Arctic Gas

BIOLOGICAL REPORT SERIES
VOLUME TWENTY-ONE

VEGETATION AND SOILS OF NORTHEASTERN ALASKA

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Prepared by

NORTHERN ENGINEERING SERVICES COMPANY LIMITED

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ABSTRACT

A survey of plant communities and soils was initiated in Northeastern Alaska in order to provide baseline information for describing community nomenclature and relationships, to ascertain relationships between vegetation, soils and landform features, to outline areas where instability may be a problem in land use and to make recommendations toward revegetation and reclamation procedures.

Quantitative sampling techniques were used to collect data from stands which were selected via air photography interpretation and air and ground reconnaissance. Forty-one associations were described using combinations of dominant species and groupings designated by hierarchial cluster analysis. These associations were placed into traditional physiognomic formation categories which were related to soil classification and terrain features. Wet sedge meadows, herb-sedge, heath shrub and lichen meadows were common vegetation types in all of the physiographic provinces. A trend for decreased physiognomic stature is present from south to north through the study area. Forest and open forest vegetation is gradually replaced by a predominance of shrub communities. Low shrub, low shrub and sedge mixtures and sedge communities are the most common in the Arctic Coastal Plain. Most of the soils were classified according to a newly developed system for northern areas. Frequent use of Turbic Great Groups and Gleysolic Subgroups in the Cryosolic Soil Order indicates the instability, poor drainage and thin active layers of most soils.

A number of successional trends are indicated for physiographic regions of the area and are related to changes in species composition, diversity, growth factors and soil conditions. The wide range in latitude of the study area increased the number of seres which were identified for any one terrain type. White spruce forests on riparian and upland sites indicate a relatively stable condition, but evidence suggests that a trend toward low shrub communities occurs in a number of habitats. Low shrub vegetation becomes more important with increase in latitude as a stable entity of seres. However, frequent disruption of the soil by frost action complicates successional interpretations. The abundance of natural instability of the land surface is used as an indicator of problems associated with land use. Silty textures, poor drainage, thin active layers and topography combine to produce unstable conditions.

ACKNOWLEDGMENTS

The authors wish to thank David Boyce and Kim Sikoryak for help in collecting data under sometimes unusual conditions and for some of the photographs. Mr. Sikoryak was especially helpful in collecting cryptogam data and specimens. Appreciation is expressed to Don Dabbs for supporting a basic synecological approach to the survey, to Dr. R.W. Wein for initial guidance and meaningful discussions on the ecology of northern plant communities and to Walt Younkin for critically reviewing portions of the manuscript. Thanks are also expressed to A.E. Helmers, Institute of Northern Forestry, Forest Service, U.S.D.A. Fairbanks, Alaska for forwarding information on northeastern Alaska fire history, and to John Klingle, Roland Quimby and Dave Roseneau, Renewable Resources Consulting Services, Fairbanks, for help in coordinating field logistics and support. Dr. George Argus, National Museum, Ottawa, verified and identified large quantities of vascular plant specimens; Dr. Dale Vitt and Mike Ostifichuk, Dept. of Botany, University of Alberta, Edmonton verified and identified the moss and lichen specimens. The species diversity computer program was obtained through Dr. George W. Douglas. For these services, we are extremely grateful.

The C.A.G.S.L. Biological Report Series of which this volume is a part, is a series of consultant project reports presenting data based on field and laboratory studies. The data for this work were obtained as a result of investigations carried out by Northern Engineering Services Company Limited for Alaska Arctic Gas Study Company. The text of this report may be quoted providing the usual credits are given.

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1.0 INTRODUCTION

The current and projected trend for development of northern Alaska will no doubt continue as the need for natural resources increases. Increase in land use of the northern boreal forest and tundra necessitates a predicting cause and effect relationships between use and associated environmental changes. The establishment of meaningful biological units, their description, assessment of their relationships to environmental factors and each other is necessary in obtaining baseline information for impact prediction of land use and for formulating land use plans.

Although the tundra and northern boreal forest comprise a large portion of Alaska, biological studies have been limited by inaccessability, short growing seasons and adverse winter conditions. Exploration parties were active along the northern coast of Alaska in both the 18th and 19th centuries, and activity near the coast increased with the arrival of whaling expeditions in 1848. Naturalists usually accompanied the exploration expeditions, and although reports were at first limited, a gradual knowledge of the main species, especially zoological, was accumulated (Wilimovsky, 1966). Botanical collections have been quite extensive to date (Hulten, 1968), although there are, undoubtedly, areas in the mountainous regions which have not been well collected. Plant community descriptions, on the other hand, have been restricted to specific areas. Coastal plain communities have been described more thoroughly than those of the mountainous regions due in part to their greater accessibility with intensive studies being conducted near Prudhoe Bay and Cape Thompson.

The major objective of the vegetation - soil survey is to provide information which will serve as a basis for making land use decisions which are aimed at maintaining the present, naturally evolved, ecosystems.

Specific objectives are:

1) To establish a framework of vegetation pattern and environmental relationships to which other biological studies can be related.

2) To establish quantified baseline data in order to predict and monitor changes in vegetation and soils which may be due to activities associated with the development of transportation facilities.

3) To characterize terrain types according to present plant cover and associated soil properties which can be important in making decisions for revegetation and restoration programs.

4) To outline areas where special techniques are necessary to insure land stability in the event of pipeline construction.

5) To inventory forested areas for clearing and right-of-way cost analysis.

2.0 REVIEW OF LITERATURE

The first botanical studies in northern Alaska were of plant collections and descriptions under the auspices of exploration parties (Hulten, 1940). These and later collections contributed to the present botanical knowledge of the area which has been coalated by Hulten (1968). Reports continue to be published in species range extensions as the more remote areas are collected (Miller *et al.*, 1973).

Studies on the composition and description of plant communities are relatively recent and have been concentrated near the more accessible areas of the Alaskan north slope (Cape Thompson and Point Barrow). The most comprehensive descriptions to date are those of Sigafoos (1952), Spetzman (1959), Britton (1957) and Johnson *et al.* (1966) which cover most of the coastal plain, foothills and parts of the northern Brooks Range. Vegetation has been described for a more limited area by Wiggins (1951) near Point Barrow, Hanson (1953) near the Noatuk and Kobuk rivers in northwestern Alaska, and Churchill (1955) near Umiat. These descriptions have included community nomenclature and the dominant species with inferences to related physiographic and other environmental factors. Rastorfer *et al.* (1973) emphasizes the importance of bryophytes in Low Arctic areas and describes the habitat of numerous moss species at Prudhoe Bay.

Community descriptions are apparently non-existent for most of the area from the interior Brooks Range to the Porcupine Plateau and Yukon boundary. Johnson and Vogel (1966) have described the vegetation of the Yukon Flats which has some similarities to vegetation of the Porcupine Plateau, and Shacklette (1963) has listed the dominant species in many communities in the Circle Hot Springs area south of the Yukon River. Dingman and Koutz (1974) have typed the vegetation in the Yukon - Tanana area north of Fairbanks, and have delineated relationships between vegetation, permafrost and insulation factors. Vegetation types have been described for the Canadian Arctic by Mackay (1963), Corns (1972), and Gill (1971) near the Mackenzie Delta and Drew and Shanks (1965) and Lambert (1968) in the British and Richardson mountains. A number of areas in the northern Yukon were described by Welsh and Rigby (1971) during a reconnaissance study and Hettinger *et al.* (1973) classified vegetation and soil types with associated terrain in the northern Yukon and adjacent N.W.T. Aspects of the tundra-forest ecotone are discussed by Krebs and Barry (1970), Larsen (1973) and Ritchie and Hare (1971).

Successional concepts for tundra areas have been reviewed by Churchill and Hanson (1958) and discussions of trends for various vegetation types of the north slope of Alaska include those of Churchill (1955) and Spetzman (1959). Succession patterns for riparian communities are discussed by Bliss and Cantlon (1957) for northern Alaska and by Gill (1971) for the Mackenzie Delta. Lambert (1972) describes recolonization features of a mudflow and alpine succession in the northern Yukon. Successional trends in northern forested regions have been described by Taylor (1932) for southeastern Alaska and by Strang (1973) for an area near the Mackenzie River in the Northwest Territories.

The interaction between vegetation types and disruptive influences (fire and frost action) have been investigated at a number of sites in the Arctic. According to Lutz (1959) wildfires have always been a factor in most northern ecosystems and some of the effects of fires on biotic and physical components of boreal forest have been documented (Lutz, 1956; Ahlgren and Ahlgren, 1960; Scotter, 1964; and Mackay, 1970). The effects of fire in Arctic tundra regions have been discussed by Cody (1954, 1965), Cochrane and Rowe (1969) and Wein and Bliss (1973b). The influence of frost action on vegetation has been discussed by Benninghoff (1952) and Viereck (1966), and a positive relationship between frost features and silty soils was noted by Hopkins and Sigafoos (1950) and Viereck (1966) in the Seward Peninsula.

Shacklette (1963) has observed that relationships between plant communities and variations in soil moisture, light, exposure, soil type and geologic formation are less evident in high latitudes than in temperate areas. Thus the vegetation mosaic in the Arctic is thought to be more difficult to interpret on the basis of controlling factors. Shacklette (1963) found no relationship between soil taxa (great group), essential elements, soil pH and discrete types of plant communities.

An increasing amount of the effect of disturbance on tundra vegetation research has been documented. The effects of seismic and road activities are discussed by Hok (1969) for northern Alaska and by Hernandez (1972 and 1973) for the Mackenzie Delta region. Seismic and oil spill disturbance tests have been discussed by Bliss and Wein (1972) and the effects of winter road use by Kerfoot (1972). Other studies related to disturbance include response of native species to fertilizer treatments (Haag, 1972) and energy budget studies near the Mackenzie River at Norman Wells and Tuktoyaktuk (Haag, 1972).

Early descriptive soil studies in northern Alaska have been concentrated near accessible coastal regions such as Point Barrow. These studies were initiated by Kellogg and Nygard (1951) who described a few profiles at Point Barrow, and later Tedrow and his associates (Tedrow and Hill, 1955; Drew and Tedrow, 1957; Tedrow and Cantlon, 1958; Tedrow *et al.*, 1958), who described several well drained profiles near Point Barrow, and others within the arctic slope. They then initiated a classification system based on drainage. More recently, several investigations have been carried out further inland, in the foothills and northern Brooks Range. Ugolini and Tedrow (1963) and Ugolini *et al.* (1963) investigated soils formed from black mountain shales, Drew and Shanks (1965) described soils in the Firth River Valley and related these to vegetation types, and Brown (1969a) has described soils in the foothills area near the Okpilak River.

It was recognized in these early investigations that soil forming processes in the Arctic are retarded in comparison to temperate regions, by low decomposition rates (Douglas and Tedrow, 1959) and by low rates of weathering of the parent material (Hill and Tedrow, 1961) due to low temperatures and high moisture contents of these soils. In addition, it was clear that the presence of permafrost and its influence on frost features and processes, had a disruptive and reverse effect on soil forming processes. The relationship of permafrost, patterned ground, frost processes and ice wedges to soil formation have been discussed by Tedrow and Harries (1960), Drew and Tedrow (1965) and Brown (1967) respectively. Buried organic matter has been commonly associated with these frost processes in permafrost regions (Mackay, 1962; Tedrow, 1965; Brown, 1969b).

In the Canadian Arctic, some soil properties of the northern Hudson's Bay and Ellesmere Island have been described by Fenstel *et al.* (1939). Other studies are limited to the Western Canadian Arctic where Day and Rice (1964) described several profiles above the Mackenzie River and Lambert (1968) has described local soils according to Kubiene (1953) near Canoe and Trout Lakes in the Richardson Mountains of the northern Yukon. Janz (1974) described a number of soils in the Tuktoyaktuk peninsula and related changes to microenvironmental differences. The present survey of northern Alaskan soils covers five physiographic regions. Only the major types could be examined in the short time available in one summer over such an extensive area. The survey accompanied the vegetation survey, limiting sampling to those areas designated for vegetation sampling.

3.0 STUDY AREA

3.1 Location

The area under investigation is about 250 x 270 km (155 x 170 miles) and extends from the Alaska-Yukon Boundary (141°W) on the east to the Ivishak River in the Brooks range (147°W) and Prudhoe Bay, Alaska (148°20'W) on the west, and from the upper Porcupine Plateau (67°40'N) on the south to the Arctic coast on the north (70°20'N) (Fig. 1).

3.2 Land Use

Settlements near the study area include Arctic Village on the east fork of the Chandalar River and Kaktovak on Barter Island both of which have less than 200 people (Alaska Fed. Field Comm. for the Develop. Planning in Alaska, 1968). These settlements traditionally have had a hunting and trapping economy. Numerous people in this area apparently still rely on animal resources for a part of their food supply (Alaska Fed. Field Committee for the Develop. Planning in Alaska, 1968). Hunting by non-native individuals for grizzly bear, caribou, moose and Dall sheep occurs especially in the southern portion of study area.

