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# THE VEGETATION OF THE MESTERS VIG DISTRICT, NORTHEAST GREENLAND

## GENERAL SUMMARY AND DISCUSSION

BY

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WITH 12 FIGURES AND 3 TABLES
IN THE TEXT

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# ABSTRACT

Six generalized types of vegetation in the Mesters Vig district are described: moss-sedge meadow, heath tundra, heath-herb tundra, turf hummock vegetation, organic crust vegetation, and the vegetation of dry sites (ledges, talus, trap and till knolls, kames and emerged delta remnants). Lake and sea shore types have been described in an earlier paper, and are of minor significance in the landscape. The six types are analyzed with respect to habitat factors of ground coverage by vascular plants, moisture, and physical disturbance by frost and nonfrost geomorphic processes. Comparisons are made among the proportions of wide, intermediate and narrow tolerances to variations on these factor gradients exhibited by the species that compose the various types. It is proposed that with present knowledge of plant-site relationships the distribution of vascular species and vegetations can be rationalized for the most part in terms of the physical properties of the soil and the moisture supply. A key to the generalized types of vegetation is presented, based primarily on the interrelations of moisture, soil texture, and degree of ground coverage by vascular plants.

# INTRODUCTION

The vegetation of the Mesters Vig district has been treated thus far in the present series in terms of the vascular flora, and then in terms of its relationships to the experimental sites and other study areas used by Washburn in his investigation of geomorphic processes. The present paper summarizes this material, describes and analyzes the general structure of the vegetation in the district as a whole, and proposes a general theory for rationalizing the distribution of major types of vegetation.

Rationalization of the behavior and distribution of the vegetation is believed to rest, ultimately, upon the behavior of individual species or ecotypes rather than upon that of "communities" of species. Evidence for this is derived not only from the difficulty of seeing and defining these aggregates in the field, but also from the observed behavior of the flora on gradients of moisture, physical disturbance, and coverage of the ground by vascular plants (Raup, 1969A).

There appear to be differences among the vascular species in their tolerance of variation on these gradients. It is probable that differences on other gradients would also have been evident had there been time and means for their study (nutrients, light, etc.). The observed differences may be described as wide, intermediate and narrow tolerance (Raup, 1969A, p. 51–52). It should be clearly understood that the ratings of the species in terms of these tolerances are judgements based only upon field observations of species behavior. No precise measurements of plant reactions to environmental factors are involved. Therefore the following analyses constitute checks upon the validity of the judgements as applied to varying vegetation complexes rather than statements of actual plant-site relationships. It is probable that their principal value lies in suggestions for clearer statements of problems touching upon these relationships—problems in ecotypic variation that may be attacked experimentally.

A general theory for the development and distribution of vegetation in the district probably should be based primarily upon the physical site rather than upon the vegetation itself or upon some combination of the two in which the vegetation is assumed to have a large influence. SØRENSEN (1937) used this concept in his organization of the fjord region vegetation in terms of "ecosystems". Geomorphic and meteorological processes, conditioned by the arctic soils and regional climate, appear to dominate the behavior of the vegetation, even though they are modified to a minor extent by the latter. They should be emphasized to a much greater extent, therefore, than supposed processes of vegetational development. This suggestion is based upon evidence that the vegetation "rests lightly" upon the physical sites it occupies, and is largely "at the mercy of" the physical processes effective in these sites. Not only does this appear to be the case now, but also it probably has been true for a long time, possibly throughout the Pleistocene.

If the preceding assumptions are correct it should be possible to organize the vegetation almost entirely upon the physical properties of the habitat. A simple method of doing this is by interrelating soil textures and moisture regimes. The behavior of the vegetation should then be determined largely by different combinations within these two systems, because the nature and distribution of the physical processes favorable and unfavorable to the growth of plants may be rationalized by the same combinations.

The theory of vegetational development in situ to form a "climax" has been applied to the arctic tundra by several students (OOSTING, 1948; POLUNIN, 1948; SPETZMAN, 1959). The nearest approach to such a "climax" in the Mesters Vig district would be the heath vegetation, which appears to develop by successional stages from moss-sedge meadows. The nearest approach to a zonal "climax soil", the Arctic Brown, is thought to have developed at Mesters Vig under such a heath, although the time required for this is unknown. However, observed changes in physical habitats, occurring rapidly and over time periods shorter than the lifespans of the plants, suggest that the assumed "climax" has no long-term continuity in time or space.

Geomorphic processes and desiccation, which appear to have major influences upon the vegetation, are altered in intensity and location by changes in water supply. These changes are due to various causes, including minor climatic fluctuations over relatively short periods of time, or changes in drainage patterns due to gelifluction, eluviation, or deflation and deposition of surface materials by wind or water. Thus the physical possibility of vegetation having long term development in situ is remote.

# ADJUSTMENT OF THE VASCULAR SPECIES TO THE MESTERS VIG ENVIRONMENT

About two thirds of the Mesters Vig vascular flora (67.5 %) are species of general circumpolar range. They belong to an "arctic-montane" group believed by HULTÉN (1937) to have been so long adjusted to arctic and northern alpine habitats that relatively large populations of them survived the Pleistocene glaciations. Thus they were not genetically depauperated, and retained enough plasticity to occupy deglaciated lands with relative ease. The high percentages of species with wide tolerances on the environmental gradients studied at Mesters Vig suggest that this plasticity is still retained and well represented there.

Most of the vascular flora of the Mesters Vig district, therefore, is here assumed to be well adjusted to the direct effects of local variations in temperature, moisture, light, and soil nutrients. Its presence and continued reproduction are the best evidence of this. Much research has been devoted to the arctic flora as a submarginal assemblage of excessively slow-growing depauperate plants, restricted to this condition by their rigorous and unfriendly habitat. Many of the terms used for it are pejorative, derived from views of vegetation acquired in temperate climates. The arctic flora, on the other hand, is made up mainly of arctic species that have lived and evolved in their "harsh" environment over a long period of time, probably at least since late Tertiary. To an Eskimo botanist the temperate flora might seem "submarginal".

Approximately 35 % (54 spp.) of the vascular species were recorded as generally common or abundant in the district. Another 49 species were noted as locally common at one or more places. Thus about 67 % of the flora is sufficiently well adjusted to its environment to be common in some or all parts of the district. Of these common species 78 have the wide circumpolar ranges noted above. Thus about half of the vascular flora is both circumpolar and common or abundant in the district. Of these 78 species 16 are widely tolerant of variations in all the environmental gradients (about 75 % of all the universally widely tolerant in the whole flora). Most of the vegetative cover is made of the circumpolar, common plants, particularly of those most adjustable to environmental variations. Thus there appears to be a strong positive correlation between the behavior of the abundant and common species on one hand, and of those that are widely tolerant of environmental variation on the other.

The underground parts of most of the Mesters Vig plants are taproots or fibrous roots (about equal in numbers). Only about 25 species (16 %) have well developed rhizomes. Taproots predominate among the species that are at once generally common or abundant, and widely tolerant of variation on all of the gradients studied. Of this group (20 spp.) 11 have taproots, 7 have fibrous roots, and 2 have rhizomes. Among species that are rare or generally occasional in the landscape, and at the same time narrowly tolerant on all the gradients (14), 4 have taproots, 6 have fibrous roots, and 4 have rhizomes. Thus the proportions are reversed in the latter group, and there is a notable increase in the percentage of rhizomatous species. These data suggest that plants with storage roots are better adjusted to prevailing desiccation and soil disturbance than are those without these organs.

# MAJOR TYPES OF VEGETATION IN THE MESTERS VIG DISTRICT: SUMMARY DESCRIPTIONS AND ANALYSES

## Introduction

For analyses in the present paper it is useful to describe generalized physiognomic "types" of vegetation at Mesters Vig and then to analyse their group behavior in terms of the behavior of their included species. The generalized types are heath tundra, moss-sedge meadow, heath-herb tundra, turf hummocks, organic crusts, and the vegetation of dry sites on ledges, talus, trap and till knobs, kames and emerged delta remnants. In practice these types interdigitate to such an extent that even the more clearly defined ones, taken together, achieve continuity on only about 20 % of the land surface of the district. Most of the surface contains a wide variety of combinations among the six major types, or is barren of vascular plants. The six types may be arranged in two groups that differ markedly in form, species composition and habitat.

First are the following three types: heath tundra, moss-sedge meadow, and heath-herb tundra. These three have the following characteristics in common: (1) they all achieve ground coverage densities that average 60 % or more; (2) they are all supplied with at least moderate moisture throughout the growing season; (3) in all of them the percentages of definitive species narrowly tolerant on the physical disturbance gradients exceed those of widely tolerant species. The first of these characteristics makes the three types conspicuous in the botanical landscape. Heath tundra is easily identified by its shrub form and dark green color. Moss-sedge meadows, though widespread, are highly localized by their dependence upon summer melt water, mainly from relict snowdrifts. They are clearly visible in the landscape as patches of light green color. Heath-herb tundra, confined mainly to warm southerly till slopes, is the least of the three in the Mesters Vig district, largely because most of the slopes in the district face north or northeast, thus receiving less insolation during the spring and summer months. This vegetation differs from heath tundra in having a large herbaceous element. The behavior of the species in the preceding three types on the disturbance gradients reflects the fact that in all of the three habitats the soils are relatively stable, or if they are unstable the disturbance is not seriously injurious to the plants.

Second are the vegetation of the dry sites mentioned earlier, the vascular flora of the organic crusts, and the turf hummocks. These three types have in common: (1) relatively low densities of ground coverage, rarely over 40 %, and ranging to less than 1 % (av. probably about 20 %) (an exception is in the maturing hummock stage in the hummock sequence where densities sometimes reach 80 %); (2) in all three of the types definitive species widely tolerant of one form or another of physical disturbance equal or outnumber the narrowly tolerant species. These types differ notably among themselves with respect to moisture: the organic crust soils are usually moist throughout the summer, while the dry sites may be wet for a short time in spring but become very dry by late summer. Both of these, however, show moderate to wide seasonal and annual variation within their differing moisture regimes. Turf hummocks, in their sequential development and deterioration, pass through moisture regimes ranging from saturation to desiccation. Taken together the three types in this second group occupy more of the Mesters Vig land area than the preceding group of three combined. They form most of the "fjæld-mark" of the district.

The areal distribution of the six types and their more conspicuous combinations can be only roughly estimated. A suggestion of it is in the map area used at ES 7 and 8 in the hills back of Nyhavn (RAUP, 1969B, Figs. 1, 2, 20 and p. 30–45). The ES 7 and 8 map area, however, is somewhat atypical in having a relatively large proportion of silty or clayey loams which are characteristic of low altitudes near the shores of Kong Oscars Fjord. Equal areas on the nearby mountain sides, up to about 700 m, have a preponderance of sandy gravels, loamy sands or sandy loams (see Tab. 3) less subject to intense summer desiccation. Although moss-sedge meadow is relatively well developed at ES 7 and 8, heath tundra is more limited than elsewhere. UGOLINI (1966A, p. 11) has estimated that soils with an Arctic Brown profile are restricted to about 10 % of the landscape in the Mesters Vig district. Because there is an approximate coincidence between this profile and the presence of heath tundra, the proportion of 10 % may be used for an estimate of the latter's extent. In view of the above notes, the following (Tab. 1) probably are fairly realistic estimates.

By these estimates about 60 % of the land has low vegetative coverage, about 20 % dense coverage, and about 20 % intermediate.

Table 1. *Estimated areas occupied by major vegetation types in the Mesters Vig district, in percents of the total area of the district.*

| | |
|---|---|
| Dense coverage by vascular plants | |
| Heath tundra .................. | 10 % |
| Moss-sedge meadows and turf hummocks .................. | 10 % |
| Heath-herb slopes ................ | 1 % |
| Intermediate coverage | |
| Heath and organic crusts ......... | 5 % |
| Heath and lichens ............... | 14 % |
| Low coverage | |
| Organic crusts, scattered vascular plants, etc. .................... | 20 % |
| Lichens, scattered vascular plants, etc., on talus, trap and till knolls, kames, emerged delta remnants.. | 40 % |

Thus between 60 % and 80 % of the vegetation of the district may be referred to as "fjæld-mark".

