FINAL REPORT
ALPINE BIODIVERSITY, FORT RICHARDSON, ALASKA

Department of Defense, Army
Legacy Resource Management Program Project DAMD17-93-J-3038

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Legacy Research Site, Alpine Tundra, Fort Richardson

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LEGACY RESOURCE MANAGEMENT PROGRAM

The Legacy Resource Management Program was established by the Congress of the United States in 1991 to provide the Department of Defense with an opportunity to enhance the stewardship of natural and cultural resources on more than 25 million acres of land under Department of Defense jurisdiction. The Legacy Program allows the Department of Defense to determine how to incorporate better the stewardship of irreplaceable natural and cultural resources into the military mission. To achieve this goal, the Department of Defense gives high priority to inventorying, protecting, and restoring its natural and cultural resources in a comprehensive, cost-effective manner, in partnership with federal, state, and local agencies and private groups. Legacy activities emphasize the protection and conservation of natural and cultural resources by fully incorporating these activities into Department of Defense mission requirements. Through the combined efforts of the various Department of Defense components, the Legacy Program seeks to achieve its legislative purposes with cooperation, creativity, and vigor and to make the Department of Defense the federal environmental leader.

The primary objective of the FY 1994 Legacy Program was to give priority to projects that demonstrated the following applications: (1) Management techniques and strategies that defined appropriate uses of a site or ecosystem, develop or test a conservation strategy, or otherwise address management of sensitive resources; (2) conservation training for installation personnel; (3) integration of natural, cultural, and earth resources stewardship; or (4) demonstration of innovative technology that benefited the management of natural, cultural, and earth resources. Additional objectives of particular interest included identification of significant and sensitive resources, including: (1) federal or state listed or candidate threatened or endangered species; (2) resources eligible for listing in the National Register of Historic Places; (3) species identified as category G 1 to G4 or S 1 to S4 in the Nature Conservancy's Natural Heritage System; or (4) unique resources such as those on the list of National Natural Landmarks and other rare or sensitive species. Regional biodiversity themes of the FY 1994 Legacy Program included: threatened and endangered species; ecosystem protection, restoration, and management; and neotropical migratory birds. Cultural Resources initiatives were associated with: Native Americans, Native Hawaiians, and Alaska Natives; settler communities on land now under Department of Defense jurisdiction; Cold War properties and history; historic family housing; and the use of the Cultural Resource Inventory System (CRIS) in support of Integrated Training Areas Management (ITAM). Earth Resources focused on the interactions of land, air, and water resources and their relationships with biological and cultural resources. Integrated Resources emphasized integration of biological, earth. and cultural resource practices.

Acknowledgments

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1. Executive Summary

The main objectives of this study were to characterize the modern alpine vegetation of Fort Richardson, and compare it with information in the paleontological record. The specific aims of paleontological portion of the study were to reconstruct the history of biotic response to environmental change in the two study regions during the postglacial period. This was achieved through studies of fossil pollen from a peat profile in the Infantry Flats region. In addition, modern pollen and insects were collected, to provide modern baseline data for the interpretation of the fossil assemblages.

In this report, we describe twelve of the most common alpine vegetation communities. From 69 studied relevés in the alpine, we found a total of 168 vascular plants, 66 mosses, 11 liverworts, and 53 lichens. Of these, 14 vascular plants, 28 mosses, 9 liverworts, and 13 lichens are new records for Fort Richardson. The highest peaks and ridges in the Snowhawk Valley are within the upper alpine or subnival belts. At the highest elevations above about 1550 m, barren and lichen covered rocks cover most surfaces; and vascular plants occur in isolated patches or individuals. The middle alpine is a much broader belt. On south and west-facing slopes, it extends from about 1550 m to 950 m, the elevation of the highest stunted spruce krummholz. On north and east facing slopes this belt extends about 150 m lower, to about 700 m. This belt is strongly affected by the combination of topography, wind, and snow. The lower alpine belt is a transitional zone consisting of scattered elfin trees mixed with forb meadows and shrublands. On south- and west-facing slopes, this zone extends from about 950 m to the open spruce forests at about 600 m. The alpine area of the Snowhawk Creek watershed is a magnificent, easily accessible, and virtually pristine example of a southern Alaskan alpine sequence. It deserves full protection from development.

The fossil pollen study showed that moist, open ground tundra vegetation was established at Infantry Flats by 7600 yrs BP (pollen Zone I). There are no analogs to the large Filicales values in the modern transect data. This suggests that there were few shrubs or trees in the area at this time. A second pollen zone (ca. 7200 - 1500 BP) represents the establishment of modern vegetation communities around the bog. Species richness is increased from Zone I. Wetlands, represented by the ferns, are still locally important, but birch and shrubby cinquefoil shrubs are now also part of the lowland vegetation. Spruce and alder now occupy the drier sites above the bog. During the past 1500 years, the expansion of shrub taxa at the expense of ferns suggests a trend to slightly drier conditions at the site.

The beetle faunal study showed that substantial numbers of tundra species live above treeline in the Chugach Mountains. The alpine beetle fauna has much in common with that of arctic Alaska. Species characteristic of the Pacific Northwest region were lacking in our collections. The reasons for this lack of affinity with the Pacific Northwestern fauna probably lie in the glacial history of the region.

2. Introduction

Fort Richardson was built during 1940-41 on the site of what is now Elmendorf Air Force Base, west of the post's current location (Fig. 1). Established as the headquarters of the United States Army, Alaska (USARAL) in 1947, the post was moved to its present location about five miles north of Anchorage in 1950.

The early 1950s saw an intensive building program designed to make the post more livable. More permanent barracks, family quarters, warehouses, a service club, underground utilities and a power plant were built. Also, the first streets were paved, the post was landscaped, the first of four school buildings sprang up and the gymnasium and theater were completed. By 1960, most of the fort's major facilities had been built.

Three off-post Nike-Hercules missile sites were built in 1959. That December, one of the mighty missiles atop Site Summit (Mount Gordon Lyon) was test fired, marking the first time a Nike Hercules had been fired from an actual operational location. The missile unit was inactivated in July 1979, after more than 20 years of defending the skies over Anchorage.

In 1969 and again in 1971, Fort Richardson was presented the Secretary of Defense Citation of Meritorious Achievement in support of the Natural Resources Conservation Program. Also in 1969, the post received the "Conservation Organization of the Year" award from the Secretary of State of Alaska, who commended the post for outstanding achievements in wildlife conservation education and its active scientific research and management of game. That commitment to wildlife enhancement continues today and many species, including moose, bear, fox and eagles, are permanent or transient residents.

The fort is authorized for 2,175 soldiers and approximately 3,800 family members to reside on post or in the adjacent communities of Anchorage, Eagle River and Palmer. The fort employs about 1,050 Army and DoD civilian employees.

The fort encompasses 62,000 acres, with 47,000 acres available for training. Military assets within that area include a heliport, a drop zone suitable for airborne and airland operations, firing ranges and other infantry training areas.

The aim of this project was to build inventories of present and past biotic communities in the alpine tundra zone at Fort Richardson, as a basis for the establishment of guidelines for mitigation and restoration. These included modern plant communities, modern insects, and Holocene plant communities. Our goal was to link these data sets together, to arrive at a synthetic view of the history of alpine biological communities and their responses to environmental change over the last 10,000 years.

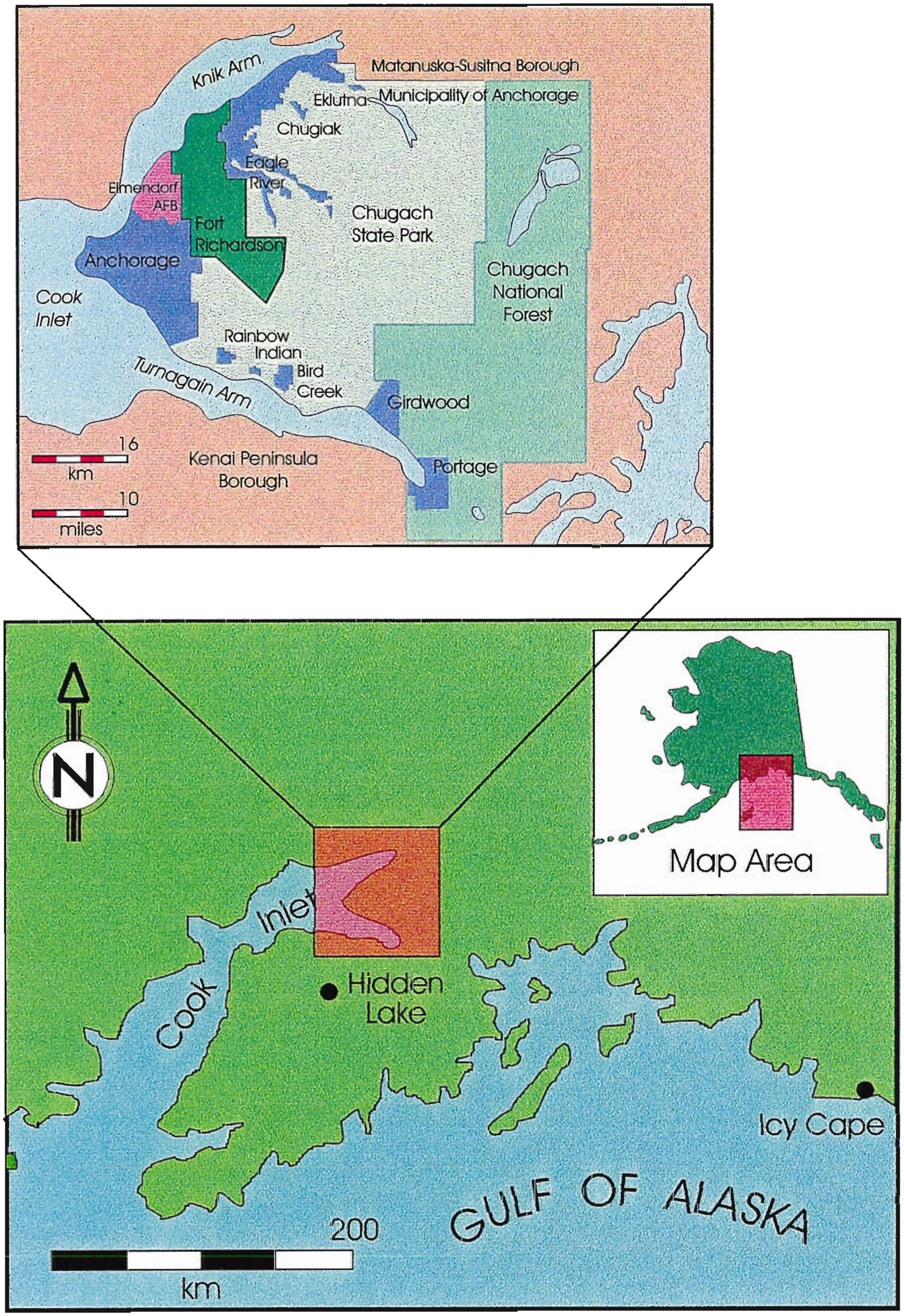

Figure 1. Map of south-central Alaska, showing location of fossil sites discussed in text, and map of the Anchorage region (inset), showing location of Fort Richardson in relation to regional communities, national forests, and Elmendorf Air Force Base.

2.1 Goals and objectives of the study

The vegetation portion of the study had two objectives. We wanted to characterize the modern natural vegetation and compare it with information in the paleontological record. The specific aims of paleontological portion of the study were to reconstruct the history of biotic response to environmental change in the two study regions during the postglacial period. This was achieved through studies of fossil pollen from a peat profile in the Infantry Flats region. In addition, modern pollen and insects were collected, to provide modern baseline data for the interpretation of the fossil assemblages.

2.2 Relevance of study to the Legacy Program

The species inventories are a vital contribution to the Legacy Program as it concerns military reservations in Alaska. The botanical composition of the alpine tundra at Fort Richardson was not fully studied before our Legacy project, but should this base be closed, our data will provide valuable information for mitigation and restoration of the sites, and for land use decision making.

3. Background

We present here a brief summary of the history of Fort Richardson, and a broader historical context of the postglacial development of regional ecosystems. It is necessary to place these sites in a broader historical context, because the forces that have shaped the alpine tundra ecosystem in this region have worked on century and millennial time scales to produce the modern biotic communities. In addition, human activities began in this region with the arrival of Paleoindian peoples, several thousand years ago. The impacts of these hunter/gatherers were probably minimal, at least in prehistoric times (i.e., before contact with Europeans).

3.1 Physiography, climate, and soils of alpine region, Chugach Mountains

The Chugach Mountains are part of an Alaskan physiographic province called the Pacific Border Ranges. Most of the framework for south-central Alaska's modern topography is associated with mountain building processes arising from the subduction of the Pacific Plate under the North American Plate. Most of the uplift of the Chugach Mountains took place during the Tertiary Period (Hunt, 1974). Pleistocene glaciers filled the valleys in the Chugach Mountains, carving glacial landforms such as cirques, U-shaped valleys, and both lateral and terminal moraines. The bedrock underlying the middle and higher elevations of the Chugach Mountains is mostly Jurassic and Cretaceous in age, and is dominated by moderately metamorphosed siltstone, graywacke, and argillite (Coney, 1981). Sandstones, basaltic greenstone, metachert, and limestone also outcrop in some regions (Magoon et al., 1976). Lower elevations (valley mouth level) have outcrops of Permian and Jurassic igneous rocks. Valley floors are mantled in unconsolidated deposits of glacial till, outwash, and morainal material (Magoon et al., 1976).

The Chugach Mountains fall within three climatic zones. The lowest elevations lie in the Boreal Zone; mid-elevations lie in the Subarctic Zone, and regions above treeline lie in the Arctic Zone. Proximity to the Pacific coast complicates this zonation pattern, however, as Chugach mountain weather tends to have characteristics intermediate between maritime and continental conditions. The former is characterized by relatively warm winter temperatures, high precipitation, and frequent high winds. The latter is characterized by relatively colder winter temperatures, low precipitation, and mild winds (Selkregg, 1974).

A meteorological station was maintained from 1946-1977 in the Chugach Mountains by Eklutna Lake in Chugach State Park, adjacent to Fort Richardson. The station was at about 1000 ft (305 m) elevation. Mean daily maximum temperature in July at the site was 64.9 F (18.2 C), and mean daily maximum January temperature was 12.5 F (-10.8 C). Daily minimum temperatures ranged from -3.2 F (-19.6 C) in January to 45.3 F (7.4 C) in July. Mean annual precipitation was 306 mm (12 inches) (Alaska Climate Center, University of Alaska, 1984). The wettest months were July, August, September, and October. The prevailing winds vary according to season and climate, but higher elevation sites in the Chugach Mountains are buffeted by southeasterly winds for most of the year.

The most common soils in the valleys of the Chugach Mountains are mostly Cryorthids, Cryochrepts, Cryaquents, Cryorthents, and Cryohemists (Marvin, 1986). The Cryorthids are mineral soils often found associated with level, well drained coniferous or mixed coniferous glacial deposits, which are quite common. The Cryochrepts are also found in well drained areas. These soils, however, develop in sloped areas and can also be found in alpine tundra (U.S.D.A. 1980). The Cryaquents are mineral soils of flood plains and very wet soils of high altitudes. They will only support plants tolerant of the very wet soil conditions present on these soils. Cryorthents are dry shallow soils on slopes, and are also found at high altitudes. These soils are usually found in tundra areas (sometimes in coniferous forest), and are often sparsely vegetated due to very cold, dry conditions (U.S.D.A. 1980). The Cryohemists are organic soils of bogs and muskegs. They contain large amounts of only slightly decomposed plant materials and are commonly found in poorly drained depressions and flat areas.

3.2 Holocene (postglacial) history of south-central Alaska

Much of south-central Alaska was covered by glacial ice during the Wisconsin (last) glaciation. This ice was produced from glaciers that flowed south from the Alaska Range and coalesced into an ice sheet that covered much of the Alaskan Gulf coast region. The ice extended down the Alaskan Peninsula to the inner Aleutian islands (Hamilton and

Thorson, 1983). As the ice age waned, the ice margin retreated, and geological evidence suggests that meltwater from glaciers north of Anchorage was dammed by late lying ice lobes in Cook Inlet, forming a proglacial lake . This has been named Glacial Lake Cook. Lake levels rose and fell repeatedly as meltwater breached the ice dam at the spillway. Such glacially-dammed lakes have also formed in recent times in southern Alaska; they are inherently unstable, and given to catastrophic drainage. The deglaciated shores of Glacial Lake Cook may have provided some of the first ice-free habitat for regional biota in the late Wisconsin interval.

Sediment cores from lakes on the Kenai Lowland register the return of plant life to the region after 14,500 yr BP. This date is quite early compared with dates from the oldest postglacial sediments from sites on nearby Kodiak Island and at Icy Cape, east of Anchorage. The earliest plant communities described from these two regions are dated at 9500 and 10,800 yr BP, respectively. Further east on the Alaskan Gulf coast, vegetation became established by 14,000 yr BP. The Prince William Sound region was still dominated by glaciers coming out of the Chugach and Kenai Mountains at this time, whereas adjacent regions were becoming free of ice.

One of the earliest postglacial environmental reconstructions in south-central Alaska comes from pollen taken from a core from Hidden Lake (Ager, 1983). This record indicates that the earliest vegetation to become established after deglaciation was herbaceous tundra, dominated by sedges, grasses, sage, and plants in the composite family. Ager interpreted this early postglacial vegetation as having been a mosaic of plant communities, growing in patches and not completely covering the deglaciated landscape. This herbaceous tundra, not unlike the steppe-tundra plant communities recorded from the Alaskan Interior, was apparently short-lived on the Kenai Peninsula. In addition, by the time postglacial vegetation began colonizing adjacent regions (i.e., Kodiak Island and Prince William Sound), this type of herbaceous tundra played no part in the succession of plant communities.

By 13,700 yr BP at Hidden Lake, herbaceous tundra gave way to shrub tundra, dominated by dwarf birch and heath plants. The dramatic expansion of shrub birch on the Kenai Peninsula, as elsewhere in Alaska, was probably brought about by rapid climatic warming.

Elements of deciduous forest were established on Kenai Peninsula about 10,300 yr BP, as dwarf birch shrub tundra gave way to a mixture of shrub tundra and deciduous scrub forest, in which *Populus* (cottonwood, balsam poplar, and aspen) and willow were important. Alder began invading the region by about 9500 yr BP, and within 500 years it was a dominant species in forests throughout the Cook Inlet region.

Conifer trees began arriving on the central Kenai Peninsula about 8000 yr BP. The first kind of conifer to get established was spruce, probably both white spruce and black spruce. These species apparently spread outward from interior Alaska early in the Holocene. Mountain hemlock and western hemlock became established between about 5,000 and 4,000 yr BP. Western hemlock grows in the Cook Inlet region, but is not common. Pollen records from the east coast of the Kenai Peninsula indicate that Sitka spruce and mountain hemlock may have arrived simultaneously, in mid-Holocene times. Coastal forest trees, including Sitka spruce and the two hemlock species, apparently did not reach the western side of the Kenai Peninsula until the mid- to late Holocene.

Heusser (1985) described the succession of plant communities following regional ice retreat at Icy Cape, a site farther east on the Gulf of Alaska coast (Fig. 1). The postglacial period also began later at Icy Cape than at Hidden Lake on the Kenai Peninsula. The earliest vegetation record at Icy Cape is dated at 10,800 yr BP. This was a shrub tundra, dominated by sedge and heath. By 10,000 yr BP, this pioneer vegetation was invaded by alder. Sitka spruce arrived about 7,500 yr BP, and western hemlock became established after 3,800 yr BP, followed by mountain hemlock, somewhat later. In recent times, alder has declined in the Icy Cape region, and closed conifer forest is now dominant throughout gulf coast regions to the east.

4. Methods

4.1 Modern vegetation

4.1.1 Field methods

The vegetation study was restricted to the alpine portion of Fort Richardson above the continuous treeline at about 600 m. Sampling occurred at the following localities: (1) Site Summit to McVeigh Valley (1200-700 m; Figure 2), (2) Infantry Flats (655-760 m; Figure 3a and b), (3) Snowhawk Creek in the vicinity of the upper Snowhawk Cabin (760 m; Figures 4a and b), and (4) Temptation Peak (1646 m; Figures 5a and b). The sampling occurred during the periods August 18-29, 1993 and July 3-14, 1994. Mr. Brad Lewis was initially given responsibility for the project and did most of the field sampling with a variety of assistants. Mr. Lewis left INSTAAR in 1995, and the analyses and descriptions were done by Dr. Skip Walker and Ms. Nancy Auerbach based on Mr. Lewis' field data, plant collections, and photos.

Because of limited time and resources, the sampling was restricted to what we deemed to be most common habitats in the Fort Richardson alpine. Much of the sampling was done in the lower alpine in the vicinity of the Infantry Flats fen, cored by Elias and Short. This was thought to be most relevant to the paleoecological investigations. Most of the other sampling was done in the continuously vegetated portion of the middle and

Figure 3b. Landscape at Infantry Flat, looking west toward the Knik Arm of Cook Inlet. The scattered trees are primarily black (*Picea mariana*) and white spruce (*P. glauca*) . Treeline in this photo is approximately at 600 m. The dark green stands of shrubs are alder (*Alnus sinuata*). Most of the gently sloping area is covered by various moist willow (*Salix* spp.) and dwarf birch (*Betula nana/glandulosa*) communities, including Community Type 8, wet *Tomentypnum nitens-Betula nana* low-shrubland. The lighter colored hillslope on the right has stands of Community Type 7, moist *Festuca altaica-Rosa acicularis* tussock-graminoid, dwarf-shrub, forb meadow.

Figure 3c. Photograph of the pollen core being taken from the fen at Infantry Flats.

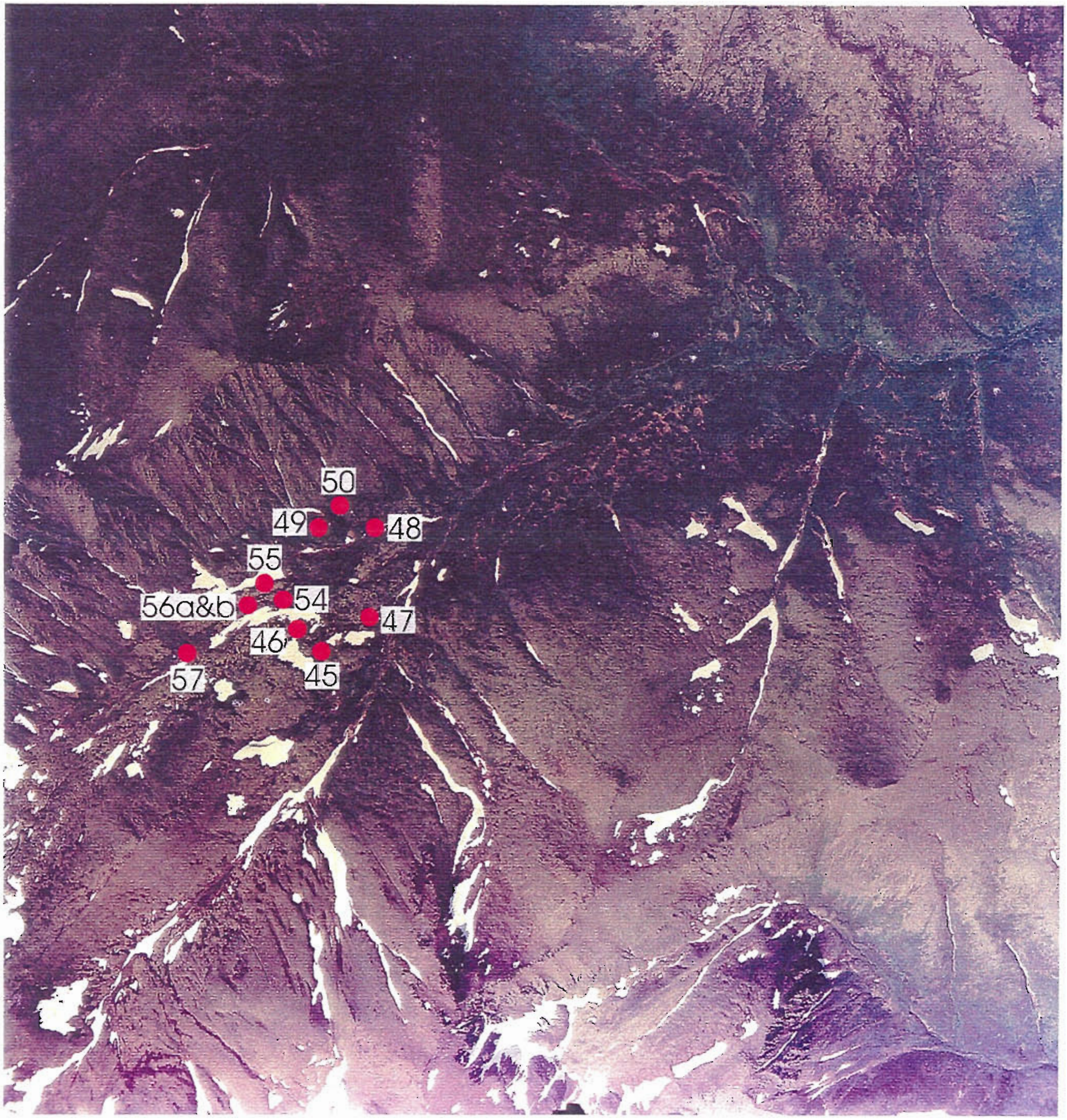

Figure 4a. Snowhawk Creek vicinity. Aerial photo showing relevé locations in vicinity of the Snowhawk Creek Hut.