Other settlements in the region are those associated with oil and gas resources such as those at Prudhoe Bay and government personnel at the Barter Island DEW-line station.

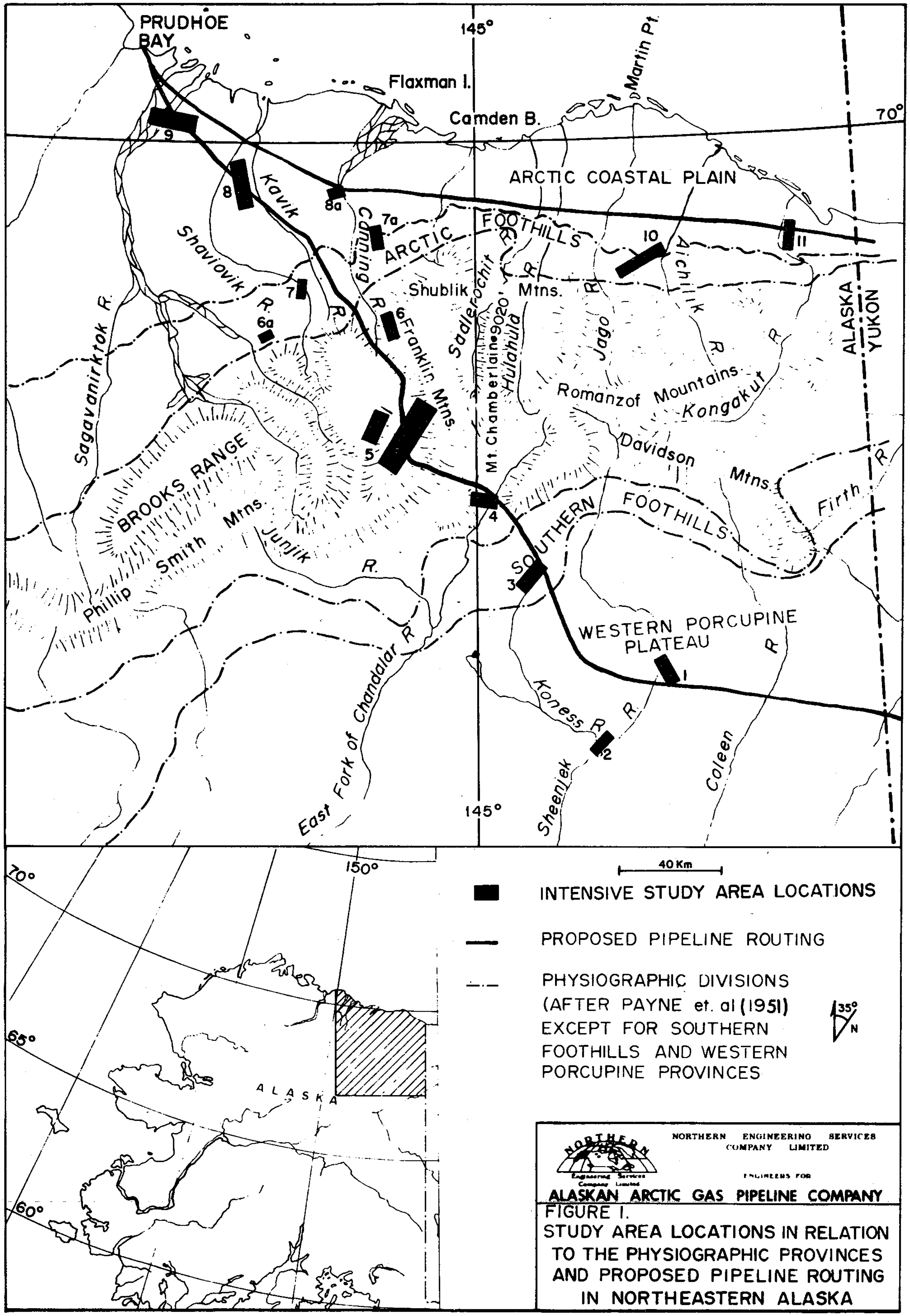


FIGURE I.
STUDY AREA LOCATIONS IN RELATION TO THE PHYSIOGRAPHIC PROVINCES AND PROPOSED PIPELINE ROUTING IN NORTHEASTERN ALASKA

3.3 Physiographic Regions

Most of the area has previously been divided into physiographic regions on the basis of elevation and topography (Payne *et al.*, 1951). These include the Arctic Coastal Plain, Arctic Foothills, Brooks Range, and Porcupine Plateau Provinces. Permafrost is mapped as continuous for the entire region, but may not be found in certain restricted habitats (Ferrians, 1965).

The Arctic Coastal Plain extends east across the northern section of Alaska from near Cape Beaufort (164°W) and has been divided into the Teshekpuk and White Hills Sections (Payne *et. al.*, 1951). The province varies in width (north to south) from about 160 km (100 mi.) at the western end to 17 km (12 mi.) at Demarcation Bay. The Teshekpuk Lake Section is mostly below 100 m (300 ft.) elevation and of low relief with much of the surface covered by wind-oriented lakes. This section extends east from Cape Beaufort to about Camden Bay (145°E) (Fig. 1). The White Hills Section includes an area of rolling hills up to 370 m (1200 ft.) elevation with fewer lakes than the Teshekpuk Lake Section, although poor surface drainage is still present (Black and Barksdale, 1949). This section is interior to the Teshekpuk Lake Section over much of the province, until near Camden Bay, where a drier aspect and hilly topography extend nearly to the coast from the foothills. The entire province exhibits ground frost features which are categorized by Washburn (1956) as circles, polygons, nets, stripes and steps.

Much of the Arctic Coastal Plain is of unconsolidated marine and non-marine gravel, sand, clay and peat of the Quarternary Gubik Formation. The White Hills Section however, also includes some non-marine sediments of the Early Tertiary Sagavanirktok Formation of poorly consolidated conglomerates, silty sandstone and siltstone with some lignite and bog-head cannel coal (Payne *et al.*, 1951). The area has apparently not been glaciated since exposed (Detterman *et al.*, 1958).

The Arctic Foothill Province extends along the base of the Brooks Range at 150 to 610 m (500 - 2000 ft.) elevation and varies from five to 80 km (50 mi.) in width (Fig. 1). Payne *et al.* (1951) divide the Province into northern and southern sections and include areas to 915 m (3000 ft.). The topography is of rolling hills with numerous resistance ridges nearer the mountains which are dissected by rivers and creeks originating in the adjacent Brooks Range. The Province is generally covered by a mantle of Lower and Upper Cretaceous rock and shale, sandstone, conglomerate, bentonite and tuff (Payne *et al.*, 1951). Glaciers covered much of the area during the Quarternary Period, the last period of glaciation occurring between 8,000 and 14,000 years ago. Maximum advance was to the south on the Anaktuvuk River where till has been found ten miles south of the braided river mouth near the coast (Pewe, 1953).

The Brooks Range Province is about 160 km (100 mi.) wide and varies from 610 to over 2750 m (2000 - 9000 ft.) in elevation. The area is composed of a number of subsidiary ranges and is here divided into the Romanzof (northeastern front range), Franklin (interior range near the Canning Range) and Davidson (interior range of the Sheenjek and Coleen River headwaters) mountains (Fig. 1).

This area was uplifted in the Early Cretaceous and again in the Late Cretaceous and is composed of exposed Devonian clastics and limestone, Mississippian limestone, chert, shale and conglomerate, and Permian sandstone (Payne *et al.*, 1951). A number of glaciation occurred throughout the area during the Pleistocene, and glaciers are still present in the higher cirques and north exposed slopes. The topography is therefore complex with outwash plains and lateral moraines at the base of steep talus slopes (Detterman *et al.*, 1958).

The Porcupine Plateau physiographic province lies between the Davidson Mountains (68°20'N) on the north and the Yukon Flats (67°N) on the south (Fig. 1). Much of the area features rolling hills and plateaus at 305 - 370 m (1000 - 1200 ft.) elevation with numerous ridges and isolated peaks to about 1070 m (3500 ft.). A number of rivers extend across the plain to the Yukon Flats from the Brooks Range.

According to Brosge and Reiser (1969) the geology of the region is complex with exposed bedrock of Mississippian shale, quartzite and chert and inclusions of black silt and clay, and outcrops of Jurrassic sandstone and chert with some ridges of exposed Lisburne limestone. The large valleys are composed of alluvial, fluvial and colluvial materials which may cover older moraines, but these may be unmodified closer to the Brooks

Range. Outwash and valley train deposits exist in the upper Sheenjek River and east fork of the Chandalar River south of Arctic Village which, with unmodified moraine, give evidence of Wisconsin glacial advance from the Brooks Range (Karlstrom, 1964).

The northern portion of the Porcupine Plateau is placed in this study into a Southern Foothill Province to facilitate dividing the vegetation portion of the landscape into geographically manageable units. The division includes an area adjacent to the Brooks Range mostly between 460 and 1070 m (1500 - 3500 ft.) elevation with an increase in the number of mountain peaks compared to the Porcupine Plateau (Fig. 1).

3.4 Climate

Barter Island is the only established weather station within the study area. Stations in nearby or similar areas include those at Point Barrow and Komakuk Beach, Yukon Territory. Temperatures at all these stations are influenced by the Arctic Ocean which may modify diurnal and annual ranges and do not give an indication of climatic conditions of the Brooks Range or interior plateaus. Even though temperature ranges are greater in the foothills than the coast, Spetzman (1951) indicates that the growing season is longer at the higher elevations. Climatic data have been recorded and averaged for a 29 year period at Point Barrow and Barter Island (Searby, 1968) and for a 20 year period at Komakuk Beach (Environment Canada, 1970) (Appendix 1). Freezing temperatures occur during each month of the year for both stations. Mean annual temperature is -12.2°C (10°F) at Point Barrow, -12.4°C (10°F) at Barter Island and -11.1°C (12°F) at Komakuk Beach. The maximum recorded temperature was 27.2°C (81°F) at Komakuk Beach and the lowest was -50.6°C (-59°F) at Barter Island with both Komakuk Beach and Point Barrow recording a low of -48.9°C (-56°F) (Appendix 1). The maximum wind velocity recorded for the three sites was 125.5 km/hr. (79 m.p.h.) at Barter Island. Barter Island also has the highest mean annual precipitation with 16.0 cm (6.28 in.) (12.1 cm as snow) and Point Barrow and Komakuk Beach have averages of 10.8 cm (4.24 in.) and 15.4 cm (6.06 in.) respectively (Searby, 1968; Environment Canada, 1970). July and August are the wettest months at all sites.

The area on the coastal plain is usually portrayed as a desert region because of the low amount of precipitation and projected water deficit. Britton (1957) reviews the problems associated with water budget interpretation in the Arctic and believes that water deficits are not as large as once supposed. This was alleged to be due to the inaccuracy of measured winter precipitation due to winds and lower real values for evaporation rates. Free water is evident in most of the area through July and many areas of the coastal plain are wet the entire summer. Low amounts of precipitation also may not be the best indicator of aridity since the amount of moisture is also a function of melting permafrost as the active layer depth of the soil increases through the summer.

4.0 METHODS

Both extensive and intensive methods were used in collecting data on the community types within the study area. The field study was not initiated until the deciduous plants were near maximum leaf size. Sampling therefore began in the southern portion of the study area in the latter part of June. Sampling on the coast and in the mountainous areas occurred in July and August, and lower and more southern areas were again sampled at the end of August.

The stand is used as the fundamental unit for vegetation sampling, each stand being a concrete representation of an abstract community and having a recognizable amount of compositional and structural homogeneity. Percent ground cover and distribution of species within each stand are used to ascertain species composition and dominance. These attributes are used to indicate the similarity among stands to establish an order of natural stand relationships and to characterize a type of plant community. Structural (including floristic) similarity among stands is used as a measure of total environmental similarity even though stand history, topography or other measurable factors may be independently different.

Using cluster analysis techniques, similar stands are grouped into associations, which are then grouped into vegetation types. Vegetation types are usually named after a constant and usually dominant species which with subordinates name the associations within the types. This classification approach is similar to that propounded by Daubenmire (1968) where an association represents a community of a particular habitat type, and Poore (1955) where associations were defined by constant species. Successional status of stands is not differentiated here since there is not enough experience with many of the plant communities to predict the climax type if in fact such a type can be defined for Arctic regions. If this classification system displays natural linages between plant communities (effect), then factors controlling (cause) vegetation distribution are easier to define.