The species in Tab. 2 represent the major portion of the vegetation in the Mesters Vig district. They contain 124 of the 154 species used in analyses of the vascular flora of the district. The remaining 30 species either are restricted to lesser types that are small and inconspicuous in the landscape, or are rare and currently difficult to place in the major types.

A group of 8 species were not seen in the Store Blydal and Tunnelelv valleys, and depend for their inclusion in the flora upon collections made in the region of Mesters Vig (bay) (see Raup, 1965 A, p. 5). Because no precise data are available on their habitats, they are excluded from analyses. They are: *Festuca baffinensis*, *Poa Hartzii*, *Carex amblyorhyncha*, *Melandrium triflorum*, *Draba groenlandica*, *Veronica fruticans*, *Pinguicula vulgaris*, *Erigeron uniflorus* ssp. *eriocephalus*.

Ten species were found to be associated more or less closely with the small and scattered seashore habitats, and have been discussed in an earlier paper (Raup, 1971 B, p. 79–84). These are as follows: *Puccinellia angustata*, *Puccinellia coarctata*, *Puccinellia phryganodes*, *Phippsia algida*, *Carex ursina*, *Carex subspathacea*, *Carex maritima*, *Stellaria humifusa*, *Cochlearia officinalis* ssp. *groenlandica*, *Matricaria ambigua*.

Three species were found only as freshwater aquatics in the extremely limited pond and small lake vegetation of the Mesters Vig district (Raup, 1971 B, p. 75–79): *Ranunculus trichophyllus* var. *eradicatus*, *Ranunculus hyperboreus*, *Hippuris vulgaris*.

Table 2. *Distribution of vascular plant species among the major vegetation types in Mesters Vig district.*

| | Moss-sedge meadows | Heath tundra | Heath-herb tundra | Turf hummocks | Organic crusts | Dry sites |
|---|---|---|---|---|---|---|
| *Equisetum arvense* | + | + | | + | + | |
| *Equisetum variegatum* | + | + | | + | + | |
| *Lycopodium Selago* | | + | | + | | + |
| *Lycopodium annotinum* | | + | | | | |
| *Botrychium Lunaria* | | | + | | | |
| *Woodsia glabella* | | | | | | + |
| *Cystopteris fragilis* | | | + | | | + |
| *Triglochin palustris* | + | | | | | |
| *Festuca brachyphylla* | | | + | | + | + |
| *Festuca vivipara* | + | | + | | + | |
| *Festuca rubra* ssp. *cryophila* | | + | + | | | + |
| *Colpodium Vahlianum* | | | | | + | + |
| *Poa pratensis* ssp. *alpigena* | + | | | | + | |
| *Poa arctica* sens. lat. | | + | + | + | + | + |
| *Poa alpina* | + | + | + | + | + | + |
| *Poa glauca* | | + | + | + | + | + |
| *Trisetum spicatum* | + | + | + | + | + | + |
| *Arctagrostis latifolia* | + | | | | | |
| *Calamagrostis purpurascens* | | | | | | + |
| *Hierochloë alpina* | | | | | | + |
| *Eriophorum Scheuchzeri* | + | | | + | | |
| *Eriophorum callitrix* | + | | | | | |
| *Eriophorum triste* | + | | | + | | |
| *Kobresia myosuroides* | | | + | | | + |
| *Kobresia simpliciuscula* | + | | | | + | |
| *Carex nardina* | | + | + | + | + | + |
| *Carex scirpoidea* | + | + | + | + | + | + |
| *Carex parallela* | + | | | + | | |
| *Carex rupestris* | | + | + | | + | + |
| *Carex microglochin* | + | | | | | |
| *Carex Lachenalii* | + | | | | + | |
| *Carex bicolor* | + | | | | | |
| *Carex Bigelowii* | + | + | | + | + | + |
| *Carex supina* ssp. *spaniocarpa* | | | | | | + |
| *Carex glacialis* | | | | | + | + |
| *Carex rariflora* | + | | | | | |
| *Carex atrofusca* | + | + | | | | |
| *Carex misandra* | + | + | | + | + | + |
| *Carex capillaris* | + | + | | + | + | |
| *Carex saxatilis* | + | | | | | |

(continued)

Table 2 (continued).

| | Moss-sedge meadows | Heath tundra | heath-herb tundra | Turf hummocks | Organic crusts | Dry sites |
|---|---|---|---|---|---|---|
| *Juncus trifidus* | | | + | | | |
| *Juncus biglumis* | + | | | | + | |
| *Juncus triglumis* | + | | | | + | |
| *Juncus castaneus* | + | | | | + | |
| *Luzula arctica* | | + | | + | + | |
| *Luzula spicata* | + | + | + | + | | + |
| *Luzula confusa* | | + | | + | + | + |
| *Luzula frigida* | | | + | + | | |
| *Tofieldia pusilla* | + | + | | + | + | + |
| *Salix herbacea* | | | | | | + |
| *Salix arctica* | + | + | + | + | + | + |
| *Salix arctophila* | | + | + | | | |
| *Betula nana* | | + | + | | | + |
| *Koenigia islandica* | | | | | + | |
| *Oxyria digyna* | | + | + | + | + | + |
| *Polygonum viviparum* | + | + | + | + | + | + |
| *Stellaria Edwardsii* | | + | | + | + | |
| *Cerastium alpinum* | | + | + | + | + | + |
| *Sagina intermedia* | | | | | + | |
| *Arenaria humifusa* | | + | | | | |
| *Arenaria pseudofrigida* | | | | | | + |
| *Minuartia rubella* | | | | | | + |
| *Minuartia Rossii* | | | | | + | |
| *Minuartia biflora* | + | + | + | + | + | + |
| *Minuartia stricta* | + | | | | | |
| *Silene acaulis* | + | + | + | + | + | + |
| *Melandrium apetalum* ssp. *arcticum* | | + | | + | + | |
| *Melandrium affine* | | + | + | | + | + |
| *Viscaria alpina* | | | + | | | |
| *Ranunculus nivalis* | + | | | | + | |
| *Ranunculus sulphureus* | + | | | | + | |
| *Ranunculus pygmaeus* | | | | | + | |
| *Thalictrum alpinum* | + | | | | | |
| *Papaver radicatum* | | | + | | | + |
| *Draba alpina* | | | + | + | + | |
| *Draba nivalis* | | | + | | + | + |
| *Draba lactea* | + | + | + | + | + | + |
| *Draba fladnizensis* | | | | | | + |
| *Draba subcapitata* | | | | | | + |
| *Draba oblongata* | | | | | + | |
| *Draba glabella* | | | + | | | + |
| *Draba cinera* | | | | | | + |

(ocntinued)

Table 2 (continued).

| | Moss-sedge meadows | Heath tundra | Heath-herb tundra | Turf hummocks | Organic crusts | Dry sites |
|---|---|---|---|---|---|---|
| *Lesquerella arctica* | | | + | | | |
| *Eutrema Edwardsii* | | | | | + | |
| *Braya purpurascens* | | | | | + | |
| *Cardamine bellidifolia* | | | | | + | |
| *Sedum Rosea* | | | | | | + |
| *Saxifraga oppositifolia* | + | + | + | + | + | + |
| *Saxifraga Nathorstii* | | | | | + | |
| *Saxifraga hieracifolia* | + | | | | + | |
| *Saxifraga nivalis* | | | + | | + | + |
| *Saxifraga tenuis* | + | | | | | + |
| *Saxifraga aizoides* | + | + | | | + | |
| *Saxifraga cernua* | + | + | + | + | + | + |
| *Saxifraga rivularis* | | | | | + | |
| *Saxifraga caespitosa* | | | + | | + | + |
| *Sibbaldia procumbens* | | + | + | | | |
| *Potentilla nivea* | | | + | | | + |
| *Potentilla Crantzii* | | + | + | | | |
| *Potentilla hyparctica* | | | + | | | |
| *Dryas octopetala* | + | + | + | + | + | + |
| *Empetrum hermaphroditum* | + | + | + | + | | |
| *Epilobium latifolium* | + | + | + | + | + | + |
| *Pyrola grandiflora* | | + | + | | | + |
| *Rhododendron lapponicum* | | + | | | | |
| *Cassiope hypnoides* | | + | | | | |
| *Cassiope tetragona* | + | + | + | + | + | + |
| *Arctostaphylos alpina* | | + | + | | | + |
| *Vaccinium uliginosum* ssp. *microphyllum* | + | + | + | + | + | + |
| *Armeria maritima* ssp. *labradorica* | | | | | | + |
| *Gentiana nivalis* | | | + | | | |
| *Veronica alpina* | | + | | | | |
| *Euphrasia arctica* | + | | + | | + | |
| *Pedicularis lapponica* | + | + | | + | | |
| *Pedicularis flammea* | + | + | | + | + | + |
| *Pedicularis hirsuta* | | + | + | + | + | + |
| *Campanula uniflora* | | + | | | | |
| *Campanula rotundifolia* | | | + | | | + |
| *Erigeron humilis* | | + | + | | + | |
| *Antennaria canescens* | | | + | | | + |
| *Antennaria Porsildii* | | | + | | | |
| *Arnica alpina* | | | + | | | + |
| *Taraxacum arcticum* | | + | + | | + | |
| *Taraxacum brachyceras* | | + | + | | | |

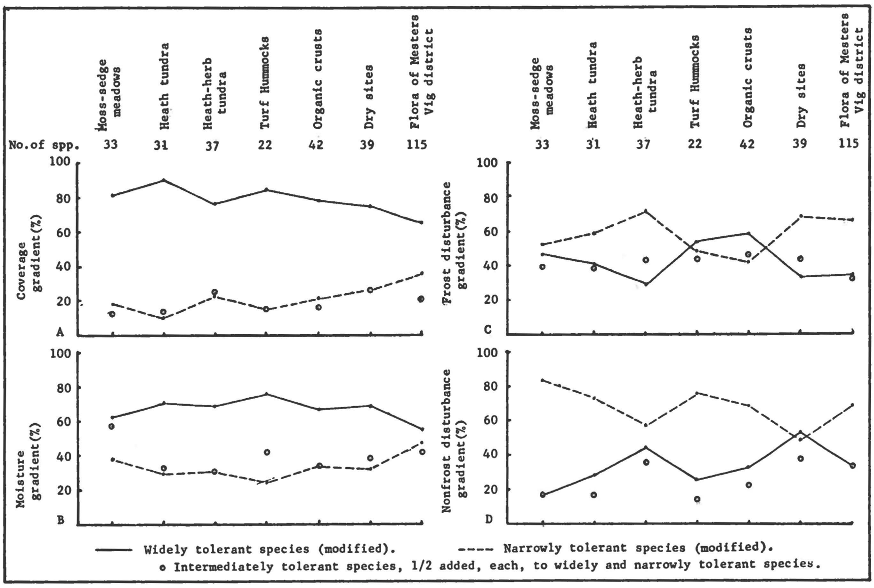


Fig. 1. Distribution of species tolerance on gradients of ground coverage, moisture and physical disturbance in the major vegetation types of the Mesters Vig district and in the total flora of the district.

The remaining 9 of the 30 species not listed in the major types appear to be restricted to small areas, most of which are greatly disturbed by one or more geomorphic processes. *Poa abbreviata* and *Taraxacum phymatocarpum* were seen only in frost-disturbed soils on the summit of Hesteskoen. *Cerastium cerastoides*, *Draba Gredinii* and *Draba crassifolia* were found mainly on the fronts of large active gelifluction lobes. *Arabis alpina*, though common, was found mainly in the sandy-gravelly soils along mountain streams where it was much disturbed by flooding. *Saxifraga foliolosa* was found only in thin, saturated moss mats along mountain streams or in sheet flow areas where it was bathed by running water. *Carex norvegica* ssp. *inserrulata* appeared to be rare in the Mesters Vig district. A single plant was found in a wet, hummocky, moss-sedge meadow, and might have been placed with the heath tundra plants. However, judging by earlier observers in the fjord region, it appears to have a wider range of habitats than the Mesters Vig observations suggest. *Cerastium arcticum* was collected only once, and appears to be rare in the district. It was growing near a roadside at an altitude of about 250 m, in moist tundra probably most nearly related to the heath-herb type.

