *Dryas* communities occurs especially at exposed localities, and then in patches or stripes (network).

Communities with *Dryas integrifolia* as the principal dominant together with *Kobresia myosuroides*, *Silene acaulis*, *Saxifraga oppositifolia* etc. occur especially in exposed and dry localities and appear to be comparable to *Rupestri-Dryadetum*.

In more sheltered localities the community develops in the direction of a dominance of *Cassiope tetragona*. It is primarily that species and *Dryas integrifolia* which dominate and make the community very much like *Tetragono-Dryadetum* in Svalbard.

These two suggested communities interchange greatly, and are jointly known as Dry Mat Plants.

From Fig. 19 F in DRURY's work (1962) it may also be seen that the vegetation on the surface of a solifluction bank is mainly dominated by *Dryas integrifolia*, *Luzula confusa* and *Carex bigelowii*, together with *Poa arctica*, *Hierochloë alpina*, *Silene acaulis*, *Kobresia myosuroides*, etc., also showing some relationship to *Rupestri-Dryadetum*.

It must be reasonable to suppose that *Dryas* communities that can be classed as *Nardino-Dryadetum*, *Rupestri-Dryadetum* and *Tetragono-Dryadetum*, according to the description of these associations from Svalbard, also occur in Canada. For *Polari-Dryadetum* it is more difficult to find parallels, but I find it probable that this community, too, is represented in arctic Canada.

Greenland

In Greenland not much work has been done by means of methods comparable to those employed in this work. Some especially useful information is found in SÖRENSEN (1937) and BÖCHER (1954).

In eastern Greenland RAUNKIÆR's circle method has mostly been used, but few of the results appear to have been published. BÖCHER, in western Greenland, used the now common method with quadrates measuring 1 sq. metre, but in other respects his grouping and classification diverge greatly from those usually found in Scandinavian phytosociology, which have been employed in the present work.

Several authors (SØRENSEN 1933, 1937, GELTING 1934, BÖCHER 1954, HOLMEN 1957) stress the difference that is found in Greenland between the vegetation of more oceanic localities and the more continental areas.

The vegetation in the oceanic areas is characterized by *Cassiope tetragona* heaths quite rich in species, especially grasses. In the continental areas the vegetation is dominated by *Dryas* heaths and *Kobresia myosuroides* vegetation. Of species mainly found in these areas may be mentioned *Kobresia myosuroides*, *Carex maritima*, *C. nardina*, *Draba cinerea*, *Potentilla pulchella*, *Dryas integrifolia*, *Poa hartzii*, *Eutrema edwardsii*, etc.

In order to understand the climatic differences between the two areas, HOLMEN has made a list of the significant factors. For the *Cassiope* areas he mentions lower summer temperature, less sunshine, occasional frost in summer, rather more precipitation, thicker snow cover, less frequent storms and less fog. By contrast the *Dryas* areas have comparatively higher summer temperatures, with long periods free of frost and plenty of sun, little precipitation, violent storms, snow cover unevenly distributed, and fog only rarely. All these differences are of great ecological importance. To some extent this can be applied to conditions in Svalbard, but a division corresponding to that in Greenland, into an oceanic *Cassiope* vegetation and a continental *Dryas* one, is not found in Svalbard.

West Greenland. The West Greenland *Dryas* communities were described by BÖCHER (1954) a.o. Even if he uses a basis for classification into plant communities which diverges greatly from the system commonly used, one still gets a good impression of these communities. BÖCHER styles his classification "the eco-geographical system", as he pays chief attention to the total distribution of the species when classifying communities of higher order, while the division into communities of lower order is made according to the ecology of the species. This means that classification is based on two main principles, one biological or ecological and one phytogeographical.

For this division into communities new terms are also introduced, being here arranged in ascending order: 1. Sociation individual, 2. Sociation, 3. Sociation group, 4. Vegetational type, 5. Vegetational complex, 6. Vegetational region. According to BÖCHER (1954 p. 12) "Sociation" corresponds approximately to what is now called association, while "vegetational type" is roughly equivalent to sub-alliance and "vegetational complex" nearly the same as the phytosociological designation "order".

