SOME SYNECOLOGICAL PROBLEMS IN THE ALPINE ZONE OF GARIBALDI PARK

by

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ABSTRACT

Ecosystematic methods were used to study synecological problems in the Alpine Zone of Garibaldi Park, British Columbia.

The influence of snow pack and its effects upon soils and the distribution of vegetation are considered. The successional trend of plant communities in the subalpine alpine ecotone and alpine zone is presented. The plant succession is closely related to environmental changes, particularly to the duration of the snow pack and soil forming processes. The Phyllodoceto - Cassiopetum mertensianae can be regarded as the zonal community in the Alpine Zone above 5,500 feet. It is shown that alpine zone ranges from 5,500 feet to the highest summits over 8,000 feet.

Environmental conditions are correlated with units of vegetation which allow the recognition of twelve plant associations. The associations are arranged in groups which tend to characterize the habitats in which they are found.

The associations are grouped as follows:-

A. Snow patch group

i) _Gymnomitrieto_ - _Polytrichetum_ _norvegici_

a. sub-assoc. _gymnomitrieto_ - _polytrichetum_ _norvegici_

b. sub-assoc. _polytrichetosum_ _piliferi_

ii) _Caricetum_ _nigricantis_

iii) _Sibbaldietum_ _procumbentis_

B. Chomophytic group

i) _Caricetum_ _spectabilis_

ii) _Luetkeetum_ _pectinatae_

iii) _Anaphaleto_ - _Lupinetum_ _arctici_

C. Alpine meadow group

i) _Mimuleto_ - _Epilobietum_ _latifolii_

ii) _Valerianetum_ _sitchensis_

D. Rupicolous group

i) _Junipereto_ - _Penstemonetum_ _menziesii_

ii) _Silenetum_ _acaulis_

E. Alpine heather group

i) _Phyllodoceto_ - _Cassiopetum_ _mertensianae_

F. Krummholz group

i) _Abieteto_ - _Chamaecyparetum_ _nootkatensis_

G. Peat bog group

i) _Sphagnum_

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I. INTRODUCTION

The severity of the climate and the short vegetative season combined with arduous terrain has resulted in the frequent neglect of vegetational studies in alpine regions. It is, therefore, not surprising that alpine studies originated in the more populous mountain regions of the European Alps, where relatively large pastoral communities derived their livelihood directly from the natural resources. The three pioneer phytosociologists instrumental in the recognition of the narrow limitations of true alpine vegetation were Heer (1836), Kerner (1863), and Schröter (1926). Their studies were not only of academic interest but had considerable application, particularly, when applied to the transhumance* pattern of culture characteristic of alpine economy. The combination of grazing and forest clearing lead ultimately, in many parts of the Alps, to the lowering of the timberline. The need to stabilize the forestry and pastoral economies resulted in a number of studies by Demontzey (1882),

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*transhumance - The movement of herds and flocks from the valleys to the mountain pastures as the snow clears during the summer months.

Flauhault (1901), Reishauer (1904), Brockmann-Jerosch (1907) and Schröter (1926), that were related to the delimitation of these altitudinal zones with regard to biotic, climatic and edaphic influences.

Although many of these studies were carried out below the limit of present day alpine regions, they led to a greater understanding of vegetation in relation to the severe arctic-alpine environment. It became evident to botanists that vegetation was not a static entity but a dynamic one.

The philosophy of vegetational trends was first considered by Kerner (1863), Warming (1897), Graebner (1895) and Moss (1907), but it later became fully expressed by Cowles (1899) and Clements (1916) in North America when they considered development and succession of plant communities as the basis of synecological studies. Today in some European Schools, for example the "Zurich-Montpellier School", vegetational development and succession is bound up in a phytosociological framework whilst the "Clemensian School" regards succession as a framework for vegetational studies.

Synecology in the Pacific Coast Mountains of B.C. has been somewhat neglected due largely to the inaccessibility of the region. In the Bella Coola region (McAvoy, 1931) carried out a series of studies related to plant succession. The relationship, however, between environment and vegetation was only superficially considered. The two most recent studies were made by Krajina (1959), and Brink (1959). Krajina (1959) in his publication on the "Bioclimatic Zones in British Columbia" delimits the Alpine Zone on a bioclimatic basis and considers the climatic climax community. Brink studied "The subalpine forest-heath ecotone", particularly in relation to vegetational changes which have taken place in response to climatic fluctuations in recent times. Brink's work, similar in scope to the present study, will be reviewed more thoroughly in the chapter dealing with history.

The object of this study is an attempt to elucidate some synecological problems in the Alpine Zone within a localized area of the Pacific Coast Range. The area is located in the southwest corner of British Columbia, some 30 miles north of Vancouver and represents the Alpine Zone in the Coast Mountains in the region.

II. REGION OF STUDY

1. GEOGRAPHY

On the basis of physiography the region can be divided into three sub-regions (as shown on map of study area, page 5):

A. Volcanic

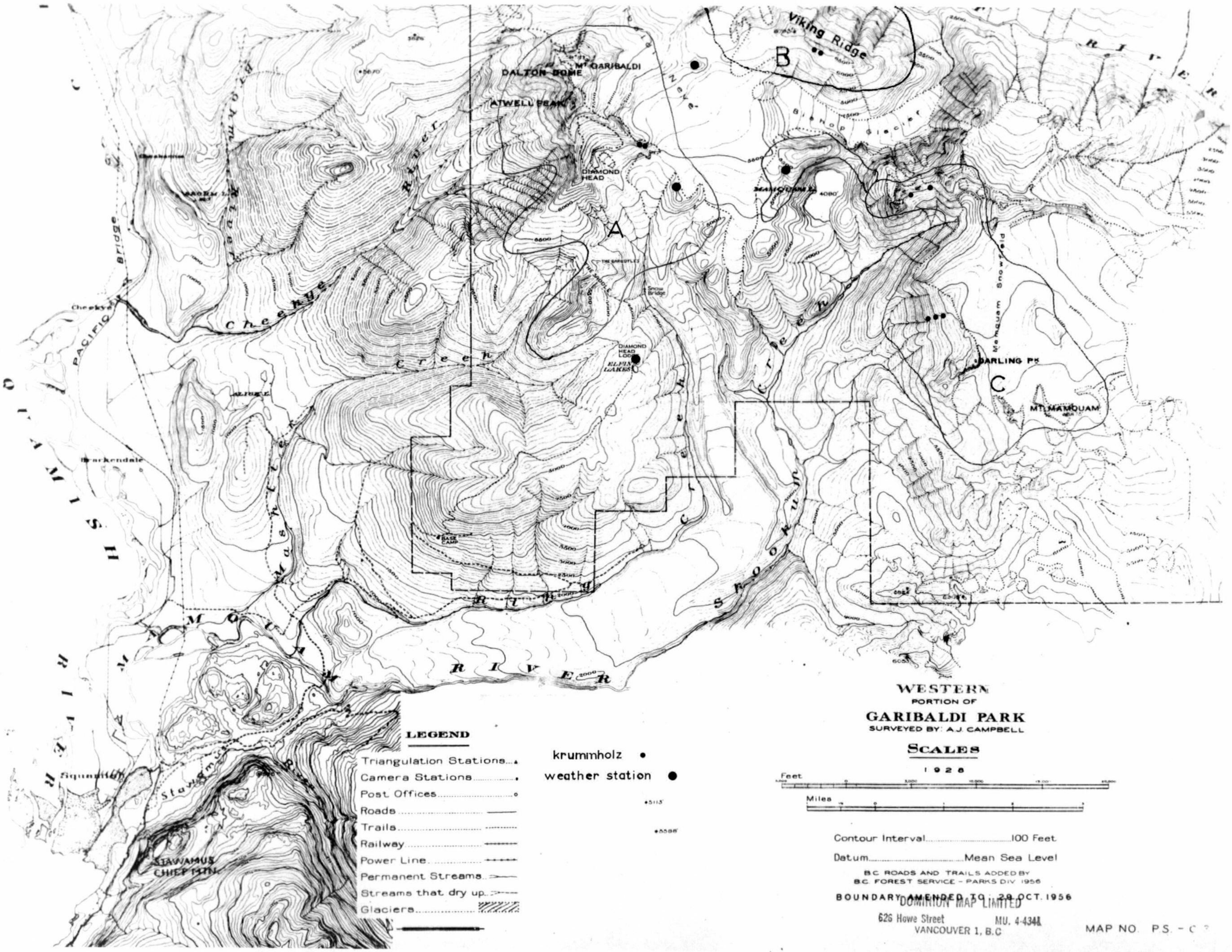
B. Viking Ridge

C. Mamquam Mountains

A. Volcanic sub-region

The volcanic rocks culminate in the Garibaldi Mountain (8,787 feet) the second highest summit within the Park. It is from this massif that the Garibaldi Névé originates and forms at its lower level a gently inclined plain of ice sloping off towards the southeast, at an average altitude of 5,400 feet. It is approximately 2.0 miles along its northeast-southwest axis. In the northeast and east, it is confined by the Viking Ridge which rises to cover 6,800 feet. In the east, where it contacts Viking Ridge, the Garibaldi Névé forms a tongue of ice referred to as the Bishop Glacier. The southern flow of ice has been impeded by a volcanic vent known as the Opal Cone. There it has been split to form an eastern and

Plate 1 - Map of the study area.


Viking Ridge
B
Mt. GARIBALDI
DALTON DOME
ATWELL PEAK
DIAMOND HEAD
MAMQUAM L.
A
Snow Bridge
DIAMOND HEAD LODGE
ELFIN LAKES
DARLING Pk
C
Mt. MAMQUAM
Mamquam Snowfield
Bishop Glacier
Cheekye
Cheekye Creek
PACIFIC
Bridge
Brackendale
Squamish
Stawamus
STAWAMUS CHIEF MTN.
SQUAMISH
RIVER
MAMQUAM
RIVER
Skookum Creek
BASE CAMP
LEGEND
Triangulation Stations
Camera Stations
Post Offices
Roads
Trails
Railway
Power Line
Permanent Streams
Streams that dry up
Glaciers
krummholz
weather station
WESTERN
PORTION OF
GARIBALDI PARK
SURVEYED BY: A.J. CAMPBELL
SCALES
1928
Feet
Miles
Contour Interval 100 Feet
Datum Mean Sea Level
B.C. ROADS AND TRAILS ADDED BY
B.C. FOREST SERVICE - PARKS DIV. 1956
BOUNDARY AMENDED TO: 29 OCT. 1956
DOMINION MAP LIMITED
626 Howe Street
MU. 4-4341
VANCOUVER 1, B.C.
MAP NO. P.S. - C

western tongue of ice. In the northeast the ice transgresses the divide and overspills northeastward into the Pitt Valley whilst the main flow terminates in the Warren Glacier ice tongue to the north-west.

Toward the south of Garibaldi Mountain at lower elevations is Little Diamond Head, 6,700 feet, composed of an accumulation of volcanic tuffs. It is connected to the south by a low col (5,300 feet), to two isolated groups of pyroclastic rocks, Columnar Peak, (5,800 feet) and Lava Mountain (5,700 feet).

The final part to this group is Opal Cone (5,600 feet) lying 1.5 miles due east of Little Diamond Head. This is a volcanic cone that abuts the southern part of Garibaldi Névé, dividing it into two tongues of ice. The western tongue gives rise to Ring Creek, flowing south into the Squamish Valley, whilst from the eastern tongue a number of unnamed glacio-fluvial drainage channels drain south-eastwards and southwards into Skookum Creek.

B. Viking Ridge sub-region

The ridge has a northwest-southeast trend. The average height of the ridge, consisting of three summits, is 6,500 feet. The most northerly summit is capped by a dome of ice from which arises a number of ice-aprons forming steep ice walls on the northeast face overlooking the headwaters of the Pitt River. The highest part of this ridge culminates in the second summit over 6,800 feet, separated by a steep gap from the northerly part of the ridge. The southern face of this ridge consists of inclined rock slabs which are repeatedly swept clean by frequent avalanches during the winter, spring and summer months.

C. Mamquam Mountain sub-region

This sub-region forms extensive highlands in the south-east corner of the area studied. These highlands have been divided into two groups by an extensive cirque. The northern group has a northeast-southwest trend and consists of ridges that are highly serrated with isolated gendarmes and aiguilles rising to over 7,000 feet. The northwest face of this ridge is precipitous and still contains a number of cirque glaciers and ice aprons, vestiges of a former more extensive valley glaciation. The southern part of the Mamquams is more extensive and culminates in Mount Mamquam (8,475 feet) from which originates the extensive Mamquam Icefield having an average elevation of over 7,000 feet. The outflow is north and eastwards into the Pitt River. The south and west faces of these mountains still contain small isolated glacierets lying in the hollows of the cirques.

Apparently many of these areas are emerging from below an extensive cover of ice. The rock outcrops are represented by both volcanic and plutonic (quartz-diorite) groups. They are situated in the midst, and on the periphery of, the large icefields. They are characterized by piles of frost - shattered debris, ice-eroded rock pavements with numerous ice gouges, and shallow kettle holes between depressions.

2. GEOLOGY

According to Mathews (1958), who published a comprehensive geological survey, the geology of the study area may be interpreted as follows:

The region consists of two rock types the Garibaldi Volcanics and the Quartz-Diorites of the Mamquam Mountains and Viking Ridge.

A. The Garibaldi Volcanics

These volcanics are apparently Pleistocene in age.

The main source was from the present site of Garibaldi Mountain. According to Mathews (1958) this was a composite cone from which a large avalanche of fragmented material was extruded. This pyroclastic material, which was largely of dacitic lava, accumulated to form an extensive area of volcanic debris with a textural range varying from volcanic bombs to fine tuffs. Today, tuff-breccia and dacitic lava form the Garibaldi and Little Diamond Head Mountains, whilst Lava Peak and Columnar Mountain to the south are of a wide range of pyroclastic debris.

The so-called Ring Creek Lava extruded from Opal Cone, a small symmetrical volcanic cone near the southern tongue of the Garibaldi Névé. These lavas are considered to be of Pleistocene origin and analysis has shown them to be dacitic.

The dacitic lava consists of a fine groundmass of amorphous material partially devitrified with a number of subhedral and euhedral phenocrysts of silica minerals, plagioclase feldspars, ortho-pyroxenes, amphiboles and accessory minerals mainly in the form of magnetite. The plagioclase feldspars range from:

Ab90 An 10

Ab70 An 30

Ab50 An 50

The range of the orthopyroxene is En 60-En 94.

The amphiboles occur mainly as pseudomorphous grains of hornblende. Mathews (1958) has located a number of zones where there has been alteration of the quartz-diorites by molten volcanic emanations. Characteristically these rocks are low in potash and iron and high in alumina and lime.

The frequency of the chemical constituents in these rocks has been represented in Figures 2 and 3.

The quartz-diorites have been converted to "silvery or iron streaked schists and rusty clays". These clays have been analyzed by Barshad, according to Mathews (1958) who found:

30% - 50% : montmorillonite

15% - 30% : hydrous mica

35% - 40% : kaolinite or halloysite

B. The Quartz-Diorites

The origin of the quartz-diorites is plutonic. In this region they are considered by Mathews (1958) to be of two different age groups. The younger quartz-diorites which form the Viking Ridge are probably of post-Upper Cretaceous age and form part of the Castle Towers batholith. The older group of pre-Upper Cretaceous age form the north and south Mamquam Mountains. Some nunataks, protruding above the Garibaldi Névé in both the central and north-eastern portions of the icefield, are composed of the quartz-diorites.

The quartz-diorites are extensively contaminated by intrusive dykes of material that underwent considerable alteration along the contact with the country rock. They are composed of migmatite, biotite, amphibolite, schist and paragneiss. The trend of these intrusions is on a general northwest-southeast axis traversing the whole length of the south face of the Viking Ridge and continuing into the north and south Mamquam Mountains. Texturally the quartz-diorites are coarsely crystalline and much more resistant to weathering than the volcanics. Chemically, however, the latter rocks, mostly in the form of dacitic lava, are the same as the quartz-diorites, being low in potash and iron but high in lime and alumina.

3. PEDOLOGY

Soils in the Garibaldi Park region have not been studied to date. Parent materials of the soils can be divided into:

A. Sedentary material

B. Transported material

C. Solifluction

A. Sedentary material

This material is formed _in situ_ and is composed of coarse angular fragments devoid of vegetation. These accumulations of rocks have been referred to as boulder-fields. The gradual colonization of the rock fragments by vegetation leads to the development of the fell-fields*. Typical fell-fields consist of areas of coarse fragmented rocks interspersed with groups of plants.

B. Transported material

This material can be divided, depending on the mode of origin, into six groups:

i) Glacial deposits

ii) Glacio-fluvial deposits

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*The term "fell-field" is synonymous with Schröter's (1904, 1908) "Gesteinsfluren" or the term "Felsen-fluren".

Figure 1. Frequency of minerals in the Dacitic Lava of Ring Creek.

DACITE FLOW RING CREEK LAVA
(DATA FROM MATHEWS)

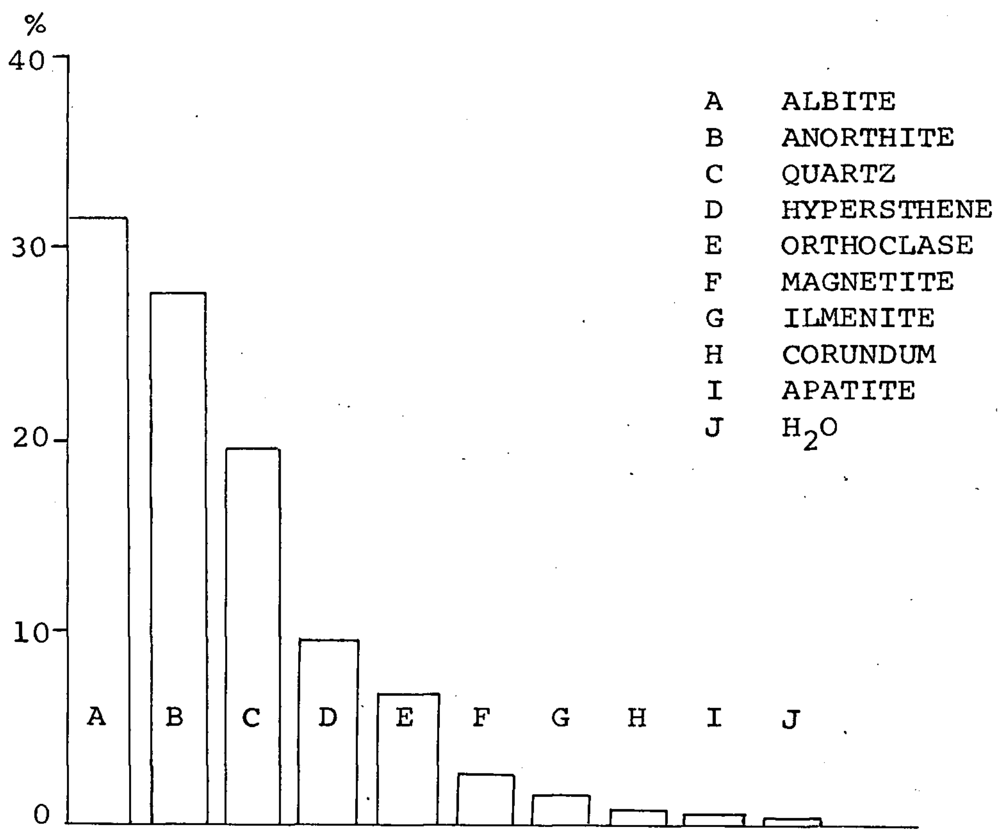
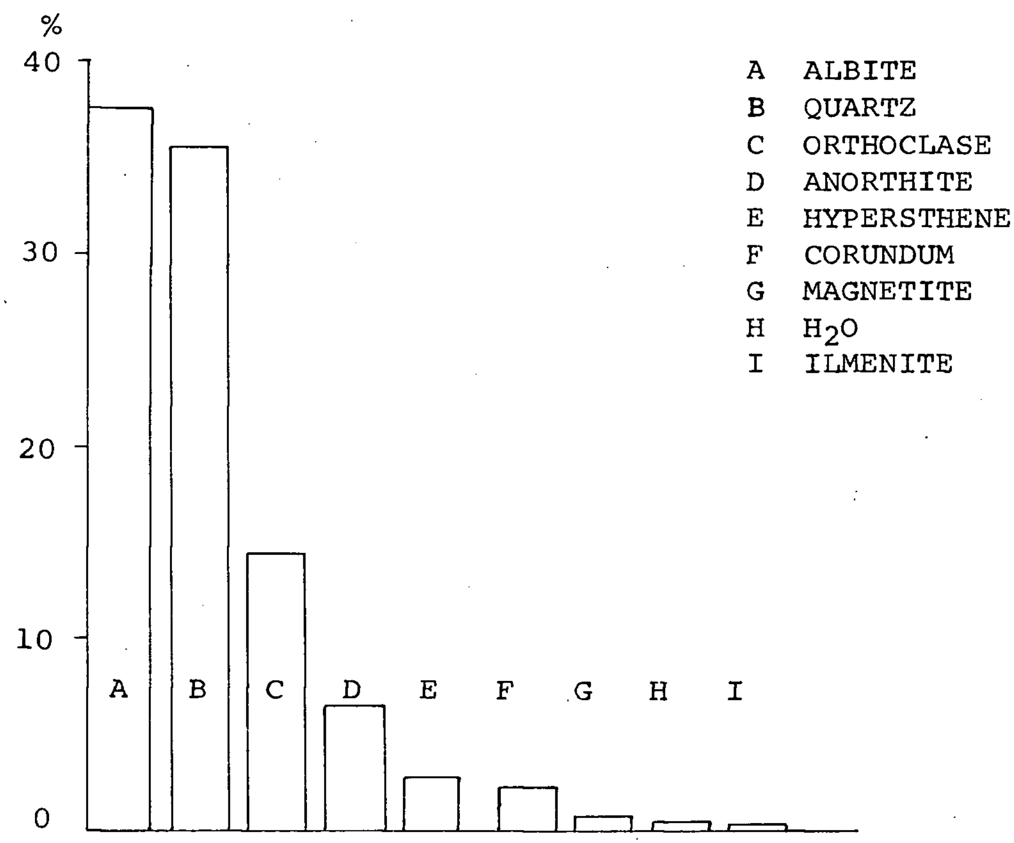


Figure 2. Frequency of minerals in the devitrified rhyodacite.

DEVITRIFIED RHYODACITE EASTERN BASE OF LAVA PEAK
(DATA FROM MATHEWS)



iii) Alluvial deposits

iv) Colluvial deposits

v) Aeolian deposits

vi) Volcanic deposits

i) Glacial deposits

As most of the region studied was at one time under the influence of ice, glacial deposits are extensive. They consist of terminal and lateral moraines in varying degrees of compaction. The older moraines are highly compacted and analysis has shown that they are becoming progressively more acid because of leaching of the basic elements.

ii) Glacio-fluvial deposits

Beyond the ice front, glacial melt water carries quantities of material in suspension. Depositional forms occur as outwash aprons, fans, eskers, valley trains, braided streams and terraces.

iii) Alluvial deposits

In the alpine zone, since the water table drops rapidly following the thaw, many of the water courses are seasonal. Their deposits are not extensive but are important in that they frequently support a luxuriant hydrophytic vegetation.

iv) Colluvial deposits

These deposits are subjected to mass movement in response to gravity and solifluction and make very unstable habitats for plant colonization. Typical of those deposits are talus slopes at the base of rock walls where a large assortment of material has accumulated from avalanches and rock falls.

v) Aeolian deposits

Within the vicinity of glaciers fine particles of rock are taken up by winds and redeposited. Evidence of this can be seen from the clouds of dust caused by winds and the fine film deposited on the vegetation at the margin of the glaciers.

vi) Volcanic deposits

The petrology of these deposits has been discussed under the section on geology. They have a wide textural range varying from fine particles of tuffs to volcanic bombs several inches in diameter.

C. Solifluction*

In the region studied, solifluction is a fairly

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*The term "solifluction" originally defined by Anderson (1906) is mass flow of water-saturated debris.

frequent phenomenon occurring in localities with fine textured soil particles developed on inclined terrain. When the regolith is saturated with melt water, mass movement of the material takes place from higher to lower ground. Solifluction is characteristic of the fine unconsolidated debris on Opal Cone and also along some of the broader inclined ridges in the Mamquam Mountains. It is common in snow patches.