Figure 4b. Lower Snowhawk Creek looking south toward the headwaters. The dark olive-green communities at the lower left are crowberry-dwarf birch (Community Type 7, moist *Empetrum nigrum-Betula nana* dwarf-shrub heath). The bright green communities along the steep slope leading down to the creek are Community Type 9, moist *Heracleum lanatum-Geranium erianthum* forb, graminoid meadow. Stands of willow (mainly *Salix alaxensis*) occur along the creek. The dark green shrublands are stands of alder (*Alnus sinuata*, lower right) and mountain hemlock (*Tsuga mertensiana*, left background and far right background).

Figure 4c. Upper Snowhawk Creek in the vicinity of the upper hut. The foreground is typical of lower alpine belt with extensive heaths, shrublands, and scattered elfin trees. The pointed peak in the background is typical of the mid alpine belt with extensive lichen tundra (Community Type 3, dry *Cladina arbuscula-Carex microchaeta* fruiticose- lichen, dwarf-shrub tundra) over much of the peak and darker areas of snowbed communities near the snow patches (Community Type 5, moist *Cassiope stelleriana-Leutkea pectinata* dwarf-shrub snowbed heath).

Figure 5a. Temptation Peak vicinity. Aerial photo showing relevé locations. Plot 51 is on the summit of Temptation Peak. The South Fork of the Eagle River is on the right.

Figure 5b. View southwest toward Tanaina Lake (1097 m) and Tanaina Peak (1585 m). The rocky cliffs and ridge tops are predominantly barren or with areas of scattered forbs and lichens (e.g. Community Type 1, dry *Silene acaulis-Minuartia macrocarpa* cushion-plant, forb barren).

Figure 5c. Cushion plant-forb community at summit of Temptation Peak (1646 m). The pink flowers are moss campion (*Silene acaulis*), and the yellow flowers are one-flowered cinquefoil (*Potentilla uniflora*).

lower alpine belts (sensu Ellenberg, 1988) above the belt of continuous subalpine alder shrublands. Seven common habitats were recognized: (1) ridgetops, (2) dry alpine heaths, (3) snowbeds, (4) moist heaths, (5) moist subalpine meadows, (6) riparian shrublands, and (7) mires. Within these habitats we defined 12 common plant community types.

We used a centralized replicate sampling procedure in representative stands of homogeneous vegetation (relevés) (Mueller-Dombois and Ellenberg, 1974; Westhoff and Van der Maarel, 1978). Sample sites were chosen subjectively as representative of plant community types covering large areas. Most relevés were about 80 m^2, but no formal boundaries were established, the objective being to obtain a complete species list from each sample site. A total of 69 relevés were sampled (see Figures 2 through 5 for plot locations). Plots were marked with a vertical 4 ft wooden lath and a metal tag at ground level.

The cover of all vascular plants, bryophytes, and lichen species were scored using the Braun-Blanquet cover-abundance scale (r = rare, single occurrence in the plot; + = numerous occurrences in the plot but less than 1% cover; 1=1-5% cover; 2=5-25% cover; 3=25-50% cover; 4=50-75% cover; and 5=75-100% cover; Mueller-Dombois and Ellenberg, 1974). A small sample of each species was collected and returned to the laboratory for final identification. Bryophytes were identified by Dr. Olga Afonina; liverworts were identified by Dr. Alexei Potemkin, and lichens were identified by Dr. Mikhail Zhurbenko at the Komarov Botanical Institute, St. Petersburg, Russia. Collections for the bryophytes and lichens are in the Komarov Botanical Institute. Vascular plant collections are at the University of Colorado Herbarium.

A brief site description of each relevé included landform, surficial geomorphology (periglacial features), microsite description, subjective site moisture, subjective soil moisture at 10 cm depth, topographic position, soil unit, exposure, estimated snow duration, slope, and aspect. The units and subjective rating scales are shown in Table 1. Soils were sampled at 10 cm depth. A plug was collected using a can of constant volume and cutting around the edges of the can. Gravimetric soil moisture, relative bulk density, and soil pH (saturated paste method) were determined in the laboratory at Fort Richardson. Soil moisture was determined for the fine portion of the soil by subtracting the weight of the >2 mm fraction from the dry weight of the soil. Relative bulk density is reported because the volume of the soil can used for collecting the sample is unknown. This value was determined for the portion of the sample that passed through a 2 mm sieve and dividing the dry weight of the soil by the highest dry weight score.

4.1.2 Classification

Classification was done using Braun-Blanquet table analysis approach. Plant communities were defined based on plant species that had differential distribution within the communities. According the Braun-Blanquet approach (Westhoff and van der Maarel, 1978),

a. Plant community types are recognized by floristic composition. The complete species composition of communities expresses the mutual relationship and the relation to environment better than any other feature.
b. Some of the species of a community express a given relation better than others. For practical classification (and characterization of the environment), it is attempted to use the species whose ecological relations make them the most effective indicators; they are called diagnostic species (character species, differential species, and constant companions).
c. Diagnostic species are used to arrange communities in a hierarchical classification, in which the *association* is the basic unit.

Associations are units within the Braun-Blanquet system that are formally defined by identification of the character taxa that differentiate the plant associations. We have not defined formal Braun-Blanquet associations for the Fort Richardson data because such designations should be based on more information from a variety of localities and should be published in the peer-reviewed literature. We have instead called the vegetation units *community types*. The communities in general are named with two species, preferably a differential species and a dominant species.

The classification was done by rearranging columns and rows of the raw data table consisting of rows of species and columns of relevés. The objective of the rearrangement is to uncover the basic structure of the vegetation data. This is done by arranging similar plots next to each other and to show the distinguishing species within each plant community. Plots that were very heterogeneous, most likely due to mixes of vegetation types, were eliminated from the table analysis.

A classification is expected to yield a clear result, and the types determined should be distinctly recognizable. The more differential taxa are included, the better these units can be recognized. In general plant community types should be distinguished by at least two clear differential taxa. Character taxa or faithful taxa are used to define associations; these are species that are restricted or nearly restricted to one vegetation type or they show a rather strong preference to the type. In practical application, especially in species-poor environments such as the alpine, this is sometimes not possible, and communities may be recognized by the abundance of a group of plant taxa, or the absence of some taxa that are dominant in other communities. We have not identified character species because this would require reference to a much broader group of communities outside of the Fort Richardson area. We have instead limited the analysis to the identification of differential species within the realm of the Fort Richardson samples. This should prove useful for later analyses that involve a much broader region. In this study we defined differential taxa according to the protocols of Daniëls (1982):

To be considered a differential taxon for a unit with more than five samples, the species had to satisfy the following criteria: if the species occurs in greater than 80% of the plots (presence of V) within the unit, it should be present in less than 40% of the other plots. If the species is present in 40-80% of the plots (presence of IV), it should be present in less than 20% of the other plots. If there are three or four plots in the unit, the species should be present in at least three of four or two of three and absent in all other samples; or present in three of three or four of four and occur in less than 20% of the other plots.

We have arranged our table such that the differential taxa for each of the community types appear at the top of the table and the non-differential taxa are at the bottom. The non-differential taxa are also sorted according the community types or combinations of community types in which they are most abundant.

4.1.3 Gradient analysis

Detrended correspondence analysis (DCA) ordination was used to examine the relationship of the relevé data to environmental gradients. The ordination displays relevés in a two dimensional space according to their species similarity to each other. Relevés that have similar species composition appear close to each other in the ordination space; whereas dissimilar relevés are far apart. DCA is based on a model of unimodal species response along gradients. The DCA produces first axes showing major directions of variation in the data and the relationship of the classification to major environmental gradients. The computer program CONOCO (ter Braak, 1987) was used to ordinate the relevés according to species composition; species were weighted equally and detrended by segments. Environmental variables were related to the ordination axes with biplot diagrams, which indicate the direction in the ordination diagram that has the maximum correlation with a particular environmental variable (Dargie, 1984; Jongman et al., 1987).

4.2 Vegetation history

4.2.1 Sample sites and sampling methods

The goals of the palynology project were two-fold: 1) to characterize the modern pollen "rain" in the alpine regions of the Fort Richardson base; and 2) to find and collect fossil exposures to analyze past vegetation and climate change. The collections are listed in Table 2. To fulfill the first objective, 48 moss and lichen polsters (i.e., clumps of moss or lichen which collect the pollen fallout over a 10-15 yr period) were collected from two attitudinal transects, one in the Infantry Flats valley (2150-2500 ft. [655-760 m]) and one from Nike Summit descending into McVeigh Valley (2000-3500 ft. [610-1067 m]) (Table 2). Pollen traps were also set out along both transects; the objective of this project was to sample the pollen "rain" over a shorter collection period. Twenty-eight of the polsters have been prepared and analyzed to date. The trap study was only partly successful; one trap in each transect was not found in successive years probably due to human or animal intervention. The trap data is unanalyzed to date.

To fulfill the second objective, we searched for lake or peat deposits in the study area. During the 1993 field season we surveyed five exposures but only found one well-preserved organic horizon in a gravel pit near Otter Lake, a low-elevation site. This

Table 1. Key to site factors measured and subjective rating scales for relevé sampling. Not all categories were used in this study, as the lists of possible selections has evolved over time and through different projects.

Landforms

1 Hills (including kames and moraines)
2 Talus slope
3 Colluvial basin
4 Glaciofluvial and other fluvial terraces
5 Marine terrace
6 Floodplains
7 Drained lakes and flat lake margins
8 Abandoned point bars and sloughs
9 Estuary
10 Lake or pond
11 Stream
12 Sea bluff
13 Lake bluff
14 Stream bluff
15 Sand dunes
16 Beach
17 Disturbed
18 Rock outcrop

Surficial Geology (Parent Material)

1 Glacial tills
2 Glaciofluvial deposits
3 Active alluvial sands
4 Active alluvial gravels
5 Stabilized alluvium (sands & gravels)
6 Undifferentiated hill slope colluvium
7 Basin colluvium and organic deposits
8 Drained lake or lacustrine organic deposits
9 Lake or pond organic, sand, or silt
10 Undifferentiated sands
11 Undifferentiated clay
12 Roads and gravel pads
13 Bedrock, sandstone

Microsites

1 Frost-scar element
2 Inter-frost scar element
3 Strang or hummock
4 Flark, interstrang, or interhummock area
5 Polygon center
6 Polygon trough
7 Polygon rim
8 Stripe element
9 Inter-stripe element
10 Point bar (raised element)
11 Slough (wet element)
12 Other

Exposure Scale

1 Protected from winds
2 Moderate exposure to winds
3 Exposed to winds
4 Very exposed to winds

Site Moisture (modified from Komárková 1983)

1 Extremely xeric - almost no moisture; no plant growth
2 Very xeric - very little moisture; dry sand dunes
3 Xeric - little moisture; stabilized sand dunes, dry ridge tops
4 Subxeric - noticeable moisture; well-drained slopes, ridges
5 Subxeric to mesic - very noticeable moisture; flat to gently sloping
6 Mesic-moderate moisture; flat or shallow depressions
7 Mesic to subhygric - considerable moisture; depressions
8 Subhygric - very considerable moisture; saturated but with < 5% standing water < 10 cm deep
9 Hygric - much moisture; up to 100% of surface under water 10 to 50 cm deep; lake margins, shallow ponds, streams
10 Hydric - very much moisture; 100% of surface under water 50 to 150 cm deep; lakes, streams

Soil Moisture (from Komárková 1983)

1 Very dry - very little moisture; soil does not stick together
2 Dry - little moisture; soil somewhat sticks together
3 Damp - noticeable moisture; soil sticks together but crumbles
4 Damp to moist - very noticeable moisture; soil clumps
5 Moist - moderate moisture; soil binds but can be broken apart
6 Moist to wet - considerable moisture; soil binds and sticks to fingers
7 Wet - very considerable moisture; water drops can be squeezed out of soil
8 Very wet - much moisture can be squeezed out of soil
9 Saturated - very much moisture; water drips out of soil
10 Very saturated - extreme moisture; soil is more liquid than solid

Estimated Snow Duration

1 Snow free all year
2 Snow free most of winter; some snow cover persistsafter storm but is blown free soon afterward
3 Snow free prior to melt out but with snow most of winter
4 Snow free immediately after melt out
5 Snow bank persists 1-2 weeks after melt out
6 Snow bank persists 3-4 weeks after melt out
7 Snow bank persists 4-8 weeks after melt out
8 Snow bank persists 8-12 weeks after melt out
9 Very short snow free period
10 Deep snow all year

Stability

1 Stable
2 Subject to occasional disturbance
3 Subject to prolonged but slow disturbance such as solifluction
4 Annually disturbed
5 Disturbed more than once annually

Surficial Geomorphology

1 Frost scars
2 Wetland hummocks
3 Turf hummocks
4 Gelifluction features
5 Strangmoor or aligned hummocks
6 High- or flat-centered polygons
7 Mixed high- and low-centered polygons
8 Sorted and non-sorted stripes
9 Palsas
10 Thermokarst pits
11 Featureless or with less 20% frost scars
12 Well-developed hillslope water tracks and small streams > 50 cm deep
13 Poorly developed hillslope water tracks, < 50 cm deep
14 Gently rolling or irregular microrelief
15 Stoney surface
16 Lakes and ponds
17 Disturbed
18 Other

Glacial Geology

1 Till
2 Outwash
3 Bedrock
4 Other

Topographic Position

1 Hill crest or shoulder
2 Side slope
3 Footslope or toeslope
4 Flat
5 Drainage channel
6 Depression
7 Lake or pond
8 Saddle

Animal and Human Disturbance

0 No sign present
1 Some sign present; no disturbance
2 Minor disturbance or extensive sign
3 Moderate disturbance; small dens or light grazing
4 Major disturbance; multiple dens or noticeable trampling
5 Very major disturbance; very extensive tunneling or large pit

TABLE 2

POLLEN SAMPLE INVENTORY, 1993 AND 1994 LEGACY PROJECT, FORT RICHARDSON, ALASKA

	Analyzed
Polsters	
McVeigh Valley Ridge #1 (3500') - 3	#1,2,3
McVeigh Valley Ridge #2 (3400') - 3	
McVeigh Valley Ridge #3 (3000') - 3	#1,2,3
McVeigh Valley Ridge #4 (2550') - 3	
McVeigh Valley Ridge #5 (2250') - 3	#1,2,3
McVeigh Valley Ridge #6 (2000') - 3	#1,2
McVeigh Valley Ridge #7 (1900') - 2	#1,2
McVeigh - Walker Transect (3000')	
FR-31 - 1	
FR-32 - 1	
FR-33 - 1	
Infantry Flat Bog (2100') - 3	#2,3
Infantry Flat #1 (2150') - 3	#1,2,3
Infantry Flat #2 (2200') - 3	
Infantry Flat #3 (2300') - 3	#1,2,3
Infantry Flat #4 (2400') - 3	#1,2,3
Infantry Flat #5 (2450') - 3	
Infantry Flat #6 (2500') - 4	#1,2,4
Infantry Flat #7 (Walker) (2350') - 2	
Otter Lake Gravel Pit (100') - 1	#1
TOTAL: 48 moss and lichen polsters	28 counted
Pollen Traps	
McVeigh Valley Ridge #1 (3500')	c & r*
McVeigh Valley Ridge #4 (2550')	not found
McVeigh Valley Ridge #6 (2000')	c & r
Infantry Flat #1 (2150')	not found
Infantry Flat #4 (2400')	c & r
Infantry Flat #6 (2500')	c & r**
Fossil Collections	
Otter Gravel Pit #1 (100')	
- 1 sample from clay lens w/in fluvial deposit	X
Otter Gravel Pit #2 (100')	
#1 - organic lens w/ charcoal, bark, twigs	X
#2 - A horizon	X
#3 - B horizon	X
Infantry Flat Bog (2100')	
- 0-210 cm at 2.5 cm intervals	10 cm intervals
TOTAL: 75 samples	23 counted

* c & r = collected and reset in 1994
** collected second year in 1995

was sampled for fossil pollen, insects, and radiocarbon dating. In 1994, a bog in Infantry Flats was cored for pollen analyses and radiocarbon dating (Fig. 3b). Both these sites have been analyzed.

4.2.2 Laboratory methods: palynology

Pollen samples include peats, organic silts, and moss and lichen polsters. Laboratory processing consisted of sieving to remove coarse organics (>0.25 mm), caustic soda, acetolysis, and hydrofluoric acid (Faegri and Iversen, 1975; Nichols, 1975), with extended boiling times because of the elevation of the laboratory. A tablet containing a known number of exotic tracer grains (Eucalyptus) was added to a weighed sample prior to chemical concentration, allowing calculation of pollen concentrations as number of grains per gram dry weight (g/gdw) of sample (Jørgensen, 1967; Stockmarr, 1971).

4.2.3 Pollen data analysis and interpretation

Pollen counts ranged from 100 to 350 grains (pollen + spores) per sample. Pollen identifications were made using the INSTAAR Palynology Laboratory reference collection plus keys and floras (Hultén, 1968; McAndrews et al., 1973; Moriya, 1976). The modern and fossil pollen data are presented in the form of pollen diagrams which illustrate major taxa only.

4.3 Modern entomology

Modern specimens were collected chiefly by pit-fall trapping along a transect from wet to dry habitats. The traps were set out in three areas: the north-facing slope of McVeigh Valley (below Site Summit); along the Site Summit road, southeast of Site Summit, and at Infantry Flats (see localities labeled in figures 2 and 3a). The pitfall traps were placed at ground level and checked each morning for several days for insects. Specimens were also collected by turning stones and debris at the study sites.

5. Results

5.1 Modern vegetation

Appendix A contains species lists of vascular plants, bryophytes, and lichens collected or recognized in the 69 relevés in the Fort Richardson alpine. Note that only Latin names are used in the following discussion, but common names are provided where possible in Appendix A. There were a total of 168 vascular plants, 66 mosses, 11 liverworts, and 53 lichens. Of these, 14 vascular plants, 28 mosses, 9 liverworts, and 13 lichens are new records for Fort Richardson.

5.1.1 Classification

The classification of 69 relevés yielded 12 common plant community types occurring in seven common habitats (Table 3). Four of the relevés were eliminated because they were either single records for a vegetation type, or the relevé was obviously heterogeneous and not representative of a single vegetation type. The final sorted table (Appendix B) shows the differential taxa and other species occurring in 10 community types with the species' Braun-Blanquet cover-abundance scores in each relevé. Table 4 is a summary table that shows the presence (frequency of occurrence) of each species in each plant community type and the average cover abundance score. Table 5 contains a summary of environmental and soil information for the community types. Complete species and environmental information for all the sampled relevés is in Appendices B and C. Where possible the following descriptions contain reference to other similar communities that have been described in Alaska using the Braun-Blanquet approach.

Table 6 contains an analysis of species diversity grouped according to growth forms in each of the vegetation types. There is a general trend of greater diversity in the dry, more exposed sites due primarily to the high diversity of lichens in these areas, and lower diversity in the wetter areas, due mainly to high competition among sedge species and the lack of lichens. A total of 117 species (43 lichen species) occurred in the *Oxytropis bryophila-Dryas octopetala* community type, whereas only 33 species occurred in the *Carex rariflora-Warnstorfia exannulata* fen.

5.1.1.1 Ridge tops

5.1.1.1.1. Community Type 1, dry *Silene acaulis-Minuartia macrocarpa* cushion-plant, forb barren (Figure 5c).

The upper watershed of Snowhawk Creek is enclosed by peaks that exceed 1500 m elevation. Only one day was spent in sampling the area of Temptation Peak, and much of this was done during a snowstorm. At the summit of Temptation Peak we were treated to a rock garden in full bloom during blizzard conditions! Only one relevé was collected, and was thus excluded from the table analysis (Table 3).

This community was dominated by cushion and rosette dicots. Principal vascular plants and their cover-abundance scores were: *Androsace alaskana* (+), *Antennaria monocephala* (+), *Cerastium beeringianum* (1), *Claytonia sarmentosa* (+), *Draba* spp. (+), *Festuca brachyphylla* (+) *Lloydia serotina* (+), *Luzula parviflora* (+), *Minuartia macrocarpa* (1), *Oxytropis bryophila* (+), *Pedicularis* sp. (+), *Poa glauca* (+), *Potentilla uniflora* (2), *Primula* sp. (+), *Rumex acetosella* (+) *Saxifraga bronchialis* (+), *S. cernua* (+), *S. flagellaris* (+), *S. hirculis* (+), *S. oppositifolia* (+), *S. serpyllifolia* (1), *Silene acaulis* (1), and *Salix polaris* (+).

Table 3. Summary of Fort Richardson alpine communities with relevé numbers.

Habitat Plant communities	**Relevés**
Ridge tops	
1. *Silene acaulis-Minuartia macrocarpa*	FR-51
Dry alpine heaths	
2. *Oxytropis bryophila-Dryas octopetala*	FR-1, 58, 14, 3, 33, 66, 53, 68, 4, 12, 13, 50, 2, 16
3. *Cladina arbuscula-Carex microchaeta*	FR-69, 46, 55, 15, 34
Snowbeds	
4. *Carex microchaeta-Cassiope tetragona*	FR-52
5. *Cassiope stellariana-Luetkea pectinata*	FR-56a, 56b, 19, 6, 20, 7, 45, 35, 32, 30
Moist heaths	
6. *Festuca altaica-Rosa acicularis*	FR-59, 60, 61, 8, 28, 29
7. *Empetrum nigrum-Betula nana*	FR-38, 41, 47, 62, 63
8. *Tomentypnum nitens-Betula nana*	FR-23, 24, 10, 22, 9, 21
Moist subalpine meadows	
9. *Heracleum lanatum-Geranium erianthum*	FR-36, 37, 5, 17, 18
Riparian shrublands	
10. *Salix barclayi-Mertensia paniculata*	FR-48, 49, 39, 42, 44, 40
11. *Alnus sinuata-Climaceum dendroides*	FR-64, 65, 43
Mires	
12. *Carex rariflora-Warnstorfia exannulata*	FR-25, 27, 11, 26

Table 4. Summary table for Fort Richardson alpine vegetation analysis. Values in table represent constancy class average cover abundance.
Braun-Blanquet constancy classes: r = taxon in < 5% of the records in a plant community, Class + = 5-10%, Class I = 11-20%,
Class II = 21-40%, Class III = 41-60%, Class IV = 61-80%, Class V = taxon in 81-100% of the records in a plant community.
For communities of four or fewer relevés, the actual number of occurrences is shown rather than the constancy class.
Braun-Blanquet cover-abundance: r = rare, + = common, but < 1% cover, 1 = 1-5%, 2 = 6-25%, 3 = 25-50%, 4 = 51-75%, 5 = 76-100%.
For the purpose of computing the average cover-abundance, class"r" was converted to 0.4 and "+" to 0.7.

Plant community codes:

- OXYBRY-DRYOCT = *Oxytropis bryophila-Dryas octopetala*
- CLAARB-CARMIC = *Cladina arbuscula-Carex microchaeta*
- CASSTE-LUEPEC = *Cassiope stellariana-Luetkea pectinata*
- FESALT-ROSACI = *Festuca altaica-Rosa acicularis*
- EMPNIG-BETNAN = *Empetrum nigrum-Betula nana*
- TOMNIT-BETNAN = *Tomentypnum nitens-Betula nana*
- HERLAN-GERERI = *Heracleum lanatum-Geranium erianthum*
- SALBAR-MERPAN = *Salix barclayi-Mertensia paniculata*
- ALNSIN-CLIDEN = *Alnus sinuata-Climaceum dendroides*
- CARRAR-WAREXA = *Carex rariflora-Warnstorfia exannulata*

Habitat	Dry Alpine Heaths		Snow-beds	Moist Heaths			Moist Subalp. Mdws	Riparian Shrublands		Mires
Plant communities	OXYBRY DRYOCT	CLAARB CARMIC	CASSTE LUEPEC	FESALT ROSACI	EMPNIG BETNAN	TOMNIT BETNAN	HERLAN GERERI	SALBAR MERPAN	ALNSIN CLIDEN	CARRAR WAREXE
Number of Releves in Communities	14	5	10	6	5	6	5	6	3	4
				Differential species for habitats and plant communties						
Differential species for dry alpine heaths										
Carex microchaeta	V/+	V/1	II/1	.	.	.	.	.	.	.
Hierochlöe alpina	V/1	V/1	I/+	II/+	I/2	.	.	.	.	.
Thamnolia subuliformis/vermicularis	V/1	V/1	I/1	.	I/+	.	.	.	.	.
Cetraria nivalis	V/1	V/1	I/+	.	I/r	.	.	.	.	.
Diapensia lapponica	V/1	IV/1	.	.	.	.	.	.	.	.
Alectoria ochroleuca	V/1	III/+	.	.	.	.	.	.	.	.
Alectoria nigricans	IV/1	IV/+	.	.	.	.	.	.	.	.
Bryocaulon divergens	IV/2	III/+	.	.	.	.	.	.	.	.
Polytrichum piliferum	IV/+	III/+	.	.	.	.	.	.	.	.
Sphaerophorus globosus	IV/1	II/+	.	.	.	.	.	.	.	.
Arctous alpina	IV/2	III/2	.	.	.	.	.	.	.	.
Ochrolechia frigida	IV/+	III/+	.	.	.	.	.	.	.	.
Differential species for *Oxytropis bryophila-Dryas octopetala*										
Dryas octopetala	V/2	II/2	+/+	.	.	.	.	.	.	.
Oxytropis bryophila	IV/1	.	+/+	.	.	.	.	.	.	.
Salix arctica	IV/1	I/+	+/+	.	.	.	.	.	.	.
Saxifraga bronchialis	III/+	.	.	.	.	.	.	.	.	.
Pertusaria dactylina	III/+	I/+	.	.	.	.	.	.	.	.
Differential species for snowbeds										
Cassiope stelleriana	.	.	V/3		.	.	.	.	.	.
Luetkea pectinata	.	.	IV/2		.	.	.	.	.	.
Sanionia uncinata	.	I/+	III/+	I/+	.	.	.	I/+	.	.
Lycopodium alpinum	+/r	.	III/+	.	.	.	.	.	.	.
Peltigera malacea	+/+		III/1	.	I/r	.	.	.	.	.
Nephroma arcticum	.	I/r	III/+	.	.	.	.	.	.	.
Huperzia selago	.	I/+	III/+	.	.	.	.	.	.	.
Differential species for moist heaths										
Betula nana/glandulosa	.	II/2	.	V/3	V/3	V/2	.	II/3	.	1/r
Rubus chamaemorus	.	.	.	.	V/1	V/+	.	.	.	.
Differential species for *Festuca altaica-Rosa acicularis*										
Rosa acicularis	.	.	.	IV/1	.	.	.	I/+	.	.
Differential species for *Empetrum nigrum-Betula nana*										
Aulacomnium turgidum	+/+	.	.	.	IV/1	.	.	.	.	.
Differential species for *Tomentypnum nitens-Betula nana*										
Tomentypnum nitens	.	.	.	.	.	V/3	.	.	.	.
Aulacomnium palustre	.	.	.	.	I/+	IV/2	.	.	.	.
Oxycoccus microcarpus	.	.	.	.	.	IV/2	.	.	.	.
Parnassia palustris	.	.	.	.	.	IV/+	.	.	.	.
Arctous rubra	.	.	.	.	.	III/2	.	.	.	.
Picea glauca	.	.	.	.	.	III/+	.	.	.	.
Picea mariana	.	.	.	.	.	III/+	.	.	.	.
Differential species for moist subalpine meadows										
Brachythecium reflexum	.	.	+/+	.	.	.	IV/1	.	1/+	.
Conioselinum pacificum	.	.	.	I/+	.	.	III/+	.	.	.
Differential species for riparian shrublands										
Climacium dendroides	.	.	.	I/+	.	I/+	.	I/1	3/+	.