Figure 1 places the results of the species tolerance analyses for the six major vegetation types in graphic form for summary and comparison. An analysis of the whole flora of the Mesters Vig district is added to the graphs to supply a "norm" from which the six vegetations depart. The total vascular flora as used for the latter purpose includes 154 species. Three species collected in 1964 are not included because their behavior on the factor gradients was not sufficiently known (see RAUP, 1965A, Addenda). Twenty-two species in the total flora of the Mesters Vig district were rated widely tolerant on all the gradients, and 17 narrowly tolerant. Thus the base number (of definitive species) for analysis of this flora was 115. Base numbers for the floras of each of the six major vegetation types were similarly calculated by subtracting from the totals the numbers of universally widely and narrowly tolerant species. Comparison of the curves is simplified by adding one half the intermediately tolerant species, each, to the widely and narrowly tolerant.

## Moss-sedge meadow

The most widespread vegetation on saturated soils is moss-sedge meadow (Fig. 2). It forms downslope from late-lying snowdrifts from which sheet flows of melt water issue during the summer. Saturated soils in the Mesters Vig district are usually on gentle slopes or in shallow depressions. Because they are dependent for moisture primarily upon melting snow, they usually lie around the lee footslopes of hills or cliffs where snowdrifts accumulate. At Mesters Vig these usually are south-easterly-facing cliffs and slopes. The meadows are found on all kinds of soils, but are most extensively developed on clayey silts or silty clays that have a relatively large water-holding capacity. Those on gravels or sands require larger water supply to keep them wet through the summer. Usually these occur in broad valleys having several sources of water from tributary basins. UGOLINI (1966B, p. 10–11) has described "Meadow-Tundra" soils as characteristic of the saturated moss-sedge vegetation areas.

Localized moss-sedge meadows have been described in treatments of turf hummocks (RAUP, 1965B), mass-wasting sites ES 6, 7, 8 (RAUP, 1969B), the vegetation of kames and emerged delta remnants (RAUP, 1971 B), and the flora of lake shores (RAUP, 1971 B). The most extensive meadow seen in the district was at an altitude of about 130 m in the hills back of Nyhavn, in a saddle between MS 162 m and MS 158 m (Fig. 2). It was about 0.2 km long and 0.1 km wide. From this the meadows ranged in area down to 5–10 square meters.

Surfaces exposed by the retreating snow too late in the season to support vascular plants are covered with organic crusts or remain barren. These are regarded as "snow-beds", and are bordered on their lower margins by mats of aquatic mosses. These moss mats are continous into the moss-sedge meadows, forming a major element not only of the mea-

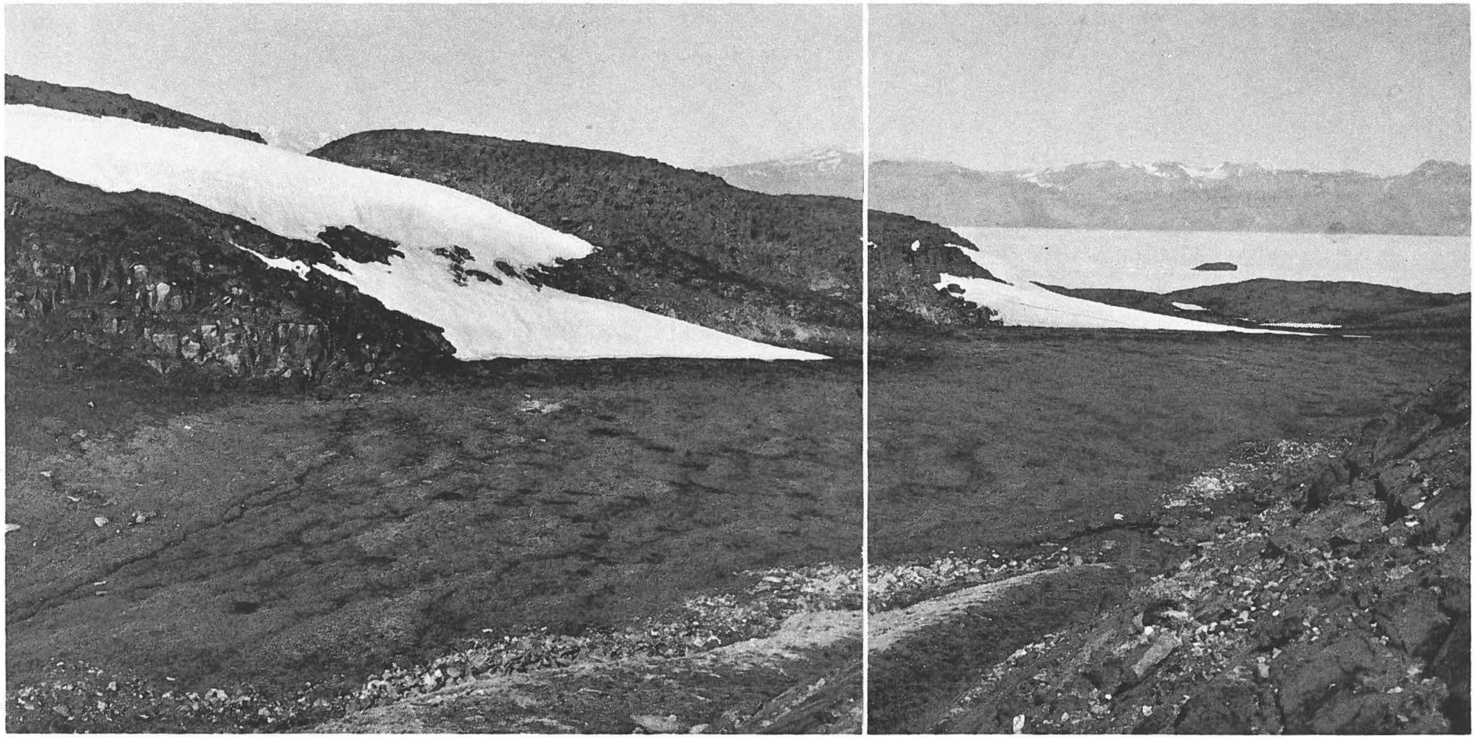

Fig. 2. Moss-sedge meadow in saddle between MS 158 m and MS 162 m, hills back of Nyhavn; alt. about 130 m; view north from MS 162 m, 13 July, 1958.

dows, but also of the turf hummocks that usually develop in them (RAUP, 1965B). Formed in this way the meadows resemble, in part, the ecosystem described by SØRENSEN (1937, p. 125–129) as "Constantly irrigated Fields". They were noted by OOSTING (1948, p. 150–153) as phases of hydrarch successions. Where the meltwater is ponded the moss-sedge meadows form in the shallow water on the shores. SØRENSEN placed pond shore vegetation of this kind in an ecosystem which he called "Water-soaked Ground – Swamps".

A survey of the tolerance ratings of the 50 species found in moss-sedge meadows showed 14 widely tolerant on all of the gradients studied and 3 narrowly tolerant on all gradients. This left 33 definitive species to be used in the following analysis (Fig. 1).

About 76 % of the wet meadow species were widely tolerant of ground coverage variation, and only about 12 % were narrowly tolerant. These proportions are consistent with the wide variation in density observed in this vegetation. In contrast, only a third of the species (33 %) proved to be widely tolerant of moisture variation, suggesting the relatively limited variability known to exist in a habitat which is characterized by a large and fairly continuous moisture supply. Only 9 % were narrowly tolerant on this gradient, though more might have been expected.

Frost disturbance in the moss-sedge meadows is moderate to low in intensity, and this is reflected in the tolerance proportions. Species narrowly tolerant on this gradient supercede the widely tolerant ones (33 %:27 %), indicating that the site is permissive for a relatively large element of plants sensitive to frost heaving. The near absence of injurious nonfrost disturbance is also reflected, for here fully three fourths of the flora (76 %) were sensitive to this kind of disturbance, with only about 9 % widely tolerant of it.

## Heath tundra vegetation

Heath tundra (Fig. 3) as defined here is composed primarily of the following species, occurring in varying mixtures: *Cassiope tetragona*, *Vaccinium uliginosum* ssp. *microphyllum*, and *Salix arctica*. Less widely distributed but having primary roles in some places are: *Arctostaphylos alpina*, *Betula nana*, *Dryas octopetala*, and *Rhododendron lapponicum*. Gound cover densities are usually between 60 % and 90 % and the ground beneath the shrubs usually is covered by living mosses. On drier sites the moss mat is thin, frequently interrupted by areas of organic crust. In some *Cassiope* heaths the living moss is replaced almost entirely by the crust. The shrubs are of low stature, rarely more than 20 cm high and usually 10–15 cm.

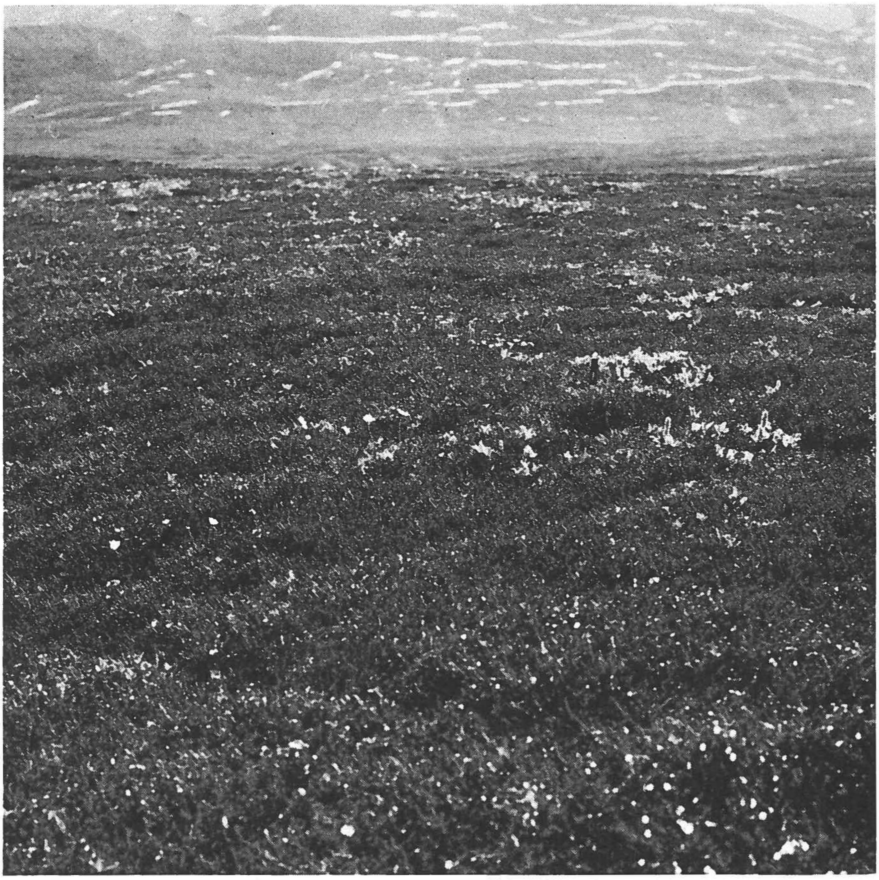

Fig. 3. Heath tundra on "90-m" emerged delta remnant about 1 km west of Tunnelelv. View southeast, 14 July, 1958. *Cassiope tetragona* with admixture of *Salix arctica, Dryas octopetala* and *Vaccinium uliginosum.*

Most of the heath tundra occurs on well-drained, relatively stable loamy sands and sandy loams (see Tab. 2, and UGOLINI, 1966A). Data for it were gathered in 10 specific localities where notes on species, coverage and site conditions were made. Many more places were sampled cursorily during trips through the landscape. Heath tundra appeared only as fragments in a few of the experimental sites (ES 7, 11–12, 17, 20; RAUP, 1969B, 1971B).