This means that BÖCHER's tables, etc., are not directly comparable with the tables that appear here, but they nevertheless give an impression of the *Dryas* communities of West Greenland.

Under the heading of a "*Carex nardina-Lesquerella-saxifraga tricuspidata* Complex" a description is given of "*The Carex nardina-Hierochloë alpina* Type" which contains sociations with *Carex nardina* and *Dryas integrifolia* as dominants. The sociations in question are listed in Table 14 in BÖCHER's work (1954, p. 143), from which it appears that sociations 1, 2, 3 and 4 are dominated by *Carex nardina* and *Dryas integrifolia*, and may naturally be compared with communities with *Nardino-Dryadetum* in Svalbard. Likewise it will be seen that sociations 7 and 8 are dominated by *Carex rupestris* and *Dryas integrifolia*, and so form a parallel to *Rupestri-Dryadetum* in Svalbard. Also with regard to the other species in the communities there is a high number of species common to the two communities.

Moreover there are to be found in West Greenland dwarf shrub communities with *Dryas integrifolia*, *Rhododendron lapponicum* and *Vaccinium uliginosum*, which are not found developed in Svalbard where the latter two species are completely lacking. On the other hand, in West Greenland there are also developed communities with a strong dominance of *Cassiope tetragona*. These occur either dominated by *Cassiope tetragona* alone or sometimes together with *Dryas integrifolia* (BÖCHER 1954, p. 175). The latter type of community is comparatively common, the more so as we go farther north. It naturally links up with the corresponding community described as *Tetragono-Dryadetum* from Svalbard.

The remaining West Greenland *Dryas* communities described by BÖCHER (pp. 202, 214 and 230) are dominated, apart from *Dryas integrifolia*, by *Kobresia myosuroides* or other species which are not represented in Svalbard.

A number of more specialized *Dryas* communities on damp subsoil (p. 230) have no obvious counterparts in Svalbard.

GELTING (1955) published a *Dryas integrifolia* community from West Greenland with a distinct dominance of *Dryas integrifolia* and *Carex rupestris*, accompanied by a very strong dominance of lichens. Mosses are poorly represented, only two species being present. The analyses were taken from two stands, one of which shows distinct similarities to *Nardino-Dryadetum*, the other to *Rupestri-Dryadetum*. Both stands, however, differ from the Svalbard communities in their very high content of lichens, a feature peculiar to these West Greenland communities.

On the whole there appears to be a high degree of agreement, both floristically and ecologically, between the *Dryas integrifolia* communities of West Greenland and the *Dryas octopetala* communities of Svalbard. This is particularly true of communities dominated by *Dryas integrifolia*, *Carex nardina* and *C. rupestris* corresponding to *Nardino-Dryadetum* and *Rupestri-Dryadetum*, and those dominated by *Cassiope tetragona* and *Dryas integrifolia* corresponding to *Tetragono-Dryadetum*.

East Greenland. A survey of some of the plant communities of East Greenland is to be found in SØRENSEN's work (1937). Even if he makes his classification on ecological principles, we can nevertheless discover common features in the vegetation. SØRENSEN uses the term "ecosystem" for a well-defined plant community. As a unit of lower order he employs the term "ecotype", which is grouped

with others in higher ranking units according to similarities in the composition of the community and the observable physical and ecological conditions. SØRENSEN (1937 pp. 108–140) gives a survey of 18 ecosystems found in East Greenland (between 74°30′ N and 79° N), of which four may be said to be of interest for a comparison with the plant communities found in *Dryadion* in Svalbard. They are the following: No. I – Dry Barren Ground, No. II – Dry Loess Fields and Terraces, No. VII – Moderately moist sheltered Precipices and Rock Ledges, and No. VIII – Fronts of (stagnant) Earth Glaciers.