Table 4. Continued.

Habitat	Dry Alpine Heaths		Snow-beds	Moist Heaths			Moist Subalp. Mdws	Riparian Shrublands		Mires
Plant communities	OXYBRY DRYOCT	CLAARB CARMIC	CASSTE LUEPEC	FESALT ROSACI	EMPNIG BETNAN	TOMNIT BETNAN	HERLAN GERERI	SALBAR MERPAN	ALNSIN CLIDEN	CARRAR WAREXE
Number of Releves in Communities	14	5	10	6	5	6	5	6	3	4
Differential species for *Salix barclayi-Mertensia paniculata*										
Salix barclayi	.	.	.	.	.	I/3	.	IV/3	.	.
Brachythecium salebrosum	.	.	.	.	.	.	.	III/+	.	.
Differential species for *Alnus sinuata-Climaceum dendroides*										
Alnus sinuata	.	.	.	.	.	.	.	.	3/5	.
Differential species for mires										
Carex rariflora	.	.	.	.	.	I/+	.	.	.	4/3
Warnstorfia exannulata	.	.	.	.	.	.	.	.	.	4/3
Eriophorum angustifolium	.	.	.	.	.	I/+	.	.	.	4/1
Hamatocaulis vernicosus	.	.	.	.	.	.	.	.	.	4/1
Trichophorum caespitosum s.l.	.	.	.	.	.	.	.	.	.	4/1
Triglochin palustris	.	.	.	.	.	.	.	.	.	4/1
Eriophorum scheuchzeri	.	.	.	.	.	.	.	.	.	4/+
Scorpidium scorpioides	.	.	.	.	.	.	.	.	.	3/2
Carex limosa	.	.	.	.	.	.	.	.	.	3/1
Cyrtomnium hymenophylloides	.	.	.	.	.	.	.	.	.	3/1
Sphagnum squarrosum	.	.	.	.	.	.	.	.	.	2/+
Non-differential species for habitats and plant communties										
Non-differential species in dry alpine heaths, snowbeds, moist heaths, riparian shrublands, and mires										
Vaccinium uliginosum s.l.	III/+	IV/2	III/1	III/3	V/2	V/1	.	II/1	.	3/r
Salix planifolia ssp. pulchra	.	II/1	II/1	.	II/+	II/2	.	III/2	.	2/+
Non-differential species in dry alpine heaths, moist heaths, and mires										
Ledum palustre ssp. decumbens	II/+	III/1	.	II/+	III/1	II/+	.	.	.	1/+
Non-differential species in dry alpine heaths, snowbeds, moist heaths, moist subalpine meadows, and riparian shrublands										
Festuca altaica	III/+	I/+	II/+	V/3	.	I/1	IV/1	III/1	.	.
Anemone narcissiflora ssp. interior	III/+	II/1	V/1	II/+	.	III/+	III/+	.	1/+	.
Cornus canadensis x suecica	+/+	.	I/+	V/2	V/1	II/+	III/2	V/1	.	.
Pleurozium schreberi	I/+	I/+	III/1	V/+	V/1	.	I/+	II/1	.	.
Artemisia arctica	+/+	I/1	IV/1	IV/1	.	.	II/2	III/+	.	.
Non-differential species in dry alpine heaths, snowbeds, moist heaths, and riparian shrublands										
Empetrum nigrum/hermaphroditum	III/1	V/2	V/2	V/3	V/5	V/2	.	III/1	.	.
Vaccinium vitis-idaea	IV/1	V/1	II/+	V/+	V/+	V/+	.	II/1	.	.
Luzula parviflora	+/+	.	III/+	.	.	IV/+	.	I/+	.	.
Polytrichastrum alpinum	.	I/+	II/+	III/+	.	.	.	I/1	1/+	.
Non-differential species in dry alpine heaths, moist heaths, and riparian shrublands										
Carex podocarpa	+/+	.	.	I/2	II/2	.	.	I/+	.	.
Ledum groenlandicum	.	I/+	.	.	II/1	II/1	.	I/2	.	.
Non-differential species in dry alpine heaths, snowbeds, moist heaths, and moist subalpine meadows										
Poa sp.	+/+	I/+	I/+	II/+	.	II/+	I/+	.	.	.
Non-differential species in dry alpine heaths, snowbeds, and moist subalpine meadows										
Ceratodon purpureus	I/+	.	+/+	.	.	.	I/+	.	.	.
Non-differential species in dry alpine heaths and moist subalpine meadows										
Rhytidium rugosum	II/1	.	.	.	.	.	I/+	.	.	.
Anastrophyllum minutum	.	I/+	.		.	.	I/+	.	.	.
Non-differential species in dry alpine heaths, snowbeds, and moist heaths										
Cladina rangiferina	III/1	IV/2	II/+	II/1	V/1	I/+	.	.	.	.
Cladina stellaris	II/1	IV/4	IV/1	II/+	IV/+	.	.	.	.	.
Cladina arbuscula/mitis	III/1	IV/3	II/2	II/+	III/1	.	.	.	.	.
Cetraria islandica	III/1	III/+	II/1	II/1	V/+	.	.	.	.	.
Cladonia gracilis	II/+	III/+	II/+	III/+	IV/+	.	.	.	.	.
Dactylina arctica	+/+	III/+	I/+	.	III/+	.	.	.	.	.
Lobaria linita	II/+	II/+	I/1	.	I/1	.	.	.	.	.
Cladonia pocillum	I/+	II/1	I/+	.	I/+	.	.	.	.	.
Dicranum bonjeanii	I/+	.	I/+	I/+	.	.	.	.	.	.

Table 4. Continued.

Habitat	Dry Alpine Heaths		Snow-beds	Moist Heaths			Moist Subalp. Mdws	Riparian Shrublands		Mires
Plant communities	OXYBRY DRYOCT	CLAARB CARMIC	CASSTE LUEPEC	FESALT ROSACI	EMPNIG BETNAN	TOMNIT BETNAN	HERLAN GERERI	SALBAR MERPAN	ALNSIN CLIDEN	CARRAR WAREXE
Number of Releves in Communities	14	5	10	6	5	6	5	6	3	4
Non-differential species in dry alpine heaths, snowbeds, and moist heaths, continued										
Peltigera aphthosa	.	I/r	II/+	IV/+	III/1	.	.	.	.	.
Lycopodium clavatum s.l.	.	I/+	II/+	II/+	I/+	.	.	.	.	.
Cladonia macroceras	.	II/+	+/+	I/+	I/+	.	.	.	.	.
Non-differential species in dry alpine heaths and moist heaths										
Cetraria cucullata	IV/+	V/1	.	II/2	V/+	.	.	.	.	.
Stereocaulon tomentosum	II/2	**IV/2**	.	I/1	III/+	.	.	.	.	.
Salix reticulata	II/+	II/1	.	.	.	**IV/1**	.	.	.	.
Nephroma expallidum	II/+	III/+	.	.	III/1	.	.	.	.	.
Polytrichum strictum	II/+	I/1	.	I/+	III/+	.	.	.	.	.
Cetraria laevigata	.	II/+	.	I/+	III/+	.	.	.	.	.
Pedicularis capitata	II/+	I/1	.	.	.	I/+	.	.	.	.
Cladonia pyxidata	II/+	I/+	.	.	I/+	.	.	.	.	.
Pedicularis labradorica	.	II/+	.	I/+	II/+	.	.	.	.	.
Peltigera leucophlebia	I/+	.	.	.	I/+	.	.	.	.	.
Cystopteris fragilis	+/+	.	.	.	.	I/+	.	.	.	.
Stereocaulon sp.	+/2	.	.	I/2	.	.	.	.	.	.
Polytrichum juniperinum	+/+	.	.	I/+	.	.	.	.	.	.
Pohlia nutans	+/+	.	.	I/r	.	.	.	.	.	.
Non-differential species in dry alpine heaths and snowbeds										
Cladonia uncialis	III/+	IV/+	II/+	.	.	.	.	.	.	.
Anemone multifida	III/+	I/+	II/+	.	.	.	.	.	.	.
Cladonia amaurocraea	II/+	I/+	I/1	.	.	.	.	.	.	.
Loiseleuria procumbens	II/+	II/1	+/r	.	.	.	.	.	.	.
Cassiope tetragona	I/+	II/1	I/+	.	.	.	.	.	.	.
Acomastyllis rossii	II/+	II/+	+/+	.	.	.	.	.	.	.
Polytrichum hyperboreum	+/+	I/+	+/+	.	.	.	.	.	.	.
Gentiana propinqua	+/+	.	II/+	.	.	.	.	.	.	.
Stereocaulon alpinum	I/2	.	+/+	.	.	.	.	.	.	.
Salix phlebophylla	I/+	.	+/+	.	.	.	.	.	.	.
Cladonia stricta	I/+	.	+/+	.	.	.	.	.	.	.
Campanula lasiocarpa s.l.	+/+	.	I/+	.	.	.	.	.	.	.
Gentiana glauca	.	I/+	I/+	.	.	.	.	.	.	.
Cladonia coccifera	.	I/r	I/+	.	.	.	.	.	.	.
Arnica lessingii	.	I/+	+/+	.	.	.	.	.	.	.
Faithful species in dry alpine heaths										
Racomitrium lanuginosum	II/1	III/+	.	.	.	.	.	.	.	.
Varicellaria rhodocarpa	+/+	II/+	.	.	.	.	.	.	.	.
Dicranum spadiceum	I/+	I/+	.	.	.	.	.	.	.	.
Ptilidium pulcherrimum	+/+	I/+	.	.	.	.	.	.	.	.
Epilobium latifolium	+/1	I/+	.	.	.	.	.	.	.	.
Dactylina madreporiformis	+/+	I/r	.	.	.	.	.	.	.	.
Cetraria nigricans	II/+	.	.	.	.	.	.	.	.	.
Minuartia macrocarpa	II/+	.	.	.	.	.	.	.	.	.
Trisetum spicatum s.l.	II/+	.	.	.	.	.	.	.	.	.
Dicranum elongatum	II/+	.	.	.	.	.	.	.	.	.
Festuca brachyphylla	II/+	.	.	.	.	.	.	.	.	.
Parmelia omphalodes	II/+	.	.	.	.	.	.	.	.	.
Saxifraga tricuspidata	II/+	.	.	.	.	.	.	.	.	.
Silene acaulis	II/+	.	.	.	.	.	.	.	.	.
Stereocaulon paschale	II/+	.	.	.	.	.	.	.	.	.
Poa glauca	I/1	.	.	.	.	.	.	.	.	.
Antennaria friesiana	I/+	.	.	.	.	.	.	.	.	.
Minuartia rubella	I/+	.	.	.	.	.	.	.	.	.
Phlox sibirica	I/+	.	.	.	.	.	.	.	.	.
Pseudephebe pubescens	I/+	.	.	.	.	.	.	.	.	.
Tofieldia coccinea	I/+	.	.	.	.	.	.	.	.	.
Ptilidium ciliare	.	II/1	.	.	.	.	.	.	.	.
Non-differential species in snowbeds, moist heaths, moist subalpine meadows, and riparian shrublands										
Sanguisorba stipulata	.	.	II/+	II/+	.	IV/+	V/2	V/2	2/2	.
Calamagrostis canadensis	.	.	I/+	III/1	.	IV/+	IV/2	IV/2	3/1	.
Valeriana sitchensis	.	.	II/2	I/+	.	V/1	V/1	.	2/2	.
Spiraea stevenii	.	.	II/+	II/+	IV/+	.	I/1	III/+	.	.
Rubus arcticus	.	.	II/+	II/1	.	I/+	IV/2	III/+	.	.
Lycopodium annotinum s.l.	.	.	II/+	II/1	I/2	.	I/+	III/+	.	.
Veratrum viride	.	.	II/r	I/r	.	.	I/1	I/+	3/+	.
Moehringia lateriflora	.	.	II/+	III/1	.	.	I/+	I/+	.	.
Trientalis europaea ssp. arctica	.	.	II/+	I/+	I/+	.	I/+	I/+	.	.
Arnica latifolia	.	.	I/1	I/+	.	.	II/+	I/1	.	.

Table 4. Continued.

Habitat	Dry Alpine Heaths		Snow-beds	Moist Heaths			Moist Subalp. Mdws	Riparian Shrublands		Mires
Plant communities	OXYBRY DRYOCT	CLAARB CARMIC	CASSTE LUEPEC	FESALT ROSACI	EMPNIG BETNAN	TOMNIT BETNAN	HERLAN GERERI	SALBAR MERPAN	ALNSIN CLIDEN	CARRAR WAREXE
Number of Releves in Communities	14	5	10	6	5	6	5	6	3	4
Non-differential species in snowbeds and riparian shrublands										
Brachythecium campestre	.	.	I/1	.	.	.	.	.	1/+	.
Non-differential species in snowbeds, moist heaths, and riparian shrublands										
Dicranum majus	.	II/+	V/1	V/1	IV/1	II/+	.	I/+	.	.
Hylocomium splendens	.	.	III/+	III/2	V/3	V/2	.	IV/1	.	.
Non-differential species in snowbeds, moist subalpine meadows, and riparian shrublands										
Rhodiola integrifolia	.	.	I/+	.	.	.	II/1	III/+	.	.
Rhytidiadelphus squarrosus	.	.	I/+	.	.	.	I/1	II/2	.	.
Non-differential species in snowbeds, moist heaths, and moist subalpine meadows										
Viola langsdorffii	.	.	+/+	.	.	I/+	II/1	.	.	.
Non-differential species in snowbeds and moist heaths										
Polytrichum commune	.	.	I/1	I/+	III/+	.	.	.	.	.
Rubus pedatus	.	.	II/1	I/+	.	.	.	.	.	.
Barbilophozia lycopodioides	.	.	II/+	I/+	.	.	.	.	.	.
Peltigera sp.	.	.	I/+	I/+	.	.	.	.	.	.
Drepanocladus sp.	.	.	I/1	.	II/+	.	.	.	.	.
Sphagnum girgensohnii	.	.	+/1	.	II/2	I/2	.	.	.	.
Rhizomnium andrewsianum	.	.	II/1	.	.	I/+	.	.	.	.
Stellaria sp.	.	.	+/r	.	.	I/r	.	.	.	.
Faithful species in snowbeds										
Peltigera scabrosa	.	.	II/+	.	.	.	.	.	.	.
Kiaeria glacialis	.	.	II/+	.	.	.	.	.	.	.
Hieracium triste	.	.	II/+	.	.	.	.	.	.	.
Barbilophozia barbata	.	.	I/1	.	.	.	.	.	.	.
Erigeron peregrinus	.	.	I/1	.	.	.	.	.	.	.
Pyrola sp.	.	.	I/+	.	.	.	.	.	.	.
Non-differential species in moist heaths, moist subalpine meadows, riparian shrublands, and mires										
Equisetum arvense	.	.	.	II/1	.	V/3	IV/1	V/2	3/2	2/+
Arctagrostis latifolia ssp. latifolia	.	.	.	.	.	I/+	IV/1	II/+	.	1/+
Non-differential species in moist heaths, riparian shrublands, and mires										
Salix sp.	.	.	.	III/+	.	II/2	.	I/1	.	1/+
Non-differential species in moist heaths and mires										
Carex sp.	.	.	.	.	I/1	.	.	.	.	1/+
Carex aquatilis	.	.	.	.	.	II/+	.	.	.	3/1
Andromeda polifolia	.	.	.	.	.	III/+	.	.	.	3/+
Sphagnum warnstorfii	.	.	.	.	.	IV/2	.	.	.	1/+
Paludella squarrosa	.	.	.	.	.	II/+	.	.	.	2/+
Pentaphylloides floribunda	.	.	.	.	.	II/1	.	.	.	1/+
Carex saxatilis	.	.	.	.	.	I/2	.	.	.	1/1
Salix glauca	.	.	.	.	.	I/1	.	.	.	1/+
Carex rostrata	.	.	.	.	.	I/+	.	.	.	1/+
Non-differential species in moist heaths, moist subalpine meadows, and riparian shrublands										
Epilobium angustifolium	.	.	.	V/1	.	.	V/2	V/2	3/1	.
Cystopteris montana	.	.	.	IV/2	.	I/+	V/1	V/1	3/2	.
Geranium erianthum	.	.	.	III/+	.	I/1	V/2	V/2	1/2	.
Linnaea borealis	.	I/+	.	V/1	I/+	I/+	III/+	IV/1	.	.
Mertensia paniculata	.	.	.	I/+	.	II/1	III/2	V/2	2/+	.
Polemonium acutiflorum	.	.	.	III/+	.	III/+	III/+	I/+	.	.
Achillea millefolium	.	.	.	III/1	.	I/+	III/1	I/+	.	.
Pyrola asarifolia var. purpurea	.	.	.	II/+	.	I/1	III/+	I/2	1/1	.
Viola epipsila	.	.	.	II/+	.	.	I/1	I/+	1/1	.
Senecio triangularis	.	.	.	.	.	I/+	III/+	.	1/2	.
Anemone richardsonii	.	.	.	.	.	III/+	I/+	.	1/+	.
Castilleja unalaschcensis	.	.	+/r	II/+	.	.	I/+	.	1/+	.
Non-differential species in moist heaths and riparian shrublands										
Equisetum palustre	.	.	.	.	.	II/+	.	II/2	1/1	.
Petasites frigidus	.	.	.	.	.	II/+	.	III/1	.	.
Plagiomnium ellipticum	.	.	.	.	.	I/+	.	I/+	.	.

Table 4. Continued.

Habitat	Dry Alpine Heaths		Snow-beds	Moist Heaths			Moist Subalp. Mdws	Riparian Shrublands		Mires
Plant communities	OXYBRY DRYOCT	CLAARB CARMIC	CASSTE LUEPEC	FESALT ROSACI	EMPNIG BETNAN	TOMNIT BETNAN	HERLAN GERERI	SALBAR MERPAN	ALNSIN CLIDEN	CARRAR WAREXE
Number of Releves in Communities	14	5	10	6	5	6	5	6	3	4
Non-differential species in moist heaths and moist subalpine meadows										
Phleum commutatum	.	.	.	III/+	.	.	III/+	.	.	.
Delphinium glaucum	.	.	.	II/1	.	.	III/1	.	.	.
Lupinus nootkatensis	.	.	.	II/1	.	.	II/1	.	.	.
Plagiomnium medium	.	.	.	.	.	I/+	II/1	.	.	.
Rumex arcticus	.	.	.	.	.	I/r	II/1	.	.	.
Faithful species in moist heaths										
Campanula rotundifolia	.	.	.	II/+	.	.	.	.	.	.
Equisetum silvaticum	.	.	.	II/+	.	.	.	.	.	.
Poa arctica s.l.	.	.	.	II/+	I/+	.	.	.	.	.
Cladonia cornuta s.l.	.	.	.	.	II/+	.	.	.	.	.
Pedicularis lapponica	.	.	.	.	I/+	I/r	.	.	.	.
Sphagnum capillifolium	.	.	.	.	.	II/1	.	.	.	.
Marchantia alpestris	.	.	.	.	.	II/+	.	.	.	.
Non-differential species in moist subalpine meadows and riparian shrublands										
Heracleum lanatum	.	.	.	.	.	.	IV/1	II/1	1/+	.
Streptopus amplexifolius	.	.	.	.	.	.	III/+	.	2/1	.
Equisetum pratense	.	.	.	.	.	.	I/+	I/1	.	.
Faithful species in moist subalpine meadows										
Carex macrochaeta	.	.	.	.	.	.	II/2	.	.	.
Aquilegia formosa	.	.	.	.	.	.	II/+	.	.	.
Brachythecium erythrorrhizon	.	.	.	.	.	.	II/+	.	.	.
Rhinanthus minor	.	.	.	.	.	.	II/+	.	.	.
Faithful species in riparian shrublands										
Artemisia tilesii	.	.	.	.	.	.	.	II/1	.	.
Single-occurence species										
Stellaria laeta	+/+	.	.	.	.	.	.	.	.	.
Arnica alpina	+/+	.	.	.	.	.	.	.	.	.
Grimmia affinis	+/+	.	.	.	.	.	.	.	.	.
Hypnum revolutum	+/+	.	.	.	.	.	.	.	.	.
Juniperus communis	+/r	.	.	.	.	.	.	.	.	.
Minuartia obtusiloba	+/+	.	.	.	.	.	.	.	.	.
Potentilla uniflora	+/1	.	.	.	.	.	.	.	.	.
Bryum caespiticium	+/+	.	.	.	.	.	.	.	.	.
Pohlia cruda	+/+	.	.	.	.	.	.	.	.	.
Arnica angustifolia	+/+	.	.	.	.	.	.	.	.	.
Candelaria sp.	+/+	.	.	.	.	.	.	.	.	.
Gymnomitrion corallioides	+/2	.	.	.	.	.	.	.	.	.
Ochrolechia upsaliensis	+/+	.	.	.	.	.	.	.	.	.
Pogonatum dentatum	+/+	.	.	.	.	.	.	.	.	.
Xanthoria sp.	+/+	.	.	.	.	.	.	.	.	.
Sticta weigelii	+/+	.	.	.	.	.	.	.	.	.
Unknown white crustose lichen	+/+	.	.	.	.	.	.	.	.	.
Lloydia serotina	+/+	.	.	.	.	.	.	.	.	.
Arnica frigida	+/1	.	.	.	.	.	.	.	.	.
Physconia muscigena	+/+	.	.	.	.	.	.	.	.	.
Bryonora castanea	+/+	.	.	.	.	.	.	.	.	.
Potentilla sp.	+/+	.	.	.	.	.	.	.	.	.
Bryum cyclophyllum	+/+	.	.	.	.	.	.	.	.	.
Diploschistes sp.	+/+	.	.	.	.	.	.	.	.	.
Lecanora epibryon	+/+	.	.	.	.	.	.	.	.	.
Dicranoweisia crispula	+/+	.	.	.	.	.	.	.	.	.
Psoroma hypnorum	+/+	.	.	.	.	.	.	.	.	.
Draba sp.	+/r	.	.	.	.	.	.	.	.	.
Hedysarum alpinum	+/1	.	.	.	.	.	.	.	.	.
Cladonia symphycarpa	.	I/+	.	.	.	.	.	.	.	.
Dactylina ramulosa	.	I/+	.	.	.	.	.	.	.	.
Anastrophyllum saxicola	.	I/+	.	.	.	.	.	.	.	.
Chandonanthus setiformis	.	I/+	.	.	.	.	.	.	.	.
Asahinea chrysantha	.	I/+	.	.	.	.	.	.	.	.
Luzula multiflora	.	I/+	.	.	.	.	.	.	.	.
Rhizomnium nudum	.	.	+/1	.	.	.	.	.	.	.
Juncus biglumis	.	.	+/+	.	.	.	.	.	.	.
Cirriphyllum cirrosum	.	.	+/+	.	.	.	.	.	.	.
Diplophyllum taxifolium s.l.	.	.	+/+	.	.	.	.	.	.	.
Ditrichum flexicaule	.	.	+/+	.	.	.	.	.	.	.
Luzula arctica	.	.	+/1	.	.	.	.	.	.	.
Mesoptychia sahlbergii	.	.	+/+	.	.	.	.	.	.	.
Peltigera canina	.	.	+/1	.	.	.	.	.	.	.
Luzula confusa	.	.	+/+	.	.	.	.	.	.	.
Pedicularis sp.	.	.	+/+	.	.	.	.	.	.	.
Saxifraga nelsoniana	.	.	+/r	.	.	.	.	.	.	.

Table 4. Concluded.

