ABSTRACT

A GEOBOTANICAL STUDY IN THE ATLIN REGION IN NORTHWESTERN BRITISH COLUMBIA AND SOUTH-CENTRAL YUKON TERRITORY

By

James Hugh Anderson

A vegetation and palynological study was conducted in the Atlin region, northwestern British Columbia/south-central Yukon Territory, with emphasis on the glaciated Atlin Lake valley. Results include a preliminary catalog of plants, descriptive analyses of upland plant communities, a discussion of the regional importance of various arboreal species, qualitative descriptions of bog plant communities, a vegetation-pollen rain comparison, and five radiocarbon-dated pollen and spore diagrams and a late Pleistocene-Holocene geobotanical chronology based upon them.

The catalog of plants is believed to be the first for the Atlin region but is only preliminary since most collecting was secondary to other activities. Included are 11 lichen, 14 bryophyte, and 237 vascular species and subspecies.

A general vegetation survey, incorporating a modification of methods of the Braun-Blanquet school, has made possible the definition of 12 upland plant communities lying between the valley floor at 2,200 ft ASL and the 3,000 ft level on the valley side slopes. In descending order of areal importance these are: (1) mixedwood forest association, (2) white spruce association/shrub-herb faciation, (3) aspen

association, (4) white spruce association/feather moss faciation, the climatic climax vegetation on mesic sites, (5) lodgepole pine brûlé (associes), (6) white spruce-lodgepole pine association, (7) lodgepole pine association, (8) herb-heath association, (9) white spruce brûlé (associes), (10) depression shrub association, (11) mixed woodland association, and (12) alpine fir association. In addition, lodgepole pine-lichen woodland, mixed coniferous forest, and, above the 4,000-4,200 ft timberline, spruce-fir woodland, shrub tundra, herbaceous tundra, and fell-field vegetation types are recognized.

A tree survey utilizing the point-quarter technique yielded frequency and basal area data for regional forest trees at lower elevations. On the basis of these data the trees can be arranged in descending order of importance as follows: white spruce, aspen, lodgepole pine, fire-killed pine, tree willow, balsam poplar, fire-killed spruce, alpine fir, alder.

Six bogs in various parts of the Atlin valley were studied. Nine roughly concentric bog vegetation zones, occurring along a hygric-mesic moisture gradient, are recognized, any two or more of which may occur in a given bog. Classified in terms of dominant plants, these are the *Carex aquatilis*-*Drepanocladus* spp., *Carex aquatilis*, *Scirpus validus*, *Salix* spp., *Salix* spp.-*Betula glandulosa*, *Picea glauca*-*Salix* spp., and three Gramineae zones.

Comparisons of bog surface sample pollen spectra with tree survey basal area data and qualitative vegetation information show that certain aspects of bog and local vs. regional upland vegetation may be distinguished in the pollen record. It is believed that the most reliable interpretations are those of regional vegetation based on composite spectra from several bogs.

The palynological record helps clarify the Holocene phytogeography of white spruce and lodgepole pine. In addition, it permits construction of a tentative, nine-zone geobotanical chronology for the Atlin region. Major features of each zone, including time in years B.P., regional vegetation type, climatic characterization relative to the present (considered warm/wet), and suggested glacial activity are as follows: (IX) ≥11,000-10,500; shrub tundra; cooler/drier; stillstand at late Wisconsinan maximum. (VIII) 10,500 (Holocene boundary)-10,000; spruce woodland; cool/dry; retreat. (VII) 10,000-9,000; shrub tundra; cooler/drier; stillstand. (VI) 9,000-8,000; spruce woodland; cool/dry; intermittent retreat. (V) 8,000-5,500; spruce forest; warm/wet; general retreat. (IV) 5,500-3,250; spruce forest with alder; warmer/wetter; maximum retreat. (III) 3,250-2,500; spruce forest with fir; warm/wet. (II) 2,500-750; spruce forest with pine; cool/dry; Neoglacial advances. (I) 750-0; spruce forest with pine; warm/wet; minor retreat.

A GEOBOTANICAL STUDY IN THE ATLIN REGION IN NORTHWESTERN BRITISH COLUMBIA AND SOUTH-CENTRAL YUKON TERRITORY

By

James Hugh Anderson

A THESIS

Submitted to
Michigan State University
in partial fulfillment of the requirements
for the degree of

DOCTOR OF PHILOSOPHY

Department of Botany and Plant Pathology

1970

This dissertation

is respectfully dedicated to my stepmother

Ione H. Anderson

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I have been unusually fortunate in terms of assistance and guidance in carrying out the Atlin project. A considerable number of outstanding individuals have been involved at various times, and I feel deeply indebted to each of them.

In 1966 I was ably assisted in the field by Bob Dilts, Dudley Field, Bert Useem, and Dave Lietzke. Dave later made available results of his soil studies, some incorporated herein, and I thank him for this.

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To Ann Tallman, Ken Johnson, Ross Mack, Stan Miller, Barry Prather, and Tink Taylor I extend my warmest regards for their help in many and various ways.

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I gratefully acknowledge receipt of a Grant in Aid of Research from The Society of the Sigma Xi. The University of Michigan Memorial-Phoenix Project Laboratory provided radiocarbon dating services for which I am also grateful.

I apologize to all of my students for a second-rate job of teaching, resulting from preoccupation with the Atlin project, during two years as an Instructor at Michigan State University.

My deepest and everlasting appreciation is extended to the members of my doctoral guidance committee for their valued counsel, intellectual discourse, and assistance in

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I hold in highest esteem Dr. Cross' efforts in furthering the Atlin project and his concern for and contributions to my education since our first meeting on the Juneau Icefield when I was still an undergraduate. Of equal regard is the long-time, unrelenting encouragement and the generosity of Dr. Miller in support of my work. He has provided the lion's share of financial and logistical aid with his grants from the National Geographic Society and with funds and facilities of the Foundation for Glacier and Environmental Research of which he is director. The value of my association with these two great men in numerous classroom and field situations is inestimable.

In spite of all this, weaknesses, idiosyncracies, and errors in this dissertation are my sole responsibility.

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INTRODUCTION

The topic of this dissertation is the vegetation and the Holocene geobotanical history of the Atlin region in northwestern British Columbia and southwestern Yukon Territory. Emphasis is placed on the Atlin valley where the bulk of the field work was carried out (Fig. 1).

Specific contributions include the following: (1) a preliminary catalog of the flora, including 262 species and subspecies (Appendix F), (2) an analysis and definition of upland plant communities based on an original modification of methods of the Braun-Blanquet school, (3) a discussion of the regional importance of arboreal species based on a tree survey utilizing the point-quarter method, (4) a qualitative description of bog plant communities and vegetation zonation, (5) an analysis of relationships between vegetation and pollen rain, (6) five radiocarbon-dated pollen and spore diagrams, and (7) a tentative Holocene geobotanical chronology for the Atlin region, based on interpretations of these diagrams and incorporating aspects of Holocene climates, glaciation and glacial geology, phytogeography, and cliseral development of major vegetation types (Fig. 32).

The term "Holocene" is used here to designate the interval between the present and the time in the past when certain climatic changes initiated world-wide retreat of the latest

substage of Wisconsinan glacial ice. The Holocene is considered to be the second of two chronological subdivisions of epoch rank of the Quaternary Period, the first being the Pleistocene Epoch. "Holocene" replaces the older term "Recent", but not "postglacial" (or "post-Glacial") which is considered to be a landscape and ecological term (Neustadt, 1967). The term "postglacial" is used in this dissertation in reference to geobotanical features of the Atlin region following deglaciation. The present usage of "Holocene" is consistent with much current thinking in the field of Quaternary paleoecology. Unequivocal use is made of the term by Ritchie (1964, 1967, 1969) in his palynological studies in west-central Canada, by Terasmae (1967d), by Leopold (1967), and by several Russian authors in a volume edited by Cushing and Wright (1967). The term was officially endorsed by the American Committee on Stratigraphic Nomenclature in 1967, and its use has been officially adopted by the United States Geological Survey (Cohee, 1968).

The discovery of gold in the Atlin region in 1896 stimulated early geological studies (Gwillim, 1901; Cairnes, 1913; Cockfield, 1925). More recent work has provided detailed information on bedrock geology over a broader area (Aitken, 1959; Wheeler, 1961; Mulligan, 1963; Monger, 1968). Glacial geology has been dealt with by these authors and others cited below only in a general way. Observations by the writer indicate a complex late Quaternary history of glacial erosion and deposition, and an attempt will be made to relate some of this activity to the geobotanical chronology established for the Atlin region (Fig. 32).

The Atlin region centers on Atlin Lake and Little Atlin Lake in the far northwestern corner of British Columbia (exclusive of the northwesternmost "peninsula" of the province) and the adjacent south-central portion of Yukon Territory (Fig. 1). For present purposes the region is considered, somewhat arbitrarily, to comprise the area between latitude 59°00' and 60°30' N and longitude 132°30' and 134°30' W. Atlin Lake is nearly 65 miles long, averages about two and one-half miles in width, and lies at a mean elevation of 2,197 ft.

The village of Atlin (Fig. 3) formerly a lively center of gold mining activity, is located about midway on the eastern shore of Atlin Lake. In 1899 Atlin and the mining camps of the surrounding Atlin district had a population peak of about 5,000 people (Bilsland, 1952), but at the present time Atlin's population is approximately 150. It is the only populated place in the study area.

An all-weather gravel road extends 60 miles from Jake's Corner, at mile 866 on the Alaska Highway, south to Atlin. For purposes of convenience in this dissertation, the Atlin road is defined as the Atlin road proper, plus the approximately 22 miles of road south and east from Atlin to the abandoned mining town of O'Donnel.

Several gravel and dirt mining roads radiate northeast, east, and south from the vicinity of the town. Most of these have remained passable by truck, and renewed mining activity in the past few years has brought about the improvement of some of them as well as the construction of a few additional miles. Access to more remote places can be made by float plane from Atlin. An old trail, the Ashcroft-Yukon telegraph-line trail, built in 1901, traverses the region from southeast to northwest, but is mostly grown over now. Much of the region, except for poorly drained valley bottoms, is passable on foot and horseback.

Groceries, mechanical repairs, and other major supplies can be obtained in Whitehorse, Yukon Territory, 110 miles from Atlin. Whitehorse lies at mile 916 on the Alaska Highway. Minor items can be bought at several stores in Atlin.

The writer's attention was first drawn to the Atlin region during a 1961 expedition to the Juneau Icefield in the nearby Northern Boundary Range. In late August, 1965, a brief reconnaissance trip was made by car into the region to explore the possibility of developing a geobotanical research project there. At that time initial impressions on the nature of the vegetation and glacial geology were developed, several bogs for palynological study were located, and a few vascular plants were collected. It was decided that a considerable amount of work could be done in the region because of the lack of human disturbance of the vegetation and glacial deposits in most areas, the existence of a number of

bogs, and the relative simplicity of logistics. Furthermore, it was concluded that the development of a research project would be especially desirable in view of the scarcity of previous botanical, ecological, paleoecological, and glacial geological studies in the region.

In 1966 two and one-half weeks were spent collecting plants, sampling bogs, and outlining the basic nature of the plant communities in the Atlin valley. With float plane support a reconnaissance was carried out in the tributary valleys of Kuthai and Simpson Lakes south of O'Donnel in conjunction with glacial geological and pedological studies of several field associates.

In 1967 field work totaled seven weeks, from 23 June to 11 July and from 14 August to 12 September. Further plant collections were made and additional bogs were sampled for palynological purposes, including Mile 47, Mile 52, and Jasper Creek Bogs. The major activities of this summer involved two different vegetation surveys carried out along a 75 mile north-south transect of the Atlin valley, from a point about two miles northwest of Little Atlin Lake southward nearly to the O'Donnel River. One of these, the general vegetation survey, involved an application of field methods of the Braun-Blanquet school to the study of plant communities distributed along the transect. The other, the tree survey, concentrated on trees and utilized the point-quarter method to obtain data on the composition of the arboreal stratum and the distribution and relative importance of the various tree species in terms of relative area occupied and pollen production.

Laboratory analyses were carried out between October, 1967, and June, 1968, including preparations and counting of palynological samples and identification of a portion of the plants collected.

In the summer of 1968 about ten more days were devoted to field work in the Atlin region. Two new bogs were located and sampled (Mile 16 and Wilson Creek Bogs) and a third was resampled (Moose Bones Bog[1]). Additional ecological observations were made, and a few trips were carried out with a four-wheeldrive vehicle and by foot into the higher alpine areas for plant collecting and geobotanical reconnaissance. The Llewellyn Glacier terminus and its valley train at the south end of Atlin Lake (Fig. 4) were also visited, where observations were made regarding the distribution of alpine fir and ideas for future research on plant succession were developed. In addition, two three-hour flights were made over a large area south and east of Atlin Lake for vegetation observations and aerial photography.

Between January and June, 1969, a major portion of the palynological laboratory work was carried out, including the preparation of pollen diagrams. During this period additional plants were identified and some were sent away for examination by specialists.

In this dissertation English units of measure are used for geographic distances and elevations and in the vegetation surveys. Metric units are used in the vegetation zonation study of Moose Bones Bog as well as in the palynological investigations.

In the palynology section "years B.P." means "years before present", where "present" is taken as 1950 A.D.

All photographs used in this dissertation are from 35 mm Kodachrome slides and were taken by the writer unless otherwise indicated.

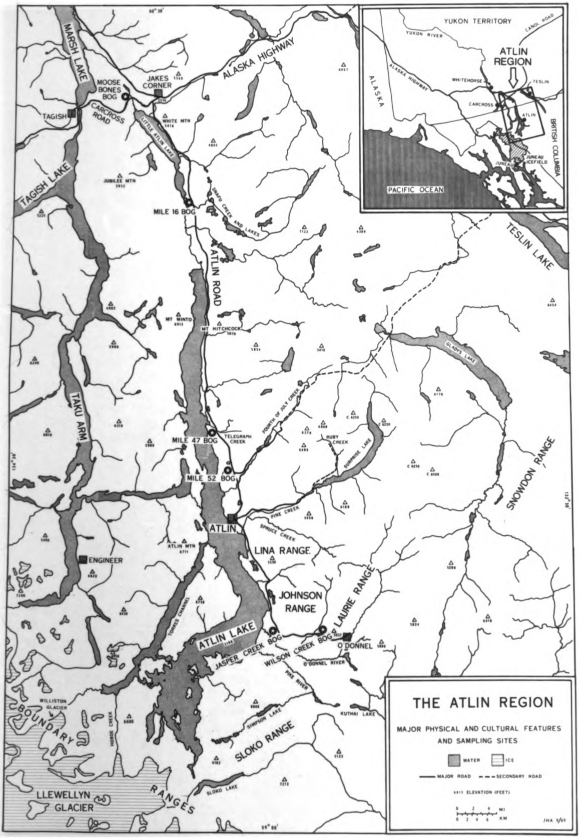
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Figure 1

Figure 2. View south in the Atlin valley from a short distance west of the Atlin road at mile 22.6.

On the skyline at the left are lower slopes of Mt. Hitchcock. The two mountains in the distance to the left of center bearing snow patches are Birch Mountain (6,758 ft) on Teresa Island and Atlin Mountain (6,711 ft). Mt. Minto (6,913 ft) is at the right of the view. Atlin Lake lies across the center and its northern shore extends from the center to the right edge of the view. The distance from the viewpoint to the lake is three miles.

In the immediate foreground is a portion of the edge of a large kame terrace, approximately 2,450 ft in elevation. The forested terrain in the middleground averages approximately 2,250 ft, and the lake, 2,197 ft in elevation.

The kame terrace is made of a loose, sandy and gravelly drift and is quite pervious. The vegetation here is primarily herbaceous and is classified in the herb-heath association. This community type is discussed on pages 104-105. Besides the well-drained nature of the substrate, strong winds blowing up the long reach of the lake and striking the edge of the terrace are considered instrumental in the persistence of this vegetation type. These winds may (1) exert a desiccative influence, (2) carry most tree seeds over and beyond the site, and (3) cause fires to burn with greater intensity here, thereby preventing arboreal species from becoming established. The edge of a mature lodgepole pine forest which occupies most of the terrace north to mile 13 occurs about 100 ft from the edge shown (behind the photographer).

The forest vegetation shown is of three tones. At the base of the slope in the foreground the medium-toned trees are lodgepole pine. The lighter vegetation is aspen, and the darkest-toned trees, scattered through the aspen and forming closed stands over the majority of the area beyond, are white spruce. The several topographic swells closer to the lake bear herb-heath vegetation and various mixtures of willow and young aspen.

Early afternoon. 10 July 1967.

Figure 2. View south in the Atlin valley from a short distance west of the Atlin road at mile 22.6.

Figure 3. Atlin village, Atlin Lake and surrounding terrain and vegetation.

The Johnson Range with Sentinel Mountain (6,316 ft) near the far end is on the left, and Mt. McCallum (6,046 ft) and the Sloko Range are in the right background. The low area extending eastward between these ranges, from the edge of the most distant visible part of the lake, is the O'Donnel-Pike River transection valley. Jasper Creek Bog is located in this area.

The light patches in the left distance are exposed bedrock. Patchy stands of vegetation in this area are various mixtures of shrub willow and several arboreal species, in cluding white spruce, lodgepole pine, and aspen. This is similar to the immediate foreground where bedrock projects through a thin, immature soil bearing an herb-heath vegetation type. Most of the vegetation between here and the dark-toned spruce across the middleground is aspen, the lightest elements being aspen which has turned a golden fall color.

Elevation of the viewpoint is approximately 2,700 ft.

Late afternoon. 10 September 1968.

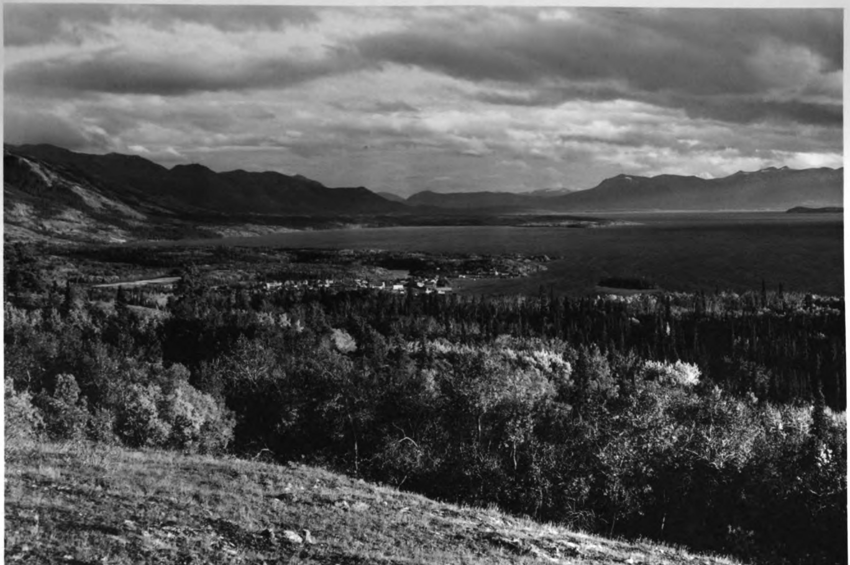

Figure 3. Atlin village, Atlin Lake, and adjacent terrain and vegetation.

Figure 4. Terminus of Llewellyn Glacier and adjacent terrain.

View south from a high bedrock ridge at south end of Llewellyn Inlet showing the western lobe of the main terminus of the Llewellyn Glacier. The elevation of the viewpoint is about 2,600 ft, and the lake at the ice front is approximately 2,250 ft. The distance to the ice front is approximately two miles. The mountains in the background are of the Northern Boundary Range, the highest being about 7,200 ft.

The trees in the foreground are alpine fir. Vegetation on the glacial outwash below includes dark-toned patches of willow and alder and a number of scattered spruce seedlings and saplings on the right. The medium-toned vegetation in the vicinity of the nearer lake probably consists mainly of sedges and mosses. Most of the lighter portion of the outwash is devoid of vegetation.

The lower slopes in the right middleground bear both white spruce and alpine fir. Although a distinct trimline occurs on valley walls above other terminal lobes of the Llewellyn Glacier, one was not produced on the slope shown here.

Mid-morning. 8 August 1968.

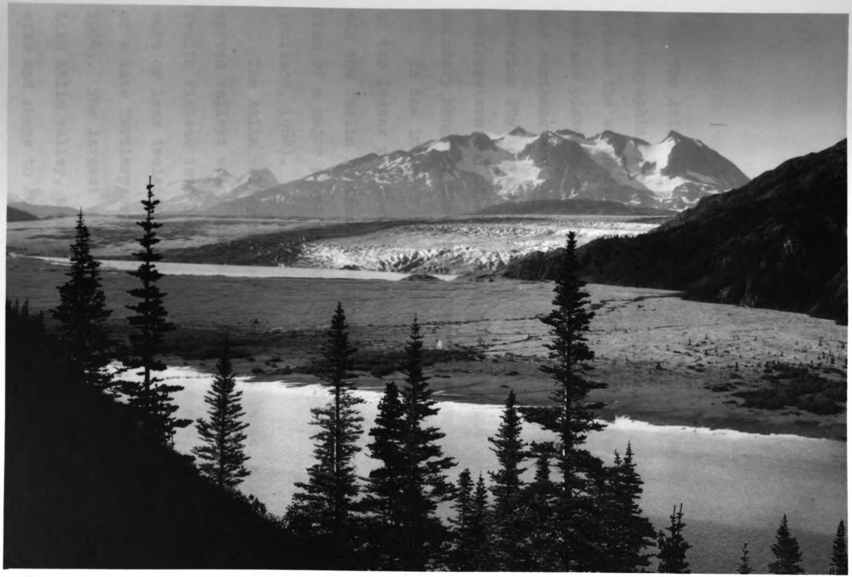

Figure 4. Terminus of Llewellyn Glacier and adjacent terrain.

PHYSICAL SETTING

I. PHYSIOGRAPHIC DELINEATION

The Atlin region lies within the Canadian Cordilleran Physiographic Province (Bostock, 1948). This province comprises the extensive system of mountain ranges and intermontane plateaus and valleys occupying westernmost Canada and southeastern Alaska. Most of the Atlin region is in the Interior Physiographic System of this province, with the southwestern end of Atlin Lake extending into the northern Boundary Range of the Western Physiographic System.

In the Interior System the Atlin valley occupies parts of two lesser physiographic subdivisions, the Tagish Highland and the Teslin Plateau. These make up the southcentral portion of a major physiographic subdivision, the Yukon Plateau (Holland, 1964).

The Atlin valley is one of several large, glacier-carved valleys which dissect the Tagish Highland and the Teslin Plateau into large, upland blocks and tablelands, more or less isolated highland massifs which are remnants of a late Tertiary erosion surface (Aitken, 1959; Holland, 1964). The largest valleys trend generally north-south. Like Atlin valley, they contain large lakes comparable in size and shape to Atlin Lake. The Lakes range in elevation

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from the 2,151 ft of Tagish Lake and 2,197 ft of Atlin Lake to 2,985 ft at Surprise Lake. The intervening highlands lie at elevations between 5,000 and 6,000 ft, with individual peaks rising several hundred feet higher. The highest mountain in the immediate study area is Mount Minto at 6,913 ft.

The Atlin valley is recognized here as a minor physiographic unit, delimited by mountains and highlands surrounding Atlin and Little Atlin Lakes as well as lower terrain adjacent to their shores (Fig. 2). On the east the valley is bordered from north to south by White Mountain (5,016 ft), Mount Hitchcock (5,878 ft), Union Mountain (about 5,500 ft), Sentinel Mountain (6,316 ft), and Mount McCallum (6,046 ft). An area of low terrain lying in the broad valley of the O'Donnel and Pike Rivers extends about eight miles to the southeast between the latter two mountains. This area represents a transection valley connecting through to the Taku valley to the south (Fig. 3). The O'Donnel-Pike River lowland is more or less continuous with the Atlin valley and, for present purposes, is considered a part of it.

Peaks on the west side of the Atlin valley are, from north to south, Jubilee Mountain (5,952 ft), Mount Minto (6,913 ft), Atlin Mountain (6,711 ft), and Birch Mountain (6,758 ft). The area lying adjacent to the southwestern part of Atlin Lake, beyond Birch Mountain and Mount McCallum, is considered, in this study, to be separate from the Atlin valley proper (Fig. 1).

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Farther to the southwest, Atlin Lake extends into the eastern flank of the Northern Boundary Range, a subdivision of the Western Physiographic System as defined by Bostock (1948). The major feature of this area is the terminus and proglacial outwash or valley train sector of the Llewellyn Glacier. This glacier extends to within two miles of the head of Atlin Lake from a source 25 miles to the south-southwest in the 6,200 foot névé at the crest of the Boundary Range, in the central highland area of the Juneau Icefield. Eastern, outlying peaks of the range bear smaller glaciers and include Mount Mussen (6,600 ft) and The Cathedral (6,950 ft), situated close to the southwestern shore of Atlin Lake (Fig. 1). From here the Northern Boundary Range, as a part of the Coast Mountain complex, extends northwestward into the Yukon Territory, forming an important climatic barrier between the Atlin region and maritime regions southwest of the Coast Mountains.

The Atlin valley and surrounding highlands contain the ultimate headwaters of the Yukon river system. All local drainage is into Atlin Lake, thence via the Atlin River into Tagish Lake, Marsh Lake, and the Yukon River. The major streams tributary to the Atlin valley and which empty into Atlin Lake are Hitchcock, Fourth of July, and Pine Creeks, the O'Donnel and Pike Rivers, and meltwater streams from the Llewellyn and Williston Glaciers. About 15 miles south and southeast of the valley a drainage divide separates the Atlin watershed from that of the Taku River. The Taku flows rough the

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through the Taku District of the Coast Mountains to the Pacific, thus separating the Northern from the Southern Boundary Range.

II. GENERAL GEOLOGY

Topographic maps of the Canadian National Topographic Series, at a scale of 1:50,000, cover parts of the Atlin region, including the Atlin valley. The entire region is covered by parts of the Atlin, Teslin, Whitehorse, and Bennett (Skagway) 1:250,000 sheets. The geology of the map-areas corresponding to these sheets has been described in a reconnaissance manner and has been mapped in the above-noted order by Aitken (1959), Mulligan (1963), Wheeler (1961), and Christie (1957).

The Teslin Plateau, including the northern and eastern parts of the Atlin region, is made up largely of sedimentary and volcanic rocks of late Paleozoic and Mesozoic ages. Most of these rocks belong to the chiefly Permian Cache Creek Group (Aitken, 1959; Mulligan, 1963). Rock types in this group are cherts, argillites, graywackes, sandstones, slates, and greenstones. In addition, limestone is a widespread and frequently outcropping member of the group, being especially common in the south-central, southeastern, and northwestern parts of the Atlin region. Limestone bedrock is also exposed over a large area of the adjoining Taku District southeast of the Nakina River, and in the study area it outcrops extensively in the O'Donnel River valley with the La

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and in the Laurie, Johnson, and Lina Ranges (Fig. 1). White Mountain, at the north end of the Atlin valley, is made of limestone, as is most of the adjacent highland area around Jubilee Mountain to the west.

Major bodies of crystalline rocks belonging to the Coast intrusion complex of Jurassic and Cretaceous ages occur east of Atlin Lake. Particularly prominent are the Mount McMaster Body of undifferentiated granitic rocks in the upper O'Donnel River area and the group of mountains around Surprise Lake comprising the Surprise Lake Batholith, composed largely of alaskite. Bedrock in the Atlin valley between Como Lake and the northern end of Atlin Lake consists of undifferentiated granites of the Black Mountain and Fourth of July Creek Bodies. Mount Hitchcock, Black Mountain, and the southeastern portion of Mount Minto are made of granitic rocks (Fig. 2).

The geology of the northern part of the Tagish Highland, including the west-central and most of the southwestern portion of the Atlin region, is similar to that of the Teslin Plateau, but it includes a higher proportion of volcanic rocks. Principal rock types are Permian andesites, basalts, cherts, and limestone (Christie, 1957). The central and southern parts contain sedimentary rocks of early Jurassic age, including greywackes, siltstones, argillites, slates, conglomerates, and limestone. Basic volcanic rocks of the late Cretaceous or early Tertiary Sloko Group outcrop over considerabl

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a considerable area around Sloko Lake in the southern part of the Tagish Highland immediately south of the Atlin valley.

The southwestern corner of the Atlin region, lying within the eastern flank of the Northern Boundary Range, contains a high percentage of metamorphic rocks, most of which are considered pre-Permian in age (Aitken, 1959). This area lies adjacent to the Coast Range Batholith and contains many exposures of crystalline rocks related to this extensive Mesozoic and early Cenozoic intrusion. A belt of late Paleozoic sedimentary and basic volcanic rocks with some limestone, possibly related to the Cache Creek Group, occurs in the narrow belt lying between the Llewellyn Glacier terminus and the southwestern shore of Atlin Lake.

In summary, the northern portion of the Atlin valley is underlain and flanked primarily by limestones and, in the area east of the south end of Little Atlin Lake and the Lubbock River, by argillaceous and quartzitic siltstones, sandstones, and greywackes. The central part of the valley, from the north end of Atlin Lake to about two miles north of Atlin village, is underlain largely by granitic rocks. The southern portion of the valley is underlain by a variety of volcanic, metamorphic and sedimentary rock types, including major proportions of limestone, particularly in the Sentinel Mountain-O'Donnel River area.

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III. GLACIATION AND GLACIAL GEOLOGY

A variety of erosional and depositional features occur throughout the Atlin region as evidence of former glaciation. Besides the broad, glacier-carved valleys, rounded and relatively smooth highland topography indicates the effect of overriding glacial ice. Glacially polished and striated erosional rock surfaces and crag-and-tail topography occur in various places, and there are abandoned meltwater channels and drumlins in others. Much of the region is covered by glacial drift of various kinds and thicknesses. There are end moraines and morainal series, lateral moraines, eskers and esker complexes, kames and kame terraces, kettles, and areas of pitted outwash. Erratic boulders have been deposited in some places, and there are a few remnants of alluvial fans, eroded deltaic deposits, and sections of ancient, glacial lake shorelines. The terrain of much of the Atlin valley, as viewed from the air, is fluted and bears a distinct linearity.

Pre-Wisconsinan glaciation

Glaciation in the Atlin region and neighboring areas has been studied by Johnston (1926), Kerr (1934, 1936), Watson and Mathews (1944), Armstrong and Tipper (1948), Denny (1952), Aitken (1959), Wheeler (1961), Mulligan (1963), and Miller (1963, 1964 a, b). There is a consensus that northwestern British Columbia and adjacent Alaskan and Yukon areas were covered by a Cordilleran Pleistocene ice sheet at least once

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at least once prior to the Wisconsinan Age, one which was far more extensive than any Wisconsinan advance. The area of buildup of this ice sheet is believed to have been in the general region of the northern Cassiar Mountains to the east of the Atlin region, about 150 miles from the Coast Mountains. Watson and Mathews (1944) believe that the center of this ice sheet was along the axis of the Cassiars. From here ice may have moved in all directions, but the majority flowed to the west and south. It flowed across the Coast Mountains, primarily through the lower trans-range river valleys, such as the Taku, and presumably formed an extensive ice shelf along the present southeastern Alaskan coast. Much of the westward moving ice was probably deflected by the Coast Mountains far to the south and eventually to the sea via valleys of the Nass and Skeena Rivers. Some was probably also deflected to the north, through the Atlin region and into southwestern Yukon Territory (Miller, 1964a). The surface of the ice during this stage may have been around 8,000 feet above sea level in some places. Johnston (1926) believed that the highest summits in the region between the Cassiar and Coast Mountains were covered by up to 3,000 feet of ice.

The time of the maximum development of Pleistocene ice in the northern Cordilleran region is not yet known with certainty. Deposits and other evidence of this ice sheet are scarce, most having been obliterated by the later, Wisconsinan Age advances.

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Kerr (1934), in a classification of glaciations in northern British Columbia, terms the maximum development of Cordilleran ice the Continental Icesheet Stage. Miller (1964a) designates it an Intermontane Icecap Glaciation, emphasizing regional accumulation in the Coast Mountains as well as in the Cassiars. He explains, in addition, that the Cordilleran ice sheet, although larger than the present Greenland Icecap, was of sub-continental, rather than continental proportions as interpreted by earlier authors. The maximum Keewatin Icesheet, with which it may have been in contact in a few places (Hansen, 1949c, 1950) and the Laurentide Ice Sheet, along with lesser ice sheets in Alaska and elsewhere, were in existence at the same time.

Wisconsinan glaciation

Most of the glacial action which was instrumental in creating existing landforms in the Atlin region took place during the Wisconsinan Age and early Holocene time. Glacial ice again covered the region, deriving from accumulation areas in the Northern Boundary Range, probably some distance northeast of the range axis (Miller, 1964a), as well as from the northern Cassiar Mountains lying parallel to the Boundary Range about 150 miles to the east. Aitken (1959) states that two major Wisconsinan ice streams entered the Atlin map-area. One of these was from a high center in the Northern Boundary Range and moved northward through the Atlin valley. The other entered the region from the

southeast and moved northwestward through the Teslin depression (Fig. 1). In addition, Mulligan (1963) describes evidence of former ice in the Teslin map-area flowing in a west-southwest- to west-northwestward direction and affecting the eastern and northeastern areas of the Atlin region. The source of the latter ice was probably also the northern Cassiars. It apparently joined the Teslin depression ice, itself of a somewhat more southerly source in the Cassiars, to continue northwestward, forming what Wheeler (1961), in the Whitehorse map-area, called the Cassiar Lobe. Northwestward flowing ice from the upper Taku River area south of the Atlin region appears also to have contributed to the Teslin depression stream (Armstrong and Tipper, 1948).

In the northwestern corner of the Atlin region, Atlin valley ice in maximum Wisconsinan time probably joined an adjacent stream in the Taku Arm valley to continue as a huge coalesced ice stream toward the north-northwest as a part of the main Coast Mountains Lobe (Wheeler, 1961). Thus the Atlin valley ice was bracketed by major contiguous ice to the west as well as to the east. Both the Cassiar Lobe and this Coast Mountain Lobe apparently terminated at the south-eastern edge of a large region in west-central Yukon Territory and Alaska which escaped Pleistocene glaciation altogether (Bostock, 1948; Heusser, 1960).

Within the Atlin region, the Atlin valley-Coast Mountains ice stream and the Teslin depression ice stream spread out into intervening lowland areas connecting these two

main valleys. One such location is manifest by inter-lobate material in the O'Donnel River-Pike River valley brought in by ice of the former stream branching off in a southeasterly direction (Aitken, 1959).

Aitken gives evidence for an additional local ice source located within the Atlin region, in the highlands around Surprise Lake. He concluded that ice flowed radially from this source area to join the surrounding valley ice streams during maximum stages of glaciation.

Certain higher peaks in the Atlin region may have remained unglaciated throughout the Wisconsinan. Various authors have indicated this possibility. Holland (1964), for example, states that the maximum elevation of ice in the Tagish Highland was 6,000 to 6,500 ft. Several mountains there are higher than this. Mount Minto, at nearly 7,000 ft, an isolated peak on the west shore of Atlin Lake, appears to be worthy of further investigation in this regard. Miller (1963) has also pointed out the probable existence of certain high nunataks near the crest of the Boundary Range during the Wisconsinan maximum.

The maximum Wisconsinan ice cover of northwestern British Columbia and adjacent regions was nearly as complete as that of the pre-Wisconsinan Inter-Montane Icecap Glaciation, even though the thickness and volume of the ice may not have been as great. Kerr (1934) designates the main Wisconsinan advance in the British Columbia-Alaska Coast Mountains as

the Mountain Ice-Sheet Stage. Miller (1964a) recognizes a Greater Stage of the Mountain Ice-Sheet Phase of glaciation corresponding to the Wisconsinan maximum, and also less extensive ice buildups designated as Intermediate and Lesser Stages of the Mountain Ice-Sheet Phase.

Holocene glaciation and glacial geology

The downwastage and retreat of the last significant substage of Wisconsinan ice is considered to be the initial event of the Holocene Epoch in the Atlin valley. Bog studies and radiocarbon dating which will be discussed later indicate that this event was well underway in the northern part of the Atlin valley by 10,000 years ago. In the course of this study several features related to the general recession in the valley and adjacent areas were observed. A knowledge of these in terms of mode and time of origin and geologic composition is basic to an understanding of geobotanical processes and the evolution of the present landscape, as well as the development of a chronology of Holocene events.

A broad and dominating kame terrace lies between 2,400 and 2,550 ft in elevation along the eastern flank of the Atlin valley in the area between the south end of Little Atlin Lake and the north end of Atlin Lake. The western and southwestern edges of this terrace slope steeply down to the broad valley between the two lakes (Fig. 2). Strand lines occur along this slope, indicating successively lower levels of impounded water along the ice margin. The terrace indicates an interval of stagnation in the general

course of ice retreat (Flint, 1957). It is composed of a light, gravelly alluvium and supports the largest continuous lodgepole pine forest in the Atlin valley. A number of kettle ponds and bogs occur on the terrace, including Mile 16 Bog.

Denny (1952) found gravel terraces a common feature along the Alaska Highway. He reports that around Squanga Lake, in the north-central part of the Atlin region, remnants of terraces occur along valley walls, and an intricate knob and kettle topography characterizes the valley floor. These features extend southwestward in the valley containing Summit Lake and Little Atlin Creek to a point northeast of White Mountain (Fig. 1). The valley directly north of White Mountain, in contrast, is relatively free of glacial drift. In the region northwest of Little Atlin Lake, where Moose Bones Bog is located, pitted outwash and drumlins occur, as described by Wheeler (1961). These various depositional features in and near the northern part of the Atlin valley could have been made during a long interval of stagnation in the retreat of ice from this area. A time of faster retreat and downwasting may have followed, with the deglaciation of the Little Atlin Creek valley north of White Mountain and the Little Atlin Lake portion of the main valley. After this, another interval of stillstand appears to have begun when the terminus reached the area of the kame terrace discussed above. It is suggested that these events, namely stagnation-active retreat-stagnation, occurred in response to a significant climatic oscillation during the early Holocene.

Coincident with these events in the Atlin valley a portion of a large proglacial lake, glacial Lake Carcross, occupied the Tagish Lake and northern Taku Arm valley in the northwestern corner of the Atlin region (Wheeler, 1961). Damming by ice farther south in Taku Arm probably was partly responsible for this lake, along with blockage by ice and complex ice front deposits farther to the northwest in the direction of present day drainage. At least two shorelines of this ancient lake are known. These too may be related to major intervals of stillstand during the general course of retreat of the ice blocking the drainage-way.

At the north end of Atlin Lake a series of even, closely-spaced, recessional moraines extends about three quarters of a mile upvalley from the edge of the water. Aerial photographs show additional moraines, less regular, but closely-spaced, occurring throughout a zone extending to approximately three miles from the lake. These appear to indicate lesser climatic fluctuations preceding a more pronounced change when recession of the ice front became more rapid and continuous.

Abundant early Holocene depositional features are found in other valleys tributary to the Atlin valley. The upper or eastern end of Fourth of July Creek valley, for example, contains terminal and lateral moraines, an extensive kame

complex, and a remarkable nest of sinuous eskers. According to Aitken (1959) these deposits were produced by two different ice fronts. One of these entered the southwest or proximal portion of the valley as an offshoot of the main Atlin valley stream. The other moved into the upper, distal section of the valley from the trunk glacier in the Teslin depression to the east. Deposition relating to stagnation of these ice bodies in the Fourth of July Creek valley may have been contemporaneous with similar events in the northern part of the Atlin valley described above.

Aitken (1959) has suggested that a large terminal moraine a few miles west of Surprise Lake in the Pine Creek valley and an esker-kame complex in the adjacent Spruce Creek valley were produced by ice which accumulated in and flowed outward from the central highland area around Surprise Lake. Lake sediments around lower Pine Creek indicate that ice extended at least as far north in the Atlin valley as the Pine Creek area at the time of formation of these features. Aitken further concludes that these were deposited in a body of water created by blockage of drainage from the glaciers to the east by extensive ice in the Atlin valley. Correlation of these deposits and others associated with ice front and ice margin deposits at various places in the Atlin valley remains to be done.

By the time that deglaciation was well underway in the major, low level valleys in early Holocene time, an alpine type of glaciation had developed in highland areas following

the previous Wisconsinan ice-sheet stages. This glaciation is considered correlative with the Extended Icefield Glaciation of the early and late post-Glacial times in the Coast Mountains (Miller, 1964a). Most evidence for alpine glaciation in the Atlin region is in the form of rejuvenated pre- or early Wisconsinan cirques (Aitken, 1959; Mulligan, 1963). This would presumably correspond with the lowest cirque level system, with a superimposed latest cirque development (the C1 and C5 systems), as described by Miller (1961) on the maritime flanks of the Juneau Icefield. At this time the high cirque basins on Mount Minto and Atlin Mountain probably supported alpine glaciers, and a rather extensive mountain glacier system, perhaps resembling one or two small ice caps, may have existed in the high area around Surprise Lake. A well developed abandoned cirque, with a floor at the 6,000 to 6,500 ft level, occurs on the northwest side of Mount Minto. Similarly, an abandoned set of tandem cirques at 5,500 and 6,000 ft on the east side of Atlin Mountain gives rise to a rock glacier today. Many rejuvenated cirques also occur on the mountains in the Surprise Lake area (Aitken, 1959: Plate 1).

It is known, on the basis of abundant evidence from other areas, that a world-wide interval of climate which was warmer and, in many places, drier than the present, the Hypsithermal or Thermal Maximum, occurred during middle Holocene time (e.g. Sears, 1942; Deevey and Flint, 1957; Heusser, 1960, 1966, 1967b). Palynological evidence from the Atlin region for this interval is presented in Chapter XIV. Between the beginning of Holocene time and the Thermal Maximum, glaciation in the Atlin region is believed to have decreased from extensive alpine stages through reduced alpine stages, correlative with the present Retracted Icefield Stage in the Coast Mountains (Miller, 1964a), in which only a few very small glaciers or glacierets occupied some of the higher cirques. After this there developed a condition of relatively complete deglaciation corresponding to the Local Glacier Phase in the higher reaches of the Coast Mountains. By this time the Llewellyn Glacier terminus as well as its transection counterpart, the Taku Glacier on the Alaskan side of the Icefield, presumably had receded to a point far up its valley and hence some miles south-southwest of Atlin Lake. Then too, the higher mountains near the southwestern shores of the lake were practically devoid of ice.

After the Thermal Maximum the climate, in most places, became cooler again, or more moist, or both, depending on the area of concern. This resulted in the readvance of shrunken main valley glaciers and the formation anew of others flanking high level cirques. This culminated in the so-called Neoglaciation, the maximum advance of which has, during the past few thousand years, ranged widely in time from one place to another (Miller, 1969). In most areas a number of Neoglacial fluctuations of glaciers and climate are recognized, and the pattern has been particularly well documented throughout south-central and southeastern Alaska by Miller (1963, 1967) and by Miller, Egan, and Beschel (1968).

Neoglacial activity in the Atlin region has been manifest primarily in the southwestern corner, in the Northern Boundary Range. Concentrated studies on the Juneau Icefield (Miller, 1963, 1964b) reveal continuing regime fluctuations in the main Llewellyn Glacier accumulation area during at least the past few hundred years. The terminus of the glacier is known, from historical records, to have reached a Neoglacial maximum considerably beyond its current position about 1925. This is also shown by a distinct trim line and well-developed scour zone on the valley walls in the terminal area. A similar situation pertains at the termini of other distributary glacier tongues in the Sloko valley and Hoboe Creek valley, as well as on the Williston Glacier at the head of Torres Channel west of the main Llewellyn Glacier terminus (M. M. Miller, personal oral communication 1969; Fig. 1).

With regard to the rest of the Atlin region, a few small glacierets or perennial snow patches exist in some of the higher cirques at the present time, and these have no doubt formed anew in late Holocene, post-Thermal Maximum times. The maximum Neoglacial development of these and their fluctuational history has not yet been studied.

IV. CLIMATE

The Atlin region lies within the South West Yukon Climatic Division (Kendrew and Kerr, 1955) and the Cordillera Climatic Region (Boughner and Thomas, 1967). The climate is basically of an interior, or continental type, but with a certain amount of oceanic influence penetrating by way of passes and river valleys through the Coast Mountains. Summers are generally warm and winters cold. Temperatures are not as extreme as deeper in the Yukon or interior of northern British Columbia, however. Precipitation is low along the base of the eastern slope of the Northern Boundary Range, revealing a "rain shadow" effect. It increases somewhat across the region toward the Cassiar Mountains. A steep precipitation gradient extends about 120 miles northeastward across the range from the coastal maritime areas, where annual precipitation is in excess of 100 inches per year, into the Atlin region, where some places receive less than nine inches. Valleys, such as the Atlin valley, are especially dry. During the summer orographic effects make for higher rainfall in the interior highlands, such as in the mountains around Surprise Lake. Topography exerts a major influence on the climate of the region, particularly the wind. The primary roles of air masses, pressure systems, and frontal zones in determining the climate of northwestern British Columbia and southern Yukon Territory are discussed by Kendrew and Kerr (1955) and Boughner and Thomas (1967).

Regional climatology

Climate-glacier relationships and climatic history in the Northern Boundary Range and surrounding areas are discussed by Miller (1963). Of fundamental importance is the movement of cyclonic storms, generally in a southeast-northwest direction, along the Arctic Front. This is the zone of interaction between the north Pacific low pressure system and the continental, high pressure cell of the Arctic interior. The paths followed by storms passing along the frontal zone are called storm tracks. Over long periods of time the positions of these are believed to change, in a generally east-west direction, as the two major pressure systems are modified by variations in the solar energy flux in the atmosphere. When the storm tracks are considerably west of the axis of the Northern Boundary Range the Atlin region receives comparatively little precipitation, and glaciers in the southwestern part of the region, particularly the Llewellyn, tend to shrink. When the storm tracks are displaced eastward or northeastward, precipitation on the lee side of the range tends to increase.

At the present time the storm tracks occupy a westerly position, and conditions in the interior are comparatively drier (Miller, 1963) and apparently also warmer. That they were located farther to the east during much of the 19th century is indicated by the fact that the Llewellyn Glacier was in a state of maximum post-Glacial advance between approximately 1900 and 1925. In the early to mid 1800's

a precipitation maximum on the lee side of the range accounted for a relatively high amount of snowfall in the glacier's main accumulation area, the effect of which reached the terminal sector after a 50 to 100 year flow lag period. During Pleistocene glacial maxima the major storm track positions are believed to have been shifted much farther to the east, to interior positions where primary centers of the major ice sheets were located. Similar storm track shifts from late-Glacial (pre-Holocene) through Neoglacial times have been postulated by Miller (1963).

Classification

In the Koeppen system the climate of the Atlin region is classified Dfc - a cold, snow-forest type, moist in all seasons, with short, cool summers (Petterson, 1958).

In the Thornthwaite system a more precise and useful classification is possible using data and maps published by Sanderson (1948). The notation for the climate of the Atlin valley is $C_1C'_1db'_1$. This means that, with respect to moisture, the valley is dry subhumid (C_1) and experiences little or no water surplus (d). Potential evapo-transpiration is in the 11 to 17 inch range, placing the valley in the cold microthermal (C'_1) category from the standpoint of thermal efficiency. Summer concentration of annual water need is 62 to 68 percent (b'_1). The climate is somewhat on

the dry side and, from the standpoint of plant growth, moderate water deficiencies are the rule. The climate does not approach aridity, although summer droughts occur. It is similar, from the moisture standpoint, to the Canadian prairies and the Mackenzie valley, as well as most other interior valleys of British Columbia and Yukon Territory. With regard to temperature, the cold microthermal climatic type is characteristic of the northern boreal forest zone all across Canada.

In most places a summer concentration of annual water need in the 76 to 88 percent range is associated with the cold microthermal climatic type (Sanderson, 1948). The fact that in the southern two thirds of the Atlin region the percentage summer concentration of annual water need is lower than this is an indication of minor maritime influence on the temperature regime. Apparently summer temperatures are not so high as to cause evapotranspiration to remove excessive amounts of moisture from the ground here. In the northeastern part of the region, however, the percentage summer concentration of annual water need is higher, more nearly corresponding to values associated with the continental, cold microthermal climatic type in most other areas where this type occurs.

The highlands around the Atlin valley are more moist. Surrounding the dry subhumid area of the valley proper is a narrow zone classified as moist subhumid (C_2) (Sanderson, 1948). Most of the rest of the region is occupied by a so-called humid climatic type (B) with four subdivisions (B_1 through B_4). On the scale of Sanderson's maps it is difficult to tell the exact location of these zones with respect to features in the region. It appears, however, that the Atlin valley and probably also the valley of Taku Arm experience dry subhumid climates, that the lower slopes of these valleys as well as those in the Teslin area are of the moist subhumid type, and that all highlands in the region are of the humid climatic type. Although there are significant differences in precipitation regimes between these various zones, seasonal fluctuations among them tend to be parallel.

With respect to thermal efficiency, the regions of higher elevation are classified as tundra climate (D'). Since thermal efficiency is based on potential evapotranspiration or water need, which in turn is controlled by temperature and daylength, tundra (as used by Thornthwaite) is defined in terms of the water needs of the vegetation, rather than in the more common reference to the vegetation itself.

In summary, the two major Thornthwaite climatic types of the Atlin region are (1) dry subhumid-cold microthermal in the lowlands, with little or no water surplus and a moderate summer concentration of water need, and (2) humid-tundra in the highlands, with seasonal distributions of temperature and precipitation parallel to distributions in the lowlands.

Meteorological observations and records

Standard weather observations have been made for various lengths of time at several stations in the Atlin region. A 41-year record, from August, 1905 to September, 1946, is available for Atlin. At Carcross the record spans the period from January, 1907 to December, 1946. A short record, from January, 1926 to September, 1929, is available from the Engineer mining camp on Taku Arm and another, from July 1898 to August, 1900, for Tagish (Canada Department of Transport - Meteorological Branch, unpublished data 1969).

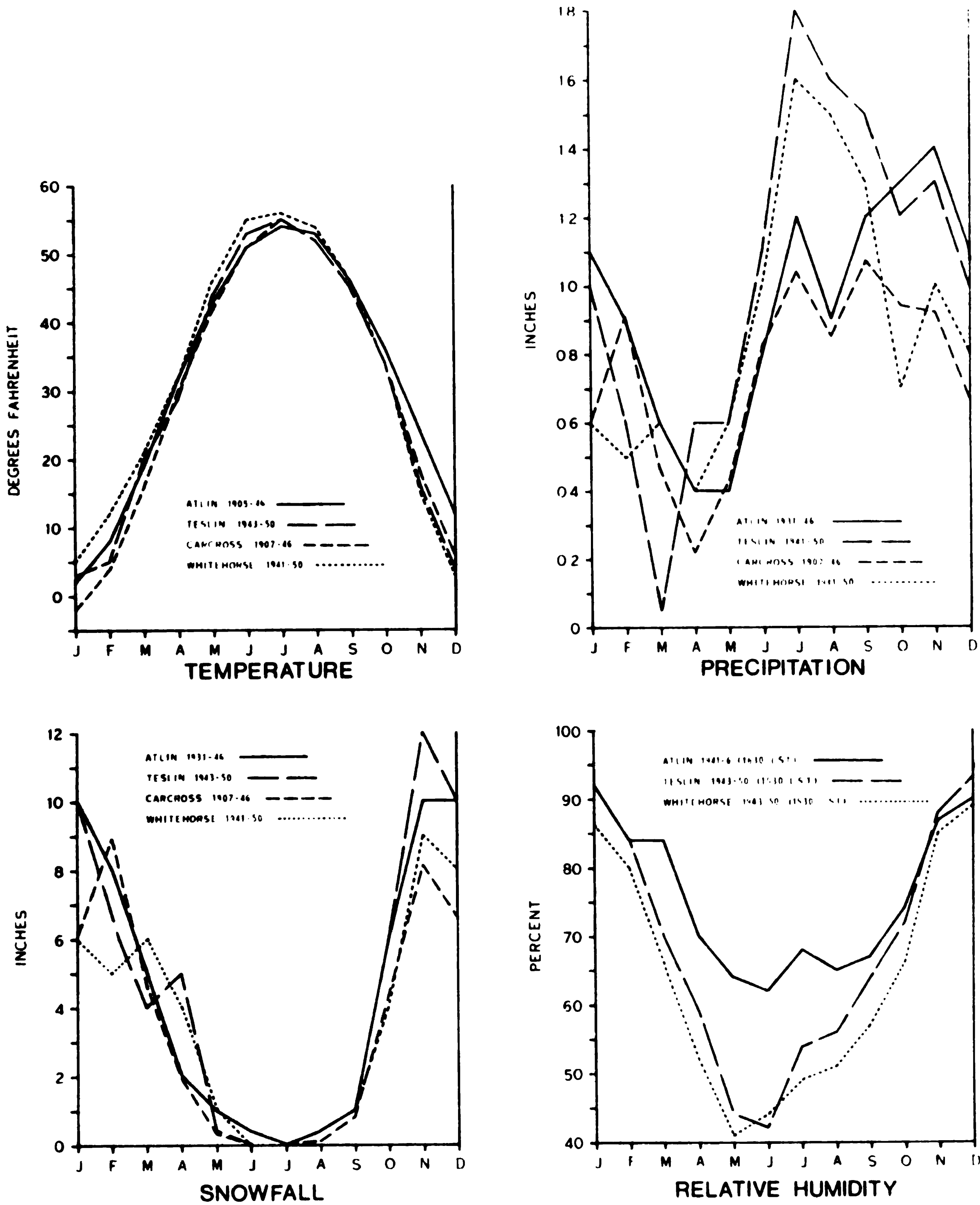
Table 1 contains basic meteorological data for five stations in and near the Atlin region. Graphs of temperature, precipitation, snowfall, and relative humidity in the region are presented in Figure 5. Wind data are given in Table 2, and wind direction frequencies are shown in Figure 6. Data are from Porsild (1951), Kendrew and Kerr (1955), Boughner (1956), and the Canada Department of Transport - Meteorological Branch (unpublished).

Table 1. Climatological data summary for five stations in the Atlin region.[1]

	Atlin	Carcross	Dease Lake	Teslin	Whitehorse
Mean annual temperature (°F)	32	29	30	30	31
Absolute range of recorded temps.	-54 to 87	-	-60 to 93	-63 to 89	-62 to 91
Average dates of frost-free season[2]	6/11 to 9/4	6/23 to 8/16	7/2 to 8/13	6/18 to 8/23	6/21 to 8/9
Mean annual precipitation (inches)	11.3	8.9	15.78	12.8	10.6
Mean annual snowfall (inches)	53	41.8	71.9	55	45

[1] Data from Porsild (1951) and Kendrew and Kerr (1955).

[2] Engineer: 6/9 to 9/12



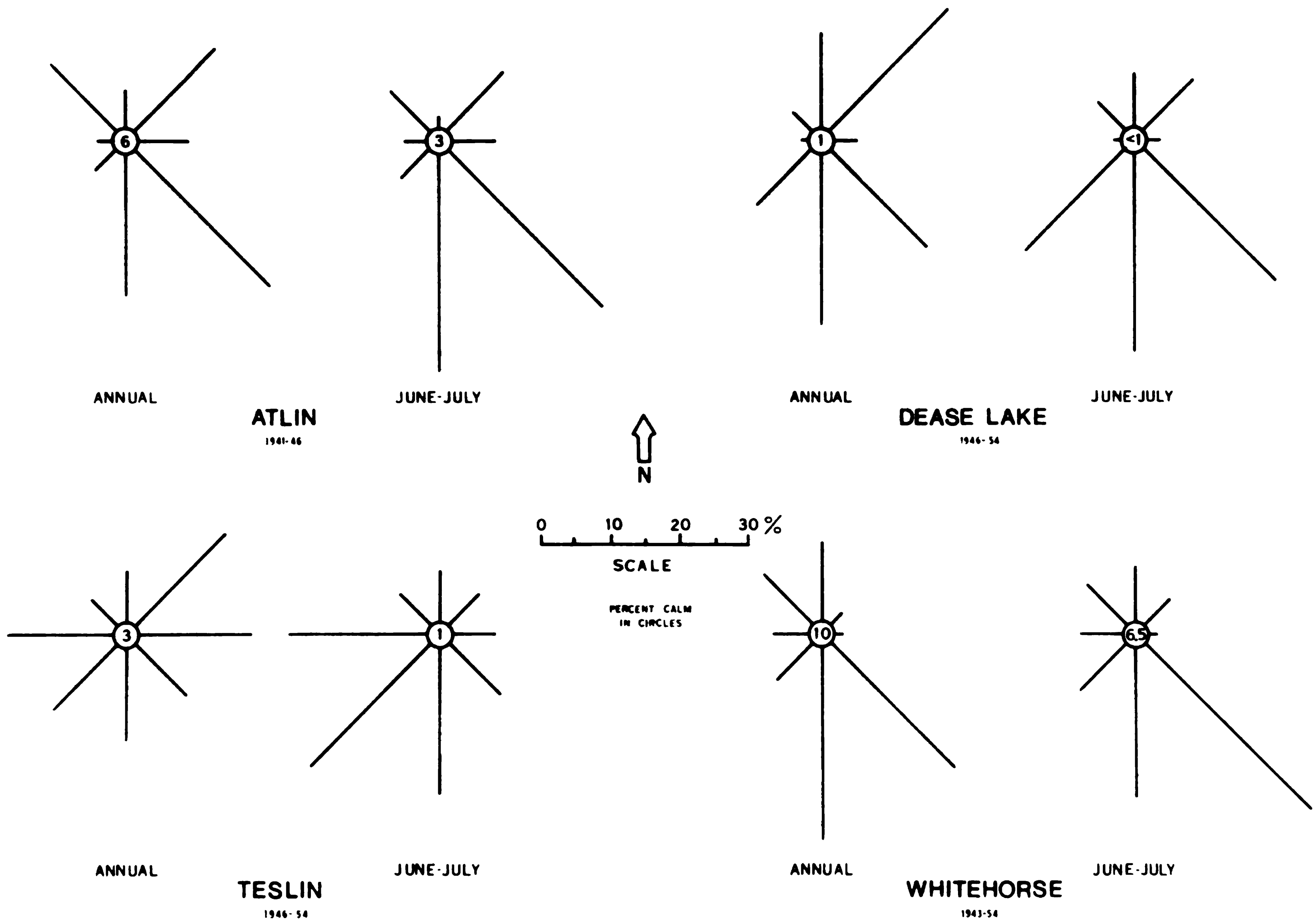
MEAN MONTHLY TEMPERATURES, TOTAL PRECIPITATION, SNOWFALL, AND RELATIVE HUMIDITY AT ATLIN, TESLIN, CARCROSS, AND WHITEHORSE

Figure 5

Table 2. Wind speeds (percentage frequencies) at four stations in the Atlin region.*

Station	Month	Hour(LST)	Calm	1-12 MPH	13-38 MPH
Atlin (1941-6)	Jan.	2230	43	48	9
		1630	45	44	11
	July	2230	35	59	6
		1630	26	64	10
Dease Lake (1945, 1947-51)	Jan.	0430	5	94	1
		1630	5	90	4
	July	0430	17	83	0
		1630	4	93	4
Teslin (1946-52)	Jan.	0330	29	67	4
		1530	21	73	6
	July	0330	38	62	0
		1530	5	82	13
Whitehorse (1943-52)	Jan.	0330	25	45	30
		1530	19	45	36
	July	0330	27	63	10
		1530	12	63	25

*Data from Kendrew and Kerr (1955).



ANNUAL AND JUNE-JULY WIND DIRECTION PERCENTAGE FREQUENCIES
AT ATLIN, DEASE LAKE, TESLIN, AND WHITEHORSE

Figure 6

V. SOILS

According to Chapman and Turner (1956) the Atlin region belongs to the Mountainous Soil Area, where Gray Wooded soils, Brown Wooded soils, Podsols, Alpine Meadow soils, Lithosols, Alluvial soils, Rendzinas, and Peats have developed.

Leahy's (1949) discussion of the general nature of soils in Yukon Territory bears upon the Atlin region. Upland soils are broadly differentiated into two groups on the basis of presence or absence of permafrost. Most of those without permafrost are well-drained and vary from dark brown grassland soils to reddish-brown forested soils which probably belong to the Brown Podsolic Great Soil Group. Although these are the most fully developed soils in the Yukon, their profiles are generally immature.

The Atlin region is located in the zone of discontinuous permafrost (Péwé, 1967). Although it is generally rare in the lowlands, permafrost, along with seasonally frozen ground, probably occurs in some valleys and broad, abandoned cirque basins into which cold air tends to drain. Such is undoubtedly common at higher elevations. Regarding soils affected by permafrost Leahy (1949) writes:

> . . . (they) are imperfectly to poorly drained and they usually have a thick covering of peat and muck. Mineral soils with permafrost horizons occur to a lesser extent. Such

> soils show little profile development beyond the fact that the upper few inches of mineral material under the thin moss cover is weathered to a reddish-brown colour.

With respect to recent alluvial soils Leahy writes:

> . . . (they) show little or no profile development and their characteristics depend chiefly on the nature of their parent material. The effect of permafrost on these soils is not well marked.

Rowe (1959), in discussing the Central Yukon Forest Section, within which much of the Atlin region lies, gives some information on parent materials and soil formation:

> Throughout . . . there is evidence of recent strong glaciation, and the soils are predominantly of unmodified or water-worked glacial drift. Soil development is generally weak, due to the youthfulness of the surface materials and to the dry climate. Brown wooded soils are usual but grey wooded and degraded dark brown profiles also occur. The rooting depth of trees and other plants is in some areas affected by layers of volcanic ash in the soils, and in other places, particularly northward, by permanently frozen ground.

Lietzke (1970) has made a preliminary investigation of soils in the Atlin valley. Regarding his findings, he states:

> A wide range of well-drained soils, some exhibiting only subsurface Cca horizons, some exhibiting only spodic or spodic-like horizons, and some exhibiting both a spodic horizon and a Cca horizon occur in the Atlin valley area of British Columbia.
>
> Besides these well-drained soils, many areas of more poorly drained soils occur in a complex pattern in the valley.

Upland soils, largely in the northern part of the Atlin region, were studied by Lietzke (1970) and included Spodosols, Inceptisols, and Entisols (U.S. Dept. of Agriculture, Soil Survey Staff, 1967). These had developed in parent materials ranging from lacustrine silts and fine sands to loam till, sandy loam till, sand and gravel outwash, and boulder fields. In areas adjacent to the eastern shore of Atlin Lake a thin capping of loess was frequently observed as a major component of the parent material.

The lime content of these soils was found to vary considerably, depending on texture of the glacial parent material and location. Glacial ice which passed over mountainous limestone bedrock in the southern part of the Atlin region gave rise to drift containing larger proportions of calcareous material than that which moved across areas where limestone outcrops were not prevalent or were absent. Ice streams in both categories have deposited material in the Atlin region. For this reason the Cca horizon, as exposed in cuts along the Carcross road, is spotty in occurrence. Along the Atlin road and the Alaska Highway between Jakes Corner and Whitehorse the lime content is quite variable, but all profiles show at least a minor Cca horizon development. The Cca horizon usually occurs between 12 and 20 inches in depth and is often the most prominent feature of a soil profile.

A very noticeable Bir horizon, occurring just beneath the surface, was found in most areas. An A2 horizon, on the other hand, was found in only a few profiles, and then was thin and poorly developed. Lietzke points out that this horizon seemed to be " . . . dependent on an optimum climate - a micro-climatic variation necessary for maximizing the podzolization process in this area."

A spodic horizon, occurring in profiles throughout the region, was found to be from two to six inches thick, beginning four to eight inches below the surface.

In finer textured parent materials a Gray Wooded sequum, containing a distinct clay accumulation in a B't horizon, was found to occur beneath the spodic sequum and above the Cca horizon. It was found that an A'2 horizon may occur just above the B't horizon. In some profiles the spodic horizon was observed resting upon the lower B't horizon. Such besequal profiles were observed at many locations in the region.

Lietzke also has found soil-vegetation relationships to be quite pronounced in the Atlin valley. He notes that well-drained soils having either a high pH throughout the profile or a Cca horizon typically support a mixed type of vegetation where aspen and lodgepole pine are prominent components. Relative proportions of these two species are believed to be, in part, a function of soil texture, with pine being favored by the coarser, and aspen by the finer materials. Also the coarser textured soils were commonly found to be less well developed, presumably because of light vegetation cover and the arid climate.

Some relatively well-drained soils have developed in parent materials ranging from loam tills to coarse sands and gravels. These were found to bear a thick, almost peaty organic layer and an alpine fir vegetation type (see below).

It is assumed that such a development of peaty material in upland areas requires the prolonged absence of fire or other disturbances.

Many poorly drained sites were found by Lietzke to support white spruce vegetation. Moderately drained sites usually support a mixedwood forest vegetation type.

Additional information from Lietzke's unpublished manuscript (1970) is given below in connection with discussions of the plant communities. Detailed descriptions of key soil profiles studied in selected vegetation stands are contained in Appendix A.

Figure 7. A mosaic of Atlin valley plant communities.

View south-southwest from bedrock knoll a short distance west of Mile 52 Bog. A part of the mid-section of Atlin Lake is shown. Birch Mountain (6,758 ft) on Teresa Island is in the left background. Torres Channel lies just to the right of this, and Atlin Mountain (6,711 ft) is the high peak to the right of center. The Atlin Mountain rock glacier is the light-toned lobate feature extending down to just above lake level. The elevation of the viewpoint is about 2,500 ft, and the distance to the lake is approximately two miles.

The vegetational aspect shown is considered typical of the Atlin valley. There are few places where a discreet stand of any particular vegetation type (e.g. association) may be described. Exceptions are the herb-heath association occupying the immediate foreground and the zones of bog vegetation shown at the right side of the view. Here a narrow, light-toned shrub willow zone can be seen around the periphery of the bog and two sedge zones inside this. The smaller, inner sedge zone, of medium tone, probably contains a strong admixture of *Triglochin* spp. The light patches at the apparent center of the bog, at the right edge of the view, are an orange marl deposit.