If the *Dryadion* associations of Svalbard are taken as the starting point, it is possible on the basis of SØRENSEN's investigations to find certain similarities in the flora in the two places.

Floristically SØRENSEN's ecosystem I (p. 116), "Dry Barren Ground", shows good agreement with *Nardino-Dryadetum* in Svalbard. It is dominated by *Saxifraga oppositifolia*, *Poa abbreviata*, *Carex nardina* and *Erigeron compositus*, the first three of which are also found in Svalbard. Of other species common to East Greenland and Svalbard, this ecosystem usually includes *Dryas octopetala*, *Minuratia rubella*, *Carex misandra*, *Luzula confusa*, *Potentilla hyparctica* and *Silene acaulis*. All of these also occur in *Nardino-Dryadetum* in Svalbard. In addition to *Dryas*, *Salix arctica* is also represented in this ecosystem in Greenland. In Svalbard, on the other hand, *Salix polaris* often occurs in the corresponding community. In ecology and manner of growth these two species appear to have much in common, and it would therefore seem reasonable to suppose that *Salix arctica* in Greenland physiognomically replaces *Salix polaris* in Svalbard. SØRENSEN introduces the concept "desert" for this ecosystem and calls it an "arctic cold desert". In many ways this designation is correct, also when viewed from the occurrence of *Nardino-Dryadetum* in Svalbard.

SØRENSEN's ecosystem II (p. 117), "Dry Loess Fields and Terraces", shows considerable floristic resemblance to the foregoing, but differs ecologically. It occurs in localities with sand and gravel, and is especially to be found developed on terraces. Above all it is characterized by *Kobresia myosuroides*, but also contains *Carex nardina*, *C. rupestris* and *Dryas octopetala*, together with several other species. This ecosystem shows floristic resemblance to both *Nardino-Dryadetum* and *Rupestri-Dryadetum*.

Ecosystem VIII, "Fronts of (stagnant) Earth Glaciers" (SØRENSEN 1937 p. 121), is mainly characterized by the profusion of grasses, viz. *Poa arctica*, *P. pratensis*, *Hierochloë alpina*, *Festuca brachyphylla*, *P. vivipara*, *Carex capillaris*, *C. rigida*, *C. misandra*, *C. nardina*, *C. rupestris*, *Kobresia myosuroides* and *Luzula confusa*, as well as a number of herbs such as *Polygonum viviparum*, and dwarf shrubs such as *Dryas octopetala* and *Salix arctica*.

A community so rich in grasses and sedges is scarcely to be found in Svalbard, and certainly none that could be thought of as belonging to *Dryadion*. There is some floristic resemblance both to *Rupestri-Dryadetum* and to *Polari-Dryadetum*. In conjunction with the fact that *Dryas octopetala* and *Salix arctica* can dominate strongly, it shows a greater ecological relationship to *Polari-Dryadetum*.

SØRENSEN's ecosystem VII, "Moderately moist sheltered Precipices and Rock Ledges", has a floristic composition which is strongly reminiscent of *Tetragono-*

Dryadetum in Svalbard. This ecosystem is mainly dominated by such dwarf shrubs as *Vaccinium uliginosum*, *Salix arctica*, *Dryas octopetala*, *Cassiope tetragona*. According to SØRENSEN this ecosystem is absent from the outer coastal regions.

SØRENSEN (l.c.) emphasizes the importance for this ecosystem of both a supply of water and the proximity of scree or slopes. This applies also to Svalbard, where likewise the community quite clearly requires moisture and a certain minimum of snow protection in winter.