The Mesters Vig heath tundra appears to be the "Ericaceous Heath" described by SØRENSEN (1937, p. 122) and placed in his ecosystem IX, "Moderately moist, well drained fields (Fossil Polygon Fields"). OOSTING (1948, p. 248–249) regarded it as the "climax" in his suggested sequence of vegetational development.

About 35 % of the heath tundra flora (19 ssp.) proved to be widely tolerant on all the factor gradients used in the study, and 5 species were narrowly tolerant on all the gradients. This left 31 species that were definitive and useful for analysis (Fig. 1).

About 84 % of the definitive species were widely tolerant of variation in ground coverage, and about 3 % were narrowly tolerant. This reflects the generally wide tolerance of Mesters Vig plants on this gradient, but it is also relatively high in comparison to the percentage of wide tolerance in the flora as a whole (about 65 %). It may reflect the sharp differences of coverage that occur within the heath type.

About 55 % of the definitive species were widely tolerant of variation in the moisture supply, about 4 times as many as were narrowly tolerant. This appears to be consistent with the well drained soils, the moderate to low summer supply of water, and the consequent partial desiccation.

There were nearly twice as many species narrowly as widely tolerant of frost disturbance, and more than three times as many narrowly as widely tolerant of nonfrost disturbance. Thus the heath tundra habitat appears especially suitable for plants that survive physical disturbance with difficulty.

This analysis suggests that most of the species sorted from the general flora as inhabitants of the heath tundra are well adjusted to the same site conditions that favor the development of Arctic Brown soil profiles—well drained loams and loamy sands that have been relatively free of physical disturbance for a considerable period of time. Heavier soils such as those of the emerged fjord bottoms have not developed Arctic Brown, nor do they support heath tundra. The same is true of loams that are subject to intense frost heaving and/or gelifluction, as illustrated on most of the diamicton slope at ES 7 and 8.

## Heath-herb vegetation

The heath-herb vegetation (Fig. 4) of warm southerly till slopes was not studied intensively in the Mester Vig district. It was present to a limited extent because of the scarcity of sites suitable for it. The vegetative cover was a mixture of the primary species of the heath tundra with herbaceous plants (particularly gramineous species). The mixture was both patchwise and stemwise. Several species were not seen at all in other Mesters Vig vegetation: *Botrychium Lunaria*, *Juncus trifidus*, *Salix arctophila*, *Viscaria alpina*, *Gentiana nivalis*. Others that were common in this type but seen only infrequently elsewhere were: *Sibbaldia procumbens*, *Campanula rotundifolia*, *Taraxacum brachyceras*. All of these species have their northern limits on the east coast of Greenland either in the Kong Oscars Fjord district or elsewhere in the southerly part of the fjord region.

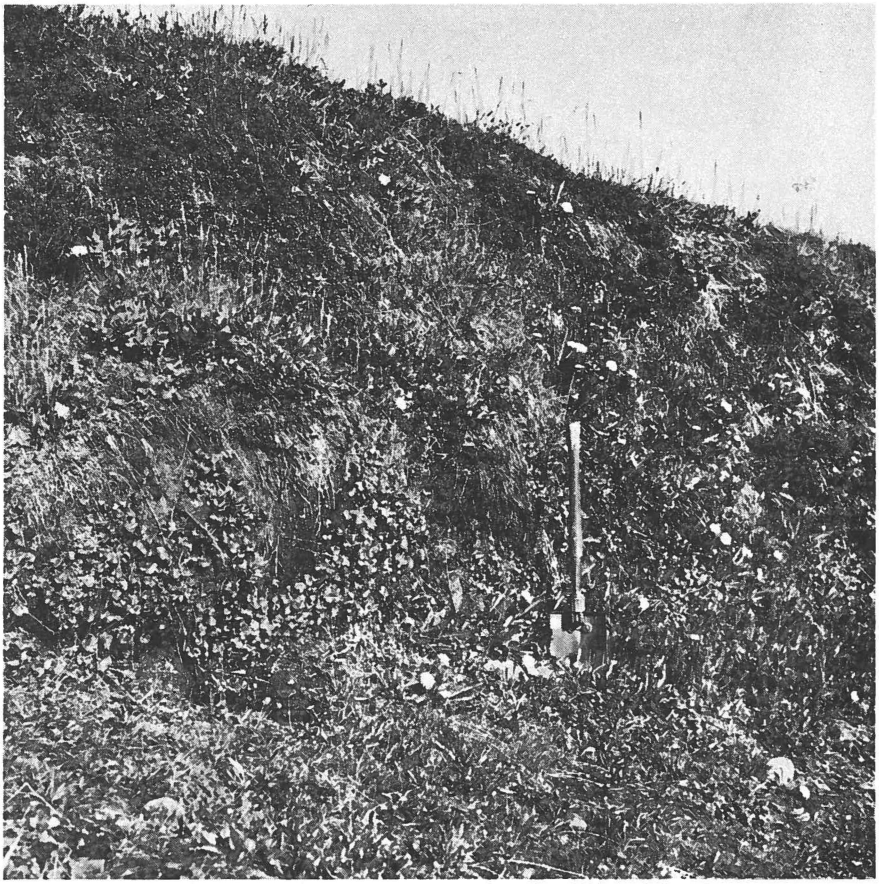

Fig. 4. Heath-herb vegetation of warm southerly till slope on marginal bank of large gelifluction lobe at about 750 m on easterly slope of Hesteskoen (ES 17), 5 Aug. 1957.

The present analysis is based upon observations in four places. One was on the southeast-facing slope of a river bluff along Nedre Gefionelv a short distance above the Nordisk Mineselskab mine (Blyklippen). The second was on the south-facing lateral bank of a large gelifluction lobe at an altitude of about 750 m on the easterly slope of Hesteskoen (ES 17) (Fig. 4). The third was at altitudes between 400 and 600 m on the southwest-facing slope of Domkirken in the valley of Store Blydal. The fourth was on a steep south-facing slope in the lower valley of Lejrelv. The nearest counterpart to this vegetation among Sørensen's ecosystems probably is in his "Dry" series: "V. Dry Sunny Slopes—Xerophilous Herb Slopes".

Twenty species in this type were eliminated for the following analysis as nondefinitive. Of these, 17 proved to be widely tolerant and

3 narrowly tolerant on all of the environmental gradients used. The base number for analysis was therefore 37 (Fig. 1).

On the coverage gradient 65 % of the definitive species were widely tolerant of variation, and 11 % narrowly tolerant. Observed variation in cover density appeared to be large, perhaps as great or greater than in heath tundra. Consequently the amount of wide tolerance on this gradient seems lower than might be expected. More than half the definitive species (55 %) were widely tolerant of moisture variation, and only about 16 % very sensitive to it. The preponderance of wide tolerance reflects the general summer desiccation of soils that do not have direct access to water from relict snow and thawing ground. This dryness is somewhat relieved by dense vegetative cover in the patches where it occurs.

A relatively large proportion of the definitive species (50 %) were narrowly tolerant of frost disturbance, and only 8 % were widely tolerant. This suggests a site relatively free of frost heaving. Although no precise data are available on heaving in this kind of site, the soil texture, vegetative cover, and general moisture regime argue for low heave intensity. On the other hand some of the localities studied were affected by dry creep, a nonfrost disturbance. On steep dry slopes some plants were being undermined by the creep and others buried by it. The definitive species showed 41 % narrowly tolerant on the nonfrost disturbance gradient, and 27 % widely tolerant. These proportions, especially when compared to those on the frost gradient, suggest a site somewhat less suitable for plants sensitive to nonfrost disturbance than for those sensitive to frost action. They suggest further that dry creep, while locally injurious to plants, is not sufficiently widespread to make most of the flora widely tolerant of it.

## Turf hummock vegetation

Turf hummock vegetation (Fig. 5) has been described in an earlier paper (RAUP, 1965 B) and has appeared also in discussions of ES 6, 7, 8 and 17 (RAUP, 1969 B) and in the treatment of kames and emerged delta remnants (RAUP, 1971 B). The hummocks are widely distributed in small areas on the lower mountain slopes, but have their most extensive development on long gentle slopes bordering the fjord. The "knolly bogs" described by SØRENSEN (1937, p. 125–129) appear to embrace the turf hummock vegetation noted here.

The flora of the turf hummocks contains 40 species of vascular plants, 18 of which proved to be widely tolerant on all of the environmental gradients used. There being no species narrowly tolerant on all gradients, 22 are regarded as definitive (Fig. 1).

Fig. 5. Maturing turf hummocks in small valley among "110-m" emerged delta remnants about 1 km west of Tunnelelv, 1 Aug. 1957. View southeast.

On the coverage gradient about 77 $^0/_0$ were widely tolerant of variation and only about 9 $^0/_0$ were narrowly tolerant. Most of the plants, therefore, appear to be well adjusted to the wide variation in coverage that is known to exist.

Over half of the definitive species (54 $^0/_0$) showed wide tolerance of variation in the moisture supply, and only about 4 $^0/_0$ were sensitive to this kind of variation. The flora in general, therefore, is predominantly of species capable of surviving considerable summer desiccation, and most of them a great deal of seasonal variation. Such variation becomes wide as the hummocks begin to deteriorate in later parts of their developmental sequence.

It was noted elsewhere that frost disturbance of the hummock flora varied from very little in species rooted in the turf, to intense disturbance of those rooted in the mineral soil. In general, then, frost injury to the total flora might be expected to be intermediate. Analyses indicate that about 32 % of the definitive species were widely tolerant on this gradient and only a few less (27 %) were narrowly tolerant. This is the expected result if the preceding assessment of the site is correct.

On the basis of known disturbance due to nonfrost processes, the plants of the turf hummocks should be little affected by this kind of disturbance. Such proved to be the case, for 68 % of the definitive species were narrowly tolerant on this gradient, and only 18 % were widely tolerant.

## Organic crust vegetation

The nature and general prevalence of organic crusts (Figs. 6–11) in the Mesters Vig district have been treated in an earlier paper (RAUP, 1969 B), and further descriptions of them are in discussions of experimental sites 6, 7, 8, 9, 15, and to some extent in 17 (RAUP, 1969 B). The vascular flora of the crusts, characteristically scattered in open formation, is highly variable from place to place; but in the aggregate it is one of the largest vegetation types in the district. The crusts were found in all but the driest of the experimental sites used for intensive study. Most of the more precise data for the present analysis came from these sites, though they were supplemented by notes from many other places. The crusts were so nearly ubiquitous that it was virtually impossible to avoid them in any localized study of the vegetation. The term "thin tundra", coined in the field and used to describe the widespread vegetation of scattered vascular plants, came to mean almost exclusively the organic crust assemblage.

Organic crust seems not to have been conspicuous in the areas studied by SØRENSEN (1937). Among the ecosystems described by him the one most nearly resembling the organic crusts in his "XI. Snow patches and (active) Polygon Fields.—Snow-patch Vegetation" (l.c., p. 124–125). His term "snow-patch" is equivalent to "snow-bed" as the latter is used here. Polygon fields in the Mesters Vig district, if they are "active", may or may not have crusts on them depending upon the intensity of frost disturbance (see RAUP, 1971 A).

Of the 22 species in the whole Mesters Vig flora regarded as widely tolerant on all the gradients studied, 21 were found in the organic crusts. Only one species narrowly tolerant on all gradients was present. Thus there were 42 species regarded as definitive and used in the following analyses (Fig. 1).