Habitat	Dry Alpine Heaths		Snow-beds	Moist Heaths			Moist Subalp. Mdws	Riparian Shrublands		Mires
Plant communities	OXYBRY DRYOCT	CLAARB CARMIC	CASSTE LUEPEC	FESALT ROSACI	EMPNIG BETNAN	TOMNIT BETNAN	HERLAN GERERI	SALBAR MERPAN	ALNSIN CLIDEN	CARRAR WAREXE
Number of Releves in Communities	14	5	10	6	5	6	5	6	3	4
Single-occurence species concluded.										
Dicranum sp.	.	.	.	I/+	.	.	.	.	.	.
Cladonia sp.	.	.	.	I/r	.	.	.	.	.	.
Brachythecium starkei	.	.	.	I/+	.	.	.	.	.	.
Angelica lucida	.	.	.	I/+	.	.	.	.	.	.
Cladonia fimbriata	.	.	.	.	I/+	.	.	.	.	.
Campylium stellatum s.l.	.	.	.	.	.	I/+	.	.	.	.
Senecio lugens s.l.	.	.	.	.	.	I/+	.	.	.	.
Sphagnum fuscum	.	.	.	.	.	I/+	.	.	.	.
Tofieldia pusilla	.	.	.	.	.	I/+	.	.	.	.
Equisetum scirpoides	.	.	.	.	.	I/1	.	.	.	.
Bistorta vivipara	.	.	.	.	.	I/+	.	.	.	.
Swertia perennis	.	.	.	.	.	I/+	.	.	.	.
Spiranthes romanzoffiana	.	.	.	.	.	I/+	.	.	.	.
Rhizomnium pseudopunctatum	.	.	.	.	.	I/+	.	.	.	.
Carex membranacea	.	.	.	.	.	I/2	.	.	.	.
Helodium blandowii	.	.	.	.	.	I/+	.	.	.	.
Arctostaphylos uva-ursi	.	.	.	.	.	.	I/+	.	.	.
Hylocomiastrum pyrenaicum	.	.	.	.	.	.	I/+	.	.	.
Rhizomnium magnifolium	.	.	.	.	.	.	I/+	.	.	.
Galium boreale	.	.	.	.	.	.	I/1	.	.	.
Lupinus arcticus	.	.	.	.	.	.	I/+	.	.	.
Rhodobryum roseum	.	.	.	.	.	.	I/+	.	.	.
Poa alpina	.	.	.	.	.	.	I/1	.	.	.
Carex atrofusca	.	.	.	.	.	.	.	I/+	.	.
Salix niphoclada	.	.	.	.	.	.	.	I/3	.	.
Salix alaxensis	.	.	.	.	.	.	.	I/1	.	.
Timmia austriaca	.	.	.	.	.	.	.	.	1/+	.
Dryopteris dilatata	.	.	.	.	.	.	.	.	1/3	.
Sambucus racemosa	.	.	.	.	.	.	.	.	1/3	.
Viburnum edule	.	.	.	.	.	.	.	.	1/1	.
Athyrium filix-femina	.	.	.	.	.	.	.	.	1/4	.
Plagiomnium cuspidatum	.	.	.	.	.	.	.	.	1/+	.
Calliergon stramineum	.	.	.	.	.	.	.	.	.	1/+
Eleocharis sp.	.	.	.	.	.	.	.	.	.	1/1
Oncophorus wahlenbergii	.	.	.	.	.	.	.	.	.	1/+
Bryum sp.	.	.	.	.	.	.	.	.	.	1/1
Cinclidium sp.	.	.	.	.	.	.	.	.	.	1/1
Limprichtia cossonii	.	.	.	.	.	.	.	.	.	1/+

Table 5. Summary of selected environmental variables for the 10 communities in the table analysis (mean ± standard error). Values for the variables snow duration, site moisture, exposure, disturbance, and stability are mean scalar values (see Table 1).

Habitat Plant communities	**Soil pH**	**Gravimetric Soil Moisture (% of dry wt)**	**Snow Duration**	**Site Moisture**	**Exposure**	**Disturbance**	**Stability**
Dry alpine heaths							
Oxytropis bryophila-Dryas octopetala	4.6 ± 0.1	56 ± 26	2.6	3.7	3.0	1.6	1.5
Cladina arbuscula-Carex microchaeta	4.3 ± 0.2	96 ± 16	3.3	3.7	1.9	1.7	0.8
Snowbeds							
Cassiope stellariana-Luetkea pectinata	4.3 ± 0.1	106 ± 15	5.7	5.9	1.4	1.0	2.0
Moist heaths							
Festuca altaica-Rosa acicularis	4.2 ± 0.2	60 ± 06	4.5	6.0	2.0	1.0	1.0
Empetrum nigrum-Betula nana	4.3 ± 0.5	148 ± 59	5.0	5.2	1.6	2.8	1.2
Tomentypnum nitens-Betula nana	5.9 ± 0.1	195 ± 67	4.5	7.0	2.0	1.0	2.0
Moist subalpine meadows							
Heracleum lanatum-Geranium erianthum	4.9 ± 0.1	62 ± 21	5.0	5.8	1.8	0.0	1.0
Riparian shrublands							
Salix barclayi-Mertensia paniculata	5.1 ± 0.2	116 ± 20	4.0	6.0	2.0	0.8	2.2
Alnus sinuata-Climaceum dendroides	4.3 ± 0.0	149 ± 00	5.3	6.0	1.0	0.7	1.0
Mires							
Carex rariflora-Warnstorfia exannulata	5.5 ± 0.0	269 ± 00	5.0	9.0	2.0	1.0	1.0

Table 6. Number of species by growth form and community.

Habitat Plant communities	Trees	Shrubs	Forbs	Grami- noids	Ferns	Horse- tails	Club mosses	Mosses	Liver- worts	Li- chens	All
Dry Alpine Heaths											
Oxytropis bryophila-Dryas octopetala	0	13	28	9	1	0	1	20	2	43	117
Cladina arbuscula-Carex microchaeta	0	15	9	5	0	0	2	9	5	32	77
Snowbeds											
Cassiope stellariana-Luetkea pectinata	0	13	26	9	0	0	4	19	4	22	97
Moist Heaths											
Festuca altaica-Rosa acicularis	0	11	23	7	1	2	2	13	1	13	73
Empetrum nigrum-Betula nana	0	10	4	4	0	0	2	9	0	21	50
Tomentypnum nitens-Betula nana	2	17	24	11	2	3	0	16	1	1	77
Moist Subalpine Meadows											
Heracleum lanatum-Geranium erianthum	0	4	31	7	1	2	1	10	1	0	57
Riparian Shrublands											
Salix barclayi-Mertensia paniculata	0	14	18	6	1	3	1	9	0	0	52
Alnus sinuata-Climaceum dendroides	0	1	16	1	3	2	0	6	0	0	29
Mires											
Carex rariflora-Warnstorfia exannulata	0	7	1	12	0	1	0	12	0	0	33

Mosses included *Grimmia* sp. (+), *Tortula* sp. (+), and *Racomitrium lanuginosum* (+). Lichens included *Alectoria nigricans* (+), *Cetraria cucullata* (1), *C. islandica* (+), *Strereocaulon* sp. (+), *and Thamnolia* spp. (1). Within the Alaska Statewide Classification (Viereck et al., 1992), this vegetation is classed as alpine herbs (Type III.B.1.c) typical of sparse vegetation on talus and blockfields. This community is similar to the association *Minuartio macrocarpae-Luzuletum arcuatae* (Cooper 1986) described from high alpine ridgetops in the Brooks Range. Perhaps the rarest plant that was collected during these surveys was *Androsace alaskana,* which occurred in rock crevices at the summit of Temptation Peak.

5.1.1.2 Dry alpine heaths

These communities occur in the more exposed, windblown sites in the alpine. These communities usually have abundant lichens, and prostrate- and dwarf-shrubs. Differential taxa for these communities include the vascular plants, *Arctous alpina, Carex microchaeta, Diapensia lapponica, Hierochloë alpina;* the lichens, *Bryocaulon divergens, Ochrolechia frigida, Sphaerophorus globosus* and *Thamnolia* spp.; and the moss *Polytrichum piliferum.* Additionally, the following species were found only in the dry alpine heaths: Vascular plants: *Antennaria friesiana, Epilobium latifolium, Festuca brachyphylla, Minuartia macrocarpa, M. rubella, Phlox sibirica, Poa glauca, Saxifraga tricuspidata, Silene acaulis, Tofieldia cocinnea, Trisetum spicatum;* bryophytes: *Dicranum elongatum, D. spadiceum, Ptilidium ciliare, P. pulchellerrimum, Racomitrium lanuginosum, Varicellaria rhodocarpa;* lichens: *Cetraria nigricans, Dactylina madreporiformis, Parmelia omphalodes, Pseudophebe pubescens,* and *Stereocaulon paschale.*

5.1.1.2.1 Community Type 2, dry *Oxytropis bryophila-Dryas octopetala* prostrate-shrub, fruticose-lichen tundra (Figure 6).

This common community type occurs in the most windblown areas with very thin winter snow cover and acidic mineral soils (pH 4.5±0.1). Typical habitats with large continuous stands of this type occur on broad saddles and ridge tops in the low and mid-alpine areas and windward east-facing slopes, and on glacial outwash terraces, such as those in the vicinity of the upper Snowhawk Creek cabin. Very steep slopes, over about 40°, are poorly vegetated but often have interrupted patches of the this vegetation type. We have grouped communities dominated by either *Dryas octopetala* or *Arctous alpina* with abundant terricolous lichens into this single type because of insufficient data to separate them at this point. However, there are clearly two groups of dry alpine heaths: one dominated by *Dryas octopetala* and one dominated by *Arctous alpina.*

Differential taxa include the vascular plants, *Dryas octopetala, Oxytropis bryophila, Salix arctica, Saxifraga bronchialis,* and the lichen *Pertussaria dactylina.* The crustose soil liverwort *Gynomitrion corallioides* was often present in areas with bare soil, but was

Figure 6. Community Type 2, dry *Oxytropis bryophila-Dryas octopetala* prostrate-shrub, fruticose-lichen tundra. (a) Windblown habitat near the Site Summit, Releve 58; (b) Close-up of Relevé 58. Bright green plants bearberry (*Arctous alpina*) and arctic willow (*Salix arctica*). Small-leaved green plants are eight-petaled mountain evens (*Dryas octopetela*). Primary fruticose lichens are *Pertusaria dactylina* (white), *Alectoria ochroleuca* (yellowish at center), *A. nigricans*, and *Bryocaulon divergens*.

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overlooked in most plots during data collection. There were also 31 other single-occurrence species that were found only in this type (see Table 4). Some of the most important vascular plants of this group include *Arnica alpina, Hedysarum alpinum, Minuartia obtusiloba, M. macrocarpa,* and *Potentilla uniflora.* Other important species include *Salix phlebophylla, Cladonia uncialis,* and *Anemone multifida.*

The Alaska Statewide Classification (Viereck et al., 1992) recognizes two primary groups of communities that occur on windswept alpine sites, dryas-lichen tundra (Type II.D.1.c) and bearberry tundra (Type II.D.2.a). Most of our relevés were from the former although some of the sites were dominated by *Arctous alpina.* The *Oxytropis bryophila-Dryas octopetala* community is very similar to the association *Selaginello sibiricae-Dryadetum octopetalae* (Walker et al. 1994) described from arctic Alaska. The major differences appear to be the lack of *Selaginella sibirica* and consistent presence of *Anemone multifida* in the southern Alaskan dry communities. As in northern Alaska, these *Dryas octopetela* communities are found on acidic substrates, contrary to the situation in the eastern North America and European Arctic where *D. octopetela* communities are found primarily on circumneutral sites (e.g., Nordhagen 1928; Rønning

1958;

Elvebakk 1982). Cooper (1986) found that limestone areas of the Arrigetch Peaks of the Brooks Range had *D. octopetela* ssp. *alaskensis.*

5.1.1.2.2 Community Type 3, dry *Cladina arbuscula-Carex microchaeta* fruticose-lichen, dwarf-shrub tundra (Figure 7).

This distinctive community type occurs in extensive areas of the middle alpine zone that are thought to have shallow to moderate winter snow cover, exposed to moderate winds but not extreme winds. It occurs on glacial outwash terraces, broad interfluvial areas, and well drained, often steep slopes. The soil normally has an organic surface horizon composed of decomposed lichens with low soil pH (4.3±0.2). This type does not have any true differential taxa. Its most characteristic attribute is the thick mat of lichens, primarily the light yellow fruticose lichens *Cladina arbuscula, C. amaurocrea C. mitis, C. rangiferina, C. stellaris, Cladonia uncialis, Cetraria cucullata, C. nivalis,* and *Dactylina arctica.* Other common lichens include *Nephroma expallidum,* and *Stereocaulon paschale.* These lichens can form a soft mat up to 20 cm thick. Important vascular plants include: *Arctous alpina, Carex microchaeta, Hierochlo' alpina, Ledum decumbens, Empetrum nigrum, Vaccinium uliginosum,* and *V. vitis-idaea.* Important bryophytes include *Chandonanthes setiformis, Dicranum majus, Ptilidium ciliare* and *Racomitrium lanuginosum.*

The *Cladonia arbuscula-Carex microchaeta* community is apparently common in many alpine areas of Alaska (foliose and fruticose lichen, Type III.C.2.b, of the Alaska Statewide Classification, Viereck et al., 1992), but it has only been described in detail from the Brooks Range, where *Cladonia* dominated heaths of the association *Carici microchaetes-Cladonietum stellaris* (Cooper 1986), are common at high elevations on granitic cirques, mountain summits, and high valleys.

5.1.1.3 Snowbeds

Strong easterly winter winds are characteristic of the Chugach Mountains in the vicinity of Anchorage, and deep late-lying snowbeds occur in many stream drainages and depressions. Two distinctive groups of snowbed communities were recognized although there is certainly more variation than this. The first community type, *Cassiope tetragona-Luzula parviflora,* is very similar to communities that have been described from interior mountain and arctic regions of Alaska and elsewhere in the Arctic. The second community is characteristic of maritime snowbed areas of southern and southeastern Alaska.

5.1.1.3.1 Community Type 4, moist *Cassiope tetragona-Luzula parviflora* dwarf-shrub, fruticose-lichen snowbed heath (no photo).

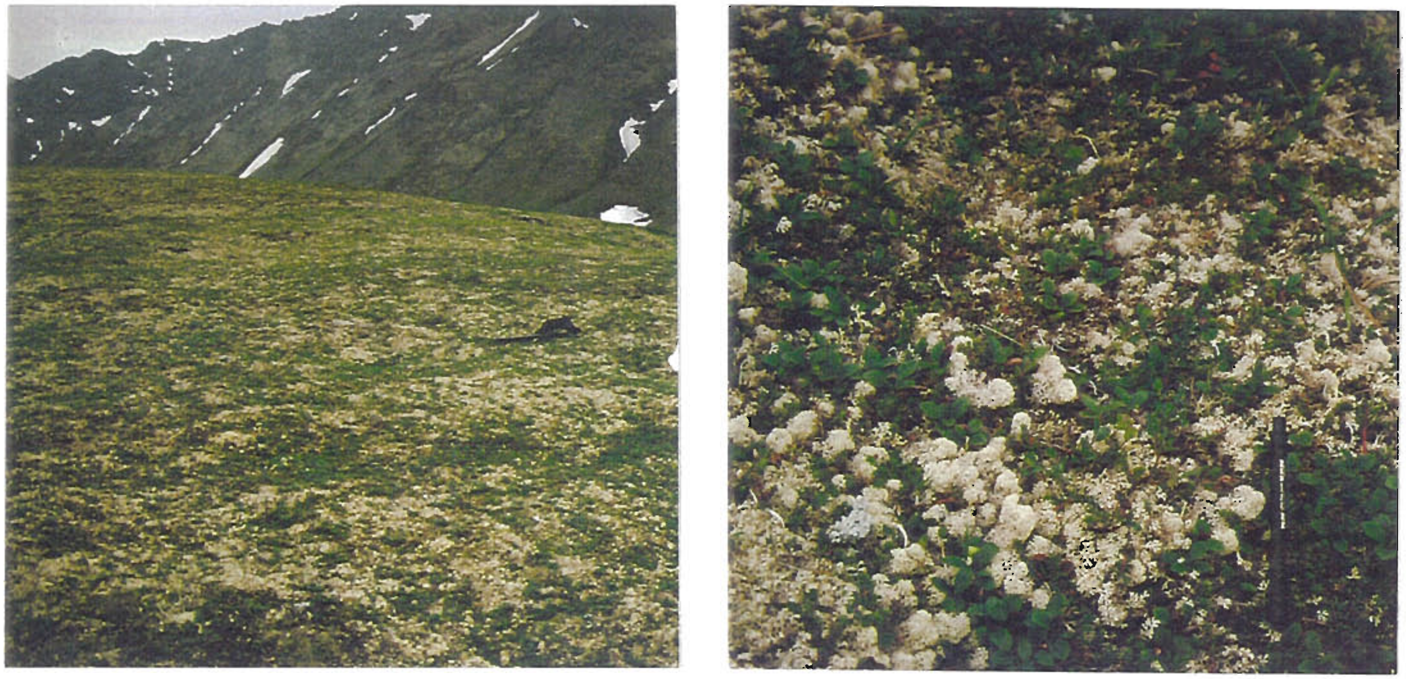

Figure 7. Landscape near Relevé 46. (a) Community Type 3, dry *Cladonia arbuscula-Carex microchaeta* fruticose-lichen, dwarf-shrub tundra. (b) Close-up of Relevé 46. Round-topped yellowish lichens are *Cladina stellaris*. Others are primarily *Cladina arbuscula* and *C. mitis*. Dwarf shrubs are mainly bearberry (*Arctous alpina*) and blueberry (*Vaccinium uliginosum*).

This community type was found at higher elevations on cold north and north-east facing slopes in the well-drained upper portion of snowbeds. Only one relevé (No. 52) was collected from this type and was thus excluded from the table analysis (Table 4). The following species occurred in the community, listed in order of their cover-abundance scores. Vascular plants: *Cassiope tetragona* (2), *Luzula parviflora* (2), *Salix polaris* (2), *Antennaria monocephala* (1), *Acomastylis rossii* (1), *Artemisia arctica* (+), *Carex microchaeta* (+), *Cassiope stellariana* (1), *Diapensia lapponica* (+), *Empetrum nigrum* (+), *Gentiana propinqua* (+), *Hierochlo' alpina* (+), *Huperzia selago* (+), *Saxifraga bronchialis* (+), *Saxifraga cernua* (+), *Festuca altaica* (r), *Vaccinium vitis-idaea* (r), Lichens: *Cladina arbuscula* (2), *C. rangiferina* (2), *C. stellaris* (2), *Cladonia gracilis* (2), *Nephroma expallidum* (2), *Thamnolia* spp. (2), *Cladonia subfurcata* (1), *Stereocaulon paschale* (1), *Alectoria ochroleuca* (+), *Cladonia pocillum* (+), *Cladonia uncialis* (+), *Dactylina arctica* (+), *D. ramulosa* (+), *Lobaria linata* (+), *Solorina crocea* (+), Bryophytes: *Dicranum majus* (3), *Polytrichum strictum* (2), *Racomitrium heterostrictum* (+), *R. canescens* (+), *Dicranoweisia crispula* (+), unknown liverwort (+).

Cassiope tetragona-dominated tundra is common in snowbed areas throughout Alaska (Type II.D.2.e of the Alaska Statewide Classification, Viereck et al., 1992). Cassiope tundra. The *Cassiope tetragona-Luzula parviflora* community is quite similar to the *Carici microchaetae-Cassiopetum tetragonae* (Walker et al. 1994) described from the Alaskan North Slope, which is found in moderately-deep acidic snowbeds. *Cassiope tetragona*-dominated communities have also been described widely across the Arctic, including Canada, Greenland, Spitzbergen, Scandinavia and the Eurosibirian Arctic. For example, the association *Cassiopetum tetragonae* (Böcher 1933) Daniëls 1982 has been described from Greenland, and *Dryado-Cassiopetum* (Fries 1913) Hadac 1946 from Scandinavia.

5.1.1.3.2 Community Type 5, moist *Cassiope stelleriana-Leutkea pectinata* dwarf-shrub snowbed heath (Figure 8).

This distinctive community forms bright green blankets in many areas with late lying snow. It occurs in on moist acidic soils (pH 4.3±0.1). These sites often have hummocks or solifluction stripes (Figure 9a, c). There is a large group of differential species including the vascular plants *Cassiope stelleriana, Huperzia selago, Luetkea pectinata,* and *Lycopodium alpinum,* the moss, *Sanonia uncinata,* and the lichens, *Nephroma arcticum* and *Peltigera malacea.* Other faithful and important species include, vascular plants: *Anemone narcissiflora* ssp. *interior, Artemisia arctica, Empetrum nigrum, Vaccinium vitis-idaea;* bryophytes: *Dicranum majus,* and *Pleurozium schreberi*; lichens: *Cladina rangiferina, C. stellaris, C. arbuscula/ mitis, C. gracilis, C. islandica,* and *Dactylina arctica.*

The *Cassiope stellariana-Luetkea pectinata* community has a much more limited worldwide distribution than the *Cassiope tetragona* snowbeds, and is characteristic of the southern maritime areas of southern Alaska. Hanson (1951) first described a very similar *Luetkea pectinata-Cassiope stelleriana-Lycopodium alpinum-Cladonia* spp. community in the Talkeetna Mountains. Within the Fort Richardson area, it occurs primarily at low and mid alpine elevations on south- and west-facing slopes. This community is also in Type II.D.2.e (Cassiope tundra) of the Alaska Statewide Classification.

5.1.1.4 Moist heaths

Moist heaths are perhaps the dominant group of communities, occurring in a wide variety of situations, particularly in the low alpine. Many of these are poorly distinguished and intergrade broadly with other communities. We have grouped the following three community types into the category of moist heaths based primarily on the abundance of a variety of heath species of the plant family Ericaceae, including *Empetrum nigrum, Ledum decumbens, Vaccinium uliginosum, V. vitis-idaea. Betula nana/glandulosa* has consistently high cover, and *Rubus chamaemorus* is restricted to this group of communities.

 

Figure 8. Community Type 5, moist *Cassiope stelleriana-Leutkea pectinata* dwarf-shrub snowbed heath. (a) Snowbed area near Relevé 45 near upper hut on Snowhawk Creek. Turf hummocks are typical of snowbed areas. (b) Close-up of Relevé 8. The flowering plant is Alaska heather (*Cassiope stellariana*); the rosette dicots are luetkea (*Luetkea pectinata*).

5.1.1.4.1 Community Type 6, moist *Festuca altaica-Rosa acicularis* tussock-graminoid, dwarf-shrub, forb meadow (Figure 9).

This is the driest of the moist heaths described here. It occurs primarily on south- and southwest-facing, well-drained slopes in the low alpine and subalpine. It also occurs on a variety of other exposures and even in some fairly moist situations. Soils are strongly acidic (pH 4.1±0.2). These communities were sampled on the knoll south of Site Summit. They are highly variable and require a great deal more sampling to fully characterize them. *Festuca altaica* is the dominant plant and the primary differential taxa is *Rosa acicularis*. Other common species include, the vascular plants: *Artemisia arctica, Betula nana/glandulosa, Calamagrostis canadensis, Cornus canadensis x suecica, Cystopteris montana, Empetrum nigrum, Epilobium angustifolium, Gerianium erianthum, Linnea borealis, Mertensia paniculata, Phleum commutatum Polemonium acutiflorum, Salix barclayi, Vaccinium uliginosum, V. vitis-idaea;* the mosses: *Pleurozium schreberi, Polytrichastrum alpinum;* and the lichens: *Cladonia gracilis, Peltigera aphthosa.* This community has consistent high cover of the low-growing fern, *Cystopteris montata*, which could be a primary contributor to the high percentages of Filicales pollen observed locally in the modern and ancient pollen samples.

Figure 9. Community Type 6, moist *Festuca altaica-Rosa acicularis* tussock-graminoid, dwarf-shrub, forb meadow. (a) Relevé 8 in Infantry Flats. Tussock grasses are rough fescue (*Festuca altaica*). Red leaved forbs are fireweed (*Epilobium angustifolium*) in fall foliage. (b) Close of up of Relevé 8 showing wide variety of heath plants, forbs, and ferns in the understory.

Within the Alaska Statewide classification, this community corresponds to midgrass-herb (Type III.A.1.d). It probably is closest to the *Festuca altaica-Calamagrostis canadensis-Cornus canadensis-Geranium erianthum* community, part of a complex of *Festuca altaica*-dominated communities described by Hanson (1951) in southwestern Alaska. Marvin (1986) described a subalpine xeric shrub-fescue meadow vegetation type that occurs on south facing subalpine slopes in the Eklutna Valley a few miles north. This is probably comparable in part to the *Festuca altaica-Rosa acicularis* community type described here. Marvin comments on the very diverse communities occurring on south-facing slopes. In addition to the species mentioned above, he notes the following common species which were also seen in similar communities at the Fort Richardson site: *Viburnum edule, Shepherdia canadensis, Rubus idaeas, Juniperus communis, Castelleja unalaschensis, Saxifraga tricuspidata,* and *Cerastium arvensis.*

Figure 10. Community Type 7, moist *Empetrum nigrum-Betula nana* dwarf-shrub heath. (a) Landscape near Relevé 47; (b) Close-up of Relevé 47. The mat of dwarf shrubs is mostly crowberry (*Empetrum nigrum*), dwarf birch (*Betula nana*), and blueberry (*Vaccinium uliginosum*). The sedges are *Carex* sp.