4.1 Field Methods

Air photo interpretation and field reconnaissance were utilized for selecting areas containing a number of representative habitats within each physiographic province. A series of stands (sample units) frequently conincided with an elevational gradient since a wide range of vegetation and terrain types could be sampled in a relatively small area. Stands had to be homogeneous in vegetation physiognomy so that no ecotone effecs were encountered, and had to be free from evidence of unnatural disturbance, in order to decrease the variability in vegetation types due to unknown quantities associated with land use.

The centre of each stand was marked with a range pole and two 50 m baselines were located on opposite sides of this central point (Fig. 2). Notes were taken on evidences of natural disturbance including fire and grazing impact, and physical characteristics including slope, aspect, azimuth and elevation. A photograph of each stand was taken 10 m from, and toward the range pole.

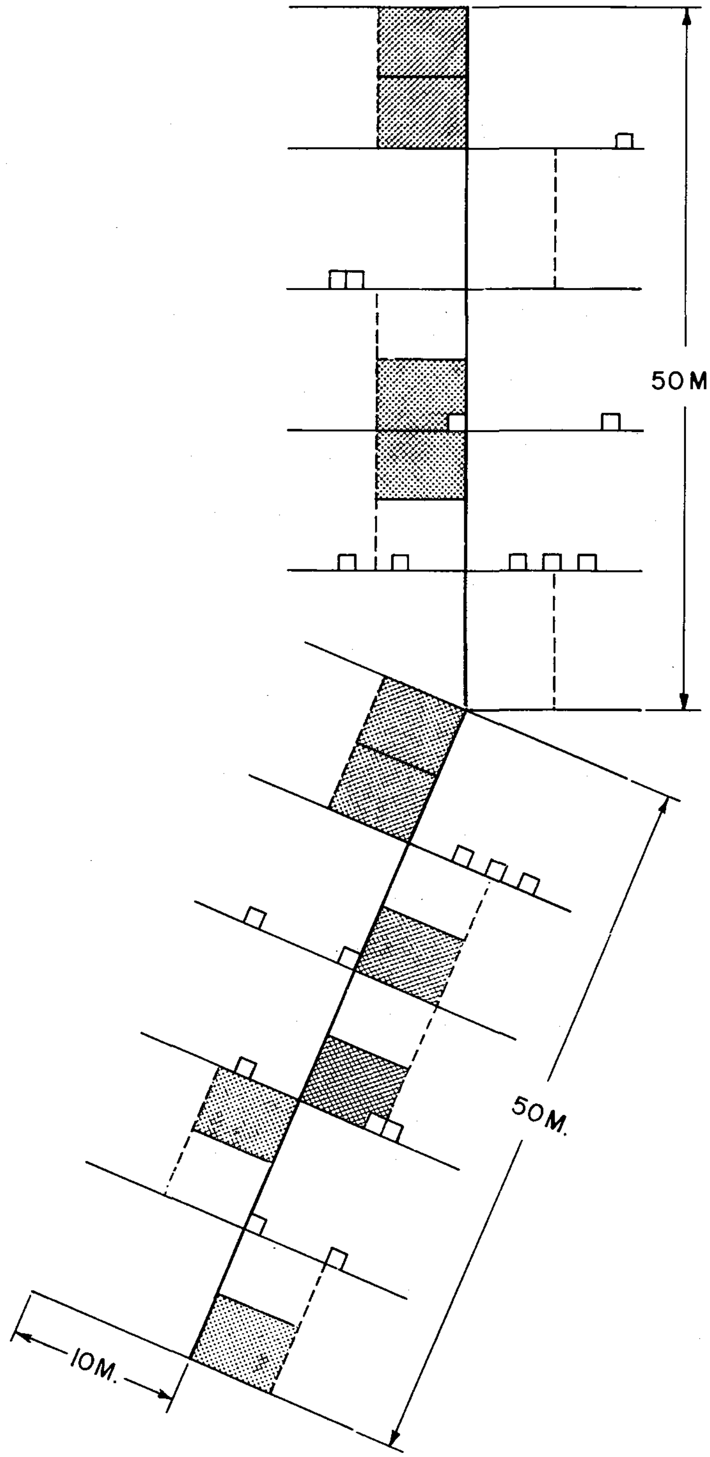


FIGURE 2. STAND SAMPLING DESIGN USING RESTRICTED RANDOMIZATION FOR TREE AND TALL SHRUB TALLIES AND 20 $1 m^2$ QUADRATS FOR OBTAINING GROUND COVER %.

NOT TO SCALE

The actual area sampled was a 20 m x 100 m rectangle, except when the irregularity of the plant community dictated irregular sample boundaries (Fig. 2). Along the baseline, ten 10 m lines were randomly located either left or right, at right angles to the line, and were used; to delineate ten 5 x 5 m quadrants for density, d.b.h. (diameter at breast height) and height measurements of the medium tall (1 - 2 m tall) and tall shrubs (> 2 m tall), tall shrubs to saplings (2 m - 2.5 cm d.b.h.) and tree (> 2.5 cm d.b.h.) species measurements; and to locate 20 random 1 m^2 quadrants for obtaining percent of total plant ground cover on an individual species basis. The latter estimate was recorded for living material of each species using a 10 point cover scale (Table 1). The species area curve of Cain (1943) was used to determine sample number adequacy. Tree and tall shrub canopy cover was estimated from a concave gridded mirror which was held in a horizontal position 1 m from the ground surface.

Ten to twenty tree and shrub cores or discs were taken from representative diameter and height classes within the stand for constructing age patterns of tree and shrub populations. Variously aged stands representing successional stages within a sere sequence after natural disturbance were sampled to complete as much of the sequence as possible. Voucher specimens were collected at each site of vascular and cryptogam species.

Soil profiles from a pit one to two metres long were described and photographed at each stand. In cases where repeated soil frost features were prevalent the profile included a full cycle of the feature. Depth of the pit varied, but seldom exceeded the estimated maximum active layer depth. Notes

Table 1. Cover scale for estimating percent ground cover in the field and midpoints for obtaining average cover for each species.

Symbol	Percent Cover Range	Midpoint
0	0 - 1	0.5
1	1 - 5	2.5
2	5 - 10	7.5
3	10 - 15	12.5
4	15 - 25	20.0
5	25 - 50	37.5
6	50 - 75	62.5
7	75 - 95	87.5
8	95 - 100	97.5

on the rooting pattern and cryopedological features were taken, but the emphasis was placed on describing and classifying the soil profile development according to the Canadian Soil Classification System (Canada Department of Agriculture, 1970 and Canada Soil Survey Committee, 1973). Field measurements included horizon depths, stoniness, microtopographic variation drainage conditions and pH. Samples were taken from organic and mineral horizons and dried for laboratory analysis.

4.2 Laboratory Methods

Route alignment sheets and air photography interpretation were used to help collate field observations on the naming of landforms and terrain types (AAGSC, 1974).

Voucher specimens were sorted and sent to various agencies for verification. Complete sets of specimens have been placed in herbaria at the National Museum of Natural Sciences, Ottawa (vasculars) and University of Alberta, Edmonton (cryptogams) to meet identification and verification obligations and for a quick return on nomenclature. Duplicate specimens have been donated to the University of Alaska, Fairbanks, and retained by Northern Engineering Services Company Limited. Nomenclature of vascular species follows Hulten (1968) and Argus (1973) (for willows), Crum *et al.* (1973) for mosses and Hale and Culberson (1970) for lichens.

After the nomenclature was verified, mean cover for each species of a stand was calculated and used to compute a prominence value (PV = $\bar{x}$% ground cover x $\sqrt{\text{quadrant frequency}}$) which is a modified procedure of

Beals (1960) and Stringer and LaRoi (1970). A series of computer programs (Fortran IV and Program Language One) were used to convert data from cover codes to midpoint percentages and thence prominence values. The prominence value combines ground cover and distributional attributes to obtain a measurement of vegetation conformation. Species diversity (a factor of the number of species/sample area and its relative importance in the sample) was computed using a computer program written in Fortran IV which is based on formulae discussed by Whittaker (1972). Although, several different indices are computed by the program, the Simpson Diversity Index was utilized to express the species diversity of each stand where

$$C = \sum_{i=I}^{S} \frac{n_1(n_1 - I)}{N(N - I)}$$

, and S = number of species i to I, n = the importance value for species i and N = the total of such importance values for all species. The importance values used were mean percent cover. The Simpson Index was chosen because it is one of the simplest, it has independence from sample size, it is an appropriate measure of diversity with the number of samples used in each stand, the number of samples was large enough to represent the major species and it gives a slope of importance values through all the sampled species (Whittaker, 1972).

Prominence value data of all stands were submitted to an agglomerative hierarchial cluster analysis (Pritchard and Anderson, 1971) using a Fortran IV computer program written by P.W. Conway (Computing Services, University of Alberta, Edmonton) which facilitates handling large amounts of data. Although other methods are available for analyzing and ranking stand characteristics, the polythetic technique of cluster analysis was thought to be superior for a diverse array of vegetation types. The reduction in the usefulness of ordination with high *beta* diversity is discussed by Gauch and Whittaker (1972). The agglomerative cluster analysis technique summarizes inter-stand relationships in a dissimilarity coefficient matrix as a first step in data treatment which is similar to ordination. The coefficient utilizes the methods of Jacard (1912) and Bray and Curtis (1957) where $C = \frac{2W}{a+b} \times 100$, and W = the lowest values of a species common to two stands and a+b represents values of all species in the two stands. However, distance values are calculated to amalgamate similar units and clusters into successively larger groupings (Pritchard and Anderson, 1971). Algorithms are used for this calculation and different methods which vary in terms of Euclidean space are available for comparing inter-cluster distances. The generalized formula used for calculating the distance ($D_{k.ij}$) from cluster K to the union of clusters I and J is $D_{k.ij}$ = $\alpha_i D_{ik} + \alpha_j D_{jk} + \beta D_{ij} + |D_{ik} - D_{jk}|$. Union of clusters so as to minimize intra-cluster variance was used where D_{ij} is inter-cluster sum of squares. In this case the distance between clusters is given as $D_{k.ij} = [(n_i + n_k) D_{ik} + (n_j + n_k) D_{jk} - N_k D_{ij}]/(n_i + n_j + n_k)$, where nk is the number of stands in cluster K, and $\alpha i = \frac{n_i + n_k}{n_i + n_j + n_k}$,

$\alpha j = \frac{n_j + n_k}{n_i + n_j + n_k}$, $\beta = (1-i-j)$ and $\gamma = 0$.

The reader is referred to Pritchard and Anderson (1971) for a more thorough discussion of calculation techniques. A subroutine which plots a dendogram and measurement of inter-cluster distance facilitates interpretation of results.

An association table was assembled where the occurrence of all species having mean cover greater than 1% was listed according to stand sequence. This information was used to identify potentially unique sites having a number of species with restricted distribution.

Tree and shrub discs and cores were smoothed and the growth rings counted under a stereo-scope. The age of all species within each stand were used as an aid in identifying successional patterns by establishing stand age structure. The practical stand age (mean of the oldest 25% of all specimens) of Stringer and LaRoi (1970) was used as an indicator of the time since stand development. Ages of the various populations were then used to identify developmental sequences within a sere (sequence of successional communities to equilibrium). The ages of shrub species are not as definitive as trees, since portions of the stems often die back and hence age estimates may be low.

Photographs and field descriptions were used as a basis for soil taxonomy which follows the Canada Soil Survey Committee (1973). A number of soil characters were used to assemble the soil into related groups. The Canadian Classification system was used for the grouping of soils so that a consistent grouping would appear in all the appropriate biological reports in this project. In addition, the Canadian system is specific in differentiating between those soils influenced by frost processes and those that are not. Appropriate corresponding groupings from the 7th Approximation (Soil Survey Staff, 1960) and the system proposed by Tedrow and Cantlon (1958), will be provided in the discussion section.

Soil samples were analyzed by Chemical and Geological Laboratories, Edmonton. Analyses included loss on ignition at 450°C, and amounts of exchangeable cations of Ca, Mg, and K, alkaline-earth carbonates and pH. Analyses followed the methods outlined in Richards (1954). Soil texture was analysed according to Boujoucos (1951) while exchangeable iron was analysed according to McKeagne and Dayl (1966).

Simple correlation was used to evaluate the degree of relationship between biotic and abiotic characters of the stands. Fortran IV computer programs from the Biomedical Computer Package (Dixon, 1968) were used as an aid in handling data. However, all environmental factors in an ecosystem are inter-dependent, and cause and effect relationships may not necessarily be elucidated by statistical significance, and therefore should be viewed as a first step in segregating important related factors. Correlation coefficients are computed using $rij = \frac{Cov\ (X_i, X_j)}{SD(X_i)SD(X_j)}$ where Cov = Covariance,

SD = standard deviation, i = 1,2 ....-n and j = 1,2 ....-n.