For the most part the vegetation exhibits either the continuous nature of changing plant assemblages or, in contrast, sharp breaks between one vegetation type and another. The former appears to be the predominant situation beyond the dark-toned spruce stand across the center. Such continua of plant assemblages occur along gradients of changing relief and exposure and related edaphic and microclimatic factors. Frequency, intensity, and spatial distribution of past fires also play an important role in perpetuating such vegetational variety.

Between the middleground spruce stand and the foreground the plant assemblages are more clearcut. Here a fire, probably within the past three or four decades, burned with considerable intensity, killing nearly all of the former vegetation and leaving an open area in which an even-aged aspen stand has developed. Scattered lodgepole pine occur in the lower portion. The rounded clumps in the foreground are willow. The intensity of fires in this area is probably a result of its exposure to southerly winds off of Atlin Lake.

Midday. 23 June 1967.

Figure 7. A mosaic of Atlin valley plant communities.

VEGETATION

VI. INTRODUCTION TO VEGETATION OF THE ATLIN REGION

General

According to Shelford (1963) the Atlin region lies within the zone of the transcontinental Boreal-Montane Coniferous Forest Biome. Three large, natural subdivisions of this biome are recognized. The northwesternmost one is called "The forest of the valleys and lower mountain slopes of the northern Rocky Mountains which is transitional between the boreal forest and the mountain forests in the west." This subdivision comprises three types of forest including, "The white spruce-lodgepole pine forest of northern British Columbia and southern Yukon." This is the basic type of forest in the Atlin region. Shelford also refers to the northwestern portion of the transcontinental boreal forest, from British Columbia to Alaska, as the "spruce-giant moose-lodgepole pine-paper birch faciation."

The Atlin region lies within the Interior Spruce and Birch Forest Region as defined by Sigafoos (1958). Rowe (1959) maps it as part of the Central Yukon Section of the Boreal Forest Region.

The boreal forest in northwestern Canada is notably simpler in species diversity than in other parts of the

country. The few important trees are lodgepole pine, white spruce, black spruce, alpine fir, balsam poplar, aspen, paper birch, plus one or more species of tree willow. All except black spruce and paper birch are important members of the general Atlin valley vegetation. White spruce, lodgepole pine, alpine fir, and aspen dominate, either singly or in various mixtures, in the associations recognized there (see below). Black spruce and paper birch were not observed in the course of this study, and the writer knows of no report of their occurrence in the valley. Raup (1945) reports a stand containing black spruce just east of Teslin along the Alaska Highway, and this is to date the nearest known occurrence of this species.

The following shrubs and subshrubs are important components of the forest vegetation in northwestern Canada: *Betula glandulosa*, *Rosa acicularis*, *Shepherdia canadensis*, *Ledum palustre* subsp. *groenlandicum*, *Arctostaphylos uva-ursi*, *A. rubra*, *Vaccinium vitis-idaea* subsp. *minus*, and *Viburnum edule*, along with various species of willow. All of these occur in the Atlin valley.

The nomenclature used in this dissertation follows Hultén (1968). Most groupings or lists of plant names are arranged in the phylogenetic order used by Hultén. Trees are referred to by common names, and all other plants by botanical names. Appendix B lists the tree common names and their botanical equivalents. Author abbreviations for other botanical names used in the text are to be found in the preliminary catalog of the flora, Appendix F.[2]

For present purposes, tree species up to about 18 inches in height in the herb stratum are referred to as seedlings. Tree species in the shrub stratum, up to about 12 feet in height, are referred to as saplings.

Previous work

After several years of studying the boreal coniferous forest of northwestern Canada, Raup (1941), in an important paper, summarized most of the geobotanical work done there by himself and others and attempted to elucidate some of the major problems remaining for future workers. The paper deals partly with questions regarding the origin and distribution of the flora and the development and distribution of plant communities following Wisconsinan glaciation. In particular, difficulties involved in attempting to describe the present boreal vegetation (including arctic and subarctic vegetation) in terms of ordinary ecological units are pointed out. Despite the relatively few species involved, ecological relationships among them are complex. The delimitation of associations, by which generalizations regarding vegetation composition and structure should apply over large areas, is considered to be more difficult than in temperate regions where community relationships are usually more clear-cut. Raup discusses the problem of applying climax theory to boreal vegetation. He suggests, as did Griggs (1934), that arctic plant communities are still adjusting to the environment and that the forests have not yet attained an equilibrium with it. He believes, however, that equilibria with "conditions in general" do exist and that edaphic sub-climaxes can be recognized. The writer has studied and attempted to classify the Atlin valley vegetation with this view in mind.

Earlier, Raup (1934) reported on his phytogeographical studies in the Peace River and upper Liard River regions. Important accounts of the history of botanical exploration and of geology, physiography, and climate, are given. A geographical analysis of the vegetation is discussed, and major vegetation types, some designated associations, are defined. A catalog of the vascular plants is included.

In a later paper, Raup (1945) discusses forest species and communities along the Alaska Highway in northern British Columbia and southern Yukon Territory. Here the complexity of vegetational relationships is again pointed out, but a fair amount of order in classification is achieved through a consideration of some of the underlying complicating factors, the major one being fire. It is recognized that lodgepole pine and aspen, although ubiquitous, are "opportunists" of only temporary significance. These species are unable to regenerate in the absence of further burning and thereby maintain their status as major forest types. On this basis Raup explains that white spruce, black spruce, alpine fir, and balsam poplar would, as nearly pure stands developing in the absence of such disturbances, form only four basic forest vegetation types. The first three of these species are capable of reproducing generation after generation on the same site, and each shows a well-defined segregation from the others according to habitat. White spruce prefers better drained uplands and alluvial soils of river flood plains; black spruce characteristically grows in muskegs or mossy bogs; alpine fir is found primarily on high slopes and in the foothills of mountains; and balsam poplar prefers recent flood plains and gravel bars where it forms a stage in the development of white spruce forest.

Raup, in his 1945 paper, writes,

> In view of these facts, and because the white spruce is widely and rather evenly distributed throughout the area, the principal criterion for the definition of natural regions in terms of forest types becomes the presence or absence of large quantities of black spruce, alpine fir, or balsam poplar in the upland timber.

Six forest cover types or associations have been recognized by Raup (1945) along the Alaska Highway. (1) The white spruce-lodgepole pine-aspen association is the most abundant and widespread. (2) The next most important, in terms of area covered, is the black spruce-white spruce-pine association, sometimes containing aspen. The others are (3) the white spruce-balsam poplar (on flood plains), (4) the white spruce-alpine fir-black spruce-lodgepole pine, (5) the white spruce-balsam poplar- aspen, and (6) the aspen groves-prairie openings associations. The only one of these six which is important along the highway through the Atlin region is the white spruce-lodgepole pine-aspen association.

Another comprehensive botanical study by Raup was published in 1947, this time dealing with the southwestern portion of the Northwest Territories. In that paper, a number of plant communities are defined, primarily in terms of the habitat type with which they are associated. As an example of the nomenclature which Raup used and an indication of his method, three of the communities are: (1) plants of loose slide rock and turf-banked terraces, (2) plants of ravines and gorges below timberline, and (3) flood plain communities. His study also includes comprehensive lists of primary and secondary species in the various community types, along with discussions of plant succession and a phytogeographical analysis.

Halliday and Brown (1943) discuss the distribution of some important forest trees in Canada. These authors deal, as did Raup, with the phytogeography of forest species in terms of reinvasion of deglaciated terrain outward from Wisconsinan refugia. The paper also attempts to show the percentage relative abundance (not actual abundance) or population intensity of the major species in the forests throughout Canada. Of interest here are the following statistics for forests in northwestern Canada: spruce (white and black), 31-60 percent (medium intensity); lodgepole pine, 1-20 percent (light); alpine fir, 11-30 percent (medium); and aspen and balsam poplar, 1-10 percent (light intensity). The Atlin valley generally parallels the pattern except for aspen, which is found to have a higher relative abundance, as discussed below.

Porsild (1951) considers plant communities along the Yukon sector of the Canol Road (Fig. 1). His mile-to-mile transect of the road shows the distribution of five main forest types: (1) white spruce-lodgepole pine-aspen (dominant on well-drained soil of the valleys and lower slopes), (2) white spruce-balsam poplar, (3) white spruce forest with scattered paper birch and occasional black spruce, (4) black spruce forest mixed with some paper birch (a climax type on poorly drained glacial boulder clay where permafrost is close to the surface and where the forest floor remains wet and swampy throughout the summer), and (5) alpine fir forest (at timberline, on moist north and east slopes).

Most of the non-forest vegetation types are described by Porsild (1951) more on the basis of habitat or physiognomy than of species composition. These include (1) copses (including several low shrub formations); (2) meadows and grassland; (3) alpine plant communities; (4) vegetation of lakes, ponds, lake shores, and sloughs; (5) vegetation of bogs and mires; (6) vegetation of burnt-over land (with a consideration of succession following fire); and (7) vegetation of disturbed sites, including apophytes and anthropochorous plants. Porsild delineates seven phytogeographical provinces for the Yukon, discusses the age and origin of the flora of southeastern Yukon, and provides an annotated list of 894 species of vascular plants, covering the entire territory to the extent of floristic knowledge at the time. Porsild's study is the most comprehensive concerning floristics, vegetation, and phytogeography in the immediate vicinity of the Atlin valley.

Moss (1953a, b) discusses forest communities and marsh and bog vegetation of northwestern Alberta. The present writer believes that here there are fundamental vegetational similarities with the Atlin valley. Forest vegetation is classified and described by Moss in terms of floristic composition and ecological relationships, the categories used being the association, faciation, and associes. This work involved regional reconnaissance, close study of selected stands, and the tabulation of species prevalence in each stand using an eight-category scale from rare to dominant.

According to Moss (1953a), dominance in the tree stratum determines the association to which the stand belongs. The faciation is based on the composition and relative importance of the lower strata. Associes include stands which were burned and are presently in earlier stages of succession. Climax vegetation is recognized, in the Clementsian sense, and some stands are designated subclimax. The latter include vegetation which is favored by prevailing edaphic conditions, e.g. high water table, exceptionally pervious substrate, etc., or periodic fires. Although there are some important floristic differences between the vegetation of northwestern Alberta and the Atlin valley, certain communities are believed to be comparable in each area on the basis of the leading species in equivalent strata.

Moss' study of marsh and bog vegetation (1953b) recognizes a wide range of conditions, often intergrading, from aquatic through subaquatic and moist. Terminology of wetland habitats and vegetation in general is clarified. In most cases vegetation types are not defined in terms of associations, etc., as in the uplands, but instead are discussed in terms of habitat types, e.g. muskeg and saline meadow, or habitat type and a characteristic species group, e.g. Drepanocladus bog and Agropyron-Carex grassland. Bog seres and their climax forest associations are considered, as are seral retrogressions caused by burning. An important distinction is made between Drepanocladus-Carex bogs and Sphagnum bogs. Only the former bog type has been found in the Atlin valley, even though the Sphagnum type is very common elsewhere.

A further paper relevant to the present study is one by Jeffrey (1961) in which 24 vegetation types in four topographic divisions of the lower Liard River region in the Northwest Territories are discussed. This paper also includes an annotated list of plants. The basis of Jeffrey's description of the vegetation is the layered physiognomy of each type. Within each of five layers (tree, underwood, shrub, herb, and lichen and bryophyte) primary, secondary, and occasional species are recognized.

LaRoi (1967) discussed preliminary work in a quantitative ecological study of boreal spruce-fir ecosystems in North America. Vegetation in stands of white spruce-fir and black spruce forests, from Alaska to Newfoundland, is described and the stands are classified on the basis of floristic criteria and coincidence of distribution patterns.

One of LaRoi's stands was located in the Central Yukon Forest Section, as defined by Rowe (1959). This includes most of the Atlin region. LaRoi's stand appears to be representative of the main forest type in the region, and species encountered in it and data about their relative population sizes are assembled in Table 3. The stand is classified in the Populus/Salix/Shepherdia stand-group of the boreal white spruce-fir stands. The present writer considers it equivalent to the shrub-herb faciation of the white spruce association in the Atlin valley study (Table 5).

Lutz' 1956 paper dealing with the ecological effects of forest fires in the interior of Alaska is of fundamental importance to vegetation studies throughout the boreal coniferous forest biome. Again the complex relationships of a relatively few forest species are brought under consideration, and it is noted that, "Only when the influence of past fires is recognized can one begin to account for the seemingly haphazard mosaic of vegetation." Lutz points out that fires have always occurred because of lightning and the activities of prehistoric man. He makes three important points regarding the nature of the vegetation mosaic: (1)

Table 3
stand

Tree st

Low tre
squa

Medium
cove

Herb a
cove

Table 3. Species encountered by LaRoi (1967) in a stand located near the Atlin region*, with data on relative population sizes.

Tree stratum (square feet per acre)	
Populus tremuloides	0-10
Picea glauca	101-150
Low tree and tall shrub stratum (stems per 100 square meters)	
Salix glauca	6-15
Medium and low shrub stratum (percent areal coverage)	
Shepherdia canadensis	2.1 -3.3
Rosa acicularis	" "
Herb and dwarf shrub stratum (percent areal coverage)	
Solidago multiradiata	0.0 -0.33
Gentiana propinqua	" "
Arctostaphylos rubra	" "
Achillea millefolium	" "
Hedysarum alpinum	0.34-1.0
Arctostaphylos uva-ursi	0.0 -0.33
Mertensia paniculata	0.34-1.0
Galium boreale	0.0 -0.33
Epilobium angustifolium	0.34-1.0
Fragaria virginiana	0.0 -0.33
Pyrola secunda	" "
Linnaea borealis	2.1 -3.3

*This is LaRoi's white spruce-fir stand no. 5 and occurs at an elevation of approximately 2,500 ft, at latitude 60°49' N and longitude 136°39'W. This is approximately 75 miles west-northwest of the northwestern corner of the Atlin region (Fig. 1).

sharp boundaries between stands of aspen and spruce are the edges of burns, (2) isolated patches, upland stringers, or even scattered individuals of spruce (and other species) are relicts of formerly extensive stands which were destroyed by fire, and (3) areas that are now treeless may have supported well-developed forest vegetation which was completely destroyed by fire. Lutz discusses in detail the effect of fire on different forest vegetation types as well as on soils, wildlife, and human welfare. He also presents a useful analysis of plant succession following fire.

A study by Horton (1956) in Alberta also provides useful information about the ecology of lodgepole pine and its relationships to burning.

In a more recent paper Oberle (1969) discusses the ecological role of forest fires, both in temperate and boreal forests. The necessity of fires for the maintenance of desirable vegetation types as well as wildlife habitats and a natural ecological balance is reiterated.

As far as the writer has been able to determine, no significant botanical work had been done in the Atlin valley prior to the present study, and very little appears to have been done elsewhere in the region except along the Alaska Highway. The only published report of a plant collection in the valley appears in Hultén's (1940) comprehensive history of botanical exploration in Alaska and Yukon Territory. This concerns the visit of Alice Eastwood, curator of the Herbarium of the California Academy of Science, to the Llewellyn

Glacier terminus area and also to Taku Lake (Taku Arm of Tagish Lake?) on Wednesday, July 15, 1914. Eastwood was concerned primarily with shrubs and trees, and the size of her collection apparently was not large.

It seems a safe guess that a number of miscellaneous, unpublished, private collections have been made in the Atlin valley, especially since completion of the Atlin road in 1949.

Other from this, personal communication with several Canadian scientists, including, among others, T. M. C. Taylor in 1967, A. E. Porsild in 1968, and J. Terasmae in 1969, shows that botanical, as well as palynological work in the Atlin valley and nearby areas has been lacking.

Very little information on other aspects of the natural history of the Atlin region is available. Swarth (1936) gives an account of mammals and birds in the Atlin Lake area. McTaggart-Cowan (1941) reports on a fossil partial cranium of *Bison bison* subsp. (cf. subsp. *athabasce*) (B. C. P. M. No. 678) of Holocene age found four feet below the surface in a muskeg at Wilson Creek. Whether this site is the Wilson Creek Bog of the present study is not known.

VII. GENERAL VEGETATION SURVEY

Purposes

Vegetation in the Atlin valley has been surveyed with two objectives in mind. First, in the absence of any

previous formal or published botanical work in the valley, it was desired to learn something of the fundamental nature of the vegetation there and to compare it with similar, previously studied vegetation in nearby areas. In this connection, it was desired to establish a preliminary classification of the major vegetational units, based primarily on physiognomy and species composition, to serve as a guideline for the development of future ecological research.

Secondly, information about the composition and spatial organization of the general plant cover was needed for a comparison with modern pollen deposition as seen in surface samples. In a palynological study, knowledge of any qualitative or quantitative relationships between modern regional vegetation and the pollen rain produced by it is, of course, helpful in determining the nature of former vegetation from fossil pollen assemblages.

Methods

Field activities. Poore (1955, 1956) reviews and criticizes the methods of the Braun-Blanquet school of phytosociology, and Kershaw (1964) and Daubenmire (1968) provide further discussion and useful information on the application of these methods in the field. Field work involves, in part, the subjective selection of stands of vegetation for detailed study. This is considered to be a worthwhile technique, capable of yielding much relevant information about the vegetation, provided that the area being

studied has been adequately reconnoitered and the flora is fairly well known.

Hansen (1949a) and Davis (1963) deal with the need for quantitative vegetational data to compare with percentages of pollen in surface samples and to establish a measure of the representation therein of various species. These studies, and others, make use of sample plots located randomly or systematically throughout the area of investigation.

The survey reported here employed a sampling procedure with both subjective and systematic aspects. The intent was twofold: (1) to apply basic field methods of the Braun-Blanquet school, particularly the subjective selection of stands, in order to be certain that in each case the assemblage of plants studied (the stand) represented a single vegetation type and was not a mixture of two or more types and (2) to obtain a measure of the relative importance, in terms of area covered, of each vegetation type.

After a certain amount of time had been spent collecting plants in the Atlin valley and reconnoitering the vegetation in general, the writer concluded that nearly all of the variations in vegetational development between lake level and about 3,000 feet were observable from points on the Atlin road. Furthermore it appeared that the relative amount of distance along the road occupied by a vegetation type was a rough function of the proportion of the total area occupied by the type in a broad zone on either side of the road. Within its elevation range (2,197 feet to approximately

2,575 feet), the road follows most topographic irregularities, and all habitat types, including bogs, are traversed or skirted. It appeared that sampling at appropriate intervals along the Atlin road could provide reasonably representative information on plant community organization and distribution in the valley.

For these reasons the Atlin road, and the first six miles of the Carcross road, was chosen as a base line. Stands of vegetation were systematically located at two-mile intervals. Every other milepost, beginning at mile two, marked the center of a small area within which two stands were located, one east and one west of the road. These areas were usually not more than about 300 feet in radius. Each stand was designated by milepost number and direction. For example, stand 2E was situated east of the road at mile two. Stands on the Carcross road were distinguished by a "C" (e.g. C2E), and stands on the road south of Atlin - the mileposts do not extend beyond Atlin - were designated by an "S" (e.g. S2E). Here the field truck odometer was used to determine two-mile intervals.

Since the general vegetation and the tree surveys were conducted in 1967, the Atlin road has been "improved." Alterations and relocations have been made in many places. Therefore some of the mileposts mentioned here do not correspond to actual mileposts on the present Atlin road.

Although each stand had to be located, according to this system, within a certain predetermined small area, the precise position depended on the surveyor's discretion. No predetermined spacing between milepost and stand was used. Instead, the most homogeneous appearing assemblage of plants closest to the post, on the side of the road in question, was selected. The quadrat size was 900 square feet, and each stand, therefore, had to be at least this large. This method precluded consideration of small stands in certain microhabitats, such as in moist gullies, etc., but this was justified on grounds that only the more important vegetation types, in terms of area covered, were of immediate interest. In each case care was taken to locate the quadrat well away from the disturbed zone marginal to the road. Even so, weedy species, e.g. _Achillea_ sp., _Polemonium pulcherrimum_, etc., were often encountered. Logged areas, which were rare, were avoided, except in a few instances where compromise seemed in order and quadrats were allowed to contain one or two very old cut stumps.

It is emphasized that in stand selection no form of vegetation or habitat was consciously discriminated against as long as a quadrat 30 feet square could be located within a contiguous unit of vegetation. It was intended to avoid laying out the quadrat in such a way that it would contain more than one vegetation type, including the ecotone between. This could happen if a quadrat were placed, according to a predetermined system, across the foot of a slope. Here, the portion lying on the slope might contain, for example,

vegetation of the aspen association, and that on the basal flat, depression shrub vegetation.

After the stand was selected a list of species and groups in it was made. Although every plant seen was accounted for, it was not possible to identify them all to species. Some, therefore, were relegated to genera, families (e.g. Gramineae) or other groups (e.g. foliose lichens).

Each quadrat was established by pacing out a 30-foot square in what was judged to be a representative part of the stand. Paper markers were placed at the corners on convenient pieces of foliage. Within the quadrat the status of every species or group on the stand list was assessed. The measure employed was one of cover and abundance according to the Domin scale (Kershaw, 1964; V. J. Krajina, personal oral communication 1969). The Domin scale is reproduced as Appendix C for the convenience of the reader. This measure, the cover-abundance (C-A) value, along with constancy (Kershaw, 1964), are the statistics upon which the vegetation classification presented in this dissertation is based. The quadrat lists are the relevés of the Braun-Blanquet method.

If representatives of 85 percent or more of the names on the stand list were found in the quadrat, the sample was considered to adequately represent the stand. If fewer than 85 percent were found, an adjacent quadrat of equal size was marked off and searched for additional species. If the number of new species was ten percent or more of the total found in the first quadrat, the assigning of C-A values to names on

the stand list was repeated for the double quadrat. If less than ten percent, the double quadrat was doubled again. In the few cases that a second doubling had to be made, the quadruple quadrat was considered representative of the stand and was used without further doubling, irrespective of the number of additional species.

All together 86 sites and quadrats were examined, from mile six on the Carcross road to mile 19-south on the Atlin road (see map, Fig. 1). Whereas time and equipment for the systematic study of soils and microclimate were not available, a few general notes were made regarding physical characteristics of each stand. Where appropriate, soil information of Lietzke (1970) is incorporated, and several of his soil profile descriptions are presented in Appendix A.

Association table. An association table was constructed by listing all species and groups in a column along each vertical margin of a large sheet of paper. All stand numbers were written across the top, heading a series of 86 columns which made up the body of the table. The data from each relevé were then written onto the table in the appropriate column (Poore, 1955).

By studying the association table it was possible to identify the relevés which were floristically similar and contained the same dominant species in the upper (usually the tree) stratum. Dominants were recognized on the basis of high C-A values. Relevés which appeared similar with respect to dominants were grouped together. If a group

consisted of four or more relevés, mean C-A values and constancy values were determined for all the species and species groups. Several relevés together were considered to represent a distinct vegetational unit if they contained additional species, besides the dominants, with a combination of high mean C-A and constancy values, and if the same species were found, upon examination of other relevé groupings, to be less common or absent there. Fidelity was noted in a few instances, but was not used to aid in establishing the groups.

The vegetation units or communities defined in this manner were classified either as associations or as associes. An association is considered to be the fundamental unit of more or less stable vegetation and characteristic of a particular ecosystem type. An associes, on the other hand, consists of vegetation in an early stage of succession, often following a fire. One association, the white spruce association, was subdivided into two faciations (Daubenmire, 1968). The various data for 12 communities in the Atlin valley are presented in Tables 4 through 15. Table 17 summarizes important data for each of the 12 communities.

Discussion

The abstraction of relevés from the association table and grouping them into associations is a subjective procedure and has been widely criticized on this basis. Poore (1955) refers to it as the "muddled and haphazard phase" of the Braun-Blanquet method. The reality of the communities determined in this manner is a function of the patience of the investigator and the extent to which the table is critically studied.

The three categories of community organization and development recognized here (association, faciation, and associes) constitute units of vegetation or plant cover which are distinguished in the field as follows: (1) Each exhibits a characteristic physiognomy with respect to four major strata - arboreal, shrub and subshrub, herb, and lichen and moss. (2) Within each there is floristic continuity from stand to stand. (3) Every community occupies a significant area, either in the valley or in other regions as determined from the literature and the writer's observations. Each, therefore, is important as a landscape component and potentially important as a producer of a characteristic pollen rain. (4) Each community is more or less directly related to a particular set of edaphic and historical factors. The edaphic factors, e.g. soil and water relations, change significantly only over periods of time measurable in terms of several generations of plant communities. Historical factors, e.g. fire and subsequent secondary succession, tend to recur, with varying intensities, at a frequency which may be greater than the frequency of community regeneration. (5) In some cases there are rather specific relationships between certain habitat factors and the plant community. Important among these are: (a) the shrub-herb-moss phase of the white spruce association - acid bedrock, (b) the

alpine fir association - higher precipitation and soil pH, (c) the depression shrub association - high water table, (d) the mixed woodland association - exceptionally pervious substrate, and (e) marsh and bog communities - water table perennially higher than ground surface; the influence of drainage basin geochemistry. (6) Each association, therefore, is believed to persist, with perhaps minor compositional changes, over major time intervals measurable in terms of a few hundred years or more. Persistence, or regeneration, is shown by the presence of fair proportions of seedlings and saplings of the dominant species in most stands studied and the relative absence of offspring of dominants of different associations.

The associations, including the two faciations of the white spruce association, can be looked upon as climax vegetation on the basis of the six criteria enumerated above. Climax in the Clementsian sense is not implied. Rather, a polyclimax concept is intended wherein several factors besides macroclimate act to perpetuate certain vegetation types. These are the edaphic climaxes of Raup (1941). Because of the prevalence of fire, this is believed to be an especially important approach in the Atlin region, as throughout the boreal forest zone. The youthfulness of the soils, the immaturity of surface drainage in some areas, the irregular glacial topography, and other factors are also important.

All but two of the 86 stands were classified or tentatively classified. This is not so much a reflection of widespread vegetational organization as of the selectiveness of the sampling procedure. Observations indicate that vegetation units in the Atlin valley, as in most places, are not sharply outlined, but instead grade into one another across transition zones or ecotones, some of which are quite broad (Fig. 7). Stand 12W, for example, falls into this category. The valley is occupied by "a variety of merging vegetation types of different successional status" (Daubenmire, 1968). Furthermore, transitional vegetation is considerably more important than is revealed by the sampling procedure alone.

Any classification which pigeonholes vegetational units must take these circumstances into account. The writer believes that strictly defining vegetation units, such as associations, must be done in terms of clusters of species or "noda" along ecological gradients (Janssen, 1967). These clusters must be defined, somewhat arbitrarily, on the basis of selected criteria such as the six listed above. In a way, plant communities (associations, etc.) are merely points along continua of constantly changing plant assemblages, where the amount of change per unit distance depends on the steepness of the ecological gradient.

The writer adheres to this view, but the associations (the "noda" or clusters) are defined broadly enough that they encompass practicable segments of actual vegetation. An examination of Tables 4 through 15 will show that, in many

cases, a certain range in C-A values is allowed for dominant species in an association as well as for less diagnostic species. In certain stands no particular amount of dominance is shown by species which are clearly dominant in other stands of the same association. Nevertheless, these stands could be included in the association because of overall floristic similarity or because the species in question was actually of higher C-A value in the stand than the quadrat data indicated. The quadrat happened to be located where the forest was thinner. Reference to field notes as well as quadrat data was ordinarily necessary to classify a stand.

It should be mentioned that aerial photographs of the entire Atlin region, at a scale of about two inches to the mile, are available from the Department of Lands, Forests, and Water Resources in Victoria and the National Air Photo Library in Ottawa. Some of these were obtained in connection with the present study for certain parts of the Atlin valley. Although an aerial photographic interpretation of landforms and vegetation was not intended as an adjunct to the present study, the potential value of aerial photos to future studies of this type is recognized. Terasmae and Mott (1964, 1965), for example, believe that aerial photograph studies are the only feasible way to adequately survey regional vegetation for palynological purposes.

Stone (1948) and Hegg (1967) show how major vegetation types can be recognized on aerial photos in parts of Alaska where the vegetation is similar to that of the Atlin region.

With this information the present writer has been able to distinguish several broad vegetation types according to tone (shade of gray) and texture on aerial photos of the Atlin region. These are: (1) coniferous forests, including spruce, pine, or mixtures of these and, in some cases, of alpine fir; (2) broad-leaved forests, including aspen, poplar, or mixtures of these; (3) depression shrub vegetation; (4) upland herbaceous vegetation; and (5) marsh and bog vegetation, including differentiation of the various herbaceous and shrub zones. The aerial photos illustrate the irregular topography and diverse landforms throughout the region. These are a result of widespread glacial activity and of the effects of postglacial erosion. The natural result of this geomorphic diversity and topographic irregularity is a general lack of continuity in single vegetation types or stands over large areas. An exception is the system of kame terraces between mile 16 and 23, where lodgepole pine forest is rather continuous. Also, in the southern part of the valley, upland mixed coniferous forests appear to be more extensive and continuous than elsewhere.

Generally, however, stands of vegetation are seen on aerial photos to be patchy and spotted across the landscape. Thus it would be difficult to measure the relative areas occupied by each vegetation type, a kind of information which is important in the present survey. Furthermore, on the photos it is not possible to make a reliable distinction between spruce, pine, and mixed coniferous forests in most

areas. Since these are the major pollen contributors, as well as dominants in major communities, the usefulness of the photos is limited in this respect too.

Examination of the aerial photos has, however, provided support for the simplifying assumption made earlier that the relative amount of distance occupied by a vegetation type along the Atlin road is, roughly, a function of the proportion of the total area that the type occupies in a broad zone on either side of the road. The photos have also been useful in obtaining a more complete view of the vegetation within and in the vicinity of the six bogs discussed later.

The plant communities

Sites. Most of the upland forest stands studied occupy sites which are flat or gently sloping to the west. Many of these are on raised swells with flanks which slope downward in two or more directions from the edges of the stand. A few sites occur on fairly steep slopes. Drainage is generally good and the sites are mesic in nature, although some are more moist than others, and many have a rather dry aspect. The most widespread soil parent material is a calcareous glacial till consisting of pervious sands and pockets of pebbles. The deposits vary in thickness from site to site. At a few there is relatively little or no glacial material so that soil is developing on bedrock.

Although there is considerable variation in substrate among the forested sites, this does not seem to be as important a factor in the differential development of forest vegetation types as is the past history of fire and subsequent successional development. The writer suggests that the regional climax vegetation type in the Atlin valley is the feather moss faciation of the white spruce association (see below). It is suggested further that, in the absence of future disturbances, succession would continue until all mesic sites eventually supported this community type. An indication of this is the fact that there is almost as much variation among the ten sites bearing stands of the white spruce association/feather moss faciation as among all the upland sites studied. To illustrate, the stand numbers are listed below with brief site characteristics.

6E	very gentle slope west; poorly drained; below limestone cliffs of Mt. White
6W	near edge of lake (Atlin Lake); moist; small, sluggish stream
26E	gentle slope west
28W	gentle slope west; dry
30E	moderate slope west; boulders
30W	steep slope west
34W	moderate slope (20^o) west
40W	high ground - upper region of a broad swell
48W	very gentle slope east; well drained
52E	gentle slope; damp

It is to be noted that stand 30W occupies the steepest forested site studied, yet has developed into the regional climatic climax vegetation type, rather than an edaphic climax.

Following Raup's (1941) discussion, all other forest associations are considered to be edaphic climaxes where site conditions, along with fire and post-fire successional

history, are involved.

Hygric habitats are widespread in the Atlin valley, and they and the plant communities in them are very important in terms of overall Holocene landscape evolution. They range from marshes and bogs to moist places bearing stands of the depression shrub association. In this study only the latter vegetation type was measured and classified, three stands being encountered in the survey. Marsh vegetation has not yet been examined. Bog vegetation is described in general qualitative terms below.

Four of the sites studied are considered xeric in terms of their exposure, excess drainage, and, in places, rocky substrate. These bear stands of the herb-heath association, the perpetuation of which is discussed below. At these sites the gentler slopes are believed also to be potentially capable of supporting climax forests.

White spruce association

White spruce forests are more widespread than any other plant community in the Atlin valley (Tables 17, 19, 20). In the survey 27 percent of the stands were of this vegetation type.

White spruce is clearly dominant in the arboreal stratum of all stands, having an average cover of about 30 percent. Tree willow occurs in a majority of the stands, but never with a cover of more than about five percent. Pine, aspen, and balsam poplar form light admixtures in a few stands.

Figure 8. Opening in the white spruce association/ shrub-herb faciation at stand 59E.

View east from near mile 59 on the Atlin road. Relatively large, old-growth white spruce (Picea glauca var. albertiana) are shown which are typical in aspect of mature spruce in the Atlin valley. The open nature of the arboreal stratum and the dense shrub stratum are characteristic of this vegetation type. Shrubs include Salix spp., Betula glandulosa, Shepherdia canadensis, and Potentilla fruticosa. The blossoms in the foreground belong to the latter species.

Glacial drift is thin or non-existent in this area and nearly bare patches, as at the lower right, are where bedrock is exposed at the surface. The absence of a calcareous substrate, unlike at most stands of this community type, is probably the major factor favoring the relatively important status of Betula and Potentilla. Table 5 (p. 109), which gives complete information on the vegetational composition of this stand, shows that other plants characteristic of acid substrata, including Ledum palustre ssp. groenlandicum and Empetrum nigrum, also occur here.

This community shares top importance, in terms of area occupied, with the mixedwood forest association at lower elevations in the Atlin valley. It is discussed on pages 77-85.

Midday. 30 June 1967.

Figure 8. Opening in the white spruce association/shrub-herb faciation at stand 59E.

The shrub and subshrub stratum varies from almost non-existent in some stands (40W) to dense (59E, S7E, and S7W). The usual situation is a light shrub cover containing five or six scattered species. The more important members of the stratum are Salix spp., Shepherdia canadensis, and Arctostaphylos uva-ursi, each of which are ubiquitous in the Atlin valley, and Arctostaphylos rubra, which occurs only rarely in other communities and therefore is of high fidelity in the white spruce association. Alnus sp., occurring in the shrub layer of three stands (6W, 30E, and 30W) and the arboreal layer of one (6W), is 100 percent faithful to the association. Diversity and density of the shrub layer appear to be a function of the moistness of the site and soil pH. Dry sites ordinarily support sparse shrub layers. Usually, the moist sites, especially those with Ledum palustre subsp. groenlandicum and Empetrum nigrum, which indicate lower pH, have dense shrub strata. In others, particularly those with thick patches of feather mosses, shrubs are scarce.

The herb stratum is more diverse than that of any other community except the mixedwood forest association. The large number of species and groups is, however, at least partly a reflection of the larger number of stands of these two associations encountered in the survey. There are no 100 percent constants, but Gramineae, Geocaulon lividum, Pyrola sp. and Linnaea borealis occur in all but two or three stands. Since these also have high constancy values in other

communities, their presence does little to characterize the white spruce association.

In the lichen and moss stratum feather mosses are common to dominant, and lichens form major admixtures in most stands.

Moss (1953) found the white spruce association to be the most prevalent as well as the best defined vegetation type in northwestern Alberta. He considered it to be the regional climax vegetation there. A similar interpretation may be applied to the Atlin valley where white spruce forests are believed to approach the status of a climatic climax. This takes into account the significant areal extent of the association as well as factors in the autecology of white spruce which enable it ultimately to replace most other forms of upland vegetation and to persist indefinitely in the absence of natural disturbances or climatic change (Hansen, 1953).

Two major variations of the white spruce association are recognized on the basis of differences in the relative importance of each of the four strata (Table 17). These variations are the feather moss and the shrub-herb faciations.

<u>Feather moss faciation</u>. This faciation is the more precisely defined (Table 4). The arboreal stratum contains old and mature spruce trees and the canopy is sometimes so dense that little direct sunlight reaches the forest floor. Shrubs and herbs are scarce, and the ground is thickly carpeted by large patches of feather mosses, primarily <u>Pleurozium</u>

schreberi and Hylocomium splendens. The moss cover is often absent around the bases of trees, especially where several trees grow in a clump and there is a thick litter layer. Patches of Geocaulon lividum and Linnaea borealis occupy significant portions of most quadrats, and scattered Lupinus arcticus, Arctostaphylos uva-ursi, Pyrola spp., and seedlings or small individuals of Shepherdia canadensis, Rosa acicularis, Mertensia paniculata, and others are sometimes encountered. Several of the sites occupy sloping terrain, some quite steep. At others, drainage is noticeably impeded. This factor appears to be responsible for the dense growths of Equisetum spp. encountered at sites 6E and 6W. The only alders found in the survey are in stands of this faciation, specifically at 6W, 30E, and 30W. Alders are associated with a small sluggish stream at 6W, and where they occur in the other sites the water table is shallow, as noted by the ground being wet at the surface.

Moss (1953) discusses the ecology of the feather moss faciation and states that, of the four white spruce faciations which he recognizes in northwestern Alberta, it is probably the climax of the association in the Clementsian sense. The writer considers the status of this community to be similar in the Atlin valley for the following reasons: (1) Charred wood was not observed in any of the ten stands studied, which indicates that, unlike other communities, fire has played no role in the perpetuation of this vegetation type. (2) The stands were made up of large and apparently old to mature trees, comparable only to trees seen in the shrub-herb-moss phase of the white spruce association/shrub-herb faciation and the white spruce-lodgepole pine forest association (see below). (3) The stands occupy sites which are level (6W) to fairly steep (30W), indicating that, on upland terrain, there is no direct control by the topography, exposure, or drainage over the type of vegetation which eventually develops in the continuing absence of disturbances.

Lietzke (1970) studied the soils in stands 48W and 52E and found actual soil development to be minimal. Parent material is a poorly drained sandy loam till beneath stand 48W and a fine-grained lacustrine material mantling till or outwash at 52E. The parent material is little altered by soil formation processes and is overlain by several inches of peat derived from the feather moss stratum. In August, 1969, a frozen layer was found at a depth of 30 inches beneath stand 48W, extending downward to at least 66 inches. At the same time of the year a frozen layer was also found between 23 and 36 inches at 52E. These may be examples of transient frozen ground, rather than stable permafrost. A description of the 52E profile is contained in Appendix A. This soil, plus that in stand 48W, is classified by Lietzke (1970) as a Histic Cryaquept, coarse-loamy, mixed calcareous.

Shrub-herb faciation. It is possible that two faciations, an herb faciation and a shrub-herb-moss faciation, could be recognized here instead of a single faciation (Table 5;Fig. 8). Only three of the stands studied, however, would fall into the latter category, and the evidence to date is not considered adequate to make such a separation at the faciation level. Instead, the shrub-herb faciation will be discussed in terms of two phases, a phase being an informal and tentative community category for purposes of discussion.

(a) Herb phase. Stands of this community type include all but 59E, S7E, and S7W in Table 5. It is distinguished from the feather moss faciation by a comparatively full herb layer and less luxuriant lichen and moss development. It differs from the shrub-herb-moss phase (see below) by its relatively sparse shrub and its lighter moss layers. The canopy is more open than in the former community, and most sites are drier than in either of the others.

Evidence of fire occurs in six of the ten stands, whereas none was found in the other white spruce forest stands. This indicates the importance of the fire factor in the development of vegetation of the herb phase. It is probable that at sites where no future disturbances occur, succession will continue until either a feather moss faciation or shrub-herb-moss phase results. Although the fire factor is recognized, the vegetation of the herb phase differs from brûlé in that succession has reached a later and slower stage, the arboreal stratum is well developed, and community relationships are generally more stable.

(b) Shrub-herb-moss phase. Stands 59E, S7E, and S7W, belong to this phase. These are grouped in the middle of Table 5 where they can easily be compared with the others.

This phase differs from the other two communities of the association in having a dense shrub and subshrub stratum in addition to moderate to dense herb and lichen-moss strata. This community also differs in the shrub stratum by a lower importance of the ubiquitous *Shepherdia canadensis*, *Rosa acicularis*, and *Arctostaphylos uva-ursi* and by the occurrence, with relatively high C-A values, of *Betula glandulosa*, *Potentilla fruticosa*, *Ledum palustre* subsp. *groenlandicum*, and *Empetrum nigrum*. A possible explanation for the presence of the two ericaceous shrubs is the development of soil from an acidic bedrock, rather than from calcareous drift which underlies the majority of sites along the Atlin road. Aitken (1959) maps greenstone and volcanic greywacke in the vicinity of mile 59, small outcroppings of which occur near stand 59E, and siliceous bedrock (high quartz content) occurs in the vicinity of stands S7E and S7W.

It is probable that the shrub-herb-moss phase of the white spruce association persists indefinitely as edaphic subclimax stands within the white spruce forests. From the writer's general observations and survey measurements, it is suggested that this phase is of minor areal extent, being restricted to geochemically acidic locales as discussed above and also to poorly drained situations. Stands S7E and S7W are quite moist, and other stands were observed to occur along small streams. The largest white spruce encountered in the Atlin valley, with DBH (diameter at breast height) measurements up to 30 inches, grow in stands

at tree survey sites 28E, 29E, and S13W (see below).

Lodgepole pine association

The lodgepole pine association has been difficult to define in the Atlin valley, but, as a community type wherein either middle-aged or mature pine trees are dominant, it is considered to be an important component of the regional vegetation (Table 17 and Fig. 9). Pure, old growth lodgepole pine forests are rare. Five of the stands studied are considered to belong to the association, and two of these still show signs of former burning. Only stand 36E fits well the lodgepole pine association concept (Fig. 9). A large amount of terrain in the northern part of the valley, including the kame terraces previously noted, is occupied by burned or partially burned forests consisting primarily of young pines and apparently redeveloping into pine forests. This will be discussed further under brûlé. Also it is noted that rather large, living pine trees are important in mixed coniferous forests in the southern part of the valley and at intermediate elevations on the valley walls.

The arboreal stratum varies from sparse, in older stands, to quite dense in the young, even-aged stand at 24E (Fig. 9). Shrub development is light to moderate, with Salix spp., *Arctostaphylos uva-ursi*, *Shepherdia canadensis*, and *Rosa acicularis* the only important components. Density is usually low in the herb layer too, consisting primarily of Gramineae, *Epilobium angustifolium*, *Linnaea borealis*, and several composites.

Figure 9. The lodgepole pine association at stand 24E.

This view shows a fairly dense stand of even-aged lodgepole pine, a situation indicative of origin on a surface cleared of former vegetation by fire. The substrate here is light and well-drained. The openness of the forest at lower levels is particularly noticeable, herbs and shrubs being scarce. The forest floor is densely covered by lichens, including reindeer lichens, and mosses.

This community type is discussed on pages 86 and 89, and phytosociological data are included in Table 6.

Late afternoon. 3 July 1967.

Figure 10. The lodgepole pine brûlé (associes) at stand 20E.

View east from near the Atlin road at mile 20. A stand of nearly even-aged lodgepole pine, killed by a fire in 1958, is shown. The roots of the trees are partially decayed and it is possible to work the trees loose from the soil and push them over by hand. A few trees survived the fire, foliage of one of which shows in the upper right of the view. The plants bearing white fuzzballs (seed structures) in the foreground are <u>Anemone</u> sp.

This vegetation type is discussed on pages 90-91 and phytosociological data are included in Table 8.

Early evening. 3 July 1967.

Figure 9. The lodgepole pine association at stand 24E.

Figure 10. The lodgepole pine brûlé (associes) at stand 20E.

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The lichen-moss layer may be sparse, as at 24W, 38W, and 50W, or quite dense, as at 24E (Fig. 9) and 36E. The vegetation of the latter two sites suggests a lichen-moss phase, analogous to the feather moss faciation of the white spruce association.

A soil profile description by Lietzke (1970) for a lodgepole pine stand in the lower Fourth of July Creek valley is presented in Appendix A. This soil is classified as a Typic Cryopsamment, sandy mixed.

Brûlé 3

The brûlé vegetation type so characteristic of the boreal forest biome is common in the Atlin valley, particularly in the northern part. It is divisible into two types depending on whether the burned wood and the seedlings are mostly spruce or lodgepole pine.

White spruce brûlé. Four of the sites encountered in the survey support stands of this vegetation type (Table 7). None appear to have been burned recently, and mature spruce trees are present. All stands contain a clutter of downed trees. The arboreal stratum is not dense, and a light admixture of aspen and tree willow is common. Good spruce regeneration is characteristic, but pine and aspen seedlings also occur.

It is suggested that forest fires can vary considerably in intensity over short distances because of vagaries of the wind coupled with topographic irregularities and the condition, whether moist or dry, of the vegetation. It is possib

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possible that the present stands were severely burned, hence the large amount of downed wood (blow-down of dead trees), yet with nearby white spruce stands being only lightly burned. Trees that survived in the latter places could have been immediate seed sources for the present stands. Coupled with an absence of nearby aspen or pine, this circumstance has enabled the stands to regenerate directly to spruce, rather than to stands of aspen, pine, or the mixed communities which are more commonly the case.

Lodgepole pine brûlé. This community type was encountered at most of the sites on the kame terraces between mile 14 and 22 and also at stand 38E. At the latter, the burn is fairly old, but at the others the fire responsible was one which local residents say occurred in 1958 (Fig. 10).

Surviving older pine trees in these stands are absent or quite scattered, a situation which reflects differences in blaze intensity from one place to another. Dead and blackened pine trees, many still standing, are a common sight. Often these are found in dense, young, even-aged stands, indicating that at the time they were killed it had not been more than a few decades since a previous fire. Pine seedlings are abundant throughout the burn area, and aspen seedlings are also common. Most stands as well contain a few spruce seedlings.

In the shrub and subshrub stratum, lodgepole pine (dead), *Salix* spp., *Rosa acicularis*, and *Arctostaphylos uva-ursi* typically have fairly high constancy values. Only the latt

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the latter species, however, is of significant cover and abundance, and since it is prostrate, shrub density is light in aspect.

The herb layer is also light, with scattered grasses, *Epilobium angustifolium*, *Anemone* spp., *Polemonium pulcherrimum*, *Linnaea borealis*, and composites in most stands. At 38E, where the stand is older, the herb layer is denser. The lichen-moss layer is characteristically moderate to dense, consisting of species especially adapted to dry and sunny conditions.

Brûlé is an important component of the regional vegetation. In brûlé communities ecological relationships are temporarily out of balance, with succession leading to the reestablishment of a stable ecosystem. Accordingly, this vegetation type is considered an associes (Daubenmire, 1968), with white spruce, lodgepole pine, and aspen associes recognized in the Atlin valley.

White spruce-lodgepole pine forest association

Spruce and pine share dominance in this community, (Table 9). These make up an arboreal stratum with an open to nearly closed canopy, in some cases comparable only with the feather moss faciation of the white spruce association (Table 4). In all stands one or the other or both species show good regeneration. A light admixture of tree willow is characteristic, and a few aspens and balsam poplars occur at 56E and 56W.

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The shrub stratum is sparse to moderate at 36E, 56E, and 56W, which are all fairly dry sites. At S19N and S19S the shrub layer is denser and more diverse, containing the infrequent Ledum palustre subsp. groenlandicum and Empetrum nigrum. As in the shrub-herb-moss phase of the white spruce association, a geochemical factor again may be responsible here. On the whole, the shrub layer is seen to be more diverse in this association than in any other, including the rich mixedwood forest association (Table 12). This is despite the fact that only five stands were included in the survey. This is taken to indicate that only a few carefully selected stands may fairly represent a given vegetation type.

The herb layer is also of moderate density at the three drier sites mentioned above, but it is quite dense at the other two sites. Lupinus arcticus is more important here than in any other community. Outside of the alpine fir stands at mile S15 and two nearby stands of the mixedwood forest association (discussed below), alpine fir was found only in the herb and shrub strata of stands 56E, S19N, and S19S of the present community during the general vegetation survey.

The lichen and moss stratum is dense at all sites and is usually dominated by feather mosses, except at 56E where foliose lichens are considerably more abundant than mosses.

It may be significant too that stands 56E and S19N contain very old charred wood indicating earlier forest fire effects.

Alpine fir association

The two sites bearing this vegetation type (Table 10) occur in an area of thermal and travertine springs 15 miles south of Atlin. Besides stands of pure alpine fir forest, the area contains species which were not found elsewhere in the valley. Also the vegetation here appears to be somewhat more lush.

Luxuriant shrub and herb vegetation in low areas near the springs outside the fir stands is probably related to the abundance of moisture and warmer substrate conditions. This may also be coupled with higher levels of inorganic nutrients carried to the plant root zone by seepage from the spring sources. Porsild and Crum (1961) describe a similar habitat at Liard Hotsprings in northeastern British Columbia where they assume that conditions for plant growth are especially favorable because of higher ambient temperatures, higher specific humidity, a more abundant snow cover in winter due to rime deposits and possibly a related longer growing season and a local absence of winter ground frost. It is probable that one or more of these factors is involved in the growth of alpine fir in pure and dense stands in the vicinity of the warm springs. In this connection it should be noted that precipitation is higher throughout the southern portion of the Atlin valley because of proximity to the Coast Mountains. The maritime climatic influence would also be greater here because of the movement of air masses up the Taku River valley, up the Gilkey Glacier trench, and across

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gently sloping névés of the Taku-Llewellyn transection Glacier system of the Juneau Icefield. That alpine fir distribution in the Atlin valley is controlled, in part, by the moisture factor is further indicated by its occurrence throughout the valley at elevations of 800 to 1,000 feet above the lake level and its abundance at lower elevations in the vicinity of the Llewellyn Glacier terminus (Fig. 4).

Soil pH is probably also a factor controlling alpine fir distribution in the Atlin valley. Porsild (1951) and Hultén (1968) state that the species is found primarily on acid soils in the Yukon and Alaska. At most places in the Atlin valley the soils are developed from a calcareous glacial drift and have pH values of 7.0 or more (Appendix A). In some places, however, the drift is thin or nonexistent and soils may be developing from crystalline rocks or from other non-calcareous bedrock types. Such a possibility was mentioned in connection with the shrub-herb-moss phase of the white spruce/shrub-herb community type (p. 84-85). This is probably the case at higher elevations throughout most of the valley where glacial drift is less abundant than on the valley floor and lower valley walls. The absence of a calcareous substrate may also be an important factor in the common occurrence of alpine fir in the area of the Llewellyn Glacier terminus (Fig. 4).

Lietzke (1970) described a soil profile in the S15W stand. Here the drainage was found to be "good to perhaps excessive" and pH was low, from 4.8 to 5.5 in the A and upper B horizons, ranging to 7.0 in the C horizon. The soil here is classified as a Boralfic Cryorthod, loamy skeletal, mixed. Lietzke also notes that alpine fir forests in general grow in soils developed from a variety of well-drained parent material types and that pH in these soils is lower than in soils associated with most other vegetation types. The complete profile description for the S15W stand is contained in Appendix A.

Alpine fir is clearly dominant in each of the two stands studied (Table 10). Quadrat measurements give high C-A values for each of the size categories, and the canopy is closed in most places. Each stand contains slight admixtures of pine and tree willow, and the stands grade into other, rather diverse stands consisting of mixtures of spruce, pine, and balsam poplar.

Where the canopy is closed the shrubs are very scattered, but where open shrubs are abundant. *Amelanchier alnifolia* and *Viburnum edule* appear to be important only in this vegetation type, and *Actaea rubra* and *Sorbus* sp. were only found here. The herb layer is sparse in alpine fir stands, but mosses are dense. Conditions in the lower two layers are analagous to the feather moss faciation of the white spruce association.

Although relatively little information on the alpine fir vegetation type is available from the present survey, stands of this type having been encountered at only two sites, it is nevertheless designated an association. This is because at the two sites studied it exhibits a structural integrity and an ecological stability. Alpine fir forests are widespread in areas outside of the Atlin region, especially in the Babine-Stikine region to the south (Halliday and Brown, 1943) and at intermediate to higher elevations throughout the interior sectors of the western Cordillera.

Alpine fir was not observed in pure stands elsewhere in the Atlin valley, but it is found as a component, along with white spruce and lodgepole pine, of mixed coniferous forests at several locations. The mixed coniferous forest vegetation type cannot be discussed in the same context as the other community types since it was not encountered and measured in the general vegetation survey. Its existence is recognized as a community type, however, which may be classified at the association level after further ecological studies. A brief description of a stand of this type located near Jasper Creek Bog is given on page 161 in connection with a discussion of bog vegetation (Fig. 18).

Aspen association

In this community the density of the arboreal stratum is high in young stands and decreases progressively in older ones, which in general are rather open and light (Table 11). White spruce often forms an admixture with the aspen, but seldom appears to be reproducing. Balsam poplar is also a common admixture, and tree willow is frequent enough to be considered characteristic of the association. In all stands Aspen shows good to vigorous regeneration.

A possible variation of the aspen association is seen in stands C4W, 42W, S3E, and S5E where aspen, balsam poplar, and tree willow are each important. This can be designated the mixed broadleaf forest phase of the aspen association. At this point there is not enough evidence to consider the mixed broadleaf forest situation at the faciation or association level. Instead, it is treated in the broader context of the aspen association.

The shrub and subshrub stratum is typically dense, usually more so than in coniferous forests. Besides aspen saplings, _Shepherdia canadensis_ and _Arctostaphylos uva-ursi_ are abundant or dominant, and _Salix_ spp. and _Rosa acicularis_ are common.

The herb layer is quite full too, with Gramineae, _Lupinus arcticus_, _Epilobium angustifolium_, _Pyrola_ spp., _Mertensia paniculata_, _Linnaea borealis_, and various composites scattered to abundant. _Fragaria virginiana_ is more important than in any other association except the herb-heath. The only Polypodiaceous fern seen during the survey was in an aspen stand of 42E.

The lichen and moss stratum is relatively insignificant, being of lower total mean C-A value than in any other community. The older, mature stands are nearly devoid of cover in this stratum (42E through 44W).

Only stand 2W contains obvious signs of former burning, but most aspen association stands, except those bearing large, old growth trees, are undoubtedly the direct result of succession following fire. The typically dense shrub stratum probably obscures most charred wood in aspen stands. The younger aspen stands discussed in this section are actually a form of brûlé, where aspen, instead of pine, because of proximity of seed source or suckering from roots of burned trees, became the pioneer seedling species following fire. These stands were not, however, discussed as a third brûlé category, along with spruce and pine brûlé, because the arboreal stratum is more fully developed and succession has progressed beyond the initial, rapid stages. Floristically and structurally they bear a closer resemblance to their mature counterparts than does typical brûlé. The best examples of mature, old growth aspen stands are 42W, 44E, and 44W. True aspen brûlé, with dense seedlings and saplings, was observed at several places in the Atlin valley, but was not encountered in the survey.

Mixedwood forest association

A mixture of spruce and broadleaf trees, primarily aspen, in the arboreal stratum characterizes this association (Table 12). In some cases, as at stands 46E, 58E, S17E, and S17W, balsam poplar replaces aspen as the major broadleaf member, and in others both aspen and balsam share dominance with spruce, as at 58W and S3W. Tree willow is typically a significant admixture. Pine, on the other hand, is generally absent; it was found only in stand S1E, and then outside the quadrat.

The shrub and subshrub stratum is quite diverse and moderately dense. *Rosa acicularis*, *Shepherdia canadensis*, and *Arctostaphylos uva-ursi* are dominant, and white spruce saplings, *Salix* spp., and *Viburnum edule* are of intermediate importance. Floristically, and in general aspect, it is similar to the aspen association shrub layer.

The herb stratum is especially important, having the highest number of species and groups and the highest total of mean C-A values (Table 17) of any community. This is, in part, a reflection of the larger number of stands studied, second only to the white spruce association. It is also related to a high diversity of site characteristics and probably to larger differences in historical development from stand to stand than are involved in other associations.

Sites vary from nearly flat or gently sloping to steep and rocky. Stand S5W is in the latter category and has bedrock outcroppings. This stand contains five species or groups which were found in no other stand of the mixedwood forest community and are quite rare in other communities, except for the herb-heath association. These are *Aquilegia formosa*, *Sedum lanceolatum*, *Potentilla* spp., *Antennaria* sp., and *Artemisia* sp.

The high diversity of the herb layer, as well as of the shrub layer, coupled with differing proportions of dominants in the arboreal stratum from stand to stand, may be explained by historical factors. These include (1) different dates of past fires, hence different stages of successional development,

Figure 11. The mixed woodland association at stand C2E.

This community type is characterized by nearly equal abundances of white spruce and lodgepole pine with aspen as an important admixture. Stands typically are open and sunny with trees thinly spaced in most areas. Shrub stratum components are scarce and herbs are usually of only moderate abundance. Subshrubs or prostrate herbs, such as *Arctostaphylos uva-ursi* and *Linnaea borealis* frequently cover significant portions of the ground, and mosses and lichens, particularly *Cladonia* spp., are abundant.

In this view the three arboreal components are shown along with several patches of reindeer lichen.

The mixed woodland association is discussed on pages 102-103 and phytosociological data are contained in table 13.

Late afternoon. 27 August 1967.

Figure 12. The depression shrub association at stand 59W.

View west across poorly drained area near mile 59 on the Atlin road. Atlin Mountain is in the right background.

The substrate in this stand is moist, but the water table is usually below the surface.

The community is characterized by shrub willows, shrub birch and, in the herb stratum, by a dense cover of grasses and sedges. The community contains many species of herbaceous dicots, though most are of low importance individually. Mosses are abundant. White spruce trees shown within the stand proper grow on minor topographic highs where drainage is somewhat better.

The depression shrub association is discussed on pages 103-104, and phytosociological data are contained in table 14.

Mid-morning. 30 June 1967.

Figure 11. The mixed woodland association at stand C2E.

Figure 12. The depression shrub association at stand 59W.

(2) different fire intensities, and (3) different seed sources following fires, depending on the nature of adjacent unburned vegetation as well as the presence of unkilled plants and serotinous seed-bearing structures (e.g. lodgepole pine cones) within the stand.

The lichen and moss stratum is of minor importance and comparable to the aspen association.

The mixedwood forest type is the most heterogeneous of all the communities in the Atlin valley, and, for this reason, it may not be well regarded as an association. Further study may require subdivisions to be recognized. These might include, for example, a tree willow faciation (cf. S17W) and a balsam poplar faciation (cf. 46E and S17E, Table 12).

A soil profile in a mixedwood forest stand at mile 3 on the Atlin road was described by Lietzke (1970). The soil here is classified as a Boralfic Cryorthod, coarse loamy, mixed. A profile description is contained in Appendix A.

Mixed woodland association

The three stands of this vegetation type were studied on the pitted outwash northwest of Little Atlin Lake (Table 13; Fig. 11). These sites are generally flat and contain an especially light, sandy soil. Fortunately, a relevant soil profile description by Lietzke (1970) is available here too, as given in Appendix A, representing the substrate for a mixed woodland stand along the Alaska Highway.

The arboreal stratum is characterized by approximately equal proportions of spruce, pine, and one or more of the broadleaf species. Except for occasional clumps, the trees are sparsely distributed, hence the name woodland. In addition, shrubs and herbs are generally only scarce to scattered, and the ground is covered by conspicuous patches of yellow lichens, i.e. _Cladonia_ subgen. _Cladina_ spp. (the "reindeer" lichens).

This vegetation type is rare in the Atlin valley, although it is widespread elsewhere. Hansen (1953) reports the occurrence of similar substrate conditions and vegetational development along the Alaska Highway approximately 100 miles to the northwest between Whitehorse and Haines Junction.

In the same general region, at mile 896 on the Alaska Highway, Lietzke (1970) studied a soil profile in a stand of vegetation which he considered to be of the mixed woodland association. This soil was classified as a Typic Cryochrepts, coarse loamy, mixed. The profile description is contained in Appendix A.

Depression shrub association

This vegetation type is characteristic of poorly drained and moist, but not necessarily saturated areas. It usually forms a prominent zone between forest and marsh or bog vegetation. A moderate to dense willow shrub layer is invariably present, and in many cases shrub birch shares dominance with willow (Table 14; Fig. 12). Trees are absent, except on drier swells which sometimes occur within a stand and hence do not belong to the community proper. The herb stratum is quite diverse but of only light to moderate density. The major exceptions to this are thick patches of *Juncus* spp. and *Carex* spp. The lichen and moss stratum is typically thick and includes major proportions of *Bryum pseudotriquetrum*, *Tomenthypnum nitens*, *Mnium affine*, and *Ceratodon purpureus*. The only *Sphagnum* found in the course of the general vegetation survey was in stand 54W of this association.

Lietzke (1970) has studied a soil profile in stand 59W, which he terms a shallow bog profile. He suggests on the basis of decreasing pH with depth that a recent trend toward a more moist climate has brought about increased runoff and drainage into the stand with the deposition of lime at the surface.

The soil in this stand was classified as a Terric Cryosaprist, euic., and the complete profile description may be seen in Appendix A.

Herb-heath association

Four stands of this vegetation type were encountered in the survey (Table 15). Stand 4E and 16E occur on steep, westerly slopes, and the other two, at mile 8, are on a large, moraine-like swell with a more gentle slope. The substrate is loose glacial sand and gravel with occasional cobbles and boulders at the surface. All stands but 4E contain a few pieces of charred wood. The sites are high and exposed, and it is believed that they, as on similar intervening terrain, are subject to frequent and sometimes strong winds blowing north up the long fetch of Atlin Lake (Fig. 2).

This vegetation type lacks trees but in some cases contains aspen seedlings. The subshrubs *Juniperus horizontalis* and *Arctostaphylos uva-ursi* are common enough to be considered a distinguishing feature (the heath component), but other shrubs are scarce. The herb stratum is diverse and often moderately dense. Lichens and mosses are relatively rare, and the stands contain quite a bit of barren surface.

In the general vegetation survey this association was found to include 13 species with high fidelity values. These are indicated in Table 15 with a plus (+).

The herb-heath association is believed to be perpetuated by periodic fires of considerable intensity sweeping across these windy sites. There is a good fuel supply in the dry grasses and other herbaceous vegetation late in the summer. Edaphic conditions, primarily lack of surface moisture, are probably unfavorable for tree seed sprouting, and those that do take hold are killed by the fires. Nearby ravines and low areas contain shrubby vegetation plus aspen and pine seedlings, saplings, and a few trees. This indicates that fires are less intense in sites protected from the wind. Also it is possible that tree seeds tend to be blown across the raised sites and dropped into these lower areas.

Unclassified stands

The vegetation at two final sites could not be placed in any one category. At site 4W the topography is quite irregular and edaphic and microclimatic conditions appear to change over short distances. No homogeneous stand large enough to contain a quadrat was found. The quadrat list for this site, such as it is, is reproduced in Table 16, along with one for the other unclassified stand, 12W. At the latter site the vegetation is transitional between depression shrub and white spruce forest. No recognizably homogeneous stand of either type which could be used for measurement occurred within a reasonable distance of the mile 12 post. It is possible that the 12W stand will eventually succeed to the white spruce vegetation type.

Summary and discussion of general vegetation survey

Data from the general vegetation survey are summarized in Table 17. Here the 12 upland plant communities are listed in the order of their relative importance, where importance of a community is based primarily on the frequency at which representative stands were encountered in the survey and, to a lesser degree, on their species diversity (i.e. total number of species and species groups per community). Data on the species diversity of each community and of the four physiognomic strata are presented, and a total mean cover-abundance value is given as a measure of relative importance for each stratum in each community. With these data comparisons of

Tables 4 through 15. Association tables for plant communities in the Atlin valley.

These tables consist of the relevés abstracted from the original association table (not reproduced in this dissertation) and grouped into associations, faciations or associes.

All species and species groups (genera, families, etc.) are arranged according to stratum in phylogenetic order.

For calculation purposes, the C-A symbol X is used numerically as 0.5. In rounding off mean C-A values, any value less than 0.75 is written X, and above 0.75, 1. Values of exactly 0.75 are rounded off to X if less than half the quadrats contain the species and to 1 if one-half or more. Mean values exactly midway between 1 and 2, 2 and 3, etc. are similarly rounded off.

An asterisk (*) indicates that the species or species group appeared on the stand list but not in the quadrat. These were not considered in calculations.

In Table 15, a + with a plant name, in the species column only, indicates high fidelity.

Constancy is the percentage of quadrats in a community containing the species in question. Constancy classes are as follows: Class 1, 0-20%; class 2, 21-40%; class 3, 41-60%; class 4, 61-80%; and class 5, 81-100%. Where there are fewer than four relevés in a community, as in Tables 10, 13, and 14, constancy values would have little meaning.

I: Heading of column of mean cover-abundance values.

II: Heading of column of constancy classes.