5.1.1.4.2 Community Type 7, moist *Empetrum nigrum-Betula nana* dwarf-shrub heath (Figure 10).

Empetrum heath (crowberry) communities are perhaps the most common vegetation unit of the lower alpine, and mid alpine belts. These communities occur on gentle slopes of various exposure and in areas of moderate snow cover with moist acidic soils (pH 4.3±0.5). This distinctive unit has dense mats of dwarf shrubs, dominated by *Empetrum nigrum* and *Betula nana.* The only differential plant species for this community type is the moss, *Aulacomnium turgidum.* Other common vascular plants include *Cornus canadensis x suecica, Rubus chamaemorus, Spiraea stevenii, Vaccinium uliginosum, V. vitis-idaea,* and *Ledum palustre* ssp. *decumbens.* Common mosses include *Aulocomnium turgidum, Dicranum majus, Hylocomium splendens, Pleurozium schreberi, Polytrichastrum alpinum, Polytrichum commune,* and *P. strictum.* Lichens are not abundant, but common species include *Cetraria cucullata, C. islandica, C. laevigata, Cladina rangiferina, C. stellaris, Cladonia gracilis, Dactylina arctica, Nephroma expallidum, Peltigera aphthosa,* and *Stereocaulon tomentosum* .

Empetrum heaths are common in maritime portions of southern Alaska and the Aleutians (Crowberry tundra, Type II.D.2.e of the Alaska Statewide Classification). Similar communities have been described from the Arctic. For example, Daniëls (1982) described an *Empetrum hermaphroditum-Vaccinium microphyllum* community from Greenland that is similar, and occasionally has high cover of *Betula nana.* Daniëls considered this community to be the climatic climax vegetation on acidic soils in southeast Greenland. The Greenland communities occur in more continental areas of inland fjords and have more luxuriant lichen growth than the Fort Richardson communities.

5.1.1.4.3 Community Type 8, wet *Tomentypnum nitens-Betula nana* low-shrubland (Figure 11).

This community occurs in moderately minerotrophic meadows near treeline. It is found on gentle slopes with fairly wet soils with relatively high soil pH (5.9±0.05). It is characterized by high cover of dwarf and low shrubs, (e.g., *Betula nana, Empetrum nigrum, Vaccinium uliginosum, V. vitis idaea* and several species of willows, including *Salix barclayi, S. lanata, S. glauca, S. planifolia* ssp. *pulchra* and an unidentified *Salix* species. The horsetail *Equisetum arvense* is abundant. Differential species include the vascular plants, *Arctous rubra, Oxycoccus microcarpus, Parnassia palustris, Picea glauca,* and *P. mariana.* Differential mosses include, *Aulacomnium palustre* and *Tomentypnum nitens.* Lichens are uncommon. Other common species include the vascular plants *Andromeda polifolia, Anemone richardsonii, Polemonium acutiflorum* ; the mosses *Hylocomium splendens,* and *Sphagnum warnstorfii.* The following species were recorded only in this vegetation type: *Campylium stellatum, Senecio lugens, Sphagnum fuscum, Tofieldia pusilla, Equisetum scirpoides, Bistorta vivipara, Swertia perennis, Spiranthes romanzoffiana, Rhizomnium pseudopunctatum,* and *Carex membranacea.*

Although extensive in the vicinity of Infantry Flats, it does not appear to cover large areas of other portions of the Fort Richardson alpine. Its high soil pH within an otherwise acidic landscape, and extensive cover of horsetails indicate that this community may be a successional community. Within the Alaska Statewide Classification, this would be probably be classified as shrub birch willow (II.C.2.f) which is found in poorly drained lowlands and on moist slopes in northern, interior, south-central, and southwestern Alaska.

5.1.1.5 Moist subalpine meadows

5.1.1.5.1 Community Type 9, moist *Heracleum lanatum-Geranium erianthum* forb, graminoid meadow (Figure 12).

These distinctive and beautiful grass-forb communities occur in fairly rich meadows that are generally void of heath species. They are often found near springs, seeps, and streams. Important vascular species include *Achillea millefolium, Anemone narcissiflora, Arctagrostis latifolia, Calamagrostis canadensis, Conioselinum pacificum, Cornus*

Figure 11. Community Type 8, wet *Tomentypnum nitens-Betula nana* low-shrubland. (a) Landscape near Relevé 10 in Infantry Flats; (b) Close-up of Relevé 10. Willows are mostly *Salix glauca,* and *S. planifolia* ssp. *pulchra.* Common horsetail (*Equisetum arvense*) is dominant in the understory.

Figure 12. Community Type 9, moist *Heracleum lanatum-Geranium erianthum* forb, graminoid meadow. (a) Landscape near Relevé 37. Large-leaved plant in the foreground is cow parsnip (*Heracleum lanatum*); (b) Close-up of Relevé 36. The dominant flowers in bloom include Sitka valerian (*Valeriana sitchensis*), northern geranium (*Geranium erianthum*), and glaucous larkspur (*Delphinium glaucum*).

canadensis x suecica, Cystopteris montanum, Delphinium glaucum, Equisetum arvense, Festuca altaica, Gerianium erianthum, Heracleum lanatum, Linnnea borealis, Mertensia paniculata, Phleum commutatum, Polemonium acutiflorum, Pyrola asarifolia, Rubus arcticus, Sanguisorba stipulata, Senecio triangularis, Streptopus amplexifolius, and *Valeriana sitchensis.* Many of these forbs and grasses occur broadly across the moist heaths snowbeds, and riparian shrublands, but they reach their maximum expression here. The tall canopy of forbs shades the soil surface, and mosses and lichens are unimportant. The only differential species are the umbel *Conioselinum pacificum,* and the moss *Brachythecium reflexum.*

This community is classed as Mixed herbs (III.B.2.a) within the Alaska Statewide classification. It corresponds most closely to the *Aconitum delphinifolium-Aquilegia formosa-Sanguisorba stipulata-Geranium erianthum* community described in Prince Williams Sound by Cooper (1942). communities are dominated by a wide variety of willow species and alders.

5.1.1.6 Riparian shrublands

Shrublands occur along streams throughout the lower and mid alpine areas. These communities are dominated by a wide variety of willow species and alders. The two communities are not described here in detail because a great deal more sampling is necessary to characterize the shrub communities.

5.1.1.6.1 Community Type 10, wet *Salix barclayi-Mertensia paniculata* forb, low-shrubland (Figure 13).

This community occurred along Snowhawk Creek near the upper hut. It consists of low to dwarf willows, primarily *Salix barclayi*, with *S. alaxensis, S. niphoclada,* and *S. planifolia* ssp. *pulchra,* and a wide variety of forbs, including *Achillea millefolium, Artemisia arctica, Calamagrostis canadensis, Cornus canadensis, Equisetum arvense, Epilobium angustifolium, Geranium erianthum, Mertensia paniculata, Rhodiola integrifolia,* and *Sanguisorba stipulata.* In the Alaska Statewide Classification, this type is classified as closed low willow (II.B.2.b).

5.1.1.6.2 Community Type 11, moist *Alnus sinuata-Climaceum dendroides* tall shrubland (Figure 14).

Alder communities are the dominant community in the subalpine. Scattered alder clumps occur well upward into the lower alpine areas. We sampled two riparian alder communities, and it is unknown how similar these are to the extensive alder communities covering broad expanses in the subalpine. The understories were highly variable consisting mostly of tall forbs, ferns and the grass *Calamagrostis canadensis.* The

Figure 13. Community Type 10, wet *Salix barclayi-Mertensia paniculata* forb, low-shrubland. (a) Landscape near Relevé 48, a streamside community near the upper Snowhawk Creek hut; (b) Close-up of Relevé 48. The dominant dwarf shrub is *Salix barclayi.* The flowering forbs are mainly Jacob's ladder (*Polemonium acutiflorum*), and tall lungwort (*Mertensia paniculata*).

Figure 14. Community Type 11, moist *Alnus sinuata-Climaceum dendroides* tall shrubland. (a) Subalpine landscape of lower Snowhawk Creek. An belt of closed alder shrublands extends about 100 above the spruce treeline. Dominant species visible in the foreground include Sitka Alder (*Alnus sinuata*) and red-berried elder (*Sambucus racemosa*); (b) Understory of of Relevé 65, including ladyfern (*Athyrium filix-femina*), tall lungwort (*Mertensia paniculata*), clasping twisted stalk (*Streptopus amplexifolius*), and bluejoint grass (*Calamagrostis canadensis*).

distinctive moss *Climaceum dendroides* appears to be a faithful taxon in these communities. Racine (1978) describes alder thickets from the Lake Clark region on the west side of Cook Inlet. He mentions the following species as important components of alder thickets near treeline. These same species were noted in the Fort Richardson area: *Veratum viride, Trientalis europaea, Dryopteris dilatata, Thalypteris phegopteris, Gynocarpium dryopteris, Spiraea stevenii,* and *Sambucus racemosa.* In the Alaska Statewide Classification the community is classed as Alder II.B.1.b and is common throughout most of the state on steep slopes, flood plains, and stream banks.

5.1.1.7 Mires

5.1.1.7.1 Community Type 12, wet *Carex rariflora-Warnstorfiana exannulata* graminoid fen (Figure 15)

Mires are uncommon in the Fort Richardson alpine because of the steep terrain. The only mire we sampled was the site of Elias and Short's core in Infantry Flats. This site had many species that were not seen elsewhere. The relatively rich flora is undoubtedly due to mineral-rich waters flowing through the fen. The principal community is dominated by the sedge *Carex rariflora,* with a wide variety of other sedges including *C. aquatilis, C. limosa, Eriophorum angustifolium, E. scheuchzeri,* and *Trichophorum caespitosum.* Arrowgrass *Trioglochin palustris* is also common. The moss *Warnstorfiana exannulata* is apparently dominant, but a great variety of other mosses also occur, including *Calliergon stramineum, Cinclidium* spp., *Cyrtomnium hymenophylloides, Hamatocaulis vernicosus, Limprichtia cossonii, Mnium* spp., *Oncophorus wahlenbergii, Scorpidium scorpioides,* and *Sphagnum squarrosum.*

Within the Alaska Statewide classification, this fen would be considered a subarctic lowland sedge bog meadow (III.A3.j). The bog designation would be incorrect according the peatland terminology used in Minnesota and similar criteria used in Europe. According to the Minnesota terminology (Glaser 1987), the Infantry Flats mire is best classified as fen. Bogs are peatlands influenced by dilute, mostly atmospheric waters, and the pH is generally very low (<4.2). Fens are minerotrophic peatlands with higher pH and nutrient concentrations. Sjörs (1950) recognized poor fens (pH 3.5 to 5.0), intermediate fens (pH 4.5-6.5), and rich fens (pH>6.0). Soil pH of the Infantry Flats fen is 5.5.

5.1.2 Controlling environmental factors

Two ordinations were done (Figure 16). The first used the entire data set. This ordination resulted in a diagram that separates the wet community type from the other plots, which are all grouped on the right side of the diagram. This is because the fen communities shared very few species with the other communities. To obtain a clearer separation between the other communities, another ordination was performed by eliminating the wet plots. This diagram shows better clusters of plots corresponding to

Figure 15. Community Type 12, wet *Carex rariflora-Warnstorfiana exannulata* graminoid fen. (a) Landscape near Relevé 11 near the site of the peat core. The dominant sedge is *Carex rariflora;* (b) Close-up of Relevé 11. The primary species visible are tall cottongrass (*Eriophorum angustifolium*), loose-flowered alpine sedge (*Carex rariflora*), *Trichophorum caespitosum,* and arrowgrass (*Triglochin palustris*).

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the vegetation types that were recognized in the field.

The biplot diagrams (blue arrows) of both ordinations shows the direction and strength of the dominant environmental gradients. The first axis of the ordination corresponds most closely to a complex mesotopographic gradient with exposure to wind increasing toward the right, and snow depth and soil moisture increasing toward the left.

The controlling role of snow cover is typical of very windy mountain ranges where there is strong contrast between exposed sites and snowbed areas. This control is less obvious in the more-protected lower alpine and subalpine areas.

Soil pH also increases toward the left side of the diagram, reflecting stronger leaching on the drier slopes and heaths. The naturally acidic bedrock contributes to the overall low variation in soil pH. The highest soil pH was found in the wetland area, and is the result of the flow of mineral-rich waters through the fen.

The second axis of the ordination is more difficult to interpret. It corresponds most closely with soil bulk density, which increases toward the upper left part of the diagram. Bulk density usually decreases with increasing soil organic matter, and this seems to be the case here where the more peaty soils occur in the moist heaths and the mineral soils occur in the dry alpine heaths and snowbeds.

5.2 Vegetation history

The pollen percentage data for all samples are listed in Tables 7 and 8. Table 9 summarizes the radiocarbon dates received for the project. Pollen diagrams are presented for the two modern pollen transects (Figs. 17 and 18) and for the Infantry Flats Bog (Figs. 19 and 20).

5.2.1 Modern Pollen Data

The McVeigh Valley Ridge transect covers approximately 1500 ft. (450 m) of elevation. The lowest elevation site (#7) is located in scattered spruce woodland, but the remainder of the sites are located in alpine tundra vegetation. Thirteen polsters have been analysed from this transect (Appendix D). The pollen spectra show few trends in the major taxa (Fig. 17). The dominant taxa are *Alnus* (alder) (39-51%), *Betula* (birch) (17-28%), and Filicales (ferns and fern allies) (11-15%). *Picea* (spruce) percentages are low (<4%), except in the lowermost site where a value of 15% was recorded. These data reflect the abundant pollen production of alder shrubs in this alpine environment. There were no alder shrubs growing at any of the polster collection sites, although scattered shrubs were often observed within 30 m.

The Infantry Flats transect covers 350 ft. (110 m) of elevation. The area is bisected by a road traversing the Flats; below the road the vegetation is dominated by a wet meadow with *Salix* (willow) shrubs, abundant *Equisetum* (horsetail), and a rich herb flora (sites #1 & 3). Above the road the vegetation is more mesic, dominated by Ericales (heaths) and *Betula* shrubs and Poaceae (grass family) (sites #4 & 6). Note that site #7 represents the modern pollen collections at Infantry Flats bog. Small spruce islands are scattered along the transect. Fourteen polsters have been analyzed (Appendix E). The pollen spectra (Fig. 18) register more variability along this transect, but again the dominant taxa are *Alnus*, (15-50%), *Betula* (14-59%), and Filicales (4.5-17%). *Salix* and Poaceae percentages are highest in the wet meadow sites, decreasing in the drier sites above the road. Ericales values show a trend from very low percentages in the wet meadow area to maximum values in the drier sites.

5.2.2 Fossil Pollen Data

Otter Lake Gravel Pit #2

The organic horizon in Otter Lake Gravel Pit #2 consisted on a peaty lens with charcoal, bark, and twigs overlaying an A and B horizon soil complex. The peaty lens

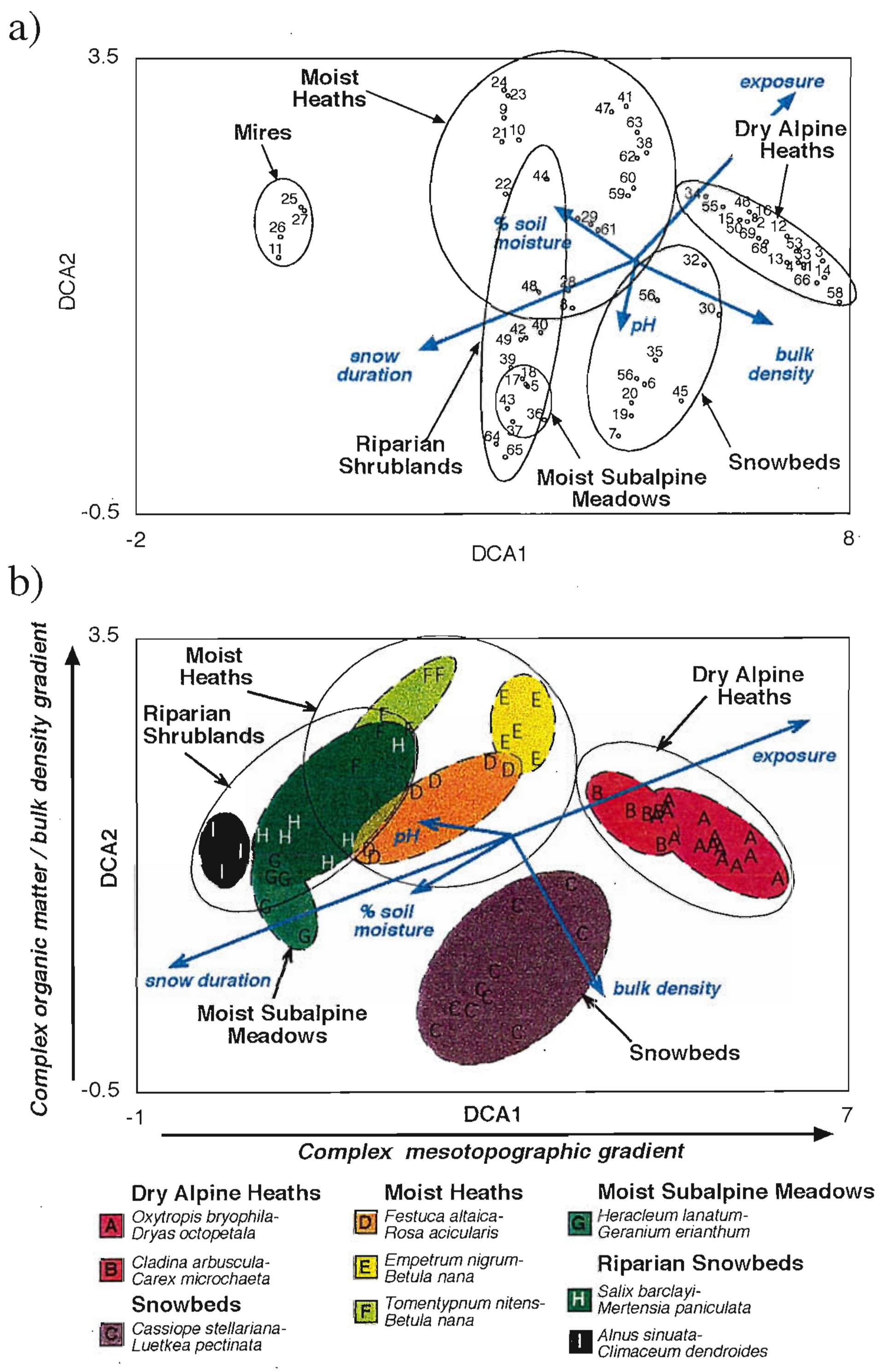

Figure 16. DCA ordination diagrams. (a) Entire data set. (b) Data set excluding the wet fen relevés. The units along the axes are sd-units where each sd-unit is equivalent to about a 50% change in species composition. The blue arrows are biplot diagrams that show the direction and strength (length) of the primary correlated environmental gradients.

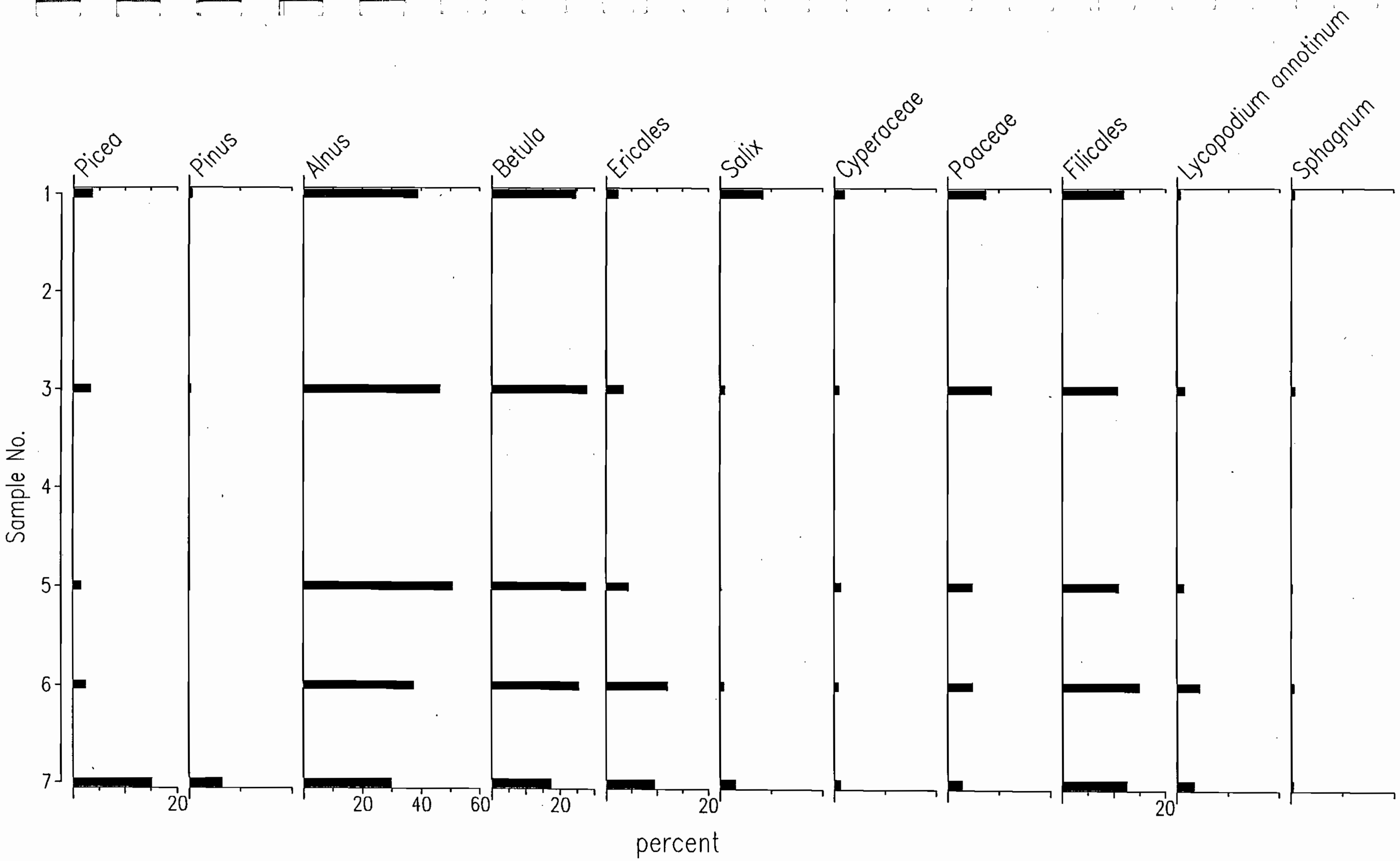

Figure 17. Percentage pollen diagram, McVeigh Valley Ridge transect, Fort Richardson, Alaska. Pollen sum includes all pollen and spores. Major taxa only.

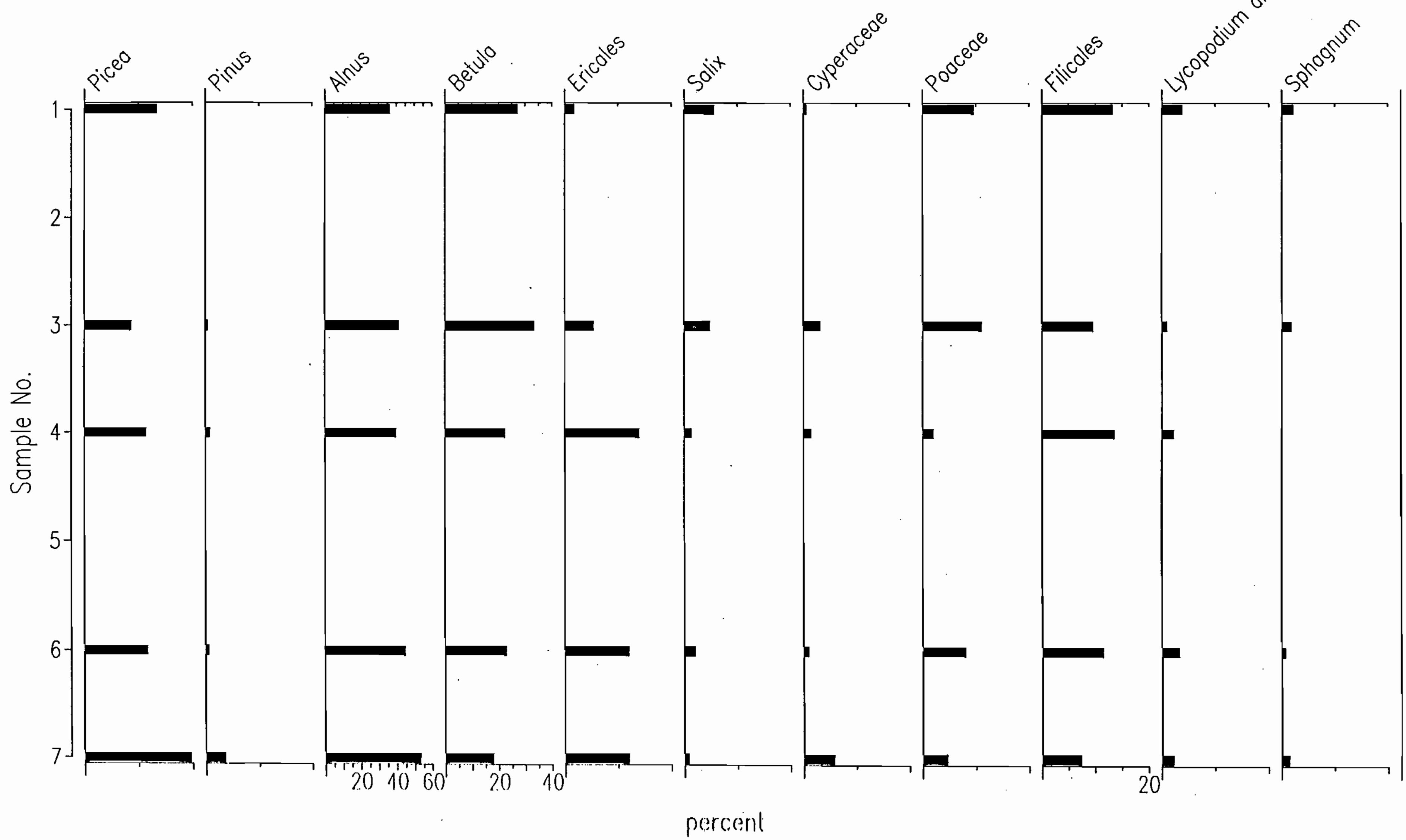

Figure 18. Percentage pollen diagram, Infantry Flats transect, Fort Richardson, Alaska. Pollen sum includes all pollen and spores. Major taxa only.