4. CLIMATE

A. Regional climate

The climate of the Alpine Zone in Garibaldi Provincial Park, on the basis of Köppen's classification, can be regarded as ET climate, characterized by a long duration of snow-cover but still able to develop and maintain alpine-tundra (Krajina, 1959).

The close proximity of this area to the coast insures a high precipitation from the Polar Maritime air mass that influences the coast for most of the year (Chapman, 1952). However, this area is by no means typical of those uplands on the immediate Pacific Coast. The climate of this study region tends to be modified by its leeward situation and becomes transitional towards the interior alpine zone, characterized chiefly by more severe winters and lower snowfall.

Practically no climatic data are available, but Mathews (1951) has recorded some figures at Garibaldi Lake. During eleven months in 1933 the annual precipitation was 95" - 100" and the mean temperature was 48°F. During the past 10 years approximate snowfall has been recorded at Diamond Head Chalet (4,900 feet a.s.) From 1952-1962 the mean annual snowfall was estimated to be 20 feet $\pm$ 2 feet.

B. Glacial retreat

Although climatic data are very scanty, glaciological evidence, produced by W.C. Taylor (1936, 1938) and W.H. Mathews (1951) is very suggestive of climatic fluctuations over the past three centuries. Mathews correlates rates of tree growth at the east tongue of the Helm Glacier with glacial movements. The rates of tree growth were reduced between 1700 - 1712 and 1830 - 1845 and increased between 1875 - 1890. Mathews considers that valley glaciers attained a greater size in the 18th and 19th centuries than at any other time since waning of the Wisconsin Ice. Using air photographs he estimates that between 1911 - 1947 the ablation of the surface of Garibaldi Névé at an altitude of 5,500 was 165 $\pm$ 25 feet with the mean annual rate of ablation of 4.5 feet.

Figure 3 shows the recession of the Warren Glacier ice tongue. This has been plotted from data collected by Mathews and represents the recession over the past 41 years. Within the area studied there is evidence of only one glaciation (Mathews, 1951). Striations and erratics have been recorded as high as 7,200 feet on the ridge southeast of Helm Peak.

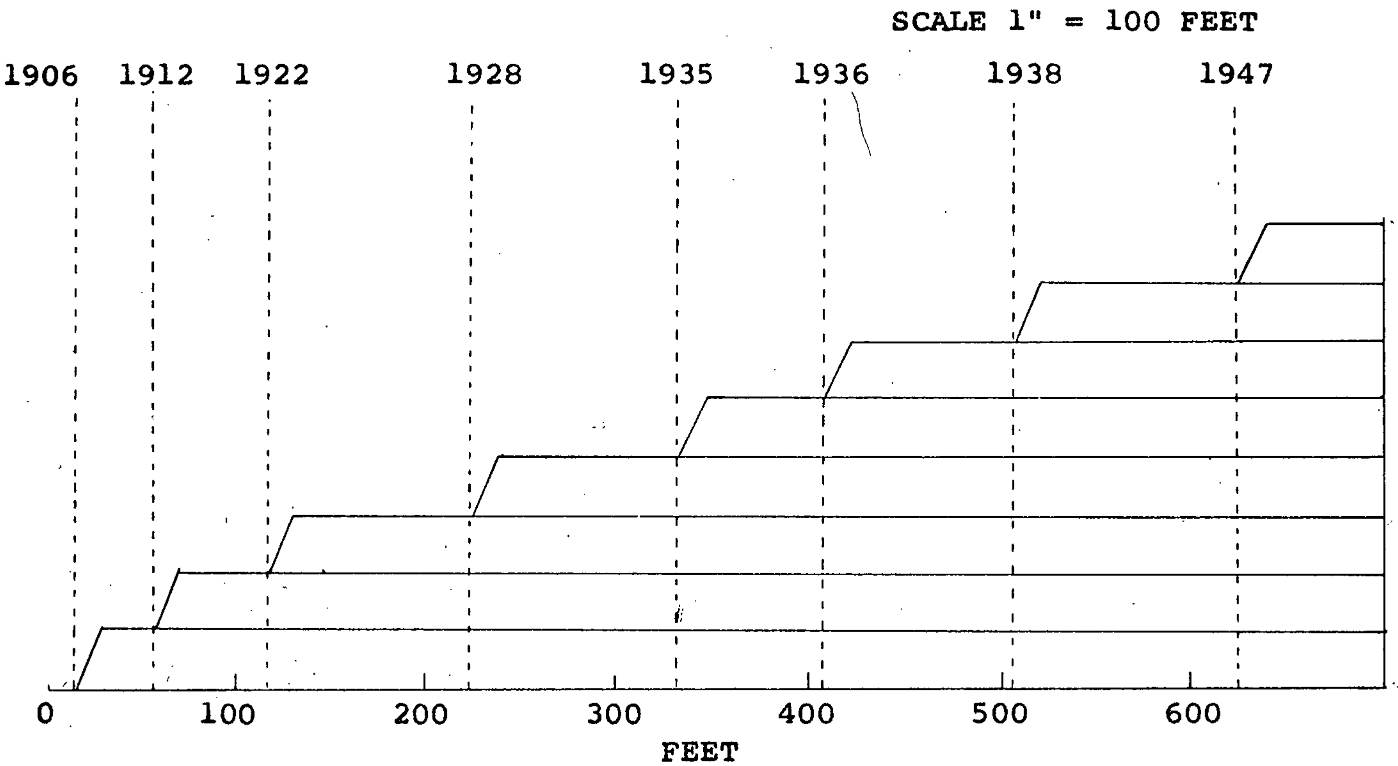
5. BRIEF HISTORY OF BOTANICAL INVESTIGATIONS

The earliest botanical investigations were concentrated in the area surrounding Garibaldi Lake. The first botanical collections were made by J. Davidson, who published his findings in 1913-1914. Later, work was undertaken by G.A. Hardy (1926) and F. Perry (1928).

The most recent work has taken place in the subalpine zone of the Park. Brink (1959) studied "A directional change in the subalpine forest-heath ecotone". He concluded that the establishment of short trees in the ecotone was a directional change. The changes may possibly have been due to the glaciers undergoing accelerated loss in volume for a century or more. Changes taking place in the forest-heath ecotone may be the result of a diminishing snow cover.

Figure 3. The retreat of the Warren Glacier Ice Front over a 41 year period.

RETREAT OF WARREN GLACIER - GLACIER ICE FRONT OVER A 41 YEAR PERIOD (DATA FROM TAYLOR AND MATHEWS)



III. METHODS OF STUDY

1. ORIENTATION

As the success of the project depended upon the penetration of a relatively inaccessible region, a reconnaissance was made in December 1960 and later in May of 1961 in order to consider possible entry into the region from the Diamond Head side. In July, 1961, when the project actually commenced, two weeks were devoted to provisionally establishing camps, weather stations and plots for soil and vegetation studies. Work continued until the end of September, 1961. Some climatic data were collected during the winter of 1961-1962 and the field season started again in June 1962 and terminated in September of the same year.

2. BASIS FOR SYNSYSTEMATIC UNITS

At the outset, plots were selected with an object of establishing such plant associations as repeatedly occurred in the region. The plant association can be regarded to be the same as that defined at the Third International Botanical Congress in Brussels in 1910 viz.: "An association is a plant community of definite floristic composition presenting a uniform physiognomy, and growing in uniform habitat conditions. The association is the fundamental unit of synecology" (Whittaker, 1962). A plant association may contain further subordinate units recognized on an edaphic basis and thus regarded as sub-associations or as variants when the association differs microclimatically (Drees, 1953).

3. CLIMATE

Owing to the short field season it was decided to confine climatic studies to snowfall and temperature as Brink (1959) and Krajina (1960) considered these two factors to be the most significant in this type of vegetation.

Observations of various phenomena were made in the summers of 1961 and 1962. Records of one station were collected during the whole year from summer 1961 up to the end of summer 1962 (Diamond Head Chalet). Local climatic stations were established in the subalpine ecotone and in the alpine zone and maintained throughout the summer and fall months. Comparative data were collected from:

Diamond Head Lodge (altitude 4,900 feet, latitude 49° 48' north, longitude 122° 49' west).

The summit of Opal Cone at the head of Ring Creek (altitude 5,600 feet, latitude 49° 50' north, longitude 122° 58' west).

Moraine above Mamquam Lake (altitude 5,200 feet, latitude 49° 50' north, longitude 122° 56' west).

The daily range of temperature was also compared between a krummholz community and a moss lichen community situated on a nunatak at the northern part of Garibaldi Névé (altitude 6,000 feet, latitude 49° 51' north, longitude 122° 58' west). These stations have been marked with a black circle on the map of the study area, page 5.

The meteorological instruments, used for the work, were as follows:

(1) Six's maximum and minimum thermometer;

(2) two different types of hygrothermographs; the small type manufactured by Goertz with the 4" clockwork drum and the larger more accurate type manufactured by Fuess which had an 8" drum.

It was impossible to calibrate the instruments together in a standardized environment, because the rough terrain over which they were carried before setting them within the Stevenson screen would have neutralized precise calibration. Hence adjustments were made when the instruments were actually at the weather station. Such inaccuracies as were encountered in the calibration of the instruments would have been detrimental if absolute data were required. However, results showed that comparative studies between stations were significant.

4. VEGETATION

The basic vegetation units were considered at the beginning of this section. The study of the vegetation was undertaken in two stages - the analytical phase and the synthetical phase (Braun-Blanquet, 1932).

A. The analytical phase

The selection of a number of plots was delimited on the basis of floristic homogeneity in a uniform environment. The demarcation of the plots according to these criteria was sometimes difficult. The whole region at present is undergoing the last stage of deglaciation, hence plant communities are frequently in a state of flux.

In the more stabilized heather and meadow communities 100 square metres was the area chosen. In the more broken terrain where the rupicolous communities grow, 2 - 6 metres square was the range generally selected. The established plots were large enough to include all characteristic species (species that characterized the association). It will be found, therefore, that the more homogeneous a plant community the more uniform will be the size of plots.

The first stage of vegetation analysis consisted of dividing the plant communities into four strata according to life form:

A layer - arborescent plants ($<$ 10 m high)

B layer - shrubby plants ($<$20 cm - $>$10 m high)

C layer - herbaceous plants ($>$ 20 cm high)

D layer - bryophytes and lichens

The cover, on a percentage basis, of each layer was assessed and recorded for every plot. The next stage of analysis was undertaken by using three scales:

a) Species significance

b) Sociability

c) Vigor

Species significance being a measure of plentifulness of a species was assessed by an eleven grade scale used by Domin and Krajina (Krajina, 1933). Sociability, which expressed the space relationship of individual plants, was also determined by an eleven grade scale adapted from Domin and Krajina (Krajina, 1933).

Vigor, a measure of the vitability of a plant, was assessed on a five grade scale:

0 - dead or dying

1 - vigor low

2 - healthy but not vigorous

3 - vigorous

When the vegetative characteristics of each species had been evaluated, a record was made of the general environmental characteristics of the plot. These may be listed as follows:

i)	Region	vii)	Wind influence
ii)	Plot	viii)	Altitude
iii)	Size of plot	ix)	Physiography
iv)	Slope or gradient	x)	Hygrotope
v)	Duration of snow	xi)	Parent material
vi)	Exposure	xii)	Soil type

B) The synthesis phase

Species were grouped into presence classes. This enabled a test to be made of the homogeneity of the accumulated data. Presence was used as a measure of occurrence of a certain species throughout a number of plots. The scale adopted was the five degree scale used by Braun-Blanquet:

V	-	81 - 100 per cent presence
IV	-	61 - 80 per cent presence
III	-	41 - 60 per cent presence
II	-	21 - 40 per cent presence
I	-	1 - 20 per cent presence

The concept of 'character' species, originated by Braun-Blanquet, is of great value in regions having a rich and varied flora. In this region, however, the flora is relatively poor, hence a combination of characteristic species was used. Braun-Blanquet (1932) determined characteristic species according to five classes of fidelity:

A. Characteristic species

Fid. 5 Exclusive species, confined completely or almost completely to one community.

Fid. 4 Selective species found frequently in more than one community, but also, though rarely, in other communities.

Fid. 3 Preferential species: species present in several communities more or less abundantly but predominantly or with better vitality in one certain community.

B. Companions

Fid. 2 Indifferent species found in many communities without pronounced affinities.

C. Accidentals

Fid. 1 Strange species, or intruders, or relicts of a preceding community.

Finally, the average significance of individual species throughout the plots which formed the association was calculated. This, in effect, was a measure of frequency of species within the association.

C. Life forms

This is a system originated by Raunkiaer (1905). The basis for this classification is the position and degree of protection afforded the perennating bud during the unfavourable growing season. All the life-forms outlined by Raunkiaer were not found in the Alpine Zone, those that were found are listed below:

Pn - Nanophanerophytes (shrubs) perennating buds about 0.25 - 2 m above the ground.

Ch - Chamaephytes (surface plants) with perennating buds just above the surface of the ground.

$Ch_{(B+L)}$ - Chamaephytes which are found in the D layer. These include the carpet mosses and fruticose lichens.

H - Hemicryptophytes, perennating bud very close to the ground.

$H_{(B+L)}$ - Hemicryptophytes which form the D layer and include the crustose lichens and the thalloid bryophytes.

When the associations had been established, the life-form spectra were calculated by determining both the percentage of life-forms and also the average cover of the life-forms per association on a percentage basis.

D. Nomenclature

The plant associations described in this study are new synsystematic units, described by the author. The

nomenclature follows the rules, laid down by Braun-Blanquet and his followers. Thus, the association is designated by attaching the suffix - etum to the stem of the genus name, and a specific name (mostly adjective) in the genitive is added to the association name.
The subassociation is indicated by attaching the suffix - etosum to the stem of the generic name and a specific name in the genitive is added to the subassociation name.

5. SOILS

The object of the soil study was not to draw up a basis for soil classification, but to obtain some information on edaphic factors of the plant communities, that might lead also to a greater understanding of plant succession. Soil samples were taken mainly from the rhizosphere. A total of sixty samples were collected from varying depths ranging from the surface to 3 feet below.

A. Chemical and physical analysés.

The basic procedures used were those discussed in Jackson's Soil Chemical Analysis, 1960.

The soils were air dried and passed through a 1.0 mm sieve, and then analyzed for the following chemical properties:

i) pH value;

ii) total nitrogen content (on a percent dry weight basis);

iii) total organic matter (on a percent dry weight basis);

iv) total exchange capacity (determined in m.e./100 grams of soil);

v) exchangeable Ca^{++}, K^{+} and Na^{+} (in m.e./100 grams of soil using the Perkin Elmer spectrophotometer).

Techniques used in the chemical determination of the soils have been included as Appendix II.

The relatively simple method of sieving the rock fragments to determine particles size of some of the superficial deposits was used. The size classes were those published in the United States Department of Agriculture Soil Survey Manual (1951), and are as follows:

Gravel	above 2 mm
Fine gravel	2 - 1 mm
Coarse sand	1 - 0.5 mm
Medium sand	0.5 - 0.25 mm

Fine sand	0.25 - 0.1 mm
Very fine sand	0.1 - 0.05 mm
Clay silt	0.05 - 0.002 mm

6. PETROLOGY

Thin sections

The geology of this region has been fully dealt with by W.H. Mathews (1951, 1958). However, some thin sections of rock samples from the plots were prepared and an approximate visual estimate of the minerals was determined using a petrological microscope. During this study aid and advice was obtained from L. Hills, research student in the Department of Geology. This study proved useful as many plots were established on transported superficial deposits, accumulated from a large number of sources. By using Mathew's data and those from the thin sections, it was possible to assess the parent material of the plots.

IV. MATERIALS AND RESULTS OF STUDY

1. CLIMATE

A. Snowline

Previous workers have shown that glacial recession is general throughout the region. In 1961 - 1962 field season, the lower limits of ice tongues and glaciers cirques were observed in a number of localities:

TABLE I - Altitude of lower limits of the ice tongues Summer 1962

Localities	Altitude (feet)
Bishop Glacier	4,500
Garibaldi Névé East Tongue	5,200
Garibaldi Névé West Tongue	5,400
Enostuck Cirque	6,400
Mamquam South-west Cirque	6,500
Glacierets North Mamquam	6,600

For the determination of the snowline Simony and Portsch (1927) used an arithmetical mean between altitude of the lower limits of the ice and the average height of crest above firn*. On this basis the present altitude

*Firn-line - Demarcation in a glacier system where the balance in snow between ablation and accumulation occurs.

of the snowline was found to be 6,500 - 6,600 feet above sea level. Figure 4 represents the altitudinal frequency of the region studied.

There are no data concerning total annual snowfall in the Coastal Alpine Zone. However, in a number of instances altitude cannot always be equated with greater depths of snow. Large areas of the zone have precipitous terrain where snow cannot accumulate to any depth. Two other factors which have considerable effect upon the distribution of snow are insolation and wind. Solar radiation is greatest on slopes perpendicular to the sun's rays. In more northerly altitudes a slope of $23\frac{1}{2}^{\circ}$ would receive more radiation than one with 30°. As most of the vegetation above 6,000 feet is confined to south and west exposures, this is of considerable significance.

The accumulation of snow in relation to physiography is of prime importance in the distribution of plant communities, particularly those of the krummholz. On steep terrain, where snow cannot accumulate to any great depth, the growing season is longer. Thus stunted trees are often able to develop and maintain their growth. The curves in Figure 5 represent snow depths and duration of snow cover in the upper limits of the subalpine forest (altitude, 5,000 feet) and on the south-west wall of the Viking Ridge (altitude, 6,800 feet). Snow cornices are related to wind direction and physiography. These large banks of snow often persist throughout the summer months, the melt water from them saturating neighbouring localities.

B. Microclimate

One of the major controlling factors of the local climate is the extent of ice sheets. Table II shows the contrast in temperature between the stations in close proximity to the icefield with those in the upper limits of the subalpine zone.

TABLE II - Comparison of accumulated and total degrees of frost between the upper limits of the subalpine and alpine zones.

Localities	Day degrees (F) Aug.1 - Sept. 8 1961	Total degrees (F) of frost Aug. 1 - Sept. 20 1961
Upper limits of the subalpine zone	526°	3°
Mamquam Moraine	339°	17°
Opal Cone	301°	32°

NOTE: Day degrees are accumulated daily mean temperatures above 43°F.

Total degrees of frost are the summation of minimum temperatures below 32°F.

Figure 4. Altitudinal Frequency of the region studied.

ALTITUDINAL FREQUENCY OF REGION STUDIED

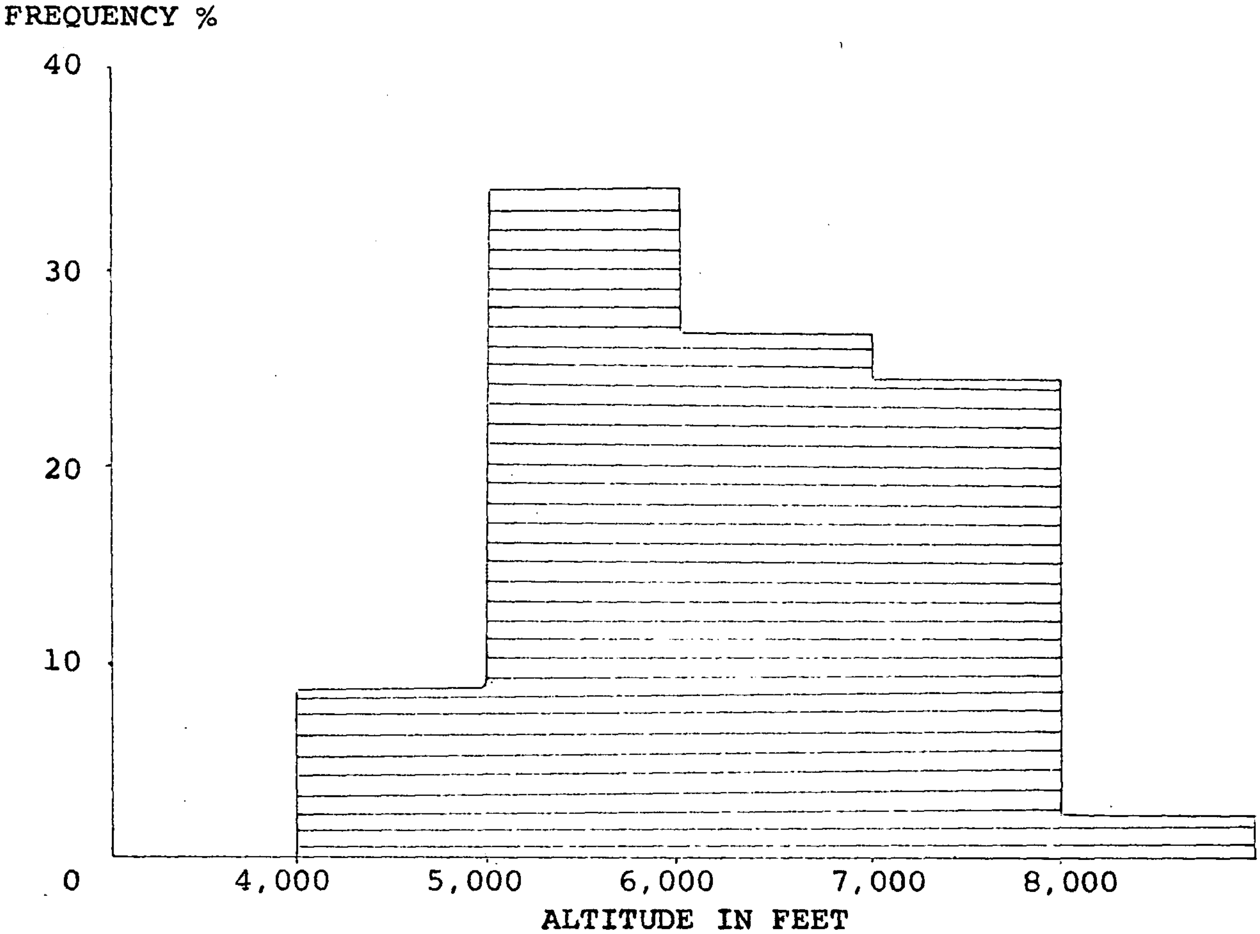
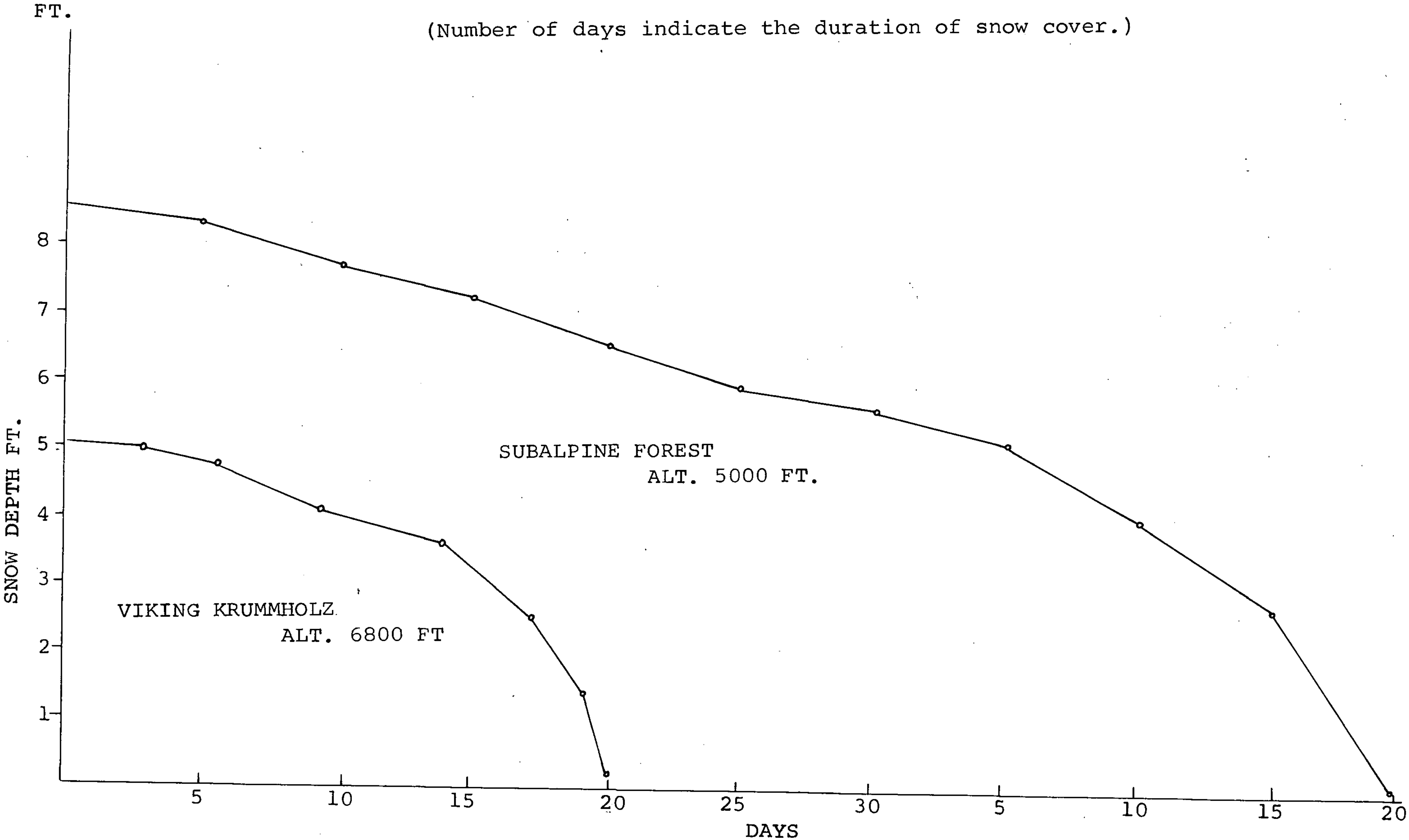


Figure 5. Comparison of snow depth in subalpine forest and krummholz.