Table 4. Association table for the white spruce association/feather moss faciation.

species or group	I	II	6E	6W	26E	28W	30E	30W	34W	40W	48W	52E
Pinus contorta	X	1	-	-	-	-	-	-	-	2	-	-
Picea glauca	6	5	5	5	6	6	6	5	7	7	6	7
P. glauca (sapling)	2	4	*	X	3	1	3	1	3	2	3	*
P. glauca (seedling)	2	5	1	-	3	2	3	1	1	2	3	X
Populus balsamifera	X	1	-	-	-	-	-	-	-	-	X	-
P. balsamifera (seedling)	*		-	-	-	-	-	-	-	-	*	-
P. tremuloides	X	1	-	-	-	-	-	-	X	-	-	-
P. tremuloides (seedling)	X	1	-	-	-	-	-	-	1	-	-	-
Salix spp.	1	3	-	3	2	2	1	1	1	-	-	*
Alnus sp.	X	1	-	1	-	-	-	-	-	-	-	-
Lycopodium sp.	X	1	-	-	-	-	2	-	-	-	-	-
Salix spp. (shrub)	2	5	4	2	2	X	1	1	2	-	3	4
S. spp. (subshrub)	X	2	-	-	-	X	-	-	-	-	X	4
Alnus spp. (shrub)	X	1	-	2	-	-	1	*	-	-	-	-
Ribes spp.	X	1	-	2	-	-	-	1	-	-	-	-
Rubus sp.	X	1	-	-	-	-	-	-	-	X	-	*
Potentilla fruticosa	*		-	-	-	-	-	-	-	-	-	*
Rosa acicularis	X	3	-	-	-	1	2	X	2	-	*	1
Shepherdia canadensis	1	3	-	-	1	-	-	2	2	-	3	1
Empetrum nigrum	*		-	-	-	*	-	-	-	-	-	-
Ledum palustre ssp. groenlandicum	1	1	3	3	-	-	*	-	-	-	-	-
Arctostaphylos uva-ursi	X	1	-	-	-	-	-	-	-	-	1	-
Arctostaphylos rubra	1	5	3	2	X	X	1	2	-	X	1	3
Vaccinium vitis-idaea	X	1	1	2	-	-	-	-	-	-	-	-
Equisetum scirpoides	X	1	-	-	-	-	-	-	-	3	-	4
E. spp.	1	2	8	6	-	-	-	-	-	X	-	*
Gramineae	1	4	X	*	-	1	1	1	3	1	1	3
Tofieldia spp.	X	2	-	-	-	X	-	-	-	1	-	X
Zygadenus elegans	X	2	-	-	-	2	-	-	X	-	-	2
Orchidaceae	X	1	2	*	-	*	-	-	-	-	-	2
Geocaulon lividum	2	5	1	2	X	3	*	X	3	2	2	3
Stellaria sp.	X	1	-	-	-	X	-	-	-	-	-	-
Delphinium glaucum	X	1	-	-	-	-	-	-	*	1	X	-
Lupinus arcticus	X	2	-	-	-	2	-	-	1	X	3	-
Hedysarum alpinum	X	1	-	-	X	-	-	-	-	-	-	2
Leguminosae	X	1	-	-	-	X	-	-	-	-	1	-
Epilobium angustifolium	1	3	-	-	*	*	2	X	2	X	2	X
Cornus canadensis	X	1	-	-	-	-	3	-	-	-	-	-
Pyrola asarifolia	X	1	-	-	-	X	-	-	-	-	-	-
P. grandiflora	X	1	-	-	-	1	-	-	-	-	-	-
P. secunda	X	1	-	-	-	2	-	-	-	-	-	-
P. spp.	2	5	2	2	2	-	2	2	2	2	X	2
Moneses uniflora	X	1	-	-	-	1	-	-	-	-	-	X
Gentiana propinqua	X	1	-	-	-	-	-	-	-	-	-	X
Polemonium pulcherrimum	X	1	-	-	*	X	-	-	-	-	-	-
Mertensia paniculata	X	3	-	-	-	2	*	1	1	1	2	-
Pedicularis labradorica	X	1	-	-	-	-	-	-	-	-	-	3
P. sudetica	X	1	-	-	-	-	-	-	-	-	-	X
P. spp.	X	1	2	-	-	-	-	-	-	-	*	-
Linnaea borealis	3	5	1	*	3	4	3	3	5	1	5	6
Solidago multiradiata	X	1	-	-	-	-	-	-	-	-	-	2
S. spp.	2	1	-	-	-	X	-	-	-	X	-	-
Antennaria sp.	X	1	-	-	-	X	-	-	-	-	-	-
Achillea spp.	X	2	-	-	-	X	-	-	-	X	1	1
Arnica louiseana	X	1	-	-	-	*	-	-	-	-	2	-
A. sp.	X	1	-	-	-	-	-	-	X	-	-	-
Senecio spp.	X	2	-	-	-	-	-	-	-	1	X	2
Foliose lichens	4	5	3	2	4	5	3	6	3	3	4	3
Cladonia subgen. Cladina spp.	X	4	*	-	1	2	X	-	2	1	X	X
C. subgen. Cladonia spp.	1	4	-	*	3	2	1	*	2	3	1	1
Stereocaulon sp.	*		-	-	*	-	-	-	-	-	-	-
Cetraria sp.	X	1	-	-	-	*	-	-	-	X	-	-
Bryophyta	8	5	9	8	7	7	8	9	8	7	6	9

Table 5. Association table for the white spruce association/shrub-herb faciation.

species or group	I	II	2E	10E	26W	28E	40E	48E	59E	S7E	S7W	S11E	S11W	S13E	S13W
Picea glauca	5	5	4	5	5	6	5	6	5	5	4	6	5	5	6
P. glauca (sapling)	3	5	4	2	3	3	2	2	3	3	3	2	3	2	3
P. glauca (seedling)	2	5	2	1	X	1	3	1	1	2	1	1	2	2	2
Populus tremuloides	X	1	-	1	-	-	-	*	-	-	-	-	-	-	-
P. tremuloides (sapling)	X	1	-	1	-	-	-	-	-	-	-	-	-	-	-
P. tremuloides (seedling)	X	1	-	X	-	-	-	-	-	-	-	*	-	-	-
Salix spp.	1	3	-	-	4	3	*	-	*	-	-	4	X	X	2
Lycopodium spp.	X	1	-	-	-	-	-	-	-	-	-	-	-	3	1
Salix spp. (shrub)	3	5	3	*	2	*	5	5	4	3	4	3	5	5	5
S. spp. (subshrub)	2	5	3	1	1	X	3	1	4	3	3	1	3	1	X
Betula glandulosa	X	2	*	-	-	-	1	-	4	3	-	-	-	-	-
Rubus sp.	*		-	-	-	-	-	-	*	-	-	-	-	-	-
Potentilla fruticosa	1	2	-	-	-	-	4	-	3	3	3	-	-	-	-
Rosa acicularis	1	2	-	2	3	2	-	-	3	-	-	-	3	-	-
Shepherdia canadensis	1	5	1	-	3	2	X	1	X	2	2	2	2	X	1
Empetrum nigrum	1	2	-	-	-	-	-	-	1	7	5	-	-	1	-
Ledum palustre ssp. groenlandicum	X	2	-	-	-	-	-	-	1	3	3	-	-	2	X
Arctostaphylos uva-ursi	2	4	-	4	X	2	5	X	2	2	-	3	5	1	*
A. rubra	2	4	4	-	1	-	2	4	4	5	2	2	2	2	2
Vaccinium vitis-idaea	X	1	-	-	-	-	-	-	-	*	3	-	-	-	X
Equisetum scirpoides	X	1	-	-	-	-	3	-	*	-	-	-	-	-	-
E. spp.	X	2	2	-	-	-	1	-	*	-	-	-	-	-	3
Triglochin maritimum	*		-	-	-	-	-	-	*	-	-	-	-	-	-
Gramineae	3	5	3	4	1	1	3	4	5	4	4	4	5	3	4
Carex spp.	X	1	-	-	-	-	-	-	*	-	1	-	-	-	-
Juncus spp.	*		-	-	-	-	-	-	*	-	-	-	-	-	-
Luzula spp.	*		-	-	-	-	-	-	*	-	-	-	-	-	-
Tofieldia sp.	X	1	-	-	-	-	1	-	*	-	-	-	-	-	-
Zygadenus elegans	X	2	-	-	-	1	*	-	2	2	2	-	-	-	2
Orchidaceae	X	2	X	-	-	-	-	-	X	-	X	-	-	-	-
Geocaulon lividum	3	5	-	2	-	2	1	X	7	3	3	4	4	3	4
Stellaria sp.	*		-	-	-	*	-	-	-	-	-	-	-	-	-
Delphinium glaucum	X	2	-	-	-	-	-	2	*	-	-	-	2	-	3
Anemone sp.	1	3	-	3	X	X	2	-	-	2	2	-	1	-	-
Pulsatilla patens	*		-	-	-	-	-	-	*	-	-	-	-	-	-
Cruciferae	X	1	-	X	-	-	-	-	-	-	-	-	-	-	-
Saxifraga tricuspidata	X	1	-	1	-	-	-	-	-	-	-	-	-	-	-
Parnassia palustris	X	1	1	-	-	-	-	-	*	-	-	-	-	-	-
Fragaria virginiana	X	1	-	-	-	-	2	-	-	-	-	-	X	-	-
Lupinus arcticus	2	4	-	*	-	3	3	3	5	-	-	3	3	3	3
Oxytropis sp.	X	1	-	-	-	-	2	-	-	-	-	-	-	-	-
Hedysarum alpinum	1	3	2	-	2	-	X	-	3	3	2	-	-	-	-
Epilobium angustifolium	2	4	2	3	2	2	3	2	*	-	-	3	4	-	2
Cornus canadensis	1	2	-	-	-	2	-	-	-	-	-	3	2	3	1
Pyrola grandiflora	X	1	-	-	-	1	-	-	-	-	-	-	-	-	-
P. secunda	X	1	-	-	-	1	-	-	-	-	-	-	-	-	-
P. sp.	1	4	2	*	2	-	-	2	1	2	1	1	1	1	2
Moneses uniflora	X	1	-	-	-	-	X	1	-	-	-	-	-	-	-
Androsace septentrionalis	X	1	-	1	-	-	-	-	-	-	-	-	-	-	-
Gentiana propinqua	X	2	1	-	1	-	X	-	-	-	-	-	-	-	-
Polemonium pulcherrimum	X	2	*	1	*	-	-	-	*	-	-	-	1	-	X
Mertensia paniculata	1	4	*	-	-	1	-	4	1	-	1	3	2	2	2
Pedicularis labradorica	*		-	-	-	*	-	-	*	-	-	-	-	-	-
P. sudetica	X	1	-	-	-	-	*	-	2	-	-	-	-	-	-
P. sp.	X	2	3	-	-	-	-	-	-	-	1	-	-	1	X
Scrophulariaceae	X	1	-	-	-	-	-	-	-	-	-	1	-	-	-
Galium boreale	X	1	-	2	-	-	-	-	*	2	-	-	-	-	-
Linnaea borealis	4	5	-	3	3	3	-	5	3	7	2	7	3	4	5
Solidago multiradiata	X	1	-	-	-	-	-	-	1	-	-	-	-	-	-
Solidago spp.	X	1	-	-	-	-	3	-	-	-	-	-	-	-	-
Achillea sp.	1	4	1	1	-	X	2	1	X	-	-	2	2	X	2
Arnica louiseana	X	1	-	-	-	X	-	-	-	-	-	-	-	-	-
A. spp.	X	2	-	-	-	-	-	*	-	-	-	1	2	1	1
Senecio spp.	X	1	-	-	-	-	3	-	1	-	-	-	-	-	-
Taraxacum sp.	*		-	-	-	-	-	-	*	-	-	-	-	-	-
Compositae	1	3	3	3	*	-	-	-	2	2	2	X	-	*	2
Foliose lichens	3	5	3	2	-	1	3	2	6	4	3	3	3	3	3
Cladonia subgen. Cladina spp.	X	3	X	1	1	1	-	-	*	1	*	-	-	1	1
C. subgen. Cladonia spp.	3	5	3	4	5	2	3	X	-	1	1	4	3	3	3
Stereocaulon spp.	X	1	-	X	1	-	-	*	-	-	-	-	-	*	-
Cetraria sp.	X	1	-	-	-	1	-	-	-	-	-	-	-	-	-
Bryophyta	5	5	5	3	5	4	2	4	6	6	8	5	3	6	6

Table 6. Association table for the lodgepole pine association.

species or group	I	II	24E	24W	36E	38W	50W
Pinus contorta	6	5	7	5	8	3	5
P. contorta (sapling)	X	1	-	-	-	*	1
P. contorta (seedling) . . .	X	3	-	1	-	2	X
Picea glauca	X	4	X	X	X	X	1
P. glauca (sapling)	X	3	-	X	*	X	1
P. glauca (seedling)	1	3	-	1	-	2	1
Populus tremuloides	X	1	-	X	-	-	-
P. tremuloides (sapling) . .	X	1	-	X	-	-	-
P. tremuloides (seedling) . .	X	1	*	2	-	-	*
Salix spp.	1	4	-	X	X	2	X
Juniperus communis	X	1	*	-	-	X	-
J. horizontalis	X	1	X	-	-	-	-
Salix spp. (shrub)	2	5	2	X	X	3	2
S. spp. (subshrub)	X	3	2	X	-	*	X
Rosa acicularis	2	5	X	3	3	2	3
Shepherdia canadensis	3	5	2	4	3	3	1
Ledum palustre ssp. groenlandicum	*		-	*	-	-	-
Arctostaphylos uva-ursi . . .	3	5	1	2	2	5	3
A. rubra	*		-	-	-	*	-
Vaccinium vitis-idaea	1	1	-	6	-	-	-
Viburnum edule	1	2	2	2	-	-	-
Equisetum scirpoides	X	1	-	-	-	-	3
Gramineae	3	5	4	3	4	2	4
Carex sp.	X	1	-	-	-	1	-
Zygadenus elegans	1	3	2	-	1	1	-
Geocaulon lividum	X	1	*	3	-	-	-
Aquilegia formosa	X	1	-	-	-	X	-
Anemone spp.	1	3	2	2	-	1	*
Cruciferae	X	1	-	-	-	X	*
Saxifraga tricuspidata . . .	1	2	3	3	-	-	-
Lupinus arcticus	1	2	-	-	3	3	-
Epilobium angustifolium . . .	2	5	2	2	2	1	3
Pyrola secunda	1	2	-	1	3	-	-
P. spp.	X	2	-	-	-	2	X
Gentiana sp.	X	1	-	-	-	2	-
Polemonium pulcherrimum . . .	X	1	-	-	-	2	*
Mertensia paniculata	X	2	-	-	*	X	2
Linnaea borealis	3	5	4	3	4	3	2
Solidago spp.	1	5	1	1	-	1	3
Antennaria sp.	X	1	-	-	-	-	1
Achillea spp.	X	2	-	-	-	1	2
Arnica louiseana	*		-	-	*	-	-
A. sp.	X	1	-	-	-	1	-
Compositae	X	1	-	-	-	X	-
Foliose lichens	4	4	8	2	6	*	6
Cladonia subgen. Cladina spp.	1	4	3	2	1	*	X
C. subgen. Cladonia spp. . .	3	5	2	3	2	4	2
Stereocaulon spp.	X	2	*	-	-	X	X
Cetraria spp.	1	2	2	2	-	-	-
Bryophyta	5	4	9	6	9	-	X

Table 7. Association table for the white spruce brûlé (associes).

species or group	I	II	C6E	C6W	10W	50E
Pinus contorta	*		-	-	-	*
P. contorta (seedling) . . .	X	2	-	-	-	3
Picea glauca	4	5	4	6	5	1
P. glauca (sapling)	3	5	2	4	3	3
P. glauca (seedling)	2	5	2	1	3	2
Populus tremuloides	1	4	1	1	*	2
P. tremuloides (sapling) . .	2	4	2	-	1	3
P. tremuloides (seedling) .	1	4	1	2	1	-
Salix spp.	1	4	X	1	-	2
Salix spp. (shrub)	2	4	*	3	X	4
S. spp. (subshrub)	X	4	1	1	X	-
Rosa acicularis	2	5	1	3	3	2
Shepherdia canadensis . . .	2	5	1	1	X	4
Arctostaphylos uva-ursi . .	2	5	1	3	2	3
A. rubra	*		-	-	-	*
Equisetum spp.	X	3	X	2	-	-
Gramineae	2	5	1	1	3	3
Carex sp.	*		-	-	-	*
Zygadenus elegans	X	3	*	X	1	-
Geocaulon lividum	X	3	1	*	1	*
Anemone spp.	X	3	X	-	X	-
Fragaria virginiana	X	2	-	2	-	-
Lupinus arcticus	1	4	X	-	1	2
Epilobium angustifolium . .	2	5	3	1	2	3
Cornus canadensis	X	2	-	X	-	-
Pyrola spp.	1	4	2	X	-	1
Gentiana spp.	X	3	-	1	X	-
Polemonium pulcherrimum . .	X	3	X	1	X	*
Mertensia paniculata	1	3	*	1	-	2
Galium boreale	*		-	-	*	-
Linnaea borealis	3	5	3	3	2	3
Solidago sp.	X	2	-	-	-	2
Achillea spp.	X	3	-	-	1	2
Compositae	X	3	-	X	1	-
Foliose lichens	4	5	4	5	6	2
Cladonia subgen. Cladina sp.	X	2	-	-	1	-
C. subgen. Cladonia spp. . .	3	5	1	4	4	3
Stereocaulon spp.	X	3	-	-	X	X
Bryophyta	X	2	2	-	-	-

Table 8. Association table for the lodgepole pine brûlé (associes).

species or group	I	II	14E	14W	16W	18E	18W	20E	20W	22E	22W	38E
Pinus contorta	2	3	2	1	-	3	2	-	-	*	X	1
P. contorta (sapling)	X	2	3	7	*	-	1	-	-	-	-	-
P. contorta (seedling)	3	5	3	2	4	3	4	4	4	3	3	3
P. contorta (dead)	4	4	1	-	5	2	7	5	5	6	7	-
P. contorta (sapling) (dead)	1	3	2	-	*	-	2	X	X	3	3	-
Picea glauca	X	1	1	-	-	-	-	-	-	-	-	1
P. glauca (sapling)	X	1	-	-	-	-	-	-	-	-	-	2
P. glauca (seedling)	1	5	X	X	-	1	X	1	2	2	X	X
Populus balsamifera (sapling)	X	1	-	-	X	-	-	-	-	1	-	-
P. balsamifera (seedling)	X	2	-	-	1	1	-	-	-	X	-	-
P. tremuloides	X	1	-	-	-	X	-	-	-	-	-	-
P. tremuloides (sapling)	X	2	-	-	-	3	X	-	-	2	-	-
P. tremuloides (seedling)	2	5	1	1	1	3	2	2	2	2	2	-
Salix spp.	X	1	-	-	-	1	-	-	-	-	-	1
Salix spp. (shrub)	1	4	2	3	1	1	3	X	1	-	-	3
S. spp. (subshrub)	1	4	2	1	-	*	2	1	2	1	1	-
Rubus sp.	X	1	-	-	1	-	-	-	-	-	-	-
Rosa acicularis	1	4	2	-	1	-	2	3	*	1	2	X
Shepherdia canadensis	X	2	-	-	2	-	-	-	-	-	2	3
Empetrum nigrum	X	1	-	-	-	-	-	-	-	-	-	2
Arctostaphylos uva-ursi	3	5	2	2	3	7	2	3	2	1	*	7
A. rubra	*		-	-	-	-	-	-	-	-	-	*
Viburnum edule	*		-	-	*	-	-	-	-	-	-	-
Equisetum sp.	X	1	X	-	-	-	-	-	-	-	-	-
Gramineae	3	5	2	3	4	4	3	4	4	2	3	2
Carex spp.	X	1	-	-	X	-	-	-	-	-	-	1
Zygadenus elegans	X	3	-	-	-	1	1	-	-	X	1	X
Stellaria sp.	X	1	-	-	-	-	-	-	X	-	-	-
Caryophyllaceae	X	1	-	-	-	-	-	-	-	-	-	1
Anemone spp.	1	5	-	1	2	2	1	2	3	1	2	-
Arabia Holboellii	X	1	-	-	1	-	-	-	-	-	-	-
Sedum lanceolatum	*		-	-	-	-	-	*	*	-	-	-
Saxifraga tricuspidata	X	2	1	-	2	-	-	-	X	X	-	-
Lupinus arcticus	1	2	-	-	-	3	2	-	-	2	-	2
Oxytropis spp.	1	2	-	-	-	-	-	2	3	*	2	-
Epilobium angustifolium	3	5	1	-	3	3	3	3	4	4	4	3
Pyrola spp.	X	1	-	-	-	-	-	-	-	-	-	2
Androsace septentrionalis	X	1	-	-	2	-	-	-	-	-	-	-
Gentiana propinqua	X	1	-	-	-	-	-	-	-	-	-	2
Polemonium pulcherrimum	2	4	-	-	2	2	2	2	3	1	1	2
Phacelia spp.	X	1	-	-	-	-	-	X	*	-	-	-
Mertensia paniculata	X	1	-	-	-	-	-	-	-	-	-	2
Pedicularis spp.	X	1	-	-	-	1	-	-	-	-	-	1
Linnaea borealis	2	5	2	1	2	4	4	4	*	X	3	2
Solidago decumbens	X	1	-	-	2	-	-	-	-	-	-	-
Solidago spp.	X	1	-	-	-	-	-	2	3	-	-	*
Achillea spp.	X	2	-	-	-	-	-	1	*	X	1	X
Arnica sp.	X	1	-	-	-	-	-	-	-	-	-	3
Compositae	1	3	2	1	-	2	2	-	-	1	2	-
Foliose lichens	2	4	-	3	-	4	1	5	1	4	3	3
Cladonia subgen. Cladina spp.	X	1	3	-	-	1	-	-	-	-	-	-
C. subgen. Cladonia spp.	1	2	7	5	-	X	-	-	-	-	-	1
Bryophyta	7	5	6	4	5	6	8	9	9	9	9	*

Table 9. Association table for the white spruce-lodgepole pine forest association.

species or group	I	II	36W	56E	56W	S19N	S19S
Pinus contorta	4	5	5	4	6	3	2
P. contorta (sapling)	X	2	-	X	*	-	X
P. contorta (seedling)	1	1	-	3	*	1	-
Picea glauca	4	5	5	4	3	4	5
P. glauca (sapling)	2	5	3	1	1	2	1
P. glauca (seedling)	1	5	2	1	X	1	2
Abies lasiocarpa (sapling)	X	2	-	X	-	1	-
A. lasiocarpa (seedling)	X	2	-	-	-	X	X
Populus balsamifera	*		-	*	*	-	-
P. balsamifera (sapling)	X	2	-	2	1	-	-
P. balsamifera (seedling)	X	2	-	1	2	-	-
P. tremuloides	*		-	*	*	-	-
P. tremuloides (sapling)	*		-	*	*	-	-
P. tremuloides (seedling)	X	1	-	*	2	-	-
Salix spp.	1	3	X	3	*	3	-
Juniperus communis	X	2	-	-	X	X	-
Salix spp. (shrub)	3	5	2	1	X	5	4
S. spp. (subshrub)	2	4	-	X	1	5	5
Betula glandulosa	X	1	-	-	-	-	3
Rubus sp.	X	1	-	-	-	-	1
Potentilla fruticosa	X	1	-	-	-	-	3
Rosa acicularis	2	4	2	3	4	*	2
Shepherdia canadensis	2	5	3	X	1	2	2
Empetrum nigrum	2	3	-	*	2	7	3
Ledum palustre ssp. groenlandicum	2	2	-	-	*	4	4
Arctostaphylos uva-ursi	2	4	2	*	3	2	1
A. rubra	1	2	-	-	-	1	3
Vaccinium vitis-idaea	2	3	-	-	6	3	2
Viburnum edule	*		-	-	*	-	-
Equisetum scirpoides	X	1	-	3	-	-	-
E. spp.	1	2	-	*	-	1	3
Gramineae	4	5	4	3	5	2	4
Zygadenus elegans	1	3	2	X	2	-	-
Orchidaceae	X	2	-	1	-	-	X
Geocaulon lividum	2	4	4	2	4	X	-
Delphinium glaucum	X	2	-	-	-	X	1
Anemone sp.	*		-	-	-	*	-
Lupinus arcticus	3	5	2	3	4	3	2
Epilobium angustifolium	2	4	3	3	3	2	-
Cornus canadensis	1	2	-	-	-	3	2
Pyrola spp.	1	4	2	2	-	2	1
Gentiana spp.	X	1	-	-	-	X	*
Polemonium pulcherrimum	*		*	-	-	-	-
Mertensia paniculata	1	3	3	-	-	2	2
Pedicularis labradorica	X	1	-	X	-	-	-
P. spp.	1	2	-	-	-	2	2
Galium boreale	X	1	-	-	-	-	X
Linnaea borealis	4	5	4	6	2	5	3
Solidago sp.	X	1	X	-	-	-	-
Achillea spp.	X	1	-	-	-	*	2
Arnica louiseana	X	1	2	-	-	-	-
A. sp.	X	1	-	-	-	2	-
Compositae	1	3	-	-	1	X	3
Foliose lichens	3	4	3	7	-	4	3
Cladonia subgen. Cladina spp.	1	4	-	2	1	2	2
C. subgen. Cladonia spp.	3	4	2	7	-	4	1
Stereocaulon spp.	1	2	-	4	-	*	1
Cetraria sp.	*		-	*	-	-	-
Bryophyta	6	5	9	3	4	8	8

Table 10. Association table for the alpine fir association.

species or group	I	S15E	S15W
Pinus contorta	X	*	1
Abies lasiocarpa	7	6	8
A. lasiocarpa (sapling) . . .	6	7	4
A. lasiocarpa (seedling) . . .	3	3	3
Salix spp.	X	*	1
Lycopodium sp.	*	*	-
Actaea rubra	1	*	2
Ribes sp.	*	*	-
Sorbus spp.	1	2	*
Amelanchier alnifolia	3	4	2
Rosa acicularis	2	2	2
Shepherdia canadensis	1	3	-
Arctostaphylos uva-ursi . . .	*	*	-
Viburnum edule	4	4	3
Gramineae	X	1	-
Zygadenus elegans	*	*	-
Orchidaceae	*	-	*
Geocaulon lividum	3	3	3
Aquilegia formosa	2	1	2
Ranunculaceae (?)	X	-	1
Fragaria virginiana	*	*	*
Epilobium angustifolium . . .	3	2	3
Cornus canadensis	3	3	3
Pyrola spp.	2	1	3
Mertensia paniculata	2	2	2
Galium boreale	2	2	2
Linnaea borealis	4	3	4
Achillea sp.	*	*	-
Arnica cordifolia	X	-	1
Foliose lichens	2	1	2
Cladonia subgen. Cladina spp.	1	1	-
C. subgen. Cladonia spp. . . .	3	3	3
Bryophyta	9	9	8

Table 11. Association table for the aspen association.

species or group	I	II	C4W	2W	12E	42E	42W	44E	44W	46W	S3E	S5E	S9W
Pinus contorta	*		-	-	-	*	-	-	-	-	-	-	-
Picea glauca	X	2	1	2	-	-	1	-	*	*	-	-	2
P. glauca (sapling)	X	3	1	2	-	-	X	-	-	X	X	2	-
P. glauca (seedling)	X	2	1	2	X	-	-	-	-	-	-	-	-
Populus balsamifera	X	2	1	*	-	-	X	-	-	-	1	X	-
P. balsamifera (sapling)	1	3	3	1	-	-	3	-	*	-	2	X	-
P. balsamifera (seddling)	*		*	-	-	-	-	-	-	-	-	-	-
P. tremuloides	6	5	6	6	8	2	6	6	5	4	6	6	6
P. tremuloides (sapling)	2	5	1	5	X	4	3	2	X	2	1	2	3
P. tremuloides (seedling)	2	5	1	3	2	2	2	2	1	2	X	1	1
Salix spp.	1	4	X	-	5	-	3	*	X	*	1	1	3
Juniperus communis	X	2	-	-	-	2	X	-	-	1	1	-	-
Salix spp. (shrub)	1	4	-	3	3	2	3	-	2	1	-	*	2
S. spp. (subshrub)	X	2	-	2	1	-	1	X	-	-	-	-	-
Amelanchier alnifolia	X	1	-	-	-	2	-	-	-	-	1	-	-
Rosa acicularis	3	5	3	-	*	3	4	4	4	4	3	2	4
Shepherdia canadensis	5	5	6	6	5	3	3	5	7	4	6	7	2
Arctostaphylos uva-ursi	5	5	4	4	3	5	8	10	9	6	3	1	7
A. rubra	X	1	-	*	-	-	-	-	-	-	-	-	2
Viburnum edule	X	1	-	-	-	-	-	-	-	-	6	X	-
Equisetum sp.	X	1	-	1	-	-	-	-	-	-	-	-	-
Polypodiaceae	X	1	-	-	-	X	-	-	-	-	-	-	-
Gramineae	4	5	3	X	1	8	4	3	4	7	4	5	4
Geocaulon lividum	X	1	-	-	-	-	-	-	-	-	-	-	4
Stellaria sp.	X	1	-	-	2	-	-	-	-	-	-	-	-
Caryophyllaceae	X	1	-	-	-	-	-	-	X	-	-	-	-
Aquilegia formosa	*		-	*	*	-	-	-	-	-	-	-	-
Delphinium glaucum	X	2	-	-	*	-	1	2	2	1	-	-	-
Sedum lanceolatum	*		-	-	-	*	-	-	-	-	-	-	-
Anemone spp.	X	2	-	1	-	2	-	-	-	X	-	-	-
Saxifraga tricuspidata	X	1	-	-	-	2	-	-	-	-	-	-	-
Fragaria virginiana	X	2	*	2	4	2	-	-	-	*	-	-	-
Potentilla spp.	X	1	-	-	-	2	-	-	-	*	-	-	-
Hedysarum alpinum	X	1	*	*	-	-	-	-	-	-	-	X	-
Lupinus arcticus	2	4	-	-	3	-	2	3	2	3	-	2	3
Leguminosae	X	1	-	-	4	-	-	-	-	-	-	-	-
Epilobium angustifolium	4	5	4	2	4	3	3	5	5	4	X	4	4
Cornus canadensis	X	1	-	-	-	-	-	-	-	-	-	3	-
Pyrola spp.	1	4	2	-	-	-	2	2	-	1	3	2	2
Gentiana spp.	X	1	-	-	-	-	-	-	-	1	-	1	-
Polemonium pulcherrimum	X	3	1	X	*	2	-	-	-	X	-	X	-
Mertensia paniculata	1	4	3	*	3	-	2	-	1	1	X	3	3
Castilleja sp.	*		-	-	-	*	*	-	-	-	-	-	-
Pedicularis labradorica	*		-	-	-	-	-	*	-	-	-	-	-
P. spp.	X	2	2	-	3	-	*	-	-	-	-	-	2
Scrophulariaceae	X	1	-	-	-	-	-	-	-	-	-	1	-
Galium boreale	1	2	2	*	-	2	*	-	-	3	2	-	-
Linnaea borealis	3	5	3	1	6	1	2	5	-	1	3	3	6
Solidago spp.	X	3	-	-	*	1	X	1	X	3	-	-	-
Antennaria sp.	X	1	-	1	-	1	-	-	-	-	-	-	-
Achillea spp.	2	5	3	X	2	2	3	3	1	2	2	1	1
Arnica louiseana	X	2	-	-	3	-	-	3	X	-	-	-	-
Arnica spp.	X	2	-	-	-	-	3	-	-	-	X	X	1
Senecio sp.	X	1	-	-	X	-	-	-	-	-	-	-	-
Compositae	X	2	3	1	-	-	-	-	-	-	1	-	-
Foliose lichens	1	3	4	2	1	3	-	-	-	1	-	*	*
Cladonia subgen. Cladina spp	X	1	-	-	-	-	-	-	-	X	-	-	-
Cladonia subgen. Cladonia spp.	X	2	1	3	1	-	-	-	-	*	-	-	1
Stereocaulon sp.	*		-	-	-	*	-	-	-	-	-	-	-
Bryophyta	1	4	3	1	1	1	X	-	-	*	3	2	2

Table 12. Association table for the mixedwood forest association.

species or group	I	II	32E	32W	34E	46E	58E	58W	S1E	S1W	S3W	S5W	S9E	S17E	S17W
Pinus contorta	*		-	-	-	-	-	-	*	-	-	-	-	-	-
P. contorta (seedling)	X	1	-	-	-	-	-	-	1	-	-	-	-	-	-
Picea glauca	2	5	4	3	4	X	2	4	1	2	2	2	4	1	2
P. glauca (sapling)	X	4	X	X	2	1	2	X	X	*	*	*	1	1	*
P. glauca (seedling)	1	4	X	X	2	1	1	*	1	1	-	*	X	X	1
Abies lasiocarpa (sapling) . .	X	1	-	-	-	-	-	-	-	-	-	-	-	3	-
A. lasiocarpa (seedling) . . .	X	1	-	-	-	-	-	-	-	-	-	-	-	X	X
Populus balsamifera	2	3	-	*	-	5	3	4	2	-	3	-	-	4	3
P. balsamifera (sapling) . . .	1	2	-	-	-	X	2	*	3	-	3	-	-	3	*
P. balsamifera (seedling) . .	X	2	-	-	-	2	X	X	X	X	-	-	-	*	-
P. tremuloides	2	4	4	4	2	X	-	3	5	3	4	3	3	-	-
P. tremuloides (sapling) . . .	X	2	-	*	2	*	-	3	*	-	1	1	2	-	-
P. tremuloides (seedling) . .	X	2	*	1	1	*	-	-	-	*	-	X	1	-	-
Salix spp.	2	4	4	5	X	-	-	-	-	1	4	2	3	3	7
Lycopodium sp.	*		-	-	-	-	-	-	-	-	-	-	-	-	*
Juniperus communis	X	2	2	-	-	-	-	-	-	-	-	X	-	X	-
Salix spp. (shrub)	1	4	X	X	2	3	4	3	1	2	-	1	*	-	X
S. spp. (subshrub)	X	1	-	-	1	*	5	*	*	*	-	-	*	*	*
Ribes spp.	X	2	-	-	-	-	-	-	-	-	-	1	-	1	2
Amelanchier alnifolia	X	1	-	-	-	-	-	-	-	-	-	1	-	X	-
Rubus spp.	X	1	-	-	-	-	2	-	-	-	-	*	-	-	-
Potentilla fruticosa	X	1	-	-	-	-	3	2	-	-	-	-	-	-	-
Rosa acicularis	3	5	2	3	3	3	3	3	3	-	3	3	3	3	1
Shepherdia canadensis	4	5	3	4	2	6	2	2	4	2	8	3	*	5	7
Ledum palustre ssp. groenlandicum	X	1	-	-	-	-	X	-	-	-	-	-	-	-	-
Arctostaphylos uva-ursi . . .	3	5	2	7	3	1	1	5	6	3	-	4	7	3	2
A. rubra	X	1	-	-	-	-	3	*	-	-	-	*	-	-	-
Viburnum edule	1	3	5	5	3	-	2	-	-	-	-	*	-	3	X
Equisetum scirpoides	X	1	-	-	-	-	1	-	-	-	-	-	-	-	-
Equisetum spp.	X	2	-	-	-	-	1	2	-	2	-	-	-	1	2
Botrychium sp.	X	1	-	-	-	-	-	-	-	-	-	-	-	1	-
Gramineae	3	5	*	1	6	5	7	X	4	3	-	4	5	7	1
Carex sp.	*		-	-	-	-	*	-	-	-	-	-	-	-	-
Tofieldia sp.	X	1	X	-	-	-	-	-	-	-	-	-	-	-	-
Zygadenus elegans	X	1	-	-	2	-	X	*	-	-	-	-	-	-	-
Orchidaceae	X	1	X	-	-	-	-	-	-	-	-	-	X	-	-
Geocaulon lividum	2	5	3	3	2	3	3	3	-	3	3	1	3	3	2
Aquilegia formosa	X	1	-	-	-	-	-	-	-	-	-	X	-	-	-
Delphinium glaucum	1	3	-	-	2	2	1	2	-	2	-	-	-	1	2
Anemone spp.	X	2	1	X	-	-	-	*	-	-	-	2	-	2	1
Sedum lanceolatum	X	1	-	-	-	-	-	-	-	-	-	1	-	-	-
Saxifraga tricuspidata	X	1	1	-	-	-	-	-	-	-	-	1	-	-	-
Parnassia palustris	X	1	-	-	-	-	1	-	-	-	-	-	-	-	-
Fragaria virginiana	X	2	-	-	-	2	-	-	-	-	-	3	-	-	1
Potentilla spp.	X	1	-	-	-	-	-	-	-	-	-	2	-	-	-
Lupinus arcticus	2	5	X	2	3	3	2	*	3	3	2	-	3	3	2
Oxytropis spp.	X	1	-	-	-	2	2	*	-	-	-	-	-	-	-
Hedysarum alpinum	X	1	-	-	-	-	3	2	-	-	-	-	-	-	-
Epilobium angustifolium . . .	3	5	3	3	-	4	3	4	3	4	4	1	2	3	4
Cornus canadensis	1	3	*	3	1	-	2	3	1	-	-	-	-	-	3
Pyrola asarifolia	X	1	3	-	-	-	-	-	-	-	-	-	-	-	-
P. grandiflora	X	1	1	1	-	-	-	-	-	-	-	-	-	-	-
P. secunda	X	1	2	2	-	-	-	-	-	-	-	-	-	-	-
P. spp.	1	4	-	-	2	1	1	2	*	X	2	X	2	2	3
Moneses uniflora	*		*	-	-	-	-	-	-	-	-	-	-	-	-
Gentiana spp.	X	2	-	-	*	-	1	*	-	-	-	-	-	X	1
Polemonium pulcherrimum . . .	X	2	-	-	-	-	-	-	3	-	-	2	-	1	-
Mertensia paniculata	2	5	1	-	3	4	3	3	2	2	2	X	2	2	3
Pedicularis labradorica . . .	X	1	2	X	-	-	-	-	-	-	-	-	-	-	-
Pedicularis spp.	X	2	-	-	3	-	X	*	-	1	-	-	1	-	-
Scrophulariaceae	*		-	-	-	-	-	-	*	-	-	*	-	-	-
Galium boreale	X	3	X	1	-	3	-	X	2	-	X	1	-	-	-
Linnaea borealis	4	5	4	7	3	4	5	3	2	5	3	1	3	4	4
Solidago spp.	X	2	X	1	-	2	2	3	-	-	-	-	-	-	-
Aster sp.	*		-	-	-	-	*	-	-	-	-	-	-	-	-
Antennaria sp.	X	1	-	-	-	-	-	-	-	-	-	X	-	-	-
Achillea spp.	2	4	-	X	*	2	2	4	3	2	-	2	-	3	3
Artemisia sp.	*		-	-	-	-	-	-	-	-	-	*	-	-	-
Arnica louiseana	X	1	3	2	-	-	-	-	-	-	-	-	-	-	-
Arnica spp.	X	2	-	-	1	X	-	2	-	-	-	-	-	*	2
Senecio sp.	X	1	-	-	-	-	X	-	-	-	-	-	-	-	-
Compositae	X	2	-	-	-	-	-	-	2	1	-	-	-	X	1
Foliose lichens	1	4	1	-	2	3	*	*	1	-	1	1	6	-	1
Cladonia subgen. Cladina spp.	X	1	-	-	1	-	-	-	-	-	-	-	1	-	-
Cladonia subgen. Cladonia spp.	1	4	2	-	2	-	*	1	-	1	-	2	4	2	X
Stereocaulon spp.	X	1	-	-	X	-	-	-	-	-	-	X	*	-	-
Bryophyta	2	5	4	-	3	3	5	2	1	1	2	1	6	2	1

Table 13. Association table for the mixed woodland association.

species or group	I	C4E	C2E	C2W
Pinus contorta	2	3	3	2
P. contorta (seedling)	X	X	X	*
Picea glauca	4	4	3	5
P. glauca (sapling)	2	2	3	1
P. glauca (seedling)	1	1	2	X
Populus tremuloides	1	1	2	2
P. tremuloides (sapling) . . .	X	*	X	X
P. tremuloides (seedling) . . .	1	2	1	*
Salix spp.	X	X	-	1
Salix spp. (shrub)	2	2	1	2
S. spp. (subshrub)	X	X	1	*
Rosa acicularis	2	2	2	2
Shepherdia canadensis	1	2	X	1
Arctostaphylos uva-ursi	3	4	4	3
A. rubra	*	*	-	-
Vaccinium vitis-idaea	*	-	-	*
Viburnum edule	*	-	*	-
Equisetum spp.	2	3	1	2
Gramineae	3	3	3	3
Zygadenus elegans	1	1	1	X
Orchidaceae	*	*	-	-
Geocaulon lividum	2	2	1	3
Anemone spp.	X	-	1	*
Lupinus arcticus	2	3	2	2
Epilobium angustifolium	X	-	1	1
Pyrola spp.	1	2	2	1
Gentiana propinqua	1	2	X	X
Mertensia paniculata	X	X	-	-
Pedicularis sp.	*	*	-	-
Linnaea borealis	3	4	1	3
Compositae	1	1	1	1
Foliose lichens	4	2	5	5
Cladonia subgen. Cladina spp.	2	X	5	X
C. subgen. Cladonia spp.	1	2	2	1
Stereocaulon spp.	X	*	X	-
Bryophyta	4	2	5	4

Table 14. Association table for the depression shrub association.

species or group	I	54E	54W	59W
Pinus contorta	X	-	1	-
P. contorta (sapling)	X	2	-	-
P. contorta (seedling)	X	X	-	-
Picea glauca	1	-	-	3
P. glauca (sapling)	*	-	-	*
P. glauca (seedling)	X	2	*	*
Populus tremuloides (sapling)	*	*	-	-
Salix sp.	*	-	-	*
Salix spp. (shrub)	7	7	7	8
S. spp. (subshrub)	3	2	2	4
Betula glandulosa	5	*	7	7
Ribes sp.	X	X	-	-
Rubus spp.	3	3	3	3
Potentilla fruticosa	1	*	3	3
Rosa acicularis	2	3	2	*
Shepherdia canadensis	X	X	X	*
Empetrum nigrum	*	-	-	*
Ledum palustre ssp. groenlandicum	*	-	-	*
Arctostaphylos uva-ursi . . .	X	2	-	*
A. rubra	1	-	-	4
Vaccinium vitis-idaea	X	-	2	-
Equisetum scirpoides	1	-	2	2
E. spp.	2	3	1	3
Triglochin maritimum	*	-	-	*
Gramineae	3	3	5	*
Carex spp.	2	2	-	5
Juncus sp.	2	-	-	5
Luzula spp.	1	2	1	*
Tofieldia sp.	*	-	-	*
Zygadenus elegans	*	-	-	*
Orchidaceae	*	-	-	*
Geocaulon lividum	*	-	*	-
Stellaria sp.	*	*	-	-
Delphinium glaucum	1	3	1	*
Anemone sp.	X	1	-	-
Pulsatilla patens	*	-	*	-
Parnassia palustris	*	-	-	*
Saxifragaceae	*	-	-	*
Potentilla spp.	1	-	3	-
Sanguisorba sp.	X	2	-	-
Lupinus arcticus	*	-	-	*
Oxytropis sp.	X	-	2	-
Hedysarum alpinum	*	-	-	*
Epilobium angustifolium . . .	2	3	3	1
Cornus canadensis	2	3	2	-
Pyrola spp.	X	-	X	1
Gentiana propinqua	1	1	2	-
Polemonium pulcherrimum . . .	X	1	1	*
Mertensia paniculata	2	3	3	*
Penstemon sp.	X	-	2	-
Pedicularis sudetica	*	-	-	*
P. labradorica	*	-	-	*
Scrophulariaceae	X	1	-	-
Galium boreale	X	-	2	*
Linnaea borealis	1	2	X	*
Solidago multiradiata	*	-	-	*
S. sp.	X	-	2	-
Aster sp.	X	-	2	-
Antennaria sp.	X	2	-	-
Achillea spp.	2	3	2	*
Petasites sagittatus	2	2	3	-
Senecio spp.	X	-	1	*
Taraxacum sp.	*	-	-	*
Compositae	1	3	X	*
Foliose lichens	1	1	2	*
Cladonia subgen. Cladina sp. .	*	-	-	*
C. subgen. Cladonia spp. . . .	1	1	2	-
Sphagnum sp.	*	-	*	-
Bryophyta	6	3	6	8

Table 15. Association table for the herb-heath association.

species or group	I	II	4E	8E	8W	16E
Pinus contorta (seedling) . . .	X	2	-	X	-	-
Populus tremuloides (sapling) .	X	3	X	-	-	X
P. tremuloides (seedling) . . .	2	4	3	X	-	3
Juniperus communis	X	2	X	-	-	*
+J. horizontalis	2	4	5	-	1	1
Salix sp. (shrub)	X	2	-	2	-	-
Amelanchier alnifolia	*		*	-	-	-
Rosa acicularis	3	5	3	3	3	3
Shepherdia canadensis	X	3	X	1	-	-
Arctostaphylos uva-ursi	5	5	6	6	6	1
Gramineae	5	5	5	5	5	5
Carex spp.	1	3	-	3	-	2
Stellaria sp.	X	2	-	1	-	-
+Cerastium arvense	2	3	2	-	-	4
Anemone spp.	3	5	4	3	3	1
+Arabis Holboellii	1	3	X	-	-	3
Cruciferae	*		*	-	-	-
Sedum lanceolatum	1	4	3	-	X	1
Saxifraga tricuspidata	1	4	2	1	-	1
Fragaria virginiana	1	3	2	*	2	-
+Potentilla Hookeriana	X	2	-	-	-	3
P. spp.	X	2	-	-	2	*
Astragalus sp.	*		*	-	-	-
Oxytropis campestris	X	4	1	X	-	1
Epilobium angustifolium	1	4	-	1	1	2
+Androsace septentrionalis . . .	2	5	1	4	1	3
Polemonium pulcherrimum	2	4	-	3	3	2
+Lappula myosotis	X	2	-	1	-	-
Mertensia paniculata	X	2	-	1	-	-
+Penstemon Gormanii	X	2	-	-	-	2
+P. procerus	1	3	1	3	-	-
Scrophulariaceae	X	2	-	-	2	-
Galium boreale	2	5	3	3	2	1
+Solidago decumbens	X	2	-	-	-	2
S. spp.	1	3	3	2		
+Erigeron compositus	1	3	2	-	-	3
+Antennaria rosea var. nitida .	X	2	3	-	-	-
Achillea spp.	3	5	3	2	2	4
+Artemisia frigida	1	3	1	*	-	3
+A. arctica	X	2	-	*	-	1
A. sp.	*		-	-	*	-
Arnica sp.	X	2	1	-	-	-
Foliose lichens	1	3	-	1	2	-
Cetraria sp.	X	2	-	1	-	-
Bryophyta	3	4	-	6	2	4

Table 16. Relevés from two unclassified stands.

STAND 4W

species or group	I
Picea glauca	1
P. glauca (sapling) . . .	2
P. glauca (seedling) . . .	1
Populus balsamifera . . .	3
P. balsamifera (sapling) .	1
P. balsamifera (seedling)	X
P. tremuloides	3
P. tremuloides (seedling)	2
Rosa acicularis	2
Shepherdia canadensis . .	2
Cornus stolonifera	*
Arctostaphylos uva-ursi .	6
Viburnum edule	8
Gramineae	2
Zygadenus elegans	1
Orchidaceae	2
Caryophyllaceae	1
Aquilegia formosa	1
Anemone sp.	2
Epilobium angustifolium .	X
Pyrola sp.	1
Gentiana sp.	1
Galium boreale	2
Linnaea borealis	1
Achillea sp.	1
Compositae	2
Foliose lichens	1
Bryophyta	2

STAND 12W

species or group	I
Picea glauca	4
P. glauca (sapling) . . .	3
P. glauca (seedling) . . .	3
Salix spp. (shrub)	7
S. spp. (subshrub)	5
Rubus sp.	3
Shepherdia canadensis . .	3
Arctostaphylos rubra . . .	5
Equisetum scirpoides . . .	3
E. sp.	2
Gramineae	2
Eriphorum sp.	1
Carex sp.	3
Orchidaceae	*
Parnassia palustris . . .	2
Fragaria virginiana . . .	2
Leguminosae	3
Epilobium angustifolium .	3
Gentiana sp.	1
Mertensia paniculata . . .	*
Pedicularis sudetica . . .	3
Linnaea borealis	1
Solidago sp.	X
Aster sp.	2
Achillea sp.	2
Petasites sagittatus . . .	2
Senecio sp.	3
unknown herb	3
Foliose lichens	4
Cladonia subgen. Cladina sp.	X
Bryophyta	9

Table 17. General vegetation survey data summary.

COMMUNITY	R.A.[1]	NO. SPP.	ARBOREAL STRATUM		SHRUB AND SUBSHRUB STRATUM		HERB STRATUM		LICHEN AND MOSS STRATUM	
			A	B	A	B	A	B	A	B
Mixedwood forest association	15	77	5	8	18	18.5	49	38.5	5	5
White spruce association/ shrub-herb faciation	15	72	3	6.5	15	18.5	48	36.5	6	12.5
Aspen association	13	60	5	8	12	20	38	32	5	3
White spruce association/ feather moss faciation	12	65	6	9	16	11	37	23.5	6	14
Lodgepole pine brûlé	5	39	4	6	8	13.5	22	19	5	8.5
White spruce-lodgepole pine association	6	59	5	9	19	23.5	29	27.5	6	14
Lodgepole pine association	6	50	4	8	14	15	26	22.5	6	14.5
Herb-heath association	5	45	-	-	8	12	34	37.5	3	4.5
White spruce brûlé	5	39	4	6	8	13.5	22	19	5	8.5
Depression shrub association	4	69	3	1.5	16	24.5	45	33	5	8
Mixed woodland association	3	36	4	7.5	10	11	17	19.5	5	10.5
Alpine fir association	2	33	3	8	10	18	16	25.5	4	15
(Bog)	1	-	-	-	-	-	-	-	-	-
(Unclassified)	2	-	-	-	-	-	-	-	-	-
	100%									

[1]R.A.: Relative abundance, % total stands. A: Number of species and groups. B: Total mean C-A value.

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whole communities and of strata within and among communities may be made.

According to the general vegetation survey and Table 17, the white spruce association/shrub-herb faciation and the mixedwood forest association share top importance in the Atlin valley. These two communities each contain vegetation representative of 15 percent of the total stands. In addition they contain larger numbers of species and species groups than any of the other communities.

In an attempt to evaluate the effect of number of stands on the total species diversity shown for each community type, a correlation coefficient, r, for the relative abundance data and the total number of species and species groups data (see the first two data columns of Table 17) was calculated according to the product-moment formula (Spiegel, 1961). As this value, 0.761, is fairly high, it indicates that more meaningful comparisons of vegetation types on the basis of species diversity would require the study of more nearly equal numbers of stands of each type.

The third most important vegetation type, encountered in 13 percent of the stands, is the aspen association. This is followed by the white spruce association/feather moss faciation and the lodgepole pine brûlé, encountered in 12 and 11 percent of the stands, respectively. Of these, the white spruce/feather moss community contains the most species and species groups and ranks fourth among all communities in this regard. The aspen association is fifth, and the lodg

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lodgepole pine brûlé appears to be seventh in species diversity in the Atlin valley.

The white spruce-lodgepole pine and the lodgepole pine vegetation types each occur in six percent of the 86 stands studied. The former contains a larger number, 59, of species and species groups and ranks sixth in overall importance, whereas the latter community, with 50, is in eighth place.

There is a prominent break in the range of relative abundances between values, from 11 to 15 percent, of the several communities listed in the preceding paragraphs and the values, from two to six percent, of the white spruce-lodgepole pine and lodgepole pine associations and of the several even less abundant vegetation types mentioned below. Because of this break, the mixedwood forest association, white spruce association/shrub-herb faciation, aspen association, white spruce association/feather moss faciation, and lodgepole pine brûlé are considered as major Atlin valley community types. Those communities which the general vegetation survey has shown to be less abundant are designated as minor types.

The herb-heath association is the eighth most important vegetation type, followed by the white spruce brûlé. These are followed in importance by the depression shrub, mixed woodland, and alpine fir communities. Importance values for each of these, except the depression shrub association, correspond to species diversity values which are considerably lower than those of the major communities. This, again, is

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believed to be largely a function of low stand number. A major exception, however, is the depression shrub community wherein only three stands, constituting four percent of the survey total, contained 69 species and species groups, thus ranking third after the mixedwood forest and white spruce/ shrub-herb communities.

The white spruce association/feather moss faciation contains an arboreal stratum with six members, the total number of tree types in the Atlin valley, making it the most diverse of any community. The total mean C-A (cover-abundance) value is 9, indicating a fuller canopy than in any other community except the white spruce-lodgepole pine association which, although containing one fewer species, also has a total mean C-A value of 9 in the arboreal stratum. Other forest communities have values ranging from 7.5 to 8, except for the white spruce brûlé and the white spruce association/shrub-herb faciation. Whereas the low value of 6 for the brûlé is easily accounted for by the higher proportions of dead and fallen trees in the stands, the total mean C-A value of 6.5 for the latter reflects the open nature of these white spruce forests and corresponds with the high species diversity and total mean C-A values in the herb stratum.

In the shrub and subshrub stratum the greatest diversity is seen in the white spruce-lodgepole pine community where 19 species and species groups were found in a relatively low number of stands. This diversity value corresponds to a

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total mean C-A value which is only slightly lower than the depression shrub value of 24.5, the highest of any community. Other communities containing prominent shrub and subshrub layers are the white spruce association/shrub-herb faciation, aspen association, and the mixedwood forest association. The white spruce association/feather moss faciation, white spruce brûlé, lodgepole pine brûlé, and mixed woodland association all have relatively unimportant shrub and subshrub strata.

The herb stratum is most diverse and dense in the mixedwood forest and herb-heath associations and the white spruce association/shrub-herb faciation. The aspen and depression shrub associations also contain prominent herb strata. The layer is relatively unimportant in the white spruce brûlé and mixed woodland association.

Diversity in the lichen and moss stratum cannot be meaningfully assessed because a total of only six groups were employed to account for what is probably a large number of species. Total mean C-A values were quite variable, however, ranging from a low of 3 in the aspen association to a high of 15 in the alpine fir association. Low values are also seen for the mixedwood forest and the herb-heath associations, and additional high values are associated with the white spruce association/feather moss faciation and the lodgepole pine and the white spruce-lodgepole pine associations.

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To date soil studies have been made in a few sites and some understanding of vegetation and soil relationships is beginning to emerge. Single stands representative of six plant communities have been examined. Associated soil types, classified according to the Seventh Approximation of the Soil Survey Staff, USDA, are: (1) White spruce association/feather moss faciation - Histic Cryaquept, coarse-loamy, mixed calcareous. (2) Lodgepole pine association - Typic Cryopsamment, sandy mixed. (3) Alpine fir association - Boralfic Cryorthod, loamy skeletal, mixed. (4) Mixedwood forest association - Typic Cryochrepts, coarse loamy, mixed. (5) Depression shrub association - Terric Cryosaprist, euic. Soil studies are needed for the other six upland communities discussed in this dissertation as well as for additional stands of the communities listed above.

VIII. TREE SURVEY

Purposes

A tree survey was conducted in order to obtain additional data for comparison with the pollen rain. These data are useful in assessing the relative status of the various tree species in the vegetation of the Atlin valley and in supplementing the results of the general vegetation survey. In addition, they make possible comparisons of the Atlin valley forests with forests in neighboring areas.

Table 18. Distribution of plant communities and sampled bogs along the Atlin-Carcross road transect.

WEST	MILE	EAST
White spruce brûlé	C6	White spruce brûlé
	MOOSE BONES BOG	
Aspen association	C4	Mixed woodland association
Mixed woodland association	C2	Mixed woodland association
Aspen association	2	White spruce association - herb phase
(unclassified)	4	Herb-heath association
White spruce association - feather moss faciation	6	White spruce association - feather moss faciation
Herb-heath association	8	Herb-heath association
White spruce brûlé	10	White spruce association - herb phase
White spruce-depression shrub transition	12	Aspen association
Lodgepole pine brûlé	14	Lodgepole pine brûlé
Lodgepole pine brûlé MILE 16 BOG	16	Herb-heath association
Lodgepole pine brûlé	18	Lodgepole pine brûlé
Lodgepole pine brûlé	20	Lodgepole pine brûlé
Lodgepole pine brûlé	22	Lodgepole pine brûlé
Lodgepole pine association	24	Lodgepole pine association
White spruce association - herb phase	26	White spruce association - feather moss faciation
White spruce association - feather moss faciation	28	White spruce association - herb phase
White spruce association - feather moss faciation	30	White spruce association - feather moss faciation
Mixedwood forest association	32	Mixedwood forest association
White spruce association - feather moss faciation	34	Mixedwood forest association
White spruce-lodgepole pine ass'n.	36	Lodgepole pine association
Lodgepole pine association	38	Lodgepole pine brûlé
White spruce association - feather moss faciation	40	White spruce association - herb phase
Aspen association	42	Aspen association
Aspen association	44	Aspen association
Aspen association	46	Mixedwood forest association
	MILE 47 BOG	
White spruce association - feather moss faciation	48	White spruce association - herb phase
Lodgepole pine association	50	White spruce brûlé
MILE 52 BOG	52	White spruce association - feather moss faciation
Depression shrub association	54	Depression shrub association
White spruce-lodgepole pine ass'n.	56	White spruce-lodgepole pine ass'n.
Mixedwood forest association	58	Mixedwood forest association
Depression shrub association	59	White spruce association - shrub-herb-moss phase
Mixedwood forest association	S1	Mixedwood forest association
Mixedwood forest association	S3	Aspen association
Mixedwood forest association	S5	Aspen association
White spruce association - shrub-herb-moss phase	S7	White spruce association - shrub-herb-moss phase
Aspen association	S9	Mixedwood forest association
White spruce association - herb phase	S11	White spruce association - herb phase
White spruce association - herb phase	S13	White spruce association - herb phase
Alpine fir association	S15	Alpine fir association
JASPER CREEK BOG	S16	White spruce-lodgepole pine ass'n. (?)
Mixedwood forest association	S17	Mixedwood forest association
White spruce-lodgepole pine ass'n.	S19	White spruce-lodgepole pine ass'n.

Methods

Again the Atlin road is used as a base line, the rationale for this being the same as in the general vegetation survey. At one-mile intervals along the road, except for two-mile intervals south of Atlin, two sites were located, one on each side of the road. A site consisted of a transect line run by compass directly east or west from the milepost into the forest. This line was followed from the road to a point which appeared to be well within the natural vegetation, so as to be away from the disturbed zone marginal to the road. From this point the line was followed 15 paces farther to another point which served as number one of a series of ten survey points located at 15-pace (approximately 45-foot) intervals.[4] The area around each survey point was then divided into quadrants according to the point-quarter technique (Curtis, 1959).

The distance from the survey point to the closest tree in each quadrant was measured, and the species and circumference at breast height were noted. The minimum tree size measured was eight inches circumference (2.55 inches diameter). This size was chosen because smaller trees were believed to be relatively unimportant contributors to the pollen rain. Curtis (1959) considers mature trees to be those which are four inches DBH (diameter at breast height) or more. Hansen (1949a) and Davis and Goodlett (1960) take into account all tree species one inch DBH and above. In the Atlin valley, few

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few conifers smaller than about three inches DBH were observed with cones.

If, in a quadrant, no tree occurred within 100 feet of the point, the quadrant was considered treeless. In areas of widely spaced trees, the closest tree in a quadrant at a given point may also have been the closest tree in a quadrant on the same side of the transect line at the preceding point, and sometimes also at the next point. The various distances to the tree from each of the two or three points were noted, but the tree, as a resident of more than one quadrant, was not counted more than once in frequency and basal area calculations.

All together 146 transect lines were run for a total of 1,460 survey points and 5,840 quadrants. This survey provides a sampling of forest trees in the Atlin valley through a zone about 1,000 feet wide, centering on the road from mile six on the Carcross road to mile 19-south on the Atlin road. Trees were encountered in 4,819 of the 5,840 quadrants, thus giving a total tree frequency of 83 percent. Data for individual species are presented in Table 19. Basal areas were determined from circumference at breast height data using a computer-printed conversion table.

Discussion

In addition to the palynological significance discussed below, data from the tree survey encourage further considerations of the nature of the forests in the Atlin valley.

Of all the terrain covered and trees examined, no species other than those in Table 19 were found. Paper birch, tamarack, and black spruce, although common elsewhere in the boreal forest zone, were absent. For this reason, and on the basis of information in Halliday (1937), Porsild (1951), Raup (1945), Hansen (1953), and Hultén (1968), the writer concludes that it is unlikely that either paper birch or tamarack will be found in the valley. With respect to black spruce, it is predicted that it will be yet found, probably growing in bogs or muskegs where the local lithology has caused conditions of lower pH and the growth of Sphagnum spp. That such conditions probably occur is indicated by the stands of the shrub-herb-moss phase of the white spruce association encountered in the general vegetation survey.

Using the figures in column one of Table 19 as indicators of relative abundance or population intensity, comparisons can be made with the data of Halliday and Brown (1943), presented on page 55 of this dissertation. The figure, 45 percent, for white spruce fits nearly midway in the population intensity range cited by Halliday and Brown for white and black spruce together. The fact that these authors' data are for both species of spruce encourages the hypothesis that white spruce replaces black spruce in the Atlin valley. Some support for this is also available from field observations. Where spruce occurs in bogs it is always found to be white spruce. Often the trees or saplings are stunted and unhealthy in appearance, or dead, and the bog spruce

Table 19. Tree survey data summary.[1]

Species	% of Trees Measured	% Freq.	Total Basal Area (in^3)	% of Total Basal Area[2]
Picea glauca	45	37	81,952	56
P. glauca (dead)	2	2		
Pinus contorta	15	13	13,067[3]	25[3]
P. contorta (dead)	11	9		
Abies lasiocarpa	1	1	3,202	2
Populus tremuloides	18	15	25,182[4]	17[4]
P. balsamifera	2	2		
Salix spp.	7	5		
Alnus spp.	1	1		
Dead trees (exc. *Pinus* & *Picea*)	2	2		

[1]All figures rounded off to nearest whole number.

[2]Percent of total of *Picea*, *Pinus*, *Abies*, and *Populus* only.

[3]Includes the dead trees of the 1958 burn between mile 14 and 23. This includes all but a small percentage of the dead pines encountered.

[4]Includes *Populus balsamifera*.

population is probably not as dense as if black spruce, often a bog species, could grow there. The usual habitat of the latter species seems to be at least partially filled by the former. Rowe (1959) mentions that in northwestern Canada white spruce sometimes invades sites which are also occupied by black spruce and that the ecological distinctions in such cases may be unclear.

The figure, 15 percent, for living lodgepole pine fits well within the range given by Halliday and Brown. If the figure for dead pine trees (most of which derive from the 1958 fire) is added, pine would appear to be somewhat heavier in population intensity in the Atlin valley than these authors show for the regional forests. It is not known whether their figures include recent, fire-killed trees. If they do not, corroboration of the writer's data would be good.

Although the alpine fir figure, 1 percent, is well below the range given by Halliday and Brown, there is probably no major discrepancy with respect to the total Atlin valley forest vegetation because the present survey was carried out below the usual lower elevation limit for this species. Observations at and near timberline indicate that alpine fir is more important than the survey shows. However, the writer doubts that it would fall in the "medium" intensity category given by Halliday and Brown.

Halliday and Brown (1943) indicate that the relative population intensity of aspen and balsam poplar in northwestern Canada is "light," i.e. in the one to ten percent range. The present survey shows that aspen, but not balsam poplar, is considerably more abundant in the Atlin valley. An explanation of this has not yet been developed since there is no reason to believe that conditions favoring aspen are more prevalent in the valley than elsewhere.

It should also be noted that conditions for balsam poplar, which is primarily a flood plain succession species (Raup 1945), are not common in the Atlin valley. Except for the appearance of unimposing individuals of balsam poplar in significant proportions in only a few stands of the mixed-wood forest association (Table 12), the only pure stands of large (up to 12 inches DBH), old growth poplars observed are along Haunka Creek at mile 8.9 and in the vicinity of mile 4, where the vegetation is unusual in other respects too (Table 16).

There are two factors which may be at least partially responsible for apparent discrepancies between the data of Halliday and Brown and the present survey. First (1) the information used by these authors was obtained 30 to 40 years or more prior to the writer's 1967 survey. An increased frequency of man-caused fires in the intervening years would favor the development of higher proportions of both pine and aspen stands. In the survey many trees were encountered which, although at least the required 2.55 inches DBH were still small enough to be not more than 25 or 30 years old. Also (2) the Halliday and Brown figures were developed from a

Table 20. Comparison of general vegetation survey and tree survey data.

Species	Freq. of Stands, C-A Value ≥ 4	Freq. of Species in Tree Survey
Picea glauca	42	37
*Pinus contorta**	15	21
Abies lasiocarpa	2	1
Populus tremuloides	16	15
P. balsamifera	4	2
Salix spp.	8	6

*Includes dead trees

form of data, i.e. relative volume of a species per unit area, somewhat different from the frequency data of the 1967 survey. Frequency, which accounts for all sizes of a species in the same category, would tend to overemphasize the species' importance. This is especially true in the case of aspen, where many individuals are young, and even most older ones don't compare in volume with spruce or pine. In this regard, the basal area figure of 17 percent for aspen and balsam poplar (Table 19) compares somewhat better with the Halliday and Brown range of up to ten percent for the population intensity of these species.

For comparison purposes Table 20 gives the frequency of general vegetation survey stands wherein the quadrat C-A values for the various tree species were four or more, along with frequency data from the tree survey. A high correlation coefficient, r, of 0.965 for these two sets of data, (calculated according to the product-moment formula of Spiegel, 1961), shows a significant relationship. Thus the two surveys corroborate each other in terms of prevalence and relative importance of these species.

As a summary of the data in Tables 19 and 20, and the tree survey in general, the following is clear: (1) Almost half (47 percent) of the trees in the Atlin valley are white spruce. With a frequency of 37 percent, this species occupies over a third of the landscape within range of the survey. With respect to basal area, white spruce is more important than all other species combined. (2) Lodgepole pine, although slightly less important than aspen in terms of numbers and area occupied, is second only to white spruce in basal area. Even so, it comprises less than half the basal area of spruce. (3) Dead (fire-killed), but standing lodgepole pine is quite important in terms of numbers and amount of occupied terrain, being fourth in both respects. The data indicate that over eight percent of the valley area has been recently burned. Observations along the Alaska Highway and elsewhere indicate that this may be a conservative measure of the effect of fire. (4) Aspen is the second most abundant tree in the valley and occupies slightly more land area than pine (disregarding dead pine trees). It is considerably less important in terms of basal area than spruce or pine, however. (5) Tree willow is common as an admixture in most forest types. (6) Alpine fir appears to be relatively unimportant compared to spruce, pine, aspen, and tree willow. As discussed above, however, it is believed to be an important component of the total regional forest vegetation when the higher elevation stands and those around the southwest end of the lake are considered. (7) Balsam poplar is relatively unimportant, although it is widespread. (8) Alder is insignificant as a tree species in the Atlin valley.

Figure 27 shows the distribution, in terms of basal area, of the four main tree species throughout the survey transect zone along the Atlin road. The significance of ti

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this distribution is considered further in the section on pollen-vegetation comparisons.

IX. BOG VEGETATION

General

Hygric habitats, including marshes and bogs, are important features of the Atlin region landscape. Detailed study of the vegetation of these habitats has only begun, but the work to date is discussed for general ecological purposes and as background for palynological sampling and interpreting the pollen and spore diagrams. The discussion is based primarily on qualitative surveys made in and around six bogs in the Atlin valley and, to a lesser extent, on aerial photograph studies.