5.0 RESULTS

5.1 Vegetation

5.1.1 General Vegetation Types

Many different vegetation types were encountered during the survey since the study area included a latitudinally large area with varied topography. Ninety-nine stands were sampled quantitatively, and notes were taken on numerous vegetation types to supplement these data. The range includes white spruce forests to barren lichen areas. Several heath-shrub types are the most common for the entire study area. Other common communities include sedge and herb-sedge-lichen meadows. Sedge meadows occur over a large portion of the Arctic Coastal Plain, especially near Prudhoe Bay. Many of the communities on the coastal plain are composed of varying mixtures of sedge-heath and cotton grass species. Tall shrub communities of mountain alder (*Alnus crispa* ssp. *crispa*) and especially willows are common in the southern portion of the study area, but are found to be restricted to riparian sites on the coastal plain and northern part of the Brooks Range (See Fig. 1 for physiographic divisions).

White spruce (*Picea glauca*) is fairly common in the Western Porcupine Plateau and occupies riparian, muskeg and upland hillside sites. Open white spruce occurs in poorly drained muskeg areas with sedge, cotton grass and heath ground cover, and represents a physiognomy usually associated with black spruce, which was not found in the study area. White spruce extends north into the Brooks Range along river systems and south slopes to about 68°40'N at 855 m (2900 ft.) elevation. It also occurs on rounded morainal hills to about 760 m (2500 ft.) elevation but is usually widely scattered.

Balsam poplar (*Populas balsamifera*) occurs less frequently with increasing latitude. It occurs only as a riparian species and only on some streambeds and terraces (especially near perennial springs) through the Brooks Range and into the Arctic Foothills. The species is a common component of early seral stages in the Western Porcupine Plateau and may act as a pioneer species in river point bars. Balsam poplar is usually replaced by white spruce if the site is not frequently reflooded.

White birch (*Betula papyrifera* ssp. *humilis*) is found only in the Western Porcupine Plateau on slopes where disturbance has occurred. White birch forests are best developed on south exposures which show evidence of past slope failure and fires. It is usually replaced by white spruce if the terrain remains stable. Consequently, it is similar to balsam poplar in that its existence is enhanced by re-occurring disturbance.

5.1.2 General Floral Characteristics

A total of 309 vascular, 68 moss and 56 lichen species was recorded for the study area. Most of those were observed in the 99 stands, but collected forays were made into areas which were not quantitatively sampled. Nomenclature of the species is given in Appendix 2 . Species richness varied from 66 for stand 30 in the Kongakut River area of the Western Arctic Coastal Plain to 20 for stand 39 on a fossil floodplain terraces on the Canning River of the Arctic Coastal Plain (Appendix 3).

Twenty-six stands contain more than 50 species and 15 have fewer than 30. The physiographic provinces are similar in species richness with means between 40 and 43 species/stand, with the Western Coastal Plain section having the highest mean of 43. The Smith Mountain section (Ivishak River area) of the Brooks Range had the lowest with an average of 36 species/stand for five stands.

Areas containing few species included recently deposited alluvium in all physiographic provinces and in areas above 1525 m (5000 ft.) in the Brooks Range. The Kongakut and Upper Okerokovik River areas of the Western Arctic Coastal Plain and adjacent mountains had a comparatively rich flora. These areas also contain a number of range extentions (Hultén, 1968). A listing of the stands, their location, vegetation type and physical features is given in Appendix 3.

Simpson species diversity indices range from 0.050 for a hummocky open willow and sedge area near the Kongakut River on the coastal plain to 0.592 for a wet sedge meadow near the Sagavanirktok River also on the coastal plain. The assumption is that the less niches left unfilled the higher the index number with 1.0 as the maximum possible. Many of the sites with high diversity are of alpine meadow vegetation on peaks in the Western Porcupine Plateau and Southern Foothill Physiographic Provinces. Although some of the sites have lower numbers of species than others, all exhibit a dense ground cover and a lush appearance. Areas on the coastal plain and Arctic Foothills regions with high diversity indices include meadow vegetation on solifluction slopes, old river terraces and older fossil lake basins. Again, the areas have a dense vegetative ground cover which included a number of species in both the herb and moss strata. Low diversity indices occur for sites with willow shrub with open white spruce vegetation in the southern foothills, a number of low willow shrub and heath vegetation types in the eastern and western Arctic Coastal Plain, and heath dominated solifluction slopes with north exposures in the Brooks Range.

All of the sites with low diversity indices have a dense cover of low willow and or heath species and dwarf birch. No consistent relationship is evident between low diversity and exposure, latitude and altitude. The high alpine sites with a predominance of rock cover also contain a low diversity (0.07 to 0,18), but usually have a large number of species (especially lichens) in relation to total importance (% cover) measurements.

Some of the species show a wide ecological amplitude, being found in a number of different habitats throughout much of the study area. Twenty-one species occur in at least 30% of the stands. The species with highest presence include; mountain avens (*Dryas integrifolia integrifolia*), feathermoss (*Hylocomium splendens*) at 61, moss (*Tomenthypnum nitens*) at 60 and *Dicranum acutifolium* at 59, netted willow (*Arctostaphylos rubra*) at 52, bluegrass (*Poa vivipara*), and moss (*Aulocomium turgidum*) at 50, Lapland cassiope (*Cassiope tetragona*) at 48 and sedge and wintergreen (*Carex bigelowii, Pyrola rotundifolia grandiflora*) at 43 percent.

Polar grass (*Arctagrostis latifolia latifolia*), willow (*Salix planifolia pulchra*) horsetail (*Equisetum arvense, E. scirpoides*), and lichens (*Dactylina arctica, Peltigera aphthosa, Alectoria nitidula*) all have between 30 and 40 percent stand presence.

Sixty-two species occur only in one stand (presence of $\leq$ 2%). It is not unusual for stands to contain a few specimens of low abundance which are restricted only to certain special habitats. These species may be at the extreme of their distribution or appear only within a certain microhabit in the community, and therefore would exist only sporadically. Forty-three stands contain at least one species which does not appear in any other samples.

Stands which contain three or more restricted species are here recognized as unique botanical habitats for the study area. Horsetail (*Equisetum pratense*), felt-leaf willow (*Salix alaxensis longistylis*) and monkshood (*Aconitum delphinifolium delphinifolium*) were only found in mature white spruce forest which were best developed on older river terraces in the Western Porcupine Plateau. Examples of the vegetation type occur along the Sheenjek and Koness rivers and Monument Creek. Club moss (*Lycopodium selago appressum*), willow (*Salix chamissonis*), moss (*Grimmia alpicola*) and lichen (*Haematoma lapponica*) were found only on high (> 1500 m) alpine fellfields with open vegetation of netted willow (*Salix reticulata reticulata*) and sedge (*Carex macrochaeta*). Other sites in the Brooks Range containing species with restricted distribution include a closed tall willow (*Salix alaxensis alaxensis*) community on river terraces in the Ivishak River valley which is the only vegetation type containing rush (*Juncus arcticus alaskanus*) and spike trisetum (*Trisetum spicatum*), and a wet sedge meadow and mountain avens backswamp along the upper Chandalar River which contains sedge (*Carex petricosa*) and phlox (*Phlox sibirica sibirica*).

The balsam poplar stands near Cache and Gilead creeks on the northern edge of the Brooks Range are also recognized as unique habitats. However, only mustard (*Cardamine microphylla*) is restricted to these sites. Dwarf raspberry (*Rubus arcticus acaulis*) and larkspur (*Delphinium brachycentrum*) occur at only two other sites in the area. None of these species represent range extensions at these particular locations (Hulten, 1968).

Marsh marigold (*Caltha palustris arctica*), mares tail (*Hippuris vulgaris*), bladder campion (*Melandrium affine*) and roseroot (*Sedum rosea integrifolia*) occur only in wet sedge meadows (*Carex bigelowii, Salix ovalifolia ovalifolia, Dryas integrifolia integrifolia* vegetation), with frost-heaved surfaces in the eastern Arctic Coastal Plain near the Kongakut River. Milkvetch (*Astragalus alpinus alpinus*), brome grass (*Bromus pumpellianus arcticus*), fescue grass (*Festuca rubra richardsonii*) and moss (*Tortula ruralis*) occur only on high gravelly terraces of dwarf willow (*Salix ovalifolia ovalifolia*) and mountain avens vegetation near the Canning River delta on the Arctic Coastal Plain. Another high terrace near the Sagavanirktok River delta of mountain avens and sedge (*Carex bigelowii*) vegetation contain the only samples encountered of milkvetch (*Astragalus alpinus arcticus*), locoweed (*Oxytropis viscida*) and dwarf willow (*Salix brachycarpa niphoclada*). A wet sedge meadow area on a fossil lake bed near Lake 188, east of the Kavik River with sedge (*Carex aquatilis*) and low willow (*Salix planifolia pulchra*) vegetation, contain the only specimens of horsetail (*Equisetum silvaticum*), aster (*Aster ciliolatus*) and moss (*Dicranum pallidisetum*). A number of the above species are classed as range extensions, yet others listed have been found regularly in the study area which may indicate that a particular type of habitat is fairly well distributed, but represents a small portion of the total land surface.

5.1.3 Cluster Analysis Classification

Fourteen distinctive clusters composed of 41 associations are recognized from the cluster analysis dendrogram using the minimum variance method of calculating inter-cluster distances. The clusters are named by one or two constant, unifying species that have relatively high PVs (prominence values) (Fig. 3), and therefore it is possible for some clusters to be composed of diverse vegetation types. The component associations within a cluster, initially recognized by distance relationships, are named by two or three unifying species having relatively high PVs. The association used here names a type of vegetation utilizing the dominant species which are usually from different strata. Association is not used in the strictest synecological form (i.e. Braun - Blanquet) since "character species" are not identified and no designation is made as to successional status. Utilization of dominant, constant species of the various strata in designating the association is most similar to the Northern (Scandanavian) System of phytosociology (Schimwell, 1971).

Similarities of stands within any level of hierachy (stands or two adjacent clusters, etc.) are usually readily identifiable, but species composition usually shifts across the cluster. Hence, stands toward the outside edges of a cluster are the most dissimilar yet show enough mathematical (and compositional) similarity to be included in the group. The amount of continuity (overlap) between clusters depends on vegetation homogeneity and somewhat on the

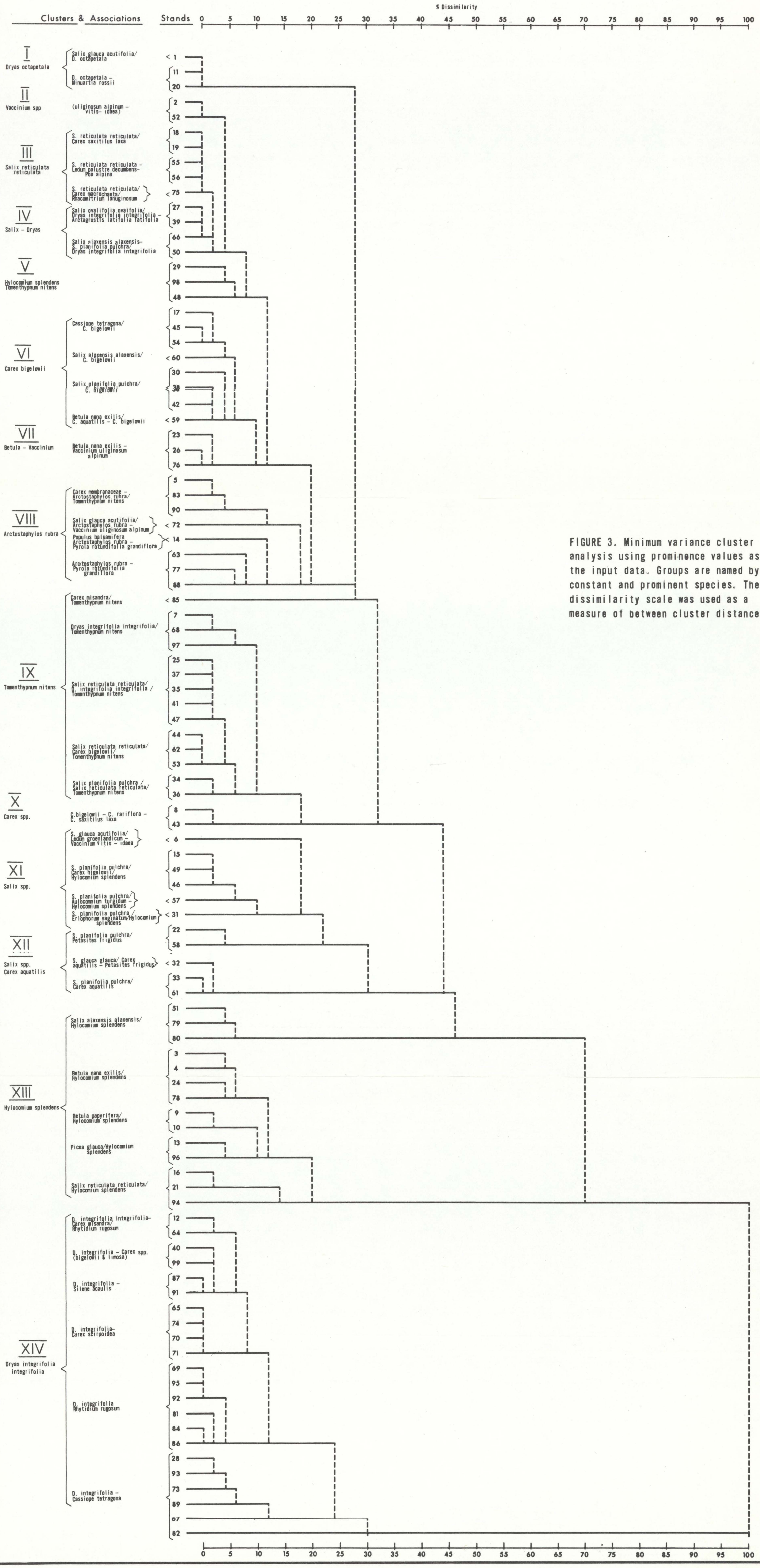


FIGURE 3. Minimum variance cluster analysis using prominence values as the input data. Groups are named by constant and prominent species. The dissimilarity scale was used as a measure of between cluster distance.