COMPARISON OF SNOW DEPTHS BETWEEN SUBALPINE FOREST
AND VIKING KRUMMHOLZ JUNE/JULY 1962
(Number of days indicate the duration of snow cover.)



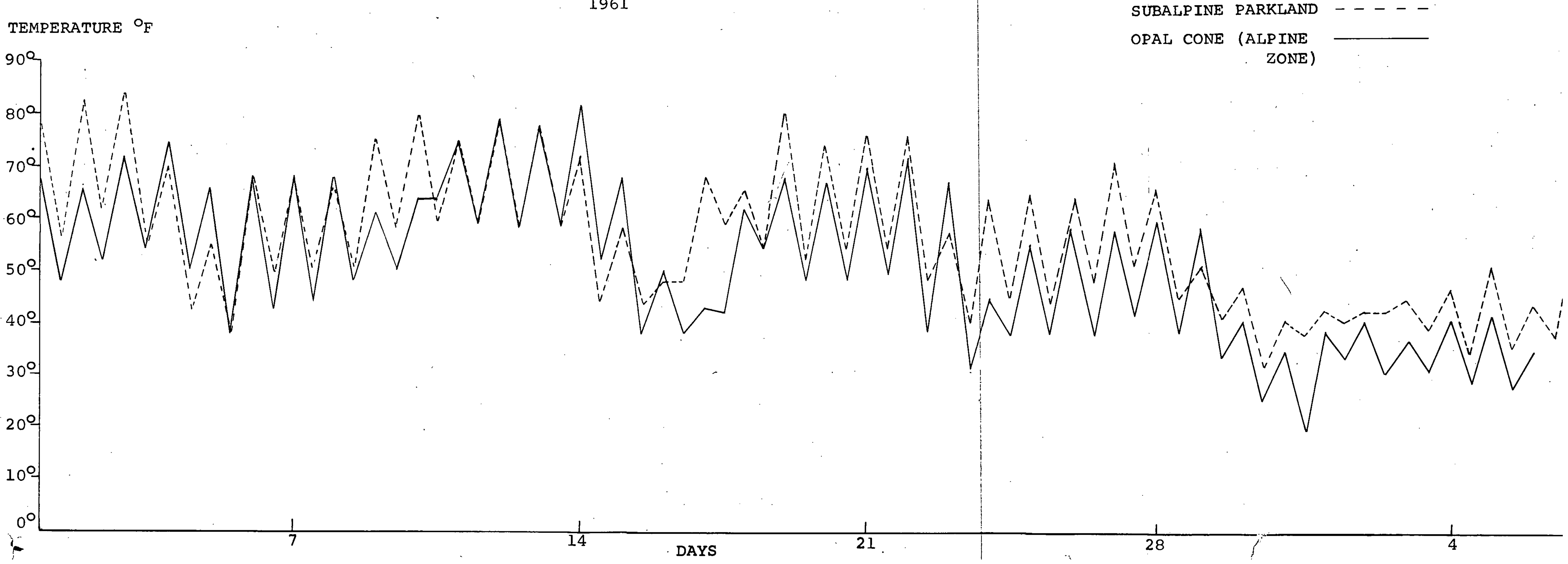
Further confirmation of contrasting temperatures is found when the trends of the daily maximum and minimum temperature between Opal Cone (altitude 5,600 feet) station and the upper limits of subalpine zone (altitude 4,900 feet) are studied (see Figure 6). The cooling effect upon local temperatures may be purely the result of atmospheric cooling by extensive icefields or cooling under the influences of localized firn winds. Both Garibalid Névé and Mamquam Icefield form localized centres of small high pressure systems. During stable weather conditions when the temperature gradient between the icefield and lower valleys is high, the firn winds will blow with great regularity at velocities of 3 - 8 m.p.h. Wind velocities were calculated using a flag and then representing this on the Beaufort scale. The effects of these firn winds are gradually reduced as one goes higher above the surface of the snowfield. The range in temperature was measured in two different plant communities on a nunatak above Garibaldi Névé. During stable weather conditions with high sunshine totals the maximum temperature in the krummholz canopy was greater than that in an adjacent moss-lichen community. The minimum temperatures were not appreciably different between the two communities.

Figure 6. Comparison of daily maximum and minimum temperature between the upper limits of the subalpine zone and the alpine zone.

COMPARISON OF DAILY MAXIMUM AND MINIMUM TEMPERATURES BETWEEN

SUBALPINE PARKLAND AND OPAL CONE (ALPINE ZONE) - AUGUST/SEPTEMBER

1961



The variation in maximum temperature did, however, result in the krummholz having a somewhat larger temperature range (see Figure 7). This could be considered as evidence that the krummholz community has a warmer eco-climate than the adjacent moss-lichen community, as it is more sheltered from the prevailing and local winds.

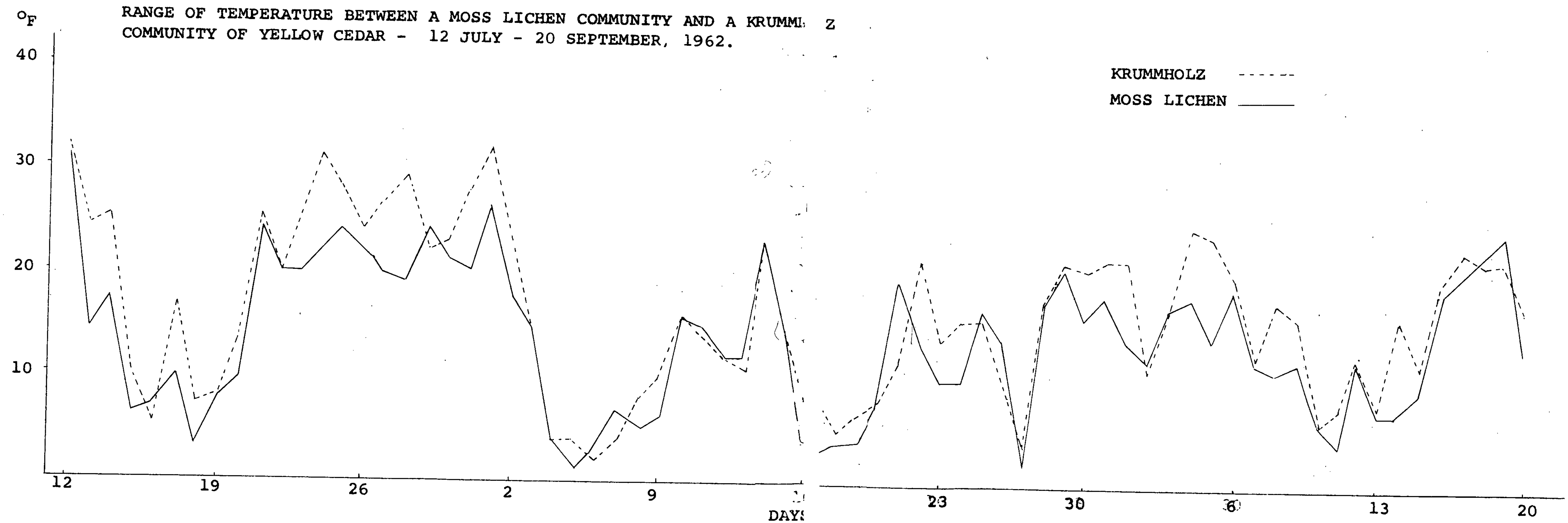
The temperature records for the upper limits of the subalpine zone during 1961 - 1962 are summarized in Table III.

2. SOILS

In the Coastal Alpine Zone, subjected to long periods of snow pack, soils are usually saturated by water for a greater part of the year. However, during the short growing season when the terrain is cleared of snow, some areas can dry out, especially those with soils which are developing on a highly permeable substrate.

The soils may be divided into two broad divisions semi-terrestrial and terrestrial (Kubiëna, 1953). The former soils may be regarded as those which are inundated during late summer by water from melting snow, and possibly drying out for a short period in autumn. The terrestrial

Figure 7. Range of temperature between a krummholz and a moss-lichen community.



°F
RANGE OF TEMPERATURE BETWEEN A MOSS LICHEN COMMUNITY AND A KRUMM Z
COMMUNITY OF YELLOW CEDAR - 12 JULY - 20 SEPTEMBER, 1962.
KRUMMHOLZ
MOSS LICHEN
40
30
20
10
12
19
26
2
9
DAY
23
30
6
13
20

TABLE III. Maximum, minimum and mean temperatures at Diamond Head Chalet, 4,900 feet (Specified months, 1961-1962).

Months	1961 Temperatures			1962 Temperatures		
	Max.	Min.	Mean	Max.	Min.	Mean
January	-	-	-	22.2	16.7	19.9
February	--	-	-	-	-	-
March	-	-	-	-	-	-
April	-	-	-	33.3	27.7	30.5
May	-	-	-	32.3	27.6	29.9
June	-	-	-	-	-	-
July	70.8	50.8	60.8	54.5	45.2	49.8
August	67.6	50.5	58.9	50.7	42.3	46.5
September	47.5	37.4	42.6	53.8	43.5	48.6
October	39.8	31.1	35.5	40.6	33.1	36.8
November	-	-	-	31.6	25.7	28.6
December	-	-	-	-	-	-

soils on the other hand develop on a highly permeable parent material with the water table well below the surface.

A. Semi-terrestrial raw soils

Two soil types were found that belong to this class. One was a very shallow soil, developed below snow patch communities. Kubiëna (1953) has referred to such soils as Snow Basin Rutmark. The other soil was Bog Peats (Moss- according to Kubiëna, 1953) that developed in depressions below Sphagnum communities on the upland plateaus.

The Snow Basin Rutmark was characteristic of localities subjected to snow cover persisting for over ten months of the year. As the snow receded ponding usually occurred and the substrate was continually saturated. This soil type was typical of rock pavements which have been relatively recently deglaciated. The pH values of 4.9 were relatively low. The vegetation consisted of groups of bryophytes composed of Pohlia drummondii, Bryum species, and Polytrichum norvegicum which grew in a relatively thick mat overlying a thin grey accumulation of silt. The profile consisted of up to 3 - 5 mm of undecomposed organic matter followed by 2 - 3 cm of fine grey silt with particles of organic matter. The origin of this silt was from direct deposition from the snow subsequent to melting and also from material carried in suspension by water running into the basin and being re-deposited. The silt was overlying a fractured hamada* of quartz-diorite rocks. In many instances, these basins were underlain by highly impermeable rocks. Outlet for the water generally occurred over a lower lip at one side of the basin. In the Alps and Scandinavia Kubiëna (1953) reports that many of these soils were formed on patterned ground, the fissures being filled with ice. There was no evidence of any patterned ground in the region of this study possibly because of the long periods of heavy snow pack forming an insulating layer. Solifluction is very common.

The Bog Peats typical of the Viking Ridge are situated below an extensive snow cornice from which a perpetual flow of melt water maintains a high degree of saturation thoughout the summer months. The profile is shallow averaging 10 - 12 cm in depth and consists of an accumulation of undecomposed and partially decomposed organic matter of Sphagnum bog moss overlying angular quartz-diorite.

*hamada = dense stone mantle, or single layer of separate stones (Kubiëna, 1953).

TABLE IV. Chemical analysis of the surface layer of Bog Peats.

Depth from surface cm	Region	pH	Organic matter %	Total % N	Total E.C.* m.e./100 gms	E.E.** m.e./100 gms K^+	Ca^{++}	Na^+
3	Viking Ridge	3.9	83.80	1.06	175.58	1.25	18.50	1.80

* E.C. Exchange capacity

** E.E. Exchangeable elements

B. Terrestrial soils

i) Lithosols

Lithosols are the most immature soils and show little, if any, differentiation into horizons. These soils are characteristic of all the superficial deposits below the ice fronts and also along the high ridges where groups of cushion plants are growing. They are generally sparsely colonized by vegetation and are therefore prone to mass movement. The fine textured lithosols developed from the volcanic rocks are susceptible to soil creep and solifluction, particularly when saturated with snow melt water.

The lithosols are the substrate for primary colonization by vegetation. Plant communities of these lithosols were represented on the hard sterile rocks by bryophytes and lichens and groups of _Silene acaulis_. On the sedentary and transported coarse materials, examples which are enumerated in Table V, basophilous and neutrophilous plants, such as _Lupinus arcticus_, _Anaphalis margaritacea_ var. _subalpina_, _Epilobium latifolium_, and _Senecio subnudus_, are typical. Tables V and VI show the chemical composition and particle sizes of these soils.

ii) Rankers

These are soils regarded by Kubiëna (1953) as being soils with A and C horizons only. It is tentatively suggested here that, in the Alpine Zone where the soil profiles are so immature, the zonal soil type is a ranker with a highly peaty organic A horizon. Chemical analysis of the organic material showed that as soil development progressed there was intensified acidification and accumulation of organic matter (see Table VII).

The samples which have been enumerated in Table VII were taken from localities undergoing, or that had

TABLE V. Chemical analysis of the surface 6 cm of selected lithosols formed on sedentary and transported parent materials.

Plot No.	Region	Depth from surface cm	pH	Organic matter %	Total % N	Total E.C. m.e./100 gm	E.E. m.e./100 gm K^+	Ca^{++}	Na^+
1	Ring Creek	0 - 6	4.60	16.05		30.44	-	0.287	0.437
9	Ring Creek	0 - 6	6.00	1.85	0.099	11.11	0.118	0.550	0.487
16	Ring Creek	0 - 6	6.70	0.77		2.41	-	0.525	0.275
32	Ring Creek	0 - 6	5.70	3.02	0.082	18.07	0.125	0.426	0.450
55	Little Diamond Head	0 - 6	5.80	0.44		10.25	-	0.675	0.237
59	Little Diamond Head	0 - 6	6.70	0.770		2.41	-	0.525	0.275
77	Little Diamond Head	0 - 6	5.90	1.57		16.00	-	0.525	0.275

TABLE VI. Particle size of lithosols taken from the upper 15 cms - Ring Creek

Description		Plot #9 %	Plot #16 %	Plot #55 %	Plot #59 %
Gravel	above 2 mm	-	60.54	34.30	29.45
Fine gravel	2 - 1 mm	-	13.31	27.10	24.13
Coarse sand	1 - 0.5 mm	6.90	3.80	18.00	11.04
Medium sand	0.5 - 0.25 mm	10.60	6.24	9.30	8.30
Fine sand	0.25 - 0.1 mm	27.60	9.33	8.70	14.10
Very fine sand	0.1 - 0.05 mm	36.60	7.03	15.90	6.90
Clay silt	0.05 - 0.002 mm	19.30	0.93	0.83	6.00
Organic matter		1.850	0.770	0.440	0.770

undergone, pioneer colonization by groups of plants. All the plots were on slopes that were inclined from 30° - 40° and were subjected to seepage from snow melt waters. The humus forming the organic matter of these soils was shown to have pH values ranging from 4.2 to 5.0. Microscopic examination of the humus showed that there were browned plant remains partially broken down but still with a well preserved cell structure. Such partially decomposed humus has been referred to by Kubiëna as moder silicate humus. At lower altitudes in the subalpine, alpine ecotone, the region has been deglaciated for a considerable period of time. The soils are therefore more mature than those at higher altitudes. Acidification and the accumulation of organic matter has resulted in the transformation of the moder silicate humus, into acid peaty material. At 4,800 under a stand of Tsuga mertensiana, immediately below the timber line, 8 - 10 cms of acid fibrous peat forms the A horizon. This organic matter differs from the semi-terrestrial sphagnum peat of Viking Ridge in that it has developed on a

TABLE VII. Chemical analysis of the upper surface of ranker soils

Plot No.	Plant Community	Parent material	Depth from surface cm	pH	Organic matter %	Total N %	Total E.C. m.e./100 gm	E.E. m.e./100 gm K^+	Ca^{++}	Na^+
35	Krummholz	Q.D.	4 - 6	4.2	58.00		81.00	.450	4.750	1.500
46	_Luetkea pectinata_	D.L.	0 - 4	5.0	6.90	0.158	16.50	.089	.425	.412
70	_Luetkea pectinata_	D.L.	2 - 6	4.9	10.90	0.202	29.90	-	.425	.400
73	_Luetkea pectinata_ with _Lupinus arcticus_	D.L.	2 - 4	5.2	25.80	0.706	63.10	.275	.550	.587

Note: D.L. - Dacitic lava

Q.D. - Quartz-diorite

highly permeable substrate, mainly from ericaceous shrubs and organic debris from the timber (see Table VIII).

TABLE VIII. Chemical analysis of the surface layer of the organic soils

Depth from surface cm	pH	Organic matter %	Total % N	Total E.C. m.e./100 gm	E.E. m.e./100 gm cations K^+	Ca^{++}	Na^+
2	4.0	88.00	1.13	149.79	1.100	11.25	1.17
4	4.7	60.00	1.02	-	0.900	-	-
10	4.7	3.05	0.177	37.63	0.187	0.465	0.837

In some localities organic soils are developing that are influenced by seepage water from melting snow. The effect of this seepage water is to maintain a relatively high base saturation and reduce the effects of leaching and podsolization (see Table IX). Such habitats are characterized by groups of <u>Valeriana sitchensis</u>, <u>Mimulus lewisii</u> and <u>Epilobium latifolium</u> which are typical plants of the Coastal Mountain Alpine Meadows.

TABLE IX. Analysis of organic soils influenced by seepage from melting snow.

Depth from surface cm	pH	Organic matter %	Total % N	Total E.C. m.e./100 gm	E.E. m.e./100 gm cations K^+	Ca^{++}	Na^+
2	5.0	72.30	2.33	131.40	1.351	10.00	1.15
6	5.4	30.22	1.52	64.29	0.210		1.57
12	5.6	20.99	0.525	60.90	0.175	1.80	1.97

C. A,B, soils

Generally, the alpine soils are extremely shallow but in isolated localities topography and parent material may be such that the depth of the solum may exceed 40 cms. Such is the case on the South Ridge of Little Diamond Head where very fine parent material consisting of volcanic tuffs has resulted in the formation of a relatively deep profile with well defined B horizon. As the result of leaching these soils are becoming progressively degraded. Table XI shows a profile in which leaching has not been excessive. The vegetation consists of a large percentage of alpine grasses such as Phleum alpinum, Trisetum spicatum, Elymus hirsutus and a low percentage of Phyllodoce glanduliflora. As leaching progresses, organic matter accumulates and the heathers, particularly Phyllodoce glanduliflora, become dominant.

TABLE X. Chemical analysis of the A, B soils

Depth from surface cm	pH	Organic matter %	Total % N	Total E.C. m.e./100 gm	E.E. m.e./100 gm cations K^+	Ca^{++}	Na^+
1	5.10	15.10					
10	5.22	5.64	0.155	25.65	0.273	1.930	0.445
15	5.42	6.55	0.202	29.80	-	0.475	0.452
20	5.65	3.06	0.159	23.90	-	0.252	0.337
30	6.05	2.50	0.090	12.16	-	0.550	0.282

3. VEGETATION

The plant associations are based upon floristic homogeneity and great similarity of environment. They are then arranged in groups that characterize the habitats where they are found.

The distributional pattern of vegetation is more closely correlated with the duration of the snow pack than with the soil characteristics. The upper limit of treeline is well represented by stunted contorted trees characteristic of the krummholz. The alpine meadows have a very low percentage of grasses. They are dominated by a few species of forbs. The alpine grasslands are also very little developed on mesic habitats. The floristic structure of the vascular plants is very simple.

The reason for this simple structure of vascular plants is due to the relatively short time since deglaciation, and to the long duration of snow cover. In the high mountains of the Interior, snowfall is less, and disappears in May and June, whereas in the high mountains of the Coast, snow remains until the beginning of August, and results in a shorter growing season. During the melting of snow the soils are saturated with cold water that maintains low soil temperature and neutralizes the effects of the high summer insolation.

A. Snow patch group

This group is characteristic of localities which are under the influence of prolonged snow pack. The vegetation typical of such localities was first recognized by Heer (1836) who referred to such habitats as "Schneetälchen". The plants growing under such conditions are chionophilous. They are not only able to withstand prolonged cover of snow, but are also able to thrive owing to lack of competition from species not adapted to such an environment. This group includes three associations:

i) Gymnomitrieto - Polytrichetum norvegici

a. sub-assoc. gymnomitrieto - polytrichetosum norvegici

b. sub-assoc. polytrichetosum piliferi

ii) Caricetum nigricantis

iii) Sibbaldietum procumbentis

i) Gymnomitrieto - Polytrichetum norvegici

This association has been subdivided edaphically. Sub-association gymnomitrieto - polytrichetosum norvegici is typical of fine silts that have accumulated from solifluction and the deposition of material trapped by wet snow before it melts. Sub-association polytrichetosum piliferi is more characteristic of the coarser sands and gravels where it is developed in habitats where snow accumulates for long periods.