Hansen (1953) discusses three major types of organic depositional formations along the Alaska Highway. These are muskegs, tussock muskegs, and bogs. Muskeg, although occurring in nearby areas, is not important in the Atlin valley, probably because of minimal permafrost conditions coupled with low precipitation and enhanced drainage in a pervious substrate. A kind of tussock muskeg has developed in some flat areas, apparently where the substrate is a finer-grained, clayey or silty material and where there may also be seasonal or residual frost layers which help to maintain a high water table. Probing and pits dug in such areas, which ordinarily are not wet, show that organic accumulation is shallow. At

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mile 50, for example, there is a grass tussock muskeg containing approximately three feet of peat underlain by a silty clay.

Moss (1953) and Hansen (1953) recognize two fundamental types of bogs. One is characterized by *Sphagnum*-ericad-black spruce vegetation and the other by *Drepanocladus-Carex*-bog birch vegetation. The former type has not been found in the Atlin valley except, perhaps, in incipient stages. Although the six bogs discussed here differ in various ways, they all are generally of the latter type. The major factor in the development of a *Drepanocladus-Carex*-bog birch bog is an abundance of calcium carbonate in the drainage basin. Marly sediments, making up a significant portion of the bog cores discussed below, indicate an abundant source of calcium carbonate in the earlier, aquatic stages of succession.

Moose Bones Bog

This bog is located near mile 4.5 on the Carcross road at an elevation of approximately 2,350 feet (Fig. 13). It is roughly teardrop shaped and is about 500 feet across the longest dimension. A small pond, about 75 feet in diameter, occupies the center. The bog surface slopes very gradually up from the pond in most directions and becomes increasingly drier toward the surrounding forest. The bog is located upon a pitted outwash just over one mile northwest of Little Atlin Lake. There are a few calcareous seeps upon otherwise

Figure 13. Moose Bones Bog.

View northeast across Moose Bones Bog. Several distinct vegetation zones are shown. The outermost, zone 6 (Table 21, page 142) is of forest vegetation, the composition of which is variable around the bog. White spruce dominates in some areas, as in the right background. Here the vegetation approximates the white spruce association/feather moss faciation (see pages 81 - 83) except that the forest floor is covered primarily by a thick accumulation of litter, and plants are scarce in the lower strata. In the center and left background there are stands of spruce which intergrade with stands of the aspen association.

A narrow shrub zone (zone 5) occurs around the periphery of the bog. The major component of this zone is shrub birch (*Betula glandulosa*), as shown in the foreground. Shrub willows form important admixtures in some places, particularly in outer parts of the zone.

Inside this zone there is a *Poa palustris* zone (zone 4) which is discontinuous around the bog. A part of this zone is shown at the right at the inside edge of the shrub zone.

The more extensive, light-toned herbaceous zone (zone 3) is dominated by *Deschampsia caespitosa*. The medium-toned zone (zone 2) next toward the center of the bog is dominated by *Calamagrostis neglecta*. A somewhat narrower and darker zone adjacent to the pond at the center of the bog (the dark patch at the right edge of the photo) is a *Carex aquatilis* zone. Only the latter two zones are continuous around the bog.

The presence of grass-dominated zones 2, 3, and 4 is believed to be related to grazing by domestic livestock. (A fence can be seen at the forest's edge in the background.) No other bogs were observed with these vegetation zones. On the other hand, no other bog contained as broad an area of medium to well-drained substrate inside the forest edge as Moose Bones Bog, and for this reason it is probable that vegetation zonation would be different here anyway. The lack of encroachment into this mesic terrain by arboreal species is not understood yet. Although trees may have been removed by logging several decades ago, few seedlings are found in the drier parts of the bog at present.

The palynological record for Moose Bones Bog is shown in Figure 21 and is discussed on pages 222-231.

Mid-afternoon. 6 September 1968.

Figure 13. Moose Bones Bog.

Figure 14. Mile 16 Bog.

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Figure 14. Mile 16 Bog.

View southeast across Mile 16 Bog. Atlin road in background.

This bog has developed in a glacial kettle. The small pond in the center is surrounded by a *Carex aquatilis* ssp. *aquatilis* zone. This is surrounded by a narrower shrub willow zone which grades abruptly into the adjacent forest vegetation where the level surface of the bog meets the moderately steep wall of the kettle.

The forest vegetation is lodgepole pine, burned in 1958, and classified as lodgepole pine brûlé (associes) (Table 8). A few trees remain alive, as the one in the upper left corner, and are believed to have a major influence on the pollen rain, particularly in the absence of spruce (Fig. 26). Shrubby vegetation in the foreground consists of aspen seedlings.

Open areas just beyond the road bear stands of the herb-heath association (Table 15). This plant community type, along with pine, is widespread in this part of the Atlin valley because of the highly pervious substrate and the exposed condition of the slopes.

The palynological record for Mile 16 Bog is shown in Figure 22 and discussed on pages 231-243.

Midday. 9 July 1968.

mesic terrain in the western part of the bog. The pond itself, however, does not appear to be particularly calcareous as there are no lime-encrusted aquatic plants nor any mineral deposits on the shore as at other bogs. The bog is located at the head of a very minor drainage divide. Drainage from it is to the northeast and into a creek about one-fourth mile away which flows south to Little Atlin Lake.

Late in the 1968 season a detailed vegetation survey of this bog was begun. Use was made of one-meter-square quadrats at five-meter intervals along compass line transects run from the edge of the water at the center of the bog out into the surrounding forest. Species within the quadrats were evaluated in terms of cover and abundance on the Domin scale (see Appendix C).

On the basis of the four transects which have been run to date, six distinct, roughly concentric vegetation zones have been characterized according to dominant species. The dominants plus some of the other species found in each zone are listed in Table 21.

The forest in the immediate vicinity of the bog is quite heterogeneous. A mature spruce stand lies on the north (zone six in Table 21 is based on this stand), a young spruce forest with aspen and shrub willow lies to the east, the vegetation to the south is mainly of the depression shrub type, and there is an aspen stand on the west. Another bog lies a short distance farther to the west. Figure 27 gives

Table 21. Moose Bones Bog vegetation zonation.

	ZONE 1	ZONE 2	ZONE 3	ZONE 4	ZONE 5	ZONE 6
Width of zone (m)	12-48	20-30	0-30	0-20	15	(indefinite)
Dominant species	Carex sp. (cf. aquatilis)	Calamagrostis neglecta	Deschampsia caespitosa	Poa palustris	Salix depressa ssp. rostrata Salix spp. Betula glandulosa	Picea glauca
Secondary species	(none)	Stellaria sp. Drepanocladus aduncus	Drepanocladus aduncus	Hordeum jubatum Ceratodon purpureus	Arctostaphylos uva-ursi Ceratodon purpureus	Picea glauca (sapling) Cladonia chlorophaea
Lesser species	Stellaria sp. Rorippa hispida var. barbareaefolia Alopecurus aequalis Ranunculus sp. Hippuris vulgaris	Carex sp. (cf. aquatilis) Deschampsia caespitosa Alopecurus aequalis Hippuris vulgaris Rorippa hispida var. barbareaefolia	Calamagrostis neglecta Stellaria sp. Hordeum jubatum Juncus arcticus Poa palustris Carex sp. (cf. aquatilis) Cladonia sp. Ceratodon purpureus	Carex sartwellii Deschampsia caespitosa Juncus arcticus Carex sp. (cf. aquatilis) Agropyron pauciflorum Arctostaphylos uva-ursi Leptobryum pyriforme	Picea glauca Hordeum jubatum Juncus arcticus Carex sartwellii Cladonia cariosa Picea glauca (sapling) Deschampsia caespitosa Peltigera aphthosa P. rufescens Poa palustris Picea glauca (seedling) Agropyron pauciflorum Stellaria sp. Arctostaphylos rubra Leptobryum pyriforme	Salix sp. Deschampsia caespitosa Peltigera aphthosa P. rufescens Arctostaphylos uva-ursi Picea glauca (seedling) Hordeum jubatum Betula glandulosa Feather mosses Arctostaphylos rubra Agropyron pauciflorum

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an idea of the relative importance of the three main tree species in the vicinity of Moose Bones Bog.

Mile 16 Bog

Mile 16 Bog, at mile 16 on the Atlin road, occupies a glacial kettle in an area of thick drift at the northern end of the kame terrace discussed on pages 26-28. It is surrounded on three sides by steep, sandy slopes and, on the south, by more gently rising terrain. The bog is circular, about 200 feet in diameter, and contains a small pond approximately 25 feet in diameter in the middle. The elevation is approximately 2,400 feet. The bog is quite level, and the periphery is well-defined where the surrounding terrain rises rather abruptly. Open, shallow water between sedge tussocks extends from the pond about two-thirds of the way to the periphery (Fig. 14).

The dominant species throughout most of the bog is *Carex aquatilis* ssp. *aquatilis*, occurring in large tussocks and forming a thick mat which is springy near the middle. Associated with the sedge, of co-dominant status, is *Drepanocladus aduncus*. Near the periphery of the bog there is a narrow zone which is not as wet and contains scattered shrub willows. A small, more mesic, northwestward extension of this outer shrub zone contains four species of *Epilobium*, several grasses, and, under a tip-up mound, *Marchantia polymorpha*, along with several other herbaceous species which are not of the bog proper nor of the surrounding, xeric slopes (lower left corner of Fig. 14).

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Reconnaissance and qualitative observations in the vicinity of Mile 16 Bog indicate that the information from the general vegetation and tree surveys, presented in Table 18 and Figure 27 portrays the upland vegetation very well. Detailed information is given in Table 8, which includes the relevé for stand 16W (lodgepole pine brûlé) and Table 15, containing the 16E relevé (herb-heath association).

An important local feature which the surveys do not show is the vegetation along Snafu Creek. This creek flows west, cutting a small canyon into the glacial drift, to a point a little over one-tenth mile south of the bog where it turns to flow south for approximately two-fifths of a mile. This latter stretch of the creek is in line with the lower terrain on the south side of the bog, and the alder and bog birch here are believed to be a significant pollen source. Relatively high percentages of these types were found in the surface sample for Mile 16 Bog (Fig. 26).

Mile 47 Bog

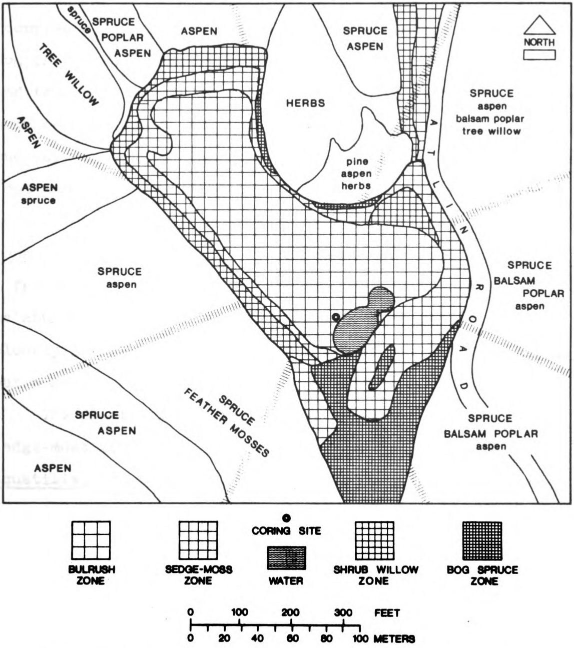
Mile 47 Bog, at approximately 2,400 feet elevation, is in the shape of a letter "V", opening to the north. The longer, western arm is about 675 feet, and the eastern arm about 500 feet long. The arms are separated by a bedrock knoll which rises steeply to about 75 feet above bog level. The bog is quite wet throughout a large, central portion and contains a small, oval-shaped pond about 75 feet long in the southern part. The bog lies near the head of a minor topographic divide with drainage from the tip of the eastern

arm through moist lowlands to swamps along Telegraph Creek about one-fourth mile to the northwest. The bog is highly calcareous as is shown by deposits of a light-brownish orange limonitic marl throughout the wetter areas and, particularly, in and around the pond.

Marl is defined here as a precipitate of calcium carbonate which may be nearly pure, in which case it is almost white in color, or contain admixtures of partially decayed organic material in various proportions. Clay and silt particles may constitute a minor fraction of some samples. The material may be colored various shades of brown, orange, pink, gray or green by the presence of iron oxides and perhaps oxides of magnesium, aluminum, or other metals. In most cases the precipitation of marl appears to be due primarily to the extraction of calcium carbonate from the water by _Chara_ spp. In some instances _Chara_ appears to be absent and marl precipitation may be under the influence of blue-green algae (Pollock, 1918). This seems to be the case in Mile 47 Bog.

Four vegetation zones are recognized (Fig. 15):

(1) Bulrush zone. This is the central and largest zone, about 125 by 350 feet in size, in the western arm and southern part of the bog. _Scirpus validus_ is dominant here. There are few other species present except for an occasional _Hippuris vulgaris_ and a few mosses and small willows on drier swells. The pond is on the southern edge of this zone.



Plant names in upper case letters indicate dominant types.
Lower case letters indicate secondary types.

Figure 15. Generalized sketch map of Mile 47 Bog vegetation zones and surrounding upland vegetation in eight compass sectors.

(2) Sedge-moss zone. This zone is more or less continuous around the bulrush zone, is about 90 feet wide, and occupies a significant portion of the eastern arm of the bog in the southeastern part. The boundary between this and the bulrush zone is ordinarily sharply defined. Sedge hummocks are common but not large, and there are barren, wet mud pockets between the better developed hummocks. The zone contains little standing surface water, in contrast to the sedge zone in Mile 16 Bog where the same species, Carex aquatilis ssp. aquatilis, is dominant. The zone contains a few stunted or dead white spruce. Xanthoria candelaria is abundant on one of these. Many spruce were examined closely for black spruce characteristics, as at other bogs, but none were found.

The plants, grouped according to prevalence in the sedge-moss zone, are: Dominant - Carex aquatilis ssp. aquatilis, Bryum pseudotriquetrum, B. rodlii; Abundant - Drepanocladus aduncus, Mnium affine; Common - Triglochin maritimum, Carex diandra, Salix myrtillifolia; Uncommon - Hippuris vulgaris, Ranunculus sp.; Rare - Triglochin palustris, Epilobium palustre (common locally), Pyrola sp., Galium trifidum ssp. trifidum (abundant with Ranunculus sp. on small, mossy hummocks in mud near the edge of the pond).

Within this zone, near the southeast edge of the pond, there is a linear swell which is 18 to 20 inches higher than the general level. The following species grow upon it: Picea glauca (seedling), Arctagrostis latifolia var.

arundinacea, Festuca altaica, Salix myrtillifolia var. pseudomyrsinitis, S. glauca ssp. glabrescens, S. glauca ssp. acutifolia, Pyrola asarifolia var. purpurea, and Mertensia paniculata, along with several of the mosses and sedges characteristic of the main zone.

(3) Shrub willow zone. A narrow shrub willow zone is of variable status around the bog. In some places it is absent, and the sedge-moss and bog spruce zones intergrade. In other places it is transitional between these two zones, or it may occur as a well defined zone between the bulrush zone and adjacent upland spruce forests, as along the western edge of the bog where both the sedge-moss and bog spruce zones are lacking. The willows are primarily the same species as occur in the sedge-moss and bog spruce zones but are more prevalent here.

(4) Bog spruce zone. From the south and southeast sectors of the bog the vegetation transition into the adjacent upland area is more gradual than elsewhere because of the low slope angle. Conditions here favor a bog spruce forest, characterized by mature white spruce and abundant mosses. The zone is rich in species as follows:

Dominant - Picea glauca

Abundant - Bryum pseudotriquetrum (dominant locally) and Tomenthypnum nitens (dominant locally).

Common - Juncus arcticus ssp. ater, Carex nardina, Geocaulon lividum, Equisetum scirpoides, Salix myrtillifolia, S. glauca ssp. glabrescens, S. glauca ssp. acutifolia.

Uncommon - *Parnassia* sp., *Pedicularis sudetica*, *Arctostaphylos rubra*, *Arctagrostis latifolia* var. *arundinacea*, *Festuca altaica*, *Petasites sagittatus*, *Cladonia* sp., *Peltigera aphthosa*, *Betula glandulosa*, *Carex aquatilis* ssp. *aquatilis*, *Picea glauca* (seedling).

Rare - *Carex capillaris*, *C. dioica* ssp. *gynocrates*, *Pyrola asarifolia* var. *purpurea*, *Platanthera obtusata*, *Erigeron elatus*, *Zygadenus elegans*, *Rubus stellatus*, *Cladonia gracilis* (abundant locally), *Moneses uniflora*, *Ledum palustre* ssp. *groenlandicum*, *Shepherdia canadensis*.

Isolated - *Parmeliella praetermissa*, *Eriophorum* sp., *Senecio lugens*.

The upland forests around Mile 47 Bog are quite variable. Some idea as to their nature can be obtained from Table 18 and Figure 27. A more detailed, qualitative description of the forest stands in the immediate vicinity of the bog can give an idea of the variability of Atlin valley forests in general. Such a description can be made in terms of 45-degree sectors, extending outward from the edge of the bog, as observed on a circumnavigation of the bog at distances up to about 200 feet (Fig. 15).

North sector. This sector includes the rounded bedrock knoll which separates the two arms of the bog, plus the slopes which trend down into the low areas, which are extensions of the arms of the bog, on either side. Trees on the knoll and its upper slopes are very scattered and include a few mature lodgepole pine and some aspen. Common herbs are *Antennaria* sp., *Potentilla* sp., *Arctostaphylos uva-ursi*, *Saxifraga tricuspidata*, *Artemisia* sp., *Galium boreale*, *Anemone* sp., and *Polemonium pulcherrimum*, all characteristic of well-drained to dry sites. On the south slope of the knoll, above the central part of the bog, aspen is abundant, and this grades downward into a narrow zone of mature spruce just above the north edge of the bog between its two arms. The west slope of the knoll is nearly devoid of trees, but extends down into a narrow spruce zone just above the east edge of the west arm of the bog. Farther to the north, beyond the end of the west arm of the bog proper, this slope bears abundant aspen. At the bottom the slope is continuous with a broad, moist swale where there is a mixed and rather lush stand of spruce saplings, balsam poplars, and large aspens up to 18 inches in diameter. There is a light admixture here of mature spruce and large balsam poplars. On the east the knoll slopes steeply down into the swale beyond the east arm of the bog. In this swale there is a dense stand of shrub willow, grass, and a few spruce saplings. The slope itself bears aspen and poplar, with a few large aspen near the bottom in the transition between dry and moist terrain.

Northeast sector. This includes the east side of the moist swale lying north of the east arm of the bog plus a portion of a more extensive, west-facing upland slope. The depression shrub vegetation of the swale grades directly into herb phase white spruce forest (see Table 5) which is more or less continuous through the sector. The stand contains a light admixture of balsam poplar, aspen, and tree willow. Large aspens are present in a ratio of about one per 100 large spruce. The shrub layer is scattered, with _Shepherdia_ _canadensis_ being dominant. Locally there are patches of thick moss. Toward the east side of the sector balsam poplar becomes abundant. There are only a few large spruce and aspen here.

East sector. Continuing into this sector, from the northeast, balsam poplar becomes dominant, with trees up to 10 inches in diameter and 30 feet tall. About half of these are dead, however, apparently of old age. _Shepherdia canadensis_ is abundant with the poplar. Spruce is scattered at first, but as the central part of the sector is approached, i.e. due east, it becomes dominant again, and poplar drops to the status of a light admixture. The spruce forest here is largely of the herb phase, but intergrades locally with small stands of the feather moss faciation. In a shallow swale spruce trees are smaller but denser, shrub willow is common, and mosses are abundant. On a swell spruce are sparser, and aspen of all sizes are common. Farther upslope to the east the spruce forest grades rather aburptly into a large aspen stand.

Southeast sector. The topography and vegetation here are similar to the east sector. Toward the south side of the sector the forest is rather open and contains quite large trees.

South sector. This sector is occupied by a broad, moist, low area which is continuous with the south end of the bog. The spruce forest extends into this area, but is considerably sparser than on the adjacent upland, being mixed with abundant shrub willow. A thick moss carpet occurs throughout. The willow and moss are continuous with the shrub willow zone of the bog.

Southwest sector. This sector is occupied by a well-developed stand of the feather moss faciation of the white spruce association. The forest is dense, spruce seedlings and saplings are common, herbs are scarce, and feather mosses are abundant. A few tree willows are present, plus occasional old aspens. The forest extends to the edge of the bog.

West sector. As this sector is approached from the SW sector old aspen become increasingly frequent in the spruce forest. Within the sector the spruce forest grades rather quickly into aspen forest across a small swale extending west from the bog and bisecting the sector. This aspen forest is located on a broad ridge which extends north from the swale, parallel to the west arm of the bog and extending into the northwest sector. The aspen forest grades downslope to the east into a rather well-developed shrub willow zone in the outer part of the bog.

Northwest sector. The aspen forest is continuous into this sector and grades into the mixed vegetation of the swale in the west side of the north sector as described above. The aspen forest is well-developed and open and, on the higher parts of the ridge, is representative of the aspen association (see page 96 and Table 11).

On the slope leading down from the ridge southeastward into the bog large clumps of shrub and tree willow appear. Farther downslope aspen drops out and tree willow becomes increasingly abundant until there is a nearly pure, old growth, tree willow forest. This forest is about 150 feet wide, from the transition with aspen higher on the ridge to the northwest down to a narrow spruce zone just above the edge of the bog. It has an open aspect, with few shrubs, herbs, or mosses. Spruce saplings are very scattered throughout. This is the only stand of nearly pure tree willow vegetation encountered in the Atlin valley.

Mile 52 Bog

This bog is somewhat rectangular in shape, oriented with its long axis trending north-northwest to south-southeast, and is approximately 650 to 1500 feet in size (Figure 16). A shallow pond, about 150 by 400 feet in size, is situated in the north part of the bog. As in Mile 47 Bog, the pond is bordered in certain places by "beaches" of light-brownish orange calcareous organic deposits. Aquatic vegetation is encrusted with calcium carbonate. A few small ponds and pools occur elsewhere in the bog. Except for narrow zones adjacent to these, the bog is dryer than Mile 16 and Mile 47 Bogs.

Figure 16. Mile 52 Bog.

View east into Mile 52 Bog from near the summit of a bedrock hill about 200 ft higher in elevation.

Vegetation in the foreground is of the herb-heath type. Next is a zone of aspen brûlé, with a strong admixture of shrub willow on the near side, which merges into the white spruce zone along the west edge of the bog. The large tree at the left is a lodgepole pine. A few other pines are scattered among the spruce.

The light colored material along the near edge of the pond, behind the tops of the white spruce, plus a few small patches on the far side, are marl-organic deposits.

On the far edge of the pond, somewhat left of center, is a patch of stunted white spruce, most of which are dead.

Patches of lighter tone in the north and northeast parts of the bog are sedge vegetation, dominated by *Carex aquatilis* ssp. *aquatilis*. Medium toned areas around them are small shrub willows and a few shrub birch.

A major shrub zone containing large *Salix* spp. and *Betula glandulosa* occupies the east, southeast, and southern parts of the bog. Young white spruce appear to be advancing, along with shrubs, across the bog just south of the pond.

A small pond is seen at the right of the photograph. In 1966 a residual frost layer, at a depth of 12-15 inches, which could only be penetrated with a special permafrost coring device, was encountered within a few feet of this pond as late as July 6.

Beyond the shrub zone is a stand of young white spruce brûlé with a strong admixture of *Salix* spp. This stand contains a great deal of charred wood and clutter.

Across the upper part of the photograph is the Atlin road, and beyond this, the edge of a stand of the feather moss faciation of the white spruce association.

The palynological sampling site is situated at the southern tip of the pond, about 3 feet from the water's edge.

The white spot at the upper right is the field truck, parked at milepost 52.

23 June 1967.

Figure 16. Mile 52 Bog.

Figure 17. Vegetation in Mile 52 Bog.

Figure 17. Vegetation in Mile 52 Bog.

View north from near the northeast shore of the pond.

Vegetation in the foreground is predominantly *Carex aquatilis* ssp. *aquatilis* with an admixture of *Salix* spp. and *Betula glandulosa*.

Across the middle of the photo is a shrub willow zone. This grades into typically heterogeneous upland forest vegetation.

The triangle-shaped mountain on the left skyline is Mt. Hitchcock (6,878 ft).

Afternoon. 4 July 1967.

Vegetation zonation is not as concentric nor distinct in this bog as in the others. Basically there are patches of sedge zone, dominated by Carex aquatilis ssp. aquatilis and of shrub zone, containing at least six species of willow and including significant admixtures of bog birch (Fig. 17). Northeast of the pond there is a large area of nearly pure sedge vegetation, but at most other places in the bog sedge and shrub vegetation is mixed. Shrubs are generally less abundant in the central parts of the bog and increase in abundance and size toward the periphery. There is a significant proportion of bog birch in the vicinity of the pond. A few stunted white spruce occur in the bog, and on the eastern edge of the pond there is an area about two acres in size containing scattered dead white spruce, some around six inches in diameter. A possible explanation for the death of these trees is that the water table has risen in recent times.

The upland vegetation surrounding the bog is similar to that around Mile 47 Bog except that the proportion of spruce is less. A considerable amount of lodgepole pine occurs higher on a bedrock hill adjacent to the bog on the west and also on higher slopes of the mountains immediately to the east.

Jasper Creek Bog

This bog is located a short distance west of the road approximately 16 miles south of Atlin (Fig. 18). It is

Figure 18. Jasper Creek Bog.

View south-southeast from Atlin road approximately 17 miles south of Atlin. An interconnected bog and pond appear in the distance at the left.

The sedge vegetation zone adjacent to the pond is dominated by *Carex rhynchophysa* and *Drepanocladus vernicosus*. The bog water table is above the surface throughout most of this zone.

In the foreground and on the far side of the bog is a shrub willow zone. White spruce seems to have begun to encroach upon this zone in the past. More recently a change in habitat conditions, possibly a rise of the water table, caused these spruce seedlings and saplings to die. In addition, a number of dead young spruce can be seen about midway between the two ponds in the left part of the photo. In the right foreground is an older lodgepole pine which also has died.

The forest vegetation on the hillside west of the bog is of the mixed coniferous forest type. Although white spruce is most abundant here, alpine fir and lodgepole pine form important admixtures in most places.

Afternoon. 11 July 1968.

Figure 19. View east from Jasper Creek Bog.

View from within the bog near the palynological sampling site, shown in the right foreground. This site is located in the middle of the open area shown in Figure 18 south of the pond.

The forest in the middleground is composed almost exclusively of lodgepole pine, in contrast to the mixed coniferous forest on the opposite side of the bog.

The mountain in the background is the southernmost peak in the Johnson Range and is composed largely of limestone.

9 September 1967.

Figure 18. Jasper Creek Bog.

Figure 19. View toward Sentinel Mountain from Jasper Creek Bog.

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about 400 by 1300 feet in size and is situated in a small north-northwest to south-southeast trending valley at an elevation of about 2,400 feet. It drains south into an interconnected bog at the headwaters of Jasper Creek. The bog contains a comparatively large pond, approximately 200 by 500 feet in size. Except for narrow peripheral areas, the entire bog is wet, with standing water up to a foot in depth in places well away from the pond. The surrounding upland terrain rises rather abruptly from the bog except where it is continuous through a narrower area with the next bog to the south. Standing water is continuous between the ponds in each of the bogs, and a lagg type of stream about two feet deep also connects them. Flow in this stream was not perceptible.

The bog is occupied almost entirely by a sedge-moss zone dominated by _Carex rhynchophysa_ and _Drepanocladus vernicosus_ (Fig. 19). There is no significant tussock development. Associated with these species are _Cinclidium stygium_, _Carex aquatilis_ ssp. _aquatilis_, _C. diandra_, _C. limosa_, _Eriophorum angustifolium_, _Utricularia intermedia_, _Potentilla palustris_ and, near the edge of the pond, _Menyanthes trifoliata_.

A narrow shrub willow zone is discontinuous around the bog. _Vaccinium oxycoccus_ is abundant locally on thick moss hummocks in this zone on the west side of the bog. _Empetrum nigrum_ was also found here, and _Ledum palustre_ ssp. _groenlandicum_ is abundant at the nearby forest edge.

The forests around Jasper Creek Bog are comparatively mature and continuous. On the north and west they are dominated by white spruce, alpine fir, and lodgepole pine. The relative abundance of these three species appears to change with elevation, with spruce somewhat more frequent at lower levels, fir more abundant at intermediate levels, and pine assuming dominance at higher levels. In general, the most vigorously regenerating species is alpine fir. The species composition and structure of the lower three layers of this forest are similar to the feather moss faciation of the white spruce association (Table 4). With Pleurozium schreberi and Hylocomium splendens forming thick mats, this forest could also be designated a feather moss type.

East and northeast of the bog, on the lower slopes of the Johnson Range, there is a fairly extensive, old-growth lodgepole pine forest (Fig. 19). Spruce is of minor importance here, and fir is absent. Spruce and fir seedlings are rare. Aspen and tree willow occur as minor admixtures. The soil here is sandy and light. The forest on this west-facing slope, although apparently mature, is much different from that on the east-facing slope a short distance away across the bog where the mixed coniferous forest occurs.

Wilson Creek Bog

This bog lies approximately six miles by road east of Jasper Creek Bog, about 200 feet north of the road, at

Figure 20. Wilson Creek Bog.

View northwest across Wilson Creek Bog toward southeasternmost peak in the Johnson Range (4,661 ft). This peak is composed predominantly of limestone.

The pond bottom is formed by lime-encrusted *Chara* spp. At the far edge of the bog a sedge-moss zone can be seen, into which a few white spruce appear to be advancing. The forest beyond is of the mixed coniferous forest type, containing white spruce, alpine fir, and lodgepole pine. The latter species appears to lead in importance here.

Late afternoon. 25 August 1968.

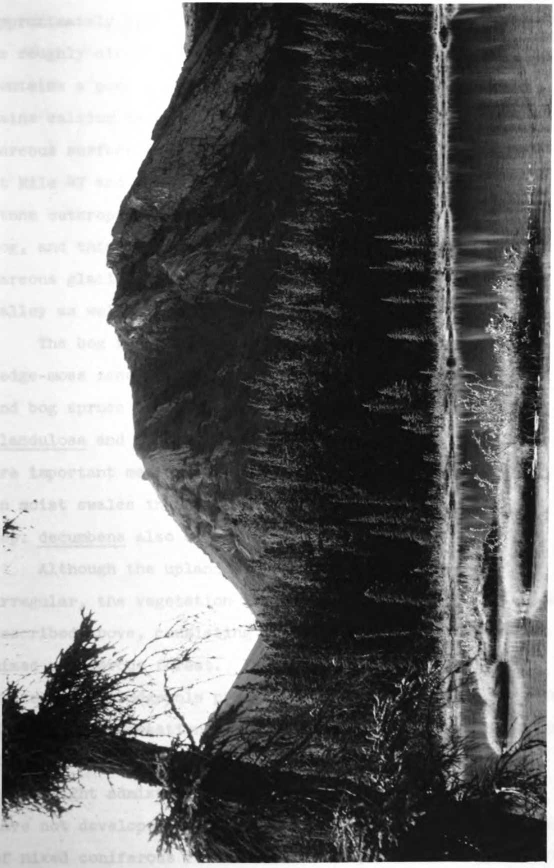


Figure 20. Wilson Creek Bog.

approximately 3,050 feet in elevation (Fig. 20). The bog is roughly circular in shape and 600 feet in diameter. It contains a pond around 200 feet in diameter. The pond contains calcium carbonate-encrusted algae, and there are calcareous surface deposits around the pond similar to those at Mile 47 and Mile 52 Bogs. It is to be noted that limestone outcrops are extensive on the mountainsides around the bog, and this is probably the source area of much of the calcareous glacial material deposited farther north in the Atlin valley as well as of the marl in Wilson Creek Bog.

The bog vegetation is contained primarily within a sedge-moss zone, and there are narrow, discontinuous shrub and bog spruce zones which intergrade in places. _Betula glandulosa_ and _Potentilla fruticosa_, along with _Salix_ spp., are important members of the shrub zone and are also found in moist swales in the surrounding forest. _Ledum palustre_ ssp. _decumbens_ also occurs here.

Although the upland terrain surrounding the bog is irregular, the vegetation is more homogeneous than in areas described above, consisting predominantly of an old growth mixed coniferous forest. It appears to be similar to the white spruce-lodgepole pine forest association described in the general vegetation survey, particularly stands S19N and S19S (Table 8), except for the greater prevalence of pine and a light admixture of mature alpine fir. Most stands have not developed to the feather moss stage characteristic of mixed coniferous forest west of Jasper Creek Bog, however.

In many places pine appears to lead in dominance and in regeneration. Aspen is of low frequency in the vicinity of the bog. This forest type appears on aerial photographs to be almost continuous around the bog within a radius of at least a half mile. In this respect it is noted that forest fires appear to be much less frequent in the Atlin valley south of Atlin than in the northern portion.

PALYNOLOGY

This section deals with (1) the development of a palynological record for the Atlin valley, (2) the interpretation of this record on the basis of the ecology of individual species and plant assemblages represented in it, and (3) the preparation of a Holocene chronology of post-glacial botanical and climatic events.

X. PALYNOLOGICAL METHODS

Bog sampling

The six bogs whose vegetation is discussed above were sampled for a palynological study. These bogs were, in fact, originally selected, not for their vegetation, but for their potential palynological value. This potential was estimated on the basis of the depth to which they could be probed, their apparent major sediment types, and their locations.

It was assumed that the deepest bogs generally have the longest record and that these were to be chosen for sampling. That this assumption is not always valid has since been shown by the Mile 16 Bog core which, although the longest (8.2 m), is also the youngest, except for the Moose Bones Bog short core. Nevertheless, sediments near the bottom of all the cores except for these two are believed to have been laid down when the ice front was still near the respective bogs. In general, glacial ice is thought to have been near the site of the future bog when clays or other mineral sediments were being deposited (Fulton, 1965). Since clay and silt or sand ordinarily are deposited at a relatively rapid rate, at least during early stages of deglaciation, and since pollen and spore preparations of this kind of material are difficult, peats and marls were preferred.

With respect to location, the major consideration was to sample several regularly spaced bogs whose interred pollen assemblages would, it was hoped, collectively reflect the general history of the Atlin valley vegetation.

In each bog, except Jasper Creek Bog, sampling was done at the edge of the pond, where the deepest probes were made (no probing or sampling was done in the ponds). In Jasper Creek Bog the deepest part of the basin was some distance away from the pond. The lowest sediments in the deepest part of a bog basin are presumed to date from the time of initiation of basin filling (Potzger, 1956). Peat and some marl samples were obtained with a Hiller sampler, and most marl and all clay samples were taken with a Davis sampler. Successive barrelfuls were taken alternately from two holes approximately one-half meter apart. Where sampling was done in standing water, as in Mile 16 and Jasper Creek Bogs, the water surface was used as a reference level. Otherwise a stick was laid on the surface next to the hole. At Jasper

Creek Bog a working platform was made of logs dragged in from the forest.

Care was taken that the samples did not become contaminated. In removing samples from the Hiller, only material from near the center of the barrel was taken in order to avoid foreign material which had been carried down from above, apparently lodged against the flange, and scooped in ahead of the material of the sample level. This was especially noticeable when marl was sampled with the Hiller. The light-colored marl was seen to form a core in the center of the barrel with dark-colored peat surrounding it. Both the Hiller and Davis samplers were rinsed in pond water each time before pushing them down again. The Hiller samples were put into plastic bags which were numbered with a felt-tip pen. Plug samples from the Davis were wrapped in Saran Wrap and aluminum foil. The level and general sediment type of each sample was recorded in a field notebook.

After a complete core had been taken and there was some knowledge of the general bog stratigraphy, a decision was made as to which levels it might be desirable to have radiocarbon dated. These levels were then resampled, usually several times each in different, nearby holes until it appeared that enough material for dating was at hand.

There were a few variations in sampling procedure. In Moose Bones Bog the sedimentary material, a firm, fine-grained peat (see below), was too stiff to sample in the usual way. Instead, a pit was dug and samples were obtained from one wall. Samples could be taken only down to the one-meter level because it was here that the rate of inseepage of water caught up with the digging rate. In Wilson Creek Bog, the upper samples were taken from the side of a plug cut from the sod with a shovel.

Surface samples consist either of mud scooped up near the sampling site or of a clump of moss. The surface sample from Jasper Creek Bog consists of the upper 25 cm of loose, watery, moss material taken with the Hiller sampler.

Preparation of samples

Most of the samples prepared and counted were selected at 15.24 cm (six inch) intervals, each sample being four to five cm thick. The laboratory procedure for macerating and preparing them for counting included deflocculation with potassium hydroxide, sieving to remove larger particles, solution of carbonates with hydrochloric acid and of silicates with hydrofluoric acid, and acetolysis. Residues were stained with Safranin-O and placed in one-dram vials in a three to one mixture of water and hydroxyethyl cellulose (HEC). Slides were made using Harleco Synthetic Resin (HSR) as a mounting medium. A complete maceration and slide-making schedule is included as Appendix D. This schedule was varied according to the nature of the samples. For example, either the hydrochloric acid or the hydrofluoric acid step or both were eliminated for samples lacking carbonates, silicates, or both.

Samples of glacial clays, occupying the lower portions of Mile 47, Mile 52, and Jasper Creek Bogs, were rather difficult to prepare, even though several different procedures and variations of them were tried. In every case a black, colloidal precipitate formed after treatment with hydrofluoric acid. It was not possible to make adequate preparations of clay samples without using this reagent, even with heavy liquid flotation techniques (e.g. Frey, 1951). It is possible that the clay accumulated relatively fast, when the ice front was still near by, and that only a short time period is represented by them. If this is true, they may not be particularly important to the overall record of postglacial environments, except to indicate some of the plants involved in invading the recently deglaciated terrain. Terasmae (personal communication 1969) told of similar difficulties with samples from various other places in Canada.

After deflocculation and sieving, but prior to treatment with hydrofluoric acid, most of the residues were inspected for volcanic ash shards using wet, temporary microscope slide mounts. None were found, although, as Hansen (1953) and Aitken (1959) indicate, there is good reason to expect at least two different volcanic ash layers in Holocene bog sediments in the Atlin area. It is possible that the ash layers, if any, occur at levels between those from which samples were selected. However, the major pollen profiles and the stratigraphy of the Atlin valley bogs are similar enough that they can, in conjunction with the radiocarbon dates, be rather closely correlated without knowing the levels in them of volcanic ash horizons.

In addition to the bog samples, pollen preparations of a number of modern species were made for reference purposes. The procedure used was devised by N. G. Miller (1969), and Appendix E comprises a list of the Atlin valley species so prepared. Slides of each of these have been deposited in the pollen and spore reference collection of the Departments of Geology and of Botany and Plant Pathology at Michigan State University. All other bog sample residues and microscope slides are also filed there.

Pollen and spore counts

Counts were made with the use of an E. Leitz Wetzlar microscope and a Lab-Count - Denominator counter. Some photography for reference purposes was done with a Leitz Orthomat automatic camera.

Slides were traversed at 250 power and all pollen and spores except moss and fungus spores were counted. The traverses were adjacent and were continued, beginning across the middle of the slide, until the desired total was reached. If an entity or a recognizable fragment of one did not extend one-half way or more into the field of view, it was not counted. Magnifications of 400 and 950 power were used for detailed examination of entities. Identifications were made with the aid of published photographs and descriptions and the reference collections of Michigan State University and of N. G. Miller, as well as the writer's own reference collections.

Early counts, involving the Mile 47 Bog samples and part of the Jasper Creek Bog samples, were made until totals were obtained of not less than 200 entities of the non-aquatic bog and extra-bog types (NEB). Counts of aquatic and semi-aquatic bog types (ASB) were additional to these so that total counts ranged from just over 200 to over 400 in a few cases. Later it was decided, primarily on an intuitive basis, that higher counts should be made to provide for a more substantial base for percentage calculations. The minimum total for non-aquatic bog and extra-bog types was raised to 300, but usually from 325 to 350 were counted, depending on the quality of the preparation. Total counts ranged up to 907 (at the 300-305 cm level in Wilson Creek Bog), and most were over 400, with many over 500. In contrast, counts of clay samples were necessarily low, usually less than 100. In a few cases total counts were from four to ten.

All together 154 samples from five bogs were counted. Samples from Mile 52 Bog were not counted, although a few samples at critical levels were examined in conjunction with interpreting the Mile 47 Bog section.

XI. POLLEN AND SPORE DIAGRAMS

Construction of the diagrams

Pollen and spore diagrams for the five bogs are included as Figures 21 through 25. Each diagram is a composite of adjacent graphs of percentages of each pollen and spore type plotted against depth. The graph for a type is called its profile. Recurring percentage scales, one for each profile, are placed along the bottom of the diagrams, and depth scales are positioned along the vertical margins. Radiocarbon dates (see below) are placed, at the appropriate levels, at the far left, with extrapolated dates in parentheses. A column showing sediment type is also included.

The entities appearing on the diagrams are arranged in several different groups. The two fundamental groups are aquatic and semi-aquatic bog (ASB) types and non-aquatic and extra-bog (NEB) types. The former include pollen and spores of plants which ordinarily are submerged or emergent in the bog pond or in shallower water near it or are otherwise dependent on wet conditions for at least part of the growing season. In the bogs, as discussed above, these plants are found primarily in the ponds, the sedge-moss zones and, in Mile 47 Bog, the bulrush zone. NEB types include pollen and spores of plants which ordinarily grow in the less wet zones of the bog and in upland areas. These include shrub and bog spruce zones as well as all forest vegetation.

ASB and NEB types are distinguished because it is believed that the abundance and the physiological condition of plants, both of which affect pollen and spore production, vary independently between the two groups. For example, a period of dry years could bring about a lowering of the bog water

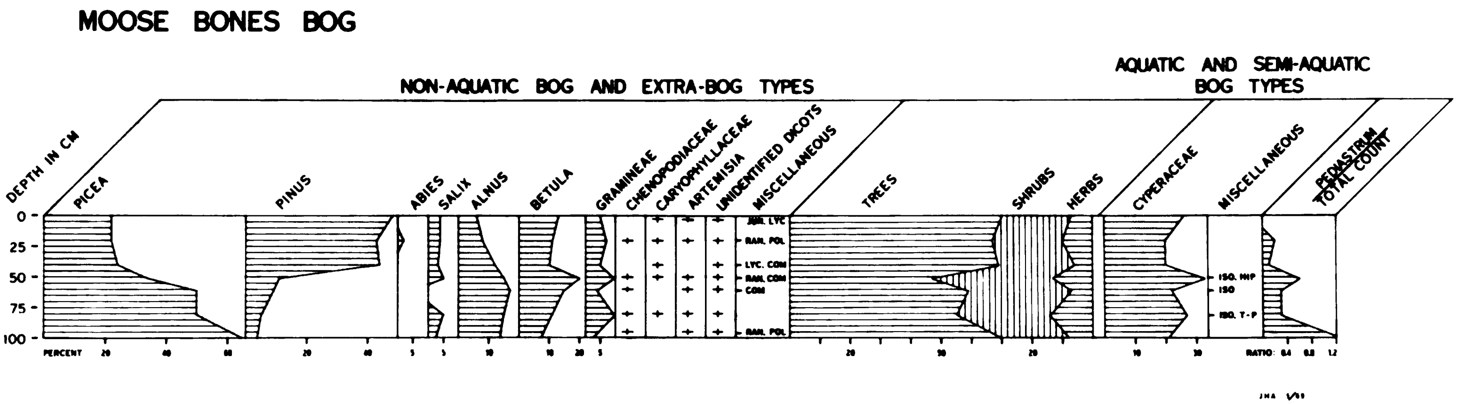


Figure 24. Pollen and spore diagram for Moose Bones Bog.

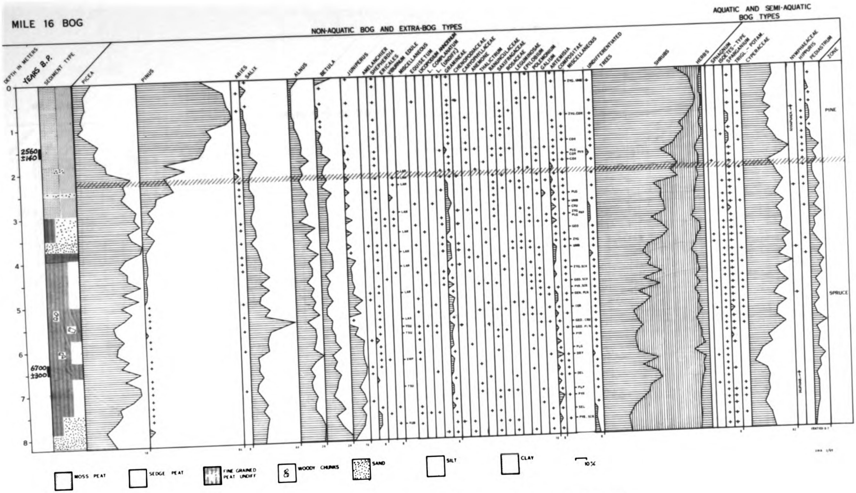


Figure 22. Pollen and spore diagram for Mile 16 Bog.

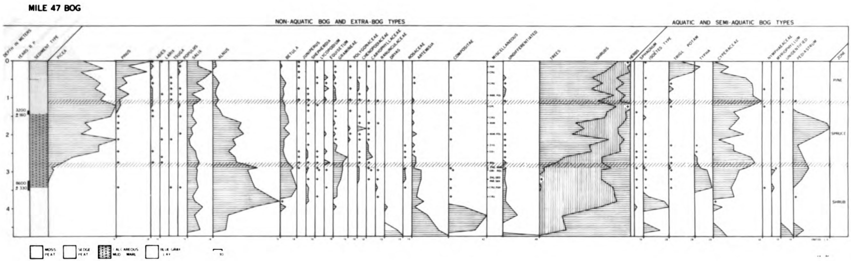


Figure 23. Pollen and spore diagram for Mile 47 Bog.

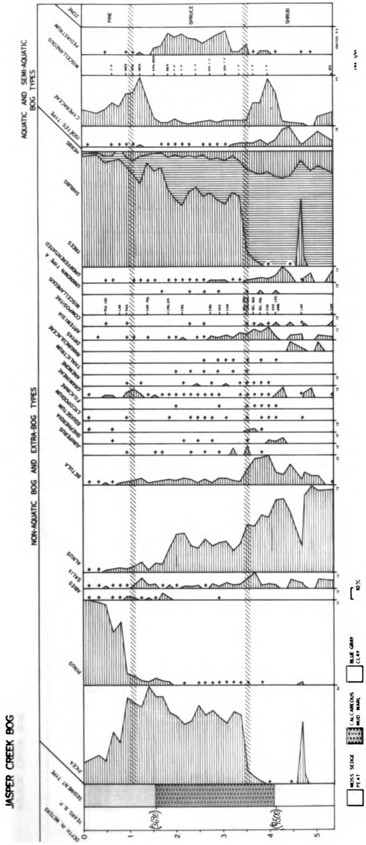


Figure 24. Pollen and spore diagram for Jasper Creek Bog.

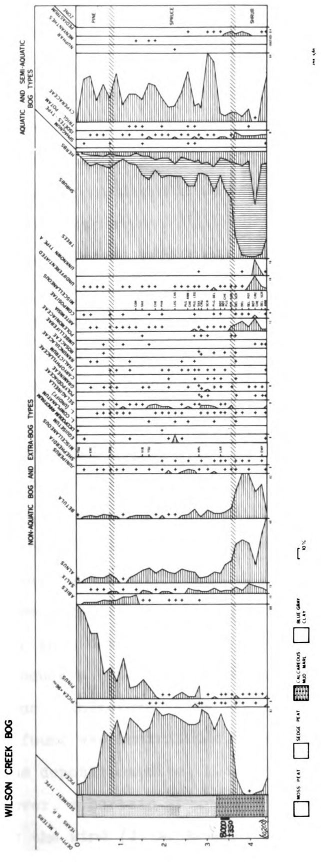


Figure 25. Pollen and spore diagram for Wilson Creek Bog.

table and cause poor growing conditions in the sedge-moss and aquatic zones. Simultaneous vegetation changes in upland areas would probably not occur in a way, or at a rate, that would balance the decrease in pollen and spores deriving from the bog zones, although it is known that pollen production by forest species varies greatly from year to year, depending on climatic conditions and individual species' physiological characteristics (Faegri and Iversen, 1964). Conversely, a major forest fire could cause pollen production by upland vegetation to be much lower than usual for a period of several decades, whereas the vegetation of the wetter bog zones might be little affected during the same period. Most importantly, the bog vegetation is only a local feature of limited areal extent and, because of proximity to the deposition site, is overrepresented in terms of its importance in the regional vegetation. For purposes of past climatic determinations, overall regional vegetation conditions are considered more significant, and the distinction must be made for this reason.

It could be argued that *Salix* spp. should be placed in the ASB, rather than the NEB group. Willows are relatively poor pollen producers (Colinvaux, 1964), and are generally non-anemophilous. Therefore it is likely that most of the willow pollen found was contributed by plants growing in the vicinity of the deposition site, i.e. in the shrub zone of the bog. However, a certain amount of willow pollen may be blown about by the wind (J. H. Beaman, personal oral communication 1969). This leaves open the possibility that some of the willow pollen in bog samples may have been derived from the larger tree willows in surrounding forests as well as from stands of depression shrub vegetation in neighboring places. This, coupled with the fact that willows in the bogs, and also bog birch, usually occupy the drier zones and appear, therefore, to be more closely related to the upland vegetation seems to justify placing them in the NEB category. As a group willows are of greater regional importance than are plants of the ASB type.

Percentages for NEB types are calculated on the basis of totals for this group alone so that they will not be affected by fluctuations in the numbers of ASB types. Percentages for ASB types are based on total pollen and spore counts. Counts of colonies and fragments of colonies of *Pediastrum* spp., which are extremely variable, were kept separate from total pollen and spore counts. In order to show its abundance relative to the other entities, ratios of *Pediastrum* spp. counts to total counts are plotted in a column on the right side of each diagram.

Description of the diagrams

The pollen and spore diagrams can be divided into three zones on the basis of major changes, at two key levels, in the shapes of the profiles of the major pollen types. Radiocarbon dating shows that the boundaries between these zones are not, in most cases, contemporaneous from one bog to another. Nevertheless, the zonation is useful as a basis for description and discussion at this point.

Shrub zone. The lowest zone is characterized by high percentages of alder and birch pollen and relatively high percentages of willow, grass, *Artemisia* spp., and Compositae (Fig. 23, 24, and 25). Very low frequencies of tree pollen occur in this zone. Shrub pollen makes up the largest percentage of the total throughout the zone, and it is more abundant here than at any other level. Herb pollen, too, is highest in this zone. Other notable features are highs for *Shepherdia* sp., Unknown type A, and *Dryas* sp., with a rather remarkable high for *Dryas* in the lowest samples from Mile 47 Bog. A number of spruce grains were counted in the lowest two samples from Wilson Creek Bog, and an isolated spruce peak occurs at about the middle of the zone in Jasper Creek Bog. A few pine grains were seen in samples from this zone. Because of the prevalence of alder, birch, and willow pollen, this zone is designated the shrub zone.

Among aquatic and semi-aquatic bog types in the shrub zone Isoëtes-type spores appear early and reach their highest percentages here. Cyperaceous pollen is moderately high in the lowest samples, drops off in the middle of the zone, and regains its status in the upper portion. In Mile 47 Bog a major peak for *Typha* sp. occurs in the upper part of the shrub zone.

In Mile 47, Jasper Creek, and Wilson Creek Bogs the shrub zone begins at the bottom and extends upward through the blue-gray clay sediments to from one-half to three-fourths of a meter into the overlying marl. Only low total counts of pollen and spores could be obtained from the clay samples. For this reason the statistical basis of the diagrams at these levels is not good. Nevertheless, the occurrence of such non-anemophilous grains as Caryophyllaceae, Cruciferae, and a number of undifferentiated dicots, along with the occurrence of high percentages of shrubs, indicates that these sediments were receptive to pollen deposition. It is believed that these assemblages provide an indication of the basic nature of the contemporaneous vegetation which is not too much less credible than indications from higher pollen counts. It should also be noted that there do not appear to be any profile changes across the clay-marl transition which are any more irregular than some other changes between adjacent samples within a single sediment type. This, too, indicates that the percentages calculated on the basis of low counts in clay samples can reasonably be compared with those based on higher counts in samples from marl and peat.

In spite of the length of the Mile 16 Bog core, it probably does not reach even the upper part of the shrub zone. The pollen assemblages in the bottommost samples correspond with those in the lower part of the next zone above, i.e., the spruce zone.

Spruce zone. This zone begins with a rapid rise of spruce pollen percentages. These remain high throughout the zone, in excess of 80 percent at some levels, and are considered

be most characteristic of it. The pollen percentages of
: three major shrubs, willow, alder, and birch, decrease
levels which are, in most cases, intermediate between
)se of the shrub zone and the overlying pine zone.
umineae pollen remains approximately the same percentage
in the shrub zone, but Artemisia spp. and Compositae drop
:. Total herb pollen decreases to a lower level in the
'uce zone but is still present in significant quantities,
eraging about ten percent.

The Mile 16 Bog core appears to begin in the lower part
the spruce zone. This is indicated by the fact that the
ruce profile appears to be undergoing its initial rise in
: lowest approximately one meter of the core. Furthermore,
: overlying zone, which is well defined in all five bogs
a marked decrease of spruce and increase of pine pollen,
approximately twice as thick in Mile 16 Bog as in the other
r bogs. This indicates that the rate of peat accumulation
approximately twice as fast. The sediments in the spruce
e of Mile 16 Bog are primarily peat. Hence, assuming the
her rate here too, this zone should be about twice as
ck as in the other bogs. In Mile 47 Bog the spruce zone
about 1.75 meters thick, in Jasper Creek Bog about 2.25
ers, and in Wilson Creek Bog it is thicker yet. If the
uce zone in Mile 16 Bog does in fact begin below the bottom
the section, at well over eight meters in depth, then it
at over six meters in thickness, more than twice as thick
in the other bogs studied. This apparent inconsistency

can be explained by the fact that the peat, occuring through most of the Mile 16 Bog section, has mixed with it at several levels sand and silt in various proportions (Fig. 22). The admixture of this material increases the thickness of the zone over what it would be if the only sediment were peat. Furthermore, the spruce zone sediments of Mile 47 and Jasper Creek Bogs are mostly marl, which has a slower accumulation rate than peat. In Wilson Creek Bog the zone contains marl only near the bottom, the rest being peat. The spruce zone here, consequently, is thicker than in Mile 47 and Jasper Creek Bogs, more nearly approaching one-half the thickness of the spruce zone in Mile 16 Bog.

Although the spruce zone is readily defined by changes in the profiles of the major non-aquatic bog and extra-bog types, its boundaries are also marked by changes in profiles of certain semi-aquatic and aquatic types. Isoëtes-type, which occurs in substantial percentages in the shrub zone, drops off across the shrub/spruce zone boundary and maintains low, although consistent percentages, usually less than two percent, upwards in the cores.

The Cyperaceae profiles in the spruce zone are somewhat erratic from section to section, but there appears to be a general pattern in Mile 47, Jasper Creek, and Wilson Creek Bogs. A peak is reached somewhere around the shrub/spruce zone boundary. Then the percentages decrease to consistently low levels, as in Jasper Creek Bog, or to variable but, on the average, intermediate levels through the major portion of the spruce zone in Mile 47 and Wilson Creek Bogs. Near the top of the zone there is another increase in Cyperaceae percentages in all three bogs. In Mile 16 Bog the Cyperaceae profile rises gradually in the lower portion of the spruce zone and then stays at consistently high levels through the major portion of the zone.

The Pediastrum spp./total count ratio also helps to characterize the spruce zone. After sporadic occurrences of Pediastrum colonies in the shrub zone, the ratio begins to rise in the upper part of this zone and, in all but the Wilson Creek Bog profile, maintains intermediate to high levels throughout the spruce zone. Near the top of this zone it again drops off, except in the Mile 16 Bog section where it occurs in moderate numbers well into the overlying zone.

Pine zone. The third and uppermost zone is characterized by a major increase in pine pollen and a corresponding decrease in percentages of spruce pollen. Fir grains, appearing occasionally in the spruce zone, make a substantial appearance across the spruce/pine zone boundary, especially in Wilson Creek Bog where a peak of 9.5 percent is reached at the boundary level. This is fairly high for fir, which ordinarily is poorly represented in pollen assemblages (Faegri and Iversen, 1964; see below). Fir retains its status through most of the pine zone in all sections, dropping off near the surface. Willow, alder, and birch profiles decrease noticeably upon entering the pine zone except in Mile 47 Bog where willow increases. Herbaceous pollen is quite low in the pine zone, dropping to zero in some samples. Here, too, the Mile 47 Bog diagram shows an exception with an increase of herb pollen in the pine zone. The pine zone in Moose Bones Bog contains grass pollen in higher quantities than in the other bogs. Unfortunately, because of the shortness of the core from this bog, the relative status of the grass, as well as other types, cannot be assessed with respect to their profile appearances in the other two zones.

The extent to which decreases in percentages of various pollen types in the pine zone are only apparent and due to suppression by the considerable increase of pine pollen itself, rather than being real and due to actual decreases of those elements of the vegetation which produced them, is a problem which is difficult to evaluate. Some indication of the extent to which pine pollen does influence the other percentages is seen in the Mile 47 Bog diagram. Here the pine increase is not as great as in the other bogs. As noted above, willow and herb pollen percentages are actually higher than in the underlying spruce zone, rather than lower as in the other bogs. These higher percentages are probably due, at least in part, to the relatively low pine percentages. Where pine does reach higher percentages at the very top of its profile in Mile 47 Bog, willow and herb, as well as alder and birch pollen percentages drop.

Other notable features of the pine zone include the occurrence of a few *Tsuga* sp. grains in Mile 47 and Wilson Creek Bogs. Also, the only significant occurrence of *Populus* spp. pollen in any of the sections is in the pine zone of Mile 47 Bog.

The scarcity of Populus pollen in the bog sediments is probably due to its low preservability, especially in an alkaline environment, rather than to a low frequency of aspen and balsam poplar in the surrounding vegetation. This situation has been noted by many palynologists, and the problem was dealt with experimentally by Sangster and Dale (1961, 1964). Populus tremuloides pollen was shown to deteriorate rapidly in various environments, with faster rates under conditions of higher pH.

Profiles of semi-aquatic and aquatic types in the spruce zone show little similarity from bog to bog. Triglochin-Potamogeton-type reaches a major peak of 34 percent in the upper part of the zone in Mile 47 Bog. In the other bogs it is of rare occurrence at these levels. The percentages of Cyperaceae are fairly consistent and average around 20 percent in Moose Bones and Mile 16 Bogs. In Mile 47 Bog, Cyperaceae is abundant in the lower layers but becomes much less so rather abruptly near the surface. A similar situation is seen in the Jasper Creek Bog profile, although the decrease occurs earlier in the section. Cyperaceae pollen in Wilson Creek Bog averages around 20 percent, but the profile undergoes major fluctuations. Pediastrum spp. continues to occur in moderate numbers in the pine zones of Moose Bones and Mile 16 Bogs. In the lowest sample of the Moose Bones Bog core it was, in fact, much more abundant than all other pollen and spores. This condition was found in only one other place, the 1.5 to 2 meter level in the spruce zone of the Mile 16 Bog core. Almost no Pediastrum colonies were observed in pine zone samples from the three other bogs.

XII. RADIOCARBON DATING

Seven radiocarbon dates are available to use in establishing a Holocene chronology for the Atlin valley. Three samples from Mile 47 Bog, two from Mile 16 Bog, and one each from Jasper Creek and Wilson Creek Bogs have been dated. In this section, background information on the dated samples is presented, and the dates and certain aspects of their significance are discussed.

First it is to be noted that there are typically three major sediment types which have been involved in the formation of the Atlin valley bogs. These are stiff, blue-gray glacial clay in the bottom portions, marl at intermediate levels, and sedge-moss peat in the upper parts. Within each of these types there is little variation, and the boundaries between them are distinct, with little intergrading in most cases. An additional type, glacial drift, may occur below these. It was not possible to tell, with the Davis sampler, the exact nature of the underlying, coarser sediments, although they appeared to be a stiffer clay, ordinarily with a few sand grains and pebbles. In Mile 16 Bog sampling was stopped at a thick sand layer.

It is to be noted that there is no correlation between the boundaries of these three sediment types and the boundaries of the three pollen assemblage zones discussed above. This is to be expected since changes in sediment type are a function of hydrarch succession whereas vegetational changes on the surrounding uplands, and therefore pollen rain, are presumed to be related to a clisere. Although it is likely that the climatic and physiographic agents controlling the clisere have influenced the bogs too, there is no apparent reason for a direct relationship between bog stratigraphy and forest development.

This fundamental clay-marl-peat sequence was recognized early in bog sampling and it was decided that appropriate levels for radiocarbon samples would be the boundaries between these types. Consequently two of the dates are for the bottommost peat in Mile 47 (Figure 23) and Mile 52 Bogs. The respective levels and dates are 140 cm: 3,200 ± 160 years B.P. and 182.5 cm: 4,160 ± 180 years B.P. With these data, peat accumulation rates could be calculated, and for each bog a rate of 0.044 cm per year, or 4.4 cm per 100 years, was obtained. Although these two bogs are only five miles apart and their developmental histories have probably been similar, they do occupy different local drainage areas, they are of different sizes, there are notable differences between them in their extant vegetation, and their peat layers are approximately 42.5 cm different in thickness. In view of these dissimilarities, the identical peat accumulation rates in these two bogs suggest that rates may have been similar in other bogs in the Atlin valley. Thus, by applying the 0.044 cm per year rate, the 155 cm level in Jasper Creek Bog is dated at 3,690 years B.P. This, and other extrapolated dates, appear on Figures 21 through 25 in parentheses.

A date for the bottom of the Moose Bones Bog core was not determinable in this manner because the peat here is of a different nature. Since standing water in the bog is confined almost entirely to the pond for most of the year, dead organic material, up to the pond's edge, is exposed more or less directly to the atmosphere and is therefore more highly oxidized. The peat, including that nearest the surface, is fine grained and dark in color. In addition, living vegetation in and near the pond, i.e., in the area of organic accumulation, is not as abundant as in the other bogs, consisting almost entirely of <u>Carex</u> sp. (cf. <u>aquatilis</u>) with little moss. If this has also been the case in the past, then it is to be expected that a unit of vertical distance in the core here is equivalent, timewise, to somewhat more than one unit in the other cores. Correlations with the other pollen and spore profiles supports this and shows, in fact, that organic build-up takes place at about half the rate in other bogs. It is believed, furthermore, that such correlations, particularly with the Mile 16 Bog diagram, allow the assigning of meaningful ages to key levels in the Moose Bones Bog section. Thus, the spruce/pine zone boundary, at the 75 cm level, is dated at 3,900 years B.P., and the bottom of the section, 5,200 years B.P.

In Mile 16 Bog, radiocarbon dates are 2,560 ± 140 years B.P. for a sample covering the 140-163 cm depth range and 6,700 ± 300 years B.P. for a sample between the 625-648 cm levels. The midpoints of the positions in the section of these samples, 150 and 635 cm, respectively, are used for calculation purposes, the same also being done for the other dated sections. On this basis, an average sediment accumulation rate of 0.1171 cm/yr is calcualted for the portion of the section lying between the two dated levels. Thus the spruce/pine zone boundary, at 225 cm, is dated at 3,920 years. The extrapolated date for the bottom of the section is 8,323 years B.P. Taking into account the higher proportion of inorganic sediments in the bottom approximately 75 cm, which probably accumulated at a faster rate than the organic material, this estimate may be somewhat high. It seems reasonable to reduce this age estimate to 8,000 years B.P.

It can be seen that the sediment accumulation rate in the Mile 16 Bog section has been at least three times that in Moose Bones Bog and well over twice as fast as in the three southern bogs where, as will be shown, peat accumulation rates are nearly equal. The sand and silt dilution factor, mentioned on page 184, may be at least partially responsible for this higher rate. The source of such material is obvious in that this bog, unlike the others, is small, deep and surrounded on three sides by steep, sandy slopes. Figure 22, in the sediment type column, shows that the proportion of sand and silt is variable. It is suggested that this variability is related, in part, to the history of forest fires on these slopes. Severe fires can expose the mineral soil and leave it vulnerable to sheet erosion. Such a situation exists at present, and vegetation survey data for the 16W stand (Table 8) show this. Shrubs, herbs, and mosses, along with live trees, are, in total, of fairly low C-A value. Soil-holding plants such as *Arctostaphylos uva-ursi*, *Linnaea borealis*, and bryophytes are only now becoming reestablished, and there is a large amount of bare ground. The influence of fires on erosion and deposition in the Mile 16 Bog basin might be coupled, furthermore, with variations in rainfall. Although the average annual precipitation at Atlin is only 11.3 inches (Table 1), a maximum of 19 inches was recorded in 1938 (Canada Department of Transport - Meteorological Branch, unpublished data). It is likely, on the basis of the writer's experience, that most of this additional precipitation came in the form of heavy and prolonged rains late in the summer. Such an occurrence, coming within a few years after a major fire, could wash excess mineral material into the bog. The sandy layers at 1.9 and 2.4 meters, for example, may be due to such a combination of conditions.

Dates for both organic and inorganic fractions of a marl sample between 325 and 348 cm in Mile 47 Bog have been obtained and are, respectively, 8,600 $\pm$ 330 and 8,670 $\pm$ 900 years B.P. Using the difference, 5,400 years, between the former date and the date at the base of the peat as the length of time required for the marl to accumulate, along with the thickness of the marl, 196 cm, an accumulation rate of 0.036 cm per year, or 3.63 cm per 100 years was calculated.

In Mile 52 Bog, the first marly sediments appear at the 480 cm level. The marl accumulation rate cannot be applied to date this level, however, because clay, in varying proportions, continues as a major admixture up to 358 cm. From here up to the peat, at 183 cm, the nature of the marl appears quite similar to that of Mile 47 Bog. Applying the rate to the 358 cm level, therefore, gives an extrapolated date of 9,038 years B.P. It appears that marl deposition began considerably more than 400 years earlier in Mile 52 Bog than in Mile 47 Bog.