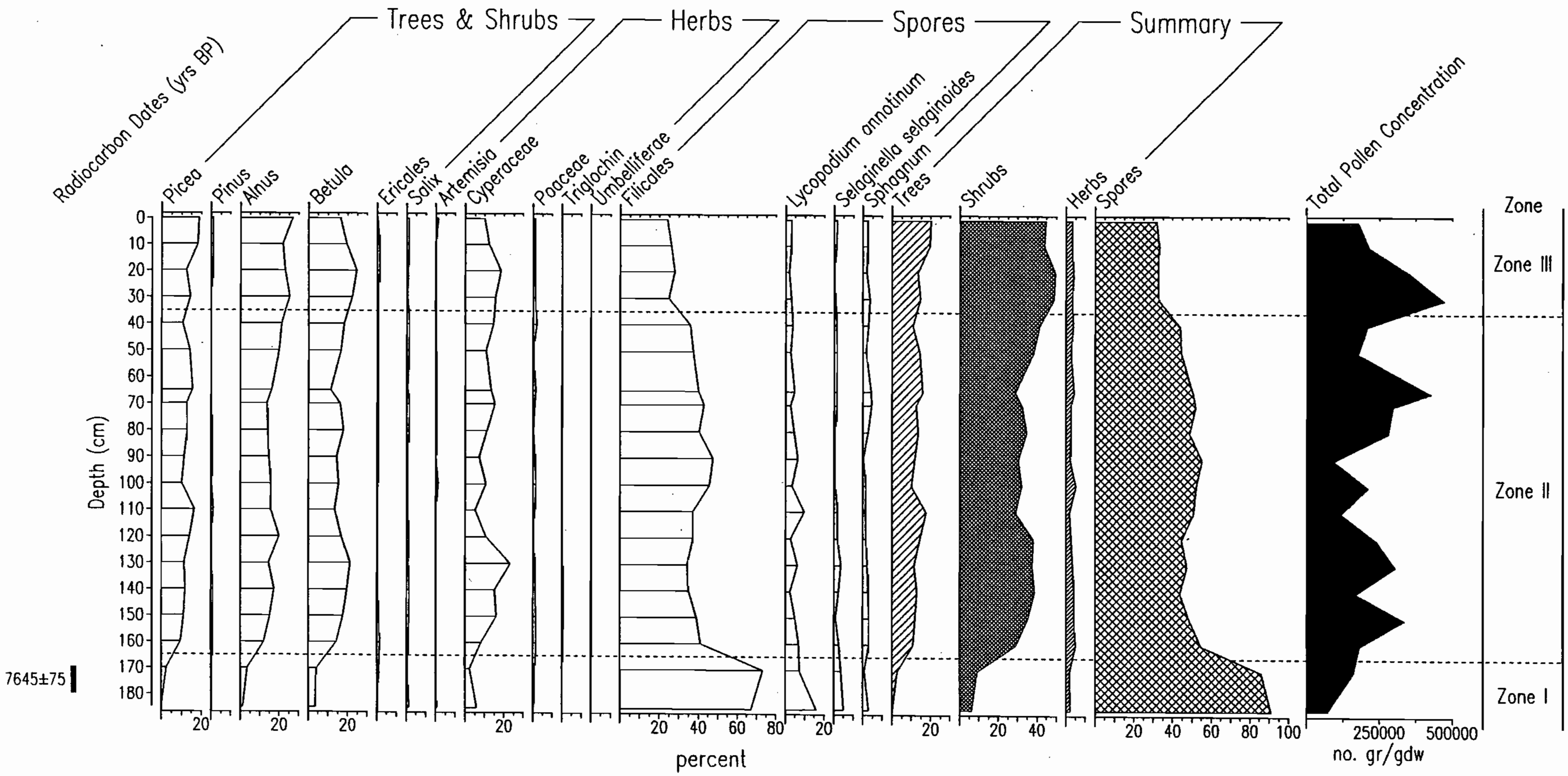

Figure 19. Percentage pollen diagram, Infantry Flats Bog 1, Fort Richardson, Alaska. Pollen sum excludes Cyperaceae, a peat former. Major taxa only.

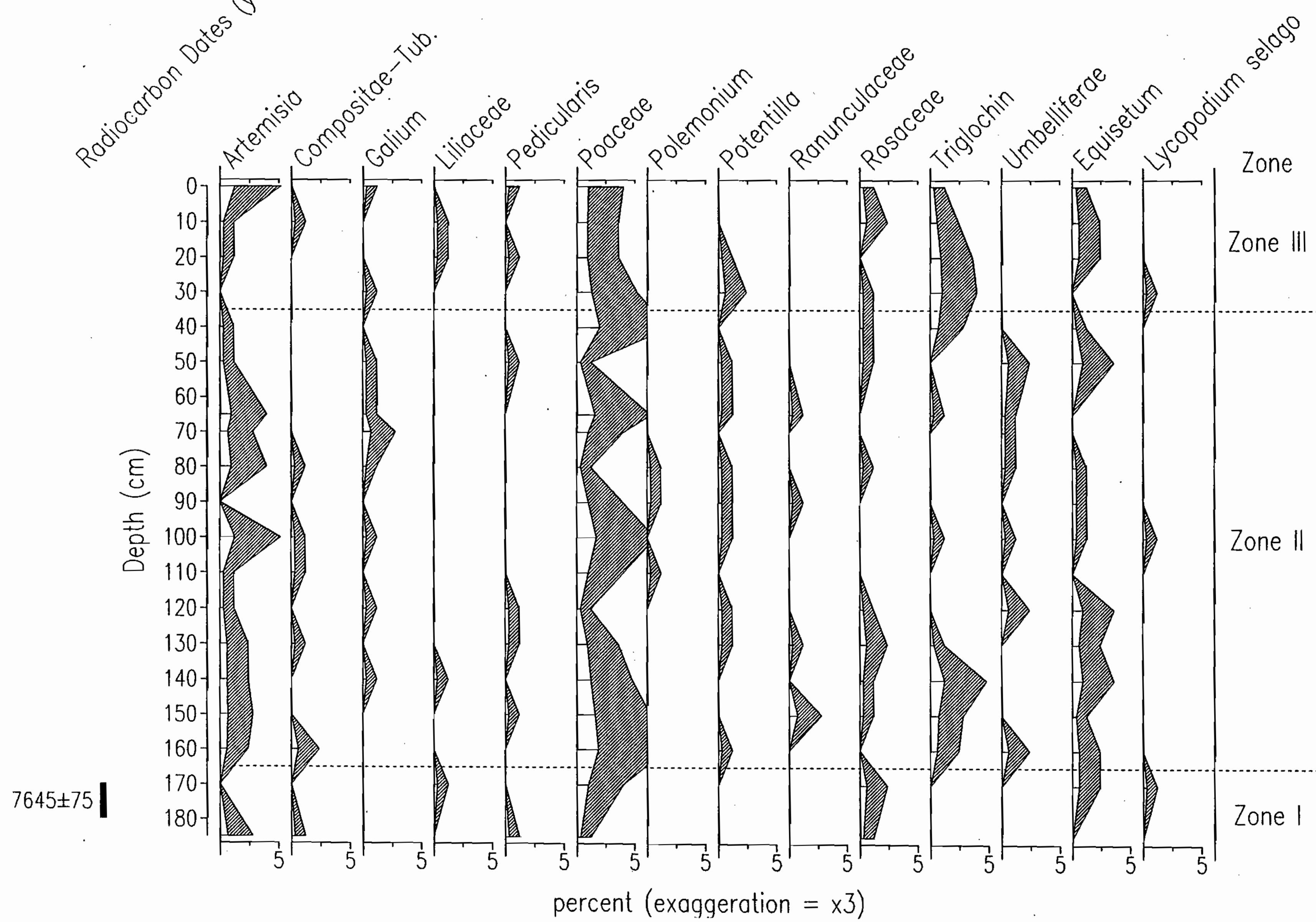

Figure 20. Percentage pollen diagram, Infantry Flats Bog 1, Fort Richardson, Alaska. Minor pollen taxa.

TABLE 7
RADIOCARBON DATES, LEGACY PROJECT, FORT RICHARDSON, ALASKA

SITE	SAMPLE NO.	DEPTH	DATE (cm)	LAB NO.
Otter Lake 2	OL2-1	--	440+/-90	GX-19652
Infantry Flats Bog	IF-1	170-180	7635+/-75	GX-20435
	IF-2	102.5-107.5	submitted	
	IF-3	32.5-37.5	submitted	

was dated to 440+/-90 BP (GX-19652) (Table 7). The pollen spectrum (Appendix F) is dominated by *Betula* (53.5%), *Picea* (20.5%), and *Alnus* (13.3%) percentages, comparable to the modern vegetation at the site. The pollen spectra of the two soil horizons are markedly different, however, and are characterized by large fern percentages (87% and 88%, respectively). Large fern values can be indicative of a disturbance event, but we did not observe evidence of this in the field. Infantry Flats Fen. The core site is located at the west end of Infantry Flats. Local vegetation includes numerous shrubs, especially *Betula, Salix* spp., *Potentilla fructicosa* (shrubby cinquefoil), *Empetrum*.

A 185-cm core was retrieved from the east edge of the site. Pollen samples were processed every 10-cm (Appendix G). The basal ^{14}C date for the core is 7645 ± 75 yr B.P. A sample from 102.5-107.5 cm yielded a date of 4750 ± 75 yr B.P., and a sample from 32.5-37.5 cm yielded a date of 3750 ± 75 yr B.P. (Table 11). The major taxa pollen diagram is illustrated in Fig. 19. It includes the major pollen taxa plus summary columns for the major growth forms (trees, shrubs, herbs, spores) and the total pollen concentration values. The minor taxa are illustrated in Fig. 20. The pollen spectra are dominated by Filicales (24-73%), *Alnus* (1-27%), *Betula* (3-25%), and *Picea* (0-19%). Three main pollen zones can be distinguished. Zone I

The basal two levels contain very large Filicales values (>65%) (Fig. 19). Other fern allies such as *Lycopodium annotinum* (shining clubmoss) (7-16%) and *Selaginella selaginoides* (low selaginella) (ca. 5%) are also important at this time. Other taxa record minimal percentages here and pollen concentration values are low - moderate (70,000-160,000 gr/gdw).

Zone II is marked by a moderate decrease in ferns and other fern allies, although the *Filicales* curve still dominates the diagram with >40% (Fig. 19). The zone boundary is marked by the sudden rise of tree, shrub, and sedge values. Pollen concentration values fluctuate in this zone, but are generally >150,000 gr/gdw. Although recorded in small values, the shrub *Potentilla* also first appears in the pollen diagram (Fig. 20) at this time, and other local taxa also make a first appearance at or just above the zone boundary in Fig. 20.

Zone III is marked by a further decline in *Filicales* percentages (<30%) to levels similar to present (see Fig. 18) and a rise in *Alnus* and *Betula* values; the increased importance of shrub pollen is clearly registered in the summary columns. Tree pollen percentages, primarily *Picea*, also rise at the zone boundary. The base of this zone is marked by peak pollen concentration values (359,000 gr/gdw), but numbers subsequently decline to moderate levels.

5.3.1 Modern insect collections

Twenty-two species of beetles were collected from alpine tundra habitats at Fort

Richardson (Table 8). Many of these species have not been recorded from the Chugach Mountains prior to this study. Some species, such as the ground beetles *Diacheila polita, Pterostichus nivalis*, and *Amara alpina,* are tundra dwellers that previously had only been collected in arctic regions of Alaska. Others, such as the ground beetle *Pterostichus adstrictus* and the rove beetle, *Tachinus elongatus*, are found in the boreal and arctic zones of Alaska, but had never before been found in the Chugach Mountains.

6. Discussion

6.1 Modern vegetation

The present-day vegetation of the Fort Richardson alpine area can be summarized using the framework of the traditional European alpine altitudinal sequence (Figure 21; Ellenberg 1988). The entire Fort Richardson alpine lies below the nival belt, or zone of permanent snowcover, where the average annual snowfall exceeds the rate at which it melts. Permanent glaciers occur about 10 km to the east in the South Fork of the Eagle River, on north-facing cirques of peaks above about 2000 m. Some of these glaciers, for example the Flute Glacier and Organ Glacier, extend down to an elevation of about 1200 m. The highest peaks at the head of Snowhawk Creek and its major tributary include Tikishia Peak (1585 m), Tanaina Peak (1585 m), and Temptation Peak (1646 m), and their cirques are not sufficiently high to support permanent glaciers, although some snowfields do persist through most summers in some of the cirques, drainages, and couloirs. The highest peaks and ridges in the Snowhawk Valley are within the upper alpine or subnival belts. They are rugged with few closed stands of vegetation. At the highest elevations above about 1550 m, barren and lichen covered rocks cover most surfaces; and vascular plants occur in isolated patches or individuals (e.g. our *Silene acaulis-Minuartia macrocarpa* cushion-plant, forb community, Figure 6). The middle alpine is a much broader belt. On south and west-facing slopes, it extends from about 1550 m to 950 m, the elevation of the highest stunted spruce krummholz. This is also the approximate upper limit for a variety of subalpine meadow species including *Geranium erianthum, Sanguisorba stipulata, Veratum viride, Valeriana sitchensis,* and *Viola* spp. On north and east facing slopes this belt extends about 150 m lower, to about 700 m. This is the zone of more or less continuous cover of alpine meadows and dwarf shrub heaths. This belt is strongly affected by the combination of topography, wind, and snow. Deep snow drift areas occur in depressions and leeward, west-facing, slopes with moist *Cassiope stellariana-Luetkea pectinata* communities (Figure 8c,d. Steep north facing slopes generally have the snowbed community, moist *Cassiope tetragona-Luzula parviflora* dwarf-shrub, fruticose-lichen tundra (Figure 8a, b). The more moderate somewhat-wind-exposed surfaces are covered with dry *Cladonia arbuscula-Carex microchaeta* fruticose-lichen, dwarf-shrub tundra (Figure 7), which is dominant over large areas, and dry *Oxytropis bryophila-Dryas octopetala* prostrate-shrub, fruticose-lichen tundra is dominant in the more exposed sites (Figure 6). Very steep slopes, greater than about 40°, are poorly vegetated, but do support extensive patches of stable Dryas

Table 8. Modern Beetle List, Fort Richardson, Alaska

Species	Collecting Localities	Dates Collected	Known Modern Range in Alaska*
CARABIDAE (Ground Beetles)			
Carabus chamissonis Fisch	Infantry Flat/Under stones, alpine meadow	VII -5-1994 VII-2-1995	Open country, boreo-arctic regions throughout Alaska
Notiophilus aquaticus L.	Infantry Flat/Under stones, alpine meadow	VII-5-1994	Open country & alpine tundra throughout Alaska
Diacheila polita Fald.	Infantry Flat/Edge of small pond, in *Sphagnum* mosses	VII-12/1993	Arctic tundra in shrubs and moist localities
Patrobus septentrionis Dej.	Infantry Flat/Under stones, alpine meadow	VII-5-1994 VII-2-1995	Subalpine zone throughout Alaska
Patrobus stygicus Chd.	Infantry Flat/Edge of small pond, in *Sphagnum* mosses	VII-12/1993	Bogs and edges of small ponds throughout Alaska
Trechus chalybeus Dej.	Infantry Flat/Under stones, alpine meadow	VII-5-1994	Common on south coast, up to alpine zone
Bembidion quadrifoveolatum Mannh.	Infantry Flat/Under stones, alpine meadow	VII-5-1994	Riparian habitats in southern Alaska
Pterostichus adstrictus Eschz.	Infantry Flat/Under stones, alpine meadow	VII-5-1994 VII-2-1995	Arctic and northern boreal regions
Pterostichus brevicornis Kby.	McVeigh Creek Drainage/Mesic tundra on N. facing slope	VII-12-1993	Arctic and alpine tundra throughout Alaska
Pterostichus nivalis Sahlb.	McVeigh Creek Drainage/Mesic tundra on N. facing slope	VII-12-1993	Arctic tundra and alpine tundra in Alaska Range
Pterostichus pinguedineus Eschz.	McVeigh Creek Drainage/Mesic tundra on N. facing slope	VII-12-1993 and VII-5-1994	Boreo-arctic and alpine in Alaska
Pterostichus ventricosus Eschz.	McVeigh Creek Drainage/Mesic tundra on N. facing slope	VII-12-1993	Boreo-arctic and alpine regions in Alaska

Species	Collecting Localities	Dates Collected	Known Modern Range in Alaska*
Calathus ingratus Dej.	Infantry Flat/Edge of small pond, in *Sphagnum* mosses	VII-5-1994	Boreal regions of southern Alaska
Amara alpina Payk.	McVeigh Creek Drainage/Mesic tundra on N. facing slope	VII-12-1993	Arctic and alpine regions of Alaska
Amara sinuosa Csy.	Infantry Flat/Under stones, alpine meadow	VII-2-1995	Southern coast of Alaska, up to treeline
HYDROPHIIDAE (Water Scavenger Beetles)			
Cercyon sp.	Infantry Flat/Edge of small pond, in *Sphagnum* mosses	VII-12/1993	Genus is widespread in boreo-arctic region
STAPHYLINIDAE (Rove Beetles)			
Tachinus elongatus Gangl.	Infantry Flat/Under stones, alpine meadow	VII-5-1994	Snow field margins in boreo-arctic regions of Alaska
ELATERIDAE (Click Beetles)			
Genus et sp. indet.	Infantry Flat/pitfall trap, alpine meadow	VII-5-1994	Family is widespread in Alaska
SCARABAEIDAE (Dung Beetles and Chafers)			
Aphodius sp.	Infantry Flat/pitfall trap, alpine meadow and by snowbank near Site Summit	VII-5-1994 VII-2-1995	Genus is widespread in Alaska
CHRYSOMELIDAE (Leaf Beetles)			
Chrysomela sp.	Infantry Flat/pitfall trap, alpine meadow	VII-5-1994	Genus widespread in Alaska
CURCULIONIDAE (Weevils)			
Genera et spp. indet.	Infantry Flat/pitfall trap, alpine meadow	VII-5-1994	Family is widespread in Alaska

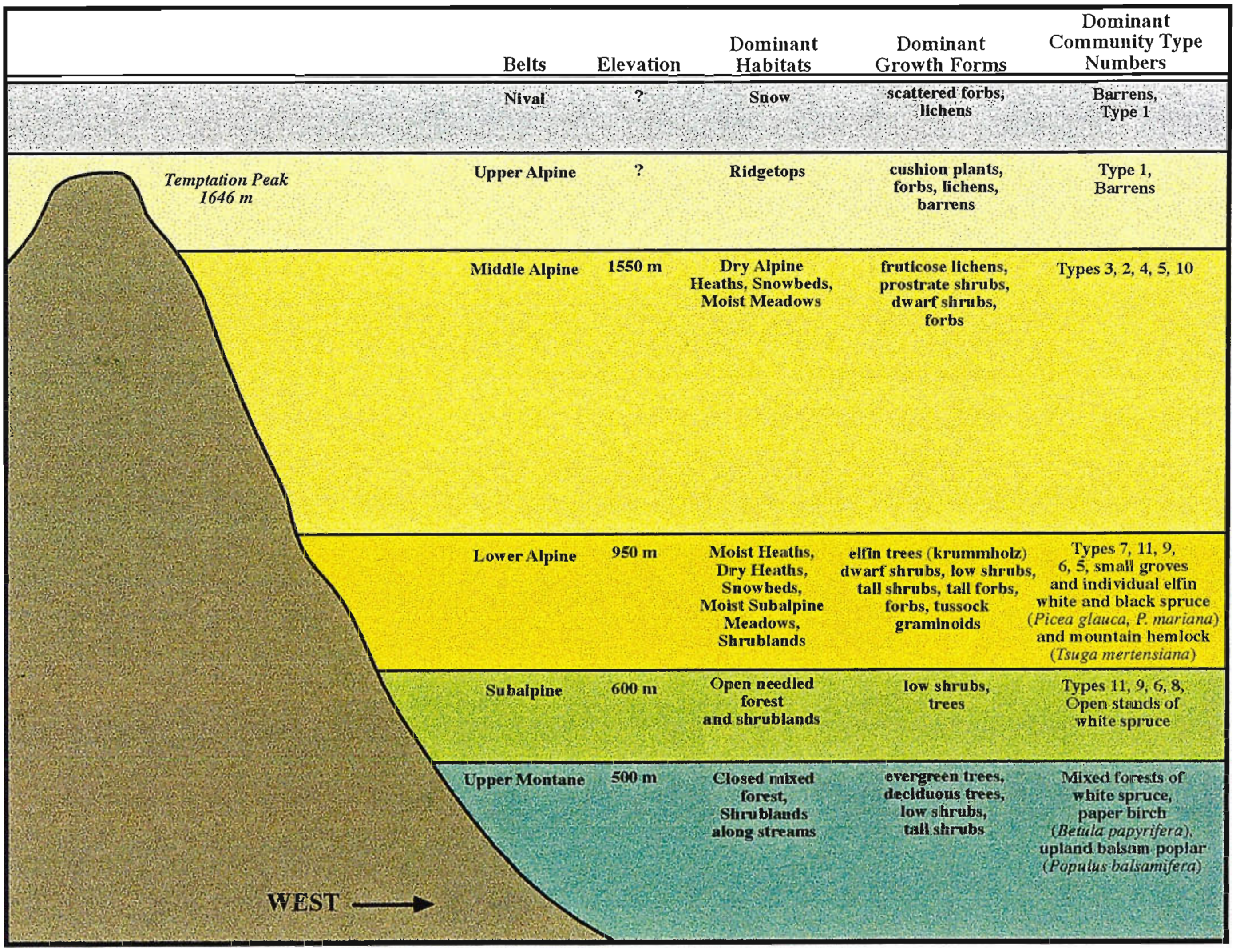

Figure 21. Idealized west facing altitudinal sequence of vegetation belts, dominant habitats, growth forms, and plant communities for the Chugach Mountains alpine area, Fort Richardson, Alaska.

and lichens. Snowy drainages typically have heath communities, either moist *Cassiope stelleriana-Leutkea pectinata* dwarf-shrub tundra or moist *Empetrum nigrum-Betula nana* dwarf-shrub tundra (Figure 10). Streams have a complex of willow and meadow communities, including the moist *Salix barclayi-Mertensia paniculata* dwarf-shrub, forb community (Figure 13).

The lower alpine belt is a transitional zone consisting of scattered elfin trees mixed with forb meadows and shrublands. On south- and west-facing slopes, this zone extends from about 950 m to the open spruce forests at about 600 m. At Fort Richardson, this belt is occupied by a wide variety of plant communities. Moist *Empetrum nigrum-Betula nana* dwarf shrublands (Figure 12) occur on most moderate surfaces. Moist *Heracleum.* The *lanatum-Geranium erianthum* forb meadows (Figure occur in somewhat wetter situations, particularly near seeps and springs. Moist *Tomentypnum nitens-Betula nana* dwarf-shrublands (Figure 11) occur in poorly-drained minerotrophic meadows. Toward the upper altitudinal limit of the lower alpine belt, *Alnus sinuata-Climaceum dendroides* tall shrublands (Figure 14) are fairly scattered, and toward the lower end of the belt, this community is dominant and forms extensive closed stands, especially along the streams. Relatively dry *Festuca altaica-Rosa acicularis* tussock-graminoid, dwarf-shrub, forb meadows (Figure 9) occur on steeper, primarily south-facing slopes. Mires such as the Infantry Flats fen are very rare due to the steep terrain, but important to this study because of the peat core from this site. The Infantry Flats peatland is situated at the present-day lower limit of the alpine belt in the transition to spruce forests. This should make the site fairly sensitive to fluctuations in treeline.

Racine (1978) described a similar altitudinal transects in the Lake Clark National Park about 130 km west of Fort Richardson. He placed the lower limit of the tundra zone (above the forest and shrub zones) at about 760-900 m on the west (more continental) side of the mountains and 600-760 m on the east (maritime) side. The upper limit of the tundra zone (approximately equal to our middle alpine belt) at Turquoise Lake on the west side of the divide is about 1280 m. The higher zone boundaries at Fort Richardson may be due to a somewhat drier climate and possibly differences in topography.

The twelve communities described here represent the most common and obvious plant communities of the Fort Richardson alpine. There are many more communities that could not be sampled in the available time. For comparison with another alpine area, Komarkova (1979) recognized 52 associations (community types) in the alpine of the Colorado Front Range using the Braun-Blanquet approach. To do this she sampled a total of 545 relevés. Obviously, a great deal more work is required to completely describe the vegetation of the Fort Richardson alpine and the adjacent Chugach Mountains.