Characteristic combination of species	Presence	Fidelity
Polytrichum norvegicum	IV	3
Gymnomitrium varians	V	3 - 4
Pohlia drummondii	I	5

ASSOCIATION TABLE : Gymnomitrieto - Polytrichetum norvegici

GYMNOMITRIETO-POLYTRICHETUM NORVEGICI

STRATIFICATION		SUB-ASSOC. POLYTRICHETOSUM NORVEGICI									SUB-ASSOC. POLYTRICHETOSUM PILIFERI									
	REGION	RING CREEK	GARIBALDI MOUNT.		NUNATAKS						LITTLE DIAMOND HEAD				NUNATAKS		AVERAGE SIGNIFI-CANCE	PRES-ENCE	LIFE FORMS	FIDELITY
	STAND	1	23	24	43	45	47	49	72	76	77	78	55	59	38	40				
	SIZE OF STAND (M)^2	5	4	3	5	5	5	5	4	4	5	5	5	5	5	5				
	SLOPE	0°	0°	0°	0°	0°	0°	2°	1°	0°	0°-5°	0°	0°-5°	0°	1°	0°				
	DURATION OF SNOW (MONTHS)	0-1/2	10-1/2	10-1/2	10	10	10	10-1/2	10-1/2	9-1/2					10	10				
	EXPOSURE	E	W	W	N.W.	N	N.W.	N.W.	N.W.	E	S	S.E.	S.E.	S.E.	N.E.	N				
	WIND INFLUENCE	+	+	+	+	+	++	++	++	+	++	++	++	++	++	++				
	ALTITUDE (FT.)	4600	6400	6300	5950	5900	5950	6000	6000	5400	5325	5250	5200	5255	6000	6000				
	PHYSIOGRAPHY	BASIN									BASIN									
	HYGROTOPE	MOIST	WET	MOIST	MOIST	MOIST	WET	WET	WET	MOIST	FRESH	FRESH	FRESH	FRESH	FRESH	FRESH				
	PARENT MATERIAL		DACITE		DACITIC DYKE	MIGMATIC VEIN	QUARTZ DIORITE		QUARTZ DIORITE		DACITIC TUFFS				QUARTZ DIORITE					
	SOIL TYPE	LITHOSOL	SNOW BASIN								LITHOSOL									
	COVER % A B C D	40% 100%	5% 90%	1% 95%	20% 60%	20% 80%	80%	85%	90%	10% 40%	3% 10% 20%	10% 70%	10% 30%	10% 70%	28% 70%	20% 80%				
B	PHYLLODOCE EMPETRIFORMIS	2-1-1								3-2-1	1-1-2		1-1-1				+/1	II	Ch	2
	PHYLLODOCE GLANDULIFLORA	1-1-2													1-1-2		+/1	I	Ch	2
	CASSIOPE MERTENSIANA		1-1-2							2-1-1							+/1	I	Ch	2
C	SAXIFRAGA TOLMIEI	3-1-2	2-1-2							1-1-2	3-2-2	2-1-2	3-3-2	4-2-2			1/2	III	Ch	4
	JUNCUS DRUMMONDII	2-1-2		1-1-1	4-3-2	2-2-3				1-1-2		1-1-2		1-1-1	1-1-2		+/1	III	H	2
	LUZULA PIPERI										3-1-2	1-1-2	1-1-2		5-2-2		+/2	II	H	2
	SIBBALDIA PROCUMBENS				1-1-2	1-1-2									1-1-2	2-2-2	+/1	II	H	3
	CAREX NIGRICANS	1-1-2	3-2-2	1-1-2	4-3-2			2-1-2		1-1-2	1-1-2	3-3-2	3-3-2	1-1-1	1-1-2	1-1-2	1/2	V	H	2
	CAREX PYRENAICA				3-2-2												+/3	I	H	2
	DESCHAMPSIA ATROPURPUREA	1-1-2									1-1-2						+/1	I	H	2
	LUETKEA PECTINATA	5-3-3	1-2-2							3-2-2	2-1-2	1-1-2	2-2-2				+/2	III	Ch	2
	LUPINUS ARCTICUS				2-2-1												+/2	I	H	2
D	POLYTRICHUM NORVEGICUM	9-4-3	4-3-2	3-2-2	5-4-2	3-2-2	2-1-2	2-2-2	1-1-2	2-2-1		2-2-2		1-1-2			2/3	IV	$Ch_{(B)}$	2
	POLYTRICHUM PILIFERUM		1-1-2							1-2-2	4-3-2	5-3-2	3-3-2	3-2-1	8-3-2	7-3-2	2/4	III	$Ch_{(B)}$	2
	KIAERIA FALCATA	8-5-3								4-2-2		2-3-2	1-1-2	1-1-1			1/3	II	$Ch_{(B)}$	2-3
	ANDREAEA NIVALIS						2-2-2		2-3-2								+/2	I	$Ch_{(B)}$	4
	POHLIA DRUMMONDII						9-4-3	9-4-3	6-3-2								1/[illegible]	I	$Ch_{(B)}$	5
	GYMNOMITRIUM VARIANS		8-5-3	9-6-3	1-1-1	8-6-3	3-2-2	4-3-2	4-3-2		2-2-2	6-3-2	1-1-1	5-4-2	2-2-1	1-1-2	3/4	V	$Ch_{(B)}$	3-4
	STEREOCAULON ALPINUM		1-2-2													2-1-2	+/1	I	$Ch_{(L)}$	2

Life form spectra

Ch	$Ch_{(B+L)}$	H	Ch	$Ch_{(B+L)}$	H
	% species			Average cover %	
13	62	25	1	12	1

a. sub-assoc. gymnomitrieto - polytrichetosum norvegici

This is typical of depressions where snow endures until the end of August. It is well developed on the quartz-dioritic nunataks above the icefields, where the accumulation of silt leads to the development of the snow basin rutmark (Kubiëna, 1953).

Within the snow basin complex, some bryophytic groups will tolerate more moisture than others. Pohlia drummondii and Gymnomitrium varians withstand continuous ponding of melt water whilst Andreaea nivalis grows vigorously in snow melt channels. Polytrichum piliferum is more typical of the highly permeable sands and grits.

b. sub-assoc. polytrichetosum piliferi

This was most typical of depressions with coarse sandy particles. The basins, due to the highly permeable substrate, are well drained and unlike the previous sub-association, there is no water saturation of the upper soil horizon from the snow melt. During the two summers that these habitats were under observation the snow had disappeared already in mid-August but by the end of October temperatures were sufficiently low to accumulate. This sub-association was noted for a relatively greater abundance of Saxifraga tolmiei than the typical sub-association. Although groups of Saxifraga tolmiei were found in the sub-assoc. gymnomitrieto - polytrichetosum norvegici, they appeared to lose vigor, due possibly to the ponding of the snow melt water. Saxifraga tolmiei communities were frequent pioneers on the grits and gravels of the coarser deposits.

ii) Caricetum nigricantis

This association has a wide range on both the plutonic and volcanic rocks. It develops where a prolongation of snow free periods reduces the competitive powers of the bryophytes and results in the

ASSOCIATION TABLE : *Caricetum nigricantis*

CARICETUM NIGRICANTIS

STRATIFICATION	Region	Ring Creek	Diamond Head	(1) Numatak	Viking	Ridge	Average Significance	Presence	Life Form	Fidelity
	Plot	56	82	61	57	84				
	Size of Plot $(M)^2$	$5M^2$	$10M^2$	$4M^2$	$5M^2$	$4M^2$				
	Slope	0°	35°	0°	0°	0°				
	Duration of Snow (Months)	9	9	9	9-1/2	9-1/2				
	Exposure	S. E.	W	S. E.	S. W.	S. W.				
	Wind Influence	++	+	+	+	+				
	Altitude (Ft.)	4300	6300	6000	6400	6400				
	Physiography	Terrace	Ridge	Basin	Basin	Basin				
	Hygrotope	Moist	Moist	Moist	Moist	Moist				
	Parent Material	Dacitic Lava	Dacitic Tuffs	Quartz Diorite	Quartz Diorite	Quartz Diorite				
	Soil Type	Ranker	Ranker	Ranker	Ranker	Ranker				
	Cover % A									
	B		5%		1%	1%				
	C	80%	90%	95%	90%	95%				
	D	20%		2%	30%	10%				
B	Phyllodoce empetriformis				2-2-1	2-1-2	+/1	II	Ch	2
	Phyllodoce glanduliflora		1-1-2				+/1	I	Ch	2
	Cassiope mertensiana		1-1-2				+/1	I	Ch	2
C	Carex nigricans	9-5-3	5-4-3	9-4-3	6-4-3	9-4-3	8/8	V	H	2
	Antennaria alpina		4-3-2				+/4	I	H	2
	Deschampsia atropurpurea	1-1-1	1-2-1				+/1	II	H	2
	Luetkea pectinata			2-1-1		1-1-1	+/1	II	Ch	2
	Luzula piperi		3-2-3	1-1-2			+/2	II	H	2
	Lupinus arcticus		1-1-2				+/1	I	H	2
	Carex spectabilis		1-1-2	1-1-1			+/1	II	H	2
	Hieracium gracile	1-1-2					+/1	I	H	2
	Saxifraga tolmiei	2-2-1					+/2	I	Ch	4
	Juncus drummondii	1-1-1		2-1-2		1-2-1	+/1	III	H	2
D	Polytrichum norvegicum	3-2-2	1-2-2	3-2-2		1-1-2	1/2	IV	Ch (B)	2
	Rhacomitrium canescens				4-2-2		+/4	I	Ch (B)	2
	Gymnomitrium varians					1-1-2	+/1	I	Ch (B)	3-4
	Marsupella ustulata				3-2-2	1-1-2	+/2	II	Ch (B)	4-5
	Sphagnum compactum				2-2-2		+/2	I	Ch (B)	4-5

encroachment and eventual establishment of homogenous communities of Carex nigricans.

Characteristic combination of species	Presence	Fidelity
Carex nigricans	V	3
Polytrichum norvegicum	IV	3

Life form spectra

Ch	$Ch_{(B+L)}$	H	Ch	$Ch_{(B+L)}$	H
% species			Average cover %		
29	29	42	+	1	95

This association is characterized by very few species. In its most typical form Carex nigricans, with its vigorous growth, quickly reduces the light and eliminates competition from other species, especially from the bryophytes. Even in exposed situations when the snow has completely gone the stocky cespitose Carex nigricans forms a thick mat that diminishes the effects of drying winds and insolation, and reduces the evaporation of soil moisture. This association is typical of snow patches on the middle summit of Viking Ridge. In summer, the communities are irrigated by melt water from snow cornices which are overhanging the northeast face. When drainage becomes impeded there is a trend towards the development of localized high moor communities of Sphagnum. On the other hand, a decrease in moisture leads to gradual encroachment of the homogenous communities of Carex nigricans by species of Cassiope and Phyllodoce. Owing to the relatively thick vegetative cover, the cold moist soils favour the accumulation of organic matter upon the surface, which is only undergoing partial decomposition. The result is a progressive acidification within the soil profile.

iii) Sibbaldietum procumbentis

The Sibbaldietum is not well expressed in this region being an association which is considerably fragmented.

Characteristic combination of species	Presence	Fidelity
Sibbaldia procumbens	V	3
Antennaria alpina	IV	2
Polytrichum piliferum	V	2

Life form spectra

% species				Average cover %			
Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$
23	16	45	16	10	5	26	+

ASSOCIATION TABLE : Sibbaldietum procumbentis

SIBBALDIETUM PROCUMBENTIS

	Region	Nunataks			Viking Ridge	Mamquam Moraine	Average Significance	Presence	Life Forms	Fidelity
STRATIFICATION	Plot	5	7	27	74	48				
	Size of Plot $(M)^2$	$5M^2$	$5M^2$	$5M^2$	$8M^2$	$3M^2$				
	Slope	3^o	5^o	5^o	0^o-30^o	0^o				
	Duration of Snow	9-1/2	9-1/2	9-1/2	9	9				
	Exposure	S	S. W.	N. E.	S	S. W.				
	Wind Influence	++	++	++	!!	++				
	Altitude	5500	5550	5500	6450	5200				
	Physiography	ICE ERODED ROCK TERRACE								
	Hygrotope	Moist	Moist	Moist	Moist	Fresh				
	Parent Material	Migmatite	Migmatite	Migmatite	Quartz Diorite					
	Soil Type	LITHOSOL								
	Cover A									
	Cover B				5%	20%				
	Cover C	35%	40%	50%	40%	65%				
	Cover D	20%	20%	5%	10%	20%				
B	Phyllodoce empetriformis				3-3-2	5-2-2	2/4	II	Ch	2
	Phyllodoce glanduliflora	1-2-2					+/1	I	Ch	2
C	Sibbaldia procumbens	5-3-2	4-3-2	6-4-2	5-3-2	6-3-2	5/5	V	H	3
	Antennaria alpina	1-1-2	2-2-2		1-1-2	3-2-2	1/2	IV	H	2
	Carex preslii	1-1-2	3-3-2				+/2	II	H	2
	Deschampsia atropurpurea					1-1-1	+/1	I	H	2
	Luzula piperi				1-1-2		+/1	I	H	2
	Carex nigricans	2-2-2	1-2-2	1-2-2			+/1	III	H	2
	Carex spectabilis					1-1-2	+/1	I	H	2
	Lycopodium sitchense		1-2-2				+/1	I	Ch	2
	Juncus drummondii	1-1-2	1-1-2	1-2-2			+/1	III	H	2
	Luetkea pectinata		3-2-1	3-2-1		3-2-2	2/3	III	Ch	2
	Polytrichum norvegicum	2-2-2					+/2	I	Ch (B)	2
	Polytrichum piliferum	4-1-1	2-2-2	2-2-2	1-2-2	3-2-2	2/2	V	Ch (B)	2
	Lecidea granulosa					1-1-2	+/1	I	H (L)	2
	Rhacomitrium canescens					1-2-2	+/1	I	Ch (B)	2
	Rhizocarpon geographicum	1-1-2		1-1-1		2-2-2	+/2	III	H (L)	2
	Umbilicaria proboscidea	1-1-2				2-2-2	+/1	II	H (L)	2

Fragments of this association are found on the terraces and exposed ridges throughout the Alpine Zone. Under such circumstances more or less pure communities of *Sibbaldia procumbens* exist in isolated groups with *Antennaria alpina*. The association is most typical of the quartz-dioritic nunataks above the icefields. From the point of view of snow cover it has distinct affinities with that of the *Caricetum nigricantis* in that both associations are characterized by chionophilous plants. However, the main difference between the two is that the *Sibbaldietum* is characteristic of very thin acid soils that show little or no profile development. Further, *Sibbaldia* itself will not tolerate the excessive moisture that is frequent in the typical *Caricetum*. *Sibbaldia procumbens* usually succeeds *Polytrichum piliferum* during the colonization of sands and grits which have accumulated in rock interstices and across the surface of the rock pavements. Once it becomes established, it has the power to emanate from its place of origin and colonize new terrain. The development and succession of the *Sibbaldietum* from the sub-association polytrichetosum piliferi of the Gymnomitrieto - Polytrichetum norvegici depends upon a reduction in the duration of the snow pack.

B. Chomophytic* group

This group is characterized by plant communities which form pioneer groups colonizing the fragmented rocks of the boulder and fell-fields. Braun-Blanquet (1954) in his studies of the French Alps referred to such groups as "groupement des éboulis".

Many of these habitats consist of coarse material, that, owing to their high permeability to moisture, could be a limiting factor for the growth of plants. However, the persistence of the snow insures an ample supply of water to colonizing communities. Further, these areas have been recently deglaciated and have not obtained the full impact of leaching and acidification. Hence such habitats have a relatively high base status. Weathering and gravity result in the gradual accumulation of fine

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*chomophytic - pertaining to plants growing on fragmented rocks (Tansley, 1939).

rock particles in the rock interstices which form loci for colonizing plants. The moment the snow disappears growth commences.

This group consists of three associations:

i) *Caricetum spectabilis*

ii) *Luetkeetum pectinatae*

iii) *Anaphaleto - Lupinetum arctici*

i) *Caricetum spectabilis*

Characteristic combination of species	Presence	Fidelity
Carex spectabilis	V	3
Lupinus arcticus	V	2
Agoseris aurantiaca	I	3 - 4

Life form spectra

Ch	$Ch_{(B+L)}$	H	Ch	$Ch_{(B+L)}$	H
	% species			Average cover %	
23	9	68	2	+	56

This association is most typical of the chomophytic habitats in that it is characteristic of the piles of rock debris which accumulate on the slopes and in the depressions. The dominant species of the association is *Carex spectabilis* which has a very vigorous fibrous root system that enables

ASSOCIATION TABLE : Caricetum spectabilis

CARICETUM SPECTABILIS

	Region	Columnar Mount		Nunatak		Little Diamond Head	Opal Cone	Average Significance	Presence	Life Form	Fidelity
	Plot	3	22	19	20	11	9				
	Size of Plot $(M)^2$	5	10	10	5	5	5				
	Slope	40°	45°	20°	20°	25°	40°				
	Duration of Snow (Months)	8	8	8-1/2	8-1/2	8-1/2	8-1/2				
	Exposure	W	S. E.	N. W.	N. W.	S. E.	S. W.				
	Wind Influence	↔	↔	!	!	!	!				
	Altitude (Ft.)	5700	5700	6000	6000	6000	6100				
	Physiography	Couloir	Couloir	Fell Field	Fell Field	Fell Field	Concave Slope				
	Hygrotope	Moist	Moist	Moist	Moist	Moist	Moist				
	Parent Material	Dacitic Lava	Dacitic Lava	Quartz Diorite	Quartz Diorite	Dacitic Lava	Dacitic Lava				
	Soil Type	LITHOSOL			LITHOSOL						
STRATIFICATION	Cover % A										
	B										
	C	90%	90%	60%	70%	90%	90%				
	D		5%	1%							
B	Phyllodoce glanduliflora			4-3-3	5-5-3		1-1-2	1/3	III	Ch	2
	Phyllodoce empetriformis				1-1-1	3-3-2		+/2	II	Ch	2
	Cassiope mertensiana				2-3-2			+/2	I	Ch	2
	Penstemon menziesii		1-2-2					+/1	I	Ch	2-3
C	Lupinus arcticus	3-4-2	3-2-2	4-3-2	4-2-2	3-2-2	1-1-2	3/3	V	H	2
	Deschampsia atropurpurea	1-1-2				1-1-2		+/1	II	H	2
	Erigeron peregrinus	1-1-2				1-1-2		+/1	II	H	2
	Luetkea pectinata	4-4-2	3-2-2			1-1-2		1/3	III	Ch	2
	Castilleja rhexifolia	1-1-2						+/1	I	H	2-3
	Campanula rotundifolia		2-2-2					+/2	I	H	2
	Sibbaldia procumbens					3-3-2		+/3	I	H	3
	Arnica latifolia					1-2-2		+/1	I	H	2
	Phleum alpinum					2-2-2		+/2	I	H	2
	Carex nigricans				2-2-2	1-1-2		+/1	II	H	2
	Trisetum spicatum					1-1-2		+/1	I	H	2
	Agoseris aurantiaca					2-2-2		+/2	I	H	3-4
	Luzula piperi				2-2-2			+/2	I	H	2
	Carex pyrenaica				2-2-2			+/2	I	H	2
	Carex spectabilis	4-4-2	7-6-3	8-4-3	7-3-2	7-5-3	8-6-3	7/7	V	H	2
	Anemone occidentalis						1-1-2	+/1	I	H	3-4
D	Polytrichum piliferum	2-2-1	1-1-1					+/1	II	Ch (B)	2
	Rhacomitrium canescens	1-1-2						+/1	I	Ch (B)	2

the plant to sustain a hold in unstable habitats.

The association is composed of a relatively few species. *Carex spectabilis* frequently forms pure continuous communities which compete so effectively that other species are unable to establish themselves. This is frequently the case on the volcanic rocks where the weathering of the rocks is relatively rapid, and the plants are able to develop a vigorous rooting system in the deep mineral profile. On the boulder-fields formed from quartz-diorite groups of *Carex spectabilis* are dispersed owing to the difficulty in becoming established in the coarse debris. From the point of view of succession, this association is a pioneer on chomophytic habitats, where there is abundant available moisture and the leaching has not progressed extensively.

ii) *Luetkeetum pectinatae*

This association is restricted to grits and coarse sands where it forms pioneer communities.

Characteristic combination of species	Presence	Fidelity
Luetkea pectinata	V	2
Hieracium gracile	V	2 - 3

ASSOCIATION TABLE : Luetkeetum pectinatae

LUETKEETUM PECTINATAE

	Region	Mamquam Moraine	Little Diamond Head	OPALCONE				Average Significance	Presence	Life Form	Fidelity
STRATIFICATION	Plot	28	42	46	70	71	73				
	Size of Plot $(M)^2$	10	10	5	5	5	10				
	Slope	30^o	20^o	40^o	30^o	35^o	40^o				
	Duration of Snow (Months)	8-1/2	9	8	9	8-1/2	8-1/2				
	Exposure	S	S.E.	W	S	N.W.	N.W.				
	Wind Influence	↔	!	!	!!	!	!				
	Altitude (Ft.)	5400	5375	5300	5400	5300	5100				
	Physiography	Fell Field	Fell Field	COLLUVIAL SLOPE							
	Hygrotope	Moist	Fresh	Fresh	Fresh	Fresh	Fresh				
	Parent Material	Quartz Diorite	Dacitic Tuffs	DACITIC LAVA							
	Soil Type	Lithosol	Lithosol	Lithosol	Lithosol	Lithosol	Lithosol				
	Cover % A										
	B	1%	2%		2%		10%				
	C	40%	10%	65%	70%	60%	60%				
	D										
B	Phyllodoce empetriformis	1-1-1	1-1-2		2-2-2		4-3-2	1/2	IV	Ch	2
	Cassiope mertensiana	1-1-1	1-1-2					+/1	II	Ch	2
	Vaccinium membranaceum	1-2-2						+/1	I	Ch	3
C	Luetkea pectinata	6-5-2	4-4-2	8-7-3	7-5-3	7-5-3	8-6-3	6/6	V	Ch	2
	Sibbaldia procumbens	1-1-2						+/1	I	H	3
	Epilobium alpinum	1-1-2						+/1	I	H	4
	Epilobium latifolium	1-1-2						+/1	I	H	3
	Valeriana sitchensis	2-3-2		1-1-2	1-1-2		1-1-2	+/1	III	H	3
	Hieracium gracile	1-1-2	1-1-2	1-1-2	1-1-2		1-1-2	+/1	V	H	2
	Deschampsia atropurpurea	2-2-2				2-2-2		+/2	II	H	2
	Luzula piperi	2-2-2		2-2-2	2-2-2			+/2	III	H	2
	Erigeron peregrinus	2-2-2				1-1-2		+/1	II	H	2
	Saxifraga tolmiei		3-3-2					+/3	I	Ch	4
	Lupinus arcticus		2-3-2	1-1-2	1-1-2		3-4-2	1/2	III	H	2
	Carex nigricans			3-3-2	3-2-2		2-2-2	1/2	III	H	2
	Arnica latifolia	5-3-2		2-2-2		1-1-1		1/2	III	H	2
	Castilleja rhexifolia				1-1-2			+/1	I	H	4-5
	Lycopodium sitchense	2-3-2						+/2	I	Ch	2
	Lycopodium alpinum			3-3-2	3-3-2			+/3	I	Ch	3-4
D	Rhacomitrium heterostichum			1-1-2		1-1-2		+/1	II	Ch (B)	2
	Dicranoweisia crispula				1-1-2			+/1	I	Ch (B)	3
	Rhacomitrium canescens	2-1-2						+/2	I	Ch (B)	2
	Polytrichum piliferum	1-1-1				1-1-1		+/1	II	Ch (B)	2
	Lecidea granulosa			1-1-2		1-1-2		+/1	II	H (L)	2

Life form spectra

Ch	H	$Ch_{(B+L)}$	Ch	H	$Ch_{(B+L)}$
% species			Average cover %		
22	57	21	36	3	+

The association is dominated by Luetkea pectinata which is a plant with great constructive value in the consolidation of unstable colluvial material of fine volcanic debris that is subject to solifluction on relatively steep gradients. On the surface this plant forms widespread green carpets, whilst below the surface an extensive stoloniferous system ramifies the debris with considerable tenacity. On steep colluvial slopes narrow fingers of this association can be seen pioneering upwards toward the unconsolidated material. Superficially it would appear that communities of Luetkea pectinata are typical of dry edaphic sites. In fact, they are usually in close proximity to readily available moisture from snow melt. Hieracium gracile has a high presence but low species significance. Thus, it has no more than a neutral effect in successional plant sociological development.

iii) Anaphaleto - Lupinetum arctici

This is an association which is a typical pioneer on the high glacio-fluvial terraces, moraines, outwash aprons and also upon the boulder fields of recently deglaciated localities which have not been subjected to extensive leaching.