intensity of sampling within a given area. Groups II through VI are shown on the cluster to be fairly closely related (Fig. 3) and contain many of the same minor species, even though the combination of those with the highest PVs change from one group to the next. Disjunction of the associated species in presence, or especially in prominence within a cluster is the feature used to first identify the different associations. Some stands (eg. 75, 50 and 80) do not fit well into a cluster and can be viewed as connective types of vegetation between two more discrete units (Fig. 3). These connective stands also seem to represent a single sample of a vegetation type according to species composition. However, affinities can be found between these stands and the adjacent groups at the lesser species level. The clusters and associations in Figure 3 are discussed below. Slashes between taxa indicate separation between different strata (tree, tall shrub/medium tall, low shrub/dwarf shrub and herb/and ground surface cover). Numbers of the following groups correspond to those on Figure 3.

I *Dryas octopetala octopetala* cluster (Open dwarf shrub)

This grouping represents low shrub vegetation from the alpine areas of Index Mountain, Koness River and Grayling Lake areas (Appendix 3). Two associations (*Salix glauca acutifolia/Dryas octopetala; D. octopetala/Minuartia rossii*) are recognized in the cluster analysis. Other important species in this group include *Betula nana exilis*, *Empetrum nigrum hermaphroditum*, *Oxytropis nigrescens pygmaea* and *Lupinus arcticus*.

II *Vaccinium* spp. cluster (Dwarf heath-shrub)

Only two stands and one association (*Vaccinium uliginosum alpinum* - *Vaccinium vitis-idaea minus*) are represented by this group. One site is of widely scattered white spruce above Grayling Lake and the other of low shrub near Gilead Creek in the Arctic Foothills (Appendix 3). Both sites have a prominent lichen (*Alectoria nitidula*, *Cladonia pyxidata*, *Stereocaulon grande*, *Pertusaria dactylina*) and *Empetrum nigrum hermaphroditum* cover.

III *Salix reticulata reticulata* cluster (Dwarf shrub meadow)

Three associations are recognized in this group. The *Salix reticulata reticulata/Carex saxitilus laxa* association represents alpine rockfields on Index Mountain in the Southern Foothill Physiographic Province. A *S. reticulata reticulata* - *Ledum palustre decumbens/Poa alpina* association represents two similar sites in the Red Hill area of the Arctic Foothills and an association of *Carex macrochaeta/Rhacomitrium lanuginosum* with *Salix reticulata reticulata* occurs in a high (1525 m) alpine area of the Brooks Range. Other important species of the association include *Cassiope tetragona*, *Hierochloe alpina*; *Empetrum nigrum hermaphroditum*, *Alectoria nitidula* in the first and second and *Dryas octopetala*, *Rhizocarpum geographicum* in the third group.

IV *Salix* spp. - *Dryas integrifolia integrifolia* cluster (Tall-dwarf shrub)

Both tall and dwarf shrub types of vegetation are represented by this group. A *Salix ovalifolia ovalifolia/Dryas integrifolia integrifolia - Arctagrostis latifolia latifolia* association occurs on two high terrace sites on the Arctic Coastal Plain. A tall shrub association of *Salix alaxensis alaxensis - Salix planifolia pulchra/Dryas integrifolia integrifolia* typifies vegetation from older stream terraces of the Brooks Range and Arctic Foothills. Other important species of both associations include *Salix arctophila, Bromus pumpellianus arcticus; Arctostaphylos rubra, Populus balsamifera* which are separated according to association affinity.

V *Hylocomium splendens - Tomenthypnum nitens* cluster (Low shrub-moss meadows)

This cluster group probably represents a single association which is named by the two moss species. Three sub-associations with *Carex vaginata, Salix arctica - Carex vaginata;* and *Carex membranaceae* as the dominant species with the moss can be recognized from the cluster analysis (Fig. 3). Sites within the group represent a wide range of areas, including the Eastern Arctic Coastal Plain, the Chandalar River area of the Brooks Range and the Red Hills of the Arctic Foothills. *Thuidium abietinum, Equisetum variegatum* and *Boykinia richardsonii* are other important species in the association.

VI *Carex bigelowii* cluster (Sedge meadows with shrub)

Four fairly diverse associations are represented by this cluster, with two of the associations containing a tall willow shrub strata. A *Cassiope tetragona/Carex bigelowii* association represents vegetation from Index Mountain and the Western Arctic Coastal Plain (Sagavanirktok River and Kadleroshilik River) (Appendix 3). Willow shrub types include *Salix alaxensis alaxensis/Carex bigelowii* and *Salix planifolia pulchra/C. bigelowii* associations which typify sites from the rolling hills of the Arctic Coastal Plain. An association of *Betula nana exilis/Carex aquatilia-C. bigelowii* depicts a low sedge meadow on the Eastern Arctic Coastal Plain.

Other important species include *Carex misandra, Salix glauca acutifolia; Bromus pumpellianus, Carex capitata; Dryas integrifolia integrifolia* and *Betula nana exilis; Salix planifolia pulchra, Tomenthypnum nitens* and *Aulocomnium turgidum* which are listed according to their respective association occurrence.

VII *Betula nana exilis - Vaccinium uliginosum alpinum* cluster (Dwarf shrub-heath)

This cluster represents a single association of typical dwarf shrub heath tundra. Sites within the group are from inter-valley areas near Index Mountain and rolling hills in the Brooks Range near the Canning River (Appendix 3). *Salix reticulata reticulata, Cassiope tetragona* and *Rhytidium rugosum* are the more prominent associated species in the group.

VIII *Arctostaphylos rubra* cluster (Dwarf shrub with low-shrubs and deciduous forest)

A diverse group of vegetation types is unified by the dominance of *Arctostaphylos rubra*. All the sites are from the lower elevations of the Arctic Foothills, Brooks Range and Porcupine Plateau physiographic areas. Four associations (*Carex membranaceae - Arctostaphylos rubra/Tomenthypnum nitens; Salix glauca acutifolia/ Arctostaphylos rubra - Vaccinium uliginosum alpinum; Populus balsamifera/Arctostaphylos rubra - Pyrola rotundifolia grandiflora;* and *Arctostaphylos rubra - Pyrola rotundifolia grandiflora*) are identified within the cluster (Fig. 3). Sites include well drained hills and river terraces to wet, level areas over till, the later in the more southern portion of the study area.

Important associated species include *Carex rariflora, Cassiope tetragona; Picea glauca, Rosa acicularis; Bromus pumpellianus arcticus;* and *Hylocomium splendens* which are listed according to the given association order.

IX *Tomenthypnum nitens* cluster (Moss-shrub tundra)

A dense ground cover of moss unifies a large group of stands from a variety of habitats within the study area (Fig. 3). These stands are separated into four associations of dwarf and low shrub vegetation. The *Dryas integrifolia integrifolia/ T. nitens* association occurs on wet areas (e.g. backswamps) in the Brooks Range and Porcupine Plateau physiographic regions. *Salix reticulata reticulata* - *Dryas integrifolia integrifolia/T. nitens* represents vegetation on rolling hills and plateaus and a closely related association of *Salix reticulata reticulata* - *Carex bigelowii/T. nitens* occurs on frost disturbed areas of peat rings and solifluction slopes, all in the Arctic Coastal Plain Physiographic Province. A *Salix planifolia pulchra/S. reticulata reticulata/T. nitens* association represents low slopes and valley floor vegetation in the Romanzof Mountains. Sedges (*Carex aquatilis, C. scirpoidea*) and *Equisetum sciropoides* are particularly prominent in the first association. *Carex membranaceae; C. misandra; C. vaginata; Salix glauca glauca* and *Aulocomnium turgidum* occur as subdominant species in the other associations and are listed according to the given association sequence (Fig. 3).

X *Carex* spp. (Sedge meadows)

An association of *Carex bigelowii* - *C. rariflora* - *C. saxitilus laxa* is recognized for two very wet sites, one near the Koness River in the Porcupine Plateau region and one near the Sagavanirktok River on the Arctic Coastal Plain. Other important species include *Vaccinium vitis-idaea minus, Betula nana exilis, Ledum palustre decumbens* at the southern backswamp site, and *Eriophorum vaginatum* and *Pedicularis sudetica* at the northern site on a fossil lake bed.

XI *Salix* spp. cluster (Willow shrub)

Tall willow shrub vegetation with a variety of understory species is represented by this group. Four associations of *Salix glauca acutifolia/Ledum groenlandicum - Vaccinium vitis-idaea minus; S. planifolia pulchra/Carex bigelowii/Hylocomium splendens; S. planifolia pulchra/Aulocomnium turgidum - Hylocomium splendens;* and *S. planifolia pulchra/Eriophorum vaginatum/Hylocomium splendens* are recognized from the cluster analysis. Sites include low shrub areas of the gentle hills of both Southern and Arctic Foothill areas and a level wet area near the Kavik River on the Arctic Coastal Plain. Associated species listed according to the association order include *Empetrum nigrum hermaphroditum, Betula glandulosa; Aulocomnium turgidum; Poa glauca;* and *Saxifraga punctata nelsoniana.*

XII *Salix* spp. - *Carex aquatilis* cluster (shrub-sedge meadow)

Three associations, *Salix planifolia pulchra/Petasites frigidus, S. glauca glauca/Carex aquatilis - Petasites frigidus* and *Salix planifolia pulchra/Carex aquatilis* compose this cluster of tall, and low shrub meadow vegetation. Sites include a sub-alpine area on Index Mountain and a number of habitat types, most of which are low, wet areas from the Arctic Coastal Plain. Other important species include *Carex bigelowii, Equisetum arvense; Eriophorum vaginatum;* and *Hylocomium splendens* and *Salix reticulata reticulata* which are listed in the association sequence.

XIII *Hylocomium splendens* cluster (Moss with forest and shrub)

The wide ecological amplitude of *Hylocomium splendens* is responsible for unifying a cluster of 14 diverse stands. However, only five associations are recognized from the cluster analysis (Fig. 3). A *Salix alaxensis alaxensis/Hylocomium splendens* association represents river terrace vegetation from the Brooks Range and Arctic Foothills physiographic provinces. Associated species include *Shepherdia canadensis, Equisetum arvense, Salix hastata* and *S. planifolia pulchra*. A *Betula nana exilis/Hylocomium splendens* association represents stands from the upland hillsides near Grayling Lake in the Porcupine Plateau Physiographic Province, gentle valley slopes near Index Mountain in the Southern Foothills and an old river terrace in the Arctic Foothills. *Vaccinium vitis-idaea minus, Aulocomnium turgidum, Salix sphenophylla* and *S. planifolia pulchra* are also prominent. A *Betula papyrifera/Hylocomium splendens* association typifies south exposed slopes with evidence of old slope failures and/or fire disturbance in the Porcupine Plateau Physiographic area (Koness River) (Appendix 3). Other important species include *Calamagrostis canadensis, C. purpurascens* and *Picea glauca*. A closely related association of *Picea glauca/Hylocomium splendens* represents well developed white spruce forests along many of the rivers in the Porcupine Plateau, Southern Foothill and the southern part of the Brooks Range physiographic regions. *Pyrola rotundifolia grandiflora, Equisetum scirpoides* and *Populus balsamifera*, on a lesser scale, are also prominent.