In Wilson Creek Bog a radiocarbon date of 8,000 $\pm$ 350 years B.P. was obtained for a sample centering on the 335 cm level, at the base of the peat (Fig. 25). With these data, a peat accumulation rate of 0.042 cm/yr was calculated, a rate very close to the 0.044 cm/yr obtained for both Mile 47 and Mile 52 Bogs.

By using the marl accumulation rate of 0.036 cm/yr calculated for the Mile 47 Bog section, it is possible to extrapolate down from the dated level in Wilson Creek Bog to an age of 10,200 years B.P. for the bottommost marl a few cm up from the bottom of the section.

A tentative chronology may be applied to the Jasper Creek Bog diagram (Fig. 24) by correlations with the Wilson Creek Bog diagram. In the latter, the shrub/spruce zone boundary is estimated, by extrapolation from the dated level, to be 8,860 years. It is believed that this date can reasonably be applied to the corresponding level in Jasper Creek Bog diagram because the two bogs are only a few miles apart and the major vegetational changes represented by this zonal boundary probably were contemporaneous around each bog. By doing this, and then extrapolating down to the base of the marl in Jasper Creek Bog, an age estimate of 11,050 years is obtained.

XIII. COMPARISONS OF SURFACE POLLEN ASSEMBLAGES WITH VEGETATION

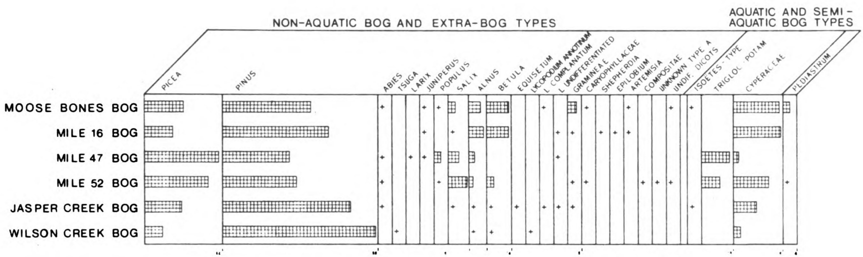
In this section an attempt is made to determine the extent to which surface pollen assemblages from the bogs reflect the nature of the general Atlin valley vegetation and local vegetation in the vicinity of each bog. Comparisons of pollen percentages with basal area percentages and with qualitative assessments of vegetation composition, particularly as discussed in the section on bog vegetation, are involved. The discussion deals largely with the four main tree species, white spruce, lodgepole pine, alpine fir, and aspen, because these are the predominant components of the Atlin valley vegetation. Three of these produce a large share of the airborne pollen. For purposes of this type of study, basal area is considered an appropriate measure of the prevalence of a tree species in terms of pollen production (Hansen, 1949a; Davis and Goodlett, 1960).

Regional comparisons

That regional vegetation, i.e., vegetation within at least several tens of miles of the deposition site, determines the composition of a pollen assemblage is shown by studies of Carroll (1943), Hansen (1949a), Davis and Goodlett (1960), and Terasmae and Mott (1964, 1965). Major factors involved are characteristics of pollen grains which make it possible for them to be carried considerable distances by the wind, the mixing of pollen types in the atmosphere, especially in mountainous areas where there is turbulence, and the location of deposition sites in open areas away from the edge of the forest. Ritchie and Lichti-Federovich (1963) and Lichti-Federovich and Ritchie (1965) analyze pollen rain-vegetation relationships from the standpoint of landform-vegetation regions and show that the latter may be recognized through characteristic pollen assemblages. Terasmae and Mott (1964, 1965) show that the basic vegetation type of the area from which a pollen sample was obtained can be distinguished, in the pollen spectrum, from the total, regional pollen rain produced by several major vegetation types. The effects of long distance dispersal, particularly with regard to the introduction of exotic types, are shown by these authors and by Ritchie and Lichti-Federovich (1966), Bartley (1967), and Terasmae (1967).

The major concern at present is to establish a reliable measure of the total Atlin valley vegetation in terms of the surface pollen samples, with the hope that this measure will make it possible to develop reasonable ideas, by studying fossil pollen assemblages, as to what the total vegetation has been like at different times in the past. It is believed that the effects of climate and climatic changes can only be interpreted from vegetation at the regional level, where the continuously varying local edaphic and historical factors, producing what is in reality a mosaic of vegetation types across the landscape, are smoothed out and the vegetation is looked upon as a composite, climatically responsive (i.e. climactic) whole. The studies cited above, and others, indicate that a reasonable correlation between surface pollen assemblages from the six Atlin valley bogs and the regional vegetation in the valley can be established with the data at hand. In addition, the possibility of local correlations, i.e. with vegetation within a few miles of the bogs, can be explored. Although a major local influence is exerted by plants of the ASB group, it is seen that some differences in surface assemblages from bog to bog can be attributed to peculiarities of the local upland vegetation too.

Figure 26 shows the pollen and spore spectra for the six bog surface samples. Table 22 compares the average pollen percentages for the four major tree species in each sample with the percent of total basal area for the species. The pollen percentages do not total 100 because they are calculated on the basis of total NEB types. R values (Davis, 1963) are given in the right hand column. Although the meaningfulness of these is dependent on several factors, as Davis (1963) and Lichti-Federovich and Ritchie (1965) point out, they are considered useful here in giving a general impression of the degree of representation of the present species on a regional scale. The R values show that spruce, at 0.43, is somewhat over twice as prevalent in the vegetation as its pollen percentage indicates, and pine, with a value of 2.3, less than half. Both fir and Populus spp. are very underrepresented. On the basis of discussion in the section on vegetation, it can be concluded that fir may be much more prevalent than its pollen record would indicate. This is especially so at Jasper Creek Bog where the fir pollen percentage is less than two, but the tree is abundant in the adjacent mixed coniferous forest west of the bog. In addition, it occurs in pure stands approximately one mile to the north (Table 18 and Fig. 27). With regard to aspen, the pollen record, to the extent that it has been developed here, permits no conclusions regarding its status in the vegetation except, perhaps, in extreme local cases. In the latter regard, Figure 28 shows a relatively high pollen percentage of about five in the Mile 47 Bog sample, along with a significantly higher prevalence of aspen in the vegetation within two miles to the north and south. The findings presented here regarding representation of these four species compare with information given by Faegri and Iversen (1964), Davis and Goodlett (1960), and McAndrews (1966).



POLLEN AND SPORE PERCENTAGES IN SURFACE SAMPLES FROM 6 BOGS IN THE ATLIN VALLEY

Figure 26

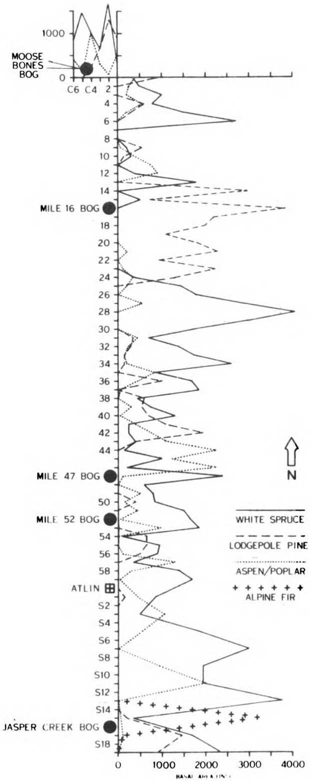
Table 22. Basal areas and pollen representation of the four major tree species in the Atlin valley.

Species	Pollen % (mean of 6 samples)	Total B.A. (in^2)	% Total B.A.	R
Picea glauca	23.8	81,952	55.5	0.43
Pinus contorta	58.3	37,067	25.2	2.3
Abies lasiocarpa	0.3	3,202	2.2	0.14
Populus spp.	1.0	25,182	17.1	0.058
	83.4	147,403	100.0	

Figure 27. Basal area distribution of the four main tree species along the Atlin road.

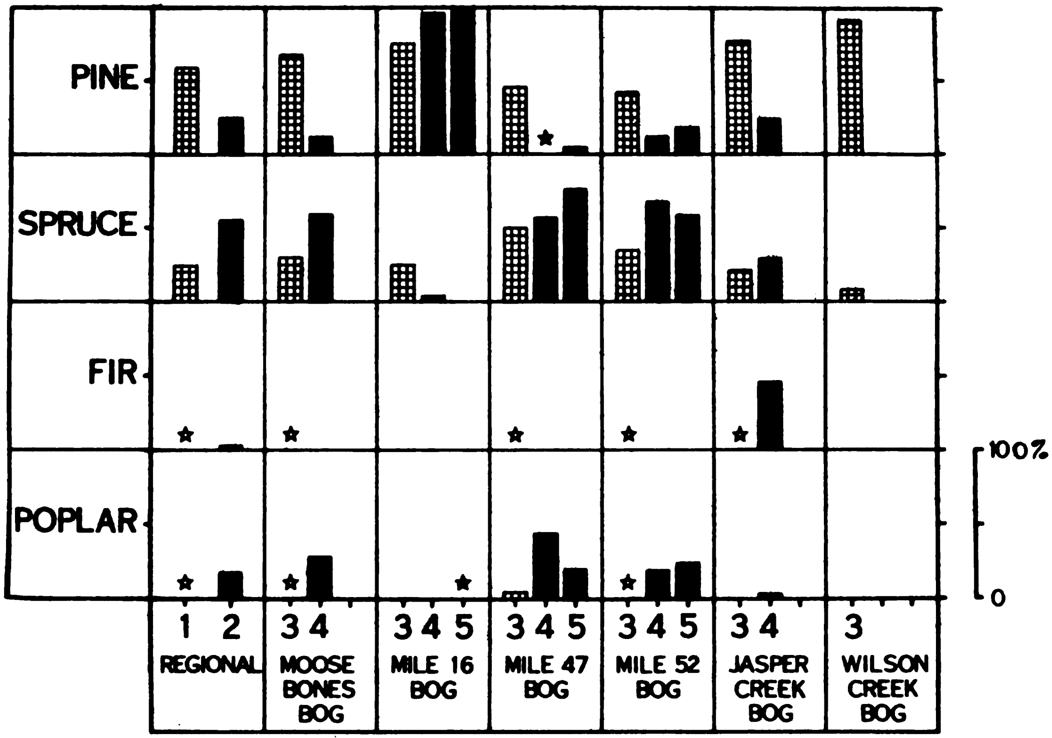
Total basal area in square inches at each site is plotted against site position along the first six miles of the west-southwest-east-northeast trending Carcross road and the north-south trending Atlin road. The two roads intersect at mile one. Sites are at every milepost, except south of Atlin where they are at two-mile intervals.

The locations of five of tne six bogs discussed in the text are shown. (The tree survey was not extended as far as Wilson Creek Bog.)



BASAL AREA DISTRIBUTION OF WHITE SPRUCE, LODGEPOLE PINE, ASPEN/POPLAR, AND ALPINE FIR ALONG THE CARCROSS/ATLIN ROAD TRANSECT

Figure 27



COMPARISONS OF SURFACE SAMPLE POLLEN PERCENTAGES WITH TREE BASAL AREA PERCENTAGES.

1. POLLEN PERCENTAGE. AVERAGE OF SIX BOG SURFACE SAMPLES. 2. BASAL AREA PERCENTAGE BASED ON SURVEY TOTAL. 3. POLLEN PERCENTAGE IN BOG. 4. BASAL AREA PERCENTAGE. TWO MILES NORTH TO TWO MILES SOUTH OF BOG. 5. BASAL AREA PERCENTAGE. FROM BOG TO FIVE MILES SOUTH.
☆/★ = LESS THAN TWO PERCENT.

JHA 12/89

Figure 28

Local comparisons

Figure 28 shows that most of the entities vary considerably from one bog to another, and it is because of this that at least five cores from the valley are considered necessary for developing a palynological record. An attempt is made now to assess the individual spectra in relation to local vegetation, using local basal area data and qualitative observations, along with regional R values for comparison (Figures 27 and 28; Table 22).

Figure 28 gives, as bars numbered "4", the basal area percentages of the four major tree species for sites at a distance of two miles and less north and south of the bogs. In addition, the same type of data is presented, as bars numbered "5", for tree survey sites located up to five miles south of the bogs. The former data are taken as a sample of local arboreal vegetation all around the bog. The latter are given for comparison and for the purpose of testing the hypothesis that the major influence on the pollen rain is from the south, due to prevailing winds from the south during the flowering season (Figure 6). Because of the way the tree survey was conducted, data of the number 4 type are not available for Wilson Creek Bog, and number 5 type data are not available for this nor for Moose Bones and Jasper Creek Bogs.

<u>Moose Bones Bog</u>. By comparing "3" in the Moose Bones Bog column of Figure 28 with "1" it can be seen that, for the four trees, the pollen spectrum here more nearly resembles

the regional average than in any other bog. However, the local vegetation relationships here also closely resemble the regional situation, as can be seen by comparing "4" and "2". Therefore it is difficult to make a distinction between local and regional influences with these data.

It is suggested that Moose Bones Bog receives pollen from a broader area than the other bogs because of its location in the northwest end of the valley. Here, low, relatively level terrain extends for a considerable distance around the bog, particularly to the west, and winds blowing north out of the Taku Arm and Tagish Lake areas, as well as the Atlin valley, could bring pollen to the bog. If so, the pollen rain here, originating from a larger and more diverse area, would be more representative of the regional vegetation than in the other bogs.

The two fir grains found in the Moose Bones Bog surface sample could have blown north from higher elevations on Jubilee Mountain. In general, the minor occurrences of fir in bogs where no fir trees were found within several miles around can be explained on the basis of this species' prevalence at elevations above approximately 3,000 feet throughout the valley.

Salix and *Betula* percentages reflect the importance of these genera in the shrub zone of the bog and in nearby places (Table 21).

The *Alnus* value, as in other bogs, is more difficult to interpret in terms of its role in the vegetation. No alders were found in any bog, and very few were found during the general vegetation and tree surveys. General observations in the Atlin valley indicate that alder is a pioneer on abandoned rocky stream beds and flood plains. A major occurrence of this kind is along lower Pine Creek about two miles southeast of Atlin village. Sites of this nature are not common at the present time, but it is recognized that alder is ordinarily overrepresented in a pollen rain and therefore of less importance than its pollen percentages indicate (Faegri and Iversen, 1964). Furthermore, alder habitat was not specifically searched out during the field work, and it may be more prevalent in local areas than is realized.

The grass pollen percentage is notably higher in Moose Bones Bog than in any other. This is explained by the presence here of the *Calamagrostis neglecta*, *Deschampsia caespitosa*, and *Poa palustris* zones. At the other bogs there are no grass zones of this type, and grasses are ordinarily only scattered in the surrounding upland vegetation. Hansen (1953) notes the scarcity of grass pollen in bogs along the Alaska Highway.

Only two Caryophyllaceae grains were counted, in spite of the abundance of *Stellaria* sp. in the *Calamagrostis neglecta* zone.

Cyperaceae pollen is abundant in the Moose Bones Bog sample, a reflection of the *Carex* sp. (cf. *aquatilis*) zone. Similar relationships are seen elsewhere, except at Mile 47 and Wilson Creek Bogs where, although there are sedge-moss zones, these are less extensive, and *Carex* spp. are relatively less important than mosses, *Juncus* spp., and *Luzula* spp.

Mile 16 Bog. Pine and spruce pollen percentages in the surface sample from this bog are similar to the regional averages, but fir and aspen grains were not found (Figure 28).

Spruce is uncommon in the vicinity of the bog, with pine nearly the exclusive arboreal species. However, spruce pollen is about 16 percent, and pine pollen, at 60 percent, is not as prevalent as might be expected from basal area data. Alder and birch pollen are as important here as in any of the surface samples (Figure 26), even though neither of these were seen in the bog nor on the sandy slopes around the bog.

In view of the fact that Mile 16 Bog is small in area and was, before the 1958 fire, nearly surrounded by pine forest, it could be expected that the sample consist of almost no grains besides pine, except for those produced by plants in the bog. This view is based on a model of pollen dispersal presented by Tauber (1967). Because pine pollen is not exclusive here, it is assumed that the material of the surface sample, a clump of mostly living *Drepanocladus aduncus* moss, accumulated subsequent to the 1958 fire. The fire, of course, considerably reduced the pine pollen source, although a few living, mature pines, in flower, were seen near the bog when it was visited in 1968 (Fig. 14). The reduction of pine pollen would have caused the percentages of spruce, alder, and birch to be higher with no change in their actual numbers. Alder and birch, however, probably were deposited in greater quantities following the fire because of elimination of forest cover, possibly a barrier to pollen dispersal, between the bog and the Snafu Creek area somewhat over one-tenth of a mile to the south. The pollen and spore diagram for Mile 16 Bog (Figure 22) shows that between 12 and 42 cm, the position in the column of the second sample[5], the pine percentage is higher, and spruce, alder, and birch percentages are lower.

The finding of only three Salix grains reflects the scarcity of willows in the bog. The few Juniperus, grass, and Artemisia grains reflect the existence of a large area of herb-heath vegetation (Table 15) on slopes above the bog to the east. The two Epilobium grains, a unique occurrence among the surface samples, may be attributed to the small enclave of several living species at the northwest edge of the bog. It is also possible that these grains were produced by Epilobium angustifolium, the common fireweed, which is widespread in the burned pine forest around Mile 16 Bog, but less frequent in upland vegetation around other bogs. Cyperaceae pollen grains are most prevalent in the present sample, a reflection of the importance of Carex aquatilis ssp. aquatilis in the sedge zone.

The spruce situation at Mile 16 Bog tends to deny the hypothesis that the major pollen source is south of the bog.

In part "5" of the Mile 16 Bog column of Figure 28, no basal area percentage is shown for spruce within five miles south of the bog. Instead, the spruce that does occur in the vicinity of the bog is shown, by part "4", to be within two miles to the north. Table 18 and Figure 27 show a prevalence of spruce within several miles to the north of the bog and its near absence up to nine miles south.

Mile 47 Bog. Figure 28 shows that pine is considerably overrepresented here, that spruce is moderately underrepresented, and that aspen, as usual, is very underrepresented in the pollen rain. The highest aspen count was, however, obtained from this sample, and this may reflect the higher abundance of the species in the vicinity, particularly north of the bog. In the general vegetation survey (Table 18), several mature, old growth aspen stands were encountered at miles 42, 44, and 46.

Aspen is less important to the south than to the north, and the general situation for this species tends to deny the hypothesis that the major pollen source is in the area south of the bog. It could be argued that the five percent of aspen pollen was actually blown north to the bog from the trees south of it, and that pollen produced by the aspen stands to the north is usually blown further in that direction. It is to be noted, however, that at Mile 52 Bog five percent more aspen, in terms of basal area, occur within five miles to the south (Fig. 28), and only negligible aspen pollen was encountered in the surface sample there. Differential preservation between the two bogs could be invoked to explain this if it were not for the fact that the upper sediments and chemistry of each appear to be similar. In any case, the actual number of aspen pollen preserved is likely to be a small fraction of the amount originally deposited.

The spruce situation at Mile 47 Bog lends support to the hypothesis. This species is represented in the pollen assemblage to a greater degree than in the other bogs. Figure 27 shows the preponderance of spruce up to seven miles south of the bog and its low to intermediate importance up to ten miles north.

A single Larix grain was seen in the Mile 47 Bog surface sample, probably the result of long distance transport. The nearest occurrence of Larix to the Atlin area is to the east (Hultén, 1968), indicating that southerly winds during the flowering season are not particularly important in pollen dispersal. However, this is only one grain; the Tsuga grain encountered in the Wilson Creek Bog sample could well have blown up from the Taku River area to the south.

The eight percent of Salix in the Mile 47 Bog surface sample, the second highest among the surface samples, may reflect, in part, the bog's shrub zone. This zone is fairly well developed in some places, though not near the sample site. The chief influence, however, may be the tree willow forest adjacent to the bog on the northwest, as described on page 153.

The _Triglochin_-_Potamogeton_-type pollen is significant here, as well as in the Mile 52 Bog sample. It is probable that the pollen belongs mostly to _Triglochin maritimum_, since _Potamogeton_ was not observed in the Mile 47 Bog pond, and _Triglochin_, as a calciphile, is common in both of these bogs close to the sampling sites.

The low value for Cyperaceae pollen is not explainable at this time. Although the sampling site is some distance away from the sedge-moss zone, it lies adjacent to the bulrush (_Scirpus validus_) zone and the pollen rain would be expected to have been influenced by this vegetation. No evidence has been found in the literature that Cyperaceae pollen does not preserve well in calcareous environments. In the Mile 52 Bog surface sample, where chemical conditions were similar, Cyperaceae pollen is of relatively high occurrence (Fig. 26). Finally, no evidence is at hand to indicate that _Scirpus_ pollen is less resistant to destruction than that of _Carex_.

Mile 52 Bog. The spruce and pine pollen percentages here are similar to those of Mile 47 Bog and reflect the similarities in distribution of these two species around the two bogs (Fig. 27, 28). _Betula_ pollen reflects the common occurrence of _B. glandulosa_ in the bog. The several grains from grasses and herbaceous dicots can be related to vegetation in a local, nearly mesic microhabitat near the edge of the pond on the east side.

Jasper Creek Bog. On the basis of pollen percentages and tree survey data, pine and spruce are both somewhat more highly represented here than on the regional average (Fig. 28). This is due to the presence of a forest comprising large and mature pines around the eastern approximately one-half of the bog and a mixed coniferous forest of mature spruce, along with pine and alpine fir, around the western half. These mature forests surrounding the bog have no doubt contributed greater amounts of spruce and pine pollen to the bog than would be expected from basal area data alone. The latter were obtained at sites approximately one mile north and south of the bog (Fig. 27).

It is mentioned above (p. 161) that alpine fir is an important component of the mixed coniferous forest adjacent to the bog on the west. Despite this, only two fir pollen grains were encountered in the surface sample. An explanation is suggested on grounds on screening of fir pollen by a narrow zone consisting predominantly of spruce along the west edge of the bog, possibly coupled with prevailing winds blowing north-northwestward through the area in which the bog is located. It is noted above that spruce is more frequent nearest the bog and that fir increases in proportion to spruce and pine some distance away. These spruce are mature, 40 to 50 feet tall, and closely spaced. There is also a narrow shrub zone at the forest-bog transition. Even if winds were from the west and down the slope upon which this forest occurs, most of the pollen from within the forest would be blocked by this barrier. With regard to fir pollen lifted into the air above the forest, Tauber's (1967) model of pollen dispersal indicates that relatively few of the grains would be deposited at the sampling site in the bog, which lies only about 100 feet from the forest edge. It is likely, in any event, that most of this pollen is dispersed to the northwest by prevailing winds, rather than eastward and into the bog.

Willows are common around the bog, although the shrub zone is narrow, and more Salix pollen might be expected (Fig. 26). Alnus and Betula were not encountered in the bog nor in upland vegetation for several miles around. Lycopodium is common in the mixed coniferous forest, a probable source of the two microspores counted, and grasses are scattered in the pine forest.

Wilson Creek Bog. Although no quantitative vegetation observations were made within several miles of this bog, general observations discussed on page 161 ff. provide a basis for understanding the pollen rain here. Pine and spruce both are important in the forest, but pine seems to lead in dominance, and large trees were seen at the bog's edge in several places. This preponderance of mature pines, coupled with a high rate of pollen production and deposition near the forest's edge (Buell, 1947), seems to account for the high proportion of pine pollen relative to spruce.

Betula is scarcely represented in the pollen rain despite its presence at places in the bog and surrounding forest. Sedges also are underrepresented compared to their importance in the bog vegetation.

Summary. Taken together the surface sample pollen data (Figure 26) provide an indication of the relative importance of some of the dominant species in the regional upland vegetation on the basis of the relationships developed above. In addition, a few conclusions are possible, on the basis of surface spectra, regarding the nature of the local vegetation, both within and around the bogs.

Lodgepole pine generally appears over twice as important in the pollen rain as it actually is in the vegetation. Spruce should be interpreted, from its relative importance in the pollen spectra, to be approximately twice as prevalent in the regional vegetation. With regard to alpine fir, the presence of one or a few grains may be taken to indicate that the species is present, if not important, somewhere in the general vicinity of the bog. Single grains of Tsuga and Larix probably result from dispersal from distant regions. Juniperus grains in the three northern bogs reflect the presence in this part of the valley of the upland, dry sites bearing the herb-heath type of vegetation. Populus is so poorly represented that nothing can be said of its vegetational status except, perhaps, in extreme cases, as at Mile 47 Bog, where it reaches four percent of the pollen total.

Tree willows of the forests in general are probably not represented, although the relatively high Salix percentage in Mile 47 Bog may reflect the presence of a nearby stand of almost pure tree willow vegetation. Except for such occurrences as this, which would be difficult to distinguish in fossil spectra (unless particular species of willow pollen can be recognized), the importance of willow shrubs in non-aquatic parts of the bogs can be reasonably determined from the percentages of willow pollen. Alnus is considerably overrepresented, and where its pollen is encountered in any amount, the indication seems to be that the plant is important as a pioneering shrub in local, relatively fresh, stream deposits somewhere not more than a few miles from the bog. Betula is also overrepresented, but not as much as alder. In general, the presence of this pollen type may be taken to indicate that shrub birch is common in and near the bog.

Lycopodium microspores are found in bogs with mature, old growth spruce or mixed coniferous forest nearby. Grass is underrepresented, particularly in Moose Bones Bog where several species occur near the deposition site and in Mile 16 Bog where the herb-heath vegetation type occurs on the slopes above the bog on the east. Epilobium pollen appeared only in Mile 16 Bog where the species was prevalent near the deposition site. Artemisia, appearing sparingly in the surface samples of Moose Bones and Mile 16 Bogs, gives, along with Juniperus, an indication of the nearby herb-heath vegetation on dry slopes.

With regard to representation of ASB vegetation, Triglochin-Potamogeton-type pollen indicates a high amount of calcium carbonate in the sediments at the time of deposition.

A relatively high proportion of Cyperaceae pollen, i.e. 20 percent or more, seems to correlate with predominance of the large sedge Carex aquatilis ssp. aquatilis in a standing water environment, as at Moose Bones and Mile 16 Bogs. Lesser quantities do not correlate as well with the status of sedge species in the bog, although even a moderate percentage, i.e. 12 percent or so, may indicate an abundance of sedge in a wet habitat, as at Jasper Creek Bog. The importance of Scirpus validus in Mile 47 Bog was not, for some unknown reason, reflected in the surface sample.

Pediastrum was not identified to species, but since nothing is known of the ecology of this alga in the Atlin region anyway, no interpretation can be made now regarding its appearance in the palynological record.

There is some evidence that pollen assemblages are biased toward vegetation located within a few miles to the south of the bogs due to prevailing southerly winds during the flowering season. But there is just as much evidence to refute this, wherein particular pollen percentages compare better with the composition of the vegetation to the north. It can be concluded, therefore, that a considerable amount of atmospheric mixing of pollen occurs, probably because of turbulence over the generally irregular topography and because of the heterogeneity of the vegetation. This is an indication that the average pollen rain, as determined in the five key bogs, bears a characteristic relationship to the vegetation of the Atlin valley and that similar relationships existed in the past.

XIV. HOLOCENE ENVIRONMENTS AND CHRONOLOGY

Previous work

In his palynological investigation of a series of bogs along the Alaska Highway, including two in the head of the Atlin valley at Mileposts 859 and 872 (see map, Fig. 1), Hansen (1950, 1953) found "little or no evidence for climatic trends in the pollen profiles, except perhaps a general amelioration throughout the time represented." Hansen considered the major evidence for climatic amelioration to be the general increase in pine pollen upward in the sections. He concluded, on the basis of the early appearance of its pollen in most sections, that pine, along with spruce and other forest elements, persisted during the Wisconsinan Age in refugia in west-central Yukon Territory and in northeastern British Columbia and western Alberta and, following deglaciation, spread southeastward and northwestward, respectively, from each refugium to revegetate the area between.

Unfortunately, Hansen's work involved, for the most part, only the upper, more abundantly polleniferous organic sediments; his diagrams lack an absolute chronology from radiocarbon dating; and the Yukon and British Columbia diagrams contain profiles for only pine, spruce, fir, and grass.

Heusser (1967a) reviewed Hansen's Alaska Highway profiles and pointed out that spruce pollen actually reached the milepost 872 bog site some time before pine and that, on the other hand, pollen of the latter was much more abundant than spruce pollen in the earliest sediments of a relatively deep section farther to the southeast at milepost 647. On this basis, Heusser reasoned that the major source of spruce was the westcentral Yukon refugium and, furthermore, that pine migrated into the deglaciated area, not from the Yukon, but from the refugium in northeastern British Columbia and western Alberta.

With regard to late Quaternary environments in southeastern Alaska and north-coastal British Columbia, Heusser (1960, 1965, 1966, 1967b) assembled a large amount of floristic, ecological, and climatological information in conjunction with his analysis and interpretation of several muskeg and bog sections from this North Pacific maritime strip. His five-part geobotanical chronology, shown here as Figure 29, can be compared with the Atlin valley chronology presented as Figure 32.

Terasmae and Hughes (1966) developed two pollen and spore diagrams for sites in the Ogilvie Mountains about 420 miles north-northwest of Atlin. Their record dates back about 13,870 years at which time an herbaceous, sedge and grass tundra, comparable to modern vegetation at Barrow, Alaska, prevailed. A second pollen assemblage zone, beginning about 12,500 years B.P., represents continuing herbaceous tundra conditions and reflects, in addition, a significant admixture of birch (_Betula glandulosa_?) and

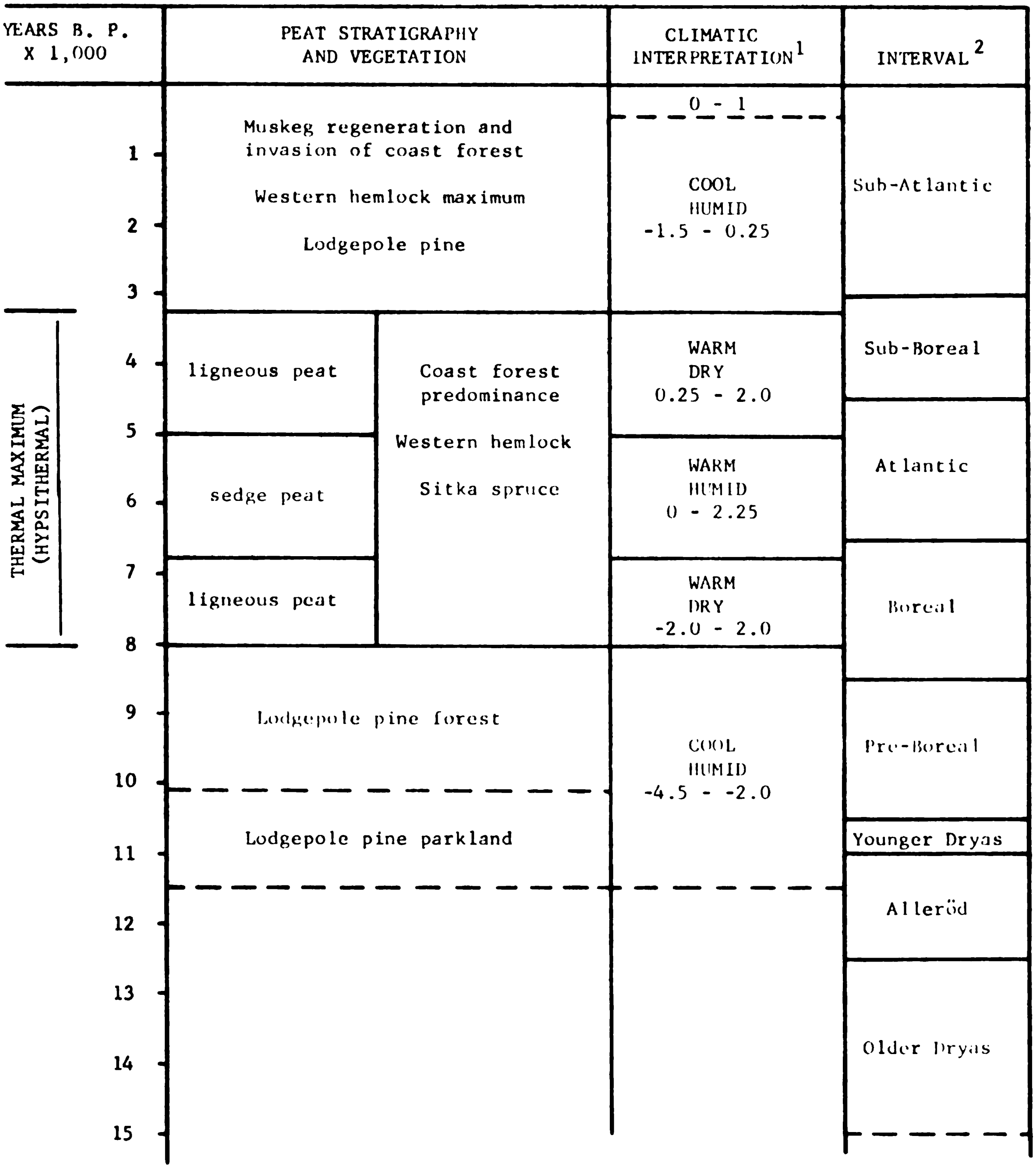


Figure 29. Geobotanical chronology for southeastern Alaska and north-coastal British Columbia (after Heusser, 1966, 1967b).

1 Including estimated range of temperature departures from present July means in °C.

2 Applicable to North Pacific North America in general.

lesser amounts of willow and alder in the regional vegetation. A third zone begins about 9,000 years B.P. with major rises in spruce and alder percentages. Although these authors evidently feel that evidence is insufficient for a climatic interpretation other than the statement that "the magnitude of the postglacial climatic changes appears to have been smaller than in the more southerly regions," the sequence of vegetation described seems to indicate a general amelioration of climate during the Holocene Epoch.

Pine pollen is not significant in the Ogilvie Mountains diagrams, and Terasmae and Hughes (1966) provide no evidence for the hypothesis that pine migrated into their area from the adjacent unglaciated part of Yukon Territory. Instead, pine seems to have arrived in relatively recent times from more distant sources. Evidence is provided, on the other hand, for the west-central Yukon refugium's having been the source of spruce, birch, alder, and willow.

Borns and Goldthwaite (1966) and Denton and Stuiver (1966) have worked out the major features of a glacio-climatological chronology covering the past 12,500 years for the Kaskawulsh Glacier region of the St. Elias Mountains in southwestern Yukon Territory on the basis of glacial geologic and geobotanical studies. About 12,500 years B.P. the glaciers of this region commenced to retreat from their maximum "classical" Wisconsinan (Kluane Glaciation) positions and continued receding until about 9,000 years B.P. when their termini reached positions a considerable distance upvalley. The glaciers remained in a retracted state during the ensuing Hypsithermal (Thermal Maximum) interval. Palynological evidence indicates that a climate wetter than today's prevailed during at least the latter portion of Hypsithermal time. A temperature decrease, apparently accompanied by a decrease in humidity, initiated a Neoglacial advance about 2,700 years B.P. Terminus positions during the Neoglacial were all downvalley from any since the end of the Wisconsinan with the greatest post-Wisconsinan advance culminating about 300 years ago. These glaciers began to recede to their present positions a short distance upvalley from their maximum Neoglacial stands 100 to 150 years ago. Denton and Stuiver (1966) show, through correlations in other areas, that Neoglacial climatic changes were essentially synchronous, at least in alpine regions, in the Northern Hemisphere.

A brief review of Quaternary paleoecological problems in the Yukon Territory and adjacent regions was published by Terasmae (1967). He pointed out that, whereas postglacial climatic changes in this area may well have been comparable to those in temperate latitudes in magnitude and time, they may be more difficult to detect by palynological means because of greater ecological amplitudes of the arctic or subarctic species involved.

Rampton (1969) studied the Quaternary glaciological, vegetational, and climatic history of the Snag-Klutlan area about 275 miles northwest of Atlin. His geobotanical chronology, beginning approximately 40,000 years B.P., is of particular significance to the present study. On page 186 he writes:

> The oldest sediments . . . represent a cold climate, with the landscape covered by fell field. . . . A short time before 37,700 B.P., the climate ameliorated and shrub tundra, dominated by shrub birch, invaded the area. Shrub tundra then dominated until 31,500 B.P. Following 31,500 B.P., the climate again cooled and the landscape was covered by sedge-moss tundra until shortly before 10,000 B.P. At 13,500 B.P., a slight change in the climatic or limnologic conditions occurred, and an aquatic vegetation developed. . . ; sedges also increased in importance relative to grasses. Shortly before 10,000 B.P. the climate ameliorated and the landscape was reinvaded by shrub tundra. Further warming allowed a spruce woodland to cover the landscape by 8,000 B.P. Since 6,000 B.P., the vegetation and climate has been similar to those prevailing today. Precipitation has been generally higher during warm intervals than during cold intervals; it also seems to have increased during the last 600 years.
>
> Logs from above the present tree line indicate that tree line and summer temperatures have been higher than present at least three times during the last 6000 years. A tree ring chronology from trees near tree line indicate(s) that summer temperatures have been generally cooler during the last 250 years than at present.

With regard to mean July temperatures, Rampton (1969) concluded that they were approximately 12° F lower between 13,500 and 10,000 years B.P., and approximately 8° F lower between 10,000 and 8,000 years B.P. than the present level of 57° at Snag. (The mean July temperature at Atlin for the 1906-1946 record period was 54° F.) Furthermore, Rampton (1969, p. iv) states:

> Logs from above the present tree line imply that summer temperatures fluctuated .4° - 2° F above the present values between 600 B.P. and

> 1220 B.P. Neoglacial ice advances suggest that the climate has been periodically more severe than present since 3250 B.P., and that the 500 years preceding 1940 was the coolest part of the last 6000 years. Tree-ring studies indicate that the last 200 years preceding 1940 were up to 2° F cooler than present.

Local interpretations

In Chapter IX the extant vegetation in and around Moose Bones, Mile 16, Mile 47, Mile 52, Jasper Creek, and Wilson Creek Bogs was described and discussed. Palynological stratigraphy and other sedimentological aspects of sections from all but Mile 52 Bog were covered in Chapter XI. Here, diagrams of these sections were described in terms of three major zones, characterized, in turn, by pollen assemblages in which shrubs, spruce, and pine were dominant. In Chapter XII radiocarbon dating and the establishment of a basis for an absolute Holocene chronology was discussed. Chapter XIII dealt with comparisons of modern pollen spectra and vegetation composition and set forth some guidelines for interpreting fossil pollen and spore assemblages.

In this chapter, interpretations will be made of the palynological record from each bog in turn, based on the background provided in these earlier chapters, in conjunction with autecological information from the literature. The possible nature of the postglacial environment in which each bog developed will be discussed. At several points it will be necessary to provide further discussion on the extrapolation and correlation of sections on the basis of a few radiocarbon dates, and additional autecological and synecological information, particularly with respect to the climatic indicator value of major vegetation types, will be brought forth. Where appropriate, aspects of phytogeography, glacial geology, and climatic change will be explored in some detail. Following this, an interpretation of regional vegetation and climatic conditions during Holocene time will be developed on the basis of a composite palynological record from the Atlin valley bogs.

Moose Bones Bog

The Moose Bones Bog section begins in the upper part of the spruce pollen assemblage zone (Fig. 21). The spruce/pine zone boundary in this section is set at the 75 cm level (not marked in Figure 21). A tentative date of 3,900 years B.P. for this level is suggested on the basis of correlation with the spruce/pine zone boundary in the Mile 16 Bog section where such a date is obtained by extrapolation from a radiocarbon dated level a short distance above. By extrapolation downward in the Moose Bones Bog section, a tentative age of 5,200 years B.P. is obtained for the bottommost sediments at 100 cm.

It is believed that by 5,200 years B.P. the Moose Bones Bog area had been free of glacial ice for at least 5,000 years (see below), that physiographic conditions had become stabilized, and that vegetation had been adjusted to the prevailing climate and various edaphic situations for a long time. The high percentage value of spruce and low value for lodgepole pine at the bottom of the section may reflect the occurrence on nearly all upland sites of a closed spruce forest comprising stands of both the feather moss and shrub-herb faciations of the white spruce association. Pine is not believed to have immigrated to the area by this time, and pine pollen percentage values are low enough to be ascribed to long distance transport.

The rapid rise of pine pollen percentages at about the 50 cm level, approximately 2,600 years B.P., is attributed to the appearance of at least a few pine trees on certain sites in the vicinity of the bog. It was shown earlier that pine is considerably overrepresented in pollen assemblages in the Atlin valley, and other investigators have also noted the high pollen productivity of pines and the tendency for wide pollen dissemination (e.g. Buell, 1947; Faegri and Iversen, 1964; Terasmae, 1967). In view of this, pine need not have become an important element in the vegetation at the time of the beginning of the increase noted here as long as there were a few trees favorably situated with respect to winds during flowering season and the location of the deposition site. Spruce may have remained nearly as abundant as before, at least during the period of initial pine pollen rise, with its relative pollen percentages becoming reduced by increasing amounts of pine pollen.

Heusser (1967a) has shown, on the basis of Hansen's (1953) work, that pine probably migrated into northwestern British Columbia and southern Yukon Territory from an unglaciated corridor in northeastern British Columbia and western Alberta, rather than from the west-central Yukon refugium. The more recent work of others (Terasmae and Hughes, 1966; Rampton, 1969) has demonstrated the improbability of pine's having persisted in the Yukon area during the Wisconsinan Age. With this being the case, pine would not be expected to have appeared in the Atlin valley until relatively recently, after migrating westward across the northern Rocky and Cassiar Mountains, a distance considerably greater than the distance between the Yukon refugium and the Atlin valley.

An alternate possibility is that pine migrated into the Atlin valley from the southwest. Heusser (1960, 1965) shows that lodgepole pine was an early pioneer invader of deglaciated terrain in southeastern Alaska, immigrating from nearby refugia along the southeastern Alaska/northwestern British Columbia coast and islands. If it had migrated across the Coast Mountains via the various trans-range river valleys, including that of the Taku River, by some time early in the Holocene, it might have moved thence northward through the interior valleys.

Critchfield (1957) shows that both a coastal subspecies (<u>Pinus contorta</u> ssp. <u>contorta</u>) and an interior subspecies (<u>P. contorta</u> ssp. <u>latifolia</u>) of lodgepole pine are distinguishable. If the present Atlin valley pine population is derived from one or more coastal refugium populations, it should be recognizable as the former subspecies. Although no detailed study has been made, it appears from the few collections examined to date that only the interior subspecies occurs in the Atlin valley.

An additional consideration is that pine persisted in unglaciated parts of British Columbia and Alberta lying to the south or southeast of the Atlin valley during the Wisconsinan Age. However, in view of the fact that most of the Rocky Mountain, Interior Plateau and Valley, and Coast Mountain portions of British Columbia were covered by ice during this time, it is unlikely that a suitable refugium existed anywhere north of the southern glacial limit in Washington, Idaho, and Montana. Two important exceptions are, of course, between the Cordilleran and Keewatin ice sheets in northeastern British Columbia and western Alberta and the extensive unglaciated area northwest of the Atlin valley (Johnston, 1926; Kerr, 1934; Armstrong and Tipper, 1948). In this regard, the greater proximity of the northeastern British Columbia-western Alberta refugium to the Atlin valley, in conjunction with the evidence of Hansen (1953) and Heusser (1967a), precludes the need to hypothesize the Holocene origin of Atlin valley pines as south of the glacial limit.

In view of the relatively recent date that pine appeared in the Atlin valley (see Figs. 21-25 plus further discussion below) and the fact that the trees here apparently belong to the interior subspecies, in conjunction with glacial geological evidence, it is concluded that the present pine population derives from one which occupied the northeastern British Columbia-western Alberta refugium during the Wisconsinan Age.

After reaching the vicinity of Moose Bones Bog, the continued expansion of lodgepole pine, as reflected in its pollen profile in the pine zone, to its present level in the vegetation may have been promoted by increasing dryness of the climate. The influence need not have been a direct one. Instead, with summers of lower rainfall, forest fires may have been more frequent, allowing pine, a fire species, to spread to additional sites throughout the area (Hansen, 1950, 1953; Lutz, 1956).

The origin, at higher elevations to the south, of the infrequent alpine fir grains in the Moose Bones Bog surface sample is discussed on page 204. A similar origin is likely for the few grains occurring in samples from other levels in the section. Therefore, the alpine fir profile in Moose Bones Bog is not particularly meaningful with respect to local environmental conditions, although fir profiles in other sections discussed below appear to have indicator value.

Alder pollen (*Alnus crispa* (Ait.) Pursh subspp. and *A. incana* (L.) Moench) occurs at levels of over ten percent through the lower approximately three-fourths of the profile, undergoing a moderate decline in the upper two-thirds of the pine zone. In the other Atlin valley sections, initial abundances of alder pollen could have been produced by early successional vegetation on the recently deglaciated valley floor. By the time the Moose Bones Bog section began, primary succession would already have led to a generally stable vegetation. Changes in the status of alder at this time, therefore, would have been more directly under the influence of changing climate. An alder increase may be brought about both by moderating temperatures and increasing moisture (Livingston, 1955; Colinvaux, 1964). In view of its apparent early postglacial abundances in the Atlin valley (see below), when temperatures were probably lower than at other times during the Holocene, it is concluded that the temperature factor has remained favorable for alder and that the plant is primarily a moisture indicator here. Firsthand evidence for this is presented in Table 5 and on page 82 where it is explained that minor amounts of alder occur at present in moist locations within stands of the feather moss faciation of the white spruce association. Also, alder was found to be relatively abundant in a few gravelly stream bank situations at several places in the Atlin valley. Some sites near timberline, where precipitation would be higher than at lower elevations, were found to contain significant quantities of alder. It is important both in forests and on proglacial terrain near the Llewellyn Glacier at the south end of the valley where, under the influence of incursions of maritime air more or less directly across the Coast Mountains, conditions are more humid. The moist habitat affinities of alder have been noted by other workers, including Lutz (1956), Mckay and Terasmae (1963), and LaRoi (1967). In view of these considerations, the decline in alder pollen percentages in the upper pine zone (above the 50 cm level) of the Moose Bones Bog section is believed to be an indication of increasing dryness during the past approximately 2,600 years. This would corroborate the similar conclusion reached on the basis of the spruce and pine profiles, and it would, furthermore, be in accordance with findings of Borns and Goldthwaite (1966) in the Kaskawulsh Glacier area in the eastern St. Elias Mountains.

It is recognized that the usefulness of alder as a climatic indicator is limited by the fact that the genus is a prolific producer of airborne pollen and tends to be overrepresented in most assemblages. Local ecological conditions favoring the occurrence of a few alder bushes can have a major influence on the pollen rain (Terasmae, 1958). Because of this possibility in the Moose Bones Bog area, the relatively modest decline in alder pollen percentages in the upper pine zone might be meaningless from a climatic standpoint. There are two considerations, however, which lend support to the conclusion reached above. First, the alder pollen profile is relatively smooth throughout, indicating a gradual and long-term change in the status of alder in the vegetation. This change could have been related to a decrease in white spruce forest, with which alder tends to be associated, under the influence of more frequent fires and a concomitant expansion of lodgepole pine (Lutz, 1956; LaRoi, 1967; Rampton, 1969). If the pollen production represented were the result of local occurrence of alder, say on the gravelly bank of a stream somewhere in the area, more erratic pollen productivity through time would be expected because of the temporary nature of such habitats and the periodic decimation of alder stands with shifting stream channels or replacement of the stands by vegetation of later successional stages. Secondly, the alder profile in Moose Bones Bog is similar to those of the other four bogs where similar interpretations appear reasonable.

The rising birch pollen percentages, from the bottom of the section to the level of the spruce/pine zone boundary, may reflect higher humidity during late spruce zone time than during the subsequent pine zone time. They may also indicate the expansion outward and into the surrounding forest of the relatively moist shrub zone. This is based on the fact that the vegetation of the shrub zone today consists primarily of *Betula glandulosa* and some willow and may have consisted of similar vegetation in the past. The drop in the birch profile in the lower pine zone might reflect the closing in again of the forest around the bog under a dryer climate. The decrease in willow percentages just prior to the time of the birch (and alder) peak might have resulted from the fact that willows, as plants ordinarily poorly represented in the pollen rain because of low pollen productivity and/or transportability, were forced farther away from the deposition site with the increase in diameter of the herbaceous zones inside the shrub zone. Such a zonal displacement would not have affected the representation of birch since it is ordinarily well represented in the pollen rain at sites located some distance from the source. In this connection it is noted that willow is abundant in a large stand of depression shrub vegetation beginning about 100 m to the south and southeast of Moose Bones Bog and extending to the head of Little Atlin Lake (p. 141-142). Although this is in the direction of prevailing spring and summer winds (Fig. 6), willow pollen grains are not numerous in the modern spectrum from the bog (Fig. 26).

At present the four herbaceous zones surrounding the pond and sample site in Moose Bones Bog are dominated by sedges and grasses (Table 21). If these zones were occupied by similar vegetation in the past, and if they did increase in size under the influence of a more humid climate, more sedge and grass pollen should have been deposited. Contemporaneous peaks in both grass and sedge profiles occur in the lower half of the diagram. Although these peaks do not represent major fluctuations and are based on only two samples, separated by a sample containing relatively lower proportions of grass and sedge pollen, they do provide some support for the interpretation made on the basis of the willow and birch profiles.

Additional, albeit minimal support for the hypothesis of a change from relatively humid to dryer conditions in pine zone times comes from the occurrence in the lower part of the diagram of several grains of miscellaneous aquatic or semi-aquatic types and, in the upper portion, of pollen of *Juniperus* and Compositae, plants ordinarily occupying dry sites (see below).

In terms of the conifer profiles, the Moose Bones Bog diagram is very similar to those of Hansen (1953) for bogs at mileposts 858 and 872 and at other points on the Alaska Highway. By correlation with these diagrams, which generally begin just prior to the major changes in shape of the spruce and pine profiles, it is seen that Hansen's record also begins approximately 5,200 years B.P. Hansen's (1953, p. 539) suggestion, then, of "perhaps a general amelioration (of climate) throughout the time represented" refers to only the latter approximately one-half of "postglacial" time. This interpretation may not conflict with the more detailed Holocene chronology developed in this dissertation provided increasing dryness is considered an aspect of "amelioration." On the other hand, the hypothesis presented here of a gradual temperature decrease during the past two to three thousand years does not agree with Hansen's interpretation. It is recognized, however, that the three profiles he considered have, by themselves, little, if any temperature indicator value in the Atlin region for this interval (Terasmae, 1967).

Mile 16 Bog

The Mile 16 Bog section begins at a depth of 8.25 m, in the lower part of the spruce pollen assemblage zone (Fig. 22). Using a sediment accumulation rate of 0.1171 cm/yr, calculated for the portion of the section between the 1.50 and 6.35 m levels which are radiocarbon dated at 2,560 ± 140 and 6,700 ± 300 years B.P., respectively, it is possible to extrapolate downward and obtain a tentative age of 8,320 years B.P. for the bottom of the section. Since the lower approximately 0.75 m contains a relatively large amount of sand and silt, which probably accumulated faster than the organic material, it seems appropriate to reduce the age estimate somewhat. An age of 8,000 years B.P. for the beginning of this section is suggested.

In view of the fact that spruce pollen was already being produced in moderate quantities at the time the first Mile 16 Bog section sediments were deposited, it is concluded that spruce trees had become established in the vicinity of the bog by at least 8,000 years B.P. Pine, on the other hand, had not yet reached the area, and the few pine grains which occur at most levels in the lower two-thirds of the spruce zone can be readily accounted for by long distance transport.

In the lower approximately 1 m of the section, where spruce undergoes an increase, alder and birch pollen percentages are at relatively high levels, and willow pollen is also present in significant quantities. There is, in addition, a moderate amount of sedge pollen. Earlier it was explained that Mile 16 Bog has developed in a glacial kettle located in a kame terrace. In early developmental stages, before the formation of a bog mat, there was probably little, if any semi-aquatic or more mesic terrain between the pond, presumably larger than at present, and the surrounding, dry sandy slopes of the kettle. This means that shrub vegetation would have been scarce or non-existant in the bog proper because of the lack of suitable peripheral habitat zones. Pollen from shrubs would have to have originated either in other bogs having the required edaphic conditions or in upland areas. Field observations show that few other bogs have existed in the vicinity of Mile 16 Bog, and upland sites are believed, therefore, to have been the major source of these pollen types. Sedge is to be included here, as this plant could not have been very abundant in the bog in the absence of a bog mat or other semi-aquatic terrain surrounding the kettle pond.

Alder pollen could have blown into the bog from many sites along streams on the main valley floor a kilometer or so away or from sites on the banks of nearby Snafu Creek. Willow, birch, and sedge pollen is believed to have been produced, along with spruce pollen, by a spruce woodland type of vegetation occupying the majority of upland sites at this time. Such a vegetation type may have been transitional between an earlier shrub tundra, in which willow, birch, and sedge were prominent components, and a subsequent white spruce forest. At the time of the beginning of the Mile 16 Bog section, white spruce is believed to have only recently migrated into the area, under the influence of a warming postglacial climate, from the west-central Yukon refugium to the northwest. Spruce trees may have existed as scattered groves and clumps as they do at timberline in the Atlin valley today (Fig. 30). Mean July temperatures were probably a few degrees lower than at present (see further climatic discussion below).

By the time of deposition of sediments at the 7 m level spruce forest had become established in the vicinity of tne bog and the spruce woodland and shrub tundra zones had been displaced to higher elevations. This is indicated, in part, by a decline in birch pollen values. That this upland, sedge-bearing vegetation type existed at an increasing distance from the bog is indicated by a drop in sedge pollen percentages just below the 6.5 m level. Soon afterwards, the initial development of a bog mat could have given rise to autochthonous sedge pollen which then increased to relatively high levels within the time represented by the accumulation of another meter of sediments. The willow pollen profile is seen to behave in a similar manner, but with the rebound in percentages occurring higher than that for sedge, reflecting the time necessary for centripetal growth of the bog mat and the appearance, in the peripheral portion of the bog, of the less wet conditions favorable to willow growth.

The peak in willow pollen at the 5.5 m level cannot be taken seriously since it is based on only one sample. It could, for example, represent the chance existence, for a relatively short time period, of a clump of willows on a drier swell close to the sampling site.

The spruce forest surrounding Mile 16 Bog, having thoroughly replaced the earlier spruce woodland by approximately 7,000 years B.P., was either of the shrub-herb faciation type, or it may have been, in the absence of pine, which might otherwise have invaded, an open and dry spruce woodland type which is rare in the Atlin region at present. The latter suggestion is based on the occurrence throughout the area of the bog of a very well-drained sandy and gravelly glacial drift, a substratum which is not well suited to white spruce growth. Further evidence is seen in the occurrence of a wide variety of shrub and herb pollen types.

The *Juniperus* profile reaches fairly high values, up to about 16 percent, in the spruce zone. Such values are not particularly reliable here because most of the grains counted as juniper were corroded or badly distorted and difficult to identify. Juniper pollen does not preserve well in moss polsters (Faegri and Iversen, 1964) and may have undergone a certain amount of destruction in Mile 16 Bog sediments. Nevertheless, there seems to have been quite a bit more juniper around Mile 16 Bog in spruce zone times than at present. Field observations and the general vegetation survey show that juniper, including *Juniperus communis* L. and particularly *J. horizontalis* Moench is an important element in the herb-heath association (Table 15). This vegetation type is, in general, characteristic of the driest and most well-drained sites, and it occurs at present near Mile 16 Bog in stand 16E. Faegri and Iversen (1964) state that juniper is a plant of arid woodland and grassland habitats. Terasmae and Mott (1965) found it on open, rocky and gravelly slopes, but also in some bogs. Ritchie (1969) found juniper to be a plant of upland, xeric sites.

The evidence suggests that juniper occurred in greater abundance in the vicinity of Mile 16 Bog during spruce zone times in response to a drier climate, an interpretation which conflicts with the interpretation of the Moose Bones Bog record. Alternatively, the climate may have been more moist but may also have been warmer, in which case potential evapo-transpiration would have been higher (Sanderson, 1948). A higher potential evapo-transpiration may have offset any moisture gain from higher precipitation, creating, in conjunction with the highly pervious substrate of the Mile 16 Bog area, a greater water need, with respect to plant growth, during the summer months. Plants adapted to xeric habitats, therefore, would have been favored. This interpretation, i.e. higher temperatures and precipitation than during subsequent pine zone times, is accepted here. Additional evidence is presented below.

Shepherdia canadensis pollen occurs throughout the section. This species, although adapted to a wide range of habitats (LaRoi, 1967), is particularly abundant on recent mineral soils or glacial deposits (Ritchie, 1967) and well-drained alluvial soils (Mckay and Terasmae, 1963). In the general vegetation survey, Shepherdia reached its highest importance values in the lodgepole pine, aspen, and mixed-wood forest associations (Tables 6, 11, and 12), stands of which ordinarily occupy well-drained sites. The species is entomophilous (McAndrews, 1966) and grossly underrepresented in fossil pollen spectra (Ritchie and Lichti-Federovich, 1968). The occurrence, therefore, of even a few grains in most samples would indicate the continuing abundance of _Shepherdia_ and, therefore, of relatively dry and open sites.

There are several additional indications in the pollen record of dry site vegetation in the vicinity of Mile 16 Bog during spruce zone time. Ericales pollen, possibly of _Arctostaphylos uva-ursi_, an inhabitant of dry, sandy places (Hultén, 1968), occurs in several samples. This species was found to be one of the few widespread members of the Ericales in the Atlin valley, reaching high importance values in stands of the lodgepole pine brûlé and the aspen and herb-heath associations (Tables 8, 11, and 15) as well as in other stands of open vegetation on dry sites.

Gramineae pollen is consistent throughout in low quantities, and Saxifragaceae pollen occurs at various levels. The latter can reasonably be attributed to _Saxifragra tricuspidata_, the only saxifrage which is abundant at the present time in the Atlin region, always on dry, rocky or sandy sites. Rosaceae, _Artemisia_, and other Compositae pollen, all produced by plants of habitat affinities similar to those mentioned above, is frequently encountered in Mile 16 Bog samples. In addition, the relative abundance of pollen produced by a wide variety of other sun-loving herbaceous dicots indicates the open nature of the forest surrounding the bog.

The possibility of recurring forest fires and destruction of the ground cover, followed by sheet wash of the relatively steep upper slopes of the kettle in which Mile 16 Bog is located, has been discussed. Three lines of palynological evidence are available to support this explanation. (1) The spruce pollen profile is quite erratic. Significant profile fluctuations are to be expected because of variability in pollen production related to the effects of short-term climatic changes and other factors affecting deposition and preservation of the pollen. However, the fluctuations here seem to be unusually large. It is suggested that they are the result of periodic decimation of the forest vegetation by fire. It is noted that dips in the spruce profile occur at levels where inorganic sediments are most abundant (Fig. 22). In view of these considerations, the interpretation of higher precipitation levels during spruce zone times gains some support in that the sheet wash proposed here would have been more effective at higher precipitation levels, possibly higher than at present. The latter possibility is indicated by the absence of inorganic admixtures in the upper approximately 1.75 m of the section, even after the establishment of pine forest, presumably under the influence of continuing periodic forest fires.

(2) There are a number of occurrences of *Lycopodium* spores in the spruce zone. In the general vegetation survey, *Lycopodium* was found to be important in stands of the shrub-herb faciation of the white spruce association at mile S13 where there was evidence of fire perhaps 50 years ago. Elsewhere, *Lycopodium* is rare in the Atlin valley except for

occurrences in stand 30E of the feather moss faciation of the white spruce association, and the mixed coniferous forest west of Jasper Creek Bog (Fig. 18). In this connection, A. T. Cross (personal oral communication 1970) states that *Lycopodium* may be characteristic of old burns in the middle Appalachians. In addition to these considerations of possible old burn affinities of *Lycopodium*, it is suggested that there may have been a greater tendency for such relationships in the past when climatic conditions, namely higher temperatures and precipitation, were different from the present.

(3) Pollen of *Epilobium*, a genus containing typical fire species, was encountered in a number of samples. Since species of *Epilobium* produce a bulky, non-anemophilous pollen grain, plants would have to have been frequently abundant close to the bog to have become so well represented in the pollen record. It should be mentioned, however, that at present a small enclave of several species of *Epilobium* occurs adjacent to the bog. If this existed in the past it could have been the major pollen source.

Toward the upper boundary of the spruce pollen assemblage zone alpine fir pollen becomes slightly more frequent. A wetter climate at this time may have caused a spread of fir onto additional sites in the Atlin valley, including some closer to Mile 16 Bog. As was discussed earlier, fir appears to be limited, in part, in its present occurrence in the valley, as is alder, by low moisture conditions, being found primarily in areas believed to receive higher amounts of precipitation. It is not likely that fir became established on the calcareous, well-drained kame terrace deposits in the immediate vicinity of Mile 16 Bog, but higher terrain, lacking a mantle of glacial material, located a short distance to the east and northeast from the bog, may have been favorable for fir growth under the more humid conditions of spruce zone times.

Although evidence for dry site vegetation around Mile 16 Bog during spruce zone time is abundant, the palynological record shows that moisture was not a limiting factor for aquatic and semi-aquatic vegetation in the bog. Since Mile 16 Bog existed in a closed basin into which there was no stream drainage, precipitation would have to have remained at significant levels. Particularly, the profiles for the aquatics, including _Isoëtes_-type, _Sparganium_, Nymphaeaceae, _Hippuris_, and _Pediastrum_ are indicative (Fig. 22).

The woody chunks shown in the sediment type column are probably pieces of water lily rhizome and not ligneous material as was found in the recurrence horizons of southeastern Alaska muskegs by Heusser (1960, 1965), interpreted there as indicative of forest invasion of the muskeg in response to a drier climate.

In the pine pollen assemblage zone of the Mile 16 Bog section, the increase in pine percentages is particularly pronounced, with spruce percentages correspondingly lower than in any other section at most levels. This relationship may indicate a return to drier climatic conditions for the reasons discussed in connection with the Moose Bones Bog section. Other palynological evidence of increased dryness during this time is lacking, however, probably because of the condition of low moisture availability which seems to have prevailed throughout the preceding spruce zone time interval. Under these circumstances, the vegetation, for the most part, would not have been as sensitive to a general change to a drier climate as at other sites.

Figure 22 shows that pine pollen first appears in significant quantities (i.e. approximately 15 percent) around 4,200 years B.P. Equivalent percentages are not registered in Moose Bones Bog until around 2,600 years B.P., and pine does not seem to have become an important element of the vegetation around Mile 47 Bog until only about 2,000 years B.P. (Fig. 23). In Jasper Creek Bog (Fig. 24), pine pollen percentages reach significant levels around 2,300 years B.P. In Wilson Creek Bog (Fig. 25), an initial peak of 12 percent is seen at approximately the 6,700 year level, but the first significant percentages in the sustained pine pollen profile appear around 3,800 years B.P.

On the average, these dates are believed to reflect the time required for pine to migrate into the Atlin valley from the east following deglaciation of the general northern British Columbia and southern Yukon Territory region. Although deglaciation has not been precisely dated throughout most of this region, it is probably safe to say that, except for higher elevation areas, it was complete by 8,000 years

B.P. Even with this conservative estimate, it can be seen that the westward migration of pine, from the refugium in northeastern British Columbia, across a distance of perhaps 450 miles, required on the order of 4,000 years.

The variability of the dates of first significant pine pollen appearances from bog to bog may provide a more detailed insight into the nature of the migration pattern. As is noted, the earliest appearances are in the Mile 16 and Wilson Creek Bog sections, and the more recent ones are at Mile 47 and Jasper Creek Bogs, lying between the former two (Fig. 1). Mile 16 is in alignment with a broad, relatively low area extending eastward into the northwest-southeast trending Teslin valley and lowlands. Wilson Creek Bog is situated in the valley of the O'Donnel and Pike Rivers which also extends, via the upper Nakina River valley, to the Teslin lowlands. Following establishment of pine in the Teslin area, westward movements of pine seeds may have occurred comparitively easily through these low elevation routes into the Atlin valley. Mile 47 Bog (also Mile 52 Bog), on the other hand, is blocked from such movements by the local mountain ranges lying directly east of the central portion of the Atlin valley (Fig. 1). Moose Bones Bog is somewhat separated also from the northern Teslin area by mountains lying immediately to the east.

After reaching the Mile 16 Bog area, the advancing pine front may have split, with migrations both to the north, to the Moose Bones Bog area, and south to Mile 47 Bog. The amount of time for the spread of pine into these latter two areas from Mile 16 Bog, approximately 1,600 and 2,200 years, respectively, is probably greater than would be required under ideal circumstances. Although no conclusive explanation for these slow rates is available at this time, site conditions and the presence of stable vegetation, in which it might have been difficult for a newcomer arboreal species to become established, may have been involved. In this connection the discussion of possible environmental conditions around Mile 16 Bog in spruce zone times is relevant. Here, with a dry, well-drained substrate and perhaps a relatively sparse spruce forest, pine may have become readily established as the first seeds reached the area. In addition, fire, a factor also promoting pine establishment, may have been more prevalent here.

The apparent delay in the establishment of pine around Jasper Creek Bog after its entering the Wilson Creek Bog area only a few miles to the east is not explainable at this time. Presumably site conditions were unfavorable, but this is not too plausible in view of the extensive sandy hillside lying immediately east of the bog whereupon lodgepole pine is dominant at present (Fig. 19).

Mile 47 Bog. The time scale for the lower approximately 135 cm of the Mile 47 Bog section is somewhat uncertain because the rate of deposition of the sedimentary material here is difficult to determine. This material, a viscous and sticky, fine-grained substance, was referred to above

(p. 188 ff.) as blue-gray glacial lake clay. Although no particle size analysis was made, the material is probably a fine-grained silt or "rock flour" of the type carried by glacial streams into proglacial lakes where it slowly settles. The silt originates from scouring of bedrock by the overriding ice mass with its bedload of rock debris (Flint, 1957) and may be carried directly to a lake for deposition. In other cases it may be incorporated in till deposits and removed and recycled later by meltwater and redeposited in lakes (Fulton, 1965).