The preponderence of wide tolerance on the coverage gradient appears greater than observed conditions warrant. Inconsistencies of this kind have been found in several sites, and suggest that small differences

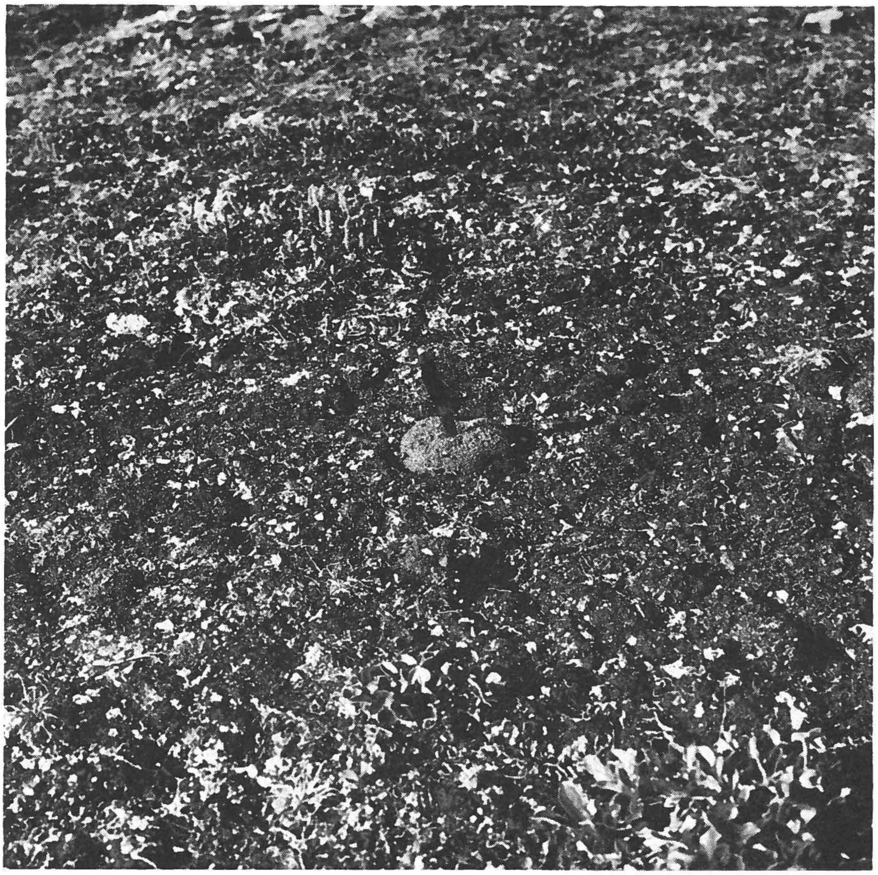

Fig. 6. Organic crust vegetation on damp sandy soil, on Labben in vicinity of ES 2' 3, 9, 19 July, 1957.

in the behavior of a flora composed of species with generally wide tolerance of coverage variation may be of little significance. Fifty percent of the definitive species were widely tolerant on the moisture gradient, and about 17 % were narrowly tolerant. These proportions are fairly consistent with the observed variation in the moisture supply to the crust areas.

Frost heaving is known to be relatively intense in the organic crust soils studied at the experimental sites, and it is presumed that similar intensity is widespread. Analysis of the definitive species on the frost disturbance gradient indicates adjustment to this, with 36 % widely tolerant and only about 19 % narrowly tolerant. Extensive partial adjustment is indicated by the intermediate group (45 %). Over half the definitive species (57 %) were narrowly tolerant on the nonfrost disturbance gradient, and only 21 % were widely tolerant, suggesting floristic

Fig. 7. Organic crust on broad till bench, at about 400 m alt. on northeast slope of Hesteskoen. View north, 11 Aug. 1964.

adjustment to the noninjurious effects of whatever disturbance of this kind may occur in the organic crusts.

**Relation of organic crusts to snow-bed vegetation:** The organic crusts are characteristic of extreme snow-bed conditions (Fig. 8), but at Mesters Vig there seems to be no necessary relationship between these conditions and the occurrence of the crusts. The latter were found wherever there was exposed, damp to wet mineral soil, whether it emerged from the winter snow early or late. One of the largest expanses of organic crust and thin tundra seen in the district was on the northeasterly slope of Hesteskoen at an altitude of about 400 m. Here it occupied a wide bench of glacial till having a sandy-stony soil (Fig. 7). It was fully exposed to northwest and northeast winds from the fjord, with no obstructions to cause deep snow accumulation. It is probable that this

Fig. 8. Snow-bed at margin of snowdrift, on Labben north of ES 5, 11 July 1958. View southeast.

surface lost its snow in spring as early as any on the northerly slopes of the mountain. Other large areas of crust were on the low terraces bordering the present outlets of Tunnelelv, at altitudes of 5 to 15 m. Here there were no large snowdrift accumulations and no late-lying snow.

**Relation of organic crusts to soil movement:** The crusts and their accompanying scattered plants were found not only in large areas, but also in patches of all sizes scattered through other types of vegetation, even in small areas involving one to several square meters in the midst of dense heath tundra. An example of the latter was seen on the lower northeast slope of Hesteskoen in early August, 1957. It was an elongated patch of black crust extending 3–4 m up and down slope and 2–3 m across in the upper part (Fig. 9). The surrounding vegetation was *Cassiope – Vaccinium – Salix – Dryas* heath with a coverage density of

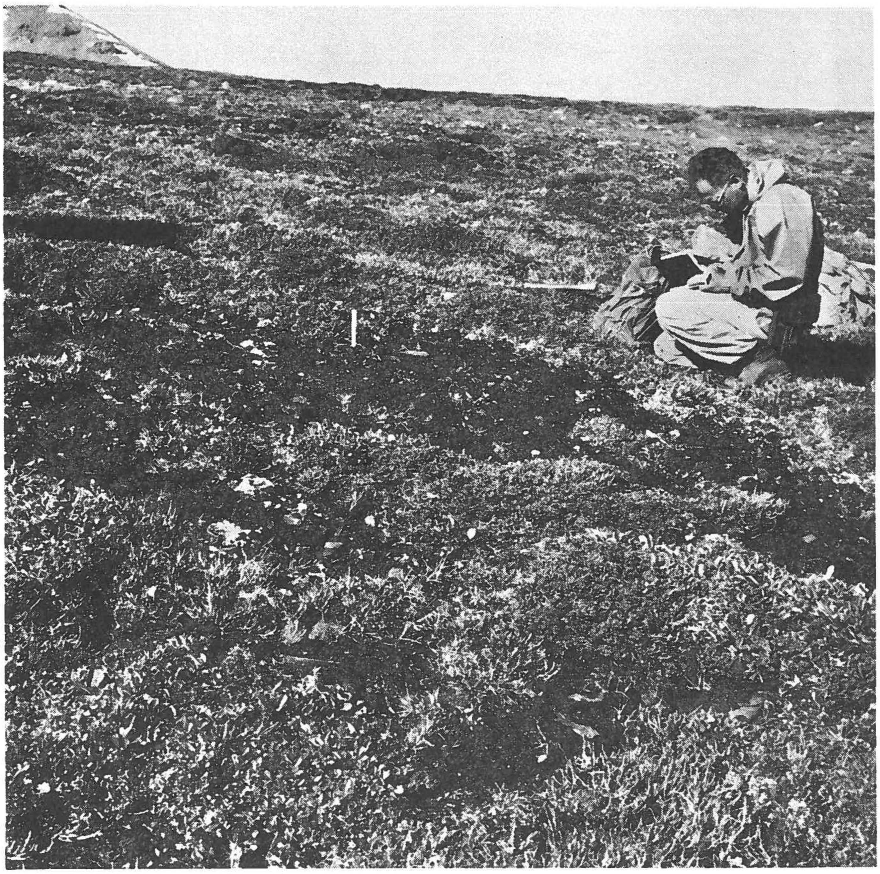

Fig. 9. Small patch of organic crust in heath tundra on northeast slope of Hesteskoen, 5 Aug. 1957. Contains stretched root of arctic willow, located at 17-cm ruler (see Figs. 10, 11).

70–90 $^{0}/_{0}$. Attention was called to this particular patch, of which there were many in the vicinity, by a root of *Salix arctica* that was exposed at the upper margin (located by the 17-cm scale in Fig. 9 and shown in detail in Fig. 10). This root was alive, but stretched so taut that it vibrated when plucked. When excavated it was found to extend straight downslope, within 10 cm of the surface of the crust, about 100 cm to a mat of *Dryas* into which it disappeared (Fig. 11). Throughout this distance it maintained its tautness.

This situation is regarded as evidence of a break or series of breaks in the continuity of the tundra heath by downslope movement of the surficial soil. The movement may have been due to a combination of gelifluction and frost creep, or perhaps to small earthflows that would have been more sudden. The result was exposure of damp mineral soil which was then covered by the crust. A willow root that had extended

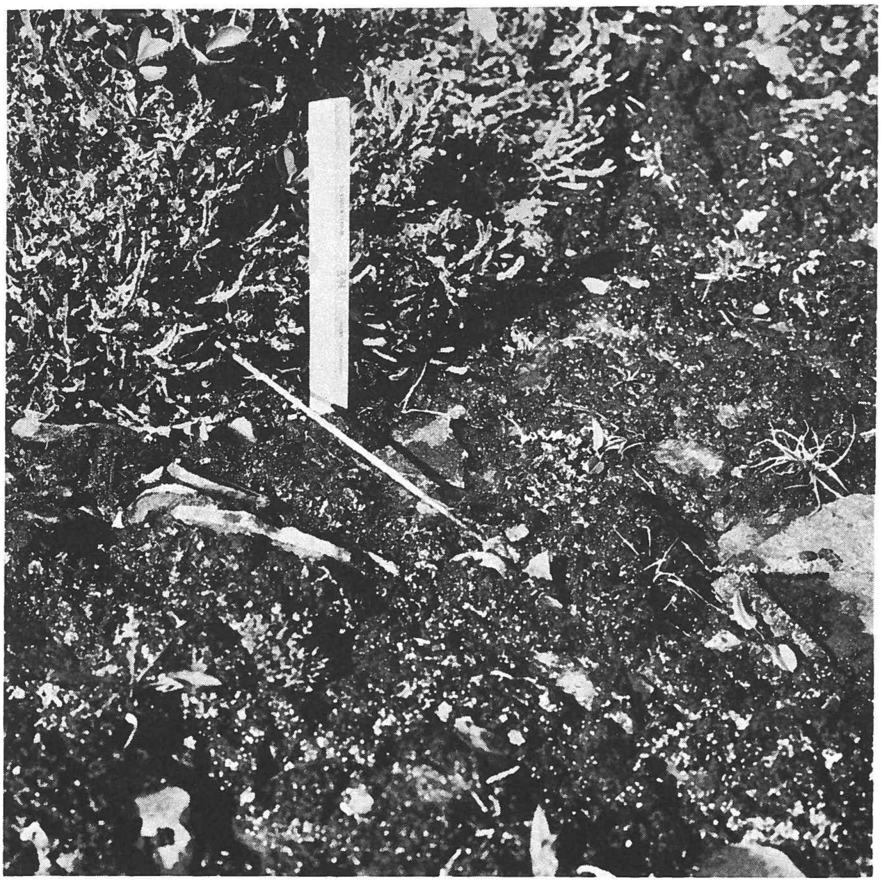

Fig. 10. Stretched root of arctic willow at upper margin of patch of organic crust in heath tundra on northeast slope of Hesteskoen, 5 Aug. 1957 (see Figs. 9, 11).

downslope with its terminals intertwined among the roots of another plant, was stretched taut when the latter plant moved away. The break or breaks must have occurred within the lifetime of the willow which, judging by the known growth rates of the species in this region and in this kind of site was probably something less than 40–50 years.

If the above interpretation is tenable, organic crusts closely resembling those of snow-beds, may be formed in the Mesters Vig district by any geomorphic process that exposes damp mineral soil. Patches of the crust and thin tundra may therefore be found adjacent to whatever type of vegetation is present in the disturbed areas.