An association of *Salix reticulata reticulata/Hylocomium splendens* typifies alpine and sub-alpine shrub in the Index Mountain area (Southern Foothills) and Cane Creek region of the Brooks Range. *Salix glauca acutifolia, Carex bigelowii* and *Cassiope tetragona* are also prominent in this vegetation type.

XIV *Dryas integrifolia integrifolia* cluster (Dwarf shrub tundra)

Dryas integrifolia integrifolia is another ubiquitous species which probably has little ecological indicator value except in combination with other species. This group encompasses the largest number of stands (22) in the cluster analysis and is subdivided into seven distinct associations (Fig. 3).

A *Dryas integrifolia integrifolia - Carex misandra/Rhytidrum rugosum* association occurs on well drained alpine areas in the Porcupine Plateau (Koness River) with *Lupinus arcticus,* and on hilly moraines throughout the lower elevations of the Brooks Range with widely scattered *Picea glauca.*

Another association with *Carex bigelowii* is described for a high river terrace on the Arctic Coastal Plain. *Astragalus alpinus arcticus* and *Salix brachycarpa niphoclada* are also abundant here. A *Dryas integrifolia integrifolia - Carex limosa* association is described for a widely scattered *Picea glauca* vegetation type on well drained gentle slopes and moraines in the southern Brooks Range. Other important species include

Salix glauca acutifolia and *Kobresia simplicuiscula*. An association of *Dryas integrifolia integrifolia - Silene acaulis acaulis* represents hilltop and alpine river terrace sites in the Brooks Range (915 - 1070 m). Other important species include *Carex concinna, Potentilla biflora, Oxytropis nigrescens pygmaea* and *Luzula multiflora frigida*. The association of *Dryas integrifolia integrifolia - Carex scirpoidea* represents a number of sites including gentle slopes, lateral moraines and solifluction slopes from the interior valleys of the Brooks Range (Marshfork of the Canning River). *Arctostaphylos rubra, Vaccinium uliginosum alpinum, Poa alpina, Rhododendron lapponicum* and *Silene acaulis* are abundant at these sites. A *Dryas integrifolia - Rhytidium rugosum* association includes a number of alpine and sub-alpine slopes in the Brooks Range (Canning and Ivishak Rivers and Cane Creek). *Salix reticulata reticulata, Cassiope tetragona, Carex misandra* and *C. lugens* are also prominent.

A *Dryas integrifolia integrifolia - Cassiope tetragona* association represents sub-alpine shrub and alpine tundra sites in the Brooks Range and one site on the eastern Arctic Coastal Plain. Other dominant species include *Vaccinium uliginosum alpinum, Empetrum nigrum hermaphroditum, Arctostaphylos rubra* and *Rhytidium rugosum*. One stand (82) had a shift of dominance from *Cassiope tetragona* to *Carex lugens* and does not fit as well as the others into the association. However, many of the same minor associated species for the group are present at this site.

5.2 Major Soils

Soils are described and classified according to Canada Department of Agriculture (1970) and Canada Soil Survey Committee (1973) except in a few cases where these classifications do not apply. Regosols, Cryosols and Brunisols are the major orders encountered.

5.2.1 Regosols

These youthful soils, which occur on active floodplains and mountain colluvium, are characterized by having no inherent horizon development. Surface organic horizons (LFH) are usually thin or lacking. Cumulic Regosols commonly occur in silt deposits near active streams. They are characterized by having alternating layers of alluvium and former surface organic horizons and occur in all physiographic regions. Lithic Regosols are common on mountain colluvium and over bedrock and are characterized by having a lithic contact within 10 to 50 cm of the surface.

5.2.2 Cryosols

This recently introduced, but tentative soil order is characterized by the presence of permafrost within 1 m of the surface of mineral soils and within 1.3 m of the surface of organic soils. Since the study area lies within the continuous permafrost zone, all soils would be expected to come under this order. However, because of rapid drainage conditions in active floodplains, old river terraces in mountain valleys, and coarse materials on colluvial slopes and bedrock ridges and outcrops, permafrost may appear to be absent, thus making classification more difficult.

Three great groups within the Cryosolic Order occur in the study area:

i) Turbic Great Groups in the Cryosolic Order occur on fine textured slopes in all physiographic regions, especially in the foothills and the Arctic slope. They occur mostly on imperfect to poorly drained gentle to moderate slopes and are characterized by having variable surface horizon thicknesses and active layer depths, with buried and mixed horizons being common.

ii) Static Cryosols occur on poorly to very poorly drained level to depressional areas and have profiles with fairly uniform surface horizon thicknesses and active layer depths. Burial and mixing of horizons is not extensive.

iii) The Organo Great Group is rare, occurring mostly on high centre polygons on the Arctic Coastal Plain. This group is characterized by having at least a 40 cm thick surface organic horizon or 10 cm over ice, which may be the case on high centre polygons where the active layer varies from 10 to 30 cm in depth.

5.2.3 Brunisols

Soils in this order are restricted to the Porcupine Plateau and Southern Foothills, where Alpine Eutric Brunisols were encountered on well drained alpine and forested ridges. These soils are characterized by a brownish Bm horizon just under the turfy (non-chernozemic) Ah or LFH (forests) horizons, and are restricted to calcareous regions.

5.3 Vegetation and Terrain Types of the Physiographic Provinces

Integration of vegetation, soil and terrain facets of the landscape facilitates making comparisons by reducing data to a common unit. The vegetation and soil components offer guidance for recognizing environmental variability. Ascertaining and understanding the relationships between abiotic and biotic elements of an ecosystem is fundamental in making predictions of vegetation and soil response to environmental changes.

Although associations transgress the various physiographic provinces, the boundaries are adhered to in order to facilitate the portrayal of results. Association nomenclature is used to describe the vegetation, but is grouped under conventional vegetation type headings along with IBP nomenclature which is listed in paranthesis (Fosberg, 1970). Hanson (1953), Churchill (1955), Bliss (1956), Britton (1959), Spetzman (1959), Drew and Shanks (1965) and Johnson *et al.* (1966) were consulted to arrive at the most conventional and traditional categories for vegetation types. These categories vary somewhat according to the reference because of differences in study area and concepts. Terms such as tussock tundra, wet sedge meadow, dwarf shrub-heath and dwarf shrub heath tussock seem to be the most universally used categories.

5.3.1 Porcupine Plateau Physiographic Province

Areas sampled in the Porcupine Plateau range from 430 to 760 m in elevation. Five major terrain types and seven subtypes were identified for the Grayling Lake, Monument Creek and Koness River areas, which are believed to be typical for the physiographic province (AAGSC, 1974). The area includes isolated mountain ranges and peaks with bedrock outcroppings, including small cliffs, and montane valley colluvium which are illustrated in Plate 1A. Most of the peaks are well rounded and weathered. The gently rolling hills and long valley slopes of outwash plain and lower submontane and montane valley colluvium found between the peaks make up the major portion of the province (Plate 1A). This terrain occurs adjacent and above the fossil floodplain and active floodplain units of a number of creeks and rivers (Fig. 4). Terrain stability classes range from fairly stable in areas on river terraces to unstable on outwash plain underlain by ice with slopes (5 - 10%), and on active solifluction of the steeper slope of the montane and submontane colluvium. Drainage classes are mostly imperfect or poor, except on steep slopes of gravel or rock (Fig. 4).

Eleven major vegetation types are identified on the basis of physiognomy, species composition and landscape position. These encompass 14 associations as outlined in the previous section (Fig. 3).

.1 Wet sedge meadow (strangmoor) (Seasonal short grass meadows, 1M21).

Backswamps along most of the river systems contain sedge communities with heath, cotton grass and sometimes widely scattered small (to 2.5 cm d.b.h. (diameter @ breast height) white spruce (*Picea glauca*) which has a density of 720 stems/Ha. Poorly drained conditions and thin active layers are probably responsible for the relatively

PLATE 1A

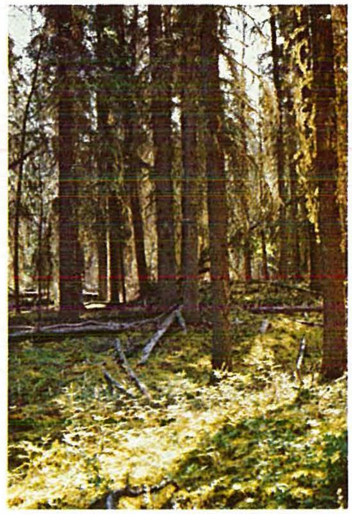


PLATE 1D

PLATE 1E

PLATE 1B

PLATE 1F

PLATE 1C

PLATE 1A: Floodplain terrain and vegetation of the Porcupine Plateau (Sheenjek River) with scattered peaks in the background.

PLATE 1B: Wet sedge meadow *(Carex)* association with Labrador tea *(Ledum palustre* ssp. *decumbens),* alpine blueberry *(Vaccinium uliginosum* ssp. *alpinum),* dwarf birch *(Betula nana* ssp. *exilis),* lingonberry *(Vaccinium vitis-idaea* ssp. *minus)* and moss *(Tomenthypnum nitens)* on poorly drained backswamp of the fossil floodplain.

PLATE 1C: Balsam poplar *(Populus balsamifera)* / Arctic bearberry *(Arctostaphylos rubra)* – wintergreen *(Pyrola rotundifolia* ssp. *grandiflora)* association on a young river terrace along Monument Creek.

PLATE 1D: White spruce *(Picea glauca)* /feathermoss *(Hylocomium splendens)* association on an older and higher river terrace.

PLATE 1E: Paper birch *(Betula papyrifera)*/ feathermoss *(Hylocomium splendens)* association with mountain alder *(Alnus crispa* ssp. *crispa)* and bluejoint *(Calamagrostis purpurascens* and *C. canadensis)* on montane and submontane valley colluvium near the Koness River. This vegetation is an indicator of past disturbances (fire and/or slope failures).

PLATE 1F: Willow *(Salix glauca* var. *acutifolia)*/ Labrador tea *(Ledum groenlandicum)* – lingonberry *(Vaccinium vitis-idaea)* association on upland strongly rolling hills.

PLATE 2A: Mountain avens *(Dryas integrifolia* ssp. *integrifolia)* moss *(Tomenthypnum nitens)* association with open white spruce *(Picea glauca)* on wet, hummocky outwash plain terrain.

PLATE 2B: Sedge *(Carex membranacea)* – Arctic bearberry *(Arctostaphylos rubra)*/moss *(Tomenthypnum nitens)* association on deformed outwash plain. Note the abundance of shrubs on frost-heaved hummocks.

PLATE 2C: Lingonberry *(Vaccinium vitis-idaea* ssp. *minus)* – alpine blueberry *(Vaccinium uliginosum* ssp. *alpinum)* association with open white spruce *(Picea glauca)* on montane and submontane valley colluvium and bedrock on a south exposed slope.