Characteristic combination of species	Presence	Fidelity
Lupinus arcticus	V	4
Anaphalis margaritacea	III	5
Carex spectabilis	V	2

Life form spectra

Pn	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$	Pn	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$
% species					Average cover %				
2	7	13	76	2	+	1	+	50	+

The association is composed of a relatively large number of Compositae which are widely distributed throughout newly deglaciated terrain. Thus, Senecio subnudus, Achillea millefolium, and Anaphalis margaritacea are common. These communities are typical of the basophilous and neutrophilous plants which characterize the open habitats, and become very susceptible to competition from invaders. The two

ASSOCIATION TABLE : Anaphaleto - Lupinetum arctici

ANAPHALETO-LUPINETUM ARCTICI

Stratification	Region	Ring Creek				Opal Cone			Diamond Head	Nunatak	Viking Ridge	Little Diamond Head	Aver. Significance	Presence	Life Forms	Fidelity
	Plot	10	16	18	32	39	83	44	26	8	30	15				
	Size of Plot $(M)^2$	5	10	10	10	10	10	10	5	5	5	5				
	Slope	2^o	5^o	35^o	40^o	30^o	30^o	10^o	30^o	10^o	30^o	20^o				
	Duration of Snow (Months)	9	8-1/2	8-1/2	8	8-1/2	9	9	8	9	9-1/2	9				
	Exposure	N.W.	W	S.W.	W	W	S.E.	W	E	W	W	S.W.				
	Wind Influence	..	..	..	..	!	..	..	!	!	!!	!				
	Altitude (Ft.)	4400	4400	4300	4500	5100	4800	4850	6000	6000	6100	6400				
	Physiography	Moraine	Moraine	Moraine	Lava Levee	Moraine	Torrent Bed	Moraine	Talus Slope	Talus Slope	Fell Field	Fell Field				
	Hygrotope	Fresh	Fresh	Fresh	Fresh	Fresh	Fresh	Moist	Moist	Fresh	Moist	Moist				
	Parent Material	DACITIC LAVA								Dacitic Dyke	Migmatite	Volcan. Tuffs				
	Soil Type	LITHOSOL														
	Cover % A															
	B						1%	1%		2%	10%					
	C	60%	50%	95%	80%	6%	70%	20%	90%	60%	80%	90%				
	D	10%				3%	4%				5%	10%				
B	Salix bella			1-1-2									-/1	I	PN	2-3
	Phyllodoce empetriformis						1-1-2	1-1-2					-/1	II	Ch	2
	Cassiope mertensiana						1-1-2						-/1	I	Ch	2
C	Anaphalis margaritacea	7-4-2	3-2-1	1-1-2	7-3-3	6-4-3	8-2-2	2-2-1	1-1-2			1-1-2	3/4	V	H	5
	Lupinus arcticus	5-3-2	6-5-3	8-3-3	7-3-3	5-3-3	6-5-2	4-2-2	9-7-3	6-5-3	7-8-3	7-5-3	6/6	V	H	2
	Carex spectabilis		2-1-2	3-4-3	6-2-3	1-1-2	2-1-2		1-2-2	1-1-2	6-8-3	2-2-2	2/3	V	H	2
	Luetkea pectinata	3-2-2	1-1-2			2-3-2	1-1-2	2-3-2	4-3-2			3-3-2	1/2	IV	Ch	2
	Epilobium latifolium	2-2-2	3-3-2	3-4-2					1-1-1				-/2	III	H	3
	Juncus drummondii	3-2-2	1-1-2		1-1-1	1-1-2	1-1-2			1-1-2			-/1	III	H	2
	Hieracium gracile	2-2-2	2-2-2	1-1-2	1-1-1		1-1-2	1-1-2				1-1-2	-/1	IV	H	2
	Luzula piperi	2-1-2	2-1-2					1-1-2			2-3-2		-/2	III	H	2
	Deschampsia atropurpurea	1-1-2				1-2-2					1-1-2	1-1-2	-/1	II	H	2
	Epilobium alpinum	1-1-2	1-1-2	2-2-2									-/1	II	H	3-4
	Valeriana sitchensis					4-2-2	1-1-2	1-1-1					-/2	II	H	3
	Carex nigricans						1-2-2		1-2-2		3-3-2		-/2	II	H	2
	Juncus mertensianus										1-1-2		-/1	I	H	2
	Arnica latifolia		1-1-2	1-1-2		3-3-2	4-3-2						-/2	III	H	2
	Saxifraga ferruginea		2-2-2	1-1-2			1-1-2						-/1	II	H	2-3
	Saxifraga arguta						1-1-2						-/1	I	H	3-4
	Carex preslii									3-2-1		1-1-2	-/2	II	H	2
	Antennaria alpina											4-3-2	-/4	I	H	2
	Trisetum spicatum								3-2-2			1-1-2	-/2	II	H	2
	Achillea millefolium									1-2-2		1-1-2	-/1	II	H	4-5
	Penstemon procerus								1-1-2				-/1	I	H	3
	Erigeron peregrinus											1-1-2	-/1	I	H	2
	Senecio subnudus									2-2-2			-/2	I	H	5
	Agoseris aurantiaca				1-1-2								-/1	I	H	4
	Heuchera micrantha									1-1-2			-/1	I	H	2-3
	Epilobium angustifolium				1-1-2					5-4-2			-/3	II	H	1
	Carex pyrenaica									2-2-2			-/2	I	H	2
	Sagina saginoides		1-1-2		1-1-2		2-1-2						-/1	III	H	4-5
	Athyrium filix-femina	1-1-2		1-1-2									-/1	II	H	3
	Athyrium alpestre		1-1-2				1-1-2						-/1	I	H	3
	Cryptogramma crispa						1-1-2						-/1	I	H	3
	Cirsium edule				2-2-2								-/2	I	H	3
D	Kiaeria falcata	1-1-2		1-1-2	1-1-2								-/1	III	Ch (B)	2-3
	Polytrichum piliferum									3-3-2	2-2-2	1-1-2	-/2	III	Ch (B)	2
	Rhacomitrium canescens		1-1-2			1-1-2	1-1-2	1-1-2					-/1	III	Ch (B)	2
	Lescurea baileyi	1-1-2				1-1-2							-/1	II	Ch (B)	2
	Dicranum fuscescens						1-1-2						-/1	I	Ch (B)	3-4
	Stereocaulon alpinum											2-2-2	-/2	I	Ch (L)	2
	Solorina crocea											1-1-2	-/1	I	H (L)	2-3

species which have most constructive effect in the development and succession are Lupinus arcticus and Carex spectabilis, which consolidate the unstable habitat and produce a considerable amount of organic matter.

C. Alpine meadow group

Wet community is represented by:

i) Mimuleto - Epilobietum latifolii

Moist community is represented by:

ii) Valerianetum sitchensis

In continental alpine regions the meadow group is characteristic of more mesic conditions where the grasses and sedges form zonal alpine grassland communities. In the Coastal Mountains however, the meadow group is represented by hydrophytic plants which grow in habitats where the base status is high due to abundant seepage water that is at least approaching base saturation. Such groups of plants are characterized by forbs and to a lesser extent by sedges.

Wet community

i) Mimuleto - Epilobietum latifolii

The association is represented by communities

ASSOCIATION TABLE : Mimuleto - Epilobietum latifolii

MIMULETO-EPILOBIETUM LATIFOLII

Stratification	Region	Moraine Lake	Ring	Ring	Creek	Diamond Head S.E. Gully	Average Significance	Presence	Life Forms	Fidelity
	Plot	92	66	29	9	6				
	Size of Plot (M)^2	10M^2	5M^2	5M^2	5M^2	5M^2				
	Slope	0°	0°	5°	2°	10°				
	Duration of Snow (Months)	9	9	9	9	9-1/2				
	Exposure	N.W.	N.W.	S.W.	E	W				
	Wind Influence	+	+	+	+	++				
	Altitude	5350	4300	4400	4600	5900				
	Physiography	Basin	Braided Stream	Braided Stream	Braided Stream	Terrace				
	Hygrotope	Wet	Wet	Wet	Wet	Wet				
	Parent Material	Dacitic Lava	Dacitic Lava	Dacitic Lava	Dacitic Lava	Dacitic Lava				
	Soil Type	Lithosol	Lithosol	Lithosol	Lithosol	Lithosol,				
	Cover % A									
	B	30%		10%						
	C	20%	80%	60%	30%	20%				
	D	70%	10%	70%	50%	50%				
B	Salix subcoerulea	6-2-2	1-1-2	2-2-2			2/3	III	PH	5
	Phyllodoce empetriformis			1-1-1			+/1	I	Ch	2
C	Mimulus lewisii		8-2-3	7-2-3	2-2-3	1-2-2	4/5	IV	H	5
	Epilobium latifolium	5-3-2	7-2-3	7-2-2	4-1-2	4-2-3	6/4	V	H	3
	Leptarrhena amplexifolia	1-1-2		3-1-2	3-1-2		1/3	III	H	5
	Luzula piperi				1-1-2		+/1	I	H	2
	Arnica latifolia		1-1-2		2-1-2		+/1	II	H	2
	Epilobium alpinum			4-3-2	1-1-2		1/2	II	H	2-3
	Athyrium filix-femina			2-1-2			+/2	I	H	4-5
	Athyrium alpestre		1-1-2				+/1	I	H	4-5
	Luetkea pectinata			1-1-2			+/1	I	Ch	2
	Saxifraga ferruginea		1-1-2				+/1	I	H	2-3
	Saxifraga arguta		1-1-2	1-1-2			+/1	II	H	4-5
	Juncus mertensianus	3-3-2			1-1-2		+/2	I	H	2-3
	Mimulus tilingii					2-2-2	+/2	I	H	4
	Carex spectabilis		3-3-2		1-1-2		+/2	II	H	2
	Valeriana sitchensis			1-1-2	1-1-2		+/1	III	H	3
	Hieracium gracile				1-1-1		+/1	I	H	2
	Juncus drummondii	2-1-2	1-2-2	1-1-2	1-1-2	1-1-2	1/1	V	H	2
D	Philonotis fontana	8-6-3	2-2-2	6-3-2	5-3-3	7-3-3	5/5	V	Ch	5
	Marchantia polymorpha			6-2-2	4-2-2		2/5	III	H	5
	Polytrichum juniperinum			1-1-1			+/1	I	Ch (B)	2
	Rhacomitrium canescens			1-1-2	1-1-2		+/1	II	Ch (B)	2
	Gymnomitrium varians	3-2-1			1-1-2		+/2	II	Ch (B)	3-4
	Scapania undulata		3-2-2	2-2-2	1-2-2	4-2-2	2/2	IV	Ch (B)	5
	Kiaeria starkei		2-1-2				+/2	I	Ch (B)	3-4
	Kiaeria blyttii		1-1-2	1-1-2			+/1	II	Ch (B)	3-4
	Dicranoweisia crispula			1-1-2			+/1	I	Ch (B)	3

having a prolific growth, thriving in a continual supply of water which originates either from melting snow banks or from ground water springs.

Characteristic combination of species	Presence	Fidelity
Mimulus lewisii	III	5
Epilobium latifolium	V	3
Leptarrhena amplexifölia	III	5
Mimulus tilingii	I	5
Saxifraga arguta	II	5
Marchantia polymorpha	III	5
Scapania undulata	IV	5
Philonotis fontana	V	5

Life form spectra

% species					Average cover %				
Pn	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$	Pn	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$
4	8	28	56	4	+	+	25	48	+

This association has two well stratified C and D layers. The C layer plant communities are grouped in close proximity to available water, particularly on the interfluves between the braided drainage channels where the water table is high. The dominant bryophyte communities are those of *Philonotis fontana* which can be seen as a green-yellow patchwork across the hillside below the melting snow banks indicating the establishment of bryophytic flushes.

Mimulus lewisii and *Epilobium latifolium* can be regarded as the two dominant plants of the association. The former plant is usually confined to habitats where the water-table is high, whilst the latter seems to be able to tolerate drier sites. *Epilobium latifolium* however finds optimum conditions in localities with a high water-table. This association is characteristic of alluviated habitats which have a relatively high base status. It is typical of the more sheltered areas at lower altitudes in the Alpine Zone below the ice tongues and large snow accumulations where a continual supply of water is available and the growing season is a few days or weeks longer. The association includes a number of isolated fern clumps, namely, *Athyrium filix-femina* and *A. alpestre* which thrive in shaded moist habitats.

Moist community

ii) Valerianetum sitchensis

This is an association which is typical of well drained sheltered slopes and valleys.

Characteristic combination of species	Presence	Fidelity
Valeriana sitchensis	V	3
Lupinus arcticus	V	2
Carex spectabilis	V	2

Life form spectra

Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$
% species				Average cover %			
15	10	65	10	5	+	75	+

This community differs from the previous association of the wet series in that it is more characteristic of hydromorphic soils which have a high organic content. In the areas of volcanic rocks this association can be found at altitudes of 5,200 - 5,400 feet on slopes which receive seepage from snow melt, thus insuring an abundant supply of moisture which percolates sub-surficially to be lower slopes. Table IX, page 53, contains details of the chemical constitution of the soil typical of this association.

ASSOCIATION TABLE : Valerianetum sitchensis

VALERIANETUM SITCHENSIS

STRATIFICATION	Region	OPAL CONE					Average Significance	Presence	Life Forms	Fidelity
	Plot	90	50	25	75	80				
	Size of Plot $(M)^2$	$5M^2$	$5M^2$	$5M^2$	$5M^2$	$5M^2$				
	Slope	30°	40°	40°	35°	30°				
	Duration of Snow (months)	9	9-1/2	9-1/2	9	9				
	Exposure	S.W.	S.W.	S.W.	W	W				
	Wind Influence	++	!	!	!	!				
	Altitude (Ft.)	4900	5300	5250	5300	5200				
	Physiography	Convex Slope	Concave Slope	Concave Slope	Concave Slope	Concave Slope				
	Hygrotope	Moist	Wet	Wet	Wet	Moist				
	Parent Material	Dacitic Lava	Dacitic Lava	Dacitic Lava	Dacitic Lava	Dacitic Lava				
	Soil Type	Organic Ranker	Organic Ranker	Organic Ranker	Organic Ranker	Organic Ranker				
	Cover % A									
	B									
	C	90	90	90	100	95				
	D	2	2							
B	Phyllodoce empetriformis		2-2-2				+/2	I	Ch	2
C	Valeriana sitchensis	7-4-3	8-5-2	7-7-3	7-5-3	5-4-3	7/7	V	H	3
	Antennaria alpina			1-1-2			+/1	I	H	2
	Phleum alpinum		1-1-2				+/1	I	H	1-2
	Lupinus arcticus	1-1-1	3-2-2	1-1-1	1-2-2	3-2-1	2/2	V	H	2
	Arnica latifolia	1-1-1		2-2-2			+/1	II	H	2
	Luetkea pectinata	4-3-2	1-1-1			4-4-2	2/3	III	Ch	2
	Deschampsia atropurpurea	1-1-2					+/1	I	H	2
	Hieracium gracile	1-1-2				3-2-2	+/1	II	H	2
	Carex nigricans	4-2-2		3-2-2		5-4-2	2/4	III	H	2
	Carex spectabilis	1-1-2	4-2-2	2-3-2	6-5-3	2-2-2	3/3	V	H	2
	Luzula piperi	1-1-2					+/1	I	H	2
	Anemone occidentalis	2-2-2	3-2-2	4-3-2	2-2-2		2/3	III	H	3
	Potentilla flabellifolia	1-1-2		1-1-2			+/1	II	H	5
	Ranunculus eschscholtzii	1-1-2					+/1	I	H	3-4
	Lycopodium sitchense					2-3-2	+/2	I	Ch	2
D	Polytrichum piliferum			1-1-1			+/1	I	Ch (B)	2
	Rhacomitrium canescens					1-1-1	+/1	I	Ch (B)	2
	Solorina crocea			1-1-2			+/1	I	H (L)	3-4
	Lecidea granulosa		1-1-2		1-1-2		+/1	II	H (L)	2

At lower altitudes, this association is often found on alluvial fans which maintain a profuse growth of vegetation. The water-table is high, but drainage is unimpeded. Such hydromorphic soils that develop on the alluvium are largely composed of organic mucks.

D. Rupicolous group

i) _Junipereto - Penstemonetum menziesii_

ii) _Silenetum acaulis_

These two associations were characteristic of the rock walls, rock pavements and the rock ridges where communities were found established in the cracks of rocks or on accumulations of fine debris in pockets and depressions.

i) _Junipereto - Penstemonetum menziesii_

This association occurs on both the volcanic and plutonic rocks where it is confined to the cracks of the rock outcrops.

Character combination of species	Presence	Fidelity
Juniperus communis	V	3 - 4
Penstemon menziesii	V	4 - 5
Festuca brachyphylla	III	3 - 4
Phyllodoce glanduliflora	IV	2

ASSOCIATION TABLE : _Junipereto_ - _Penstemonetum menziesii_

JUNIPERETO-PENSTEMONETUM MENZIESII

STRATIFICATION	Region	Columnar Mountain	Nunatak	Viking	Ridge	Diamond Head	North Mamquam	Average Significance	Presence	Life Form	Fidelity
	Plot	41	21	2	4	62	65				
	Size of Plot (M)^2	2M^2	3M^2	2M^2	4M^2	2M^2	2M^2				
	Slope	50°	40°	50°	30°	40°	45°				
	Duration of Snow (Months)	8	9	8	9	8-1/2	8-1/2				
	Exposure	N. E.	S. E.	S. W.	S. W.	S	S. W.				
	Wind Influence	!	!	!	!	!!	!!				
	Altitude (Ft.)	5550	6000	6400	6500	6300	6900				
	Physiography	Rock Wall	Rock Pavement	Rock Wall	Rock Pavement	Rock Wall	Rock Pavement				
	Hygrotope	Fresh	Dry	Fresh	Dry	Fresh	Fresh				
	Parent Material	Dacitic Lava	Quartz Diorite	Quartz Diorite	Quartz Diorite	Dacite	Migmatite				
	Soil Type	LITHOSOL									
	Cover A										
	B	70%	40%	30%	80%	95%	40%				
	C	20%	1%								
	D	10%	30%	20%	10%	10%	10%				
B	Cassiope mertensiana				2-2-1			+/2	I	Ch	2
	Juniperus communis	6-3-3	6-3-2	9-2-2	6-4-3	9-5-3	7-5-3	7/7	V	Pn	3-4
	Phyllodoce glanduliflora	2-2-3		1-1-2	4-2-2	5-3-2		2/3	IV	Ch	2
	Arctostapylos uva-ursi					5-4-2		+/5	I	Ch	4-5
	Penstemon menziesii	2-2-3	2-2-1	2-1-1	1-1-1	1-1-1	2-1-1	1/1	V	Ch	4-5
C	Carex pyrenaica			1-1-1				+/1	I	H	2
	Carex preslii		1-1-2					+/1	I	H	2
	Agrostis humilis			1-1-2				+/1	I	H	3-4
	Festuca brachyphylla	2-2-2	1-1-2				1-2-2	+/1	III	H	3-4
	Deschampsia atropurpurea	1-1-2			1-1-1			+/1	II	H	2
	Carex spectabilis	2-2-2				1-1-2		+/1	II	H	2
	Penstemon procerus	1-1-2				1-1-2		+/1	II	H	3
	Saxifraga ferruginea	2-2-2					1-1-2	+/1	II	H	3-4
	Heuchera micrantha	1-1-2		1-1-1				+/1	II	H	3
	Silene acaulis						2-2-2	+/2	I	Ch	5
	Saxifraga bronchialis	2-1-2				2-1-2		+/2	II	H	4-5
D	Rhacomitrium canescens	3-2-2			2-1-2			+/2	II	Ch (B)	2
	Rhacomitrium lanuginosum	1-1-2					1-1-2	+/1	II	Ch (B)	4-5
	Andreaea nivalis		1-1-1					+/1	I	Ch (B)	4-5
	Dicranoweisia crispula		1-1-1					+/1	I	Ch (B)	4-5
	Drepanocladus uncinatus		2-2-2					+/1	I	Ch (B)	4-5
	Polytrichum piliferum	1-1-2			1-2-1	1-1-1		+/1	III	Ch (B)	2
	Solorina crocea	1-1-2		1-1-1	2-1-2			+/1	III	H (L)	3-4
	Stereocaulon alpinum	1-1-2		2-2-2			1-1-2	+/1	III	Ch (L)	3-4
	Lecidea granulosa	1-1-2						+/1	I	H (L)	2-3
	Cladonia gracilis var. chordalis			1-1-2				+/1	I	Ch (L)	2-3
	Cladonia chlorophaea		2-2-2					+/2	I	Ch (L)	3-4
	Cladonia pyxidata				1-1-2			+/1	I	Ch (L)	3-4
	Cetraria islandica		2-2-2	2-2-2				+/2	II	Ch (L)	3-4
	Cladonia impexa		3-2-1					+/3	I	Ch (L)	3-4
	Thamnolia vermicularis	2-2-2	2-2-2			2-2-2		+/2	III	Ch (L)	3-4
	Parmelia pubescens			2-2-2				+/2	I	Ch (L)	2-3
	Umbilicaria proboscidea	1-2-2	3-2-2			2-1-2	1-1-2	+/2	IV	H (L)	2
	Rhizocarpom geographicum	2-2-2	2-2-2	1-2-1	2-1-2	1-1-2	2-1-2	1/1	V	H (L)	2

Life form spectra

Pn	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$	Pn	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$
% species					Average cover %				
3	14	41	29	13	50	6	+	+	+

Juniperus communis grows most vigorously on the volcanic rocks, which weather very rapidly as witnessed by the soft friable nature of the material accumulating in the crevices. Such habitats frequently maintain fragments of other associations. Carex spectabilis for example, being a characteristic chomophyte, is often found growing in close proximity to Juniperus communis.

The association is found on the quartz-diorite rocks along the exposed ridges of the Viking Ridge and Mamquam Mountains, where it colonizes the more exposed drier sites of rock pavements and walls. Juniperus communis, under such conditions, is a short stunted shrub, frequently very closely matted, rising only few inches above the substrate. Penstemon menziesii is another low trailing shrub found along exposed ridges where it has to obtain a root-hold in any available crevice. Festuca brachyphylla and

Phyllodoce glanduliflora grow on the terraces where rock particles and organic matter have accumulated. The two commonest bryophytes, which form pioneer colonizers on the fine rock debris, are *Rhacomitrium canescens* and *Polytrichum piliferum*. The fruticose and foliose lichens in such habitats occur in scattered groups. These groups are confined mainly to localities sheltered from winds, or where the lichen finds adequate anchorage. The commonest crustose and foliose lichens are *Rhizocarpon geographicum*, *Parmelia pubescens* and *Umbilicaria proboscidea*. The fruticose forms which are confined to sheltered habitats include: *Thamnolia vermicularis*, *Cladonia impexa*, and *Cetraria islandica*.

ii) *Silenetum acaulis*

Life form spectra

Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$
% species				Average cover %			
4	19	57	20	5	+	2	+

Unfortunately only four plots were established owing to the limited distribution of this association

ASSOCIATION TABLE : *Silenetum acaulis*

SILENETUM ACAULIS

	Region	North Mamquam	North Mamquam	South Mamquam	South Mamquam	Average Significance	Life Form
STRATIFICATION	Plot	31	33	36	37		
	Size of Plot $(M)^2$	$2M^2$	$3M^2$	$2M^2$	$3M^2$		
	Slope	10^o	5^o	5^o	15^o		
	Duration of Snow (Months)	9	9	9	9		
	Exposure	E	S	N.W.	S		
	Wind Influence	!!	!	!	!		
	Altitude (Ft.)	7000	6725	6950	6700		
	Physiography	Colluvial Slope	Colluvial Slope	Rock Ridge	Colluvial Slope		
	Hygrotope	Fresh	Fresh	Fresh	Fresh		
	Parent Material	Quartz Diorite	Quartz Diorite	Migmatite	Quartz Diorite		
	Soil Type	LITHOSOL					
	Cover % A						
	B						
	C	30%	20%	10%	15%		
	D	1%					
B	Penstemon menziesii			1-1-1	1-1-1	+/1	Ch
C	Silene acaulis	3-2-3	4-3-3	2-2-2	4-2-2	3/3	Ch
	Carex spectabilis	2-1-2		1-1-1		1/1	H
	Carex nigricans		1-1-1		1-1-2	+/1	H
	Phacelia sericea	2-2-2		1-1-2		+/1	Ch
	Saxifraga bronchialis			2-2-2	2-2-2	1/2	H
	Heuchera micrantha	1-1-2	1-1-2			+/1	H
	Carex preslii		1-1-1	1-1-2		+/1	H
	Luzula piperi			2-1-2	1-1-2	+/1	H
	Carex pyrenaica			1-1-1	2-2-2	+/1	H
D	Polytrichum piliferum	1-1-1				+/1	Ch_D
	Polytrichum norvegicum	2-2-2		1-1-2		+/1	Ch_D
	Parmelia pubescens			1-1-2		+/1	H_D
	Umbilicaria proboscidea	1-2-2		2-2-2		+/1	H_D
	Phizocarpon geographicum		1-1-2	1-1-2		+/1	H_D

along the narrow ridges of the North and South Mamquam Mountains. It is typical of the fine weathered debris which is accumulating on the exposed summits and ridges. In a number of instances the quartz-diorite had been intruded with dykes of migmatite, which was weathering into a fine substrate, onto which *Silene acaulis* was colonizing. Griggs (1956) considers *Silene acaulis* to be a most aggressive pioneer plant. Solifluction phenomena are evident with this fine debris where mass movement is taking place in response to the high saturation of the particles by melting snow. The vigorous tap root system enables the plant to sustain itself in these unstable soils. *Silene acaulis* colonizes both the rock crevices and more open ground. The communities of this association are widely dispersed, being confined to their special habitats. Growing in conjunction with *Silene acaulis* is *Saxifraga bronchialis*, *S. ferruginea*, isolated clumps of *Oxyria digyna*, and *Phacelia sericea*.