## The vegetation of dry sites

For purposes of analysis and general comparison several kinds of vegetation are grouped together here because they have a major site

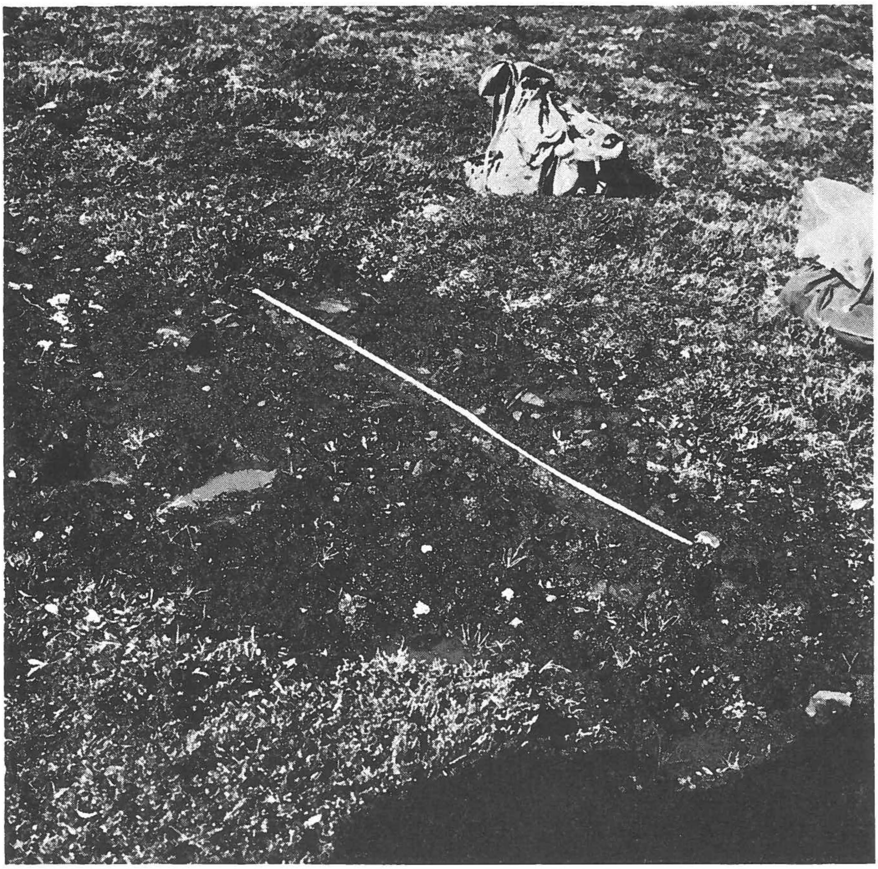

Fig. 11. Excavation of stretched root of arctic willow in patch of organic crust, northeast slope of Hesteskoen, 5 Aug. 1957.

condition in common (Fig. 12). All of them, though their soils may be wet or very moist for a short period (1–3 weeks) after snow-melt in spring, undergo severe desiccation during the summer. They are found on the thin sandy soils of rock ledges and crevices, on talus accumulations around cliff-bases, on the very well drained soils of kames and some till knolls, on the coarse grus soils of trap knobs, in the driest parts of the emerged delta remnants, and in many areas of clayey silt on emerged fjord bottom deposits. Discussions of localized representatives of them have appeared in treatments of ES 7, 8, 9, 16 and 20, of ledge, crevice and talus floras, and of kames and delta remnants (RAUP, 1969B, 1971B).

In SØRENSEN's ecosystems (1937) these types are found mainly in his "Dry" series: "I. Dry Barren Ground.—Desert"; "II. Dry Loess Fields and Terraces.—Steppe"; "III. Dry Disintegrating Summits and Crests"; "IV. Bird Places"; "VI. Dry Clayey Flats and Raised Beaches".

Fig. 12. Dry site vegetation on trap knob MS 180 m, on lower NE slope of Hesteskoen. View north, 4 Aug. 1957.

Twenty of the 60 species proved to be widely tolerant, and one narrowly tolerant on all the gradients. Thirty-nine were therefore considered definitive and used in the following analysis (Fig. 1).

Sixty-one percent of the definitive species were widely, and 13 % narrowly tolerant on the coverage gradient. The proportion of widely tolerant species is relatively low compared to that in other vegetations, suggesting correlation with the low variability observed in the dry sites. On the moisture gradient about half the definitive species (51 %) were widely tolerant and 13 % were narrowly tolerant of variation. Although, as noted above, total moisture variation in many of the dry sites may be very great, effective variation may be small or moderate. If the latter is a valid conception, the median percentage of widely tolerant species is consistent with it.

Disturbance of the dry soils by frost action being relatively minor, a preponderance of narrowly tolerant species on the frost gradient was to be expected. About 46 % of the definitive species were in this category, against about 10 % widely tolerant. In contrast, although nonfrost disturbance was only locally effective, widely tolerant species slightly outnumbered the narrowly tolerant on the nonfrost gradient (33 %, 31 %).

## Comparison of vegetation types by factor gradients

**The coverage gradient:** Over half the total flora of the Mesters Vig district (55 %, 85 spp.) was found in ground coverages ranging over at least 2/3 of the possible variation, and was therefore of species considered widely tolerant on the coverage gradient. This set a relatively high level of wide tolerance likely to be found in any segment of the vegetation. It appeared in all of the analyses that have been made. It is present again in Fig. 1 A where wide tolerance percentages range between 60 % and 84 % of the definitive species.

The significance of variations within this range of 24 % may be questionable in a flora clearly dominated by species that are relatively insensitive to differences in vegetative density. It may be suggestive, however, that in general the larger proportions of wide tolerance are in the vegetation with the greater density. An apparent exception is in the flora of heath-herb vegetation, but field data on densities in this type are scanty, and the variations of coverage in it may be less than assumed.

Discontinuities of cover are frequent in all of the denser vegetations, and the range of variation is consistently wide, from less than 1 % to 90 %. The more open types such as occur on organic crusts and dry sites have a much smaller range because they rarely show coverages above 40–50 %. The floras of the denser types could be expected to have higher proportions of the species most insensitive to coverage variation, as they do. If the heath-herb vegetation has in reality a major proportion of low to median densities, its percentage of wide tolerance should be low to median in comparison to other types, as it appears to be in Fig. 1 A.

**The moisture gradient:** An outstanding feature of the graph in Fig. 1 B is the preponderance, in all of the vegetation types compared, of definitive species widely tolerant of moisture variation. They range from 3 to 12 times as many as the narrowly tolerant species. Another outstanding feature is the relatively high and uniform percentage (50–55 %) of wide tolerance of moisture variation in five of the six types of vegetation compared. The exception is in the moss-sedge meadows, where the percentage is about 20 % lower.

The prevalence of summer desiccation is characteristic of the Mesters Vig climate (RAUP, 1965 B, p. 96–99; WASHBURN, 1965, p. 17–24). It appears to be generally reflected in the higher percentage of widely tolerant than narrowly tolerant species in the flora as a whole. Although nearly all of the soils are wet in spring, most of them are more-or-less dried during the summer giving rise to greater or less (though usually greater) seasonal variation.

The moss-sedge meadows are restricted to sites that have a fairly constant source of summer moisture from melting snow or thawing ground. As snowdrifts melt back during the summer the immediate water sources become farther from the meadows, so that there is a certain amount of desiccation. But the meadow soils remain wet, even in unusually dry summers such as that of 1964. Thus seasonal variability of the moisture, though present, is much less than in most of the other sites in the district. The lower percentage of species widely tolerant of variation therefore accords with expectations.

All of the other vegetation types compared in Fig. 1B have considerably smaller or more uncertain supplies of summer moisture, and therefore greater variation in their supplies. Heath tundra, heath-herb vegetation, and the dry sites are almost entirely dependent upon spring melt water. The same is true of most of the organic crust vegetation, though a small and relatively insignificant portion of this is in the snowbeds where summer moisture may be abundant. Turf hummocks, though wet in their early stages, develop through phases of desiccation within the life spans of many of their plants, producing wide variations in available moisture. Under these conditions it is to be expected that species particularly adjusted to wide moisture variation should be more numerous in these floras than in the moss-sedge meadows.

The extremes of moisture variation probably are in some of the dry sites, and it seems anomalous that these sites do not show, collectively, a higher proportion of widely tolerant species than less extreme habitats. A suggested explanation is that in many desiccated sites such as the grus soils the spring melt water is lost so quickly that plants rarely have time to germinate and become established. Thus effective variation, as far as the plants are concerned, is very small, and the plants that do become established are those with universally wide tolerance on all gradients, or those with preferences more-or-less restricted to extremely dry soils. If this proposal is tenable, the proportion of wide tolerance in the dry sites generally would be reduced, perhaps to the level seen in Fig. 1B.

**The frost disturbance gradient:** In contrast to its relations with moisture and ground coverage the whole flora of the Mesters Vig district shows much higher percentages of species narrowly than widely tolerant on the physical disturbance gradients. This suggests that the moisture factor is in general more significant in determining the character of the flora than physical disturbance, and supports SØRENSEN's view expressed in 1937.

On the frost disturbance gradient (Fig. 1 C) the floras of the major vegetation types depart from the preponderance of narrow tolerance in two cases. The most striking of these is in the vascular flora of the organic crusts where it is to be expected because of the intense frost heaving known to occur there. The other case is in the turf hummock vegetation where the contrast, though present, is much less prominent. Heaving is intense in some stages of turf hummock development, but its effect upon the total flora probably is reduced because the moss-turf phase of the habitat is relatively free of frost action.

The four remaining vegetations are sufficiently free of frost heave to allow the establishment of more species very sensitive to it than widely tolerant of it. The most striking cases of this are in the driest sites, where late summer and autumn moisture are least. Late season moisture is greatest in the moss-sedge meadows, and considering the moisture supply alone, a vegetational reaction similar to that of the organic crusts might be expected. But frost heaving in the meadows usually is greatly reduced by the moss mats and/or humic horizons nearly always associated with the living vascular plants. Nonetheless there appears to be enough heaving to bring species widely tolerant of it to within 6 % of the more numerous narrowly tolerant ones. The heath tundra, as would be expected, is intermediate between the meadows and the dry sites with respect to the effects of frost heaving.

**The nonfrost disturbance gradient:** The only vegetation type in which much wide tolerance of nonfrost disturbance seems to be required is in the drier sites (Fig. 1 D). It supercedes narrow tolerance only in the very dry soils of trap and till knobs, talus, delta remnants, kames and clayey silts. Dry creep and/or wind cause most of the disturbance in these habitats. The nearest approach to them elsewhere is on the warm southerly till slopes where some dry creep was observed. The data summarized in Fig. 1 D indicate again that gelifluction per se is essentially noninjurious to most plants. Among the vegetations compared here it is probable that the most active gelifluction is in the saturated meadows, which have the highest proportion of species narrowly tolerant of nonfrost disturbance. Other high percentages of sensitive species are in turf hummock and organic crust vegetations where gelifluction was also seen to be active in some places. Early season gelifluction in the clayey silts of the dry parts of ES 7 and 8 appeared to be partially limiting, probably to germination and establishment in soils that become very dry in late summer. In this way gelifluction may have contributed to the high percentage of wide tolerance in the dry sites.

# MATERIALS FOR A KEY TO THE MESTERS VIG VEGETATION TYPES BASED ON ENVIRONMENTAL FACTORS

## Coverage of the ground by vascular plants

The effects of agencies restrictive to the vegetation appear to be rather clearly expressed by degrees of coverage of the ground by vascular plants. It is convenient, therefore, to let the variables of moisture and texture express themselves against average coverage subdivisions of dense (61–90 %), medium (31–60 %), and low (0–30 %). It is recognized that this requires subdivision of some of the six major vegetation types previously described. Heath tundra appears not only as dense coverage but also in medium coverages, and occasionally in low, as isolated patches that affect the total coverage percentages in other types. Moss-sedge meadows, though they show dense coverage when fully developed, sometimes have medium coverage under certain moisture conditions. Maturing turf hummocks, in a developmental stage prior to the formation of deep inter-hummock channels by dissection, have medium to dense heath tundra on them. In later, deteriorating stages they share space with organic crust vegetation and thus appear in medium coverages. Organic crust vegetation, characteristically low in coverage, thus shares medium coverage with heath in some sites. The vegetation of dry sites, a composite type in the general description of the vegetation, though most of it has low coverages, appears also in medium coverages which it shares with *Cassiope* or *Vaccinium* heaths.