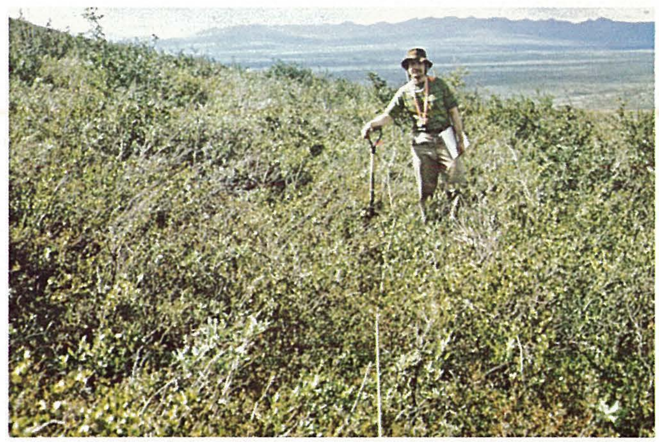
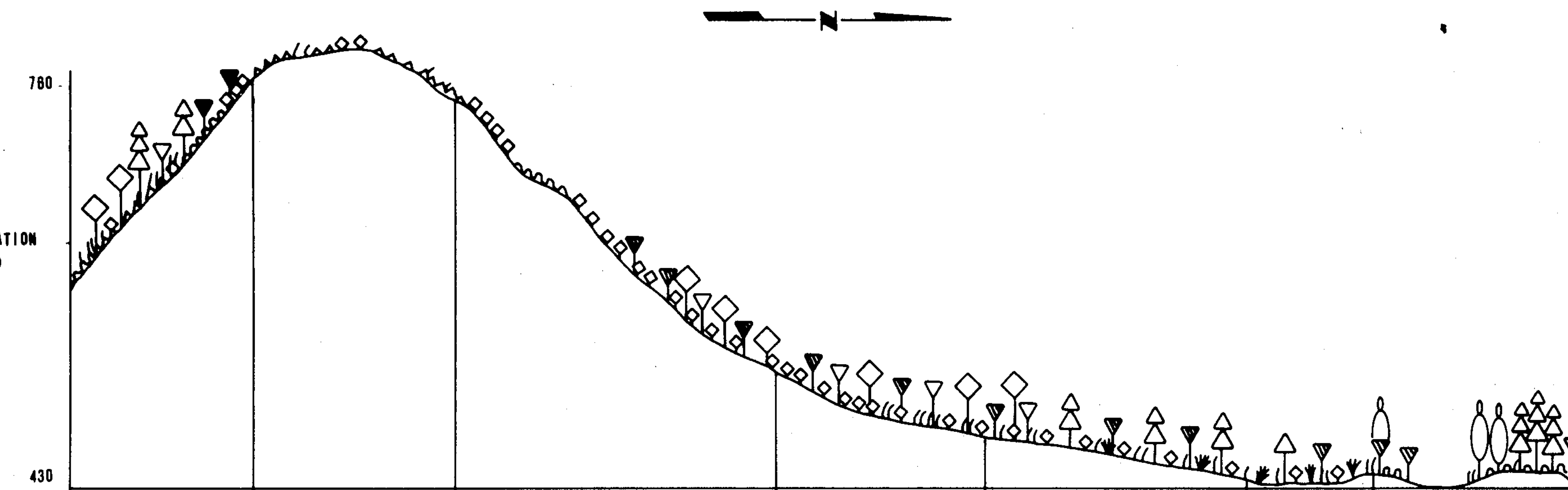


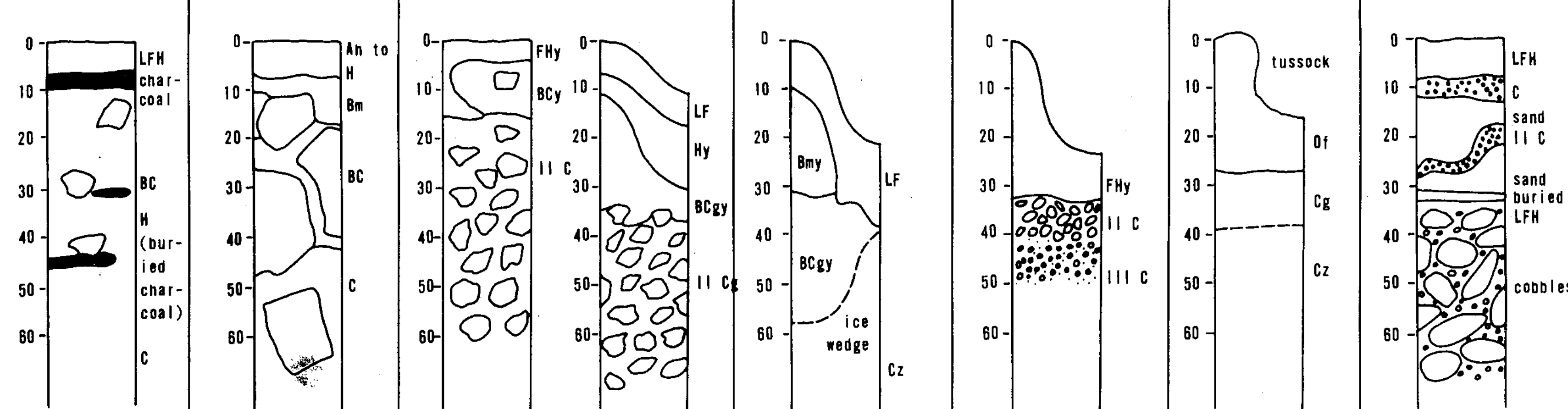
PLATE 2D: Dwarf birch *(Betula nana* ssp. *exilis)*/ feathermoss *(Hylocomium splendens)* association on montane and submontane valley colluvium above Grayling Lake.

PLATE 2E: Low willow *(Salix glauca* var. *acutifolia)* – mountain avens *(Dryas octopetala* ssp. *octopetala)* association on ridges, solifluction slopes and plateaus with western or southern exposures above 760 m (2500 ft.).

PLATE 2F: Mountain avens *(Dryas octopetala* ssp. *octopetala)* – Minuartia *(Minuartia rossii)* and mountain avens *(Dryas integrifolia* ssp *integrifolia)* – sedge *(Carex misandra)*/ moss *(Rhytidium rugosum)* form two associations on bedrock terrain.



Terrain type:	MTV	BR	MTV	MTV	OW(d)SB	FFP	AFP
Subtype:	Old slope failures and some colluvial hills	Rock outcrop and ridges	Old slope failures and some colluvial hills	Rilled slopes with some colluvium	Polygonal features on outwash plain	Black swamp	High and low river terraces
Topography:	Steeply sloping	Moderately rolling	Steeply sloping	Strongly rolling	Level to moderately rolling	Gently sloping to level	Depressional to level
Average % Slope:	20	13	20	20	0 - 10	2	0
General Vegetation Type:	White birch forest, dwarf heath shrub w/white spruce & low heath shrub	Low shrub herb, alpine & sub-alpine Dryas meadows	Tall willow shrub - heath & low shrub heath	Tall willow shrub heath, wet sedge & low shrub heath	Dryas - moss - shrub w/white spruce & wet sedge meadow	Wet sedge meadow	White spruce forest & balsam poplar forest
General Soil Profile:							
Soil Texture:							
Drainage Class:	Well	Rapid	Well / Imperfect	Imperfect	Imperfect	Poor	Moderately Well
Terrain Stability	3 - 4	4-5	2 - 3	3	2 - 3	3	4



LEGEND

Vegetation

- White spruce
- Balsam poplar
- Willow
- Alder
- White birch
- Low and dwarf shrubs (heath, birch, willow)
- Cottongrass
- Sedge and grass
- Herbs
- Moss and lichen

Terrain Types

FFP - fossil flood plain
AFP - active flood plain
MTV - montane and submontane valley colluvium
BR - bedrock outcroppings
OW (d)SB - outwash plain with ice-rich silt and ice mantle

Terrain Stability

1. Very unstable
2. Unstable
3. Unstable with disturbance
4. Fairly stable
5. Stable

FIGURE 4. Stylized landscape profile with terrain, vegetation and soil types in the Western Porcupine Plateau Physiographic Province

slow tree growth. These areas are represented by a sedge (*Carex bigelowii - Carex rariflora - Carex saxatilis laxa*) association (e.g. stand 8 in cluster #10, Fig. 3).

Other species with high prominence include northern Labrador tea (*Ledum palustre decumbens*), alpine blueberry (*Vaccinium uliginosum alpinum*), dwarf birch (*Betula nana exilis*), lingonberry (*Vaccinium vitis-idaea minus*) and moss (*Tomenthypnum nitens*) (Plate 1B).

.2 Balsam poplar forests (Winter-deciduous orthophyll forest, 1A21).

Balsam poplar (*Populus balsamifera*) forms deciduous forest communities on many of the younger (low and middle) river terraces. This community occurs along the Koness and Sheenjek rivers and Mounment Creek. Balsam poplar may also occur with willow and alder which colonize newly deposited river bars forming a shrub community. Balsam poplar is eventually replaced by white spruce if spring floods do not inundate the area too severely. The association of *Populus balsamifera/Arctostaphylos rubra - Pyrola routundifolia grandiflora* represents the more mature forest sites (Plate 1C). Other important species at these sites include white spruce, prickly rose (*Rosa acicularis*), river beauty (*Epilobium latifolium*), polar grass (*Arctagrostis latifolia latifolia*) and willow (*Salix alaxensis longistylis*). Density of balsam poplar is 440 stems/Ha with an average d.b.h. range of 10 to 15 cm. White spruce has the highest density with 1640 stems/Ha, but most of the trees have a d.b.h.

of less than 5 cm (Appendix 4, stand 14). Both polar grass and river beauty represent remnants from earlier stages in a successional sere and usually decrease in abundance at sites where white spruce has a greater percentage cover.

.3 White spruce forests (Resinous evergreen narrow sclerophyll forest, 1A17 (a)).

Older terraces along the same river systems contain well developed stands of white spruce which are depicted by the *Picea glauca/Hylocomium splendens* association (Plate 1D). Balsam poplar and willow (*Salix glauca acutifolia*) are included in the tree and tall shrub strata and lupine (*Lupinus arcticus*) and wintergreen (*Pyrola rotundifolia grandiflora*), together with feathermoss form a dense ground cover. Prickly rose may still exist where the stand is more open. Density of white spruce is 760 stems/Ha with an average d.b.h. range of 20 to 25 cm. Diameters range from 2.5 to 45 cm. Willow density of 120 stems/Ha is composed of specimens below 2.5 cm d.b.h. (Appendix 4, stand 13).

.4 White birch forests (Winter-deciduous orthophyll forest, 1A21).

Sites on old slope failures on montane and submontane valley colluvium support mature white birch forests. The degree to which white birch is dominant depends on the amount of time since the failure, since white spruce slopes, eventually occupy these sites, especially if south exposed. Terrain types include montane and submontane valley colluvium. The sites are represented by a paper birch and feathermoss (*Betula papyrifera/Hylocomium splendens*) association with mountain alder (*Alnus crispa crispa*), lingonberry, reed bent grass and bluejoint (*Calamagrostis purpurascens* and *C. canadensis*) occurring as sub-dominants (Plate 1E). White birch, mostly between 5 and 10 cm d.b.h., were found to have densities ranging from 1320 to 3200 stems/Ha. Densities usually decrease with slope and elevation on sites of comparable age since disturbance. Young white spruce had densities up to 960 stems/Ha with most d.b.h.s below 8 cm. Alder also is more abundant with higher densities (2400/Ha) on the steeper slopes and younger surfaces (Appendix 4, stands 9 and 10). This vegetation type can also be found on slopes that have been burned, especially those with south exposures.

.5 Tall willow - heath shrub (Mesophyllous deciduous orthophyll scrub, 1B21 (a))

Many of the upland areas, especially those with N, NE or NW exposures contain a tall shrub - heath community represented by a willow, Labrador tea and lingonberry (*Salix galúca acutifolia/Ledum groenlandicum - Vaccinium vitis-idaea minus*) association (Plate 1F). This vegetation type occurs predominantly on montane and submontane valley colluvium on strongly rolling slopes between 450 and 600 m elevation. Other important species include dwarf birch (*Betula glandulosa*), crowberry (*Empetrum nigrum hermaphroditum*), moss (*Aulocomnium turgidum*), lichen (*Peltigera aphthosa*) and alpine blueberry. Trees and shrubs over 1 m in height consist of white birch with 3124 stems/Ha, willow with 1200 stems/Ha and dwarf birch with 760 stems/Ha, all of which have a high percentage of stems in the small d.b.h. size classes (Appendix 4, stand 6).

.6 Mountain avens - moss - shrub with open white spruce (Evergreen narrow-sclerophyll low savanna, 1J13).

Much of the area between the upland plateaus and river systems contains a medium tall shrub vegetation with widely scattered white spruce. The outwash plain terrain type is usually level to moderately rolling with abundant ground water in evidence throughout June. The density of both white spruce (2200/Ha) and the taller shrubs (willow and alder) varies since they are restricted somewhat to the higher frost heaved areas. The majority of white spruce are below 2.5 cm d.b.h. (Appendix 4). White spruce and willow are absent in the depressional areas which are more common closer to the river systems. The vegetation is typified by a mountain avens/moss (*Dryas integrifolia integrifolia/Tomenthypnum nitens*) associated with sedge (*Kobresia simpliciuscula*), Arctic bearberry (*Arctostaphylos rubra*), sedge (*Carex aquatilis*), horsetail (*Equisetum arvense*) and moss (*Dicranum acutifolium, Scorpidium turgescens*) as important associates (Plate 2A).

.7 Dwarf heath - sedge wetland (Microphyllous evergreen dwarf heath, 1C12 (c)).

A wet sedge - low shrub vegetation is interspersed with the last described avens - moss - shrub type to form the bulk of the vegetation mosaic across the lowland areas of the Porcupine Physiographic Province. The terrain is mostly of deformed outwash plain and fossil floodplain with a nearly level to depressional topography. A sedge - Arctic bearberry/moss (*Carex membranacea - Arctostaphylos* *rubra/Tomenthypnum nitens*) association typifies the vegetation. Other important species include bog rosemary (*Andromeda polifolia*), willow (*Salix glauca acutifolia*), sedge (*Carex rariflora*), rush (*Trichophorum caespitosum austriacum*) and moss (*Rhytidium rugosum*) (Plate 2B).

.8 Dwarf heath shrub with open white spruce (Evergreen narrow sclerophyll low savanna, 1J13).