6.2 Ancient Vegetation

The pollen spectra from Zone I suggest moist, open, homogeneous conditions at the site at about 7600 yrs BP. There are no analogs to the large Filicales values in the modern transect data (5-17%) (Fig. 19), suggesting few shrubs or trees in the area at this time. Zone II (ca. 7200 - 1500 BP) represents the establishment of modern vegetation communities around the fen. Species richness is increased from Zone I. Fens, represented by the ferns, are still locally important, but birch and shrubby cinquefoil shrubs are now also part of the lowland vegetation. Spruce and alder now occupy the drier sites above the bog. In Zone III, the expansion of shrub taxa at the expense of ferns suggests a trend toward shrubbier conditions in the past 1500 years at Infantry Flats Fen.

6.3 Beetle fauna

The beetle faunal study showed that substantial numbers of tundra species live above treeline in the Chugach Mountains. Faunistically, this alpine region has much in common with Arctic Alaska. If the collecting data for these specimens were missing, an examination of the faunal list (Table 12) would lead an entomologist to conclude that these specimens had been collected at and beyond northern treeline in the Brooks Range.

Interestingly, beetle species characteristic of high elevation localities in the Pacific Northwest region were lacking in our collections from the Chugach alpine region. The reasons for this lack of affinity with the Pacific Northwestern fauna probably lie in the glacial history of the region. Given that the Chugach Mountains were covered by glacial ice until about 10,000 yr B.P., by the time the high country in the Chugach was ice-free, the intervening lowland regions between south-central and south-eastern Alaska had become too warm to allow the spread of cold-adapted alpine beetle species.

7. Conclusions

This study had two main objectives. We wanted to characterize the modern natural vegetation and compare it with information in the paleontological record. The specific aims of paleontological portion of the study were to reconstruct the history of biotic response to environmental change in the two study regions during the postglacial period. This was achieved through studies of fossil pollen from a peat profile in the Infantry Flats region. In addition, modern pollen and insects were collected, to provide modern baseline data for the interpretation of the fossil assemblages.

The Snowhawk Creek watershed is an outstanding ecological and recreational resource, deserving a high level of protection. *Androsace alaskana* is a rare plant found at the highest elevations in the watershed.

In this report, we have described twelve vegetation communities. These represent the most common and obvious alpine plant communities of Fort Richardson. From 69 studied relevés in the alpine, we found a total of 168 vascular plants, 66 mosses, 11 liverworts, and 53 lichens. Of these, 14 vascular plants, 28 mosses, 9 liverworts, and 13 lichens are new records for Fort Richardson.

The highest peaks and ridges in the Snowhawk Valley are within the upper alpine or subnival belts. They are rugged with few closed stands of vegetation. At the highest elevations above about 1550 m, barren and lichen covered rocks cover most surfaces; and vascular plants occur in isolated patches or individuals. The middle alpine is a much broader belt. On south and west-facing slopes, it extends from about 1550 m to 950 m, the elevation of the highest stunted spruce krummholz. On north and east facing slopes this belt extends about 150 m lower, to about 700 m. This is also the approximate upper limit for a variety of subalpine meadow species. This is the zone of more or less continuous cover of alpine meadows and dwarf shrub heaths. This belt is strongly affected by the combination of topography, wind, and snow. The lower alpine belt is a transitional zone consisting of scattered elfin trees mixed with forb meadows and shrublands. On south- and west-facing slopes, this zone extends from about 950 m to the open spruce forests at about 600 m. At Fort Richardson, this belt is occupied by a wide variety of plant communities.

The most important environmental factors controlling the distribution of plant communities are related to snow distribution. The snowbed plant communities are among the most interesting at the site. They include maritime communities that are found only in southern Alaska and Arctic communities with circumpolar affinities.

The fossil pollen study showed that moist, open ground tundra vegetation was established at Infantry Flats by 7600 yrs BP (pollen Zone I). There are no analogs to the large Filicales values in the modern transect data. This suggests that there were few shrubs or trees in the area at this time. A second pollen zone (ca. 7200 - 1500 BP) represents the establishment of modern vegetation communities around the fen. Species richness is increased from Zone I. The large fern percentages in both the modern and ancient pollen data are unusual and apparently have not been reported from other Alaskan sites. Ferns are still locally important, but birch and shrubby cinquefoil shrubs are now also part of the lowland vegetation. Spruce and alder now occupy the drier sites above the fen. During the past 1500 years, the expansion of alder and birch taxa at the expense of ferns suggests a trend to shrubbier conditions at the site.

The beetle faunal study showed that substantial numbers of tundra species live above treeline in the Chugach Mountains. The alpine beetle fauna has much in common with that of Arctic Alaska. Interestingly, beetle species characteristic of high elevation localities in the Pacific Northwest region were lacking in our collections from the Chugach alpine region. The reasons for this lack of affinity with the Pacific Northwestern fauna probably lie in the glacial history of the region. Given that the Chugach Mountains were covered by glacial ice until about 10,000 yr B.P., by the time the high country in the Chugach was ice-free, the intervening lowland regions between south-central and south-eastern Alaska had become too warm to allow the spread of cold-adapted beetle species.

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APPENDICES

Appendix A. Species list for the Fort Richardson alpine vegetation analysis

Appendix B. Sorted plant community data for Fort Richardson alpine vegetation analysis

Appendix C. Raw environmental data for Fort Richardson alpine vegetation analysis

Appendix D. McVeigh Valley-Ridge polster pollen percentage data

Appendix E. Infantry Flats polster pollen percentage data

Appendix F. Otter Lake Gravel Pit polster data

Appendix G. Infantry Flats ancient pollen percentage data

APPENDIX A

Appendix A . Species list for the Fort Richardson alpine vegetation analysis.
Vascular plant nomenclature is according to D.F. Murray, Electronic authority file, Herbarium, University of Alaska, Fairbanks, AK, USA, Hultén (1968) and Murray (1995).
Common names are according to Anderson (1959) and Viereck and Little (1972).
Non-vascular plant nomenclature is according to Anderson et al. (1990) for mosses, Stotler and Crandall-Stotler (1977) for liverworts, and Egan (1987) for lichens.

Growth Form	Botanical Name	Common Name
<u>Vascular Plants</u>		
1	*Achillea millefolium* L.	Common Yarrow
2	*Acomastyllis rossii* (R.Br.) Ser	Ross Avens
3	*Alnus sinuata* (Regel) Rydb.	Sitka Alder
	[= *Alnus crispa* (Ait.) Pursh ssp. *sinuata* (Regel) Hult.]	
4	*Andromeda polifolia* L.	Bog Rosemary
5	*Anemone multifida* Poir.	Cut-leaved Anemone
6	*Anemone narcissiflora* L. *ssp. interior* Hult. *	Narcissus-flowered Anemone
7	*Anemone richardsonii* Hook.	Yellow Anemone
8	*Angelica lucida* E. Nels.	Sea Coast Angelica
9	*Antennaria friesiana* (Trautv.) Ekman	Pussy Toe
10	*Antennaria monocephala* DC.	Pussy Toe
11	*Aquilegia formosa* Fisch.	Western Columbine
12	*Arctagrostis latifolia* (R. Br.) Griseb. var. *latifolia*	Polar Grass
13	*Arctostaphylos uva-ursi* (L.) Spreng.	Kinnikinnick, Bearberry
14	*Arctous alpina* (L.) Niedenzu	Alpine Bearberry
	[= *Arctostaphylos alpina* (L.) Spreng.]	
15	*Arctous rubra* (Rehd. & Wilson) Nakai	Alpine Bearberry
	[= *Arctostaphylos rubra* (Rehd. & Wilson) Fern.]	
16	*Arnica angustifolia* M. Vahl. *	Arnica
17	*Arnica frigida* C.A. Mey. *	Arnica
18	*Arnica latifolia* Bong. *	Arnica
19	*Arnica lessingii* Greene	Arnica
20	*Artemisia arctica* Less.	Arctic Wormwood
21	*Artemisia tilesii* Ledeb.	Wormwood
22	*Athyrium filix-femina* (L.) Roth	Lady Fern
23	*Betula nana* L. / *glandulosa* Michx.	Dwarf/Alpine Birch
24	*Bistorta vivipara* (L.) Gray [= *Polygonum viviparum* L.]	Alpine Bistort
25	*Calamagrostis canadensis* (Michx.) Beauv.	Bluejoint
26	*Campanula lasiocarpa* s.l. Cham.	Mountain Harebell
27	*Campanula rotundifolia* L.	Bluebells of Scotland
28	*Carex aquatilis* (Wahlenb.) ssp. *aquatalis*	Water Sedge
29	*Carex lachenalii* Schkuhr	Arctic Hare's Foot Sedge
30	*Carex limosa* L.	Shore Sedge
31	*Carex membranacea* Hook.	Fragile Sedge
32	*Carex microchaeta* Holm.	Sedge
33	*Carex podocarpa* C.B. Clarke	Short Stalked Sedge
34	*Carex rariflora* (Wahlenb.) Smith	Loose Flowered Alpine Sedge

Appendix A. Continued.

Growth Form	Botanical Name	Common Name
Vascular Plants Continued.		
35	*Carex rostrata* Stokes	Beaked Sedge
36	*Carex saxatilis* L.	Sedge
37	*Cassiope stelleriana* (Pall.) DC.	Alaska Heather
38	*Cassiope tetragona* (L.) D. Don	Four Angled Mountain Heather
39	*Castilleja unalaschcensis* (Cham. and Schlecht.) Malte	Indian Paintbrush
40	*Cerastium beeringianum* Cham. and Schldl.	Beering Chickweed
41	*Claytonia sarmentosa* C.A. Meyer	Alaskan Spring Beauty
42	*Conioselinum pacificum* (S. Wats.) Coult. & Rose [= *C. chinense* (L.) BSP]	Hemlock Parsley
43	*Cornus canadensis x suecica* L.	Bunchberry
44	*Cystopteris fragilis* (L.) Bernh.	Fragile Fern
45	*Cystopteris montana* (Lam.) Bernh.	Mountain Cystopteris
46	*Delphinium glaucum* S. Wats.	Glaucous Larkspur
47	*Diapensia lapponica* L.	Diapensia
48	*Dodecatheon frigidum* Cham. and Schelcht. *	Shooting Star
49	*Douglasia alaskana* (Cov. and Standl. *x* Hult.) S. Kelso [= *Androsace alaskana* Cov. & Stand.]	Primrose
50	*Dryas octopetala* L.	Eight Petaled Mountain Avens
51	*Dryopteris dilatata* (Hoffm.) Gray	Spreading Wood Fern
52	*Eleocharis palustris* (L.) Roem. & Schult.	Creeping Spike Rush
53	*Empetrum nigrum* L.	Crowberry
54	*Epilobium angustifolium* L.	Fireweed
55	*Epilobium hornemannii* Rchb.	Hornemann Willow-Herb
56	*Epilobium latifolium* L.	Dwarf fireweed/Riverweed
57	*Epilobium sertulatum* Haussk. *	Evening Primrose
58	*Equisetum arvense* L.	Common Horsetail
59	*Equisetum palustre* L.	Marsh Horsetail
60	*Equisetum pratense* L.	Meadow Horsetail
61	*Equisetum scirpoides* Michx.	Little Horsetail
62	*Equisetum silvaticum* L.	Wood Horsetail
63	*Erigeron peregrinus* (Pursh) Greene	Coastal fleabane
64	*Eriophorum angustifolium* Honck.	Tall Cotton Grass
65	*Eriophorum scheuchzeri* Hoppe	White Cotton Grass
66	*Festuca altaica* Trin.	Rough Fescue
67	*Festuca brachyphylla* Schultes and Schultes F. *	Alpine Fescue
68	*Galium boreale* L.	Northern Bedstraw
69	*Gentiana glauca* Pallas	Glaucous Gentian
70	*Gentiana propinqua* (Richards.) *	Four-parted Gentian
71	*Geranium erianthum* DC.	Northern Geranium
72	*Hedysarum alpinum* L.	American Hedysarum
73	*Heracleum lanatum* Michx.	Cow Parsnip
74	*Hieracium triste* Willd.	Wooly Hawkweed
75	*Hierochlöe alpina* (Sw.) Roemer & Schultes	Alpine Holy Grass

Appendix A. Continued.

Growth Form	Botanical Name	Common Name
Vascular Plants Continued.		
76	*Huperzia selago (L.)* C. Martius [= *Lycopodium selago* L.]	Fir Club Moss
77	*Juncus biglumis* L.	Two Flowered Rush
78	*Ledum groenlandicum* Oeder [= *L. palustre* L. ssp. *groenlandicum* (Oeder) Hult.]	Labrador Tea
79	*Ledum palustre* L. ssp. *decumbens* (Ait.) Hult.	Narrow Leaved Labrador Tea
80	*Linnaea borealis* L.	Twinflower
81	*Lloydia serotina* L. (Rchb.)	Alp Lily
82	*Loiseleuria procumbens* (L.) Desv.	Alpine Azalea
83	*Luetkea pectinata* (Pursh) Ktze.	Luetkea
84	*Lupinus nootkatensis* Donn	Nootlea Lupine
85	*Luzula confusa* Lindeb.	Northern Wood Rush
86	*Luzula multiflora* (Retz.) Lej.	Many Flowered Wood Rush
87	*Luzula parviflora* (Ehrh.) Desv.	Small Flowered Wood Rush
88	*Luzula tundricola* Gorodk. *	Wood Rush
89	*Lycopodium alpinum* L.	Alpine Club Moss
90	*Lycopodium annotinum* L.	Stiff Club Moss
91	*Lycopodium clavatum* L.	Running Pine
92	*Lycopodium clavatum* L. ssp. *clavatum*	Common Club Moss
93	*Mertensia paniculata* (Ait.) G. Don	Tall Lungwort
94	*Minuartia macrocarpa* (Pursh) Ostenf.	Long Padded Sandwort
95	*Minuartia obtusiloba* (Rydb.) House *	Alpine Sandwort
96	*Minuartia rubella* (Wahlenb.) Graebn.	Sandwort
97	*Moehringia lateriflora* (L.) Fenzl	Blunt Leaved Sandwort
98	*Oxycoccus microcarpus* Turcz.	Swamp Cranberry
99	*Oxytropis bryophila* (E. Greene) Yurtsev [= *O. nigrescens* (Pall.) Fisch. ssp. *bryophila* (Greene) Hult.]	Blackish Oxytrope
100	*Parnassia palustris* L. s.l.	Northern Grass of Parnassus
101	*Pedicularis capitata* J. Adams	Lousewort
102	*Pedicularis labradorica* Wirsing	Lousewort
103	*Pedicularis langsdorffii* Fisch. *ex* Steven	Lousewort
104	*Pedicularis lapponica* L.	Lousewort
105	*Pentaphylloides floribunda* (Pursh) A. Loeve [= *Potentilla fruticosa* L.]	Shrubby Cinquefoil, Yellow Rose
106	*Petasites frigidus* (L.) Franchet	Arctic Sweet Coltsfoot
107	*Phleum commutatum* Gandoger var. *americanum* (Fourn.) Hult.	Mountain Timothy
108	*Phlox sibirica* L.	Siberian Phlox
109	*Picea glauca* (Moench) Voss	White Spruce
110	*Picea mariana* (Mill.) Britt., Sterns & Pogg.	Black Spruce
111	*Poa alpina* L.	Alpine Bluegrass
112	*Poa arctica* R. Br. s.l.	Arctic Bluegrass
113	*Poa glauca* M. Vahl	Glaucous Spear Grass
114	*Polemonium acutiflorum* Willd.	Jacob's Ladder

Appendix A. Continued.

Growth Form	Botanical Name	Common Name
Vascular Plants Continued.		
115	*Potentilla uniflora* Ledeb.	One Flowered Cinquefoil
116	*Pyrola asarifolia* Michx. var. *purpurea* (Bunge) Fern.	Liver Leaf Wintergreen
117	*Rhinanthus minor* L.	Rattlebox
118	*Rhodiola integrifolia* Raf. [= *Sedum rosea* (L.) Scop. ssp. *integrifolium* (Raf.) Hult.]	Roseroot, Rosewort
119	*Rosa acicularis* Lindl.	Prickly Rose
120	*Rubus arcticus* L. s.l.	Nagoon Berry, Kneshenaka
121	*Rubus chamaemorus* L.	Cloud Berry, Baked Apple Berry
122	*Rubus pedatus* Sm.	Five Leaved Bramble
123	*Rumex acetosella* L. s.l.	Sheep Sorrel
124	*Rumex arcticus* Trautv.	Arctic Dock
125	*Salix alaxensis* (Anderss.) Cov.	Alaska Willow
126	*Salix arctica* Pallas	Arctic Willow
127	*Salix barclayi* Anderss.	Barclayi Willow
128	*Salix brachycarpa* Nutt. ssp. *niphocladam* (Rydb.) Argus	Willow
129	*Salix glauca* L.	Willow
130	*Salix lanata* L. *	Woolly Willow
131	*Salix phlebophylla* Andersson *	Skeleton Leaf Willow
132	*Salix planifolia* ssp. *pulchra* Pursh.	Willow
133	*Salix polaris* Wahlenb. *	Willow
134	*Salix reticulata L.*	Netted Willow
135	*Sambucus racemosa* L.	Red Berried Elder
136	*Sanguisorba stipulata* Raf.	Burnet
137	*Saxifraga bronchialis* Raf.	Spotted Saxifrage
138	*Saxifraga cernua* L.	Nodding Saxifrage
139	*Saxifraga flagellaris* Willd.	Flagellate Saxifrage
140	*Saxifraga hirculus* L.	Yellow Marsh Saxifrage
141	*Saxifraga lyallii* Engler s.l.	Red-stemmed Saxifrage
142	*Saxifraga nelsoniana* D. Don [= *S. punctata* L. ssp. *pacifica* Hult.]	Brook Saxifrage
151	*Spiranthes romanzoffiana* Cham.	Hooded Ladies' Tresses
152	*Stellaria laeta* Richardson	Shining Starwort
153	*Stellaria longifolia* Muhl.	Long Leaved Starwort
154	*Streptopus amplexifolius* (L.) DC	Cucumber Root, Clasping Twisted Stalk
155	*Swertia perennis* L.	Gentian
156	*Tofieldia coccinea* Richards.	Narthern Asphodel
143	*Saxifraga oppositifolia* L.	Purple Mountain Saxifrage
144	*Saxifraga reflexa* Hook. s.l. *	Yukon Saxifrage
145	*Saxifraga serpyllifolia* Pursh	Thyme Leaved Saxifrage
146	*Saxifraga tricuspidata* Rottb.	Three Toothed Saxifrage
147	*Senecio lugens* Richards.	Groundsel, Ragwort
148	*Senecio triangularis* Hook.	Groundsel, Ragwort
149	*Silene acaulis* L.	Moss Campion, Moss Pink

Appendix A. Continued.

Growth Form	Botanical Name	Common Name
Vascular Plants Concluded.		
150	*Spiraea stevenii* Schneid. [= *S. beauverdiana* Schneid.]	Beavered Spiraea
157	*Tofieldia pusilla* (Michx.) Pers.	Scothc/False Asphodel
158	*Trichophorum caespitosum* (L.) Hartm. s.l. [= *T. caespitosum* L. ssp. *austriacum* (Pall) Hegi]	Sedge
159	*Trientalis europea* L.	Starflower
160	*Triglochin palustris* L.	Arrow Grass
161	*Trisetum spicatum* (L.) Richter s.l.	Downy Oat Grass
162	*Vaccinium uliginosum* L.	Bog Blueberry
163	*Vaccinium vitis-idaea* (L.) Hult.	Mountain Cranberry, Lingen Berry
164	*Valeriana sitchensis* Bong.	Sitka Valerian
165	*Veratrum viride* Ait.	American White Hellebore
166	*Viburnum edule* (Michx.) Raf.	Few Flowered High Bush Cranberry
167	*Viola epipsila* Ledeb.	Northern Marsh Violet
168	*Viola langsdorfii* Fisch.	Alaska Violet
Mosses		
1	*Aulacomnium palustre* (Hedw.) Schwaegr.	
2	*Aulacomnium turgidum* (Wahlenb.) Schwaegr. *	
3	*Bartramia ithyphylla* Brid.	
4	*Brachythecium campestre* (C. Müll.) Schimp. *	
5	*Brachythecium erythrorrhizon* Schimp. *	
6	*Brachythecium reflexum* (Starke *in* Web & Mohr) Schimp. *	
7	*Brachythecium salebrosum* (Web & Mohr) Schimp. *	
8	*Brachythecium starkei* (Brid.) Schimp. *	
9	*Bryum caespiticium* Hedw.	
10	*Bryum cyclophyllum* (Schwaegr.) Bruch and Schimp. *in* B.S.G. *	
11	*Calliergon stramineum* (Brid.) Kindb.	
12	*Campylium stellatum* s.l. (Hedw.) C. Jens.	
13	*Ceratodon purpureus* (Hedw.) Brid.	
14	*Cirriphyllum cirrosum* (Schwaegr. *in* Schultes) Grout	
15	*Climacium dendroides* (Hedw.) Web. & Mohr	
16	*Cyrtomnium hymenophylloides* (Hüb.) Nyh. *ex* T. Kop. *	
17	*Dicranoweisia crispula* (Hedw.) Lindb. *ex* Milde	
18	*Dicranum bonjeanii* De Not *in* Lisa *	
19	*Dicranum elongatum* Schleich. *ex* Schwaegr. *	
20	*Dicranum majus* Sm.	
21	*Dicranum spadiceum* Zett. *	
22	*Ditrichum flexicaule* (Schwaegr.) Hampe *	
23	*Hamatocaulis vernicosus* (Mitt.) Hedenäs	
24	*Helodium blandowii* (Web. & Mohr) Warnst. *	
25	*Hylocomiastrum pyrenaicum* (Spruce) Fleisch. *in* Broth.	
26	*Hylocomium splendens* (Hedw.) Schimp. *in* B.S.G.	
27	*Kiaeria glacialis* (Berggr.) Hag. *	

Appendix A. Continued.

Growth Form	Botanical Name	Common Name

<u>**Mosses Concluded.**</u>

28 *Limprichtia cossonii* (Schimp.) And. Crum & Buck
[= *Drepanocladus intermedius* (Linkb) Warnst.] *
29 *Mnium blyttii* Bruch & Schimp. *in* B.S.G. *
30 *Oncophorus wahlenbergii* Brid. *
31 *Orthotrichum speciosum* Nees *in* Sturm *
32 *Paludella squarrosa* (Hedw.) Brid
33 *Plagiomnium cuspidatum* (Hedw.) T. Kop. *
34 *Plagiomnium ellipticum* (Brid.) T. Kop.
35 *Plagiomnium medium* (Bruch & Schimp. *in* B.S.G.) T. Kop.
36 *Pleurozium schreberi* (Brid.) Mitt.
37 *Pogonatum dentatum* (Brid.) Brid.
38 *Pohlia cruda* (Hedw.) Lindb.
39 *Pohlia nutans* (Hedw.) Lindb.
40 *Polytrichastrum alpinum* (Hedw.) G.L.
41 *Polytrichum commune* (Hedw.)
42 *Polytrichum hyperboreum* R. Br.
43 *Polytrichum juniperinum* Hedw.
44 *Polytrichum piliferum* Hedw.
45 *Polytrichum strictum* Brid.
46 *Racomitrium canescens* (Hedw.) Brid. *
47 *Racomitrium heterostichum* (Hedw.) Brid. *
48 *Racomitrium lanuginosum* (Hedw.) Brid.
49 *Rhizomnium andrewsianum* (Steere) T. Kop. *
50 *Rhizomnium magnifolium* (Horik.) T. Kop. *
51 *Rhizomnium nudum* (Britt & Williams) T. Kop. *
52 *Rhizomnium pseudopunctatum* (Bruch & Schimp.) T. Kop. *
53 *Rhodobryum roseum* (Hedw.) Limpr.
54 *Rhytidiadelphus squarrosus* (Hedw.) Warnst. *
55 *Rhytidiadelphus triquetrus* (Hedw.) Warnst.
56 *Rhytidium rugosum* (Hedw.) Kindb.
57 *Sanionia uncinata* (Hedw.) Loeske
58 *Scorpidium scorpioides* (Hedw.) Limpr. *
59 *Sphagnum capillifolium* (Ehrh.) Hedw.
60 *Sphagnum fuscum* (Schimp.) Klinggr.
61 *Sphagnum girgensohnii* Russ.
62 *Sphagnum squarrosum* Crome
63 *Sphagnum warnstorfii* Russ.
64 *Timmia austriaca* Hedw.
65 *Tomentypnum nitens* (Hedw.) Loeske
66 *Warnstorfia exannulata* (Schimp. *in* BSG) Loeske *
[= *Drepanocladus exannulatus* (Schimp. in BSG) Warnst]

Appendix A. Continued.