The rate of glacial lake clay (silt) deposition would appear to depend on physiographic conditions around the deposition site, including proximity of the ice front, rate of melt, courses of meltwater stream channels, and the composition and distribution of glacial deposits. A study of existing glacial deposits can provide some knowledge of these factors. From reconnaisance observations it is known that Mile 47 Bog is surrounded by glacial drift, but the composition and extent of this material has not been determined.

Although there is not enough information at hand to estimate the rate of silt deposition in Mile 47 Bog, it may be reasonable to assume that at least a few hundred years, perhaps up to a thousand, were required for the approximately 135 cm to accumulate (Fig. 23). On this basis, and on the basis of the radiocarbon date of 8,600 ± 330 years B.P. at the base of the overlying marl section, it is concluded that the Mile 47 Bog record goes back at least 1,400 years farther than the 8,000-year Mile 16 Bog record, to about 9,400 or 9,500 years B.P.

Pollen and spore counts for samples deposited during the first 300 to 400 years, up to about the 4 m level, are so low that only tentative interpretations are possible. It appears, primarily on the basis of the willow, alder, Dryas, Artemisia, and Compositae profiles, that succession on proglacial terrain in the vicinity of the bog was well underway at this time, but little can be inferred regarding vegetation on the lower valley walls some distance away. Sites here would have been available to colonization by plants earlier because ice would have melted below their level before disappearing from the valley floor. Some evidence for an herbaceous tundra vegetation at these sites is provided by the occurrence of significant quantities of sedge pollen near the bottom of the section. It is possible that at least some of the relatively large amounts of Artemisia and Compositae pollen also originated in such a vegetation type.

Additional evidence for the existence of some form of tundra vegetation on the lower valley walls is provided by the Dryas peak at the bottom of the section. On Vancouver Island, Terasmae and Fyles (1959) found leaves, tentatively identified as Dryas drummondii, associated with pollen and spore assemblages in 12,000-year-old samples which indicated a climate substantially colder than at present, perhaps similar to climates in certain present-day arctic areas. The writer has observed extensive patches of Dryas sp. on outwash within several miles of the terminus of the Dusty Glacier in the eastern St. Elias Mountains. Although no meteorological records are available for this area, shrub tundra occupying the lower valley walls above this portion of the Dusty Glacier valley floor indicates that mean summer temperatures are lower than in the Atlin valley at present. On the valley walls above the Dusty Glacier, upvalley from the terminus, the vegetation grades into an herbaceous tundra, and a short distance downvalley from the terminus the shrub tundra grades into a spruce woodland type of vegetation on the valley walls.

Since Dryas is probably not anemophilous (J. Terasmae, personal oral communication 1969), it must have been fairly abundant in the area of Mile 47 Bog to be so well represented at the bottom of the section. It can be seen from the preceding evidence that such a Dryas abundance may have been related to climatic conditions associated today with an herbaceous or shrub tundra vegetation type. The Dryas occurrence indicated here might as well have been associated with a spruce woodland type of vegetation as in the Dusty Glacier area downvalley from the terminus,but the absence of spruce pollen from the samples in question precludes such an interpretation.

Although a more exact inference as to the vegetation on the valley walls in the vicinity of Mile 47 Bog around 9,400 years B.P. cannot be made because of the low total pollen counts in the lowest samples, it appears fairly certain that a shrub tundra had developed by about 9,000 years B.P. This is indicated primarily by the appearance of significant quantities of birch pollen and, to a lesser degree, by decreases in *Dryas*, *Artemisia*, Compositae, and Cyperaceae pollen. Such a vegetation change would indicate an amelioration of the climate, a situation to be expected during a period of deglaciation. As is discussed above, shrub tundra is also believed to have existed in the Mile 16 Bog area some time prior to the beginning of the record there at 8,000 years B.P. The fact that spruce had become established in the Mile 16 Bog area by this time, creating what is believed to have been a spruce woodland vegetation, a type which may be considered transitional between shrub tundra and spruce forest, also indicates ameliorating climatic conditions, particularly with respect to temperature.

The spruce pollen profile shows that spruce forests did not become established in the Mile 47 Bog area until about 7,200 years B.P. Spruce pollen deposited before this time, back to around 8,000 years B.P., was in low quantity and may have been delivered to the site by long distance transport. If the Mile 47 Bog record is a reliable indicator, it is probable that spruce was completely absent from the vicinity of the bog prior to about 8,400 years B.P. since no spruce grains were found in the samples deposited then. The lack of spruce pollen cannot be attributed to conditions unfavorable for deposition or preservation because counts of up to 300 other types were obtained.

In order to confirm the apparent absence of spruce from the Mile 47 Bog area of the Atlin valley prior to around 8,400 years B.P., samples estimated to be of comparable age from nearby Mile 52 Bog (see Chapter XII) were examined in a cursory way for spruce pollen content. A number of traverses were made of each slide and a subjective estimate made of the proportion of spruce grains. At the estimated 7,200 year level, spruce pollen was encountered frequently. Downward from here, however, the amount of spruce pollen relative to other types decreased noticeably until, in samples from approximately the 8,000 year level, spruce grains were only rarely encountered. In a sample at the 8,400 year level only two or three grains were seen in at least a dozen traverses of the slide, and at the 8,700 year level, no grains were encountered in at least 30 traverses of two slides.

The Mile 52 Bog record for spruce appears, therefore, to parallel the Mile 47 Bog record. The few spruce grains deposited in Mile 52 Bog between 8,400 and around 7,500 years B.P. can be accounted for by long distance transport, as in Mile 47 Bog. In both places spruce pollen may have come from farther north, from the advancing spruce woodland there, or it may have blown into the Mile 47-Mile 52 Bog area from the south. It will presently be shown that spruce forests had become established in the Jasper Creek-Wilson Creek Bog area by about 9,000 years B.P. During the flowering season, prevailing winds in the Atlin region are southerly and southeasterly (Fig. 6) and, if this was the case in early Holocene times too, there could be an important southern element in the record.

The early Mile 47 Bog record, coupled with that of Mile 16 Bog, provides evidence that mean July temperatures in the Atlin valley were less than 50° F prior to at least 8,000 years B.P. in the north and until about 7,500 years B.P. in the mid-latitude portion of the valley. This is based on the apparent nature of spruce migration into the vicinities of Mile 16, Mile 47, and Mile 52 Bogs. The northern limit of white spruce forests in Canada has been correlated with the 10° C (50° F) July isotherm by Griggs (1937), Halliday and Brown (1943), and others. The assumption is made that ecological requirements of white spruce were similar in the past and that its distribution was similarly limited by mean July temperatures of less than 50° F. Had the mean July temperature been higher than this, it is believed that white spruce would have migrated into the Atlin valley from the north-central Yukon refugium earlier and that its pollen would appear, therefore, lower in the Mile 47 and Mile 52 Bog sections. White spruce is considered an aggressive or opportunist species, capable of rapidly immigrating into recently deglaciated areas and colonizing all but the coarser grained of fresh mineral soils (Ritchie, 1964, 1967). Given these attributes, spruce migration into the northern part of the Atlin valley should have followed closely upon the receding ice front had climatic conditions been favorable. Even if it had not been able to invade proglacial terrain on the valley floor until several hundred years of plant succession had taken place, the adjacent lower valley walls would have been available for colonization at an earlier time. It is suggested that, had climate not been inhibiting, spruce would have been growing on the lower valley side slopes near the Mile 47 and Mile 52 Bog sites by the time sediments and pollen had begun to accumulate. The fact that no spruce pollen was found in the lower samples is an indication that spruce had not entered the area.

In the absence of spruce woodland or spruce forest, a shrub tundra appears to have developed on the exposed portions of the valley walls at lower elevations and perhaps also to some extent on the more physiographically stable parts of the valley floor in the north. Rampton (1969) cites evidence that shrub tundra in the Snag-Klutlan area existed when the mean July temperature was around 48° F, or 6° lower than at present in the Atlin village area (Table 1; Fig. 5). At present, a shrub tundra vegetation type dominated by _Betula glandulosa_, _Salix_ spp., and _Vaccinium_ spp. exists at higher elevations. In proceding upslope in many areas, timberline is encountered around 4,000 to 4,200 ft. Here a zone of shrub tundra begins and extends up the elevation gradient several hundred feet farther. In broad, subalpine valleys lying above approximately 4,200 feet, such as the upper Ruby Creek valley north of Surprise Lake (Fig. 1, 30), shrub tundra occurs over rather extensive areas. No meteorological data are available for shrub tundra areas in the Atlin region. It is certain, however, that summer temperatures are several degrees lower in such areas than at lower elevations because of the summer lapse rate. There are no data for the Atlin or other weather stations in the region which would make possible the computation of this factor, but a summer lapse rate of 3.8° F/1,000 ft was determined by Rampton (1969) for the Snag-Klutlan area where climatic conditions are generally similar. Applying this rate to the Atlin region, it can be seen that summer temperatures at the 4,200 foot level would be at least 7° F lower than at the elevation of Atlin Lake, about 2,200 ft. On this basis it is concluded that early Holocene summer temperatures just above the present elevation of Atlin Lake, where a shrub tundra appears to have existed on the lower valley walls, may have averaged around 47 or 48° F.

If, as is suggested above, an herbaceous tundra vegetation type persisted in the vicinity of Mile 47 Bog prior to about 9,000 years B.P., summer temperatures may have been as much as 10° F lower than at present, or around 44° F. Rampton (1969) shows this vegetation type (his "sedge-moss tundra") to be associated with such temperatures. In addition, a tentative summer lapse rate analysis can be applied, as was done above, to obtain a similar estimate of temperature conditions. At present an herbaceous tundra vegetation occupies sites lying above approximately 5,000 ft in the Atlin region.

Figure 30. Upper Ruby Creek valley.

View northwest in upper Ruby Creek valley. The valley floor is approximately 4,300 ft in elevation just beyond the immediate foreground. The mountains in the background are somewhat over 6,000 ft in elevation and are covered with snow from a late summer storm.

The vegetation here is considered to be of the spruce woodland type on lower valley side slopes and of the shrub tundra type on the valley floor. Alpine fir forms an important admixture in the spruce woodland. The two trees at the right are alpine fir. Across the foreground are shrub birch and shrub willows, the cnief components of the shrub tundra vegetation.

Cold air drainage and excess soil moisture, perhaps coupled with permafrost in many places, are probably responsible for the lack of spruce and fir on the valley floor.

Vegetation at lower elevations in the Atlin valley is believed to have been similar to this between approximately 10,500 and 10,000 years ago and again between approximately 9,000 and 8,000 years ago (zones VIII and VI, Figure 32).

Photo by D. A. Lietzke. Late August 1969.

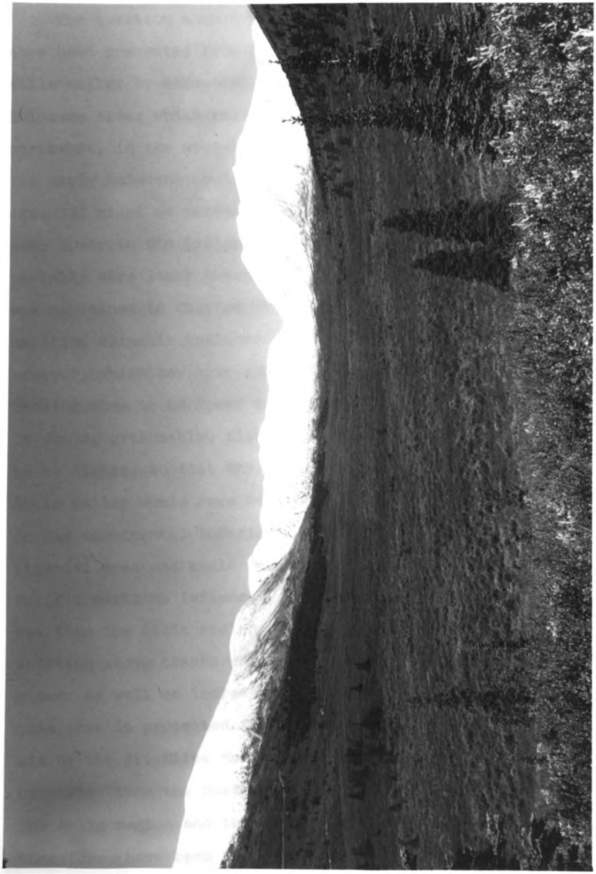


Figure 30. Upper Ruby Creek valley.

The question should be raised as to how spruce could have been prevented from entering the northern part of the Atlin valley by unfavorable temperature conditions in early Holocene times while existing in abundance farther to the northwest, in the west-central Yukon refugium, not only in the early Holocene, but also during the preceding Wisconsinan Age. It might be assumed that temperatures would have been even lower in the latter place. Mean annual temperatures probably were lower there than in the Atlin valley where, as was explained in Chapter IV, there is somewhat of a moderating maritime climatic influence. It is just this influence, however, which may have conditioned the summer temperatures, causing them to be lower than in more continental regions. It would, presumably, also have caused winter temperatures to be higher, so that the mean annual temperature in the Atlin valley would have been higher than in regions deeper in the continental interior. The Yukon refugium is a continental area and would not have experienced as much of a Pacific maritime influence. This area is farther from the sea than the Atlin region and is outside the zone of the shifting storm tracks which bring cooler temperatures in the summer as well as increased precipitation. Furthermore, this area is protected from incursions of Pacific maritime air by the St. Elias Mountains which are higher and more extensive than the Northern Boundary Range which lies between the Atlin region and the sea. Summer temperatures would, therefore, have been higher, and winter temperatures lower, presumably low enough that the mean annual temperature would have been lower than in the Atlin region.

Meteorological data show that such relationships exist in northwestern Canada at present. Figure 5 shows that at Whitehorse, lying some distance southeast of the west-central Yukon refugium, summer temperatures are significantly higher than at Atlin. At both Whitehorse and Carcross, winter temperatures, in most cases, are lower than at Atlin. An examination of temperature conditions at stations lying well within the Yukon refugium area shows this situation even more clearly. For example, at Dawson, mean temperatures for June, July, and August are 56.9, 59.8, and 54.5° F, respectively, and for November, December, and January they are, respectively, 2.5, -21.9, and -17.6° F (Canada Dept. of Transport - Meteorological Branch, 1967). The reader may compare these figures with the Atlin data in Figure 5 and note the considerably greater yearly range of temperatures at Dawson. In addition, the mean annual temperature at Dawson is 23.6° F, compared with 32° F at Atlin (Table 1).

The two peaks in _Isoëtes_-type spores in the shrub zone portion of the Mile 47 Bog diagram would be difficult to reconcile with the low temperature conditions hypothesized here if these spores are really of _Isoëtes_ spp. _Isoëtes_ is a plant of temperate to north-temperate climates. It occurs today in south-coastal Alaskan regions, and its northward advance in mid-Holocene time, as far as the Brooks Range, is considered an indicator of Thermal Maximum climatic conditions (Livingston, 1955; Heusser, 1967). In view of the uncertainty as to the identity of these spores, however, the hypothesis cannot be nullified in view of this information. There is no apparent basis for further discussion of the *Isoëtes*-type spore profile at this point.

The major increase of Cyperaceae pollen percentages around the 9,000 year level may indicate the development of a bog mat around the edge of the Mile 47 Bog pond, a body of water which would have been considerably larger at this time, i.e. during the early stages of organic accumulation.

The several samples from the upper part of the shrub zone in the Mile 47 Bog section containing high proportions of *Typha* pollen, deposited between approximately 8,600 and 7,000 years B.P., are puzzling in view of the environmental interpretations being developed (Fig. 23). Jansen (1967) states that *Typha* sp. indicates high pH and a high base content of the soil. It is significant that the plant appears to have become established in Mile 47 Bog around the time of initiation of marl deposition, when, with dissolved calcium carbonate being brought into the bog in increased quantities, the pH would have been higher than previously. It cannot be said with certainty why *Typha* did not remain in the bog any longer than is indicated by its pollen record, nor why it did not appear in any of the other bogs. Possible factors include a change to less favorable, i.e. lower pH levels, increasing competition from other plants on the developing bog mat, or a change to less favorable climatic conditions.

Typha is considered a plant of temperate affinities (Ritchie and de Vries, 1964), but it is doubtful that the climate was more temperate during the time that *Typha* appears to have grown in the Mile 47 Bog than at other times. Sangster and Dale (1961, 1964) have shown the low preservability of *Typha* pollen in various kinds of sediments, suggesting that the answer to the present problem is lack of representation at all but certain levels where unusual chemical conditions prevail in the sedimentary environment.

At approximately the 7,200 year level in the Mile 47 Bog diagram a major rise in spruce pollen percentages occurs, indicating that the transitional spruce woodland vegetation, represented by lower pollen percentages, was relatively short-lived and that spruce forests were developing, probably over most of the valley floor as well as upon increasingly large areas of the valley walls as the climatically controlled timberline receded upslope. Accompanying this rise is a decrease in willow, birch, and *Artemisia* percentages, indicating that the shrub tundra vegetation zone was being displaced upslope to sites more distant from the deposition site. By this time temperatures probably had risen to around the present levels. A concomitant increase in dryness is indicated by a drop in the alder and a significant rise in the grass profiles. Accompanying this is the appearance of a few grains of juniper pollen and a somewhat higher frequency of *Shepherdia* pollen in several samples from this part of the section. Both of these plants occur more commonly on dry sites.

At approximately the 5,200 year level a major decline in spruce pollen percentages occurs, accompanied by a moderate increase in alder and a slight increase in birch percentages (Fig. 23). Because of the notable drawback of the method of plotting relative percentages of pollen, wherein a change in the numerical abundance of one type in a series of samples automatically influences the percentages and apparent abundances of other types, even though the actual, numerical abundances of the latter remain unchanged, it is not possible to say whether only spruce, only alder, or whether both varied in importance in the vegetation around Mile 47 Bog.

It is possible, nevertheless, that alder became somewhat more important in the vegetation at this time. Spruce importance may or may not have declined concomitantly. As has been shown, one type of habitat for alder at present is wet sites in stands of the feather moss faciation of the white spruce association. By invading such sites, alder may have increased with no corresponding decrease in spruce, a change which might have resulted from the onset of a period of higher precipitation. The moisture indicator value of alder is discussed in connection with the Moose Bones and Mile 16 Bog records. The discussion of the birch profile in the Moose Bones Bog record may also be applied here as support for the interpretation of a return to a wetter climate.

The Cyperaceae profile may be significant at this point. Figure 23 shows that Cyperaceae percentages decrease considerably, beginning some time prior to the decrease in spruce percentages, and remain low during the period of lower spruce and higher alder percentages. Keeping in mind the method of construction of the diagram (Chapter XI), it can be seen that the profiles for spruce, alder, etc., are independent of the Cyperaceae profile insofar as the mechanics of diagram construction are concerned. All of these profiles may be related, however, in reflecting the influence on all plant types of changes in environmental conditions. In the present case, an increase in precipitation may not only have promoted a return of alder to greater importance in the upland vegetation, but may also have raised the water table in the bog. This may have caused flooding of the bog mat, thereby reducing the amount of semi-aquatic Carex and/or Scirpus habitat. With the areal extent of this vegetation reduced, in conjunction with its displacement to a greater distance from the deposition site, Cyperaceae pollen deposition at the site would have dropped to lower levels. (See Figure 31 and discussion in Wilson Creek Bog section.)

At approximately the 2,500 year level in the Mile 47 Bog section pine pollen makes an appearance and, in general, increases upwards to the surface as in the other bogs. The significance of this increase is believed to be related, as in Moose Bones and Mile 16 Bogs, to increasing dryness of the climate during the time represented.

Further evidence for such a climatic trend is provided by the Cyperaceae profile. As was explained above, the reduction in Cyperaceae pollen percentages through spruce zone times is believed to be related to increased precipitation and a rise of the mean water level in the bog. If precipitation began to decrease around 3,000 years B.P., then the water level may have begun to fall, bringing about a corresponding increase in size of the sedge zone, or the bulrush zone, as the case may have been (Fig. 15). This could have caused the major increase in supply of Cyperaceae pollen indicated by the rise in the profile around the spruce/pine zone boundary.

It is suggested that as dryness increased, the bog water table continued to fall, bringing about a reduction again in size of the sedge zone. In this case, however, the encroachment upon this zone was from the periphery, as the shrub zone increased centripetally, rather than from the inside, as when the water table rises and there is flooding (Fig. 31). If this process actually occurred, then an increase in shrub pollen would be expected to correspond with the decrease in sedge. It is seen (Fig. 23) that willow pollen percentages do, in fact, increase in samples from the uppermost levels. At present there are no alder or birch in the shrub willow zone of the bog and, if this were also true in the past, only willow percentages would be expected to rise here. It can be seen that alder and birch percentages remain at low values in approaching the surface.

Although evidence from the Mile 47 Bog section presented so far indicates a return to drier conditions by upper spruce zone time, the alpine fir profile indicates rather strongly that conditions remained moist, perhaps becoming more so by the end of spruce zone time around 2,500 years B.P. (Fig. 23). Such an interpretation has been developed already for the Moose Bones and Mile 16 Bog records. At present, alpine fir in the Atlin valley appears to grow in places of higher precipitation, i.e. in the southern part of the valley and at higher elevations in northern areas. Thus as a moisture indicator the appearance of alpine fir pollen in later spruce zone times would support the hypothesis of increased precipitation. Infrequent earlier occurrences, back to the 7,100 year level, may be explained by long distance transport. During earlier, drier times, fir would probably have existed only at higher elevations at the latitude of Mile 47 Bog. Since alpine fir tends to be quite underrepresented in pollen spectra (Fig. 28), it is difficult to estimate its actual vegetational status. It is fairly certain, however, that by late spruce zone times the species had become established as a fairly important member of the vegetation at lower elevations. Later, its status appears, by virtue of less frequent pollen occurrence, to have declined somewhat during pine zone times when, as is suggested above, precipitation probably also decreased.

There is no evidence in the alpine fir profile, in the form of a re-increase in pollen percentages, of a return to wetter conditions during the last several hundred years, a hypothesis which will be developed presently on the basis of the willow and Cyperaceae profiles. However, this does not negate the hypothesis because it would probably take fir longer to respond to such a change, i.e. to invade certain sites at lower elevations in significant quantities and grow to pollen producing age, than it would willow and sedge in the bog.

Such considerations as this may be important with regard to the question of why alpine fir did not appear earlier in the record, i.e. around 5,200 years B.P. when, as is discussed above, the climate is believed first to have become wetter. There may be a lag time for fir establishment after climatic conditions change to favor its occurrence in an area because of difficulty in invading an already stable vegetation. The palynological record shows that this vegetation was probably white spruce forest (Fig. 23).

The drop in the willow profile near the top of the section indicates that precipitation may have increased again during the past several hundred years. Evidence for this was first presented in the discussion of Mile 52 Bog vegetation. Here it was suggested that a stand of dead spruce trees near the northeastern edge of the pond may have been killed by a recent rise of the water table. Several dead white spruce trees have also been encountered in Mile 47 Bog, primarily in the sedge-moss zone (Fig. 15) and a number of small dead spruce occur in the sedge zone of Jasper Creek Bog. These can be seen in Figure 18 toward the left side of the photo in the area between the two ponds. In addition, Lietzke (1970) in his study of the soil in stand 59W, suggested that a recent trend to a more moist climate may be responsible for increased deposition of lime near the surface there.

Contrary to expectation, confirmation of the present interpretation of the upper willow profile in Mile 47 Bog is not found in the Cyperaceae profile, which generally continues to decline toward the surface. The anomalously low proportion of Cyperaceae pollen in the Mile 47 Bog surface sample, in spite of the abundance nearby of *Scirpus validus*, is discussed on page 210. Although no explanation is available it can be reasonably assumed that the low Cyperaceae percentages are not related to climate, but instead to some problem in pollen productivity or preservation in recent times. *Scirpus validus* is obviously present in abundance in a relatively extensive, semi-aquatic zone (Fig. 15). There is no evidence, other than lack of Cyperaceae pollen in the record, that this zone has not increased in size during the past few hundred years. Thus, the hypothesis cannot be nullified on this count.

The appearance and rapid rise to considerable percentage levels of the *Triglochin-Potamogeton* pollen type during the time interval in question probably relates to these low Cyperaceae pollen values. Since percentages for *Triglochin-Potamogeton* type and Cyperaceae are calculated on the basis of the same total, i.e. the total pollen and spore count exclusive of Pediastrum, a major increase in the former would obviously influence the relative abundance of the latter pollen type, thereby partially explaining its low values.

If the pollen type in question here is Potamogeton, its abundance in the upper levels of the section would support the hypothesis of increased precipitation during the time represented. With an increase in the bog water table, there would have been an enlargement of the area of open pond water, and therefore of Potamogeton habitat. This, of course, leaves open the question of why Potamogeton did not appear during earlier times of higher precipitation. A temperature control cannot be invoked in this case, as Potamogeton, a low arctic species (Porsild, 1964), could probably have existed under the range of temperatures proposed here for Holocene time. In view of this, and in view of the fact that Potamogeton does not occur at present in the Mile 47 Bog pond, whereas Triglochin was found to be common in the bog, the pollen profile here is probably that of the latter genus. Because of the broad geographic distribution of both Triglochin maritimum and T. palustris, these species have little climatic indicator value.

Jasper Creek Bog

In many ways the Jasper Creek Bog record is similar to that of Mile 47 Bog and, in the upper part, to the records of Mile 16 and Moose Bones Bogs (Fig. 21-24). However, there are a few important differences which must be discussed.

Additional significance lies in the fact that the record from Jasper Creek Bog appears to go back farther than in the other bogs.

There are no radiocarbon dates for the Jasper Creek Bog section, but dates from Mile 47 and Wilson Creek Bogs permit the application of a tentative chronology. As was shown in Chapter XII, the peat accumulation rate in Mile 47 and Mile 52 Bogs has been 0.044 cm/yr, on the average, and the Wilson Creek Bog rate has averaged 0.042 cm/yr, a very similar value. It seems reasonable to assume that the peat accumulation rate for Jasper Creek Bog has been of the same order of magnitude. Since Jasper Creek Bog is closer to Wilson Creek Bog, the rate from the latter is used to calculate a tentative age of 3,690 years B.P. for the base of the peat. Extrapolating upward from this level, the spruce/pine zone boundary is set at 2,500 years B.P. (Fig. 24).

The only available marl accumulation rate is the one for the Mile 47 Bog section of 0.036 cm/yr. Applying this to the Jasper Creek Bog section gives a date of 11,050 years B.P. for the beginning of marl deposition. This estimate is probably too great because of the likelihood that marl has accumulated at a faster rate here than in Mile 47 Bog due to proximity of an extensive source of calcium carbonate (p. 18; Fig. 18). The age of this level should therefore be reduced somewhat.

An indication of the amount of reduction required may be obtained from the Wilson Creek Bog record (Fig. 25).

There, peat accumulated over a much longer period of time, the base of the peat being radiocarbon dated at 8,000 $\pm$ 350 years B.P. The base of the peat there lies only a short distance above the shrub/spruce zone boundary, a reasonable age estimate for which may be obtained by applying the aforementioned Mile 47 Bog marl accumulation rate. Since the thickness of marl between the shrub/spruce zone boundary and the base of the peat is relatively small, any error in extrapolation should be correspondingly small. In addition, Wilson Creek Bog is not so directly influenced by drainage from nearby extensive areas of carbonate rocks as is Jasper Creek Bog. Thus the marl accumulation rate may have been somewhat less than in the latter bog, perhaps more nearly the rate in Mile 47 Bog. Applying this rate, 0.036 cm/yr, in extrapolating downward from the 8,000 year level in the Wilson Creek Bog section gives a date of 8,860 years B.P. for the shrub/spruce zone boundary. To be conservative, and to account for the probability that the marl accumulated at least a little faster here than in Mile 47 Bog, this estimate is reduced to 8,500 years B.P.

Wilson Creek and Jasper Creek Bogs are only about six miles apart and lie at the same latitude (Fig. 1). Therefore major vegetation changes on the uplands around each of them, of the type reflected in the pollen profiles across the shrub/spruce zone boundary, were probably contemporaneous. On this assumption it is believed that the Jasper Creek and Wilson Creek Bog diagrams correlate closely and that the estimated shrub/spruce zone boundary age of 8,500 years B.P. in Wilson Creek Bog may reliably be extended to the Jasper Creek Bog section. This provides a date for a level only a short distance from the base of the marl in the latter. Extrapolating to the base of the marl, and taking the precautions discussed above, it can be seen that the age of the first marl deposits in Jasper Creek Bog is, at most, 10,000 years, and probably considerably less. An age of 9,500 years is suggested.

The problem of establishing a time scale for the blue-gray clay portion of the section is the same as for the Mile 47 Bog section as discussed on pages 243-245. It is possible that only a few hundred years are represented here, or perhaps one or two thousand. By correlation with the Wilson Creek Bog diagram, the outstanding spruce pollen peak at the 4.7 m level appears to have occurred around 10,200 years B.P. In Wilson Creek Bog, this peak may be more accurately dated because of a radiocarbon date within the section (Fig. 25).

The earliest pollen assemblages from Jasper Creek Bog, below the 4.9 m level (Fig. 24), reflect a tundra vegetation consisting of elements of both herbaceous tundra and shrub tundra vegetation types. Indicative of the herbaceous tundra are Cyperaceae, Gramineae, *Artemisia*, Compositae, and possibly the undifferentiated types, believed to consist primarily of herb pollen. Shrub tundra is indicated by willow, alder, and, particularly, birch pollen.

The exceptionally high alder percentages in this case are not believed to represent a moist climate so much as the proximity of glacial outwash terrain upon which alder may have been relatively abundant as a pioneer species. Since alder is favored by a somewhat warmer climate than is generally associated with herbaceous tundra, it is concluded that the area in the immediate vicinity of Jasper Creek Bog was occupied primarily by shrub tundra and that herbaceous tundra occurred somewhat farther away at higher elevations on slopes of the nearby Johnson Range (Fig. 19).

The lower Dryas pollen peak, probably produced by plants colonizing the surrounding, then recently deglaciated terrain, may, in conjunction with the tundra types, reflect a significantly cooler climate than at present. On the basis of these vegetation interpretations and other evidence presented earlier, the mean July temperature at this time may have been on the order of 47-48° F.

A striking feature of the Jasper Creek Bog record is the high spruce peak centered on the 4.7 m level, a level dated, as explained above, at 10,200 years B.P. Since a similar peak occurs at the bottom of the Wilson Creek Bog diagram, at what is probably a comparable level in time, it appears that a major change in the vegetation occurred in the vicinity of these two bogs and that a spruce-rich flora dominated the scene for at least a few hundred years. Such a peak as this might be attributed to reworking and redeposition of older deposits containing high proportions of spruce pollen. In view of the fact that the two bogs involved are located in different local drainage basins, this explanation does not appear reasonable.

In attempting to explain these early, isolated spruce pollen peaks, consideration must be given to the possibility that a temporary invasion of Sitka spruce was responsible. An important indication of this is the fact that the average size of the spruce pollen grains in the samples in question from both Jasper Creek and Wilson Creek Bogs is significantly less than the average for white spruce. In the Wilson Creek Bog diagram the frequency of spruce grains measuring less than 96 μ between the tips of the bladders are plotted in a separate column (Fig. 25). In Jasper Creek Bog, all five of the spruce grains encountered at the 4.75 m level were of this size category, and at the 4.70 level, about one-half of the 91 spruce grains counted were less than 96 μ in size.

It has been shown by several investigators that the mean measure between the tips of the bladders of white spruce grains is somewhat greater than 100 μ, and for black spruce, less than 100 μ. A statistical study made by the writer indicates that 96 μ is probably a more appropriate measure for distinguishing the two species in this region. The probability, however, that the spruce grains in the below 96 μ size category in the Jasper Creek and Wilson Creek Bog samples are of black spruce is low in view of the fact that this species is not known to occur in the Atlin valley at present, and there is no reason to believe that conditions, namely an acid substrate, were more favorable for it in this area in the past. On the other hand, Heusser (1960) shows that Sitka spruce grains are also smaller, on the average, than those of white spruce.

At present the environment of Sitka spruce is characterized by fairly high precipitation and humidity and mean July temperatures ranging from around 52 to 64° F (Heusser, 1960). The species is believed to have occupied a refugium in the northern Queen Charlotte Islands during the Wisconsinan (Heusser, 1960). Summer temperatures in the southern part of the Atlin valley might have risen rather sharply around 10,400 to 10,500 years B.P. Similar changes may have occurred in the general region between the valley and the Taku River and within this valley and others even farther south where they transect the Coast Mountains. This temperature change, in conjunction with higher precipitation levels, may have promoted the migration of Sitka spruce through one or more of the trans-range valleys and into or near the southern part of the Atlin valley.

A return to cooler conditions within a few hundred years might have brought about the demise of the Sitka spruce population in this area and a return to a shrub tundra vegetation type, evidence for which is well shown in both diagrams just below the shrub/spruce zone boundary (Fig. 24, 25). It is to be noted that the proposed mean July temperature decrease need not have been of the same magnitude as the increase, from the level of perhaps 47° F suggested above for the time prior to spruce immigration, to the 52° F or more which would have been necessary to bring this immigration about. A decrease to just below 52° F may have been sufficient for removal of the Sitka spruce population. Although the temperature regime may then have remained favorable for white spruce, i.e. mean July temperature greater than 50° F, this species, if it migrated into the region from the north, would not yet have reached the Jasper Creek Bog area. As was explained earlier, it apparently did not reach the Mile 47-Mile 52 Bog area until around 8,000 years B.P. (p. 247-250).

The shrub-spruce zone boundary, as discussed above, is set at the 8,500 year level in Jasper Creek Bog. At this level spruce pollen becomes very abundant again, a condition which is maintained through the remainder of the section. If the record of white spruce migration into the Atlin valley, as interpreted earlier and reiterated above, is reliable, then this species could not have reached the Jasper Creek Bog area until at least 7,500 years B.P. In view of this, the first thousand years or so of continuous spruce occurrence in the area may have involved a return of Sitka spruce under the influence, again, of higher summer temperatures and rainfall. Then, if the climate had gradually become drier during early spruce zone times, Sitka spruce would again have died out. But by this time white spruce, having finally migrated into the southern part of the valley, could have replaced Sitka spruce in the upland vegetation. Given that this replacement occurred gradually and continuously, there need not appear any break in the pollen record to mark the event, save for a shift to slightly higher mean pollen size. Such a shift was observed.

Unfortunately the evidence against the migration of Sitka spruce into the southern Atlin valley area in early Holocene times is rather strong, and the temperature conditions which would have been necessary conflict with the low summer temperature interpretation developed earlier for the pre-spruce period in the northern part of the valley (p. 249-251).

In the first place, the summer temperature increases which this hypothesis proposes, including a mean July increase of at least 5° F, are not likely to have occurred within a space of only two or three hundred years.

Secondly, a return of summer temperatures, around 8,500 years B.P., to levels favoring a return of Sitka spruce would most likely have been accompanied by comparable, and perhaps, in view of the more continental location, even higher temperatures in the northern part of the valley. Under such circumstances the rate of southward migration of white spruce would have been greater, and spruce pollen would be expected to appear considerably earlier in the Mile 47 and Mile 52 Bog sections than it does.

If Dryas is as good an indicator of a cooler climate as has been discussed earlier, then the occurrence of a second Dryas pollen peak within a short time of the spruce peak in Jasper Creek Bog would tend to nullify the hypothesis.

A fourth consideration involves precipitation. The minimum mean annual precipitation within the present range of Sitka spruce is around 32 inches, and at most stations it is considerably higher (Heusser, 1960). The mean annual precipitation at Atlin is approximately 11 inches (Table 1), and it is probably several inches higher than this in the southern part of the valley at present. Although the precipitation may have been higher yet in this area prior to the first spruce pollen peak, a possibility indicated by the high alder pollen percentages, it is difficult to see how it could have been greater than around 20 inches. In the Snag-Klutlan area Rampton (1969) associates the shrub tundra vegetation type with mean annual precipitation levels of only eight to ten inches, and the herbaceous tundra there is believed to have existed under an even scantier regime. However, alder pollen is of low percentage value or absent from the record in shrub and herbaceous tundra times there. Nevertheless, alder in the Atlin valley may thrive at precipitation levels considerably lower than 32 inches per year. It appears that a more than plausible precipitation increase, as well as a major temperature increase, would have been necessary for Sitka spruce to enter the southern part of the Atlin valley.

If, in spite of all this, Sitka spruce did migrate from the northern Queen Charlotte Islands into the southern part of the Atlin valley by 10,200 years B.P., significant quantities of spruce pollen should be found in samples of comparable age from bogs in the southern portion of the southeastern Alaska panhandle and in north-coastal British Columbia. These areas would have lain across the hypothetical migration route. However, Heusser's (1960) investigations show that Sitka spruce did not become established here until around 8,000 years B.P., the time of beginning of the Thermal Maximum.

Finally, it is not likely that Sitka spruce, or any other non-alpine species, could have migrated through any of the more northerly of the trans-range river valleys, such as that of the Taku, prior to around 8,000 years B.P. Before this time the valleys were still occupied, at lower elevations, by ice of the dwindling cordilleran glacier complex (Heusser, 1954a).

The pros and cons of the hypothesis of a Sitka spruce migration into the southern part of the Atlin valley during early Holocene time, or perhaps during late Pleistocene Alleröd time, have been explored because without it, or a similar hypothesis, an explanation of the prominence of spruce in the lower part of the profiles in both the Jasper Creek and Wilson Creek Bog sections becomes very difficult. Additional information is required to settle the problem. Particularly, several sections are needed from bogs south of the Atlin valley in areas adjacent to the eastern flanks of the Coast Mountains and in the vicinity of the Taku River valley. Besides the radiocarbon dating of these sections, careful identifications will have to be made of the spruce pollen grains in an attempt to differentiate between white spruce, Sitka spruce, and perhaps also black spruce which may have occupied some of the areas involved.

In spite of the present phytogeographic problem, some useful conclusions can be drawn on the basis of the information at hand. In view of the occurrence at approximately the 10,200 year level of considerable quantities of spruce pollen of one species or another in both the Jasper Creek and Wilson Creek Bog sections, it is clear that the local vegetation contained at least a few spruce trees. It is concluded that the mean July temperature, accordingly, was at least 50° F, the minimum for white spruce, if not 52° F, the approximate minimum for Sitka spruce.

This short, warmer interval appears similar to the Alleröd or Two Creeks of other areas and the Late Glacial II of Heusser (1960, 1965) for the Olympic Peninsula. Although the Two Creeks interval had ended by at least 11,000 years B.P. (Broecker and Farrand, 1963; Heusser, 1966), the present interval appears not to have begun until about 500 years later. Unfortunately the latter age estimate is determined by extrapolation and correlation from too few radiocarbon dates. Until more dates for the Jasper Creek and Wilson Creek Bog sections, or comparable sections from nearby areas, are available, the true magnitude of the time differential, if any, between the early warm interval (Zone VIII, Fig. 32) of the Atlin valley and the Two Creeks of mid-Continental North America, or the Alleröd of Europe, cannot be known.

On pages 26-32 the Holocene glaciation and glacial geology of the Atlin valley and adjacent areas is discussed and some preliminary interpretations with respect to climatic oscillations are made. It appears that the lower sediments of the Jasper Creek and Wilson Creek Bog sections were deposited while ice still occupied the main Atlin valley and the glacial features discussed earlier, including pitted outwash, knob and kettle topography, and gravel terraces, were being formed in the northernmost part of the valley. The Jasper Creek and Wilson Creek Bog sites are situated in the O'Donnel-Pike River transection valley, which opens into the main Atlin valley. These sites were covered by a distributary from the main ice stream flowing northward out of the Northern Boundary Range (Aitken, 1959; Fig. 1). The distributary ice would have been thinner in the O'Donnel-Pike River valley and over the bog sites than in the main valley because these sites lie at a higher elevation than the floor of the main valley, i.e. the bottom of Atlin Lake. Because of being thinner here, ice would have disappeared from the bog sites earlier. Thus bog succession and the development of a pollen record could have been underway while ice still occupied the main Atlin valley, including the Moose Bones and Mile 16 Bog areas.

It is suggested that the early climatic oscillation represented by the first spruce peaks in the records from Jasper Creek and Wilson Creek Bogs (Figs. 24, 25) is related to a period of fairly rapid retreat of the glacier terminus in the northern part of the valley. Specifically, the gravel terraces and knob and kettle topography located northeast of White Mountain and the pitted outwash in the Moose Bones Bog area (Denny, 1952; Wheeler, 1961: Fig. 1 ; p. 27) were formed during a time of stagnation correlated with the lowest portion of the Jasper Creek Bog record. This provides a date for the origin of these features of around 10,400 years B.P.

During the next few hundred years, under a temporarily warmer climate, the ice melted out of the Little Atlin Creek valley north of White Mountain and the Little Atlin Lake portion of the main valley.

It is suggested that after this, with a return to cooler conditions around 10,000 years B.P., stillstand of the ice front again occurred, bringing about the formation of the kame terrace in which Mile 16 Bog is located (p. 143).

As the climate became warmer again, about 9,000 years B.P., a more continuous retreat of the main ice stream from the Atlin valley appears to have begun. Although another period of slower retreat, with periodic halts of the ice front, probably was responsible for the series of closely spaced recessional moraines at the head of Atlin Lake (p. 28), this is not reflected in the records from Jasper Creek and Wilson Creek Bogs.

Continuing upward in the Jasper Creek Bog diagram (Fig. 24), interpretations comparable to those developed for the Moose Bones, Mile 16, and Mile 47 Bog sections seem reasonable. A transitional spruce woodland vegetation type is indicated by the moderate, although increasing, spruce pollen percentages and the declining birch percentages at the shrub/spruce zone boundary. The mean July temperature at this time was, again, at least 50° F, and probably continued to rise through early spruce zone times. A peak in juniper pollen at the boundary, followed by another a short distance above, indicates that conditions were drier than before. The drop in Cyperaceae percentages, following a peak in the upper shrub zone which probably reflects the development of a bog mat, may also indicate drier conditions. In this case, a lowering of the bog water table may have brought about the destruction of sedge habitat (see p. 281-284 and Fig. 31).

The willow and birch profiles may reflect the occurrence of these plants in a large moist, but not wet, zone around the bog pond in early spruce zone times, a zone which increased in size as the water level fell. This interpretation seems reasonable in view of the fact that willow pollen is scarce in the surface and near-surface samples from the bog, in spite of the fact that at present a few willow shrubs occur around the periphery of the bog. In order to have had even the moderate willow representation shown for early spruce zone times (Fig. 24), willow habitat must have been more extensive than now.

That precipitation increased again in later spruce zone time is indicated first by the alder pollen percentage rise beginning at about the 2.45 m level. The extrapolated date for this level is 5,400 years B.P. Although the alder profile drops to quite low levels at approximately 1.75 m, significant proportions of alpine fir pollen occur here, and this, as was argued earlier, may indicate continuing moistness in upland areas. In addition, the rise to a considerable percentage of the Cyperaceae percentage just below the spruce/pine zone boundary may be related to a redevelopment of sedge brought about by a rise in the bog water table.

A return to drier conditions in pine zone time is indicated by the notable expansion of the lodgepole pine profile and the decreases of fir, alder, and sedge percentages (Fig. 24). Although it may be a little too early in the profile, the Gramineae pollen observed across the zonal boundary may also be related to such conditions.

As is discussed elsewhere (p. 258-260, 281-284), the slight rise in the Cyperaceae profile at the top of the section is an indication of a return to wetter conditions within the past few hundred years.

Wilson Creek Bog

Because dating and important profile features of the Wilson Creek Bog section have been discussed earlier, particularly with respect to establishing a chronology for the Jasper Creek Bog section and in working out the Holocene phytogeography of spruce and lodgepole pine, only a brief review of the record and of local environmental interpretations need be made here.

The record is believed to begin at least 10,200 years B.P. (Fig. 25). At this time the spruce profile appears to be undergoing a decline from what may have been an even greater peak, comparable to the one in Jasper Creek Bog (Fig. 24), in response to an interval of notably warmer climate. At this time values are quite low for willow and particularly birch, indicating that the earlier shrub tundra vegetation, occurring at lower elevations in the vicinity of the bog, had been largely replaced by spruce forest. High alder values at this time may indicate that, while warm, the climate was also somewhat more moist. Much of the alder may have grown as an early colonizer of nearby meltwater stream bars, but the moist climate interpretation is given some additional support by the appearance of a few Umbelliferae grains near the bottom of the section along with spores of Polypodiaceae and *Selaginella* and high values of Cyperaceae pollen. In addition, pollen of plants which often indicate dry conditions, such as juniper, grass, and *Artemisia*, are infrequent.

Following closely upon this interval, approximately 10,000 years B.P., a return to cooler conditions is indicated by the near disappearance of spruce pollen and the increase of willow and birch. That it may also have been drier is indicated by the drop in alder and sedge percentages and the rise of *Artemisia* and Compositae. At this time the major vegetation surrounding the bog was probably a shrub tundra.

The mean July temperature may have been around 48° F, and precipitation probably was low.

By about 9,000 years B.P. spruce entered the area again and a spruce woodland appears to have occupied most upland sites until around 8,500 years B.P. By this time stands of closed spruce forest may have become established on many sites (See Figure 30.)

Except for low values of alder and the appearance of a few juniper, grass, and _Thalictrum_ grains, evidence for dryness in early spruce zone times, unlike the other sections, is lacking. The occurrence of significant quantities of _Selaginella_ spores and of high Cyperaceae pollen percentages would seem to indicate more moist conditions. However, these latter two observations might be reconciled with increased dryness. _Selaginella_, i.e. _S. selaginoides_, is a plant of wet or damp places (Colinvaux, 1964; Hultén, 1968) and may therefore have been limited to the bog, in which case there would be no relationship with dry, upland terrain. With regard to the Cyperaceae profile, it has been suggested that a lowering of the bog water level in response to a lower precipitation regime could bring about an increase in amount of habitat suitable for sedge growth in an area where the water had previously been too deep.

It is recognized that this is contrary to the mechanism suggested for changes in amount of sedge habitat in Jasper Creek Bog (p. 279), although comparable with the suggested Mile 47 Bog situation (p. 259). These arguments need not conflict. It is believed that the size of the bog basin and the configuration of its floor, or of the surface of the overlying sediments in which plants take root, determine the environmental effects of changes in water level. Figure 31 illustrates two hypothetical cases. In A, under the conditions of water level 1, the sedge zone, a zone observed in the Atlin valley to occur where the water table is ordinarily at or just above the ground surface, is larger than under conditions of water level 2. In case A the water is too deep for sedge growth in the former sedge zone (1), and there is little terrain where the new water level (2) bears the appropriate relationship to the ground surface for sedge growth. In B, the reverse situation is illustrated. In this case a rise in the water table causes a major increase in sedge habitat. It is also to be noted that sedge zone 2 may have been a shrub willow zone during the time of lower water level.

It can be seen that, depending on the physiography of Mile 47, Jasper Creek, and Wilson Creek Bog basins, lowering of their respective water tables might bring about the suggested results. Mile 47 and Wilson Creek Bogs may be exemplified by case A, whereas B is intended to show what may be the Jasper Creek Bog situation. Further field work in these bogs will be necessary to confirm or disprove this hypothetical mechanism, although it is doubtful that any meaningful conclusion about the mechanism, as it may have operated in the past, can ever be drawn because of the impossibility of knowing the surface configuration of the sediments in the bogs in

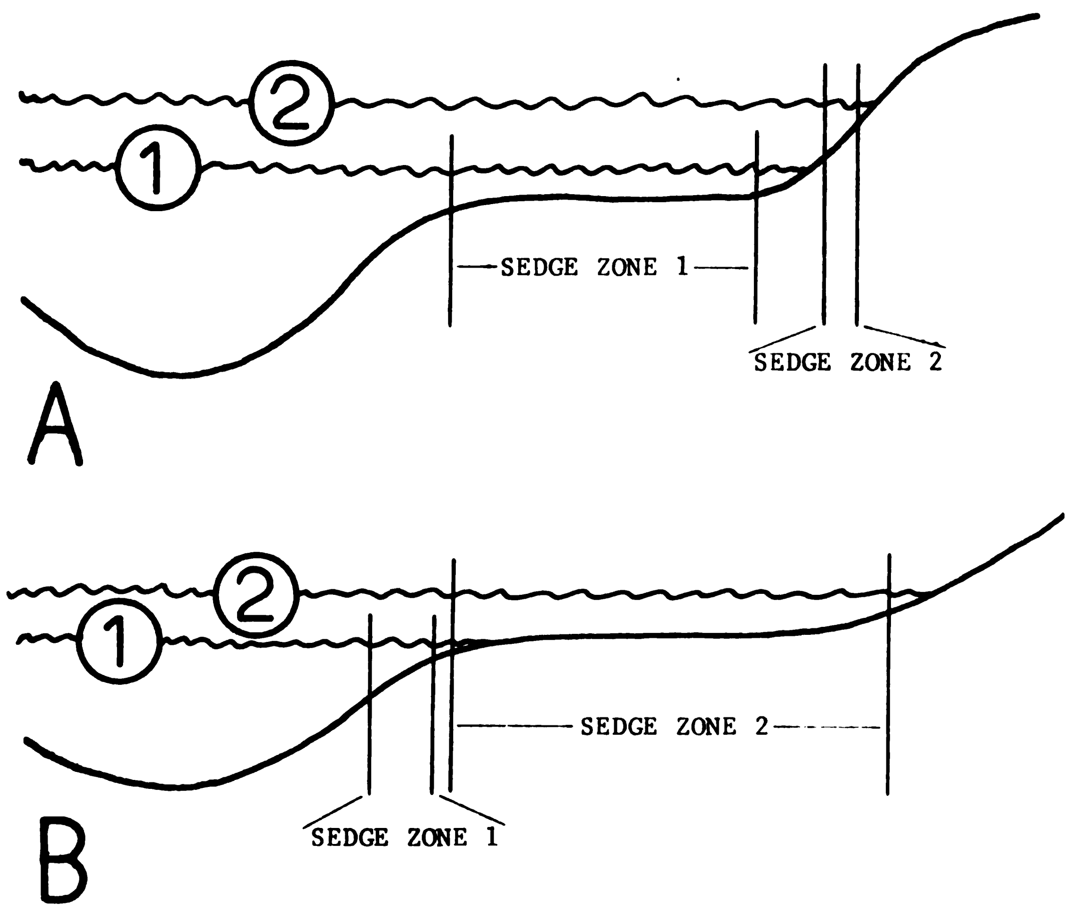


Figure 31. Hypothetical effects of changes in levels of bog water tables on sizes of sedge vegetation zones. (See text.)

the past. In addition it is believed possible that, as sediments of different types accumulated at different rates in different parts of a bog, the overall surface configuration may have changed in such a manner that the effects of fluctuations in the water level may also have changed.

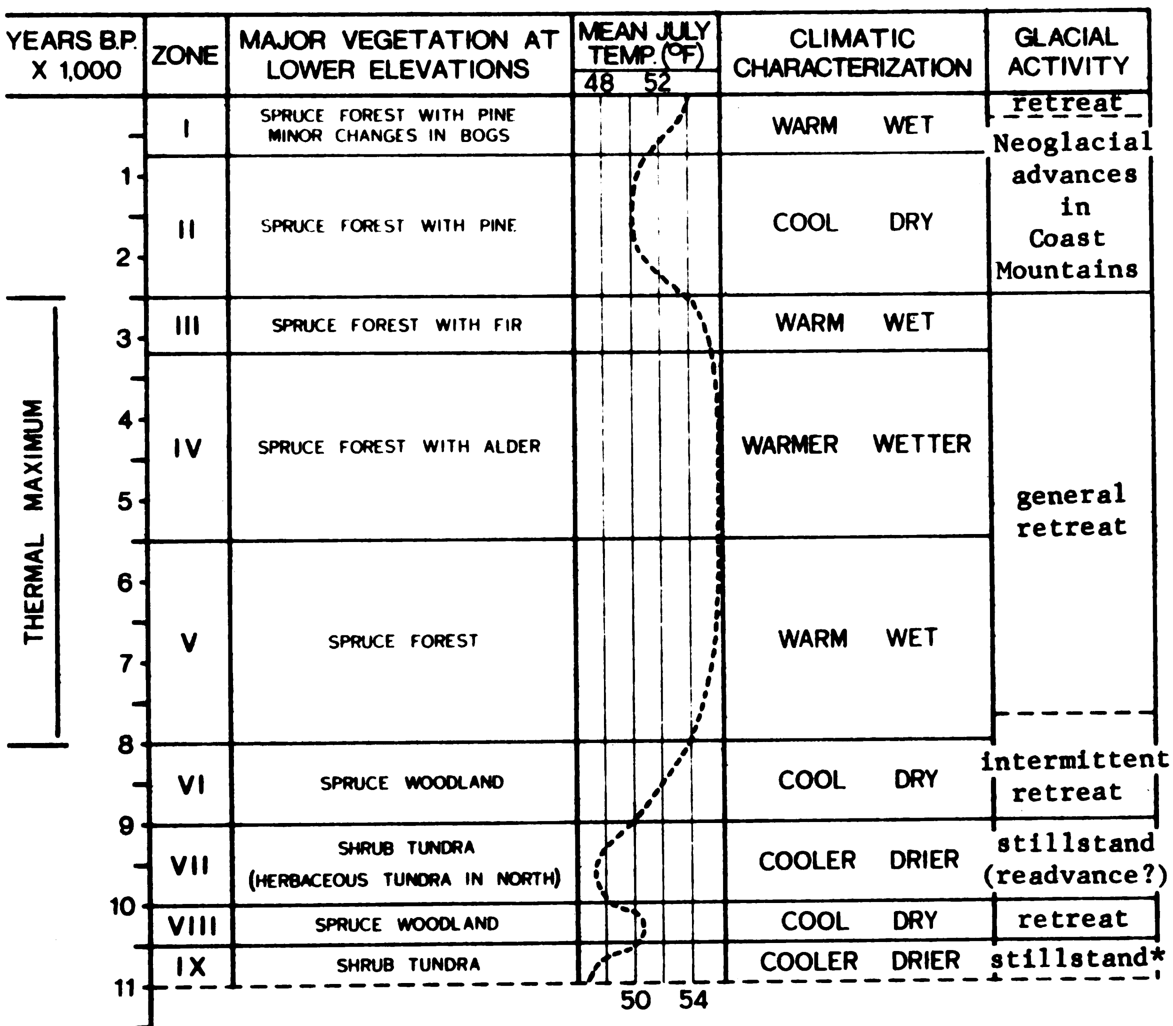
Continuing upward in the Wilson Creek Bog diagram (Fig. 25), somewhat more moist conditions are indicated by a slight rise, beginning around 2.75 m, of the alder profile, followed by a rather significant rise in the fir profile at 1.4 m. Above the spruce/pine zone boundary, beginning about 2,600 years B.P., conditions again appear to have become drier. This is indicated by the continuing increase in pine, the declining fir and alder profiles, and perhaps also by the continuation of the Cyperaceae profile at moderate to high levels.

For reasons discussed above the prominent decrease in the Cyperaceae profile within the upper approximately 25 cm of the section may indicate a return to more moist conditions during the past several hundred years.

Regional interpretations

The analysis of the extant vegetation and environments in the Atlin valley presented in the first part of this dissertation, in conjunction with interpretations and discussions of the five sections constituting the general palynological record for the valley presented in this chapter, make it clear that conditions have not been the same in all areas during the Holocene. Because of minor maritime climatic influences the southern part of the valley has been, and remains, different from the northern, more continental part. The Jasper Creek and Wilson Creek Bog records indicate higher precipitation levels than at Mile 47, Mile 16, and Moose Bones Bogs. There seems also to be evidence in the palynological record of differences in summer temperatures, the southern part of the valley being, on the average, somewhat cooler than the northern part. It is emphasized that these precipitation and temperature differences, and corresponding vegetation differences, are not considered to have been large, nor are they at present. The Atlin region is distinctly continental throughout and cannot be considered as lying along a major maritime-continental climatic gradient. Furthermore, the present study can only provide some indication of the qualitative nature of the differences. To estimate the true magnitude of present and past climatic differences in different parts of the Atlin valley and in the region as a whole, meteorological data will have to be obtained from several new stations, and additional palynological studies will have to be made. Particularly, the determination of absolute rates of pollen deposition in bogs, rather than of percentage frequencies of pollen occurrence in bog samples which represent variable periods of deposition, may provide a more accurate indication of past vegetation types and associated environmental conditions.

Different rates and patterns of migration of certain species into the Atlin region under early postglacial



* at late Wisconsinan maximum

A tentative Holocene geobotanical chronology for the Atlin region

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environmental conditions were also responsible for differences in vegetation in various parts of the region until more recent times.

An attempt has been made to synthesize the information provided in the records from each of the five bogs and to develop a composite Holocene geobotanical chronology for the Atlin valley and, by inference, for the Atlin region in general. The results of this synthesis are depicted in Figure 32. Here the differences in time of occurrence of key indicator species, such as spruce and pine, and differences in the extent to which major vegetation types are represented are averaged, as it were, for the purpose of constructing the general record. A nine-zone chronology is shown, and each zone, beginning with the oldest, No. IX, is briefly discussed below. Although many palynologists number their zones from the bottom up, the zones here are numbered from the top down in anticipation of extending the record back in time, with the establishment of additional zones, as future work is conducted in the Atlin region.

In order to characterize the climate which is believed to have prevailed during the time of each zone, the relative terms "cooler, cool, warm, and warmer" and "wetter, wet, dry, and drier" are used. There is little basis for quantitative definitions of these terms at this point, except that "cooler" may be associated with shrub tundra, "cool", with spruce woodland, "warm" with spruce forest, as at present, and

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"warmer" with vegetation which existed when summer temperatures were somewhat higher than at present.

Whereas the present climate of the Atlin region is considered "warm" on the temperature scale, it is also designated "wet". However "wet" in the absolute sense is not implied. Instead the climate is considered wet relative to what it was at various times in the past when precipitation levels appear to have been substantially lower than at present. In general, cooler times tend to be associated with lower precipitation, and higher precipitation tends to occur when growing season temperatures, on the average, are higher.

Zone IX. Only the Jasper Creek record extends back into this interval of time (Fig. 1, 24, 32). As has been discussed, the lower time boundary of the zone cannot be determined with certainty because radiocarbon dates at appropriate levels in the section are lacking, and the sedimentation rate is too uncertain for accurate correlation and extrapolation. The upper time boundary may be set at 10,500 years B.P. on the basis of correlation of the isolated spruce pollen peak with a similar one, more accurately dated, at the bottom of the Wilson Creek Bog diagram (Fig. 25).

It is possible that vegetation and climate characteristic of the Zone IX time interval was already prevalent in the vicinity of the bog at the time the Jasper Creek record began (Fig. 24). In view of the thickness of sediments between the tentatively dated 10,200 year level and the bottom

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of the section, this may have been about 11,000 years B.P. It may have been about this time that late Wisconsinan ice first retreated from the site, leaving behind a water-filled basin in which the present bog has developed. By the time of this retreat, a shrub tundra vegetation had become established on sites exposed earlier at somewhat higher elevations, giving rise to the various pollen types shown. Alder appears to have begun colonizing sites around the new basin only shortly after the terrain was available.

Because of the nature of the vegetation it is believed, for reasons discussed earlier, that the mean July temperature during Zone IX time was around 47 or 48° F, some 6 or 7° F below the 1906-1946 mean at Atlin (Table 1). Precipitation was probably less at this time, averaging perhaps 8 or 9 inches per year. Zone IX climate is characterized as cooler (i.e. substantially lower temperatures than at present) and drier. The late Wisconsinan advance (i.e. Valders) of the Atlin valley glacier is believed to have culminated during or just prior to zone IX time. The northernmost position of the terminus was in the Moose Bones Bog-White Mountain area. These climatic conditions appear to have been responsible for a stillstand or even stagnation of the terminus in this area during the latter part of the interval.

<u>Zone VIII</u>. This interval, indicated by the Jasper Creek Bog record and, in part, by the Wilson Creek record (Fig. 24, 25, 32), is interpreted as warmer than in zone IX time because of the temporary appearance, in the southern part

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of the valley, of spruce. In view of an earlier discussion, (p. 269-275) it appears more likely that white spruce, rather than Sitka spruce, was involved, even though this leaves a phytogeographic enigma. With white spruce, mean July temperatures would have been at least 50° F. As the climate would have to have been favorable before spruce immigration could take place, the beginning of the interval is set at 10,500 years B.P., approximately 300 years before the spruce pollen peak at the 4.7 m level in the Jasper Creek Bog diagram (Fig. 24). Shortly after the time of this peak temperatures decreased again, bringing an end to zone VIII time by 10,000 years B.P.

Precipitation levels in zone VIII time are not easy to determine from the general record, as changes among the profiles of types which can often be used as indicators of moisture levels are not contemporaneous in Jasper Creek Bog (Fig. 24). In Wilson Creek Bog there is some indication that conditions were more moist than in subsequent zone VII time. This, in connection with the fact that spruce forest usually occurs where mean annual precipitation is at least a few inches higher than where tundra occurs, indicates the climate was relatively moist.

With higher temperatures the freezing level in the Coast Mountains, particularly during the spring and fall when the major storms occur, would have been at a higher elevation than before. This may have changed the annual balance in rain- and snowfall so that, in spite of higher overall precipitation, critical névé areas east of the crest of the

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Coast Range feeding Atlin region glaciers would have received less snow and more rain. It is suggested that a retreat of the terminus of the Atlin and Taku Arm valley glaciers took place under these conditions during zone VIII time.

Zone VII. Around 10,000 years B.P. the landscape was again covered by shrub tundra in response to a decrease in summer temperatures and precipitation to levels comparable to zone IX time. The zone VII climate is characterized as cooler and drier. It is suggested that these climatic conditions caused a halt in the overall pattern of glacial recession, resulting again in stillstand of the terminus, this time in the area of the kame terrace between Little Atlin and Atlin Lakes.

During the zone VII interval ice probably receded for the first time from the Mile 47 Bog site. However, the bog would have remained in close proximity to the glacier margin for some time. With the terminus in the Mile 16 Bog area, approximately 30 miles to the north, a large portion of the valley just west of Mile 47 Bog would still have been occupied by ice.

The record at Mile 47 Bog appears to have begun about the midpoint of zone VII time, and from this it appears that an herbaceous tundra existed in the vicinity of the bog contemporaneously with shrub tundra in the Jasper Creek-Wilson Creek Bog area. Such vegetational differences in these two areas may be explained by differences in microclimates. In the Mile 47 Bog area local climatic conditions were probably str

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strongly influenced by downglacial drainage of cold air from higher elevations to the south and southwest. The Jasper Creek-Wilson Creek Bog area, located away from the main valley, would not have been directly affected by such cold air movements (Fig. 1). A vegetation type adapted to relatively colder conditions would therefore have persisted longer in the Mile 47 Bog area than in the latter area where warmer conditions would have existed earlier.

This local climatic influence may not only explain the lag in appearance of shrub tundra around Mile 47 Bog, but may also be a factor in the relatively late appearance of spruce there. Be that as it may, it is difficult to see how white spruce could have reached the Jasper Creek-Wilson Creek Bog area without having migrated southward through the Atlin valley. Having done so, spruce pollen, at least in small quantities, should appear earlier in the Mile 47 Bog record than it does. In its absence at lower levels in the section (Fig. 23) the problem of the early Holocene phytogeography of white spruce in the valley remains. The present considerations do, however, suggest the possibility that spruce migrated southward through the valley during the preceding, warmer, zone VIII interval, an interval not contained by the Mile 47 Bog record, hence giving rise to the zone VIII peaks in Jasper Creek and Wilson Creek Bogs. Spruce may then have disappeared from mid-latitude parts of the valley during the relatively cooler zone VII time. To account for the reappearance of spruce in the southern part of the valley in

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zone VI time at least 500 years before its appearance in the Mile 47 Bog record, it might be hypothesized that spruce survived the cooler, zone VII interval some place south of the Jasper Creek-Wilson Creek Bog area. Additional palynological studies will be required to test this hypothesis.

Zone VI. The beginning of this zone, 9,000 years B.P. (Fig. 32), is marked by pollen assemblages from Jasper Creek and Wilson Creek Bogs which suggest the establishment of spruce woodland and the return of the climate to a somewhat less cool and less dry condition. Again, areas to the north, as around Mile 47 Bog (Fig. 23), appear to have lagged behind in the development of a corresponding vegetation type. Because temperatures had increased, and apparently continued to increase into the following zone V interval, instead of turning downward again as during the spruce woodland times of zone VIII, glacial recession resumed, to continue until at least mid-Holocene time. This may have been caused, as before, by changes in the seasonal distribution of rain and snow at critical elevations in the Northern Boundary Range where the Atlin valley ice originated. Recession during zone VI time appears, on the basis of glacial deposits at the north end of Atlin Lake (p. 28), to have been intermittent due to minor climatic oscillations which are not reflected by the general palynological record.

Zone V. By 8,000 years B.P. spruce forest had become widespread in the southern part of the valley and spruce woodland was succeeding to spruce forest in the Mile 47 and

Mile 16 Bog areas (Fig. 22-25, 32). Temperatures were continuing to rise, and they probably reached present day levels around the beginning of zone V time. As such this may be considered the beginning of the Thermal Maximum in the Atlin valley. Precipitation levels are also considered to have increased so that the climate now may be characterized as warm and wet. Under these conditions of higher temperatures and precipitation glacial accumulation areas probably received a greater proportion of rain than before. Thus glacial retreat gained momentum. By the end of zone V time at 5,500 years B.P. glaciers may have shrunken to near their post-Wisconsinan minima. Also, with the disappearance of ice from the Atlin valley, the effect of downglacier movements of cold air on vegetation around Mile 47, Mile 16, and Moose Bones Bogs no longer was important. Therefore major vegetation changes among the five bogs appear to have become more nearly synchronous, more nearly reflecting regional climatic changes during the remainder of Holocene time.

Zone IV. Zone IV is marked by pollen assemblages indicating temperature and precipitation levels higher than at present. Thus the climate can be characterized as warmer and wetter (Fig. 32). It is speculated that temperature and precipitation may have reached their Holocene maximum levels and then begun to decrease somewhat toward the end of zone IV time, although there is no real evidence of this in the palynological record.