The same division into ecosystem is largely retained by SØRENSEN in a later work (1941) as the basis for the division into phenological aspects. This shows (1941 p. 57) that three of the ecosystems that can be likened to *Dryadion* associations in Svalbard belonging to the typical spring aspects, with an early flowering in the second half of July. These are Nos. I, II and VII. The fourth ecosystem under consideration here, No. VIII, with *Cassiope tetragona*, has on the other hand a somewhat later thaw. Flowering in East Greenland occurs in July and the beginning of August. During my visits to Svalbard I have also systematically observed the time of flowering in the various localities. The general impression is that the phenological periods which SØRENSEN arrived at may also be applied to Svalbard, possibly with some displacement towards a slightly later beginning of the flowering.

GELTING (1937 pp. 23–45) refers to certain phytososiological conditions in East Greenland, but only in so far as these are of importance for the Greenland ptarmigan. Thus they fall rather outside the scope here.

A typical community developed on solifluction soil, and fully in agreement with *Tetragono-Dryadetum* in Svalbard, is mentioned by SEIDENFADEN (1931 p. 5), but the purpose of his investigations was not phytosociological, and therefore further comparison is difficult.

It seems clear that there are *Dryas* communities in East Greenland corresponding to *Nardino-Dryadetum* and *Tetragono-Dryadetum* in Svalbard. The occurrence of *Rupestri-Dryadetum* is not so clear, but is probable. *Polari-Dryadetum* is not found in its typical form, but may be presumed to be replaced by a *Dryas octopetala–Salix arctica* community.

Iceland

The *Dryas* communities of Iceland in many ways show their connection with those of Svalbard, but there are also distinct differences, especially in their floristic composition.

In 1962 I myself had an opportunity of studying certain *Dryas* communities in the field, and even though this was not the main purpose of the visit I got a good impression of the most important *Dryas* communities. Since the number of species found in Iceland is greater than in Svalbard, thanks to a more favourable climate, etc., the number of species in the associations is considerably greater.

According to my opinion there is a tendency towards two different plant communities, one dominated by *Dryas octopetala*, *Salix herbacea* and other species, and the other dominated mostly by grasses as *Festuca rubra* and *Agrostis tenuis*.

The first is much alike certain *Dryas* communities in Svalbard belonging to *Polari-Dryadetum*.

A more detailed impression of Iceland's *Dryadion* is obtained by studying two botanical works from Iceland, HANSEN (1930) and STEINDORSSON (1945).

HANSEN's work concentrates in the first place on plant communities in low-lying country, and only touches on higher ground. Communities which may be assigned to *Dryadion* are found in those types of vegetation which HANSEN describes as "Melar" and "Mo". Melar vegetation is virtually free of snow in winter, with open vegetation and large patches of gravel between, often solifluction soil or polygon. Mo vegetation is characterized by tussocky continuous vegetation and normal snow cover in winter.

Among the Melar vegetation are to be found communities dominated by *Dryas octopetala*, *Agrostis canina*, *Salix herbacea*, *Thymus arcticus*, *Juncus trifidus*, *Polygonum viviparum*, *Festuca rubra*, *F. ovina*, etc.

Of rather more interest are the communities which HANSEN describes from higher land. Plant communities belonging to *Dryadion* are found more commonly there than at lower altitude.

Also at higher levels there occur two types of vegetation, Melar and Mo. Melar vegetation occurs along ridges and moraines. The dominant species are *Dryas octopetala*, *Salix herbacea*, *Thymus arcticus*, *Cerastium alpinum*, *Arabis petraea*, *Saxifraga oppositifolia*, *Empetrum nigrum*, *Polygonum viviparum*, *Silene acaulis*, *Juncus trifidus*, *Festuca ovina*, etc. *Salix herbacea* occurs both here and in the related "*Betula Nana* Mo".

Similarly some of the communities which HANSEN assigns to "The knolly Mo, can be included in *Dryadion*. Here again come most of the species named above, but there is a dominance of *Kobresia myosuroides*, *Thalictrum alpinum* and *Festuca rubra*. It is interesting that here, too, *Salix herbacea* is a dominant. This fact, together with the qualitative as well as the quantitative composition makes it, in my opinion, correct to suppose that the Icelandic communities sketched here are related to *Polari-Dryadetum* in Svalbard.