Growth Form	Botanical Name	Common Name

Liverworts

1 *Anastrophyllum minutum* (Schreb.) Schust.*
2 *Anastrophyllum saxicola* (Schrad.) Schust.*
3 *Barbilophozia barbata* (Schmid. *ex* Schreb.) Loeske*
4 *Barbilophozia lycopoidoides* (Wallr.) Loeske
5 *Chandonanthus setiformis* (Ehrh.) Lindb. *
6 *Diplophyllum taxifolium* (Wahlenb.) s.l. *
7 *Gymnomitrion corallioides* Nees *
8 *Marchantia alpestris* (Nees) Burgeff *
9 *Mesoptychia sahlbergii* (Lindb. et S. Arnell) Evans *
10 *Ptilidium ciliare* (L.) Hampe *
11 *Ptilidium pulcherrimum* (G. Web.) Hampe

Lichens

1 *Alectoria nigricans* (Ach.) Nyl.
2 *Alectoria ochroleuca* (Hoffm.) A. Massal.
3 *Asahinea chrysantha* (Tuck.) Culb. & Culb.
4 *Bryocaulon divergens* (Ach.) Kärnef. [= *Cornicularia divergens* Ach.]
5 *Bryonora castanea* (Hepp) Poelt *
6 *Cetraria cucullata* (Bellardi) Ach. *
7 *Cetraria islandica* (L.) Ach.
8 *Cetraria laevigata* Rass. *
9 *Cetraria nigricans* Nyl.
10 *Cetraria nivalis* (L.) Ach. *
11 *Cladina arbuscula/mitis* (Nyl.) Harm.
12 *Cladina rangiferina* L. (Nyl.)
13 *Cladina stellaris* (Opiz) Brodo
14 *Cladonia amaurocraea* (Flörke) Schaerer
15 *Cladonia coccifera* (L.) Willd.
16 *Cladonia cornuta* (L.) Hoffm.
17 *Cladonia fimbriata* (L.) Fr.
18 *Cladonia gracilis* (L.) Willd.
19 *Cladonia macroceras* (Delise) Ahti *
20 *Cladonia pocillum* (Ach.) O. Rich
21 *Cladonia pyxidata* (L.) Hoffm.
22 *Cladonia stricta* (Nyl.) Nyl.
23 *Cladonia subfurcata* (Nyl.) Arnold *
24 *Cladonia symphycarpa* (Ach.) Fr. *
25 *Cladonia uncialis* (L.) Weber *ex* Wigg.
26 *Dactylina arctica* (Richardson) Nyl.
27 *Dactylina madreporiformis* (Ach.) Tuck. *
28 *Dactylina ramulosa* (Hook.) Tuck.
29 *Lecanora epibryon* (Ach.) Ach. *
30 *Lobaria linita* (Ach.) Rabenh.

Appendix A. Concluded.

Growth Form	Botanical Name	Common Name
Lichens Concluded.		
31	*Nephroma arcticum* (L.) Torss.	
32	*Nephroma expallidum* (Nyl.) Nyl.	
33	*Ochrolechia frigida* (Swartz) Lynge	
34	*Ochrolechia upsaliensis* (L.) Massal.	
35	*Parmelia omphalodes* (L.) Ach.	
36	*Peltigera aphthosa* (L.) Willd.	
37	*Peltigera canina* (L.) Willd.	
38	*Peltigera leucophlebia* (Nyl.) Gylnik	
39	*Peltigera malacea* (Ach.) Funck	
40	*Peltigera scabrosa* Th. Fr.	
41	*Pertusaria dactylina* (Ach.) Nyl. *	
42	*Physconia muscigena* (Ach.) Poelt *	
43	*Pseudephebe pubescens* (L.) M. Choisy	
44	*Psoroma hypnorum* (Vahl) Gray	
45	*Solorina crocea* (L.) Ach.	
46	*Sphaerophorus globosus* (Huds.) Vainio	
47	*Stereocaulon alpinum* Laurer *ex* Funck	
48	*Stereocaulon paschale* L. Hoffm.	
49	*Stereocaulon tomentosum* Fr.	
50	*Sticta weigelii* (Ach.) Vainio *	
51	*Thamnolia subuliformis/vermicularis* (Ehrh.) Culb./(Swartz) Ach.	
53	*Varicellaria rhopocarpa* (Körber) Th. Fr. *	

* = species not found on The Nature Conservancy species list

APPENDIX B

APPENDIX C

Appendix C. Raw environmental data for Fort Richardson alpine vegetation analysis (see Table 2 for legend key.)

Relevé	Landform	Surficial Geology	Surficial Geomorphology	Site Moisture	Soil Moisture	Topographic Position	Exposure	Snow Duration	Animal/ Human Disturbance	Stability	Gravimetric Soil Moisture (%)	Relative Bulk Density	Soil pH	Slope (degrees)	Aspect (degrees)	Elevation (m)
FR-1	18	13	15	3	3	1	4	3	0	2	nd	nd	nd	30	140	1075
FR-2	1	6	15	5	4	2	1	6	3	1	nd	nd	nd	30	283	1037
FR-3	1	13	15	3	2	1	4	2	1	4	nd	nd	nd	5	70	1067
FR-4	1	1	4	4	3	1	3	2	2	1	nd	nd	nd	25	225	1021
FR-5	1	6	14	6	5	3	2	5	0	1	nd	nd	nd	5	330	724
FR-6	1	6	8	6	5	2	1	6	0	3	nd	nd	nd	20	330	777
FR-7	1	6	8	6	5	2	1	6	0	3	nd	nd	nd	20	330	777
FR-8	1	6	14	6	5	3	2	4	1	1	47	0.4	4.0	5	340	701
FR-9	1	6	3	7	7	8	2	5	1	3	128	0.5	5.9	2	310	668
FR-10	3	7	2	7	6	4	2	4	1	1	nd	nd	nd	0	--	634
FR-11	3	7	2	9	9	4	2	5	1	1	nd	nd	nd	0	--	633
FR-12	1	1	4	4	3	1	2	2	2	1	nd	nd	nd	25	225	1014
FR-13	1	1	4	4	3	1	2	2	2	1	nd	nd	nd	25	225	1006
FR-14	1	13	15	3	2	1	4	2	1	4	nd	nd	nd	5	70	1067
FR-15	1	6	15	5	4	2	1	6	3	1	nd	nd	nd	30	283	1037
FR-16	1	6	15	5	4	2	1	6	3	1	nd	nd	nd	30	283	1037
FR-17	1	6	14	6	5	3	2	5	0	1	22	0.4	4.9	5	330	732
FR-18	1	6	14	6	5	3	2	5	0	1	116	0.5	4.7	5	330	739
FR-19	1	6	8	6	5	2	1	6	0	3	85	0.4	4.6	20	330	777
FR-20	1	6	8	6	5	2	1	6	0	3	91	0.4	4.4	20	330	777
FR-21	1	6	3	7	7	8	2	5	1	3	262	0.2	5.9	2	310	666
FR-22	1	6	3	7	7	8	2	5	1	3	nd	nd	nd	2	310	665
FR-23	3	7	2	7	6	4	2	4	1	1	nd	nd	nd	0	--	634
FR-24	3	7	2	7	6	4	2	4	1	1	nd	nd	nd	0	--	634
FR-25	3	7	2	9	9	4	2	5	1	1	nd	nd	nd	0	--	633
FR-26	3	7	2	9	9	4	2	5	1	1	269	0.1	5.5	0	--	633
FR-27	3	7	2	9	9	4	2	5	1	1	nd	nd	nd	0	--	633
FR-28	1	6	14	6	5	3	2	4	1	1	55	0.4	3.9	5	340	701
FR-29	1	6	14	6	5	3	2	4	1	1	45	0.5	3.6	5	340	701
FR-30	1	1	3	6	7	2	1	6	3	1	46	0.5	4.8	20	0	1090
FR-31	1	1	14	5	7	2	2	5	3	1	209	0.1	5.9	12	315	1000
FR-32	1	6	11	4	6.5	2	3	4	2	1	58	0.5	4.2	20	315	980
FR-33	1	6	11	3	2	1	4	1	0	1	23	0.6	4.9	15	45	940
FR-34	1	1	14	4	7.5	2	2	5	2	1	129	0.4	4.2	30	315	900
FR-35	1	1	14	7	7.5	2	1	6	1	1	138	0.4	4.7	35	0	820

Appendix C. Continued.

Relevé	Land-form	Surficial Geology	Surficial Geomor-phology	Site Moisture	Soil Moisture	Topo-graphic Position	Expo-sure	Snow Dura-tion	Animal/ Human Disturbance	Stability	Gravimetric Soil Moisture (%)	Relative Bulk Density	Soil pH	Slope (degrees)	Aspect (degrees)	Eleva-tion (m)
FR-36	1	1	14	5	3	2	1	5	0	1	37	0.4	4.9	15	270	800
FR-37	1	1	11	6	3.5	3	2	5	0	1	71	0.2	5.2	30	315	780
FR-38	1	1	14	4.5	3	2	2	5	2	1	92	0.2	3.7	5	337	740
FR-39	6	5	11	7	3	5	2	4	1	4	57	0.5	5.7	40	0	710
FR-40	1	1	11	6	3	3	2	4	1	1	109	0.2	4.8	5	292	690
FR-41	1	1	3	5	2.5	2	1	5	3	1	105	0.3	4.4	5	337	720
FR-42	1	1	10.5	5	7	3	2	4	0	1	126	0.4	4.2	nd	nd	660
FR-43	1	1	11	7	6	4	1	5	0	1	nd	nd	nd	0	--	690
FR-44	1	1	11	5	2	3	2	4	3	1	nd	nd	5.8	20	0	720
FR-45	1	6	3	6	5	2	1.5	7	1.5	3	154	0.2	4.2	10	290	808
FR-46	1	1	14	5	4	2	2.5	3	1	1	86	0.4	4.0	nd	315	808
FR-47	3	1	3	7	8	6	2	4	6	2	nd	nd	nd	2	270	792
FR-48	6	5	14	7	5	5	2	4	0	4	183	0.2	4.8	0	--	747
FR-49	1	5	12	6	4	5	2	4	0	2	106	0.2	5.1	25	100	747
FR-50	1	6	11	4	3	2	3	2	6	1	19	0.7	4.6	30	90	747
FR-51	1	6	15	4	2	1	4	3	1	3	5	1.0	5.5	nd	nd	1646
FR-52	1	6	3	6	6	2	1	5	2	1	72	0.4	4.1	15	34	1311
FR-53	1	6	11	4	4.5	1	3	2	1	1	21	0.9	4.7	5	5	1311
FR-54	6	5	14	7.5	9	5	1.5	4	1	4	341	0.2	6.2	0	--	808
FR-55	1	1	14	4	3	1	3	3	1	1	57	0.5	4.2	4	34	808
FR-56a	1	1	3	6	6	5	1.5	5	1	1	140	0.3	3.8	7	20	808
FR-56b	1	1	3	6	6	5	1.5	5	1	1	140	0.3	3.8	7	20	808
FR-57	6	5	11	7.5	8	5	1	5	2	4	130	0.3	6.4	nd	nd	823
FR-58	1	13	11	3	2	1	4	1	0	1	45	0.7	4.2	0	0	1000
FR-59	1	1	14	6		2	2	5	1	1	67	0.5	4.5	28	225	900
FR-60	1	1	14	6		2	2	5	1	1	65	0.4	4.6	28	225	914
FR-61	1	1	14	6	3	3	2	5	1	1	82	0.3	4.5	10	135	762
FR-62	1	1	14	4.5	3	2	1	5	0	1	325	0.1	5.7	15	315	716
FR-63	1	1	11	5	6.5	6	2	6	3	1	72	0.3	3.4	0	--	716

Appendix C. Concluded.

Relevé	Land-form	Surficial Geology	Surficial Geomor-phology	Site Moisture	Soil Moisture	Topo-graphic Position	Expo-sure	Snow Dura-tion	Animal/ Human Disturbance	Stability	Gravimetric Soil Moisture (%)	Relative Bulk Density	Soil pH	Slope (degrees)	Aspect (degrees)	Eleva-tion (m)
FR-64	1	1	14	5	3	3	1	5	1	1	149	0.2	4.3	4	292	686
FR-65	1	1	14	6	7	6	1	6	1	1	nd	nd	nd	0	--	634
FR-66	1	13	11	3	1	1	4	1	0	1	41	0.6	4.5	0	--	1075
FR-68	1	6	11	4	1.5	2	3	4	2	1	184	0.3	4.4	22	180	1000
FR-69	1	6	11	4	1.5	2	3	3	3	1	114	0.3	4.8	18	180	1100

nd = no data

APPENDIX D

APPENDIX D

MCVEIGH VALLEY RIDGE POLSTER PERCENTAGE DATA

Sample No.	*Picea*	*Pinus*	*Alnus*	*Betula*	Ericales	*Myrica*	*Salix*	Cyperaceae	Poaceae	*Artemisia*	*Campanula*	Caryophyllaceae	Comp.-Tub.
1-1	1.2	0.5	41.7	27	1.9	0	6.8	0.2	3.5	0.9	1.2	0.2	1.6
1-2	4.4	0	47.7	29.8	3.8	0	3.5	0.9	5.3	0.6	0	0.3	0
1-3	5.3	0.3	36.9	16.6	1.3	0.3	2.2	1.9	2.2	0.6	0.3	0	0
3-1	1.8	0.3	44.1	27	4.8	0	0.8	0.3	5.1	0.3	0	0	0
3-2	2.9	0.2	53.1	21.3	2.4	0	0.5	0.5	4.6	0.65	0	0	0
3-3	5.3	0	42.4	35.1	2.9	0	0.3	0.6	3.2	0.3	0	0	0
5-1	1.9	0.2	48.2	29.6	3.1	0	0.2	0.5	2.2	0.2	0	0	0
5-2	1.9	0.2	53.5	23.6	3.4	0	0.2	0.7	1.2	0.2	0	0	0
5-3	1.1	0	50.4	29.5	7.1	0	0	0.8	3.7	0	0	0	0
6-1	1.1	0	38.7	28.6	9.1	0	0.8	0	2.2	0.5	0	0	1.4
6-2	3.8	0	36.5	22.3	15.1	0	0	0.8	2.5	0.3	0	0	0
7-1	1.2	3.3	28.8	20.9	18.2	0	0.7	3	1	1	0	0	0.7
7-2	1.9	3.1	30.8	13.7	0.8	0	2.2	0.8	1.7	0.6	0	0	0.3

APPENDIX D

MCVEIGH VALLEY RIDGE POLSTER PERCENTAGE DATA

Cornus	*Dryas*	*Galium*	Leguminosae	*Pedicularis*	*Polemonium*	*Potentilla*	Ranunculaceae	Rosacaee	Saxifragaceae	Umbelliferae	Unknown
0	0	0	0	0	0	0.2	0.2	0.9	0	0.2	0.5
0	0.6	0	0	0.3	0	0	0	0	0	0	0
0	18.1	0	0	0	0	0	0.3	0	0	0	0
0	0	0	0	0.8	0	0.3	0.3	0.3	0	0	0.3
0	0	0	0.3	0.2	0	0	0	0	0	0	0
0	1.5	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	0.2
0	0	0	0	0	0	0	0	0	0.3	0	0
0	0	0	0.3	0	0	0	0	0	0.8	0	0
0	0	0	0	0	0.3	0	0	0.3	0	0.3	0
0.3	0	0	0.3	0	0	0	1	1.3	0.3	0.3	0.7
1.1	0	1.2	0	0	0.3	0	0.8	1.4	0	0.8	0

APPENDIX D
MCVEIGH VALLEY RIDGE POLSTER PERCENTAGE DATA

Equisetum	Filicales	*L. annotinum*	*L. selago*	*Sphagnum*
0	10.7	0.2	0.2	0
0	12.3	0.6	0	0.3
0.3	12.8	0	0.3	0.6
0.8	12.2	0.5	0	0.5
0	12.3	1.2	0	0.2
0.3	7.6	0.6	0	0.6
0	12	1.4	0	0.2
0.2	14	0.5	0.2	0.2
0	6.8	0.3	0	0
0	14.3	2.2	0	0.5
0.3	15.4	2.2	0	0
1	5.6	2.3	0	0.3
0	19.3	1.1	0	0

APPENDIX E

APPENDIX E
INFANTRY FLATS POLSTER PERCENTAGE DATA

Sample No.	*Abies*	*Juniperus*	*Larix*	*Picea*	*Pinus*	*Tsuga*	*Alnus*	*Betula*	Ericales	*Salix*	Cyperaceae	Poaceae	*Artemisia*	*Campanula*
1-1	0	0	0	4	0	0	29.6	38.9	0.9	4.6	0.3	5.6	0.3	0
1-2	0	0	0	9.2	0	0	40.3	20.7	0.7	2	0.7	4.6	0.7	0
1-3	0	0	0	7	0	0	38.7	22	1	1.9	0.3	4.2	0.6	0
3-1	0	0	0	3	0.3	0	39.3	17.7	1.7	1.7	1.3	11.7	0	0
3-2	0	0	0.6	3.2	0.3	0	15.3	58.6	4.5	3.2	2.2	2.2	0.3	0
3-3	0	0	0	6.8	0	0	39.5	23.6	1.9	2.3	2.6	2.6	0.3	0
4-1	0	0	0	4	0	0	38.5	26.5	0	0.3	0.9	0.9	0.9	0
4-2	0	0	0	1	0.7	0	49.5	26.8	3.3	0.3	0.7	0.7	0.3	0
4-3	0	2.5	0	12.1	0.6	0.3	36.5	13.7	6	1.6	1.3	1.3	0.3	0.3
6-1	0	0	0	3.1	0	0	41.2	28.3	8.4	1.1	1.4	1.4	0.8	0
6-2	0	0	0	9.6	0	0	43.3	17.3	5.7	1.5	5.7	5.7	0.9	0
6-4	0	0	0	4.8	1	0	49.8	23.2	3.9	0.3	4.8	4.8	0.7	0
7-2	0	0	0	7.9	1.9	0	61	15.3	0.3	0	1.9	1.6	0	0
7-3	0.3	0	0	11.7	1.6	0	45.2	20.7	0.8	0.8	3.8	3	0	0

APPENDIX E
INFANTRY FLATS POLSTER PERCENTAGE DATA

Chenopod	Comp.-Tub.	*Cornus*	*Galium*	Liliaceae	*Pedicularis*	*Potentilla*	Rosaceae	*R. chamaemorus*	*Sanguisorba*	*Triglochin*	Umbelliferae	*Valeriana*
0	0	0	0	0	0.3	0	0	0	1.2	0	0	0
0.3	0	0	0	0	0.7	0.7	0	1	0.7	0	0.3	0
0	0	0	0	0	0	0	0	0	0	0.3	1.6	0
0	0.7	0	0	0	0.7	1	1	0	0.3	0	0	0
0	0.6	0	0	0	0	0	0	0	1	0	0	0
0	0	0	0	0	0	0	1.3	0.3	0	0	0	0
0	0	0	0	0	0.3	0	0	0.3	0	0	0	0
0	0	0	0	0	0	0	0.3	0	0	0	0	0.3
0	0.3	12.7	0	0	0.6	0	0.3	0	0.3	0	1.6	0
0	0	0	0	0	0.6	0	0	0	0	0	0	0
0	0.3	0	0	0	0	0	0	0	0.6	0	0	0
0	0.3	0	0	0	0	0	0	0	0	0	0	0
0	0	0	0.3	0	0	0	0	0	0	0	0	0
0	0	0	0.5	0.3	0.3	0	0.5	0	0	0.5	0.3	0

Unknown	*Equisetum*	Filicales	*L. annotinum*	*Sphagnum*
0.3	1.9	9.6	2.5	0
1	1	13.1	1.6	1
0.3	0	17.3	1.6	2.2
0.3	2.7	15	1	0.3
0.6	1.6	4.5	0.3	1
0.3	8.7	9.4	0.3	1.3
0.3	0	14.8	1.5	0
0	0	14.4	1.3	0
0.3	0	11.5	0.6	0
0	0	12.3	2.2	0.3
0	0	12.2	1.8	0.3
0	0	9.6	0.7	0.7
0	0	7.5	1.6	0.6
0	0.5	7.1	0.5	0.8

APPENDIX F

APPENDIX F
OTTER LAKE GRAVEL PIT
PERCENTAGE DATA

Sample No.	*Picea*	*Pinus*	*Populus*	*Alnus*	*Betula*	Ericales	*Salix*	Cyperaceae	Poaceae	*Artemisia*	Comp.-Tub.	*Epilobium*
Polster	49	0	0.5	25.1	58.9	0.3	0.5	0.3	3.5	0	0.5	0
2-1	20.5	0.6	0	13.3	54.5	0.3	0.3	0	1	0.3	0	0
2-2	0	0	0	0	0	0.7	0	0.7	0.7	0	0.3	0
2-3	0	0	0	0	0	0	0	0	0	0	0	0.7

Sample No.	Filicales	*L. annotinum*	*Sphagnum*
Polster	4.6	0.8	0
2-1	6.8	2.3	1.6
2-2	87.1	10.5	0
2-3	88.2	11.1	0

APPENDIX G

APPENDIX G
INFANTRY FLATS FEN
PERCENTAGE DATA

Depth (cm)	*B. papyrifera*	*Picea*	*Pinus*	*Alnus*	*Betula*	Ericales	*Salix*	*Artemisia*	Caryophyllaceae	Comp.-Tub.	*Galium*	Liliaceae	*Pedicularis*
0	0	18.8	1.3	26.8	16.3	0.3	1.3	1.3	0	0	0.3	0	0.3
10	0.3	18.2	1.3	21.9	19.4	1.3	1.3	0.3	0	0.3	0	0.3	0
20	0.3	12.3	0.9	23	24.5	1.2	0.9	0.3	0	0	0	0.3	0.3
30	0.3	14.4	0	25.2	22.3	0.6	0.6	0	0	0	0.3	0	0
40	0	10.6	0.7	21.2	18.2	0.3	1.7	0.3	0	0	0	0	0
50	0	14.2	0.3	20	16.6	0.3	1.5	0.3	0	0	0.3	0	0.3
65	0	15.5	0.7	16.1	11.2	1	0.7	1	0	0	0.3	0	0
70	0	12.8	0	13.8	16.1	1	1.6	0.7	0	0	0.7	0	0
80	0	13	0.7	14.3	18	1	1.3	1	0	0.3	0.3	0	0
90	0	11.3	0.6	14.9	14.2	0.6	0.6	0	0	0	0	0	0
100	0	10	0.3	15.9	15.3	0.3	0.7	1.3	0	0.3	0.3	0	0
110	0	16.6	1.3	15.6	13.2	0	0.3	0.3	0	0.3	0	0	0
120	0	14.2	0.3	20	16.6	0.3	1.5	0.3	0	0	0.3	0	0.3
130	0	11.5	0	14.6	21.1	0.9	0.9	0.6	0	0.3	0	0	0.3
140	0	11.8	1.2	17.4	19.6	0.3	1.6	0.6	0	0	0.3	0.3	0
150	0	11.1	1	15.3	17.6	1	1.3	0.7	0	0	0	0	0.3
160	0.3	9.6	1	12.2	14.4	1.6	1	0.6	0.3	0.6	0	0	0
170	0	2.5	0.3	3.5	4.1	1	0.6	0	0	0	0	0.3	0
185	0	0	0.3	1.3	3.3	0.3	1.3	0.7	0	0.3	0	0	0.3

APPENDIX G
INFANTRY FLATS FEN
PERCENTAGE DATA

Cyperaceae	Poaceae	*Polemonium*	*Potentilla*	Ranunculaceae	Rosaceae	*R. chamaemorus*	Saxifragaceae	*Triglochin*	Umbelliferae	Unknown	*Equisetum*
9.9	1	0	0	0	0.3	0	0	0.3	0	0	0.3
12.2	0.9	0	0	0	0.6	0	0	0.6	0	0	0.6
18.4	0.9	0	0.3	0	0	0	0.3	0.9	0	0.3	0.6
15.7	1.3	0	0.6	0	0.3	0	0	1	0	0	0
14.6	2	0	0	0	0.3	0	0	0.7	0	0	0.3
10.6	0.3	0	0.3	0	0.3	0	0	0	0.6	0.3	0.9
13.2	1.6	0	0.3	0.3	0	0	0	0.3	0.3	0	0
15.4	1	0	0	0	0	0	0	0	0.3	0.3	0
11.3	0.3	0.3	0.3	0	0.3	0	0	0	0.3	0	0.3
7.1	1	0.3	0.3	0.3	0	0	0	0	0	0.3	0.3
10.6	1.7	0	0.3	0	0	0	0	0.3	0.3	0.3	0.3
5	1	0.3	0	0	0	0	0	0	0	0	0
10.6	0.3	0	0.3	0	0.3	0	0	0	0.6	0.3	0.9
23.2	0.9	0	0.3	0.3	0.6	0	0	0.3	0	0	0.6
15.2	1.2	0	0	0	0.3	0.3	0	1.2	0	0	0.9
16	1.6	0	0	0.7	0.3	0	0	0.7	0	0	0.3
8.3	1.9	0	0.3	0	0	0	0	0.6	0.6	0	0.6
2.2	1	0	0	0	0.6	0	0	0	0	0	0.6
5.9	0.3	0	0	0	0.3	0	0	0	0	0.3	0

APPENDIX G
INFANTRY FLATS FEN
PERCENTAGE DATA

Filicales	*L. annotinum*	*L. clavatum*	*L. selago*	*Polypodium*	*S. selaginoides*	*Sphagnum*	Total Pollen Concentration
24	3.2	0	0	0	1.5	2.6	176592
26	2.8	0	0	0	1.3	2.5	215532
27.9	1.8	0	0	0	0.3	2.1	358787
24.8	2.9	0	0.3	0	1	3.8	473184
35.8	3.6	0	0	0	1.3	3	211743
37.2	2.7	0	0	0	1.8	1.8	179766
40.1	4.6	0	0	0	1.6	4.3	429454
43	2.6	0	0	0	1.6	4.6	298930
40.3	4.3	0	0	0	0.7	2.7	282493
47.6	6.4	0	0	0	0.6	0.3	98564
45.8	3.3	0	0.3	0	1	1.7	213743
37.4	9.9	0.3	0	0	2	1.3	121543
37.2	2.7	0	0	0	1.8	1.8	242729
34.1	6.2	0.3	0	0.3	3.7	2.2	306390
35.1	2.5	0	0	0	2.5	2.8	172509
39.1	4.9	0	0	0	1	3.3	337475
41	7.1	0.3	0	0	2.6	3.2	183090
73.2	7.3	0	0.3	0	3.8	0.6	163655
67.3	15.8	0	0	0	5	3	73540