Zone III. It appears that by some time prior to 3,000 years B.P. the climate began to deteriorate from the conditions of maximum warmth and moisture of zone IV times. During the zone III interval climatic conditions are believed to have been, as in zone V time, more like the present. The zone IV/zone III boundary is defined as the time when temperature and precipitation had decreased to present levels. This is believed to have occurred approximately 2,500 years B.P. As such, this also marks the end of the Thermal Maximum in the Atlin region.

Zone II. As was discussed at various points in interpreting the individual records from the five Atlin valley bogs, temperature and precipitation in the region appear to have been decreasing by about 2,500 years B.P. It is believed that after this point in time conditions were both cooler and drier than at present and remained so until only several hundred years ago. The climate is therefore characterized as relatively cool and dry.

Such conditions may have been responsible for a lowering of the freezing level and a redistribution in the annual balance of rain and snowfall in accumulation areas east of the crest of the northern Boundary Range. With an increase here of snowfall, Neoglacial advance of the Llewellyn and Williston Glaciers could have begun during zone II time.

Although the climatic conditions responsible for this advance are characterized in the same manner as the climates of zone VIII and zone VI times (i.e. cool and dry), when ice in the northern part of the Atlin valley is believed to have been receding (Fig. 32), the present interpretation does not necessarily conflict with these earlier interpretations. Levels of accumulation during the Neoglacial, following a long Thermal Maximum interval of maximum glacial retreat, even if sustained indefinitely, would probably not have brought about an advance of the Llewellyn Glacier of more than a few miles into the main Atlin valley. Here, under the prevailing "cool and dry" climate, there would have been significant downwastage in the terminal zone. A balance between accumulation and wastage would have maintained a certain optimum terminus position at some point in the southern part of the valley (Fig. 1). Given, then, a maximum extension of the glacier to a point well northwest of the valley during the Wisconsinan, under climatic conditions substantially more glacial, the relatively warmer climatic conditions of zone VIII and of zone VI times, even though comparable to Neo-glacial conditions, could have brought about the earlier suggested periods of recession into and through the northern part of the valley.

Zone I. This zone is believed to have begun within the past several hundred years. The lower boundary of the zone in Figure 32 is set somewhat arbitrarily at the 750 year level. The zone is characterized by changes in bog vegetation which indicate a general rise in water level, hence of precipitation, subsequent to zone II time. Increased lime accumulation in the upper few inches of the soil profile studied in vegetation survey stand 59W also indicates increased precipitation in recent times. Although no evidence of a concomitant rise in summer temperatures is discernable in the general palynological record, glacial geological considerations, in conjunction with the parallel relationship of temperature and precipitation changes shown for the majority of the present chronological scheme, indicate that summer temperatures have also undergone a moderate increase to present levels during zone I time. Such changes appear to be related to a general, though moderate, post-Neoglacial retreat of glaciers in many areas.

A complex and well documented history of lesser glacial fluctuations during the past few hundred years, including the Llewellyn Glacier and others of the Northern Boundary Range, (see citations in Chapter III), is believed to have been caused by lesser climatic oscillations which are not reflected in the palynological record. Generally, climatically controlled vegetation changes are so slow that the palynological method is insensitive to such short term climatic changes of lesser magnitude, especially in northern interior regions where the number of indicator species is small and their ecological tolerances are broad.

XV. SUMMARY AND CONCLUSIONS

A study of plant communities and of Holocene vegetation and climatic history in the Atlin region has been made.

Specific emphasis has been placed on the Atlin Lake valley (Atlin valley) where the bulk of the field work was done.

The term "Holocene" is used to designate the interval between the present and the time in the past when certain climatic changes initiated world-wide retreat of the latest substage of Wisconsinan glacial ice. In a nine-zone geobotanical chronology developed for the Atlin region the lower Holocene boundary is tentatively placed at the 10,500 year level, the beginning of the zone VIII time interval.

The Atlin region centers on Atlin Lake and Little Atlin Lake in northwestern British Columbia and south-central Yukon Territory. Secondary roads, including the Atlin road, constructed in conjunction with past mining operations, have been important to the work reported here. The Atlin road begins at mile 866 on the Alaska Highway and runs approximately 82 miles south and southeast through the Atlin valley serving as a transect of the vegetation at lower elevations. Atlin village (latitude 59°54' N; longitude 133°42' W; elevation 2,200 ft), located at mile 60, mid-way on the east shore of Atlin lake, is the only populated place in the region and served as the base of operations for most of the field work.

At the time the study was initiated in the summer of 1966 little knowledge of the glacial geology, soils, flora, plant communities, nor of the geobotanical history of the region was available. In an attempt to remedy this situation plant collections have been made and upland plant communities analyzed and defined using techniques based, in part, on the methods of the Braun-Blanquet school. A quantitative tree survey has been conducted using the point-quarter method, and bog vegetation has been studied and described in general terms. Several bogs have been sampled for pollen analysis, and the results of such analyses have been used as the basis for a geobotanical chronology for the region.

The plant collections have made possible the appending to this dissertation of a preliminary catalog of vascular and non-vascular plants of the Atlin region (Appendix F). This catalog contains 11 lichen, 14 bryophyte and hepatic, and 237 gymnosperm and angiosperm species.

To obtain information about upland plant communities a general vegetation survey was conducted. At two-mile intervals along the Atlin road transect two stands of vegetation were selected within a radius of about 300 feet around the mileposts. Using the Domin cover-abundance scale as a measure of species importance, relevés were drawn up for 30-ft-square quadrats laid out in the stands. The relevés were later assembled on a general association table. After inspection of this table, relevés of stands showing similarities in cover and abundance of dominant species, usually in the arboreal stratum, were regrouped into community association tables.

The major vegetational unit recognized here is the association, represented by a community association table. Where the relevés of a community association table show major differences in composition and/or importance of lower strata, two or more subdivisions of the association, termed faciations, are recognized. A third category, the associes, is applied to vegetation still in early stages of succession, usually following fire.

Twelve community association tables, representing nine associations, one of which is divided into two faciations, and two associes, are presented. The composition and structure of each of these community types, certain aspects of their physical environments, and their importance in terms of frequency of stands and species diversity are discussed. These communities are listed here in descending order of importance:

(1) Mixedwood forest association. Dominated by white spruce and aspen and sometimes also by balsam poplar, tree willow, and lodgepole pine; contains diverse and usually dense shrub and herb strata, the latter being the most dense of any community type; lichen and moss stratum unimportant. Fire history and proximity of a variety of seed sources are considered instrumental in the development of this community type. Associated soils are Boralfic Cryorthods.

(2) White spruce association/shrub-herb faciation. Dominated by white spruce; minor admixtures of other species variable from stand to stand; two faciation subdivisions considered: an herb phase and a shrub-herb-moss phase, the former characterized by greater importance of the herb stratum

and the latter, by high importance of the shrub, herb, and moss strata together.

(3) Aspen association. Dominated by aspen, usually with an admixture of tree willow and sometimes of balsam poplar and white spruce; a mixed broadleaf forest phase is recognized in stands where aspen, balsam poplar, and tree willow are approximately equal in importance; shrub stratum usually denser than in coniferous forests; herb stratum usually quite full; lichen and moss stratum insignificant. Most of the stands of this association lacked signs of former fires.

(4) White spruce association/feather moss faciation. Dominated by white spruce, typically forming a dense canopy; shrubs and herbs scarce; large patches of feather mosses on forest floor. Frozen ground was encountered beneath the moss carpet in two stands. This association is considered the climatic climax on mesic sites in the Atlin valley.

(5) Lodgepole pine brûlé (associes). Abundant fire-killed pine trees present; pine seedlings, and often aspen seedlings abundant. The frequency of this vegetation type indicates the importance of fire in the ecology of the Atlin region.

(6) White spruce-lodgepole pine association. Dominated by white spruce and lodgepole pine. Canopy density and importance of shrub and herb layers variable; some stands approach the feather moss condition.

(7) Lodgepole pine association. Middle-aged or older lodgepole pine trees may dominate; pure, old-growth lodgepole pine forests are rare; shrub and herb strata of low to moderate importance; lichen and moss stratum insignificant to quite dense, particularly where reindeer lichens occur. A soil, classified as a Typic Cryopsamment, was studied in one stand.

(8) Herb-heath association. Arboreal stratum lacking; subshrub and herb strata predominant; occupies exposed, wind-swept sites where frequent, intense fires may be a major perpetuating factor.

(9) White spruce brûlé (associes). Stands contained evidence of older burning only; white spruce generally slow in becoming reestablished; composition and physiognomy of this community type quite variable, probably a result of major differences in fire intensity and degree of burning over short distances, coupled with variable seed sources.

(10) Depression shrub association. Arboreal stratum lacking; shrub stratum dominant; herb stratum diverse but light; moss stratum thick. Characteristic of poorly drained, moist, but not necessarily saturated areas; associated soil a Terric Cryosaprist.

(11) Mixed woodland association. Dominated by widely spaced white spruce, lodgepole pine, and one or more of the broad-leaved species in an open and sunny, parklike aspect; shrubs and herbs only scattered; much of the ground covered by reindeer lichens.

(12) Alpine fir association. Dominated by alpine fir, often forming a dense canopy; shrub stratum sparse or dense depending on openness of canopy; herb stratum sparse; lichen and moss stratum dense. This vegetation type is believed to occur largely in response to higher moisture levels and is therefore found more commonly in the southern portion of the Atlin valley and at higher elevations, outside the range of the general vegetation survey.

Two of the 86 stands studied are unclassified, representing transitional, or ecotonal vegetation. General observations show that ecotonal conditions are of considerable areal importance in the Atlin valley. The survey was designed to exclude stands containing vegetation of this type and therefore the results do not portray the true status of it.

Two other community types which were observed but not measured in the general vegetation survey are the lodgepole pine woodland, characterized by widely spaced, mature pine trees and a dense reindeer lichen ground cover, and the mixed coniferous forest, wherein white spruce, alpine fir, and lodgepole pine share dominance. A more detailed analysis of general vegetation survey data is provided on pages 106-126.

In the tree survey, point-quarter transects were run at one-mile intervals along most of the Atlin road. Trees in a zone about 1,000 feet wide, centering on the road, were included. The survey has resulted in the following information:

(1) Almost half (47 percent) of the trees in the Atlin valley are white spruce. With a frequency of 37 percent, this species occupies over a third of the landscape within range of the survey. With respect to basal area, it is more important than all other species combined.

(2) Lodgepole pine, although slightly less important than aspen in terms of numbers and land area occupied, is second only to spruce in basal area. Even so, it has less than half the basal area of spruce.

(3) Dead (fire-killed) lodgepole pine is quite important in terms of numbers and amount of occupied terrain, being fourth in both respects. The data indicate that over eight percent of the valley area has been recently burned. Observations along the Alaska Highway and elsewhere indicate that this may be a conservative measure of the effect of fire.

(4) Aspen is the second most abundant tree in the valley and occupies slightly more land area than pine (disregarding dead pine trees). It is considerably less important in terms of basal area, however.

(5) Tree willow is common as an admixture of most forest types.

(6) Alpine fir appears to be quite unimportant compared to spruce, pine, aspen, and tree willow. As discussed above, however, it is believed to be an important component of the total valley forest, growing primarily at higher elevations.

(7) Balsam poplar is relatively unimportant, although it is widespread.

(8) Alder is insignificant as a tree species in the Atlin valley.

(9) A comparison of tree survey and general vegetation survey data shows a high degree of correlation with regard to the frequency, abundance, and dominance of the forest tree species.

(10) Eighty-three percent of the 5,840 quadrants observed contained trees.

Bog vegetation was studied in six bogs which were also sampled for palynological purposes. From north to south in the Atlin valley these are: Moose Bones, Mile 16, Mile 47, Mile 52, Jasper Creek, and Wilson Creek Bogs. Although these bogs are quite variable, several general, more or less concentric vegetation zones, occurring along a moisture gradient, can be recognized. No one bog contains all of these.

(1) Sedge-moss zone. Dominated by *Carex aquatilis* ssp. *aquatilis* and *Drepanocladus aduncus*. Water table ordinarily above the surface. (2) Sedge zone. Dominated by *Carex aquatilis*, with few other plants present. Water table at or below the surface. (3) Bulrush zone. Dominated by *Scirpus validus*, with few other species present. Water table above surface. (4) Shrub willow zone. Dominated by *Salix* spp., sometimes with an admixture of *Betula glandulosa*. (5) Grass zone. Dominated by various species of Gramineae. Subdivided into *Calamagrostis neglecta*, *Deschampsia caespitosa*, and *Poa*

palustris zones. (6) Bog spruce zone. Dominated by white spruce, shrub willows, and a variety of herbs and mosses.

Ericaceous plants and *Sphagnum* spp. were rare, reflecting, along with other, positive indicator species, such as *Triglochin maritimum*, the generally alkaline growing conditions in Atlin valley bogs.

A circumnavigation of Mile 47 Bog, with a description of the upland vegetation in eight sectors up to a distance of approximately 200 feet from the bog, shows the typical heterogeneity and variability over short distances of upland vegetation adjacent to the bog and in the Atlin valley in general.

A palynological record, in the form of five pollen and spore diagrams, is presented. Seven radiocarbon dates have permitted the application of an absolute chronology to the diagrams, beginning approximately 11,000 years B.P. in the Jasper Creek Bog record. Some extrapolations and interpolations, using calculated sediment accumulation rates, have had to be made.

Palynomorphs whose percentage frequencies are plotted on the pollen and spore diagrams are separated into two categories: (1) aquatic and semi-aquatic bog (ASB) types and (2) non-aquatic bog and extra-bog (NEB) types. The pollen diagrams are divided into three major pollen assemblage zones for purposes of description and discussion. These include, from bottom to top, the shrub, spruce, and pine zones. In most cases the zonal boundaries are not contemporaneous from bog to bog, showing that major vegetation changes occurred at different times in different parts of the Atlin valley.

As background for interpreting the palynological record, a comparison of surface pollen spectra and data from the tree survey was made. Consideration is made of the extent to which both the regional vegetation and the local vegetation, i.e. within a few miles of the bogs, is reflected by the spectra.

Lodgepole pine generally appears over twice as important in the pollen rain as it actually is in the vegetation. Spruce should be interpreted, from its relative importance in the pollen spectra, to be approximately twice as prevalent in the regional vegetation. With regard to alpine fir, the presence of one or a few grains may be taken to indicate that the species is present, if not important, somewhere in the general vicinity of the bog. Single grains of Tsuga and Larix probably result from dispersal from distant regions. Juniperus grains in the three northern bogs reflect the presence in this part of the valley of the upland, dry sites bearing the herb-heath type of vegetation. Populus is so poorly represented that nothing can be said of its vegetational status except, perhaps, in extreme cases, as at Mile 47 Bog, where it reaches four percent of the pollen total.

Tree willows of the forests in general are probably not represented, although the relatively high Salix percentage in Mile 47 Bog probably reflects the presence of a nearby stand of almost pure tree willow vegetation. Except for such occurrences as this, which would be difficult to distinguish in fossil spectra (unless individual species of willow pollen could be recognized), the importance of willow shrubs in non-aquatic parts of the bogs can be reasonably determined from the percentages of willow pollen. *Alnus* is considerably overrepresented, and where its pollen is encountered in large quantities the indication seems to be that the plant is important as a pioneering shrub in local, relatively fresh stream deposits somewhere not more than a few miles from the bog. *Betula* is also overrepresented, but not as much as alder. In general the presence of this pollen type may be taken to indicate that shrub birch is common in and near the bog.

Lycopodium microspores are found in bogs with mature, old-growth spruce or mixed coniferous forest nearby. Grass is underrepresented, particularly in Moose Bones Bog where several species occur near the deposition site and in Mile 16 Bog where the herb-heath vegetation type occurs on the slopes above the bog on the east. *Epilobium* pollen appeared only in Mile 16 Bog where the species was prevalent near the deposition site. *Artemisia*, appearing sparingly in the surface samples of Moose Bones and Mile 16 Bogs, gives, along with *Juniperus*, an indication of the nearby herb-heath vegetation on dry slopes.

There is some evidence that pollen assemblages are biased toward vegetation located within a few miles to the south of the bogs due to prevailing southerly winds during

the flowering season. But there is just as much evidence to refute this, wherein particular pollen percentages compare better with the composition of the vegetation to the north. It is concluded, therefore, that a considerable amount of atmospheric mixing of pollen occurs, probably because of turbulence over the generally irregular topography and because of the heterogeneity of the vegetation. This is an indication that the average pollen rain, as determined in the five bogs, bears a characteristic relationship to the vegetation of the Atlin valley and that similar relationships may have existed in the past.

The palynological record sheds light on the Holocene phytogeography of white spruce and lodgepole pine. White spruce appears to have migrated southwestward from the west-central Yukon refugium and to have reached the northern part of the Atlin valley by at least 10,500 years B.P. During a warmer interval, from approximately 10,500-10,000 years B.P., it may have migrated southward through the valley and into the Jasper Creek-Wilson Creek Bog area. During a subsequent interval lasting approximately 1,000 years, when temperatures were too low for spruce, it retreated both to the northwest and south from the valley. With the return of warmer conditions approximately 9,000 years B.P. white spruce reentered the valley from each of these directions. By around 7,200 years the two spruce migration fronts met somewhere in the mid-latitude region of the valley. Thus the Holocene afforestation of the valley was complete.

Lodgepole pine is believed to have migrated from a refugium in northeastern British Columbia and western Alberta. It became established first around 4,000 years B.P. in the Mile 16 and Wilson Creek Bog areas. These areas were more directly accessible to the westward migrating pine than were intervening areas because they are in line with low terrain extending eastward to the Teslin depression. Later pine migrated north and south from the Mile 16 Bog area to the vicinities of Moose Bones and Mile 47 Bogs. Direct westward migration of pine into the latter areas is believed to have been blocked by mountains lying east of them.

The knowledge which has been developed thus far of the extant Atlin valley vegetation, in conjunction with the observed relationships between the vegetation and the modern pollen rain, provide a basis for a broad interpretation of past vegetation types from the palynological record. Additional observations of the distribution and climatic conditions associated with vegetation types not occurring in the Atlin valley at present, but at higher elevations in the region, along with vegetation-climate relationships discussed in the literature, allow certain conclusions regarding past environments to be made.

The time sequence of Holocene environments as interpreted for the Atlin region is represented by a provisional geobotanical chronology comprising nine discrete intervals or time zones.

Zone IX. ≥11,000-10,500 years B.P. During this interval the main Atlin valley was still occupied by a lengthy glacier, the surface of which was relatively level and averaged about 3,000 feet in elevation, or 800 feet above the present level of Atlin Lake. The glacier sloped gently to a terminus in the northernmost part of the valley and was characterized by a more or less equilibrium regime tending toward downwasting and stagnation. It is believed that the terminus at this time still lay close to its maximum late Wisconsinan position. The pitted outwash in the Moose Bones Bog area and the knob and kettle topography and associated gravel terraces in the White Mountain-Squanga Lake region were formed at this time. The Mile 16, Mile 47, and Mile 52 Bog sites were still covered by ice, but the Wilson Creek and Jasper Creek Bog sites had recently become exposed by the glacial thinning subsequent to the late Wisconsinan maximum. Vegetation in the vicinity of the latter bogs was a shrub tundra, indicative of mean July temperatures of 46-48° F and of mean annual precipitation of 6-8 inches. Zone IX climate is characterized as relatively cooler and drier than any subsequent climatic interval, except possibly zone VII as discussed below. Presumably these conditions were contemporaneous with cooler and wetter (more maritime) conditions along the Alaskan coast. On this basis it is suggested that the Arctic Front, or line of demarcation between the generally anticyclonic continental weather conditions of the Atlin area and the normal cyclonic, oceanic conditions of the coast, lay near or partly within the southwestern portion of the Atlin region.

The zone IX interval is believed to represent approximately the last 500 years of the Wisconsinan Age of the Pleistocene Epoch in the Atlin region. As such it is probably comparable to the Valders maximum of the American mid-continent chronology and to the Younger Dryas in other regions. This would make it contemporaneous with the Late Glacial III phase outlined by Heusser in his palynological studies in the overall North Pacific maritime region.

Zone VIII. 10,500-10,000 years B.P. Under the influence of a warmer climate the Atlin valley glacier terminus underwent a retreat of 10-15 miles from its zone IX position. Vegetation in the Jasper Creek-Wilson Creek Bog area changed to a spruce woodland type, similar to, but drier than the present vegetation lying between approximately 4,200 and 4,500 feet in the Atlin region. Mean July temperatures were somewhat above the 50° F level, and annual precipitation may have risen to perhaps 8-10 inches. Though slightly warmer than zone IX time, the climate is still characterized as cool and dry. Presumably the mean position of the Arctic Front was farther toward the coast than in zone IX time, i.e. well south and west of the Atlin region.

Zone VIII is recognized as the first distinct subdivision of the Holocene Epoch in the Atlin region. Thus the lower Holocene boundary is set at 10,500 years. This represents the beginning of the Pre-Boreal or the Early Postglacial interval as recognized by Heusser in southeastern Alaska.

Zone VII. 10,000-9,000 years B.P. A return to cooler conditions caused a halt in the retreat of the Atlin valley glacier ice front. This resulted in a stillstand or possibly even a slight readvance. The large kame terrace lying along the valley side slope between Little Atlin and Atlin Lakes provides the clue to this interpretation.

Vegetation in the Jasper Creek-Wilson Creek Bog area during this interval was a shrub tundra. Summer temperatures and precipitation may have been as low as during zone IX time, with the mean position of the Arctic Front again shifted inland, closer to the Atlin region.

The zone VII interval is considered a part of Pre-Boreal or Early Postglacial time, and represents a climatic oscillation not generally delineated in other areas. It may correlate with the Sumas Stade of southwestern British Columbia, and possibly the valders II stillstand (or readvance) in the mid-continent chronology.

Zone VI. 9,000-8,000 years B.P. An intermittent retreat of the Atlin valley glacier seems to have occurred during this interval, resulting in the formation of the series of closely spaced recessional moraines in the vicinity of the northern end of Atlin Lake. Recession probably continued to gain momentum throughout this interval and into zone V time under the influence of a generally ameliorating climate. The Mile 47-Mile 52 Bog area was first exposed during zone VI time. The Mile 16 Bog site was probably also exposed, but the ice block buried there had not yet melted out to create the kettle in which the bog subsequently developed.

A spruce woodland vegetation again developed in the vicinity of Jasper Creek and Wilson Creek Bogs. A shrub tundra may have persisted around Mile 47 Bog because spruce had not yet re-migrated to this area. The proximity of the Mile 47 Bog site to the margin of the glacier, whose terminus was still 20-25 miles farther north, and the effects of cold, downglacier winds may also have delayed the development of a warmer-habitat vegetation.

This interval is considered a third and final subdivision of a period comparable to the Pre-Boreal in other regions or the contemporaneous Early Postglacial recognized by Heusser in southeastern Alaska.

It is suggested that during zone VI time the mean position of the Arctic Front was again shifted coastward through the dominance of the continental high pressure anticyclone. This resulted in the cool-dry conditions believed to have existed in the Atlin region as opposed to the contemporaneous cool-humid conditions previously described by Heusser for the coastal areas of Alaska.

Zone V. 8,000-5,500 years B.P. By the beginning of zone V time temperatures in the Atlin valley had more or less reached present levels. As such this marks the beginning of the Thermal Maximum interval which, including its waxing and waning phases, was to last for upwards of 5,000 years. At the beginning of this time precipitation was at least as great as at present, i.e. 11-12 inches per year. The zone V climate is generally characterized as warm and wet. Again the term "wet" is used not in an absolute sense, but to designate a precipitation regime which was wet relative to the much drier and more continental conditions associated with earlier tundra vegetation.

The Atlin valley was occupied primarily by white spruce forest during zone V time. The glacier continued to oscillate, but the general trend now was downwastage and recession. By the end of the interval the terminus may have reached a position not far from the present Llewellyn Glacier terminus.

Zone V corresponds to the Boreal of other areas. In the Atlin region this warm-wet interval begins at the same time as the warm-dry Boreal of southeastern Alaska as determined by Heusser. Therefore the mean position of the Arctic Front during this interval may be assumed to have been shifted even farther toward the coast. Furthermore, regional temperatures, higher than in any previous interval, including zone VIII, probably resulted in increasing storminess and hence an increasing wetness, particularly during the summer months, reaching its maximum in the subsequent zone IV interval.

Zone IV. 5,500-3,250 years B.P. During this interval Holocene temperatures and precipitation attained their maximum levels. It is suggested that mean July temperatures may have been as high as 56° F and that precipitation was several inches higher than at present. Thus the zone IV climate is characterized as (relatively) warmer and wetter. At this time glaciers are believed to have shrunken to their post-Wisconsinan minima. The main Atlin valley glacier terminus is presumed to have receded well into the Boundary Range source valley of the present Llewellyn Glacier, and in fact some distance upvalley from its 20th century terminus. This, of course, would represent the ultimate retreat of the main Atlin valley ice that began about 7,000 years earlier, i.e. in zone IX time.

Vegetation in the Atlin valley under these conditions may have been more luxuriant than at present. It may have resembled the present vegetation of the southwestern part of the region where the maritime climatic influence is greater. In particular, alder is believed to have been abundant as an inhabitant of wet sites in old-growth spruce forests, such sites being significantly more widespread than at present.

Zone IV may be comparable to the Atlantic period of other areas and to the middle Hypsithermal as recognized by Heusser in southeastern Alaska, although its time boundaries appear to be later than in the latter area.

As for the general position of the Arctic Front during this time, it still lay farther toward the coast. In fact it is believed to have been sufficiently withdrawn from the Juneau Icefield itself that even the strongly maritime Taku Glacier receded some dozen miles north of its subsequent Neoglacial positions (M. M. Miller, personal oral communication, 1970). As in the case of zone V time the increased temperatures in zone IV accompanied increased atmospheric turbulence and storminess which in turn resulted in continuing wetter conditions.

Zone III. 3,250-2,500 years B.P. The appearance of alpine fir in the Atlin valley spruce forests is considered an indication of continuing high precipitation levels but of decreasing temperatures. By the end of this interval mean July temperatures are believed to have decreased to the present level of about 54° F. The time this temperature level was attained is designated the end of the Thermal Maximum.

The zone III interval is considered comparable to the Sub-Boreal of other areas. It appears to have ended about 1,000 years later in the Atlin region than as reported by Heusser with respect to southeastern Alaska. On the other hand, it is nearly contemporaneous with the end of Sub-Boreal (and of Thermal Maximum) time in more southerly regions. As for the position of the Arctic Front, it began to shift inland during this time, as climatic conditions more closely approached those characterizing Neoglacial time. With this return to generally colder conditions, there was generally less storminess in the Atlin area, hence less precipitation during the growing season.

Zone II. 2,500-c 750 years B.P. During this interval climate was somewhat cooler as well as drier than at present. Now the Arctic Front and storm tracks were apparently shifted inland with increased dominance of the maritime pressure cell. Consequently there was decreased storminess and precipitation in the Atlin region. Neoglacial advances of mountain and valley glaciers in the northern Boundary Range reflect these conditions of lower temperature and increased maritimity in that sector; but decreased storminess is reflected by the increase in dry climate vegetation in the interior Atlin region as shown by the palynological record. In this regard it is noted that a greater proportion of pine in the Atlin valley forests reflects a higher frequency of forest fires resulting from the generally drier conditions. The Atlin valley climate is thus characterized as cool and dry and therefore out of phase with that over the Alaska coast. It is believed to have been similar to climatic conditions in zones VI and VIII.

Zone I. c 750 years B.P. to present. The palynological record does not indicate the complex, short-term climatic oscillations which may have occurred in the Atlin region during late Neoglacial (Little Ice Age) time. Further studies in dendrochronology, lichenometry, glacial geology, and perhaps more detailed palynological analyses of recent bog sediments and of lake bottom sediments will be necessary to work out this pattern. It appears that there has been a general, minor warming trend to present temperature levels during the past several hundred years. There is evidence in the bogs, furthermore, of an increase in precipitation during this time. In the existing glaciers of the Boundary Range and along the Alaskan Coast there has been a much more sensitive fluctuational response to late Neoglacial climatic pulsations. This further supports the contention that the Arctic Front in Holocene time generally shifted back and forth in a linear belt paralleling either side of the axis of the Boundary Range somewhat south and west of the Atlin valley.

The sequence of biogeochronological subdivisions of the Holocene Epoch in the Atlin region is similar to sequences which have been worked out by others in many different regions. In some cases subdivision boundaries are contemporaneous. In particular, such synchroneity appears to exist in chronologies of the maritime regions west and southwest of the Coast Mountains and the interior Atlin region lying to the northeast. A contribution to understanding the nature of these complex relationships is given by the palynological evidence discussed in this dissertation. The key to broad regional interpretations lies in recognizing that cool and moist conditions in the Alaskan coastal zone have been approximately contemporaneous with cool and dry climatic conditions in the northern British Columbia-Yukon interior, and that warm and relatively dry coastal climatic conditions appear to have prevailed at times when the interior experienced a warm and wet climate. The explanation of these seemingly opposite secular trends appears to relate to the delicately shifting position of the Arctic Front in and near the Atlin region at least in the late Pleistocene, and on through the Holocene Epoch.

FOOTNOTES

FOOTNOTES

[1]Moose Bones Bog: an informal, unofficial name for the bog located northwest of the Jakes Corner-Carcross road at mile 4.5.

The other bogs are named for their locations along the Atlin road or for nearby creeks which appear on maps of the National Topographic Series published by the Surveys and Mapping Branch, Canada Department of Mines and Technical Surveys, Ottawa.

[2]A complete set of the Atlin region vascular plant collections through 1968 is housed in the Beal-Darlington Herbarium of Michigan State University. Nearly complete duplicate sets are to be given to the herbarium of the National Museum of Natural Sciences in Ottawa and to the herbarium of the University of Alaska. A fourth set may be given to the herbarium of Queen's University in Kingston, Ontario. Additional collections from the Atlin region will be deposited primarily in these four herbaria.

A set of the cryptogams has been given to the Cryptogamic Herbarium of Michigan State University, and a second set remains in the writer's private collection.

Voucher specimens for the pollen reference sample preparations (Appendix E) are housed in the Beal-Darlington Herbarium of Michigan State University.

[3]Brûlé. This term is French and applies to areas burned over within approximately 30 years prior to investigation and whose vegetation is still in early stages of secondary succession.

[4]The writer's pacelength on smooth and level terrain is approximately 38 inches.

[5]This sample, like the uppermost "surface" sample in Jasper Creek Bog, was loose, coarsely fibrous, and watery. It was not considered feasible to sample it at close intervals because of the likelihood of settling, or differential settling of pollen and spores in this portion of the column.

LITERATURE CITED

LITERATURE CITED

Aitken, J. D. 1959. Atlin map-area, British Columbia. Geological Survey of Canada Memoir 307. 89 p.

Armstrong, J. E. and H. W. Tipper. 1948. Glaciation in north central British Columbia. American Journal of Science 246: 283-310.

Bartley, D. D. 1967. Pollen analysis of surface samples of vegetation from arctic Quebec. Pollen et Spores 9: 101-105.

Bilsland, W. W. 1952. Atlin, 1898-1910: The story of a gold boom. British Columbia Historical Quarterly 26: 121-180.

Borns, H. W., Jr. and R. P. Goldthwait. 1966. Late-Pleistocene fluctuations of Kaskawulsh Glacier, southwestern Yukon Territory, Canada. American Journal of Science 264: 600-619.

Bostock, H. S. 1948. Physiography of the Canadian cordillera, with special reference to the area north of the 55th parallel. Geological Survey of Canada Memoir 247. 106 p.

Boughner, C. C., R. W. Longley, and M. K. Thomas. 1956. Climatic summaries for selected meteorological stations in Canada. Volume III. Frost data. Department of Transport, Meteorological Division. Toronto. 94 p.

Boughner, C. C. and M. K. Thomas. 1967. The climate of Canada. Meteorological Branch, Air Services, Department of Transport, Toronto. 74 p.

Broecker, W. S. and W. R. Farrand. 1963. Radiocarbon age of the Two Creeks forest bed, Wisconsin. Geological Society of America Bulletin 74: 795-802.

Buell, M. F. 1947. Mass dissemination of pine pollen. Journal of the Elisha Mitchell Scientific Society 63: 163-167.

Cairnes, D. D. 1913. Portions of the Atlin district, British Columbia. Geological Survey of Canada Memoir 37.

Carroll, G. 1943. The use of bryophytic polsters and mat in the study of recent pollen deposition. American Journal of Botany 30: 361-366.

Chapman, J. D. and D. B. Turner (ed.). 1956. British Columbia atlas of resources. Climatic maps p. 14-22. British Columbia National Resources Conference, 1956.

Christie, R. L. 1957. Bennett, Cassiar District, British Columbia. Geological Survey of Canada, Map 19-1957.

Cockfield, W. E. 1925. Silver-lead deposits in the Atlin district, British Columbia. Geological Survey of Canada Summary Report, 1925: 15A-24A.

Cohee, George V. 1968. Holocene replaces recent in nomenclature usage of the U. S. Geological Survey. American Association of Petroleum Geologists Bulletin 52.

Colinvaux, P. A. 1964. The environment of the Bering Land Bridge. Ecological Monographs 34: 297-329.

Critchfield, W. B. 1957. Geographic variation in Pinus contorta. Maria Moors Cabot Foundation Publication No. 3. Harvard University, Cambridge.

Curtis, J. T. 1959. The vegetation of Wisconsin: An ordination of plant communities. The University of Wisconsin Press, Madison. 655 p.

Cushing, E. J. and H. E. Wright, Jr. (ed.). 1967. Quaternary Paleoecology. Yale University Press, New Haven and London. 433 p.

Daubenmire, R. 1968. Plant communities: A textbook of plant synecology. Harper and Row, New York. 300 p.

Davis, M. B. 1963. On the theory of pollen analysis. American Journal of Science 261: 897-912.

Davis, M. B. 1969. Palynology and environmental history during the Quaternary Period. American Scientist 57: 317-332.

Davis, M. B. and J. C. Goodlett. 1960. Comparison of the present vegetation with pollen spectra in surface samples from Brownington Pond, Vermont. Ecology 41: 346-357.

Deevey, E. S., Jr. and R. F. Flint. 1957. Postglacial Hypsithermal interval. Science 125: 182-184.

Denny, C. S. 1952. Late Quaternary geology and frost phenomena along the Alaska Highway, northern British Columbia and southeastern Yukon. Geological Society of America Bulletin 63: 883-922.

Denton, G. H. and M. Stuiver. 1966. Neoglacial chronology, northeastern St. Elias Mountains, Canada. American Journal of Science 264: 577-599.

Faegri, K. and J. Iversen. 1964. Textbook of pollen analysis. Hafner Publishing Co., Inc., New York. 237 p.

Flint, R. F. 1957. Glacial and Pleistocene geology. John Wiley & Sons, Inc., New York. 553 p.

Frey, D. G. 1951. Pollen succession in the sediments of Singletary Lake, North Carolina. Ecology 32: 518-533.

Fulton, R. J. 1965. Silt deposition in late-glacial lakes of southern British Columbia. American Journal of Science 263: 553-570.

Griggs, R. F. 1934. The problem of arctic vegetation. Journal of the Washington Academy of Science 24: 153-175.

Griggs, R. F. 1937. Timberlines as indicators of climatic trends. Science 85: 251-255.

Gwillim, J. C. 1901. Atlin mining district. Geological Survey of Canada Annual Report 1899 12: B5-48.

Halliday, W. E. D. 1937. A forest classification for Canada. Canada Department of Mines and Natural Resources, Forest Service Bulletin 89: 1-50.

Halliday, W. E. D. and A. W. A. Brown. 1943. The distribution of some important forest trees in Canada. Ecology 24: 353-374.

Hansen, H. P. 1949a. Pollen content of moss polsters in relation to forest composition. American Midland Naturalist 42: 473-479.

Hansen, H. P. 1949b. Postglacial forests in west central Alberta, Canada. Bulletin of the Torrey Botanical Club 76: 278-289.

Hansen, H. P. 1950. Postglacial forests along the Alaska Highway in British Columbia. Proceedings of the American Philosophical Society 94: 411-421.

Hansen, H. P. 1953. Postglacial forests in the Yukon Territory and Alaska. American Journal of Science 251: 505-542.

Hegg, K. M. 1967. A photo identification guide for the land and forest types of interior Alaska. U. S. Forest Service Research Paper NOR-3. 55 p.

Heusser, C. J. 1954. Alpine fir at Taku Glacier, Alaska, with notes on its postglacial migration to the territory. Bulletin of the Torrey Botanical Club 81: 83-86.

Heusser, C. J. 1960. Late-Pleistocene environments of North Pacific North America. American Geographical Society Special Publication No. 35. 308 p.

Heusser, C. J. 1965. A Pleistocene phytogeographical sketch of the Pacific Northwest and Alaska, p. 469-483. In H. E. Wright, Jr. and D. G. Frey (ed.). The Quaternary of the United States. Princeton University Press, Princeton. 922 p.

Heusser, C. J. 1966. Pleistocene climatic variations in the western United States, p. 9-36. In Pleistocene and post-Pleistocene climatic variations in the Pacific area. Bishop Museum Press, Honolulu.

Heusser, C. J. 1967a. Pleistocene and postglacial vegetation of Alaska and the Yukon Territory, p. 131-151. In H. P. Hansen (ed.) Arctic Biology. Oregon State University Press, Corvallis. 318 p. 2nd ed.

Heusser, C. J. 1967b. Polar hemispheric correlation: Palynological evidence from Chile and the Pacific Northwest of America, p. 124-141. In J. S. Sawyer (ed.). Proceedings of the International Symposium on World Climate, 8,000 to 0 B. C. Royal Meteorological Society, London. 229 p.

Holland, S. S. 1964. Landforms of British Columbia, a physiographic outline. British Columbia Department of Mines and Petroleum Resources Bulletin No. 48. 138 p.

Horton, K. W. 1956. The ecology of lodgepole pine in Alberta and its role in forest succession. Canada Department of Northern Affairs and Natural Resources, Forestry Branch, Forest Research Division, Technical Note No. 45. 29 p.

Hultén, E. 1940. History of botanical exploration in Alaska and Yukon Territories from the time of their discovery to 1940. Botaniska Notiser 1940: 289-346.

Hultén, E. 1968. Flora of Alaska and neighboring territories. Stanford University Press, Stanford. 1008 p.

Janssen, C. R. 1967. A floristic study of forests and bog vegetation, northwestern Minnesota. Ecology 48: 751-765.

Jeffrey, W. W. 1961. Notes on plant occurrence along lower Liard River, Northwest Territories. National Museum of Canada Bulletin 171: 32-115.

Johnston, W. A. 1926. The Pleistocene of Cariboo and Cassiar districts, British Columbia, Canada. Transactions of the Royal Society of Canada Ser. 3, Vol. 20, Sec. 4: 137-147.

Kendrew, W. G. and D. P. Kerr. 1955. The climate of British Columbia and the Yukon Territory. Edmund Cloutier, Ottawa. 222 p.

Kerr, F. A. 1934. Glaciation in northern British Columbia. Transactions of the Royal Society of Canada 28: 17-31.

Kerr, F. A. 1936. Quaternary glaciation in the Coast Range, northern British Columbia and Alaska. Journal of Geology 44: 681-700.

Kershaw, K. A. 1964. Quantitative and dynamic ecology. Edward Arnold, Ltd., London. 183 p.

La Roi, G. H. 1967. Ecological studies in the boreal spruce-fir forests of the North American taiga. I. Analysis of the vascular flora. Ecological Monographs 37: 229-253.

Leahey, A. 1949. Factors affecting the extent of arable lands and the nature of the soils in the Yukon Territory. Proceedings of the 7th Pacific Science Congress 6: 16-20.

Leopold, E. B. 1967. Late-Cenozoic patterns of plant extinction, p. 203-246. In P. S. Martin and H. E. Wright, Jr. (ed.) Pleistocene extinctions, the search for a cause. Yale University Press, New Haven. 453 p.

Lichti-Federovich, S. and J. C. Ritchie. 1965. Contemporary pollen spectra in central Canada. II. The forest-grassland transition in Manitoba. Pollen et Spores 7: 63-88.

Lietzke, D. A. 1969. Soils and soil-vegetation relationships in the Atlin valley, British Columbia, Canada. Unpublished manuscript. Department of Soil Science, Michigan State University, East Lansing. 21 p.

Livingston, D. A. 1955. Some pollen profiles from arctic Alaska. Ecology 36: 587-600.

Lutz, H. J. 1956. Ecological effects of forest fires in the interior of Alaska. U. S. Dept. of Agriculture Technical Bulletin No. 1133. 121 pp.

Mackay, J. R. and J. Terasme. 1963. Pollen diagrams in the Mackenzie Delta area, N.W.T. Arctic 16: 228-238.

McAndrews, J. H. 1966. Postglacial history of prairie, savanna, and forest in northwestern Minnesota. Memoirs of the Torrey Botanical Club 22(1): 1-72.

McTaggart-Cowan, I. 1941. Fossil and subfossil mammals from the Quaternary of British Columbia. Transactions of the Royal Society of Canada 35. Section IV: 39-50.

Miller, C. D. 1969. Chronology of neoglacial moraines in the Dome Peak area, North Cascade Range, Washington. Arctic and Alpine Research 1: 49-66.

Miller, M. M. 1961. A distribution study of abandoned cirques in the Alaska-Canada Boundary Range, p. 833-847. In Geology of the Arctic, Vol. II. University of Toronto Press.

Miller, M. M. 1963. Taku Glacier evaluation study. State of Alaska Department of Highways (mimeo.) 200 p. plus appendices.

Miller, M. M. 1964a. Inventory of terminal position changes in Alaskan coastal glaciers since the 1750's. Proceedings of the American Philosophical Society 108: 257-273.

Miller, M. M. 1964b. Morphogenetic classification of Pleistocene glaciations in the Alaska-Canada Boundary Range. Proceedings of the American Philosophical Society 108: 247-256.

Miller, M. M. 1967. Alaska's mighty rivers of ice. National Geographic Magazine 131: 194-217.

Miller, M. M., C. P. Egan, and R. E. Beschel. 1968. Neoglacial climatic chronology from recent radiocarbon and dendrochronological dates in the Alaskan Panhandle, No. 16. In Science in the North. Glaciological and Arctic Sciences Institute, Michigan State University, East Lansing. (mimeo.) (abstr.)

Miller, N. G. 1969. Late- and postglacial vegetation change in southwestern New York state. Ph. D. Thesis, Michigan State University, East Lansing. 325 p.

Monger, J. W. H. 1968. Late Paleozoic rocks of northwestern British Columbia and south-central Yukon: A progress report, p. 49-50. In Program and Abstracts, 19th Alaskan Science conference. Alaska Division, American Association for the Advancement of Science, Whitehorse. 72 p.

Moss, E. H. 1953a. Forest communities in northwestern Alberta. Canadian Journal of Botany 31: 212-252.

Moss, E. H. 1953b. Marsh and bog vegetation in northwestern Alberta. Canadian Journal of Botany 31: 448-470.

Mulligan, R. 1963. Geology of Teslin map-area, Yukon Territory. Geological Survey of Canada Memoir 326. 96 p.

Neustadt, M. I. 1967. The lower Holocene boundary, p. 415-425. In E. J. Cushing and H. E. Wright, Jr. (ed.). Quaternary Paleoecology. Yale University Press, New Haven. 433 p.

Oberle, M. 1969. Forest fires: Suppression policy has its ecological drawbacks. Science 165: 568-571.

Petterssen, S. 1958. Introduction to meteorology. McGraw-Hill Book Co., Inc., New York. 327 p. 2nd ed.

Péwé, T. L. 1967. Permafrost and its effect on life in the North, p. 27-65. In H. P. Hansen (ed.) Arctic Biology. Oregon State University Press, Corvallis. 318 p. 2nd ed.

Pollock, J. B. 1918. Blue-green algae as agents in the deposition of marl in Michigan lakes. 20th Michigan Academy of Science Report, 1918: 247-262.

Poore, M. E. D. 1955. The use of phytosociological methods in ecological investigations. I. The Braun-Blanquet system. II. Practical issues involved in an attempt to apply the Braun-Blanquet system. III. Practical application. Journal of Ecology 43: 226-244; 245-269; 606-651.

Poore, M. E. D. 1956. The use of phytosociological methods in ecological investigations. IV. General discussion of phytosociological problems. Journal of Ecology 44: 28-50.

Porsild, A. E. 1951. Botany of southeastern Yukon adjacent to the Canol road. National Museum of Canada Bulletin No. 121: 1-400.

Porsild, A. E. 1964. Illustrated flora of the Canadian Arctic Archipelago. National Museum of Canada Bulletin 146: 1-218, 2nd ed., revised.

Porsild, A. E. and H. A. Crum. 1961. The vascular flora of Liard Hotsprings, B. C., with notes on some bryophytes. National Museum of Canada Bulletin 171: 131-197.

Potzger, J. E. 1956. Pollen profiles as indicators in the history of lake filling and bog formation. Ecology 37: 476-483.

Rampton, V. N. 1969. Pleistocene geology of the Snag-Klutlan area, southwestern Yukon Territory, Canada. Ph. D. Thesis, University of Minnesota, Minneapolis. 237 p.

Raup, H. M. 1934. Phytogeographic studies in the Peace and upper Liard River regions, Canada, with a catalogue of the vascular plants. Contributions from the Arnold Arboretum of Harvard University VI. 230 p.

Raup, H. M. 1941. Botanical problems in boreal America. I and II. The Botanical Review 7: 147-248.

Raup, H. M. 1945. Forests and gardens along the Alaska Highway. Geographical Review 35: 22-48.

Raup, H. M. 1947. The botany of southwestern MacKenzie. Sargentia. A continuation of the Contributions from the Arnold Arboretum of Harvard University VI. 275 p.

Ritchie, J. C. 1964. Contributions to the Holocene paleoecology of westcentral Canada. I. The Riding Mountain area. Canadian Journal of Botany 42: 181-196.

Ritchie, J. C. 1967. Holocene vegetation of the northwestern precincts of the glacial Lake Aggassiz basin, p. 217-229. In W. J. Mayer-Oakes (ed.) Life, land and water. Univ. of Manitoba Press, Winnipeg. 414 p.

Ritchie, J. C. 1969. Absolute pollen frequencies and carbon-14 age of a section of Holocene Lake sediment from the Riding Mountain area of Manitoba. Canadian Journal of Botany 47: 1345-1349.

Ritchie, J. C. and B. de Vries. 1964. Contributions to the Holocene paleoecology of west-central Canada: a late-glacial deposit from the Missouri Coteau. Canadian Journal of Botany 42: 677-692.

Ritchie, J. C. and S. Lichti-Federovich. 1963. Contemporary pollen spectra in central Canada. I. Atmospheric samples at Winnipeg, Manitoba. Pollen et Spores 5: 95-114.

Ritchie, J. C. and S. Lichti-Federovich. 1967. Pollen dispersal phenomena in arctic-subarctic Canada. Review of Paleobotany and Palynology 3: 255-266.

Ritchie, J. C. and S. Lichti-Federovich. 1968. Holocene pollen assemblages from the Tiger Hills, Manitoba. Canadian Journal of Earth Sciences 5: 873-880.

Rowe, J. S. 1959. Forest regions of Canada. Dept. of Northern Affairs and Natural Resources, Forestry Branch Bulletin 123: 1-71.

Sanderson, M. 1948. The climates of Canada according to the new Thornthwaite classification. Scientific Agriculture 28: 501-517.

Sangster, A. G. and H. M. Dale. 1961. A preliminary study of differential pollen grain preservation. Canadian Journal of Botany 39: 35-43.

Sangster, A. G. and H. M. Dale. 1964. Pollen grain preservation of underrepresented species in fossil spectra. Canadian Journal of Botany 42: 437-449.

Sears, P. B. 1942. Xerothermic theory. Botanical Review 8: 708-736.

Shelford, V. E. 1963. The ecology of North America. University of Illinois Press, Urbana. 610 p.

Sigafoos, R. S. 1958. Vegetation of northwestern North America, as an aid in interpretation of geologic data. U. S. Geological Survey Bulletin 1061-E: 165-185.

Spiegel, M. R. 1961. Schaum's outline of theory and problems of statistics. Schaum Publishing Co., New York. 359 p.

Stone, K. H. 1948. Aerial photographic interpretation of natural vegetation in the Anchorage area, Alaska. Geographical Review 38: 465-474.

Swarth, H. S. 1936. Mammals of the Atlin region, northwestern British Columbia. Journal of Mammalogy 17: 398-405.

Tauber, H. 1967. Differential pollen dispersion and filtration, p. 132-141. In E. J. Cushing and H. E. Wright, Jr. (ed.) Quaternary Paleoecology. Yale University Press, New Haven. 433 p.

Terasmae, J. 1958. Contributions to Canadian palynology. Part I. The use of palynological studies in Pleistocene stratigraphy. Part II. Non-glacial deposits in the St. Lawrence lowlands, Quebec. Part III. Non-glacial deposits along Missinaibi River, Ontario. Geological Survey of Canada Bulletin 46: 35 p.

Terasmae, J. 1961. Notes on late-Quaternary climatic changes in Canada. Annals of the New York Academy of Science 95: 658-675.

Terasmae, J. 1967a. Notes on Quaternary palaeoecological problems in the Yukon Territory, and adjacent regions. Geological Survey of Canada Paper 67-46. 12 p.

Terasmae, J. 1967b. Postglacial chronology and forest history in the northern Lake Huron and Lake Superior regions, p. 45-58. In Cushing, E. J. and H. E. Wright, Jr. (ed.) Quaternary Paleoecology. Yale University Press, New Haven. 433 p.

Terasmae, J. 1967c. Recent pollen deposition in the north-eastern District of Mackenzie, Northwest Territories, Canada. Palaeogeography, Palaeoclimatology, and Palaeoecology 3: 17-27.

Terasmae, J. 1967d. A review of Quaternary palaeobotany and palynology in Canada. Geological survey of Canada Paper 67-13. 12 p.

Terasmae, J. and J. G. Fyles. 1959. Palaeobotanical study of late-glacial deposits from Vancouver Island, British Columbia. Canadian Journal of Botany 37: 815-817.

Terasmae, J. and O. L. Hughes. 1966. Late-Wisconsinan chronology and history of vegetation in the Ogilvie Mountains, Yukon Territory, Canada. The Paleobotanist 15: 235-242.

Terasmae, J. and R. J. Mott. 1964. Pollen deposition in lakes and bogs near Ottawa, Canada. Canadian Journal of Botany 42: 1355-1363.

Terasmae, J. and R. J. Mott. 1965. Modern pollen deposition in the Nichicun Lake area, Quebec. Canadian Journal of Botany 43: 393-404.

U. S. Department of Agriculture, Soil Survey Staff. 1967. Soil classification, a comprehensive system. 7th approximation and supplements. Soil Survey Staff, Soil Conservation Service, U. S. Department of Agriculture, Washington, D. C.

Watson, K. DeP. and W. H. Mathews. 1944. The Tuya-Teslin area, northern British Columbia. British Columbia Department of Mines Bulletin 19: 52 p.

Wheeler, J. O. 1961. Whitehorse map-area, Yukon Territory. Geological Survey of Canada Memoir 312: 156 p.

APPENDICES

APPENDIX A

SELECTED SOIL PROFILE DESCRIPTIONS

Soil profile descriptions made by David A. Lietzke in August, 1969. (From Lietzke, 1970).

I. Boralfic Cryorthods, coarse loamy, mixed. (Canada: Bisequal Gray-Wooded.)

Site: West of mile 3, Atlin road. Westerly exposure; 15-20 percent slope.

Vegetation: Mixedwood forest association.

HORIZON	DEPTH (inches)	DESCRIPTION
O1	2-0	Organic root mat.
A1	0-2	Black (10YR2/1) silt loess. Weak fine granular structure; very friable. Abrupt wavy boundary. Mildly alkaline. pH 7.5.
A2	2-4	Light brownish gray (10YR6/2) silt loess. Weak fine granular structure; very friable. Abrupt wavy boundary. Mildly alkaline. pH 7.0.
B21ir	4-6	Reddish brown (5YR4/4) silt loess with sand grains in the lower part (pebble line). Weak fine granular structure. Very friable. Clear wavy boundary. Mildly alkaline. pH 7.3 Quick test (10YR6/3).
IIB22ir	6-8	Dark reddish brown (5YR3/4) gravelly loam. Weak fine granular structure; very friable. Abrupt wavy boundary. Mildly alkaline. pH 7.5. Quick Test (10YR6/3).

IIA'2	8-14	Yellowish brown (10YR5/4) loam. Weak fine granular structure; very friable. Abrupt wavy boundary. Mildly alkaline. pH 7.5.
IIB't	14-20	Grayish brown (10YR5/2) to light olive brown (2.5Y5/4) fine loam. Weak fine subangular blocky structure; very friable. Clear wavy boundary. Mildly alkaline. pH 7.8
IIC21ca	20-23	Light brownish gray (2.5Y6/2) loam. Weak fine subangular blocky structure; very friable. Clear wavy boundary. Highly effervescent. pH 8.2.
IIC22ca	23-33	Light brownish gray (2.5Y6/2) and brown (7.5YR4/4) loam. Weak thin platy structure; very friable. Gradual wavy boundary. Highly effervescent. pH 8.2. The entire horizon had a pinkish gray appearance, the result of many fine rootlets in this layer.
IIC23ca	33-49	Light olive gray (2.5Y6/2) loam. Weak fine platy structure; very friable. Gradual wavy boundary. pH 8.0
IIC3	49-69	Olive gray (5Y6/2 - 5/2) loam. Moderate fine subangular blocky structure; very friable. Gradual wavy boundary. pH 8.0.
IIC4	69-75	Gray (5Y5/1) loam. Moderate medium subangular blocky structure; very friable. pH 8.0.

II. Typic Cryochrepts, coarse loamy, mixed. (Canada: Orthic Brown-Wooded.)

Site: Gravel pit exposure east of Alaska Highway one-third mile north of milepost 896.

Vegetation: Mixed woodland association.

HORIZON	DEPTH (inches)	DESCRIPTION
O1	½-0	Organic root mat.
A2	0-1	Yellowish brown (10YR5/4) silt loess. Weak thin platy structure; very friable. Abrupt wavy boundary. pH 7.5.

B2ir	1-3	Dark reddish brown (5YR3/4) sandy loam (a combination of loess and sandy underlying material). Weak fine granular structure; very friable. Clear wavy boundary. pH 7.9. Quick test (10YR7/3).
IIB'2	3-20	Light olive brown (2.5Y5/4) fine and very fine sands. Single grain. Loose. Abrupt irregular boundary. pH 7.3.
IICca	20-36	Gray (10YR6/1) lacustrine silts. Weak thin platy structure; very friable. Abrupt wavy boundary. Highly effervescent in dilute acid.
IIIC2	36+	Gray (10YR5/1) coarse sand and gravel. Single grain. Loose. pH 7.8.

III. Entic Cryorthods, coarse loamy, mixed. (Canada: Orthic Brown-Wooded.)

Site: Moraine at east end of Simpson Lake. Nearly level.

Vegetation: White spruce-lodgepole pine forest association (?).

HORIZON	DEPTH (inches)	DESCRIPTION
A1	0-1	Dark reddish brown (5YR3/3) loam. Weak fine granular structure. Very friable. Abrupt wavy boundary. pH 4.8.
A2	---	Only a few traces. Not sampled.
B21ir	0-4	Reddish brown (5YR4/3) loam. Weak fine granular structure. Very friable. Abrupt wavy boundary. pH 5.0.
B22ir	4-8	Strong brown (7.5YR5/6) sandy loam. Weak fine subangular blocky structure. Very friable. Clear wavy boundary. pH 5.7.
B31	8-15	Dark brown (7.5YR4/4) sandy loam. Weak fine subangular blocky structure. Very friable. Clear wavy boundary. pH 5.9.
B32	15-21	Dark yellowish brown (10YR4/4) sandy loam. Weak fine subangular blocky structure. Very friable. Abrupt wavy boundary. pH 6.0

IIC2	21-27	Dark brown (10YR3/3) sand and loamy sand. Weak fine granular structure. Very friable. Abrupt wavy boundary. pH 6.1.
IIC3	27-32	Dark yellowish brown (10YR4/4) stratified very fine sand and silts. Massive. Structureless. pH 6.2.

IV. Typic Cryopsamments, sandy mixed.
(Canada: Orthic Regosols.)

Site: Road cut in kame terrace in southwestern end of Fourth of July Creek valley.

Vegetation: Lodgepole pine association.

HORIZON	DEPTH (inches)	DESCRIPTION
O1	0-1	Organic mat.
A1	0-2	Dark grayish brown (10YR4/2) sand and gravel. Weak fine granular structure. Very friable. Clear wavy boundary. pH 6.4.
B	2-10	Grayish brown (10YR5/2) sand and gravel. No evidence of clay accumulation. Single grain. Loose. Gradual wavy boundary. pH 6.4.
C1	10-28	Grayish brown (2.5Y5/2) sand and gravel. Single grain. Loose. Gradual wavy boundary. pH 6.4.
C2	28+	Light brownish gray (2.5Y6/2) sand and gravel. Single grain. Loose. pH 6.4.

V. Boralfic Cryorthods, loamy skeletal, mixed.
(Canada: Bisequal Gray-Wooded.)

Site: West of Atlin road at the Warm Springs, c 15 miles south of Atlin. (Stand S15W) Northeasterly exposure; well-drained.

Vegetation: Alpine fir association.

HORIZON	DEPTH (inches)	DESCRIPTION
O1	6-2	Organic mat. Identifiable plant remains mostly of acid mosses.
O2	2-0	Black (10YR2/1) well decomposed organic matter.
A1	0-½	Brown (10YR4/3) sandy loam. Weak fine granular structure. Dry. Soft. pH 4.8.
Bir	½-5	Brown (7.5YR5/4) sandy loam. Weak fine granular structure. Dry. Soft. pH 5.5.
B'2	5-17	Yellowish brown (10YR5/6) loam. Weak fine granular structure. Dry. Soft. pH 4.8.
B'23	17-22	Olive brown (2.5Y4/4) loam. Weak fine granular structure. Dry. Soft. pH 5.8.
C1	22-35	Light olive brown (2.5Y5/4) loam. Weak fine granular structure. Dry. Soft. pH 7.0.

VI. Histic Cryaquepts, coarse loamy, mixed calcareous.
(Typic Cryaquepts?)
(Canada: Carbonated Humic Gleysol.)

Site: East of Atlin road at mile 52. (Stand 52E) Poor drainage; 4-6 percent slope; westerly exposure.

Vegetation: White spruce association/Feather moss faciation.

HORIZON	DEPTH (inches)	DESCRIPTION
O1	8-2	Reddish, acid raw peat.
S1	2-0	Black (5YR2/1) sapric muck.
C1g	0-23	Light olive gray (5Y6/2 - 5/2) lacustrine silts and very fine sands. Massive. Very friable. Calcareous.
C2g	23-36	Same as the C1g horizon except frozen hard and difficult to auger.
C3g	36-62	Same as the C1g horizon except drier. Not frozen.

VII. Terric Cryosaprists, euic.
(Canada: Terric Unic Humisol.)

Site: West of Atlin road at mile 59. (Stand 59W) Level, depressed area; poorly drained.

Vegetation: Depression shrub association.

HORIZON	DEPTH (inches)	DESCRIPTION
S1	0-8	Recent vegetation remains. Snail shells on the surface and throughout the horizon. pH 8.0.
S2	8-18	Black (10YR2/1) muck. Very wet. pH 7.2.
S3	18-36	Black (5YR2/1) muck. Fairly dry and compact. pH 7.0.
IIC	36+	Dark gray (5Y4/1) silt to silt loam with a few prominent olive brown (2.5Y4/4) mottles. Structureless; massive. pH 6.5.

APPENDIX B

TREE COMMON NAMES USED IN THIS DISSERTATION AND EQUIVALENT SCIENTIFIC NAMES

Alaska yellow cedar (Alaska cypress). *Chamaecyparis nootkatensis* (Lamb.) Spach

Alder. *Alnus crispa* (Ait.) Pursh subsp. *crispa*; *A. crispa* (Ait.) Pursh subsp. *sinuata* (Regel) Hult.; and *A. incana* (L.) Moench subsp. *tenuifolia* (Nutt.) Breitung

Alpine fir. *Abies lasiocarpa* (Hook.) Nutt.*

Aspen (Quaking aspen; trembling aspen). *Populus tremuloides* Michx.

Balsam poplar (Cottonwood). *Populus balsamifera* L. subsp. *balsamifera**

Black cottonwood. *Populus balsamifera* L. subsp. *trichocarpa* (Torr. & Gray) Hult.

Black spruce. *Picea mariana* (Mill.) Britt., Sterns & Pogg.

Douglas fir. *Pseudotsuga Menziesii* (Mirb.) Franco

Engelmann spruce. *Picea Engelmannii* (Parry) Engelm.

Jack pine. *Pinus Banksiana* Lamb.

Larch (Tamarack). *Larix laricina* (Du Roi) K. Koch var. *alaskensis* (Wight) Raup

Lodgepole pine. *Pinus contorta* Dougl. *ex* Loud. subsp. *latifolia* (Engelm.) Critchfield*

Mountain hemlock. *Tsuga Mertensiana* (Bong.) Sarg.

Paper birch. *Betula papyrifera* Marsh. subsp. *humilis* (Regel) Hult. and *B. papyrifera* Marsh. var. *commutata* (Regel) Fern.

Sitka spruce. *Picea sitchensis* (Bong.) Carr.

Tree willow. Salix spp.

Western hemlock. Tsuga heterophylla (Raf.) Sarg.

Western red cedar. Thuja plicata D. Don

White spruce. Picea glauca (Moench) Voss var. albertiana (S. Brown) Sarg.* **

* When used in the text the simple names "fir", "poplar", "pine", and "spruce" refer to the species listed here in nearly all cases.

** It is believed that Picea glauca var. Porsildii Raup also occurs in the Atlin region, particularly at intermediate elevations. The abundance of Porsild's white spruce relative to Alberta white spruce has not yet been determined.

APPENDIX C

THE DOMIN COVER-ABUNDANCE SCALE

(From Kershaw, 1964: Table 1.5)

Cover about 100 percent	10	5*
Cover greater than 75 percent	9	
Cover 50-75 percent	8	4
Cover 33-50 percent	7	3
Cover 25-33 percent	6	
Abundant, cover about 20 percent	5	2
Abundant, cover about 5 percent	4	
Scattered, cover small	3	1
Very scattered, cover small	2	
Scarce, cover very small	1	
Isolated, cover usually small	X	X

* Braun-Blanquet equivalent values

APPENDIX D

PROCEDURE FOR PREPARATION OF BOG SEDIMENT SAMPLES, INCLUDING PEATS, MARLS, AND PARTIALLY INORGANIC MATERIALS

1. Plan to work with as many samples in a set as can be placed in the centrifuge, usually 6. A vigorous worker should be able to prepare 2 sets of 6 samples simultaneously using 2 centrifuges, etc. This should require 8-10 hours.

2. Clean and number 6 40 ml round-bottom glass centrifuge tubes.

3. Select from each bog sample a chunk of material about the size of a pebble. The sample does not have to be weighed nor its volume determined because the procedure is not meant for determining absolute pollen and spore content per unit quantity of sediment. As the proportion of inorganic material in the samples rises, larger chunks should be selected. If the sample is largely sand or silt, the amount to be prepared should be approximately equivalent to a teaspoonful.

4. As they are selected place the chunks into the tubes.

5. Fill each tube 1/3 to 1/2 with 5-10% KOH. Place a clean glass stirring rod in each.

6. Let the samples sit a few minutes. Stir and break up the samples as much as possible during this period.

7. Place tubes in boiling water bath for 5 minutes. Stir constantly and vigorously. This is the deflocculation step.

8. Remove tubes from boiling water bath. Remove stirring rods, washing them off into tubes with a jet of distilled water from squirt bottle.

NOTE: For convenience, place the six stirring rods in numerical order on a paper towel near the test tube rack. Place tubes in rack in the same order each time they are removed from centrifuge. This way the rods can be used over and over without having to be washed between stirrings. It will be easy to keep track of the rods so that they can be returned to the same tubes each time. If there is ever any question as to which rod goes to which tube, all the rods should be washed.

9. Wash hot suspensions through No. 80 sieve and into 250 ml beaker. The amount of water used in washings will cool the samples and dilute the KOH to inhibit any further deterioration of palynomorphs. Wash each residue through the sieve until its beaker is full. Wash the sieve thoroughly between each operation.

10. Pour beaker contents into 90 ml polyethylene tubes. Balance the tubes and centrifuge 4 minutes at 1,500 rpm. (At this point the beakers could be allowed to stand for c 24 hours. The supernatant could then be decanted directly).

NOTE: All subsequent centrifugations will involve balancing the tubes and will be performed at 1,500 rpm for 3-4 minutes.

11. Repeat until all material is washed from beakers. Usually requires 4 repeats.

12. Wash at least twice more. (Ample washings at all stages have been found to give better results.)

NOTE: Always be sure that samples are thoroughly dislodged from the bottoms of the tubes each time water is added for another washing. Use a spatula and stir, or use a super mixer. The super mixer probably breaks bisaccate grains, and its use should therefore be kept to a minimum.

13. Make a visual inspection of the residue and estimate the amount of inorganic material. Silt and sand will go to the bottom first during centrifugation and can be seen as a light gray layer below the darker organic materials. Record the approximate amount of inorganics on the preparation schedule, e.g. "a minor amount of silt" or "a moderate amount of sand", etc.

    If there is no inorganic material, or a very minor amount, delete steps 19 through 23.

    If it is determined that the samples contain no calcareous material, steps 14-18 may also be omitted.

14. Fill tube about 1/2 with 10% HCl. Add slowly at first in case the reaction is vigorous.

15. Heat in boiling water bath for 5 minutes. Keep well stirred.

16. Centrifuge and decant.

17. Wash. Wash well, at least 3 times.

18. Prepare some 50% HF. (To 100 ml of 70% HF add 40 ml of H_2O.)

NOTE: When working with HF and when conducting the acetolysis procedure (steps 18-29), use gloves, apron, and face shield. Perform all of these steps under a ventilation hood. No glass implement should be brought near the HF hood nor come in contact with HF. Use polyethylene or copper containers and stirring rods. Acetolysis may be performed with glass equipment but under a different hood.