Coverage estimates (RAUP, 1969A, p. 39–49) were based first upon percentages of the ground in small areas (50 × 50 cm) intercepted by vascular plants when viewed from directly above. For application to vegetation types these estimates were roughly averaged over larger areas (usually 30–50 sq. m).

## Soils

From the standpoint of plant growth and survival the soil is regarded as the surficial layer of materials in which most of the roots are found. Most of the root and underground stem systems of the plants are in the

Tab. 3. *Textural composition and physical characteristics of major soils in the Mesters Vig district. (Adapted from Soil Survey Manual, U.S.D.A. Handbook No. 18, 1951).*

| | Clay % | Silt % | Sand & fine sand % | Gravel % | Soil cast | Soil thread | Soil ribbon |
|---|---|---|---|---|---|---|---|
| Clean gravel | Trace | Trace | Trace | > 90 | Nonplastic | | |
| Sandy gravel | Trace | Trace | < 50 | > 50 | Nonplastic | | |
| Sand and loamy sand | < 15 | < 30 | > 70 | | Nonplastic | | |
| Sandy loam | < 20 | < 50 | > 50 | | Bears careful handling without breaking | Thick, crumbly, easily broken | Will not form ribbon |
| Silty loam | < 28 | > 50 | < 50 | | Varies from breakage w/o careful handling to no breakage when freely handled | Thick, soft, easily broken | Will not form ribbon |
| Clayey loam | > 28 | < 50 | < 45 | | Bears much handling without breaking | Strong thread can be rolled to a pinpoint | Forms thin ribbon that breaks under its own weight |

uppermost 10–15 (20) cm of these materials, and it is here that most of the effective moisture variations and physical disturbance occur. Disturbances at greater depths, however, sometimes affect the materials of the root zone.

Six textural categories of soils are used in the present analysis (Tab. 3). The categories are generalized from many grain size analyses made at the experimental sites (WASHBURN, 1967, App. D, p. 224–269; 1969, App. B).

Considered from the standpoint of pedogenic processes, most of the Mesters Vig soils show very little horizon development (see UGOLINI, 1966, A, B, for discussion of these soils). The major exception is a well drained soil called "Arctic Brown" (TEDROW & HILL, 1955). It has developed in relatively undisturbed loams and loamy sands, and is manifested by a reddish-brown horizon under an organic layer (which may be very thin) and over a gray or gray-brown layer. It is found on the tops and upper slopes of emerged delta remnants, till benches or kame knolls and terraces, and in small isolated masses of diamicton in the centers of large fossil sorted nets. Some profiles were found to be disrupted by frost churning and by the intrusion of frost heaved material (UGOLINI, l. c. Figs. 2, 3), suggesting that the Arctic Brown soil is subject to "make-and-break" in situ depending upon changes in disturbance activity. This was seen also in places where windblown sand had buried Arctic Brown profiles.

## The moisture supply

Most of the moisture available to plants comes from melting snow or thawing ground. A small amount comes from summer precipitation (see WASHBURN, 1967, pl. C 1 – 1 to 17, C 2 – 1 to 40, C 3 – 1 to 21), but this is extremely variable, never great, and commonly negligible. The distribution and movement of water in the soils is correlated with texture, topographic position, and the amount of water available.

The driest sites are the sandy and gravelly soils of emerged delta remnants, alluvial terraces and talus slopes where internal drainage is unimpeded. Next are the sandy loams or loamy sands of glacial knolls and terraces. Closely related to the last are the lateral banks of large gelifluction lobes, and the scarps formed by earthflow. Somewhat more moist are sandy or silty loams on gentle to moderate, relatively smooth slopes not supplied with surface water. Masses of diamicton isolated in the centers of large fossil sorted nets have moisture similar to this. Still more moist are soils with sandy or loamy textures that lie in shallow depressions on gentle slopes where the water is concentrated during part or all of the growing season. In some places snow lies a little longer in these depressions than on neighboring convex surfaces, but in many places it does not. The wettest soils are those immediately in the path of sheet flow from snowdrifts or thawing ground, or those with high water tables around lakes, along streams, or on low seashores.

A special position with respect to moisture is occupied by the clayey loams derived from marine silts. These soils are widespread near the shores of the fjord, and found locally in till at higher elevations. They are very wet in spring, during and for a short time after snow-melt. At this time they would be described as wringing or dripping wet. During the summer the uppermost 2–4 cm dry out to brittle hardness which persists into the autumn. Thus extreme desiccation probably is the basic factor limiting to plants in soil that in spring and early summer would be classed as wet.

Soil moisture is here classified in three major divisions: dry soils, moist to wet soils, and soils having free water over the surface. These are variously subdivided as follows. The divisions are supported by numerous analyses at experimental sites (WASHBURN, 1967, 1969).

Dry soils: give no feeling of dampness to the fingers when handled, and run freely through the fingers. The principal processes affecting these soils are desiccation, dry creep and wind deflation and deposition, all of which are determined largely by slope and exposure. The following topographic subdivisions are used:

Level to gently rolling surfaces: slopes 1–5°.
Moderate slopes: 6–15°.
Steep slopes: > 15°.

Moist to wet soils, with no free water over the surface: The principal processes affecting these soils are frost heaving and churning, frost and desiccation cracking, gelifluction and earthflow. The soils may or may not remain moist or wet throughout the growing season. They are subdivided as follows:

Slightly moist to moist: dampens the fingers when handled.
Wringing wet: water does not flow freely from the soil when the latter is handled, but may be squeezed out by hand.
Dripping wet: water drips out freely when the soil is handled without squeezing.

Soils with free water over the surface during the growing season: Principal processes affecting these soils are temperature equalization in the surface materials; fluvial, lacustrine and marine erosion and deposition. Two main subdivisions are:

Water supply continuous through all or most of the growing season: sheetflow and lake shore sites.
Water supply periodic (annual or tidal): flood plains and tidal shores.

There is evidence that the Mesters Vig district is in a period of general desiccation that may or may not have reached or passed its peak. The evidence suggests that the period of desiccation began about 60–75 years ago. Lichens seem to have grown more luxuriantly at some recent time than they do now on sand-polished traprock. Traces of these lichens are common on a trap ridge on Labben where sand blasting is currently active. Perched willows of known age are common on dry slopes where their forms indicate that they must have begun their growth in wet mossy meadows within the period suggested above (RAUP, 1965B, p. 78–99). Large inactive patterned ground and mass-wasting features appear to have become stabilized in many parts of the landscape by reduction of their water supplies. There is widespread mortality among plants on well to moderately drained soils. This is particularly notable among woody species such as *Cassiope tetragona*, *Dryas octopetala* and *Salix arctica*, many of which have taproots capable of long penetration for moisture. Arctic Brown soil profiles were found buried under recent deposits of wind-blown sand in the emerged delta remnants, suggesting an increase of eolian activity due to desiccation.

Correlations between increasing numbers of species or increasing density of coverage of the ground by vascular plants on one hand, and an increasing supply of soil moisture on the other, are not entirely direct. The correlations are fairly good at the very wet and very dry ends of the moisture gradient, *i. e.* on dry rocky till or kame knolls, rocky hill-tops, and glacio-fluvial sands and gravels at one extreme, and at the other in sheet flow areas or lake margins where free water is present during the summer. In soils with medium moisture, even though the moisture may persist throughout the growing season and is adequate for abundant plant growth, the vegetation is commonly scanty, with scattered vascular plants among which there is relatively high mortality. Drier soils of similar textures, immediately adjacent, commonly have a much denser cover.

## Snow cover

Thick (1–3 m) continuous snow cover in the Mesters Vig district throughout the winter eliminates most of the common interpretations of vegetational distribution in terms of variations of snow cover (see Raup, 1965B, p. 28–30; 1969A, p. 29). When the snow disappears in spring the tops of knolls and the margins of terraces appear first, as would be expected. Snow lies longest on the lee slopes of terraces, ridges and other such topographic eminences. In many seasons it remains all summer in these places. Typical "snow-beds" appear as the drifts melt back. But these differences in the timing of soil exposure do not begin to account for all of the vegetational variation that occurs in the district. Many slopes that have moist soils and convex surfaces have organic crusts and scattered vascular plants like those in snow-beds that are not exposed until midsummer. Some of these are in exposed situations where the soil appears relatively early (Fig. 7). Vegetation on the tops of knolls and ridges, composed of scattered vascular plants immediately adjacent to dense mats of heath, comes out from under the snow all at the same time. Patches of *Cassiope* heath, interdigitated with equally large areas of lichens or organic crust, lie under deep snow on the tops of emerged delta remnants and are all exposed at the same time.

It is possible that the great abundance of organic crust vegetation in the Mesters Vig district is due in part to the deep continuous snow blanket which covers most of the area and persists late in many seasons. In dry, well drained and moderately drained soils, frost heaving and gelifluction have moderately injurious effects or none at all. Under these conditions, given sufficient moisture, plants can germinate or begin their seasonal growth as soon as the snow disappears. In moist to wet soils there is much more physical disturbance, and plants have more difficulty with establishment and growth. In soils bathed by sheet flow there is at once abundant moisture and little disturbance. A general shortening of the growing season by the deep, persistent snow blanket is therefore most injurious to plants in dry or moist to wet soils, for in these situations the season is too short to allow recovery from injury due to desiccation or to geomorphic processes. In the wet, stable soils such as occur in sheet flow areas neither desiccation nor physical disturbance limits the plants, and the effects of the short season are not obvious. It is here that the densest vegetations appear to have their origin.

## Factors restrictive to plant growth: Desiccation and physical disturbance

Agencies restrictive to plants are desiccation and the several geomorphic processes that are conditioned by the general climatic, topographic and geologic situation of the district. The arctic climate is responsible for a base of permafrost in the soils, and an active thawed layer in spring and summer above it. It also causes a great deal of the prevailing summer drought, for westerly winds off the inland ice carry very little moisture that can be precipitated as rain or snow during the summer growing season.

With little or no deep drainage, thaw moisture concentrates in the active layer. If soil texture and topographic position permit, this layer is subject to frost heave and to flow. Heaving appears to be most active in the autumn, and gelifluction in the spring. If the thawed layer is well drained, as in coarse textured soils, little disturbance by frost heaving or gelifluction occurs, and the soils remain relatively stable. An analogous result appears in clayey silt loams where summer moisture, though it may be present in considerable quantity at depth, moves too slowly through the fine textured soil to keep pace with summer evaporation from the surface. These soils become extremely dry and hard during the summer, and show slight evidence of disturbance.

Frost heaving and churning, creep, and gelifluction probably are the most effective and areally widespread soil disturbing processes in the district. By far the most injurious to vascular plants probably is frost heaving by the growth of ice lenses and interstitial ice in the mineral soils. The most intense frost disturbance was seen in active forms of sorted nets and stripes, nonsorted circles, debris islands, pingos, and in some gelifluction lobes. In some of these plant life is entirely precluded, but all of them are localized in relatively small areas. More important is the less intensive but widespread frost action in moist to wet soils where all the plants are more or less affected.

In situations where free water occurs on the soil surface during the summer, as in sheet flow areas or on broad lake shores, the surficial soils remain relatively free of frost heaving, though they may be subject to gelifluction if fine-textured. This environment is one of the very few available in the landscape wherein conditions of moisture, soil texture, and lack of significant physical disturbance permit the development of a dense vegetation on bare soil (see Raup, 1965 B). Moss-sedge meadows appear, in which heath tundra develops on turf hummocks. If desiccation by the retreat of snowdrifts (Raup, 1965 B) or by changes in drainage systems does not occur too rapidly, this heath tundra may persist as relatively dense cover for considerable periods of time. It is probable that most of the heath tundra in the Mesters Vig district now on moist soils originated in this way. Having become established on the wet stable soils its dense mat has protected it to some extent from heaving and thus allowed it to persist.