This association is a typical pioneer on *terra nova* which as yet has not been subjected to extensive leaching, and the base status of the substrate was still relatively high. Although it is characteristic of the high exposed terrain, it finds adequate protection in the lee of rock bluffs and couloirs where it usually obtains abundant moisture from snow melt. Compared with the Junipereto - Penstemonetum menziesii the latter is more characteristic of thin podzolized soils.

E. Alpine heather group

This has been referred to as the heather group because it is dominated by Cassiope mertensiana, Phyllodoce empetriformis, and Phyllodoce glanduliflora. In the region studied, due to the precipitous terrain and paucity of plateau and undulating topography, these groups of plants are not so well developed as those in the lower altitudes at 4,000 - 5,000 feet in the upper limits of the Subalpine Zone. Heather communities are typical of the older nunataks, particularly that of the middle summit of the Viking Ridge, and also in the basins of the deglaciated cirques where progressive podzolization and the accumulation of organic matter results in the succession and dominance of the heathers.

i) Phyllodoceto - Cassiopetum mertensianae

This association can be regarded as the zonal community within the Alpine Zone.

Character combination of species	Presence	Fidelity
Phyllodoce empetriformis	V	3
Phyllodoce glanduliflora	II	3
Cassiope mertensiana	V	3

Life form spectra

Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$
% species				Average cover %			
19	36	36	9	16	1	2	+

Subsequent weathering and colonization by plants influenced by severe climatic conditions, heavy snow cover and a short growing season have resulted in leaching, progressive acidification and the accumulation of organic matter. The chemical analysis of the typical heather soils is tabulated in Table VIII. The vigor of the shrub communities can be used as an indicator for the duration of snow cover. The shrubs are very susceptible to long snow cover and if the snow pack is lasting long they will

ASSOCIATION TABLE : Phyllodoceto - Cassiopetum mertensianae

PHYLLODOCETO-CASSIOPETUM MERTENSIANAE

STRATIFICATION	Region	MID-SUMMIT VIKING		L.P.H.	OPAL CONE		MAM-QUAM MORAINE	VIKING	L.D.H.	D.H.	D.H.	AVERAGE SIGNIFI-CANCE	PRESENCE	LIFE FORM	FIDELITY
	Plot	60	91	53	79	81	67	86	58	68	69				
	Size of Plot $(M)^2$	$6M^2$	$5M^2$	$5M^2$	$10M^2$	$10M^2$	$10M^2$	$10M^2$	$5M^2$	$5M^2$	$10M^2$				
	Slope	10^o	9^o	5^o	35^o	35^o	20^o	3^o	3^o	35^o	35^o				
	Duration of Snow (Month)	8-1/2	8-1/2	8-1/2	9	9	9	9	8-1/2	8-1/2	8-1/2				
	Exposure	S. W.	S	S. W.	S. W.	N. W.	N. E.	S. E.	S. E.	S. E.	S. W.				
	Wind Influence	!	!	!	•	••	•	!!	!	!	!				
	Altitude (Ft.)	6500	6550	6500	5300	5200	5400	6600	6100	6100	6200				
	Physiography	RIDGE	RIDGE	RIDGE	CONCAVE SLOPE	CONCAVE SLOPE	ROCK BLUFF	PLATEAU	RIDGE	RIDGE	RIDGE				
	Hygrotope	Wet	Wet	Moist	Moist	Moist	Moist	Fresh	Fresh	Fresh	Fresh				
	Parent Material	QUARTZ DIORITE	QUARTZ DIORITE	DACITE	DACITE	DACITE	QUARTZ DIORITE	QUARTZ DIORITE	DACITE	DACITE	DACITE				
	Soil Type	ORGANIC RANKER													
	Cover % A														
	B	80%	80%	75%	90%	90%	80%	50%	80%	30%	80%				
	C	10%	10%	30%	10%	10%	5%	5%	10%	10%	10%				
	D	40%	40%	1%			10%	40%	10%	25%					
B	Phyllodoce empetriformis	2-1-2	1-1-1	3-1-2	9-3-3	7-3-3	6-3-2	5-3-2		1-2-2		3/4	V	Ch	3
	Phyllodoce glanduliflora	2-1-2							8-7-3	6-5-3	8-7-3	2/6	II	Ch	3
	Cassiope mertensiana	9-3-2	9-3-3	6-3-3		1-1-2	3-2-1	4-2-1		2-2-1	1-2-1	3/4	V	Ch	3
	Vaccinium deliciosum						1-1-1					+/1	I	Ch	1
	Vaccinium membranaceum						2-1-1					+/2	I	Ch	3
	Vaccinium caespitosum	3-2-2	2-3-2									+/2	I	Ch	4
C	Carex spectabilis	1-1-1	3-2-2		2-1-2	2-2-2	2-1-2			1-2-1	3-3-2	1/2	IV	H	2
	Carex preslii			1-1-1				1-1-1				+/1	II	H	2
	Carex nigricans	2-1-2										+/2	I	H	2
	Antennaria alpina		3-1-2	3-1-2					3-2-2	3-2-1	1-2-1	1/2	III	H	2
	Penstemon procerus									3-3-1	1-1-1	+/2	II	H	3
	Erigeron peregrinus			1-1-2			1-2-2	1-1-2	1-1-2	1-1-1	1-1-1	+/1	III	H	2
	Erigeron aureus									1-2-1	1-1-2	+/1	II	H	3-4
	Deschampsia atropurpurea			1-1-2			1-1-2	1-1-1	1-1-2	3-2-2		+/1	III	H	2
	Phleum alpinum			4-1-2								+/4	I	H	2
	Agrostis humilis									1-2-2		+/1	I	H	4
	Sibbaldia procumbens			4-1-2					1-1-1	1-2-1		+/2	II	H	3
	Lupinus arcticus				3-2-2	3-2-2			1-1-2		2-2-1	+/2	III	H	2
	Arnica latifolia			1-1-1	2-2-2	2-2-2			1-1-1			+/1	III	H	2
	Luetkea pectinata						3-2-2	2-1-2	1-1-2			+/2	II	Ch	2
	Hieracium gracile	1-1-2										+/1	I	H	2
	Valeriana sitchensis				3-2-2	4-2-2						+/3	II	H	3
	Pedicularis groenlandica						1-1-2	1-1-2				+/1	II	H	5
	Anemone occidentalis				1-1-2							+/1	I	H	3
	Lycopodium sitchense				1-2-2		1-2-2		4-3-2			+/3	II	Ch	2
	Lycopodium alpinum							1-1-2				+/1	I	Ch	3-4
D	Dicranum muhlenbeckii	3-3-3	2-2-2									+/2	II	Ch (B)	4
	Plagiothecium striatellum	1-1-2	1-1-2									+/1	II	Ch (B)	5
	Polytrichum piliferum						2-2-2	3-2-2	3-2-1	4-3-2		+/3	III	Ch (B)	2
	Polytrichum juniperinum									1-2-2		+/1	I	Ch (B)	2
	Rhacomitrium canescens		1-1-2	1-1-2			1-1-2	4-3-2		4-3-2		1/2	III	Ch (B)	2
	Sphagnum capillaceum	2-1-2	1-1-1									+/1	II	Ch (B)	4-5
	Sphagnum plumulosum	1-1-2	1-1-1									+/1	II	Ch (B)	4-5
	Rhacomitrium heterostichum							1-2-2				+/1	I	Ch (B)	3
	Kiaeria blytii						2-2-1					+/2	I	Ch (B)	3-4
	Gymnomitrium varians						3-2-2					+/3	I	Ch (B)	3-4
	Lecidea granulosa	1-1-2						3-2-2		2-2-2	2-2-2	+/2	III	H (L)	2
	Cladonia impexa	2-2-2						1-1-2				+/1	II	Ch (L)	3
	Cetraria islandica	1-2-1	2-2-2									+/1	II	Ch (L)	3
	Cladonia chlorophaea	1-2-1	1-2-1					2-2-2	2-2-2			+/2	III	Ch (L)	4
	Stereocaulon alpinum						2-2-2	2-1-2				+/2	II	Ch (L)	2
	Solorina crocea	1-2-1		1-1-1								+/1	II	H (L)	3-4
	Cornicularia aculeata								2-2-2			+/2	I	Ch (L)	5
	Thamnolia vermicularis									2-2-2	2-2-2	+/2	II	Ch (L)	2
	Rhizocarpon geographicum		1-1-2				1-1-2	1-1-2			1-1-2	+/1	III	H (L)	2
	Umbilicaria proboscidea		1-1-2					1-1-2				+/1	II	H (L)	2
	Parmelia pubescens							1-1-2				+/1	I	Ch (L)	3

be eliminated. Optimum conditions for growth are found close to krummholz communities or on steep south and west slopes where snow melts relatively early in the summer. As one moves to habitats of more prolonged snow cover one enters the pioneer fringe of the shrub communities, which form scattered isolated groups varying in vigor. In years when summers are cool and the snow pack persists, many plants of these isolated communities are killed. As the shrubs become established they form a nodus for the development of lichen communities which are able to maintain themselves in the shelter of the shrubs.

It is possible that the Phyllodoceto - Cassiopetum mertensianae in the Alpine Zone can be divided into two associations, one dominated by Phyllodoce empetriformis and represented in the lower parts of Alpine Zone, the other by Cassiope mertensiana, more typically evolved at higher altitude.

F. Krummholz group

i) Abieteto - Chamaecyparetum nootkatensis

This association is characteristic on the steep

ASSOCIATION TABLE : Abieteto - Chamaecyparetum nootkatensis

ABIETETO-CHAMAECYPARETUM NOOTKATENSIS

Stratification	Region	NUNATAK (I)	DIAMOND HEAD			VIKING RIDGE				MAMQUAM MTS.		AVER. SIGNIF.	PRESENCE	LIFE FORM	FIDELITY
	Plot	17	14	12	13	34	35	52	69	89	88				
	Size of Plot (M)^2	5x2M	10M^2	10M^2	5M^2	5M^2	10M^2	5M^2	5M^2	5M^2	5M^2				
	Slope	0°-10°	30°	40°	45°	35°	30°	45°	20°	35°	40°				
	Duration of Snow (Months)	8-1/2	8-1/2	8-1/2	8-1/2	9	8-1/2	8-1/2	8-1/2	8-1/2	9				
	Exposure	S	S.W.	S.W.	W	S.W.	W	W	S.W.	S.E.	E				
	Wind Influence	++	!!	!	!	!!	++	!	!	!	!				
	Altitude (Ft.)	6000	6100	6150	6200	6350	6400	6500	6450	6600	6600				
	Physiography	NUNATAK	RIDGE OF TUFFS	ROCK OUTCROP	ROCK OUTCROP	RIDGE	TERRACES ON ROCK OUTCROP								
	Hygrotope	Fresh	Moist	Fresh	Fresh	Fresh	Moist	Fresh	Fresh	Fresh	Fresh				
	Parent Material	QUARTZ DIORITE	DACITIC LAVA			DACITIC TUFFS	QUARTZ DIORITE								
	Soil Type	Ranker													
	Cover % A	95%	90%	90%	90%	70%	80%	70%	95%	90%	90%				
	B	1%	5%	10%	10%	10%	15%	20%	1%	5%	10%				
	C														
	D	5%	5%	5%	10%	5%	5%	5%	3%	3%	5%				
B	Tsuga mertensiana		2-1-2				6-3-3					+/4	I	PN	5
	Abies lasiocarpa		7-3-1	8-3-1	8-3-2	8-3-1	4-2-2	7-4-2	3-3-2	2-2-1	6-3-2	6/6	V	PN	5
	Chamaecyparis nootkatensis	8-4-2							6-3-3	7-4-2		2/7	II	PN	5
	Juniperus S.L. communis	1-1-1		2-1-1	2-2-2	3-2-2	1-2-1	5-2-2				1/2	III	PN	3-4
	Phyllodoce empetriformis	1-1-1	3-2-2	2-2-3	1-1-1	2-2-1	4-2-1	1-1-1		1-1-1	4-3-2	1/2	V	Ch	2
	Phyllodoce glanduliflora			3-2-2	3-2-2	2-2-1	1-1-1	2-2-2		2-1-1		1/2	III	Ch	2
	Cassiope mertensiana		1-1-2		1-1-2		3-2-2	2-2-1		2-1-1	4-3-2	1/2	III	Ch	2
	Vaccinium caespitosum						3-2-2					+/3	I	Ch	4
C	Saxifraga ferruginea				1-1-2			1-1-2				+/1	I	H	2-3
	Heuchera micrantha							1-1-2				+/1	I	H	3
	Festuca brachyphylla	1-2-2			1-1-2				1-1-2			+/1	II	H	4
D	Rhytidiopsis robusta			2-2-2	1-1-1	3-2-1	6-3-2	2-2-2	1-2-2	2-2-2	3-2-2	2/3	V	Ch (B)	5
	Dicranum fuscescens	1-1-2		2-2-1	2-2-1		2-2-2	1-1-1	3-2-2		1-2-2	1/2	IV	Ch (B)	3-4
	Dicranum muhlenbeckii						3-2-2					+/3	I	Ch (B)	4
	Mnium spinulosum						2-2-2		1-2-2			+/1	I	Ch (B)	5
	Brachythecium reflexum		1-1-2	1-1-2					2-2-2	1-2-2	2-2-2	+/1	III	Ch (B)	5
	Lescurea baileyi		1-1-2	2-2-2				2-2-2	1-1-1	2-2-2	2-2-2	+/1	III	Ch (B)	2
	Polytrichum piliferum	3-2-2	2-2-2		2-2-1	2-2-1		1-1-1		1-1-2		1/2	III	Ch (B)	2
	Kiaeria blyttii	1-1-2		1-1-2	1-1-2							+/1	II	Ch (B)	3-4
	Kiaeria starkei				1-1-2							+/1	I	Ch (B)	3-4
	Cornicularia aculeata				2-2-2							+/2	I	Ch (L)	5
	Cladonia impexa	1-1-2			1-1-2						2-2-2	+/1	II	Ch (L)	3
	Stereocaulon alpinum	1-1-2			1-1-2							+/1	I	Ch (L)	2
	Cetraria islandica	1-1-2							1-2-2	2-2-2		+/1	II	Ch (L)	3
	Cladonia degenerans						3-2-2				3-2-2	+/3	I	Ch (L)	5
	Cladonia gracilis chordalis	2-1-2										+/2	I	Ch (L)	3-4
	Thamnolia vermicularis	2-2-2		1-1-2	2-2-2							+/2	II	Ch (L)	2
	Lecidea granulosa		1-1-2	1-1-2			1-1-2		1-2-2			+/1	II	H (L)	2
	Umbilicaria proboscidea	1-1-2			1-1-2		2-2-2	1-2-2	1-1-2	2-2-2		+/1	III	H (L)	2
	Rhizocarpon geographicum	2-2-2	2-2-2		2-2-2	1-1-2	1-2-2	2-2-2	2-2-2	3-2-2		+/2	V	H (L)	2
	Parmelia pubescens	1-2-2	2-2-1	1-1-2								+/1	II	Ch (L)	2
	Parmelia vittata		2-2-2	2-2-2		1-1-2						+/2	II	Ch (L)	4-5
	Rhacomitrium canescens			3-2-2	1-1-2	3-2-2		1-1-2	2-2-2	2-1-1		+/2	III	Ch (B)	2
	Rhacomitrium heterostichum			1-2-2								+/1	I	Ch (B)	3

terrain and rocky outcrop where snow is melted by the end of June or at the beginning of July.

Character combination of species	Presence	Fidelity
Abies lasiocarpa	V	5
Chamaecyparis nootkatensis	II	5
Juniperus communis	V	3 - 4
Rhytidiopsis robusta	V	5

Life form spectra

Pn	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$	Pn	Ch	$Ch_{(B+L)}$	H	$H_{(B+L)}$
		% species				Average cover %			
9	14	59	9	9	40	4	7	-	-

This association occurs in the Alpine Zone at altitudes ranging from 6,000 - 6,800 feet. It is a community which develops only on those habitats with shortest duration of snow cover. It should be considered here as fragments of a forest community, situated in the Alpine Zone beyond the fringe of its zonal distribution in the Subalpine Zone. Its habitats in the alpine zone are intrazonal.

The terminal shoots of Abies lasiocarpa are generally withered from wind and snow blast, but the lower lateral branches, protected by snow cover, maintain a vigorous growth. This represents a candelabrum form of growth. Even in the most exposed situations _Chamaecyparis nootkatensis_ produces cones, whilst _Abies lasiocarpa_ has limited quantities of cones only at lower, more sheltered, elevations.

A striking characteristic of this association is its highly localized distribution and spatial disjunction. In some cases these communities can be regarded as relicts from the last glacial advance 200 years ago (Mathews, 1951). Evidence of the extinction of a former treeline can be seen on a nunatak, 5,800 feet above the northeast portion of the Garibaldi Névé. In other instances groups of krummholz have been established by re-seeding from neighbouring trees.

From the point of view of physiognomy, communities of the krummholz show a very high degree of sociability. Even on steep rocky terrain the close grown stunted trees (up to 2 m tall) cast a dense shade which allows only a sparse vegetation in the moss-lichen layer. Gaps which appear in the canopy contain heather plants which show considerable vigor. The soils which are typical of the krummholz group are thin A - C soils, which have a well defined undecomposed litter horizon and a partially decomposed humus horizon. The chemical analysis of these soils is indicated in Table VIII.

G. Bog Peat group

Isolated localities of bog peat occur on large terraces below the Viking Ridge, varying in altitude from 6,200 - 6,500 feet. This bog peat develops in small depressions which are saturated by melting snow water. The chemical analysis of these peats has been recorded in Table IV, page 46. This group is restricted to small habitats, approximately 1 square metre in area and is characterized by such active peat forming mosses as *Sphagnum capillaceum*, *S. plumulosum* and *S. compactum*.

V. DISCUSSION

1. SOIL

The relationship between pedogenic factors and soil properties has been expressed by Jenny (1941) in an equation $S = \int(Cl, o, r, p, t)$ where S = any soil property, cl = climate, o = organisms, r = relief, p = parent material, t = time. The Coastal Alpine Zone of British Columbia is characterized by a snowy tundra climate. Because snow is a factor of climate, it is obvious that, in this Coastal Alpine Zone, snow is a major agent controlling soil formation, even in intrazonal habitats, although relief may somewhat modify its influence. This modification may either increase the effects of snow, drifted in from other localities, or reduce its effect. However, even there, where the effect of snow cover is diminished, snow as a climatic factor still prevails. This affects both vegetation and soil development.

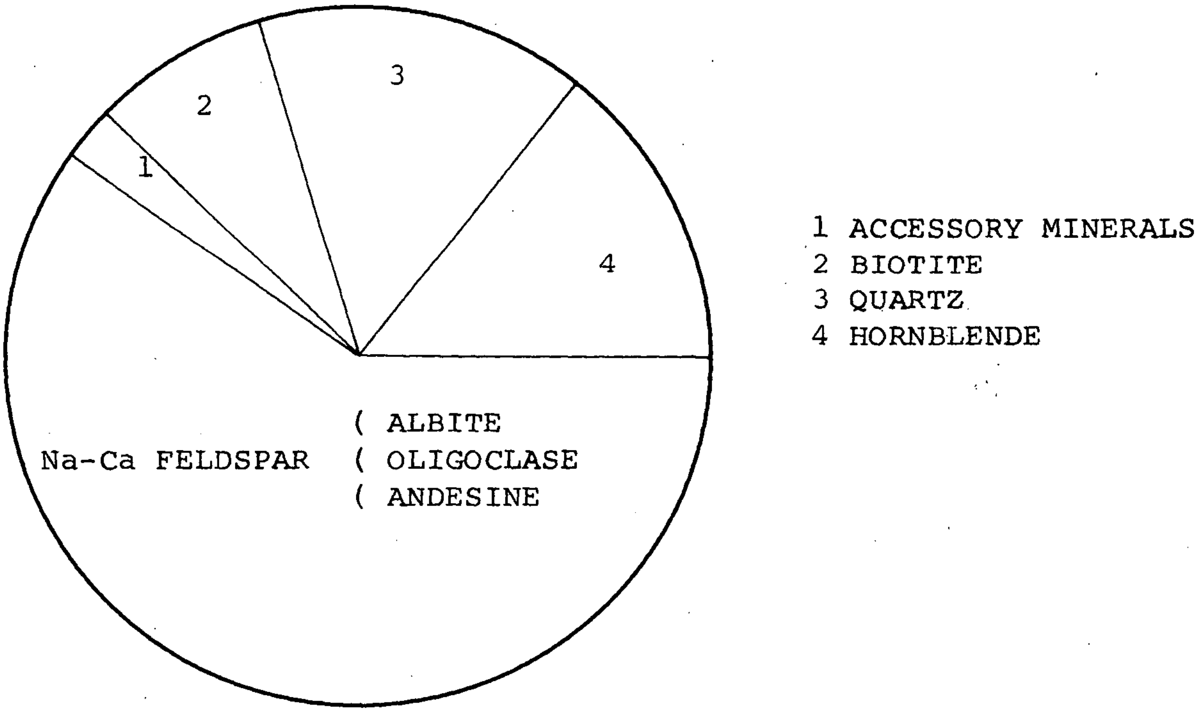
The soils in the Coastal Alpine Zone are so strongly influenced by great masses of snow that the whole region resembles one which has been recently deglaciated. This explains why profiles of alpine soils in this zone are very immature.

It is evident in this region that the time factor, so important for soil maturation, is seemingly shortened due to the yearly repeated duration of snow masses.

The volcanic and plutonic rocks are chemically similar, but due to the contrasting mode of origin, have widely differing textures. Compared to plutonic rocks, the volcanic rocks are undergoing relatively rapid physical weathering, largely resulting from disintegration of the devitrified ground mass which contains the more crystalline phenocrysts. Figures 8 and 9 show the comparison of the textures between the volcanic and plutonic rocks. From the point of view of physical weathering a certain analogy can be drawn between sandstones and these volcanic rocks. Hilger and Erlangen (1897) showed that sandstones had very little resistence to physical weathering. This was due to breaking down of the matrix which bound the coarser grains together. The matrix can be compared with the devitrified groundmass of the volcanic rocks which is easily weathered and results in the phenocrysts breaking away.

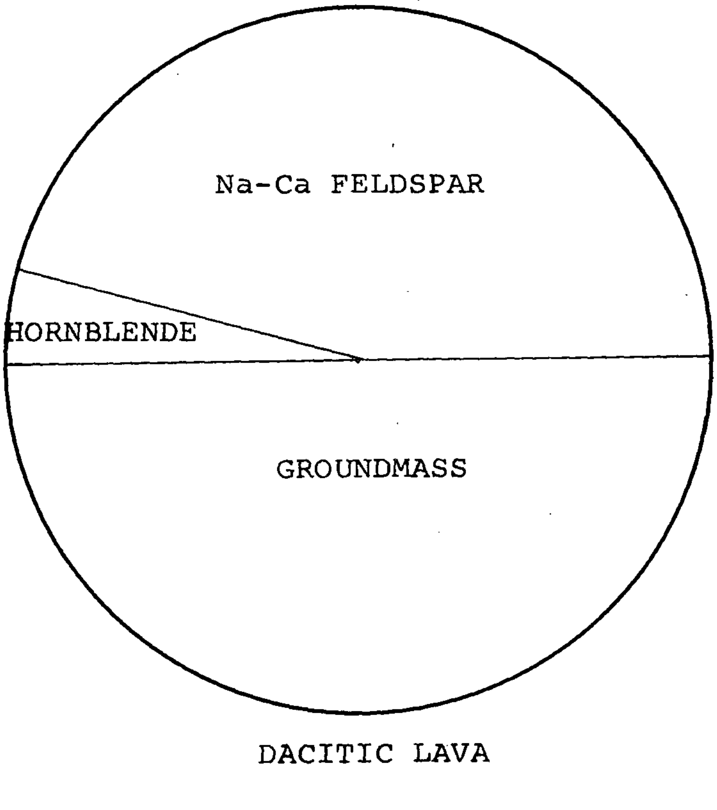
The plutonic rocks composed of quartz-diorites are holocrystalline and are relatively very resistent to

Figures 8 & 9. Comparison of textures between the volcanic and plutonic rocks.



QUARTZ-DIORITE

PERCENTAGE OF MINERALS OF THE PARENT MATERIAL FORMING THE SOILS IN THE REGIONS OVERLYING THE VOLCANIC AND PLUTONIC ROCKS



DACITIC LAVA

physical weathering. Debris which is produced is usually of coarse, partially altered crystals of plagioclase feldspars, biotite, hornblende, and quartz.