19. Place samples in 90 ml polyethylene centrifuge tubes and add c 20 ml of 50% HF.

20. Carefully place tubes in boiling water bath. Allow to heat 3-5 minutes. Stir occasionally.

21. Centrifuge and decant.

22. Wash 3 times with water.

23. Transfer residues back into original (cleaned) 40 ml tubes.

24. Wash with glacial acetic acid. Use c 1/3 tubefull for each. Be sure that samples are dislodged and thoroughly mixed with the acid. Use a glass or copper stirring rod for this.

NOTE: The purpose of washing the samples with glacial acetic acid is to dehydrate them. Water should never come in contact with acetic anhydride nor with the acetolysis solution because the reaction can be violent. Therefore all equipment should be dry before using or washed with glacial acetic acid.

25. Mix acetolysis solution: 1 part concentrated sulfuric acid to 9 parts acetic anhydride. For six samples, put 54 ml of acetic anhydride into a graduated cylinder. Slowly, drop by drop, add 6 ml of sulfuric acid. This will allow 10 ml of solution for each sample.

26. Add c 10 ml acetolysis solution to each sample and stir well.

27. Place tubes into boiling water bath. Allow to heat for 1-1¼ minutes and no longer. Stir occasionally.

28. Centrifuge. Decant into a special beaker under the hood. Set this aside to discard after several days into the sink.

29. Wash with glacial acetic acid. Centrifuge and decant.

30. Wash with water 3 or 4 times.

NOTE: If aggregations of the residues form, break them up with the super mixer or a spatula.

31. Fill tubes to about 1/2 way to top of taper with water.

32. Stain with Safranin-O. Ordinarily only a few drops are required, but the optimum amount depends on the amount of residue, the condition of the stain, and the degree of staining desired.

33. Add 2 drops of 10% ammonium hydroxide.

34. Place a clean spatula into each tube and stir. Begin timing from the moment of first stirring.

35. After 3 minutes remove spatulas and fill tubes with water. Centrifuge and decant.

36. Wash once. Examine a wet mount of 1 or more of the residues to see if staining is adequate. If so, continue washing until supernatant is clear or only faintly colored.

37. Transfer residues into 1-dram vials using a clean bulb pipette for each.

38. Allow vials, which will be full of residue suspended in water after washing out the tubes, to settle for 3 hours or longer.

39. Siphon off excess water to concentrate residues.

40. Add approximately 1/3 by volume of hydroxyethyl cellulose (HEC).

41. Make permanent microscope slides using Harleco Synthetic Resin (HSR) as a mounting medium.

APPENDIX E

PLANTS OF THE ATLIN REGION USED IN THE PREPARATION OF POLLEN REFERENCE SLIDES

The first number following each plant name is its collection number. Numbers with an M are catalog numbers in the pollen and spore reference collection of the Departments of Geology and Botany and Plant Pathology, Michigan State University.

Achillea borealis	295	M797
Agropyron sp.	?	M820
Agrostis scabra	?	M818
Amelanchier alnifolia	261	M790
Anemone multifida	327	M800
Aquilegia formosa	100, 118, 194	M772
Arabis Holboellii	189	M781
Arctostaphylos uva-ursi	232	M787
Arnica cordifolia	338	M801
Artemisia arctica	267	M793
Aster sibiricus	251-A	M789
Astragalus americanus	340	M803
Carex sp.	?	M821
Castilleja unalaschensis	101	M773
Cerastium arvense	370	M807
Chenopodium capitatum	55	M768

Delphinium glaucum	386	M811
Erigeron eriocephalus	239	M788
Erysimum cheiranthoides	384	M809
Fragaria virginiana subsp. glauca	399	M815
Galium boreale	136	M777
Gentiana propinqua	385	M810
Geocaulon lividum	157	M779
Geum macrophyllum subsp. perincisum	222	M785
Hordeum jubatum	?	M817
Lupinus arcticus	397	M814
Mimulus guttatus	276	M795
Moehringia lateriflora	345	M804
Oxytropis campestris	212	M784
Parnassia palustris	69	M791
Pedicularis labradorica	229	M786
P. sudetica	325	M799
Penstemon procerus	396	M813
Phacelia Franklinii	361	M806
Polemonium pulcherrimum	279	M796
Polygonum aviculare	53	M767
P. viviparum	275	M794
Potentilla anserina	391	M812
P. diversifolia	95	M771
P. pennsylvanica var. glabrata	339	M802
Pyrola asarifolia var. purpurea	142	M778
P. secunda var. secunda	191	M782
Rubus idaeus subsp. melanolasius	113	M774

APPENDIX F

PRELIMINARY CATALOG OF THE FLORA OF THE ATLIN REGION

Index of groups and families

* Number of representatives of group or family given in parenthesis.

LICHENS

Alectoria ochroleuca (Hoffm.) Mass.

925. Mt. Vaughan. Tundra vegetation in summit area on west side of mountain. c 5,700 ft. 20 August 1968.

Cladonia cariosa (Ach.) Spreng.

967. Moose Bones Bog. c 2,350 ft. Mesic site in spruce forest south of bog. 1 September 1968.

Cladonia chlorophaea (Floerke) Spreng.

985. White spruce forest west of Moose Bones Bog. c 2,350 ft. 3 September 1968.

Cladonia gracilis (L.) Willd.

818. Mile 47 Bog. c 2,400 ft. Dry summits of swells, sometimes in dense mats with Peltigera aphthosa. 10 July 1968.

Lecanora epibryon (Ach.) Ach.

924. Mt. Vaughan. Tundra vegetation in summit area on west side of mountain. c 5,700 ft. 20 August 1968.

Parmeliella praetermissa (Nyl.) P. James

807. Low, mossy swell in Mile 47 Bog. Rare. c 2,400 ft. 10 July 1968.

Peltigera aphthosa (L.) Willd.

816. Mile 47 Bog. c 2,400 ft. Uncommon.
969. Moose Bones Bog. c 2,350 ft. Common in shrub willow stand southeast of bog. 1 September 1968.

Peltigera rufescens (Weiss) Humb.

970. Moose Bones Bog. c 2,350 ft. Shrub willow and mixed forests around bog. 1 September 1968.

Pertusaria dactylina (Ach.) Nyl.

923. Mt. Vaughan. Tundra vegetation in summit area on west side of mountain. c 5,700 ft. 20 August 1968.

Psoroma hypnorum (Vahl) S. Gray

968. Moose Bones Bog. c 2,350 ft. Mesic site. 1 September 1968.

Xanthoria candelaria (L.) Th. Fr.

820. Mile 47 Bog. c 2,400 ft. A corticolous lichen on dead white spruce tree in sedge-moss zone. 10 July 1968.

MOSSES AND LIVERWORTS

Bryum pseudotriquetrum (Hedw.) Schwaegr.

803. Mile 47 Bog. In thick mat, associated with Juncus arcticus subsp. ater. Abundant. Dominant locally. c 2,400 ft. 10 July 1968.

823-C. Mile 47 Bog. c 2,400 ft. Intermixed with 823-A. 10 July 1968.

Bryum roellii Phil.

823-D. Mile 47 Bog. c 2,400 ft. Intermixed with 823-A. 10 July 1968.

Catoscopium nigritum (Hedw.) Brid.

949. Wilson Creek Bog. c 3,050 ft. Major moss with Carex spp. in sedge-moss zone. 23 August 1968.

Ceratodon purpureus (Hedw.) Brid.

908-A. Moose Bones Bog and forest west of bog. c 2,350 ft. Abundant from outer herb zone of bog through shrub zone and into white spruce forest. 3 September 1968.

Cinclidium stygium Sw.

843-B. Mile 47 Bog. c 2,400 ft. Intermixed with Drepanocladus vernicosus particularly near edge of open water.

Drepanocladus aduncus (Hedw.) Warnst.

823-B. Mile 47 Bog. c 2,400 ft. Intermixed with 823-A. 10 July 1968.

835. Mile 47 Bog. c 2,400 ft. Common in sedge-moss zone. 10 July 1968.

896. Mile 16 Bog. c 2,400 ft. Major associate of Carex aquatilis subsp. aquatilis in sedge-moss zone. Partly to mostly submerged. 21 August 1968.

979. Moose Bones Bog. c 2,350 ft. Common in moist bog vegetation zones. Associated with Calamagrostis neglecta and obscured by dead foliage of this species in many areas. Decreasing abundance toward outer herb zone where Ceratodon purpureus becomes increasingly abundant. 3 September 1968.

Phleum commutatum Gandoger var. americanum (Fourn.) Hult.

91. Near Atlin. 6 July 1966.

198. Near Atlin road several miles south of Atlin. 8 July 1966.

223. Wright Creek road south of Surprise Lake. 9 July 1966.

858. Near upper Ruby Creek road, north-northeast of Ruby Mountain. c 4,500 ft. 19 August 1968.

Drepanocladus vernicosus (Lindb.) Warnst.

836. Jasper Creek Bog. c 2,400 ft. The dominant moss of the sedge (Carex rhynchophysa)-moss zone. Both moss and sedge in standing water, most of moss submerged with greener parts above water. 11 July 1968.

843-A. (Same as 836).

Hylocomium splendens (Hedw.) B.S.G.

847-B. Intermixed with Pleurozium schreberi (847-A). Relative abundance at site not determined.

Leptobryum pyriforme (Hedw.) Wils.

980-B. Intermixed with Ceratodon purpureus (980-A). Relative abundance not determined.

Marchantia polymorpha L.

894. Mile 16 Bog. c 2,400 ft. At base of root-soil mass of blown down tree near edge of bog. Common locally. 21 August 1968.

895. (Same as 894).

Mnium affine Bland. var. rugicum (Laur.) B.S.G.

823-A. Mile 47 Bog. c 2,400 ft. Very abundant in open water and muddy depressions. Frequently in thick mats. 10 July 1968.

<u>Pleurozium</u> <u>schreberi</u> (B.S.G.) Mitt.

847-A. Mixed coniferous forest west of Jasper Creek Bog. c 2,500 ft. Abundant in soft mats over large portions of forest floor. 11 July 1968.

<u>Sphagnum</u> <u>capillaceum</u> (Weiss) Schrank var. <u>tenellum</u> (Schimp.) Andr.

898. Upper west branch of Ruby Creek below Mt. Leonard. c 4,800 ft. Wet stream bank. Common locally. 19 August 1968.

<u>Tomenthypnum</u> <u>nitens</u> (Hedw.) Loeske

814. Mile 47 Bog. c 2,400 ft. Abundant, dominant locally. 10 July 1968.
815. (Same as 814.)

EQUISETACEAE

<u>Equisetum</u> <u>scirpoides</u> Michx.

38. Gravel pit on O'Donnel (Atlin) road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.
808. Mile 47 Bog. Common. c 2,400 ft. 10 July 1968.

CUPRESSACEAE

<u>Juniperus</u> <u>horizontalis</u> Moench

291. North of Atlin road at mile 6. c 2,400 ft. 11 July 1966.

JUNCAGINACEAE

<u>Triglochin</u> <u>maritimum</u> L.

70. Near Warm Bay c 14.5 miles south of Atlin. Area of mineral springs and seepage; ground covered by mineral deposits. c 2,250 ft. 27 August 1965.
821. Mile 47 Bog. c 2,400 ft. 10 July 1968.

<u>Triglochin</u> <u>palustris</u> L.

392. In Mile 52 Bog, Atlin road. c 2,350 ft. 5 July 1967.

GRAMINEAE

Hierochloe alpina (Sw.) Roem. & Schult.

915. Mt. Vaughan. In alpine tundra zone near summit. c 5,700 ft. 20 August 1968.

Muhlenbergia Richardsonis (Trin.) Rydb.

976. Moose Bones Bog. Common to locally abundant in outermost, mesic, herbaceous zone. 3 September 1968.

Phleum pratense L.

33. Warm Springs, c 15 miles south of Atlin. Open, moist, and grassy. c 2,300 ft. 27 August 1965.
88. Near Atlin. 6 July 1966.

Alopecurus aequalis Sobol.

954. Moose Bones Bog. Uncommon in inner, moist, herbaceous zones. Flowering. 1 September 1968.

Arctagrostis latifolia (R. Br.) Griseb. var. arundinacea (Trin.) Griseb.

812. Mile 47 Bog. On drier swells in turfy or hummocky sites at edge of spruce forest. Common. Low cover value. Scattered. c 2,400 ft. 10 July 1968.
832. Mile 47 Bog. In spruce zone near edge of bog. Common on drier swells. c 2,400 ft. 10 July 1968.

Agrostis stolonifera L.

907. Mile 16 Bog. Near inside edge of bog. 21 August 1968.

Agrostis scabra Willd.

31. Gravel pit on O'Donnel (Atlin) road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.
90. Near Atlin. 6 July 1966.
225. Wright Creek road south of Surprise Lake. 9 July 1966.
231. Wright Creek road south of Surprise Lake. 9 July 1966.

Calamagrostis canadensis (Michx.) Beauv.

905. Mile 16 Bog. Near edge of bog. 21 August 1968.
906. Mile 16 Bog. Near edge of bog. 21 August 1968.

<u>Calamagrostis</u> <u>inexpansa</u> Gray

256. Near outlet of Surprise Lake. c 3,000 ft. 10 July 1966.

<u>Calamagrostis</u> <u>neglecta</u> (Ehrh.) Gaertn., Mey. & Schreb.

955. Moose Bones Bog. Dominant in zone. 1 September 1968.

<u>Calamagrostis</u> <u>purpurascens</u> R. Br.

379. Mile 56 Atlin road, west of road. c 2,450 ft. 3 July 1967.

<u>Deschampsia</u> <u>caespitosa</u> (L.) Beauv.

255. Near outlet of Surprise Lake at water's edge. c 3,000 ft. 10 July 1966.

957. Moose Bones Bog. Dominant in zone. 1 September 1968.

<u>Trisetum</u> <u>spicatum</u> (L.) Richter

3. Ruby Creek road north of Surprise Lake. Nearly level, bulldozed area next to road; easterly exposure. c 3,800 ft. 23 August 1965.

21. Gravel pit on O'Donnel road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.

22. Dry, open gravel pit on O'Donnel (Atlin road) c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.

107-B. Near Atlin. 6 July 1966.

224. Wright Creek road south of Surprise Lake. 9 July 1966.

234. Early July 1966.

879. Mt. Leonard, c 4,800 ft. on east side of mountain. Herbaceous tundra zone. 19 August 1968.

922. Mt. Vaughan. In herbaceous tundra zone in summit area on west side of mountain. c 5,700 ft. 20 August 1968.

<u>Trisetum</u> <u>spicatum</u> (L.) Richter var. <u>Maidenii</u> (Gand.) Fern.

104. Near the Grotto approx. 16 miles south of Atlin. c 2,400 ft. 6 July 1966.

153. Several miles south of Atlin, near road. 8 July 1966.

178. Several miles south of Atlin, near road. 8 July 1966.

186. Several miles south of Atlin, near road. 8 July 1966.

190. Several miles south of Atlin, near road. 8 July 1966.

Danthonia intermedia Vasey

866. Ruby Creek road. On north-northeast side of Ruby Mountain. c 4,500 ft. 19 August 1968.

Poa alpina L.

23. Gravel pit on O'Donnel road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.
78. Near Atlin. 6 July 1966.
89. Near Atlin. 6 July 1966.
230. Wright Creek road south of Surprise Lake. 9 July 1966.

Poa pratensis L.

28. Gravel pit on O'Donnel road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.

Poa palustris L.

103. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 6 July 1966.
107-C. Near Atlin. 6 July 1966.
185. Several miles south of Atlin. 8 July 1966.
336. Near Mile 52 Bog. 23 June 1967.
375. East of Atlin road at mile 16. Dry, sandy, west-facing slope. c 2,600 ft. 3 July 1967.
961. Moose Bones Bog. Dominant of zone. 1 September 1968.

Poa lanata Scribn. & Merr.

861. Near upper Ruby Creek road, north-northeast of Ruby Mountain. c 4,500 ft. 19 August 1968.

Poa annua L.

29. Gravel pit on O'Donnel road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.

Poa leptocoma Trin.

913. Mt. Vaughan. In tundra zone in summit area on west side of mountain. c 5,700 ft. 20 August 1968.

Festuca altaica Trin.

257. Near outlet of Surprise Lake. c 3,000 ft. 10 July 1966.
326. Near Mile 52 Bog. 23 June 1967.
349. East of Atlin road at mile 59 in open spruce forest. c 2,300 ft. 1 July 1967.

813. Mile 47 Bog. Scattered on dry swells. 10 July 1968.

Festuca ovina L. var. brevifolia (R. Br.) Wats.

20. Gravel pit on O'Donnel road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.
32. Gravel pit on O'Donnel road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.
987. Moose Bones Bog. In outermost, mesic, herbaceous zone. 6 September 1968.

Bromus inermis Leyss.

130. Several miles south of Atlin. 8 July 1966.

Agropyron subsecundum (Link) Hitchc.

293. Near mile 6, Atlin road. c 2,300 ft. 11 July 1966.

Agropyron pauciflorum (Schwein.) Hitchc.

105. Near the Grotto approx. 16 miles south of Atlin. c 2,400 ft. 6 July 1966
107-A. Near Atlin. 6 July 1966.
176. Several miles south of Atlin. 8 July 1966.
177. Several miles south of Atlin. 8 July 1966.
187. Several miles south of Atlin. 8 July 1966.
960. Moose Bones Bog. Uncommon in outer herbaceous zone and in shrub and forest zones. 1 September 1968.

Agropyron sp. (possibly X Agroelymus)

128. Near the Grotto approx. 16 miles south of Atlin. c 2,400 ft. 6 July 1966.

Hordeum jubatum L.

25. Gravel pit on O'Donnel (Atlin) road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.
179. Several miles south of Atlin. 8 July 1966.

CYPERACEAE

Eriophorum angustifolium Honck.

59. Near Warm Bay, c 14.5 miles south of Atlin, an area of seepage and mineral springs. Calcium carbonate crust on ground. 27 August 1965.
839. Has some characteristics of E. viridi-carinatum (Engelm.) Fern. and may therefore be a hybrid. Jasper Creek Bog. In wet moss & sedge zone. Uncommon. c 2,400 ft. 11 July 1968.

<u>Scirpus</u> <u>validus</u> M. Vahl

834. Mile 47 Bog. Dominant in Scirpus zone, occupying major portion of bog. c 2,400 ft. 10 July 1968.

<u>Carex</u> <u>nardina</u> E. Fries

805-B. Mile 47 Bog. Common. c 2,400 ft. 10 July 1968.

<u>Carex</u> <u>dioica</u> L. subsp. <u>gynocrates</u>

805-A. Mile 47 Bog. c 2,400 ft. Uncommon. 10 July 1968.

<u>Carex</u> <u>scirpoidea</u> Michx.

162. Several miles south of Atlin. Male plant. 8 July 1966.
164. Several miles south of Atlin. 8 July 1966.

<u>Carex</u> <u>diandra</u> Schrank

826. Mile 47 Bog. c 2,400 ft. 10 July 1968.
841-B. Jasper Creek Bog. In Carex (<u>C</u>. <u>rhynchophysa</u>) zone. c 2,400 ft. 11 July 1968.

<u>Carex</u> <u>Bebbii</u> Olney

26. Gravel pit on O'Donnel road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.

<u>Carex</u> <u>praticola</u> Rydb.

108. Near Atlin. 6 July 1966.

<u>Carex</u> <u>Mackenziei</u> Krecz.

218. Wright Creek road south of Surprise Lake. 9 July 1966.
227. Wright Creek road south of Surprise Lake. 9 July 1966.
240. Wright Creek road south of Surprise Lake. 9 July 1966.

<u>Carex</u> <u>Bigelowii</u> Torr.

910. Mt. Vaughan. In tundra zone in summit area on west side of mountain. c 5,700 ft. 20 August 1968.

<u>Carex</u> <u>aquatilis</u> Wahlenb. subsp. <u>aquatilis</u>

310. Mile 52 Bog. Dominant in zone. 31 August 1966.

801. Mile 16 Bog. Dominant bog plant, forming thick mats & tussocks. Springy close to open water. c 2,400 ft. 9 July 1967

824. Mile 47 Bog. Dominant in sedge zone. c 2,400 ft. 10 July 1968.

842. Jasper Creek Bog. In wet _Carex rhynchophysa_ zone. c 2,400 ft. 11 July 1968.

Carex aurea Nutt.

163. Several miles south of Atlin. 8 July 1966.
393. Mile 52 Bog. 5 July 1967.

Carex Rossii Boott

974. In closed spruce forest north of Moose Bones Bog. Common. 3 September 1968.

Carex Sartwellii Dewey

971. Moose Bones Bog. Scarce to common locally in outer herbaceous and shrub zones. 3 September 1968.

Carex limosa L.

841-A. Jasper Creek Bog. In wet _Carex rhynchophysa_ zone. 11 July 1968.

Carex petricosa Dew.

882. Mt. Leonard. Moist area near stream c 4,800 ft on east side of mountain. 19 August 1968.

883. (Same as 882).

859. Ruby Creek road. On north-northeast side of Ruby Mountain. c 4,500 ft.

Carex capillaris L.

161. Several miles south of Atlin. 8 July 1966.

Carex capillaris L. var. _major_ Drej.

804. Mile 47 Bog. Uncommon. c 2,400 ft. 10 July 1968.

Carex Williamsii Britt.

236. Wright Creek road south of Surprise Lake. 9 July 1966.

Carex Oederi Retz. subsp. _viridula_ (Michx.) Hult.

938. Wet, north-facing slope above Warm Bay, approx. 14.5 miles south of Atlin. c 2,300 ft. 25 August 1968.

Carex rhynchophysa C. A. Mey.

837. Jasper Creek Bog. Dominant sedge of wet sedge zone. c 2,400 ft. 11 July 1968.

JUNCACEAE

Juncus arcticus Willd.

81. Near Atlin. 6 July 1966.
129. Several miles south of Atlin. 8 July 1966.
226. Wright Creek road south of Surprise Lake. 9 July 1966.
259. Near outlet of Surprise Lake. c 3,000 ft. Specimen from one large clump in wet soil near water. 10 July 1966.
959. Moose Bones Bog. Uncommon in drier herbaceous zones. 1 September 1968.

Juncus arcticus Willd. subsp. ater (Ryde.) Hult.

802. Mile 47 Bog. Abundant. Moist site with moderately dense to dense moss cover. c 2,400 ft. 10 July 1968.

Juncus Drummondii E. Mey.

884. Mt. Leonard. Moist area near stream. c 4,800 ft on east side of mountain. 19 August 1968.

Juncus falcatus E. Mey.

887. Mt. Leonard. Moist area near stream c 4,800 ft on east side of mountain. 19 August 1968.

Juncus alpinus Vill.

60. Near Warm Bay c 14.5 miles south of Atlin. Area of seepage and mineral springs. Calcium carbonate deposits on ground. Some plants in shallow water. c 2,200 ft. 27 August 1965.

Luzula parviflora (Ehrh.) Desv.

246. Wright Creek road south of Surprise Lake. 9 July 1966.
215. Wright Creek road south of Surprise Lake. 9 July 1966.

Luzula parviflora (Ehrh.) Desv. subsp. parviflora

860. Near upper Ruby Creek road, north-northeast of Ruby Mountain. c 4,500 ft. 19 August 1968.

Luzula arcuata (Wahlenb.) Sw.

911. Mt. Vaughan. In herbaceous tundra zone in summit area on west side of mountain. c 5,700 ft. 20 August 1968.

LILIACEAE

Tofieldia pusilla (Michx.) Pers.

56. Near Warm Bay c 14.5 miles south of Atlin. Area of mineral springs and carbonate deposits. Some plants growing in shallow water. c 2,250 ft. 27 August 1965.
158. Near road south of Atlin. 7 July 1966.
237. Wright Creek valley south of Surprise Lake. 9 July 1966.

Tofieldia glutinosa (Michx.) Pers. subsp. brevistyla Hitchc.

57. Near Warm Bay c 14.5 miles south of Atlin. Seepage and mineral springs with carbonate deposits on ground. c 2,250 ft. 27 August 1965.

Zygadenus elegans Pursh

61. Near Warm Bay c 14.5 miles south of Atlin. Moist; seepage and mineral springs with carbonate deposits on ground. c 2,250 ft. 27 August 1965.
82. Near Atlin. 6 July 1966.
168. Vicinity of road south of Atlin. 6 July 1966.

ORCHIDACEAE

Cypripedium passerinum Richards.

159. Several miles south of Atlin. 8 July 1966.
401. Vicinity of Atlin road at mile 4. Shady, moist, mixed poplar and spruce stand west of road. c 2,300 ft. Early July 1967.

Amerorchis rotundifolia (Banks) Hult.

403. In dense, moist, mixed poplar and spruce forest west of Atlin road at mile 4. c 2,300 ft. Early July 1967.

Platanthera hyperborea (L.) Lindl.

46. Warm Springs c 15 miles south of Atlin. Open, moist, grassy area. c 2,300 ft. 27 August 1965.

64. Near Warm Bay c 14.5 miles south of Atlin. Seepage and mineral springs, carbonate deposits on ground. c 2,250 ft. 27 August 1965.

390. Mile 52 Bog. Common. 5 July 1967.

402. Vicinity of Atlin road at mile 4. In moist, mixed spruce and poplar forest west of road. c 2,300 ft. Common. Early July 1967.

Platanthera obtusata (Pursh) Lindl.

160. Vicinity of road several miles south of Atlin. 8 July 1966.

254. Near outlet of Surprise Lake. Damp, mossy site. c 3,000 ft. 10 July 1966.

335. Vicinity of Atlin road at mile 52. c 2,400 ft. 23 June 1967.

357. Vicinity of Atlin road at mile 52. Shady, mossy spruce forest east of road. c 2,400 ft. 1 July 1967.

404. Vicinity of Atlin road at mile 4. West of road in moist, dense, mixed spruce and poplar forest. c 2,300 ft. Early July 1967.

810. Mile 47 Bog. Rare. c 2,400 ft. 10 July 1968.

Spiranthes Romanzoffiana Cham.

934. Wet northerly slope above Warm Bay, c 14.5 miles south of Atlin. Flowering. Common. c 2,300 ft. 25 August 1968.

Listera borealis Morong

356. In shady, mossy spruce forest east of Atlin road at mile 52. c 2,400 ft. 1 July 1967.

406. In dense, moist, mixed poplar and spruce stand west of Atlin road at mile 4. c 2,300 ft. Early July 1967.

Corallorrhiza trifida Chatelain

358. Vicinity of Atlin road at mile 52. Shady, mossy spruce forest east of road. c 2,450 ft. 1 July 1967.

365. Specimens from sites at miles 24 and 28, Atlin road. Early July 1967.

405. Vicinity of Atlin road at mile 4. Dense, moist, mixed poplar and spruce forest west of road. c 2,300 ft.

SALICACEAE

Salix reticulata L.

208. In boggy area near Wright Creek road south of Surprise Lake. 9 July 1966.

886. Mt. Leonard. Moist area near stream c 4,800 ft on east side of mountain. 19 August 1968.

Salix arctica Pall. subsp. torulosa (Trautv.) Hult.

317. Collected at miles 1, 40, 50, 60, Atlin road. 31 August 1966.

Salix arctophila Cockerell

909. Mt. Vaughan. In tundra zone in summit area on west side of mountain. c 5,700 ft. 20 August 1968.

Salix glauca L. subsp. acutifolia (Hook.) Hult.

819-B. Mile 47 Bog. Common. In clumps with 819-A. Appears to be result of introgression between subspp. acutifolia & glabrescens, with a closer resemblance to acutifolia. c 2,400 ft. 10 July 1968.

Salix glauca L. subsp. glabrescens (Anderss.) Hult.

819-A. Mile 47 Bog. Growing in clump w 819-B. Common. c 2,400 ft. 10 July 1968.
830. Mile 47 Bog. Common on small hillock in sedge zone. c 2,400 ft. 10 July 1968.

Salix myrtillifolia Anders.

71. Near Atlin. 6 July 1966.
322. Adjacent to south side of Mile 52 Bog. Dominant. 23 June 1967.
811. Mile 47 Bog. Common. c 2,400 ft. 10 July 1968.
825. Mile 47 Bog. c 2,400 ft. 10 July 1968.

Salix myrtillifolia Anders. var. pseudomyrsinitis (Anderss.) Ball

831. Probably a hybrid form, with S. Barclayi Anderss. Mile 47 Bog. Common on small embankment near pond within sedge zone. c 2,400 ft. 10 July 1968.

Salix Barclayi Anderss.

353-A. Shrub willow and birch thicket west of Atlin road at mile 54. c 2,400 ft. 1 July 1967.

Salix Chamissonis Anderss.

315. East of Atlin road at mile 50. c 2,400 ft. Young spruce stand developing after fire. 31 August 1966.

Salix depressa L. subsp. *rostrata* (Anderss.) Hiitonen

983. Mile 4.5, East Carcross road, across from Moose Bones Bog. Abundant. Common roadside shrub willow. 2 September 1968.

BETULACEAE

Betula glandulosa Michx.

817. Mile 47 Bog. Uncommon. c 2,400 ft. 10 July 1968.

SANTALACEAE

Geocaulon lividum (Richards.) Fern.

157. Near Atlin. Widespread in spruce forests. 6 July 1966.
806. Mile 47 Bog. Uncommon. c 2,400 ft. 10 July 1968.

POLYGONACEAE

Rumex maritimus L.

964. Moose Bones Bog. Rare in inner, moist, herbaceous zones. 1 September 1968.
966. (Same as 964).

Polygonum viviparum L.

275. Vicinity of road north of Surprise Lake. c 3,300 ft. 10 July 1966.

Polygonum aviculare L.

53. Bulldozed, rocky area near Atlin road at Fourth of July Creek. c 2,400 ft. Common. 24 August 1965.
184. Edge of road several miles south of Atlin. Common. 6 July 1966.

CHENOPODIACEAE

Chenopodium capitatum (L.) Aschers.

55. Mile 54, Atlin road. Open, rocky, bulldozed area adjacent to road on west, c 2,400 ft. Common. 24 August 1965.

294. Near Atlin road at mile 6. c 2,300 ft. 11 July 1966.

<u>Chenopodium</u> <u>rubrum</u> L.

963. Moose Bones Bog. In inner, moist herbaceous zones. 3 September 1968.

CARYOPHYLLACEAE

<u>Stellaria</u> <u>crassifolia</u> Ehrh.

200. Wright Creek road south of Surprise Lake. c 3,500 ft. 9 July 1966.

<u>Stellaria</u> <u>monantha</u> Hult.

Near road several miles south of Atlin. 7 July 1966.

<u>Cerastium</u> <u>Beeringianum</u> Cham.& Schlecht.

277. Vicinity of road north of Surprise Lake. c 3,300 ft. 10 July 1966.

<u>Cerastium</u> <u>arvense</u> L.

126. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 7 July 1966.
174. Near road south of Atlin. 8 July 1966.
299. Mile 6, Atlin road. c 2,300 ft. 11 July 1966.
324. Vicinity of Atlin road at mile 52. Rocky area on small hill west of bog. c 2,400 ft. 23 June 1967.
370. Vicinity of Atlin road at mile 16. Open, sandy, west-facing slope. c 2,500 ft. Common. 3 July 1967.

<u>Moehringia</u> <u>lateriflora</u> (L.) Fenzl

172. Near road several miles south of Atlin. 6 July 1966.
233. Wright Creek road south of Surprise Lake. 9 July 1966.
345. Near Atlin road at mile 52. c 2,350 ft. 23 June 1967.

<u>Silene</u> <u>Menziesii</u> Hook. subsp. <u>Williamsii</u> (Britt.) Hult. comb. nov.

175. Vicinity of road south of Atlin. 8 July 1966.

RANUNCULACEAE

<u>Aquilegia</u> <u>formosa</u> Fisch.

100. Near Atlin. 6 July 1966.
118. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. Dry site. Rare. 6 July 1966.
194. East of Atlin road several miles south of Atlin. Rocky, exposed site. Rare. Early July 1966.

<u>Delphinium</u> <u>glaucum</u> S. Wats.

4. Ruby Creek road. Open, bulldozed area. c 3,800 ft. Common. 23 August 1965.
9. Gravel pit on O'Donnel (Atlin) road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.
127. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 7 July 1966.
386. Mile 8.9, Atlin road, at Haunka Creek. c 2,300 ft. Gravelly, bulldozed area. 6 July 1966.

<u>Anemone</u> <u>parviflora</u> Michx.

155. Near road several miles south of Atlin. 7 July 1966.
350. West of Atlin road at mile 59. c 2,300 ft. 30 June 1967.

<u>Anemone</u> <u>multifida</u> Poir.

83. Near Atlin. 6 July 1966.
109. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 6 July 1966.
123. Near Atlin. 7 July 1966.
138. Near Atlin. 7 July 1966.
302. Mile 6, Atlin road. c 2,300 ft. 11 July 1966.
327. Mile 52, Atlin road. c 2,350 ft. 23 June 1967.

<u>Pulsatilla</u> <u>patens</u> (L.) Mill. subsp. <u>multifida</u> (Pritz.) Zamels

332. Near summit of low, rocky hill west of Mile 52 Bog. c 2,500 ft. 23 June 1967. Setting seed.

<u>Thalictrum</u> <u>alpinum</u> L.

943. Wilson Creek Bog. Common in thick moss of sedge zone. 25 August 1968.

FUMARIACEAE

<u>Corydalis</u> <u>aurea</u> Willd.

169. Several miles south of Atlin. Early July 1966. Flowering.

CRUCIFERAE

<u>Barbarea</u> <u>orthoceras</u> Ledeb.

260. Vicinity of outlet of Surprise Lake. c 3,000 ft. 10 July 1966.

<u>Rorippa</u> <u>nasturtium-aquaticum</u> (L.) Hayek

51. In water in Warm Springs area c 15 miles south of Atlin. c 2,300 ft. Abundant. Flowering. 27 August 1965.

<u>Rorippa</u> <u>hispida</u> (Desv.) Britt. var. <u>barbareaefolia</u> (DC.) Hult.

953. Moose Bones Bog. Common in inner herbaceous zones.

<u>Cardamine</u> <u>oligosperma</u> Nutt.

242. Vicinity of road in Wright Creek valley south of Surprise Lake. Wet moss cushion. 9 July 1966.

<u>Capsella</u> <u>bursa-pastoris</u> (L.) Medic.

117. Near the Grotto c 16 miles south of Atlin, c 2,400 ft. 6 July 1966.

<u>Draba</u> <u>borealis</u> DC.

119. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 6 July 1966.

<u>Draba</u> <u>aurea</u> Vahl

266. Vicinity of road north of Surprise Lake. c 3,400 ft. 10 July 1966.

<u>Draba</u> <u>lanceolata</u> Royle

1. Ruby Creek road. Bulldozed area next to road c 3,800 ft. Easterly exposure. 23 August 1965.
102. Near Atlin. 6 July 1966.
110. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 6 July 1966.

<u>Descurainia</u> <u>sophioides</u> (Fisch.) O. E. Schulz

173. Several miles south of Atlin. 8 July 1966.

<u>Arabis</u> <u>arenicola</u> (Richards.) Gelert

337. Near mile 52, Atlin road. In shrub willow stand south of bog near edge of spruce forest. Semi-open and dry. c 2,350 ft. 23 June 1967.

<u>Arabis</u> <u>lyrata</u> L. subsp. <u>kamchatica</u> (Fisch.) Hult.

274. Near road north of Surprise Lake. c 3,400 ft. 10 July 1966.

<u>Arabis</u> <u>Drummondii</u> Gray

15. Gravel pit on O'Donnel (Atlin) road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.

94. Near Atlin. 6 July 1966.

<u>Arabis</u> <u>Holboellii</u> Hornem. var. <u>retrofracta</u> (Graham) Rydb.

189. Near road several miles south of Atlin. 8 July 1966.

309. Snafu Lake. Open, sandy hillside east of camping area. c 2,500 ft. 11 July 1966.

376. East of Atlin road at mile 16. Unforested, sandy hillside. c 2,600 ft. 3 July 1967.

<u>Erysimum</u> <u>cheiranthoides</u> L.

50. Warm Springs area c 15 miles south of Atlin. Open, moist site. c 2,300 ft. 27 August 1965.

384. Mile 8.9, Atlin road, at Haunka Creek. Bulldozed, gravelly site. c 2,300 ft. 6 July 1967.

933. Warm Springs c 15 miles south of Atlin. Abundant locally. 2,300 ft. 22 August 1968.

CRASSULACEAE

<u>Sedum</u> <u>lanceolatum</u> Torr.

135. South of Atlin. 7 July 1966.

170. Near road several miles south of Atlin. 8 July 1966.

304. Snafu Lake. On dry, sandy hillside east of camping are. c 2,500 ft. 11 July 1966.

<u>Sedum</u> <u>rosea</u> (L.) Scop.

344. Opening in spruce and aspen stand on low hill west of Mile 52 Bog. c 2,400 ft. 23 June 1967.

SAXIFRAGACEAE

Saxifraga tricuspidata Rottb.

171. Near road several miles south of Atlin. 6 July 1966.
228. Wright Creek road south of Surprise Lake. In clump on sandy creek bank near old mine. c 3,700 ft. 9 July 1966.
278. Vicinity of road north of Surprise Lake. c 3,300 ft. 10 July 1966.

Saxifraga punctata L. subsp. insularis Hult.

196. Several miles south of Atlin. 8 July 1966.
202. Wright Creek road south of Surprise Lake. c 3,800 ft. 9 July 1966.

Chrysosplenium tetrandrum (Lund) T. Fries

243. Wright Creek road south of Surprise Lake. Mossy, wet area in broad valley. c 3,800 ft. 9 July 1966.
939. Growing in mats on open water on wet, north-facing slope above Warm Bay, approx. 14.5 miles south of Atlin. c 2,300 ft. 25 August 1968.

Parnassia palustris L.

69. Near Warm Bay c 14.5 miles south of Atlin. Area of seepage and mineral springs. Calcium carbonate deposits. c 2,250 ft. 27 August 1965.

Parnassia palustris L. subsp. neogaea (Fern.) Hult.

263. Vicinity of road north of Surprise Lake. c 3,200 ft. 10 July 1966.

Parnassia palustris L. var. montanensis (Fern. & Rydb.) Hitchc.

394. Mile 52 Bog. 5 July 1967.

Parnassia Kotzebuei Cham. & Schlecht.

79. Near Atlin. 6 July 1966.
201. Center of Wright Creek road south of Surprise Lake at old mine. c 3,900 ft. 9 July 1966.
347. In damp shrub birch and willow stand west of Atlin road at mile 59. c 2,300 ft. 1 July 1967.

Ribes triste Pall.

314. Spruce forest near mile 30, Atlin road. c 2,400 ft. 31 August 1966.

<u>Aconitum</u> <u>delphinifolium</u> DC.

6. Ruby Creek road. Bulldozed area next to road, easterly exposure. c 3,800 ft. 23 August 1965.
206. Wright Creek road south of Surprise Lake. Dry, spruce-pine forest. Uncommon. 9 July 1966.

ROSACEAE

<u>Amelanchier</u> <u>alnifolia</u> (Nutt.) Nutt.

134. East of Atlin road c 12 miles south of Atlin. Open, sandy slope. 7 July 1966.
261. Near outlet of Surprise Lake, c 3,000 ft. Steep, barren embankment below road, just above water. 10 July 1966.

<u>Rubus</u> <u>arcticus</u> L. subsp. <u>acaulis</u> (Michx.) Focke

203. Wright Creek road south of Surprise Lake, in vicinity of old mine. c 3,700 ft. 9 July 1966.
409. Early July 1967.

<u>Rubus</u> <u>arcticus</u> L. subsp. <u>stellatus</u> (Sm.) Boiv. emend. Hult.

145. 7 July 1966.

<u>Rubus</u> <u>idaeus</u> L. subsp. <u>melanolasius</u> (Dieck) Focke

113. Near the Grotto, c 16 miles south of Atlin. c 2,400 ft. 6 July 1966.
182. Near road several miles south of Atlin. 6 July 1967.

<u>Fragaria</u> <u>virginiana</u> Duchesne subsp. <u>glauca</u> (S. Wats.) Staudt

144-A. Near road several miles south of Atlin. 7 July 1966.
252. Near outlet of Surprise Lake on dry hillside in lodgepole pine forest. c 3,000 ft. Common. 10 July 1966.
369. Vicinity of Atlin road at mile 32. c 2,600 ft. 3 July 1967.
399. In dense, young aspen stand east of Atlin road at mile 12. c 2,550 ft. 6 July 1967.

<u>Potentilla</u> <u>palustris</u> (L.) Scop.

844. Jasper Creek Bog. In wet sedge zone. Uncommon. c 2,400 ft. Flowers in pre-anthesis condition. 11 July 1968.

<u>Potentilla</u> <u>uniflora</u> Ledeb.

917. Mt. Vaughan. In tundra zone in summit area on west side. c 5,700 ft. 20 August 1968.

921. Mt. Vaughan. In tundra zone in summit area on west side. c 5,700 ft. 20 August 1968.

Potentilla norvegica L. subsp. monspeliensis (L.) Aschers. & Graebn.

18. Gravel pit on O'Donnel road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.
72. Near Atlin. 6 July 1966.
262. Near outlet of Surprise Lake. c 3,000 ft. 10 July 1966.

Potentilla nivea L. var. tomentosa Nilsson-Ehle

152. Several miles south of Atlin. 7 July 1966.

Potentilla Hookeriana Lehm. subsp. Hookeriana

381. Mile 16 Atlin road. Dry, sandy, west-facing slope east of road. c 2,600 ft. 3 July 1967.

Potentilla multifida L.

330. Vicinity of Atlin road at mile 52. c 2,400 ft. 23 June 1967.

Potentilla arguta Pursh subsp. convallaria (Rydb.) Keck

133. Open, sandy slope east of road c 12 miles south of Atlin. 7 July 1966.
150. Near road several miles south of Atlin. 7 July 1966.

Potentilla pennsylvanica L.

382. East of Atlin road at mile 16. Unforested, sandy, west-facing slope. c 2,600 ft. 3 July 1967.

Potentilla pennsylvanica L. var. strigosa Pursh.

851. Near Atlin in dry, gravelly area.

Potentilla pennsylvanica L. var. glabrata S. Wats.

339. Vicinity of Atlin road at mile 52. c 2,400 ft. 23 June 1967.

Potentilla gracilis Dougl.

852. In Atlin. Abundant in open, gravelly area around old outpost hospital bldg. c 2,200 ft. 15 August 1968.

Potentilla diversifolia Lehm.

95. Near Atlin. 6 July 1966.
217. Wright Creek road south of Surprise Lake. On bank above road. 9 July 1966.

Potentilla diversifolia Lehm. var. glaucophylla Lehm.

132. Near road several miles south of Atlin. 7 July 1966.
249. Wright Creek road south of Surprise Lake. 9 July 1966.

Potentilla anserina L.

391. Mile 52 Bog. Open, moist area. Rare, in a local patch. 5 July 1967.

Potentilla Egedii Wormsk. subsp. yukonensis (Hult.) Hult.

207. Sandy soil near inside edge of dried up pond near Wright Creek road south of Surprise Lake. c 3,500 ft. 9 July 1966.

Chamaerhodos erecta (L.) Bunge subsp. Nutallii (Torr. & Gray) Hult.

389. Vicinity of Atlin road at mile 16. Dry, sandy, unforested, west-facing slope. c 2,600 ft. 6 July 1967.

Geum macrophyllum Willd. subsp. perincisum (Rydb.) Hult.

222. Wright Creek road south of Surprise Lake. 9 July 1966.

Dryas integrifolia M. Vahl

354. Vicinity of Atlin road at mile 59. Dry, open spruce forest east of road. c 2,300 ft. Rare. 1 July 1967.

Prunus sp. (cf. melanocarpa (A. Nels.) Shafer.)

311. Near mile 30, Atlin road. In closed spruce forest. c 2,400 ft. 31 August 1966.

Rosa acicularis Lindl.

316. Collected at miles 1, 10, 20, and 40, Atlin road. Widespread. 31 August 1966.

LEGUMINOSAE

<u>Lupinus</u> <u>arcticus</u> S. Wats.

2. Ruby Creek road. c 3,800 ft. 23 August 1965.
74. Near Atlin. 6 July 1966.
97. Near Atlin. 6 July 1966.
204. Wright Creek road south of Surprise Lake. Sandy soil in dry, spruce and pine forest. c 3,600 ft. 9 July 1966.
397. In dense, young aspen stand east of Atlin road at mile 12. c 2,550 ft. 3 July 1967.

<u>Medicago</u> <u>lupulina</u> L.

47. Warm Springs area near road c 15 miles south of Atlin. Open, moist, grassy. c 2,300 ft. 27 August 1965.

<u>Astragalus</u> <u>americanus</u> (Hook.) M. E. Jones

146. Near road south of Atlin. 7 July 1966.
253. Near outlet of Surprise Lake. c 3,000 ft. 10 July 1966.
340. Near Atlin road at mile 52. 23 June 1967.
371. Near Atlin road at mile 56(?). 3 July 1967.

<u>Astragalus</u> <u>alpinus</u> L.

80. Near Atlin. 6 July 1966.
121. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 6 July 1966.
235. Wright Creek road south of Surprise Lake. 9 July 1966.
298. North of Atlin road at mile 6. 11 July 1966.
400. In young aspen forest east of Atlin road at mile 12. c 2,550 ft. 6 July 1967.

<u>Oxytropis</u> <u>Maydelliana</u> Trautv.

140. Near road several miles south of Atlin. 7 July 1966.

<u>Oxytropis</u> <u>campestris</u> (L.) DC. subsp. <u>gracilis</u> (Nels.) Hult.

212. Wright Creek road south of Surprise Lake. Embankment above road. c 3,200 ft. 9 July 1966.
290. Mile 6, Atlin road. c 2,300 ft. 11 July 1966.
323. Near Mile 52 Bog. c 2,400 ft. 23 June 1967.
372. Mile 56, Atlin road. c 2,450 ft. 3 July 1967.
377. East of Atlin road at mile 16. Sandy, west-facing slope. c 2,600 ft. 3 July 1967.

<u>Hedysarum</u> <u>alpinum</u> L. subsp. <u>americanum</u> (Michx.) Fedtsch.

112. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 6 July 1966.

300. North of Atlin road at mile 6. c 2,400 ft. 11 July 1966.

VIOLACEAE

<u>Viola</u> <u>adunca</u> Sm.

972. Moose Bones Bog. Common in outermost, mesic, herbaceous zone and in shrub zone. 3 September 1968.

ONAGRACEAE

<u>Epilobium</u> <u>angustifolium</u> L.

17. Gravel pit on O'Donnel (Atlin) road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.

68. Near Warm Bay c 14.5 miles south of Atlin. c 2,250 ft. Seepage and mineral springs. Calcium carbonate crust on ground. 27 August 1965.

<u>Epilobium</u> <u>latifolium</u> L.

93. Near Atlin. 6 July 1966.

139. Several miles south of Atlin. Early July 1966.

213. Wright Creek road south of Surprise Lake. 9 July 1966.

220. Wright Creek road south of Surprise Lake. 9 July 1966.

248. Wright Creek road south of Surprise Lake. 9 July 1966.

<u>Epilobium</u> <u>palustre</u> L.

822. Mile 47 Bog. In dense moss, rooting in the moss, of <u>Hylocomium</u> type. Locally abundant. c 2,400 ft. 10 July 1968.

<u>Epilobium</u> <u>Hornemannii</u> Rchb.

19. Gravel pit on O'Donnel (Atlin) road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.

HALORAGACEAE

Hippurus _vulgaris_ L.

883. Mile 47 Bog. Sparse in open mud near edge of water & in Scirpus zone. c 2,400 ft. 10 July 1968.

UMBELLIFERAE

Heracleum _lanatum_ Michx.

42. Warm Springs area c 15 miles south of Atlin. Open, moist, grassy area. Growing in open water of mineral springs. c 2,300 ft. 27 August 1965.

PYROLACEAE

Pyrola _asarifolia_ Michx.

167. Near road several miles south of Atlin. 6 July 1966.

Pyrola _asarifolia_ (Michx.) var. _purpurea_ (Bunge) Fern.

142. Near road several miles south of Atlin. 7 July 1966.
348. Vicinity of Atlin road at mile 59. 1 July 1967.
359. Shady, mossy spruce forest east of Atlin road at mile 52, c 2,450 ft. 1 July 1967.
366. Vicinity of Atlin road at mile 32. c 2,600 ft. 3 July 1967.
809. Mile 47 Bog. Rare. c 2,400 ft. 10 July 1968.

Pyrola _chlorantha_ Sw.

166. Several miles south of Atlin. 8 July 1966.
368. East of Atlin road at mile 32. c 2,600 ft. 3 July 1967.

Pyrola _minor_ L.

149. Several miles south of Atlin. 7 July 1966.

Pyrola _secunda_ L. subsp. _secunda_

191. Near road several miles south of Atlin. 6 July 1966.
367. Vicinity of Atlin road at mile 32. c 2,600 ft. 3 July 1967.

Pyrola secunda L. subsp. *obtusta* (Turcz.) Hult.

116. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 6 July 1966.

Moneses uniflora (L.) Gray

156. Vicinity of road several miles south of Atlin. 8 July 1966.
238. Wright Creek road south of Surprise Lake. 9 July 1966.
407. Shady, mossy spruce forest east of Atlin road at mile 52. c 2,400 ft. 5 July 1967.

ERICACEAE

Ledum palustre L. subsp. *groenlandicum* (Oeder) Hult.

73. Near Atlin. 6 July 1966.

Arctostaphylos uva-ursi (L.) Spreng. var. *adenotricha* Fern. & Macbr.

232. Wright Creek road south of Surprise Lake. 9 July 1966.

Vaccinium vitis-idaea L. subsp. *minus* (Lodd.) Hult.

85. Near Atlin. 6 July 1966.
271. Vicinity of road north of Surprise Lake. c 3,300 ft. 10 July 1966.

Vaccinium caespitosum Michx.

86. Near Atlin. 6 July 1966.

Oxycoccus microcarpus Turcz.

214. Wright Creek road south of Surprise Lake. Boulder-strewn area covered with moss. c 3,200 ft. 9 July 1966.
845. Jasper Creek Bog. Locally abundant on moss hummocks in shrub willow zone. c 2,400 ft. 11 July 1968.

PRIMULACEAE

Androsace septentrionalis L.

269. Near road north of Surprise Lake. c 3,400 ft. 10 July 1966.

270. (Same as 269).
284. North of Atlin road at mile 6. c 2,400 ft. 11 July 1966.
343. Near Atlin road at mile 52. c 2,350 ft. 23 June 1967.
373. East of Atlin road at mile 16. c 2,600 ft. Dry, sandy, west-facing slope. 3 July 1967.
395. East side of Atlin road at mile 8. c 2,500 ft. Late June 1967.

GENTIANACEAE

Gentiana amarella L. subsp. acuta (Michx.) Hult.

16. Gravel pit on O'Donnel (Atlin) road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.

Gentiana propinqua Richards.

282. Vicinity of road north of Surprise Lake. c 3,400 ft. 10 July 1966.
285. Vicinity of Atlin road at mile 6. c 2,300 ft. 11 July 1966.
385. Mile 8.9, Atlin road, at Haunka Creek. c 2,300 ft. Bulldozed, gravelly site. 6 July 1967.

Menyanthes trifoliata L.

840. Jasper Creek Bog. Common at edge of open water. Fruits developed. c 2,400 ft. 11 July 1968.

POLEMONIACEAE

Polemonium acutiflorum Willd.

245. Wright Creek road south of Surprise Lake. 9 July 1966.
331. Moss, shady spruce forest in vicinity of Atlin road at mile 52, c 2,400 ft.
408. Early July 1967.

Polemonium pulcherrimum Hook.

14. Gravel pit on O'Donnel (Atlin) road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.
84. Near Atlin. 6 July 1966.
99. Near Atlin. 6 July 1966.
183. Vicinity of road several miles south of Atlin. 6 July 1966.

221. Wright Creek road south of Surprise Lake. 9 July 1966.
279. Vicinity of road north of Surprise Lake. c 3,300 ft. 10 July 1966.
301. Mile 6, Atlin road. c 2,300 ft. 11 July 1966.

HYDROPHYLLACEAE

Phacelia Franklinii (R. Br.) Gray

361. East of Atlin road at mile 16. Steep, sandy, west-facing slope. c 2,600 ft. Rare. 3 July 1967.
388. Mile 8.9, Atlin road, at Haunka Creek. Bulldozed, gravelly area. c 2,300 ft. 6 July 1967.

BORAGINACEAE

Lappula myosotis Moench

292. North of Atlin road at mile 6. c 2,400 ft. 11 July 1966.
387. Mile 8.9, Atlin road, at Haunka Creek. c 2,300 ft. Bulldozed, gravelly site. 6 July 1967.

Myosotis alpestris F. W. Schmidt subsp. asiatica Vestergr.

197. Wright Creek road south of Surprise Lake. c 3,700 ft. 9 July 1966.

Mertensia paniculata (Ait.) G. Don

75. Near Atlin. 6 July 1966.
96. (Same as 75).

LABIATAE

Dracocephalum parviflorum Nutt.

888. Near summit of ridge east of mile 16, Atlin road. c 2,700 ft. Burned lodgepole pine stand. 21 August 1968. Uncommon.

SCROPHULARIACEAE

Penstemon Gormani Greene

287. Vicinity of Atlin road north of mile 6. c 2,300 ft. 11 July 1966.
305. Snafu Lake. Dry, sandy hillside east of camping area. c 2,500 ft. 11 July 1966.
374. East of Atlin road at mile 16. Open, sandy, west-facing hillside. c 2,600 ft. Common. 3 July 1967.

Penstemon procerus Dougl.

141. Near road several miles south of Atlin. 7 July 1966.
193. Near road several miles south of Atlin. 8 July 1966.
205. Wright Creek road south of Surprise Lake. Open spruce and pine stand on dry, sandy soil. c 3,400 ft. 9 July 1966.
281. Vicinity of road north of Surprise Lake. c 3,300 ft. 10 July 1966.
296. Mile 6, Atlin road. c 2,300 ft. 11 July 1966.
396. Unforested, well-drained, grassy area, east of Atlin road at mile 8. c 2,500 ft. 6 July 1967.

Mimulus guttatus DC.

48. Warm Springs c 15 miles south of Atlin. c 2,300 ft. Growing in or next to stream of mineral water. Abundant. 27 August 1965.
276. Vicinity of road north of Surprise Lake. c 3,400 ft. Moist. 10 July 1966.

Veronica Wormskjoldii Roem. & Schult.

199. Wright Creek valley south of Surprise Lake. Wet shrub stand. c 3,700 ft. 9 July 1966.
273. Vicinity of road north of Surprise Lake. c 3,300 ft. 10 July 1966.

Castilleja unalaschcensis (Cham. & Schlecht.) Malte

101. Near Atlin. 6 July 1966.
211. Wright Creek road, south of Surprise Lake. Unforested bank above road. c 3,200 ft. 9 July 1966.

Castilleja caudata (Pennell) Rebr.

66. Near Warm Bay c 14.5 miles south of Atlin. Seepage and mineral springs. Calcium carbonate crust on ground. c 2,250 ft. 27 August 1965.
148. Vicinity of road south of Atlin. 7 July 1966.

869. Ruby Creek Road. c 4,500 ft on north-northeast side of Ruby Mountain.

Rhinanthus minor L. subsp. borealis (Sterneck) Love

853. In Atlin. Abundant in open, gravelly area around old outpost hospital bldg. c 2,200 ft. 15 August 1968.

Pedicularis ornithorhyncha Benth.

914. Mt. Vaughan. In tundra zone in summit area on west side. c 5,700 ft. 20 August 1968.

Pedicularis labradorica Wirsing

229. Wright Creek road south of Surprise Lake. 9 July 1966.
334. Mile 52, Atlin road. c 2,400 ft. 23 June 1967.
355. Shady, mossy spruce forest east of road at mile 52. c 2,400 ft. Common. 1 July 1967.
398. Dense, young aspen stand east of Atlin road at mile 12. c 2,550 ft. 6 July 1967.

Pedicularis sudetica Willd.

264. Vicinity of road north of Surprise Lake. c 3,300 ft. 10 July 1966.
325. Shrub willow stand west of Atlin road at mile 52. c 2,400 ft. 23 June 1967.
352. Moist shrub birch and willow stand west of Atlin road at mile 59. c 2,300 ft. Common. 30 June 1967.

OROBANCHACEAE

Orobanche fasciculata Nutt.

889. Open, rocky, southwesterly slope above mile 16, Atlin road. c 2,700 ft. Parasitic on Artemisia frigida. 21 August 1968. Common.

LENTIBULARIACEAE

Utricularia intermedia Hayne

838. Jasper Creek Bog. Common in wet sedge zone. c 2,400 ft. 11 July 1968.

PLANTAGINACEAE

Plantago eriopoda Torr.

973. Moose Bones Bog. Common in patches in outermost, mesic, herbaceous zone. 3 September 1968.

RUBIACEAE

Galium boreale L.

13. Gravel pit on O'Donnel (Atlin) road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.
131. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 7 July 1966.
136. Open, sandy slope above road several miles south of Atlin. 7 July 1966.

Galium trifidum L. subsp. trifidum

829. Mile 47 Bog. Growing abundantly on small moss hummock in open mud of sedge zone near edge of pond. c 2,400 ft. 10 July 1968.

CAPRIFOLIACEAE

Viburnum edule (Michx.) Raf.

115. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 6 July 1966.
312. Vicinity of Atlin road at mile 1. c 2,400 ft. 31 August 1966.
320. Spruce and aspen stand southwest of Mile 52 Bog, Atlin road. c 2,400 ft. Common. 23 June 1967.

VALERIANACEAE

Valeriana dioica L. subsp. sylvatica (Soland.) F. G. Meyer

268. Vicinity of road north of Surprise Lake. c 3,300 ft. 10 July 1966.

CAMPANULACEAE

Campanula lasiocarpa Cham. subsp. lasiocarpa

857. Upper Ruby Creek road north-northeast of Ruby Mountain. c 4,500 ft. 19 August 1968.

LOBELIACEAE

Lobelia kalmii L.

936. Common in wet sedge meadow on north-facing slope above Warm Bay, approx. 14.5 miles south of Atlin. c 2,300 ft. In flower. 25 August 1968.

COMPOSITAE

Solidago multiradiata Ait.

45. Warm Springs area c 15 miles south of Atlin, c 2,300 ft. Shady, moist, and grassy. 27 August 1965.
63. Near Warm Bay c 14.5 miles south of Atlin, c 2,250 ft. Seepage and mineral springs with carbonate crust on ground. 27 August 1965.
122. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 7 July 1966.
216. Wright Creek road south of Surprise Lake. 9 July 1966.
272. Vicinity of road north of Surprise Lake. c 3,300 ft. 10 July 1966.

Solidago decumbens Greene var. oreophila (Rydb.) Fern.

288. Vicinity of Atlin road north of mile 6. c 2,400 ft. 11 July 1966.
362. East of Atlin road at mile 16. Steep, sandy, west-facing slope. c 2,600 ft. 3 July 1967.

Solidago lepida DC.

43. Warm Springs area c 15 miles south of Atlin. c 2,300 ft. Open, moist, and grassy. 27 August 1965.

Aster sibiricus L.

383. Mile 8.9, Atlin road, at Haunka Creek. Bulldozed, gravelly area next to road. c 2,300 ft. Abundant. 6 July 1967.

251. Near outlet of Surprise Lake. c 3,000 ft. 10 July 1966.
280. Near road north of Surprise Lake. c 3,400 ft. 10 July 1966.

Aster laevis L.

49. Warm Springs area c 15 miles south of Atlin. Open, moist, and grassy. c 2,300 ft. 27 August 1965.
62. Near Warm Bay c 14.5 miles south of Atlin. Seepage and mineral springs. Calcium carbonate crust on ground. Some plants in shallow water. c 2,250 ft. 27 August 1965.

Erigeron compositus Pursh var. glabratus Macoun

341. Vicinity of Atlin road at mile 52. On low hill west of bog. c 2,400 ft. 23 June 1967.
363. Vicinity of Atlin road at mile 16. Sandy, west-facing hillside. c 2,600 ft. 3 July 1967.

Erigeron eriocephalus J. Vahl

239. Wright Creek road south of Surprise Lake. 9 July 1966.

Erigeron elatus Greene

192. Vicinity of road south of Atlin. 8 July 1966.
848. Jasper Creek Bog. Rare. c 2,400 ft. 11 July 1968.
944. In gravel pit on O'Donnel road approx. 20 miles south of Atlin. c 2,900 ft. 25 August 1968.
958. Moose Bones Bog. 3 September 1968.

Antennaria rosea Greene

124. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 7 July 1966.
286. North of Atlin road at mile 6. c 2,400 ft. Unforested, well-drained site. 11 July 1966.
308. Snafu Lake. Dry hillside east of camping area. c 2,500 ft. 11 July 1966.
333. Vicinity of Atlin road at mile 52. Unforested, well-drained area near summit of low hill west of bog. c 2,400 ft. 23 June 1967.
342. Vicinity of Atlin road at mile 52. Unforested, well-drained area near summit of low hill west of bog. c 2,400 ft. 23 June 1967.

Antennaria rosea Greene var. nitida (Greene) Breitung

5. Ruby Creek road. Bulldozed area next to road, easterly exposure. c 3,800 ft. 23 August 1965.

329. Near Atlin road at mile 52. Southwest of bog. c 2,400 ft. 23 June 1967.
380. East of Atlin road at mile 16. Open, sandy, west-facing hillside. c 2,600 ft. Common. 3 July 1967.

Achillea borealis Bong.

7. Ruby Creek road. Bulldozed area near road, easterly exposure. c 3,800 ft. Abundant. 23 August 1965.
10. Gravel pit on O'Donnel road c 20 miles south of Atlin. c 2,900 ft. 24 August 1965.
58. Near Warm Bay c 14.5 miles south of Atlin. c 2,250 ft. Unforested, wet area of springs and calcium carbonate crusts on ground. 27 August 1965.
295. North of Atlin road at mile 6. c 2,400 ft. 11 July 1967.

Matricaria matricarioides (Less.) Porter

54. Open, rocky, bulldozed area next to Atlin road near Fourth of July Creek. c 2,400 ft. 24 August 1965.
856. Moist depression in gravel pit on Fourth of July Creek road, near McDonald Lks. c 3,100 ft. 18 August 1968.

Artemisia frigida Willd.

303. North of Atlin road at mile 6. c 2,300 ft. 11 July 1966.
360. East of Atlin road at mile 16. Unforested, sandy, west-facing hillside. c 2,600 ft. 3 July 1967.

Artemisia alaskana Rydb.

307. Snafu Lake. Unforested, dry, sandy hillside east of camping area. c 2,600 ft. 11 July 1966.

Artemisia arctica Less.

267. Near road north of Surprise Lake. c 3,400 ft. 10 July 1966.
306. Snafu Lake. Unforested, sandy hillside east of camping area. c 2,500 ft. 11 July 1966.

Artemisia borealis Pall.

378. Dry, sandy, west-facing hillside above Atlin road at mile 16. c 2,600 ft. Common. 3 July 1967.

Petasites sagittatus (Banks) Gray

321. Moist shrub willow thicket west of Atlin road at mile 52. c 2,400 ft. 23 June 1967.

<u>Arnica</u> <u>frigida</u> C. A. Mey.

44. Warm Springs area c 15 miles south of Atlin. c 2,300 ft. Open, moist, and grassy site. 27 August 1965.

<u>Arnica</u> <u>cordifolia</u> Hook.

76. Near Atlin. 6 July 1966.
98. (Same as 76)
144-B. Exposed, rocky slope above road several miles south of Atlin. 7 July 1966.
283. Near road north of Surprise Lake. c 3,400 ft. 10 July 1966.
297. Mile 6, Atlin road. c 2,300 ft. 11 July 1966.
338. Vicinity of Atlin road at mile 52. In spruce-aspen forest southwest of bog. c 2,400 ft. Common. 23 June 1967.

<u>Arnica</u> <u>Chamissonis</u> Less. subsp. <u>foliolosa</u> (Nutt.) Maguire

854. In Atlin. Common in open gravelly area near old outpost hospital bldg. c 2,200 ft. 15 August 1968.

<u>Senecio</u> <u>cymbalarioides</u> Nutt.

289. Vicinity of Atlin road north of mile 6. c 2,400 ft. 11 July 1966.

<u>Senecio</u> <u>pauperculus</u> Michx.

65. Near Warm Bay c 14.5 miles south of Atlin. Seepage and mineral springs with carbonate crust on ground. c 2,250 ft. 27 August 1965.
195. Near road several miles south of Atlin. 8 July 1966.
265. Near road north of Surprise Lake. c 3,300 ft. 10 July 1966.

<u>Senecio</u> <u>triangularis</u> Hook.

120. Near the Grotto c 16 miles south of Atlin. c 2,400 ft. 6 July 1966.
874. Ruby Creek road. Gravelly alluvium on north-northeast side of Ruby Mountain. c 5,000 ft. 19 August 1968.

<u>Senecio</u> <u>lugens</u> Richards.

147. Several miles south of Atlin. 7 July 1966.

<u>Agoseris</u> <u>glauca</u> (Pursh) Raf.

945. In gravel pit on O'Donnel road approx. 20 miles south of Atlin. c 2,900 ft. 25 August 1968.

Agoseris _aurantiaca_ (Hook.) Greene

868. Ruby Creek road. Gravelly alluvium on north-northeast side of Ruby Mountain. c 5,000 ft. 19 August 1968.

Crepis _nana_ Richards. var. _nana_

946. On bulldozed and stream-cut gravels and sand near mine on Spruce Creek. c 3,100 ft. 28 August 1968.

Hieracium _gracile_ Hook.

878. Mt. Leonard. Moist area near stream c 4,800 ft on east side of mountain. 19 August 1968.