Where dense vegetation develops on moist to wet soils and there is a surficial horizon of moss and humus, the vegetation mat produces a microenvironment in which the effects of frost heaving are greatly reduced. Plants rooted in the humus are relatively unaffected, and heaving in the underlying mineral soil is reduced by the insulation if the latter is continuous. If it is discontinuous, the heaving in the humus may remain insignificant and its plants undisturbed, while deeper rooted plants may be injured by heaving in the intervals between organic mats.

If internal drainage is intermediate, as in moist to wet sandy or silty loams, and if the moisture supply is enough to keep it in the soil during the growing season and into the autumn, the soil is subject to more (often intense) heaving, especially in autumn. The amount of gelifluction disturbance in these soils increases with steepness of slope, increasing moisture, and increasing fineness of texture. This trend is in part modified in the clayey soils, which demand much larger quantities of moisture to make them flow because of their losses to evaporation.

Next in magnitude of disturbance probably are earthflow and slushflow. In earthflow large masses of material suddenly move downslope leaving breakway scarps. Many till slopes are pockmarked by scars of these flows in various stages of healing, and fresh ones are seen occasionally (Raup, 1971 B, p. 39-50). In slushflow large quantities of snow and slush at the time of spring thaw are dammed temporarily at the heads of gullies on the mountainsides. When the dams break the gullies are intensely scoured by the precipitate flow, which dumps fans of debris on the slopes below (Raup, 1971 B, p. 51–68; Washburn and Goldthwait, 1958). Both of these processes are exceedingly destructive to plants, and though common in the landscape they are effective in a relatively small part of the district at any one time.

Stream erosion and deposition are confined largely to the immediate valleys of the main streams (Tunnelelv, Store Blydal, Lille Blydal). Small eroded channels and alluvial deposits are locally common on the mountain sides, but occupy limited space in the aggregate. The largest area affected by streams is in the gravel, sand and mud flats at the mouth of Tunnelelv where annual flooding makes extensive surfaces nearly or quite devoid of plants. Deflation and deposition by wind are confined to a few sandy or silty areas near the seashore and in the emerged delta remnants. Dry creep is mainly limited to grus on steep slopes, but it is seen also on steep south facing till slopes, and on steep sandy slopes in the emerged delta remnants. Wave and ice action on the seashores eliminate most of the small halophytic flora available for occupance of such sites except in a few protected places (RAUP, 1971 B, p. 79–84).

## Injurious effects of physical disturbance

The injurious effects of the more violent geomorphic processes are obvious. Earthflow, slushflow, intensive erosion and deposition by wind or water, wave and ice action on shores may take out whole plants or segments of vegetation, and the soils they grow in. Injuries due to intense frost heaving are also evident in high plant mortality, root breakage or injury, or the heaving of root systems partially or entirely out of the soil (RAUP, 1965 B). It is impossible with present knowledge to define the nature of varying kinds of injury due to less intense disturbances such as those of milder frost heaving and creep, gelifluction, occasional or partial flooding. Analyses of the species' behavior with respect to these disturbances has required a division of them into two categories: frost- and nonfrost-induced. Although the differences between these in their injurious effects are not clear, the division appears necessary because many plants react differently to them. Some are more sensitive to frost than to nonfrost processes, and others the reverse.

Most if not all of the processes noted above are conditioned in some degree by soil frost, though heaving, churning and cracking are most directly affected. Gelifluction usually is considered a frost action process, but plants either react to it as if it were nonfrost and more nearly related in its effects to dry creep or stream action, or they appear to be indifferent to it. In fact it probably is not very injurious to plants. Soil does not move by gelifluction unless its moisture content is at or above its liquid limit. Thus the displacement occurs in a semifluid state, and root systems usually are not strained or broken by fracture of their soils (RAUP, 1969B). Hence gelifluction is included with nonfrost processes in this discussion. In frost heaving on the other hand the roots are frozen or being frozen into the mineral soil mass, so that when the latter increases in volume by the formation of ice, and cracks are formed, roots or underground stems may be strained to the breaking point. Plants rooted in humus appear to suffer little injury from frost heaving. Although ice forms in the humus and increases its volume, the ice is mainly in the form of crystals, and the humus has enough internal flexibility to prevent fracture and sheering. It is probable that roots embedded in it are therefore not subjected to much strain.

### Effects of vegetation upon geomorphic processes

The vegetation, in the aggregate, probably has only a minor deterrent effect upon the activity of the geomorphic processes. In the ES 7 and 8 area some of the most rapid gelifluction movement was in the most heavily vegetated areas, while the slowest was in the most barren. Movement at ES 16, due primarily to dry creep, was in very thinly vegetated soil and was also very slow. WASHBURN (1967, p. 104–5) indicates that moisture supply is far more significant in determining the rate and kind of movement than either vegetation or slope. The lower margins of gelifluction lobes usually are banked with more or less dense vegetation, and it is commonly thought that this vegetation "holds" the bank in place. But when specific cases are examined it usually is difficult or impossible to determine whether the vegetation is a cause or an effect. Dissection of lobe fronts sometimes reveals pebble concentrations that may have obstructed the movement of the soil and caused the build-up of the front; or the latter may have been merely a function of the distance from the water supply and the resulting dispersion or loss by evaporation. When a front begins to stabilize the vegetation can become established. Once established it can aid in further stabilization by acting as a physical "dam". A case of this kind was studied at ES 15 (WASHBURN, 1967, p. 73–77; RAUP, 1969B, p. 140).

The large gelifluction lobe studied at ES 17 had dense vegetation on its steep lower margin (3 m high in places). It was clear that though this turf probably hindered the downslope movement of the active layer on the lobe tread, it was incapable of holding it. Masses of the turf and vegetation were being pushed over the crest of the lobe front to form an overhang in some places while in others blocks were falling off.

Probably the most conspicuous effect of vegetation upon geomorphic process is seen in the sequence of turf hummock formation and deterioration on fine textured soils. Here the thick moss of turf hummocks, functioning as insulation over isolated areas of mineral soil, gives rise to differences of frost action between these areas and intervening thinly vegetated spaces. Heaving and thrusting by frost pushes up the mound-like earth cores under the thick hummock turf (RAUP, 1965B).

The above notes suggest that the deterrent effects of vegetation upon the geomorphic processes at Mesters Vig are limited, and largely restricted to areas marginal to the full effectiveness of the processes. In these marginal areas the processes are reduced, usually by causes external to the vegetation, though the vegetation may add to the causes once it becomes established.

## Suggested causes of "Fjæld-mark"

The preceding analyses suggest that the open vegetation of "fjæld-mark" has multiple causes. In the dry sites most of it may be due to desiccation, but concomitants of the dryness in many places are the injurious effects of dry creep and wind action. These may be as limiting as the desiccation. Open vegetation is also widespread on moist soils, notably those under organic crusts. There is obviously enough water in these soils to support dense vegetative cover, but frost heaving is intense and apparently becomes a major deterrent to plant establishment and growth. Other causes are equally effective but so localized in the landscape that they do not affect much of the vegetation at one time. Such causes are earthflow, slushflow and stream erosion. The significance of the physical disturbance factors is emphasized by the fact that the denser vegetation types (the first three, L-R, in Fig. 1) are those in which species especially sensitive to disturbance are preponderant on all the gradients. Further evidence of the importance of the disturbance factors was found in the soils by UGOLINI. The only well defined profile, the Arctic Brown, was coincident with lack of major disturbance and the presence of heath tundra. Gleying in the moss-sedge meadow soils probably also indicates relative stability. The soils under the third type of dense vegetation, heath-herb tundra on warm southerly till slopes, were not investigated.

# A KEY TO THE VEGETATION TYPES BASED ON THE VASCULAR PLANT COVER AND THE PHYSICAL PROPERTIES OF THE HABITAT

Utilizing materials and ideas from the preceding discussion the following "key" is proposed. Its basic subdivisions are the three degrees of coverage of the ground by vascular plants. Within each of these the major divisions are those of moisture supply, which are in turn subdivided on the basis of soil texture, with topographic modifications. The key must be regarded merely as a first attempt to rationalize the local distribution of the Mesters Vig vegetation.

1. Dense coverage by vascular plants (61–90 %)
    2. Soils slightly moist to moist, with no free water over surface during the summer; sandy or silty loams
        3. On northerly-facing (occasionally on very moist south-facing silty loams) gentle to moderate slopes; disturbance intensities low or medium, and if present due to frost heaving and/or gelifluction .......... Heath tundra
        3. On southerly-facing, gentle to moderate slopes; sandy loams; disturbance intensities low or medium, and if present due in part to frost heaving but mainly to dry creep in late summer ............ Heath-herb fields
    2. Soils with free water over surface during the summer; developed on all soil textures except clean gravel; low disturbance intensities; sheet flow areas and lake shores Moss-sedge meadows and developing turf hummocks

1. Medium coverage by vascular plants (31–60 %)
    4. Soils moist to wet or with free water over surface during the summer
        5. Soils slightly moist to wringing wet; sandy gravels, or sandy or silty loams; disturbance intensities medium, due to frost heaving .................. Heath-crust veg. and mature turf hummocks
        5. Soils with free water over surface during the summer; developed on all soil textures except clean gravel; disturbance intensities low ............. Moss-sedge meadows and developing turf hummocks

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|---|---|
| 4. Soils dry (or rarely slightly moist); sandy gravel, sand and loamy sand, sandy or silty loam; disturbance intensities low, or medium on steep slopes and hilltops due to wind or dry creep ........................ | Scattered vasc. plants and/or heath mats, loose cover of grasses & sedges, lichens, etc. |
| 1. Low coverage by vascular plants (0–30 %) | |
| 6. Free water over surface of soils during the summer | |
| 7. Water supply periodic | |
| 8. Flood plains | |
| 9. On clean or sandy gravels; high disturbance intensities due to annual flooding ......... | Bare stones or a few, much scattered vascular plants |
| 9. On sands or loams; high disturbance intensities due to annual flooding ............. | Organic crusts, usually with a few scattered vascular plants; clayey loams nearly barren |
| 8. Tidal shores; high disturbance intensities due to daily flooding, wind, wave and ice action..... | Barren rock or nearly barren sand or mud; very few widely scattered vascular plants |
| 7. Water supply continuous; clean gravel or boulders on lake shores or in sheet flow areas; low disturbance intensities.................................. | Crustose and foliose lichens |
| 6. Soils moist to wet during the summer and autumn | |
| 10. Soils dripping wet | |
| 11. On clean gravels; low disturbance intensities | Lichens, mosses, & occasional vascular plants in crevices |
| 11. Sandy gravels, loamy sands, or sandy loams; high disturbance intensities due to frost action | Organic crusts with scattered vascular plants |
| 11. Silty or clayey loams; high disturbance intensities due to frost action .................. | Soils nearly bare; very infrequent vascular plants or fragments of organic crust |
| 10. Soils moist or wringing wet | |
| 12. On clean gravels; low disturbance intensities. | Lichens, mosses, & occasional vascular plants in crevices |

12. On silty or clayey loams; medium to high disturbance intensities due to frost action... Organic crusts, with or without scattered vascular plants and/or heath mats; wringing wet clayey loams usually bare or nearly so

6. Soils dry through most of the summer and autumn

13. On clean gravels; low disturbance intensities .... Crustose and foliose lichens

13. On sandy gravel, sand, sandy loam or silty loam

14. On level ground or on gentle to moderate slopes ($<15^\circ$); disturbance due to wind and/or dry creep of low intensity, or medium on moderate slopes.......................... Crustose, foliose and fruticose lichens, with scattered *Cassiope* mats and/or scattered vascular plants

14. On steep slopes ($>15^\circ$); medium to high disturbance intensities due to wind and/or dry creep .................................. Soil barren, or with lichens and/or a few scattered vascular plants

13. On clayey loams; low disturbance intensities.... Soil barren or with a few widely scattered vascular plants

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