It is tentatively suggested in the section under soils that the zonal soil type is a ranker. The absence of B horizon in these zonal soil may be due to the slow maturation of the profile owing to the prolongation of a heavy snow cover. Jenny (1941) notes that in the Central Alps on limestone parent material the "climax humus soils" developed below the *Caricetum curvulae* has a very narrow B horizon. In the European Continental Alps however, such climax soils mature more rapidly under climatic conditions where snowfall is less and the vegetative season is longer.

2. DELIMINATION OF THE ALPINE ZONE

The Alpine Zone is usually regarded as that region above timberline (Daubenmire, 1943, Braun-Blanquet, 1954).

Climatologists have equated timberline as the thermal limit of tree growth. Koppen (1931) proposed that the limit of tree growth coincides with the isotherm of 50°F for the warmest month. Miller (1957) regarded 50°F as highly significant, but considered three months above 43^{o}F would reflect conditions more truly. He accumulated temperatures, by summing up the degrees above 43^{o}F for each month and expressing the value in "month degrees". He found a close correspondence between 18 month degrees and the timberline.

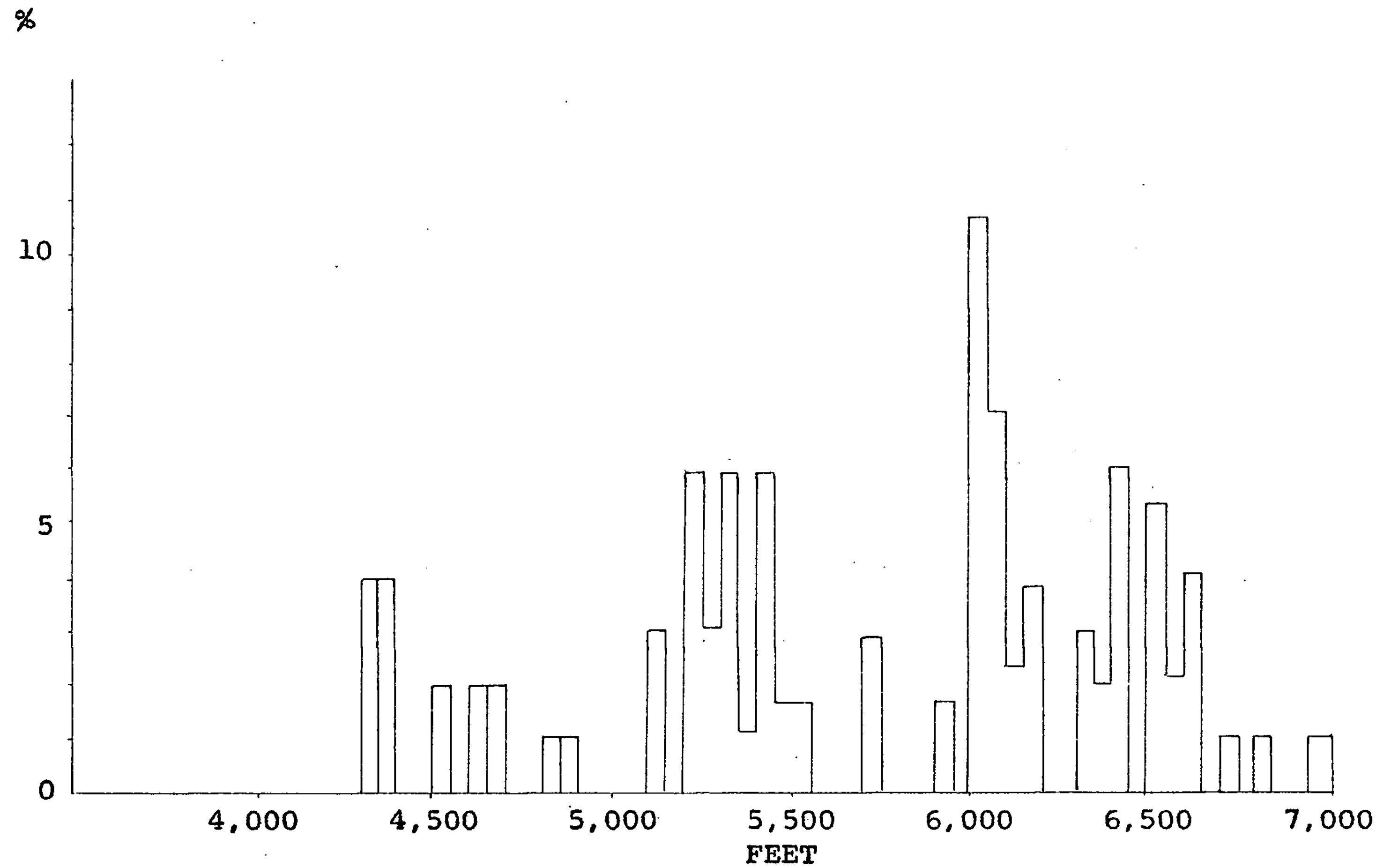
Within the region studied the altitudinal frequencies of sample plots could be used to give some indication of the altitudinal range over which plots were located (Figure 10). The Alpine Zone should be considered to include all elevations above 5,500 feet up to the highest summits (Garibaldi Mountain, 8,787 feet). As the result of snow being translocated from the Alpine Zone into the Subalpine Zone, this latter zone is penetrated by communities that are characteristic of the Alpine Zone. Such a penetration could be interpreted as the alpine ecotone of the subalpine zone.

3. DISTRIBUTION OF VEGETATION

The three major factors that have had the most important impact upon the distribution of the vegetation are Pleistocene volcanic intrusions, the geographical situation,

Figure 10. Altitudinal frequencies of sample plots.

ALTITUDINAL FREQUENCY OF SAMPLE PLOTS



which is transitional between the Coastal and Interior regions, and recent glaciation. The impact of the Pleistocene volcanic intrusions upon the pattern of vegetation has been probably felt most strongly in the Black Tusk Region, northwest of Garibaldi Mountain, where a wide range of rock types (from basalts to dacites) was extruded. Although the rocks on the Diamond Head side are largely dacitic, there is a considerable variation in soil types compared to those on the older plutonic rocks. These extrusions will, therefore, considerably effect vegetational development particularly in the soil formation and the kinds of colonizing plants.

The macroclimate of this area is somewhat modified to form a transitional zone between the Coastal and the Interior regions, owing to the fact that it is in the lee of the Coastal Mountains. Vegetational evidence can be found in the form of _Pinus albicaulis_ krummholz above Garibaldi Lake, reported by Brink (1959), and also _Abies lasiocarpa_ both of which species belong to the Cordilleran element (Prosild, 1958). Evidence of the effects of glaciation upon the pattern of vegetation is found on the northeast corner of the Garibaldi Névé, where a former treeline once overridden by ice, has been revealed and the decayed wood is found adjacent to pockets of old soil. Further evidence of ice retreat is found on some of the smaller nunataks above Garibaldi Névé where there occur fragments of plant communities having distinct affinities with those of lower altitudes. For example, Epilobium angustifolium, and Calamagrostis canadensis grow below the divide between Diamond Head and Garibaldi Lake.

Churchill and Hanson (1958) consider that the primary habitat factors for the determination of gradients and patterns of vegetation, are precipitation, temperature, soil moisture, snowbeds and wind exposure. Of these factors, the two most important agents in the Coastal Alpine Zone in determining the succession of phytocoenoses are precipitation in the form of snow and the duration of the snowbeds.

Pioneer plant communities, just maintaining themselves on the very threshold of existence, are susceptible to environmental changes. Hence development and succession will tend to be due to allogenic factors (Tansley, 1939). Microclimate, parent material and physiography are allogenic factors that largely determine the course of pioneer succession.

Once the local environment is suitable for plants to colonize extensively, then autogenic (Tansley, 1939) succession can take place. The replacement of communities by one another is largely due to changes induced in the environment by the vegetation itself.

On dacitic parent material the sequence of plant succession goes according to the following scheme:

The debris of coarse dacitic fragments is colonized by the chomophytic association of Anaphaleto - Lupinetum arctici, whilst the finer textured material of dacitic tuffs, etc., by the Luetkeetum pectinatae. Progressive acidifcation will ultimately lead to the accumulation of organic matter and the transition of the lithosols into the rankers. Further podzolization will lead to encroachment by acidophilous ericaceous species, notably, species of Phyllodoce and Cassiope. This will result in the development and succession of the zonal communities forming the Phyllodoceto - Cassiopetum mertensianae. The zonal soil profile will be characterized by organic ranker with relatively deep acid organic horizon.

In the upper limits of the subalpine zone, trees are established on insolated hillocks, where snow recedes

Figure 11. Generalized succession in the Alpine Zone on Dacitic Lavas.

GENERALIZED SUCCESSION
IN THE ALPINE ZONE ON VOLCANIC
DACITIC LAVAS

Anaphaleto - *Lupinetum arctici*
(Pioneer stage Chomophytic
habitats)

Luetkeetum pectinatae
(Pioneer on fine debris)

Phyllodoceto - *Cassiopetum*
mertensianae
(Organic ranker)
(Zonal type)

→ Reduction of snow cover
subalpine forest
(Dry edaphic)

Carex nigricans
Carex spectabilis
(stage)

Valerianetum sitchensis
(Hydromorphic soils)

Mimuleto - *Epilobietum*
latifolii
(Seepage sites)

Note: This succession takes place in altitudes between 4,800-6,000 feet. Subalpine forest community develops up to about 5,500 feet. Thus part of this succession is pertaining to the alpine ecotone of the Subalpine Zone.

rapidly and the growing season is longer. In the higher altitudes where snow is a controlling factor for the growth and distribution of life forms, such communities must be regarded as topographically controlled. If snow cover progressively decreases during the succeeding years we can assume that these isolated groups of trees will expand to become the zonal communities. However, if the duration of the snow pack increases, natural regeneration will be gradually eliminated, as a result of the shortened growing season, and ultimately these tree groups will cease to exist.

The hydrophytic succession commences with the *Mimuleto - Epilobietum latifolii*. This association is characterized by basophilous communities growing in seepage habitats. Progressive accumulation of organic matter will lead to the development of the *Valerianetum sitchensis*. Subsequent accumulation of organic matter and acidification will depend upon the source of seepage water. Usually during the summer thaw, flood waters will remove all vestiges of organic matter. If accumulation is able to take place, the *Valerianetum sitchensis* will be superseded by the *Caricetum nigricantis* and ultimately by the zonal association, *Phyllodoceto - Cassiopetum mertensianae*.

Statistical analysis was carried out to determine the significance between progressive acidification measured in terms of pH and the succession from basophilous to acidophilous communities. Three species were selected which characterized the extremes: *Lupinus arcticus*, *Carex spectabilis* and *Phyllodoce empetriformis*. Ten plots were randomly selected from the association tables, and the frequencies of each species calculated on a linear scale. The regression of the frequencies on pH was computed. It was found that regression between *Carex spectabilis* and pH was not significant, but the other two species had high correlation coefficients. Thus, with decreasing pH there was a reduction in frequency of *Lupinus arcticus*. Whereas, with *Phyllodoce empetriformis* the frequency increased with a decrease in the pH.

TABLE XI. Regression equations

	% 100 R	S_y	F
Lupinus arcticus 25.0839 pH - 1.166062 pH^2 - 123.1031	84	± 14.15	19.26***
Carex spectabilis 16.5517 pH - 51.18568 pH^2 - 52.47042	27	± 31.93	1.6
Phyllodoce empetriformis 33.71045 pH - 1.21240 pH^2 - 2.309014	77	± 28.20	7.20**

***Significant at 0.005 P with df 7,2
**Significant at 0.025 P with df 7,2

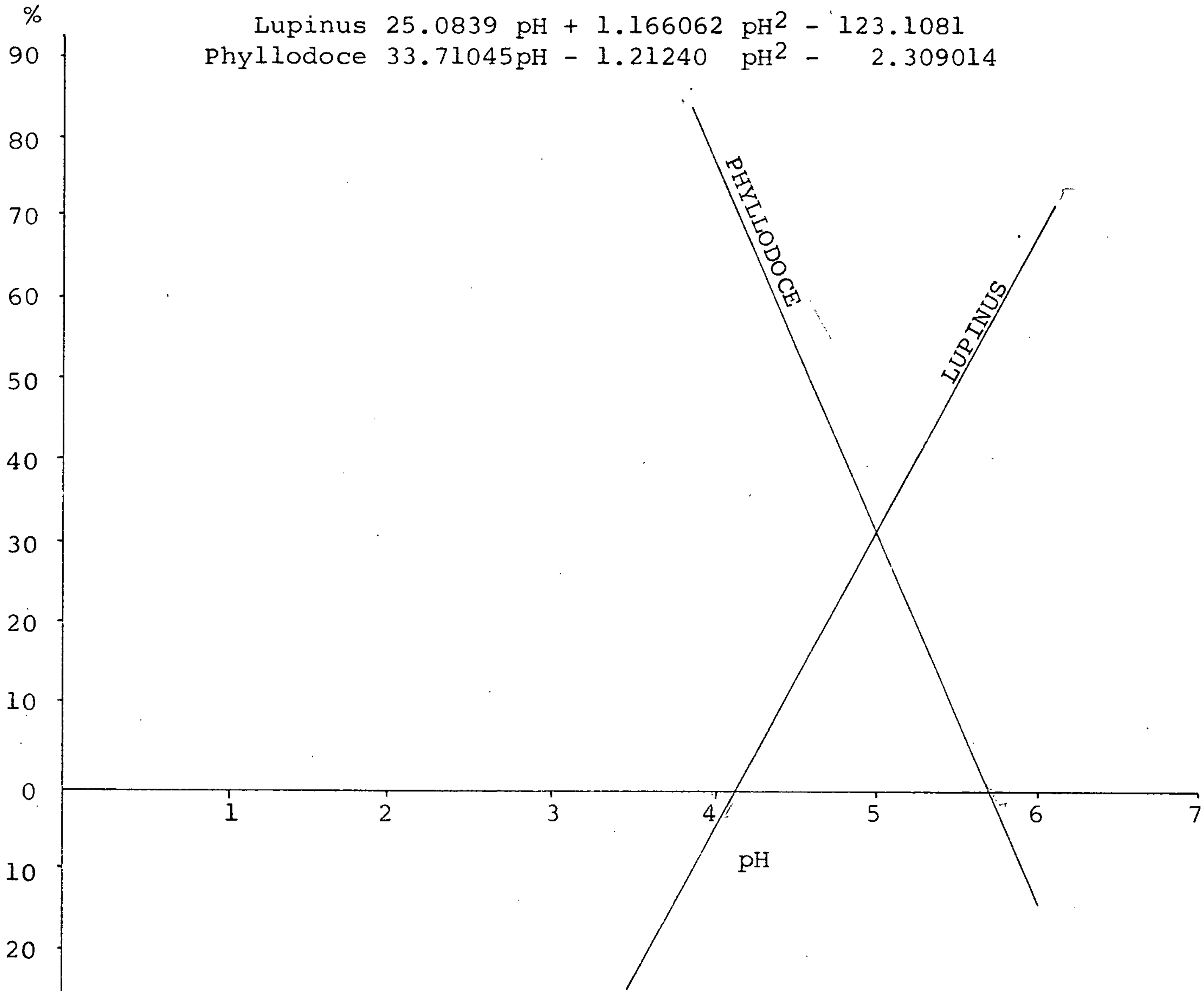
where - F - Variance ratio
S_y - Standard error of regression
df - degree of freedom
MS - Mean square
$100R^2$ - Coefficient of determination

Succession at higher altitudes on the quartz-dioritic rocks takes a somewhat different course (see Figures 13 and 14):

On the high plateaus above 6,000 feet, three pioneer stages can be recognized:

(1) Snow patch communities, in localities where the snow pack has reduced the length of growing season to a minimum;

Figure 12. Graphical representation of the regression analysis.



REGRESSION ANALYSIS OF LUPINUS AND PHYLLODOCE

(2) a stage dominated by Rhacomitrium species on grits accumulating on rock pavements;

(3) the dry rock outcrop pioneer stage characterized by species of Polytrichum. The rock is resistent to weathering and the mineral soil profile is very shallow.

The first two pioneer stages lead to the development of the Caricetum nigricantis. Conditions for the formation of soil and the succession of plants are always extreme upon these highland plateaus. On exposed situations winds usually erode accumulated organic matter from the thin mineral profiles. However, on less exposed localities, particularly in depressions, the abundance of moisture, impermeable strata and the accumulation of organic matter ultimately leads to high moor formation. The Caricetum nigricantis is typified by shallow organic soils. Further accumulation of organic matter will result in more mesic conditions and the succession of the zonal heather communities which are typical of the Phyllodoceto - Cassiopetum mertensianae. During the succession of the Caricetum nigricantis if drainage

Figure 13. Quartz-diorite succession.

QUARTZ - DIORITE SUCCESSION

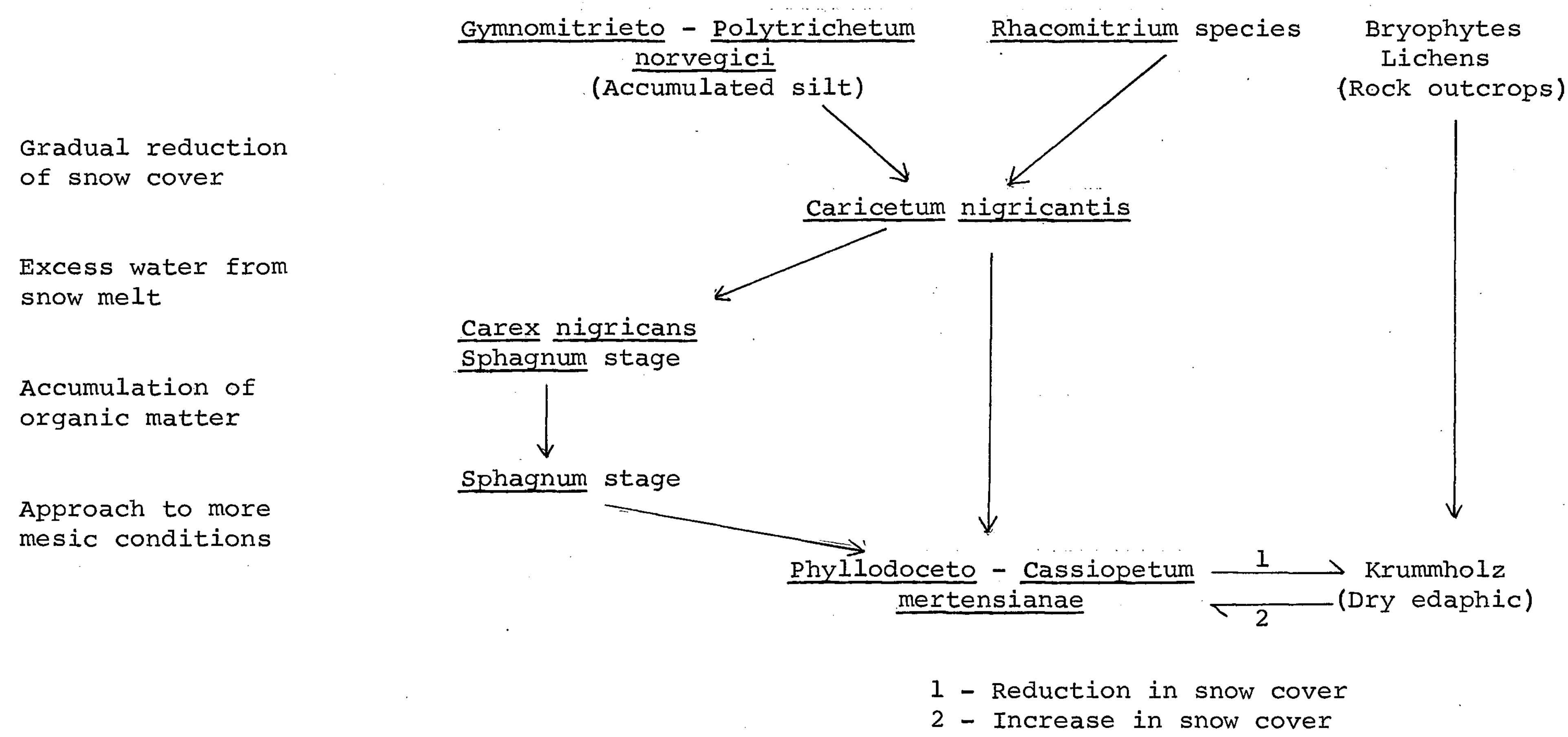
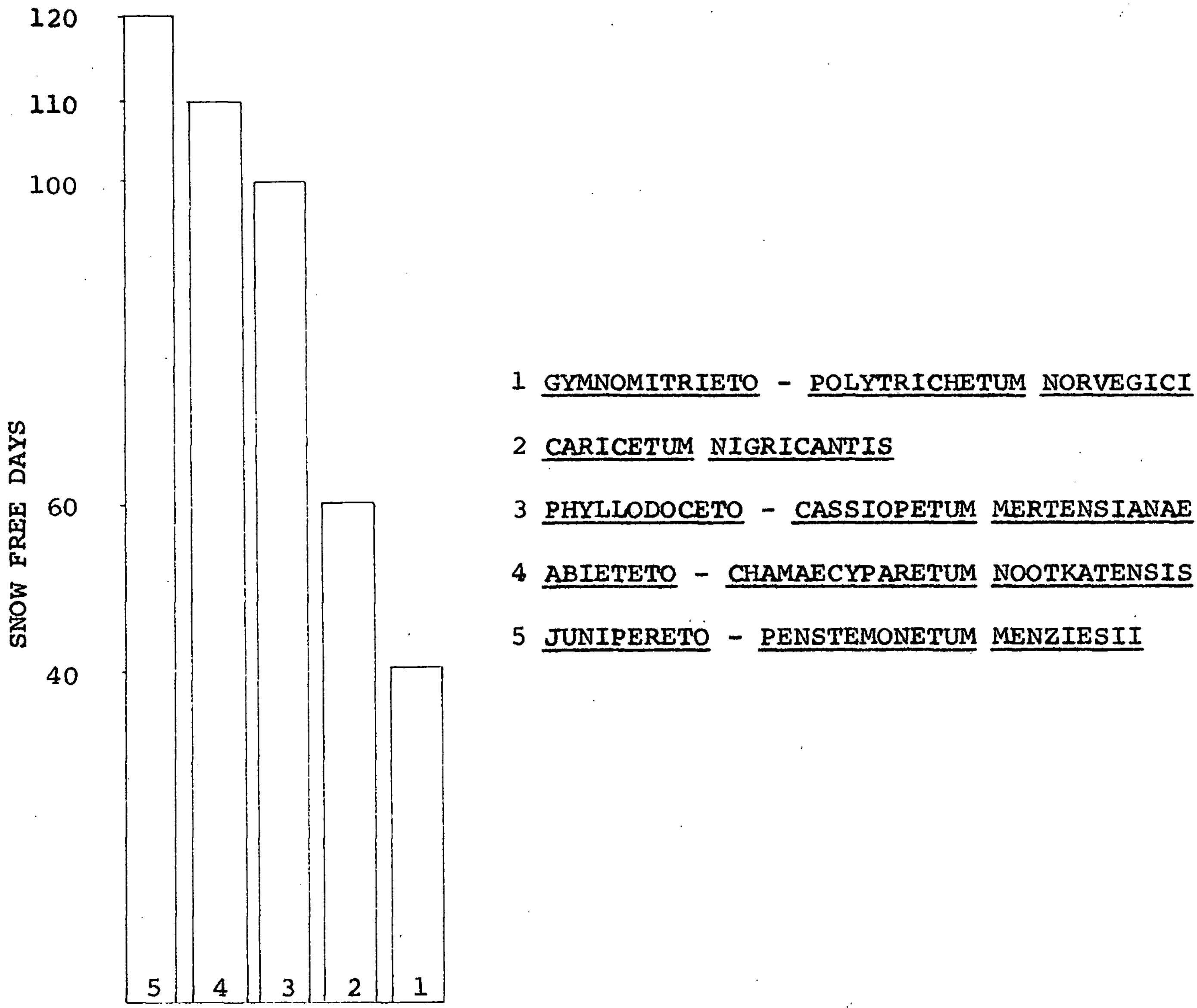


Figure 14. Average frequencies of snow free days throughout a number of associations.