A more detailed survey of the plant communities of the central highlands of Iceland is given by STEINDORSSON (1945). Of the communities described here are also some that display kinship with *Dryadion* communities in Svalbard, as in the case of the results arrived at by HANSEN (l.c.) outlined above.

Basis for comparison with *Dryadion* in Svalbard is found in the "Fell-field series". Here the vegetation is characterized by being open and occurring in tussocks. According to STEINDORSSON the physiognomy of the community varies with the effects of wind erosion, soil moisture and snow cover in winter. All the formations have one thing in common – they are unstable.

In the Fell-field series it is only among the "Melar" vegetation that a plant community occurs which can be assigned to *Dryadion*, and which is related to *Dryas* communities in Svalbard. STEINDORSSON (1945 p. 464) emphasizes the distinct dominance of arctic species, in some cases as much as 100 %, to be found in this type of vegetation. This suggests, for one thing, that we are here dealing with communities which are arctic in character.

The association which can most easily be placed is the *Salix herbacea–Dryas*

octopetala association. This is clearly distinguished from the other Melar associations by the presence of *Dryas octopetala* as a dominant together with *Salix herbacea*, *Silene acaulis*, *Polygonum viviparum*, *Kobresia myosuroides*, *Armeria maritima* and *Empetrum nigrum*. Here one meets the same thing as indicated above, a significant occurrence of *Salix herbacea*.

Two other plant communities analysed by STEINDORSSON also show some similarity to *Dryadion* in Svalbard, i.e. *Salix herbacea–Elyna bellardi–Polygonum viviparum* ass. and *Salix herbacea–Saxifraga oppositifolia* ass. But here the resemblance is less pronounced, and any comparison with *Dryas* communities in Svalbard is hardly possible.

In his description of the bogs in the Icelandic highlands (the Icelandic tundra bogs) the vegetation is divided into four belts with altogether 17 associations according to their requirement of moisture. Of these, belt 4, the top of the tussocks, is where the most pronounced xerophilous vegetation is found, dominated by such species as *Dryas octopetala*, *Salix herbacea*, *Kobresia myosuroides*, *Silene acaulis*, *Empetrum nigrum*, *Salix glauca* and *Armeria maritima*. It shows many points of resemblance to *Dryas* communities in Svalbard. Here again it is a characteristic feature that *Salix herbacea* is an important and sometimes a dominant species.

If one considers the Icelandic *Dryas* communities outlined here as a whole, and tries to compare them with those already described from Svalbard, some things that connect them will emerge, but also some distinct differences.

A number of plants are common to the *Dryas* communities of Iceland and Svalbard. *Polari-Dryadetum* is one of the *Dryas* communities described here which can be compared to those in Iceland. There are distinct similarities, but a number of plants that are peculiar to Iceland serve to emphasize the clear differences that also exist. These dissimilarities consist in the first place in the common occurrence of such species as *Armeria maritima*, *Kobresia myosuroides*, *Cassiope hypnoides*, *Empetrum nigrum*, *Thymus arcticus*, etc. in the *Dryas* communities of Iceland.

Conclusion

On the basis of the *Dryas* communities from Svalbard described above, and the descriptions and references to *Dryas* communities to be found in other arctic regions, there is reason to suppose that the *Dryadion* alliance appears as circumpolar plant community. The most important and dominant species are *Dryas octopetala* and *D. integrifolia*, each of which within its own area of distribution are the basic components of the *Dryas* communities.

Not only do the arctic circumpolar *Dryas* communities show floristic similarities, but it seems clear that also ecologically they show a high degree of agreement. Everywhere they are typically developed with their characteristic split-up physiognomy, at higher altitudes and on wind-swept ridges. In most cases they are found in conjunction with stony and gravelly basic subsoil. From the most xerophilous communities in the most exposed localities, transitions are found to *Dryas* communities chiefly developed in damper places with good snow protection in winter. But an important requirement which must be met is that the subsoil be well drained.