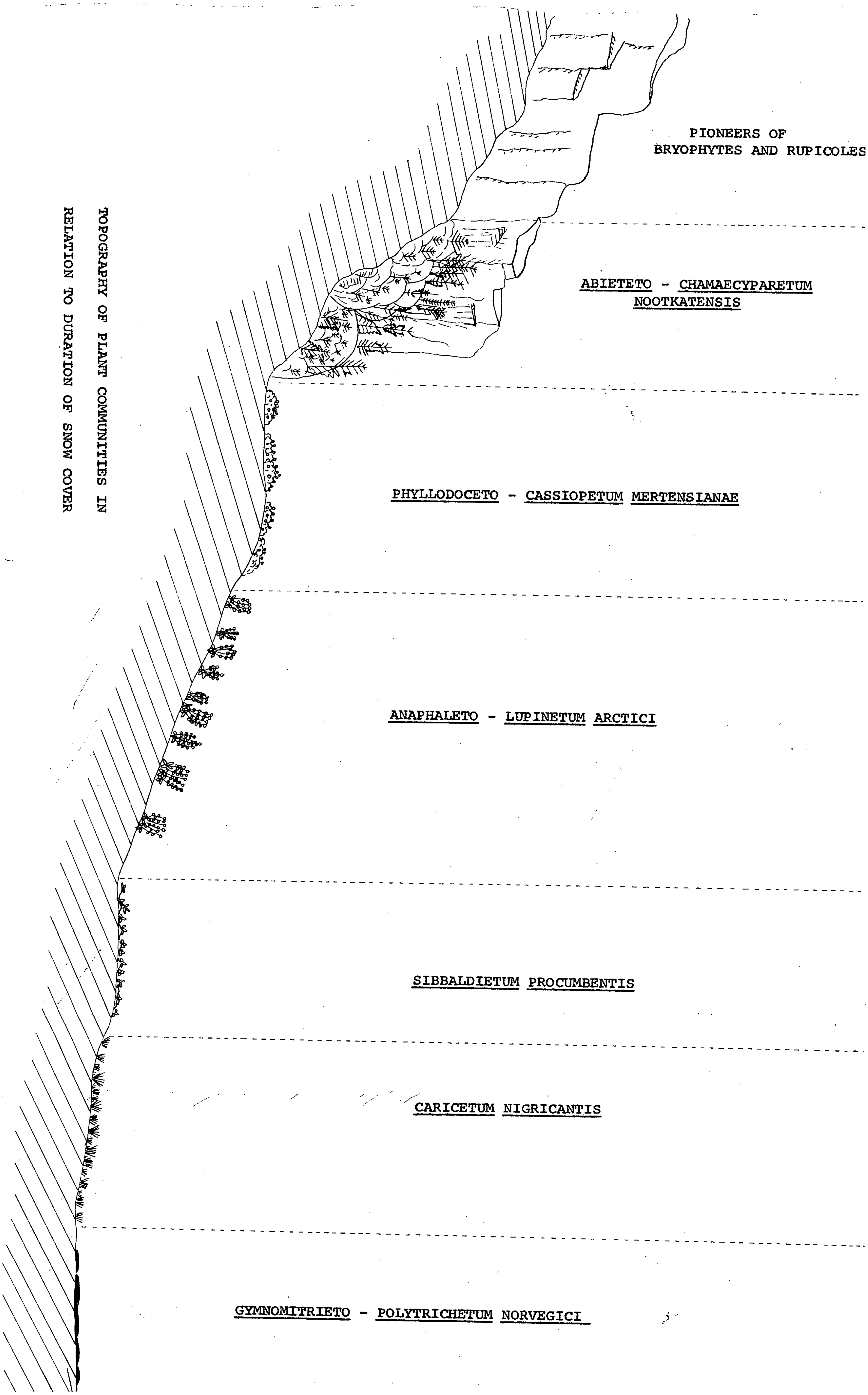


COMPARISON OF SNOW FREE DAYS THROUGHOUT A NUMBER OF ASSOCIATIONS becomes impeded, accumulated organic matter and progressive acidification will lead to high moor formation.

The bryophytic and lichen pioneer stage of rock outcrops is followed by the development of krummholz communities, which at the higher altitudes are confined to steep rock outcrops. It has already been stated the Abieteto - Chamaecyparetum nootkatensis is characteristic of dry edaphic sites maintained upon precipitous terrain. The three species in this particular region which form the treeline are Tsuga mertensiana, Chamaecyparis nootkatensis and Abies lasiocarpa. Of the three, Chamaecyparis nootkatensis grow in small isolated communities not more than 6 feet square in areas at altitudes approaching 7,000 feet. From a number of observations it appears that Chamaecyparis nootkatensis is succeeded by Abies lasiocarpa. With the accumulation of organic matter and progressive leaching Abies lasiocarpa is followed by Tsuga mertensiana.

It is on the relatively flat terrain at these higher altitudes that the present pattern and succession of vegetation indicates a gradual reduction in snow cover. Within the vicinity of the treeline, heather communities of considerable vigor grow from the periphery of the trees upwards along the slopes. Above this heather association, where snow masses lie longer, snow patch communities are developed. They represent the initial vegetational units developed, where snow does not become perennial. Reversing this scheme of description in the sense of the actual plant succession, the sequence is obtained indicating the successional changes from snow patch communities into the zonal _Phyllodoceto - Cassiopetum mertensianae._ Such a zonal community will develop where snow does not persist for a long duration.(see Figure 14). Figure 15 summarises the relationship of the plant communities to the duration of snow cover.

Figure 15. Topography of plants in relation to duration of snow cover.



TOPOGRAPHY OF PLANT COMMUNITIES IN
RELATION TO DURATION OF SNOW COVER

VI. SUMMARY AND CONCLUSION

1. Twelve plant associations were established:

A. Snow patch group

(1) Gymnomitrieto - Polytrichetum norvegici

a. sub-assoc. gymnomitrieto - polytrichetosum norvegici

b. sub-assoc. polytrichetosum piliferi

(2) Caricetum nigricantis

(3) Sibbaldietum procumbentis

B. Chomophytic group

(4) Caricetum spectabilis

(5) Luetkeetum pectinatae

(6) Anaphaleto - Lupinetum arctici

C. Alpine meadow group

(7) Mimuleto - Epilobietum latifolii

(8) Valerianetum sitchensis

D. Rupicolous group

(9) Junipereto - Penstemonetum menziesii

(10) Silenetum acaulis

E. Alpine heather group

(11) Phyllodoceto - Cassiopetum mertensianae

F. Krummholz group

(12) Abieteto - Chamaecyparetum nootkatensis

G. Peat bog group

(13) Sphagnum

2. The most important single factor responsible for the present distribution patterns, development and succession of vegetation in the Alpine Zone is the snow cover and its duration.

3. The thickness and persistence of snow pack, in certain habitats in the middle of the summer, results in the establishment of the Alpine ecotone in the upper parts of the Subalpine Zone. The Alpine Zone is developed in the altitudes above 5,500 feet.

4. The successional trend of the plant communities is presented. Pioneer stages are characterized by plant communities which require soils of relatively high base exchange capacity and do not tolerate leached soils. Progressive leaching results in

the depauperation of the base status in the soils and a gradual accumulation of organic matter, with an increase in the carbon/nitrogen ratio. These soil changes are indicated by a gradual increase of more acidophilous species, until the establishment of Phyllodoceto - Cassiopetum mertensianae which could be regarded as the zonal (climax) type.

5. There is evidence, indicated by changes in the pattern of the vegetation, that over the last few decades snow cover is being reduced (Brink, 1959).

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PLATE II

1. *Luetkea pectinata* colonizing a moraine composed largely of quartz-diorite and dacitic lava. (Weather Station, above Mamquam Lake)

2. Invasion of *Carex nigricans* community by groups of *Phyllodoce glanduliflora*. (Nunatak, above Garibaldi Névé)

3. *Mimuleto - Epilobietum latifolii* (Upper Ring Creek)

4. Invasion of snow patch communities by *Phyllodoce empetriformis*, *P. glanduliflora* and *Cassiope mertensiana*. (Viking Ridge)

5. *Caricetum nigricantis* (Nunatak, above Garibaldi Névé).

6. Snow melt channel with *Andreaea nivalis* growing in channel bed, and groups of *Carex spectabilis* on the side (Nunatak, above Garibaldi Névé).

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PLATE III

7. *Gymnomitrieto - Polytrichetum norvegici* (Nunatak, N.W. Mamquam Lake).

8. Groups of *Pohlia drummondii* and *Carex nigricans* colonizing a snow patch (Nunatak, above Garibaldi Névé).

9. *Anaphaleto - Lupinetum arctici* (Nunatak, above Garibaldi Névé).

10. *Valerianetum sitchensis*, penetrated by colonies of *Phyllodoce empetriformis* (South Face, Opal Cone).

11. Fingers of *Luetkea pectinata* colonizing colluvial slopes of dacitic parent material (West Face, Opal Cone).

12. Hygrophytic groups of plants colonizing glacio-fluvial deposits (in the Subalpine Zone) (Ring Creek).

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PLATE IV

13. Phyllodoceto - Cassiopetum mertensianae (South Face, Opal Cone).

14. Junipereto - Penstemonetum menziesii (Ridge below Garibaldi Mountain on the southern exposure).

15. Groups of Phyllodoce empetriformis, Cassiope mertensiana and krummholz communities on the Viking Ridge.

16. Groups of Abies lasiocarpa forming treeline below Diamond Head Mountain.

17. Abieteto - Chamaecypartetum nootkatensis on nunatak above Garibaldi Névé (with a climatic station).

18. Tsuga mertensiana, forming subalpine timberline (5,400 feet above Mamquam Lake).

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PLANT LIST

Lichens

<u>Buellia stigmaea</u> Tuck.

<u>Caloplaca elegans</u> (Link.) Th.Fr.

<u>Cetraria islandica</u> (L.) Ach.

<u>Cladonia chlorophaea</u> (Flörke) Spreng.

<u>Cladonia coniocraea</u> (Flörke) Sandst.

<u>Cladonia gracilis</u> var. <u>chordalis</u> (Flk.) Schaer.

<u>Cladonia degenerans</u> (Flörke) Spreng.

<u>Cladonia impexa</u> Harm.

<u>Cladonia pyxidata</u> (L.) Fr.

<u>Lecidea granulosa</u> (Enrh.) Ach.

<u>Lepraria chlorina</u> Ach.

<u>Ochrolechia inaequatula</u> (Nyl.) Zahlbr.

<u>Omphalodiscus decussatus</u> (Vill.) Scholander

<u>Parmelia pubescens</u> (L.) Wain

<u>Parmelia vittata</u> (Ach.) Nyl.

<u>Placopsis gelida</u> (L.) Nyl.

<u>Rhizocarpon geographicum</u> (L.) DC.

<u>Sarcogyne clavus</u> (Ram.) Krempelh.

<u>Sarcogyne pruinosa</u> (Sm.) Körber

<u>Solorina crocea</u> (L.) Ach.

Stereocaulon albicans Fr.

Stereocaulon alpinum Laur.

Thamnolia vermicularis (Sw.) Ach.

Toninia candida (Web.) Th.Fr.

Umbilicaria cylindrica (L.) Del.

Umbilicaria deusta (L.) Baumg.

Umbilicaria mammulata (Ach.) Tuck.

Umbilicaria proboscida (L.) Schrad.

Bryophytes

Andreaea nivalis Hook.

Brachythecium glaciale reflexum (Starke) Bry.Eur.

Dicranum fuscescens Turn.

Dicranum muhlenbeckii Bry.Eur.

Dicranoweisia crispula (Hedw.) Lindb.

Drepanocladus uncinatus (Medw.) Warnst.

Kiaeria falcata (Hedw.) Grout.

Kiaeria blyttii (Bry.Eur.) Grout.

Kiaeria starkei (Wed. & Mohr.) Grout.

Gymnomitrium varians (Lindb.) Schiffn.

Lescurea baileyi Best & Grout.

Marchantia polymorpha L.

Marsupella ustulata (Hueb.) Spruce.

Mnium spinulosum Bry.Eur.

Plagiothecium striatellum (Brid.) Lindb.

Philonotis fontana (Hedw.) Brid.

Pogonatum alpinum (Hedw.) Roehl.

Pohlia drummondii (CM) A.L. Andr.

Polytrichum juniperinum Hedw.

Polytrichum norvegicum Hedw.

Polytrichum piliferum Hedw.

Rhacomitrium cancescens Brid.

Rhacomitrium heterostichum (Hedw.) Brid.

Rhacomitrium lanuginosum (Hedw.) Brid.

Rhytidiopsis robusta (Hook.) Broth.

Scapania undulata (L.) Dumort.

Sphagnum capillaceum (Weiss.) Schrank.

Sphagnum compactum D.C.

Sphagnum plumolosum Roell.

Ferns

Athyrium alpestre (Hoppe.) Rylands.

Athyrium filix-femina (L.) Roth.

Crypotogramma crispa (L.) R.Br.

Lycopodium alpinum L.

Lycopodium sitchense L.

Polystichum lonchitis (L.) Roth.

Trees

Abies lasiocarpa (Hook.) Nutt.

Chamaecyparis nootkatensis (Lamb.) Spach.

Tsuga mertensiana (Bong.) Sarg.

Shrubs

Arctostaphylos uva-ursi (L.) Spreng.

Cassiope mertensiana Bong.

Gaultheria humifusa (Grah.) Rydb.

Juniperus communis L.

Linnaea borealis L. var. americana (Forbes) Rehder.

Penstemon menziesii Piper.

Phyllodoce empetriformis (Sm.) D.Don.

Phyllodoce glanduliflora (Hook.) Cov.

Ribes sanguineum Pursh.

Salix bella Piper.

Salix subcoerulea Piper.

Vaccinium caespitosum Michx.

Vaccinium deliciosum Piper.

Vaccinium membranaceum Dougl.

Herbs

Achillea millefolium (L.) Yarrow.

Agoseris aurantiaca (Hook.) Greene.

Agrostis humilis Vas.

Anaphalis margaritacea var. *subalpina* (L.) B. & H.

Anemone occidentalis Wats.

Antennaria alpina (L.) Goertn.

Arnica latifolia Bong.

Calamagrostis candadensis (Michx.) Beauv.

Campanula rotundifolia L.

Carex nigricans C.A. Mey.

Carex preslii Steud.

Carex pyrenaica Wahl.

Carex spectabilis Desv.

Castilleja rhexifolia Rydb.

Cirsium edule Nutt.

Collinsia parviflora Dougl.

Deschampsia atropurpurea (Whal.) Scheele.

Elymus hirsutus Presl.

Epilobium alpinum L.

Epilobium angustifolium L.

Epilobium latifolium L.

Erigeron aureus Greene.

Erigeron peregrinus (Pursh.) Greene.

Festuca brachyphylla (Schult.) Piper

Heuchera micrantha Dougl.

Hieracium gracile Hook.

Juncus drummondii (E.) Mey.

Juncus mertensiansus Bong.

Leptarrhena amplexifolia (Sternb.) Ser.

Luetkea pectinata (Pursh.) Hook.

Lupinus arcticus Wats.

Luzula piperi Cov.

Mimulus caespitosus Greene

Mimulus lewisii Pursh.

Parnassia fimbriata Konig.

Pedicularis racemosa Dougl.

Pedicularis groenlandica (Beth.) Piper.

Penstemon procerus Dougl.

Phacelia sericea Gray.

Phleum alpinum L.

Potentilla flabellifolia Hook.

Ranunculus eschscholtzii Schlecht.

Sagina saginoides (L.) Dalla - Torre.

Saxifraga arguta D.Don.

Saxifraga bronchialis L.

Saxifraga ferruginea Grah.

Saxifraga tolmiei T. & G.

Sedum divergens Wats.

Senecio subnudus DC.

Senecio triangularis Hook.

Sibbaldia procumbens L.

Silene acaulis L.

Trisetum spicatum (L.) Richt.

Valeriana sitchensis Bong.

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CHEMICAL ANALYSIS OF SOILS

Soil samples used for chemical analysis were air dried and passed through 1.0 mm sieve.

Determination of pH

Apparatus: Beckman pH meter Model N
25 ml beakers.

Procedure: Soil was mixed with distilled water in a 25 ml beaker until a thick paste-like consistency was obtained. The soil pH value was then determined using the Beckman pH meter.

Determination of organic matter

Ignition method for organic matter determination for peats:

Owing to the high organic content of the peats it was impossible to use the wet combustion method. The organic matter was ignited in a muffle furnace and burnt off leaving an ash residue. The organic matter was then calculated on a percentage loss in weight of the peat sample.

The wet combustion method

Reagents

(1) N - Potassium Dichromate

Dissolve 98.06 gm of $K_2Cr_2O_7$ in water and dilute to 2 litres.

(2) sulphuric acid, conc. (not less than 96%)

(3) 0.5 N Ferrous sulphate

Dissolve 278 gm. $FeSO_4.7H_2O$ in water and add 80 ml conc. H_2SO_4, cool and dilute to 2 litres.

(4) (Ortho) Phenanthroline Ferrous Sulphate Indicator.

Procedure

Weigh out 0.5 gm of soil for soils suspected to be low in organic matter and 0.25 gm of soil for soils thought to be high in organic matter and place in a 250 ml Erlenmeyer flask. Accurately measure out 5 ml of N dichromate and add to the flask. Next add 10 ml of concentrated sulphuric acid. Shake for about 15 seconds and let stand for about 30 minutes without shaking. Then add 30 ml of water, and two drops of (Ortho) Phenanthroline Ferrous Sulphate Indicator. Titrate with standard ferrous sulphate until the colour flashes from green to gray or brown-red. If the endpoint is over-run, add 0.5 ml more of the dichromate solution and titrate again dropwise to a light gray endpoint with standard ferrous sulphate.

The dichromate is a readonably stable solution and may be taken as the standard. The ferrous sulphate is subject to oxidation. Hence, it should be standardized against the dichromate daily as follows: Place 5 ml of standard dichromate solution in a 250 ml flask, add 10 ml of concentrated sulphuric acid and mix; then add 30 ml of distilled water, and two drops of the (Ortho) Phennanthroline Ferrous Sulphate Indicator. Titrate with ferrous sulphate to the light gray endpoint. Assuming the dichromate to be 1N, calculate the normality of the ferrous sulphate.

$$\% \text{ organic matter} = \frac{\text{ml of 1 N } K_2Cr_2O_7 \times 0.69}{\text{wt of sample (gm)}}$$

Nitrogen determination

Weigh out five g of soil and transfer using folded filter paper to an 800 ml Kjeldahl flask. Add approximately 30-40 ml conc. H_2SO_4, 10 gms (1 tsp) of a mixture of 10 parts anhydrous Na_2SO_4 and 1 part $CuSO_4$. Mix ingredients by swirling the glask. Add 2 - 3 selenized granules.

Digest until the solution is clear and continue digestion for twenty minutes. Cool and then add gradually 300 ml of tap H_2O. Shake well. Cool again. Now add about 1 teaspoonful of glass beads and/or .5 gm of granulated Zn and an excess (90 ml) of conc. NaOH solution. (40%), pouring down the side of the flask to prevent mixing of solutions and loss of NH_3. Connect to the distilling apparatus immediately and then swirl the flask gently to mix the contents. Distill into a 300 ml. Erlenmeyer flask containing 25-50 ml of saturated boric acid solution, measured with a graduate (50 ml of boric acid takes care of

95 mg of N as NH_3). Also add 4 drops of a mixed indicator of Bromocresol green and methyl red. The tube from the distilling apparatus must extend below the surface of the acid to prevent loss of NH_3.

Collect approximately 150 ml of the distillate and titrate the boric acid on the complex with standard N/14 H_2SO_4. A blank should be run in every case as there is a slight correction. Substract the blank from the total amount of acid required for the sample.

$$\frac{\text{ml of acid} \times \text{normality} \times .014}{\text{wt of sample}} \times 100 = \%N$$

Determination of exchange capacity

a) Reagents

IN NH_4OAc, pH=7.0

- 70 ml NH_4OH
- 58 ml conc. HOAc
- make to 1 l and adjust pH to exactly 7.00 by adding either of the constituents

95% pure C_2H_5OH

NaCl, C.P.

NaOH solution, approx. IN, tech.

Standard 0.2 N H_2SO_4

Standard 0.1 N NaOH (CO_2-free)

Methyl red indicator

Antifoam agent (spray)

b) Apparatus

1 - 125 ml Erl. flask

1 - 500 ml Erl. flask (wide mouth)

1 - Buckner funnel, 70 mm.

1 - 100 ml graduate cylinder

1 - 250 ml graduate cylinder

1 - 400 ml beaker

1 - 50 ml burette

1 - 25 ml pipette

#42 filter paper (70 mm)

c) Procedure

NOTE: Analyze samples in duplicate and include a reagent blank with each set of determination.

Place 20 gm of air dry soil in a 125 ml Erl. flask, add 50 ml of NH4OAc stopper flask. Shake for several minutes and allow to stand for several hours or overnight.

Transfer the soil to a Buchner funnel, containing a disc of filter paper. Fit the funnel to the filtrator and collect the filtrate in a 400 ml beaker.

Leach the sample with an additional 150 ml NH_4OAc, using gentle suction (take about ½-hour). Place the filtrate on a steam bath or hot plate and evaporate to dryness. Retain dry residue for determination of exchangeable cations.

Leach the soil with approximately 80 ml of C_2H_5OH in several portions to remove all the acetate. Discard filtrate.

Transfer soil and filter paper into a Kjeldahl flask. Add 400 ml H_2O, approximately 10 gm NaCl (sponful), and a few Zn-granules which have been sprayed with antifoam agent.

Pipette accurately 25 ml (or 50 ml for highly organic soil) of standard 0.2 N H_2SO_4 into a 500 ml flask. Add 3 - 5 drops of methyl red indicator and place under Kjeldahl distillation apparatus to collect NH_3.

To the Kjeldahl flask (step 6) add approximately 25 ml IN NaOH.

Connect flask immediately to distillation apparatus and apply heat. (Make sure the condenser is cooled with running tap water.)

Distill approximately 200 ml of liquid, containing NH_3, into the acid (step 7). If the indicator in the acid turns yellow, immediately add 10 - 20 ml more H_2SO_4. Record exact amount of acid used.

Titrate excess acid with standard 0.1 NaOH until end-point is reached (colour changes from pink to yellow).

Tabulate results and calculate the exchange capacity as meq/100 gm of air dry soil.

d) Calculation

The calculations are performed in meq units; thus the number of meq's of exchangeable cations is equal to the number of meq's of acid neutralized during distillation. This number is determined by the difference between all the acid provided and the acid neutralized with NaOH. Finally, the answer is converted to the number of meq/100 gm of air dry soil.

Determination of exchangeable cations

a) Stock solutions

180 meq/l Li (7.6315 gm LiCl per l. solution)

100 meq/l Na (5.8448 gm NaCl per l. solution)

100 meq/l K (7.4557 gm KCl per l. solution)

100 meq/l Ca (5.0045 gm $CaCO_3$ dissolved in 15 ml conc. HCl, then made to volume of 1 l.)

NOTE: These stock solutions should be made up using oven dried salts.

b) Standard solutions

The standard solutions are prepared from the above stock solutions for the purpose of obtaining a standard curve from which to determine the concentration of unknown solutions.

All standard solutions contain 5 ml of the Li-stock solution and are then made to volume of 250 ml.

The quantities of stock solutions used are calculation by the dilution ratio of stock to standard solution.

For Na and K:

prepare solutions for the following concentrations:-

0, 0.1, 0.25, 0.5, 1.0, 2.5 meq/l

For Ca:

prepare solutions of the following concentrations:-

0, 1.0, 2.5, 5.0, 10.0, 25.0 meq/l

c) Reagents for the preparation of the unknown samples

1:1 H_2O_2, reagent grade

Conc. HCl

Conc. HNO_3

1:1 HCl

d) Preparation of unknown samples

NOTE; Use the evaporated filtrate containing the exchangeable cations.

Add approximately 5 ml conc. HNO_3 and 1 ml conc. HCl (aqua regia), and evqporate to dryness.

Add 5 ml 1:1 H_2O_2 and heat gently on the hotplate for several hours.

Add 5 ml 1:1 HCl and evaporate to dryness (repeat until residue is free of organic matter).

Dissolve residue in 2 ml conc. HCl, add some water and rub beaker walls with rubber-tipped stirring rod.

Filter solution into the 250 ml volumetric, washing beaker and filter paper several times with H_2O. Add accurately 5 ml of Li-Stock solution and then make to volume with H_2O.

Keep solution stoppered in a 250 ml Erl. flask for flame photometric analysis and EDTA-titration.