The differentiation which has been demonstrated in the *Dryadion* of Svalbard must not be supposed to appear only as an isolated phenomenon for Svalbard, but to have its corresponding plant communities or parallels developed also in other arctic areas.

If one considers the four associations from Svalbard as described above, it is in my opinion also possible to demonstrate closely related *Dryas* communities which perhaps belong to the same associations in other arctic regions.

Nardino-Dryadetum occurs, apart from Svalbard, in the northern Scandinavian mountain areas, and also in western and eastern Greenland, so that it is a west-arctic, amphi-atlantic plant community. Its distribution is of course the same (except Iceland) as for *Carex nardina*. There is reason to suppose that in eastern arctic regions, where *Carex nardina* does not occur, the community gives place to other *Dryas* communities which are closely related to *Rupestri-Dryadetum*.

For *Rupestri-Dryadetum* it is more difficult to find direct comparisons. It must be regarded as certain that identical or closely related communities, dominated by *Dryas octopetala* and *Carex rupestris* occur to the east in Novaya Zemlya and arctic Russia, in arctic Canada and West Greenland. Its occurrence in East Greenland is probable but not clearly demonstrated. On the other hand it is more doubtful whether the community is found typically developed in subarctic or alpine regions, e.g. Scandinavia and Iceland. Here *Kobresia myosuroides* will be a dominant species and will characterize these communities, as is the case in Scandinavia, Iceland, and to some extent in Alaska (*Kobresia simpliciuscula*). It is, of course, also possible that *Rupestri-Dryadetum* may be an arctic form of the last-named *Kobresia myosuroides* community.

Polari-Dryadetum is a community which is far more difficult to place. I consider that the main reason for this is inadequate research. Investigations in other arctic regions have been more concerned with purely ecological conditions rather than phytosociological ones, and this may have led to the paying of little attention to this plant community. In Alaska there occur communities which may be related

to *Polari-Dryadetum*, but it is probable that the *Salix polaris* of Svalbard there is replaced by *Salix chamissonis*. The Scandinavian community *Dryadetum octopetalae* (NORDHAGEN) probably also occupies a position close to *Polari-Dryadetum*.

In Iceland there are found *Dryas* communities with a significant occurrence of *Salix herbacea*, a species very like *Salix polaris*, which also makes a comparison with *Polari-Dryadetum* natural. It is to be noticed that in the low arctic and alpine regions, e.g. Iceland and Scandinavia, communities are found which to some extent show similarities to *Polari-Dryadetum*. The question therefore be raised whether *Polari-Dryadetum* may not be regarded as the arctic form of the corresponding low arctic or alpine communities that have been mentioned. It is still difficult to say anything more definite about this.

In the high arctic areas *Polari-Dryadetum* appears to be developed to the east in Novaya Zemlya and arctic Russia, while in Greenland very similar communities are developed, but with *Salix arctica* as the dominant species.

Among the *Dryadion* of Svalbard, *Tetragono-Dryadetum* is the association which can most easily be identified in other arctic regions. NORDHAGEN's *Cassiopetum tetragonae dryadetosum* in Scandinavia must be said to be identical with *Tetragono-Dryadetum* in Svalbard and with communities dominated by *Cassiope tetragona* in arctic Canada and West and East Greenland.

On the other hand the community is not found, as far as can be judged from available literature, in Novaya Zemlya and eastwards in arctic Russia and Siberia where *Cassiope tetragona* is a rare species. Nor is this community found in Iceland.

As yet the investigation of the arctic plant communities has only just begun, and information as to their character and distribution is very fortuitous and sparse. From what has been said here it is apparent that the arctic *Dryas* communities belonging to the alliance *Dryadion* are circumpolar, and that in their ecology and distribution they show such great similarities that many parallels between them may be drawn. Floristically and physiognomically their relationship appears to be quite pronounced. The ecological requirements of the various associations appear to agree to a very great extent.

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