An open white spruce vegetation type with a dwarf shrub understory is exemplified by a lingonberry and alpine blueberry (*Vaccinium vitis-idaea minus - V. uliginosum alpinum*) association Dwarf birch (*Betula nana exilis*), spring beauty (*Claytonia acutifolia graminifolia*), crowberry (*Empetrum nigrum hermaphroditum*), moss (*Rhytidium rugosum*) and lichen (*Stereocaulon grande, Cladonia* spp.) are also important with white spruce (Plate 2C). The vegetation type covers a number of well drained south slopes on montane and submontane valley colluvium at about 650 m and also appears on some of the ridges at subalpine elevations (500 - 650 m) in the physiographic region. This association may represent a quasi-climax of the white spruce forest vegetation type since those stands sampled are usually at least 150 years old. White spruce density is 960 stems/Ha with sizes well distributed from 1 m tall to 25 cm d.b.h. and a majority between 5 and 15 cm (Appendix 4, stands 2 and 6).

.9 Low heath - shrub (Microphyllous evergreen dwarf heath, 1C12 (c) and evergreen narrow sclerophyll low savanna, 1J13).

Dense low-shrub communities cover many of the rolling hills and upland areas on montane and submontane valley colluvium. This vegetation type is exemplified by a dwarf birch and feathermoss (*Betula nana exilis/Hylocomium splendens*) association, with scattered white spruce, and alpine blueberry, lingonberry, willow (*Salix glauca acutifolia*), northern Labrador tea (*Ledum palustre decumbens*) and moss (*Aulocomnium turgidum, Polytrichum commune*) appearing as important subdominants (Plate 2D). It is most common on moderately rolling topography and was found on different exposures at 500 - 700 m. White spruce density ranges from 2020 to 3080 stems/Ha (Appendix 4, stand 4). Most of the trees have a d.b.h. of less than 2.5 cm. Dwarf birch and mountain alder over 1 m in height have densities of 880 and 720/Ha respectively.

.10 Low shrub - herb meadows (Seasonal orthophyll meadows, 1M21).

Alpine areas between 600 and 650 m contained shrub meadows which are represented by a low willow and mountain avens (*Salix glauca acutifolia/Dryas octopetala octopetala*) association (Plate 2E). Ridges, solifluction slopes and plateaus with western or southern exposures are most often associated with this vegetation type. Other species of importance include dwarf birch (*Betula nana exilis*), crowberry, lupine (*Lupinus arcticus*), sedge (*Carex capillaris*) and moss (*Rhytidium rugosum*).

.11 Alpine and subalpine Dryas meadows (Deciduous orthophyll dwarf scrub, 1C21 (a) and seasonal short grass meadows, 1M21).

Two species of mountain avens form a matrix of typical alpine tundra on the higher ridges and peaks. Two associations with minuartia, sedge and moss (*Dryas octopetala octopetala/Minuartia rossii; Dryas integrifolia integrifolia - Carex misandra/Rhytidium rugosum*) typify a major portion of the alpine vegetation between 700 and 760 m with the first association being restricted to the higher plateaus (Plate 2F). Lupine, polar grass (*Arctagrostis latifolia latifolia*), prickly saxifraga (*Saxifraga tricuspidata*), sedge (*Carex membranacea*) and moss (*Rhizocarpon concentricum*) occur as subdominants in the first association and lupine, dwarf willow (*Salix glauca acutifolia*) and moss (*Hylocomium splendens*) in the second. Although most of the area is categorized as a bedrock terrain colluvium, plateaus and solifluction lobed slopes are found in the area.

5.3.2 Southern Foothills Physiographic Province

Terrain types include bedrock outcrops, montane and submontane colluvium, old hummocky moraine and fossil and active floodplains (AAGSC, 1974). A mixture of bedrock outcropping and montane and submontane colluvium occurs on the peaks and includes most alpine tundra conditions. Montane and submontane colluvium with old moraine deposits covering most of the interior valleys constitute a large portion of the province (Fig. 5). Drainage conditions range from rapid to poor with the poor and imperfect classes occurring more frequently on the old moraine terrain. The bedrock and colluvial terrain are usually found to be well drained, but poor drainage was common on the plateaus and solifluction terraces on side slopes (Fig. 5).

Land stability was assessed as unstable for areas with active solifluction slopes and hummocky frost heaved areas underlain by permafrost in the old moraine terrain type. The two unstable classes (2 and 3) are applied to areas showing natural instability which usually have silty soils, permafrost and slopes > 5% (Fig. 5).

Low shrub forms are the most abundant of the fairly diverse array of vegetation types which occur in this area. Six major types of vegetation with 12 associations are identified for this province.

.1 Low heath - shrub (Evergreen narrow - sclerophyll low savanna, 1J13).

An association of *Betula nana exilis* - *Vaccinium uliginosum alpinum* typifies a dwarf birch-alpine blueberry shrub with scattered white spruce (Plate 3A). The vegetation appears on deformed lateral and end moraines, especially on south exposed slopes adjacent to the fossil floodplain (760 m) and on rounded hills (to 850 m) submontane valley with colluvium also more frequently having south exposures. This vegetation type alternates with sedge - horsetail and/or alder, willow shrub vegetation to form the striped horsetail drainage pattern which occurs more frequently in the eastern part

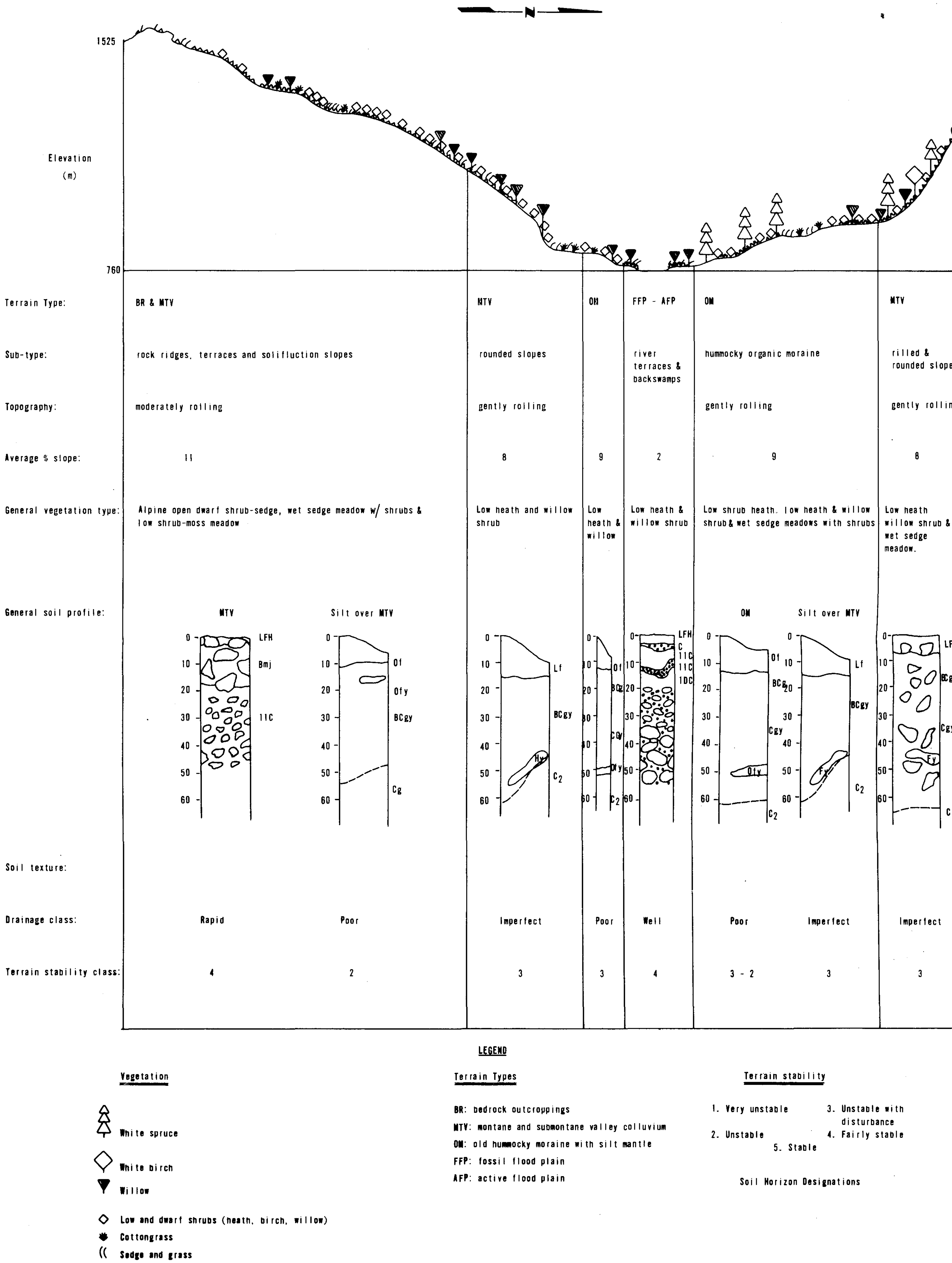


FIGURE 5. Stylized landscape profile with terrain vegetation and soil types in the Southern Foothills Physiographic Province


PLATE 3A

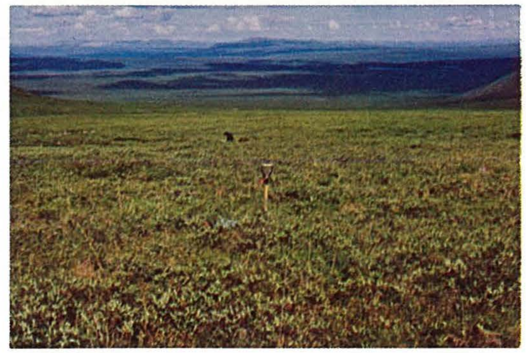


PLATE 3B

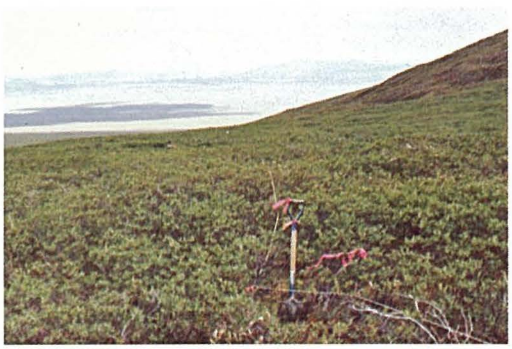


PLATE 3C


PLATE 3D

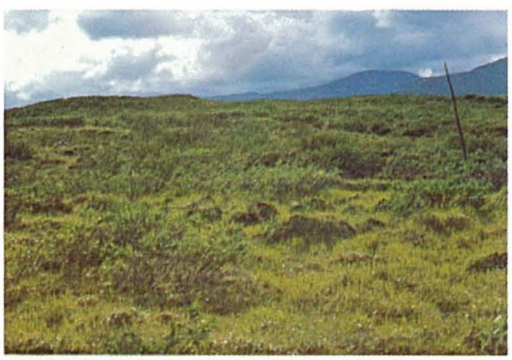


PLATE 3E


PLATE 3F

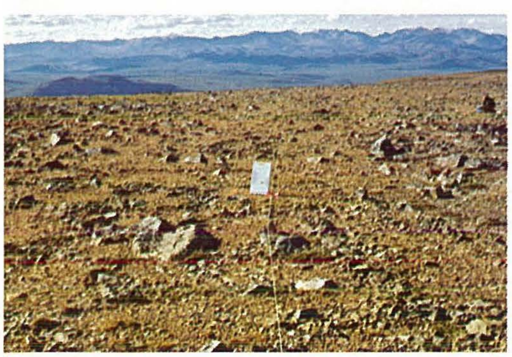


PLATE 3G

PLATE 3A: Dwarf birch *(Betula nana* ssp. *exilis)* - alpine blueberry *(Vaccinium uliginosum* ssp. *alpinum)* association with open white spruce *(Picea glauca)* on old moraine and submontane valley colluvium.

PLATE 3B: Dwarf birch *(Betula nana* ssp. *exilis)* - alpine blueberry *(Vaccinium uliginosum* ssp. *alpinum)* association with willow *(Salix glauca* var. *glauca)* at higher elevations on submontane colluvium of rounded gentle slopes of the interior valley plateau.

PLATE 3C: Closed low willow *(Salix planifolia* ssp. *pulchra)* - sweet coltsfoot *(Petasites frigidus)* association on intermountain valleys with cross drainage from surrounding slopes.

PLATE 3D: Netted willow *(Salix reticulata* ssp. *reticulata)*/ feathermoss *(Hylocomium splendens)* association on the montane valley colluvium between the islands of bedrock outcroppings on gentle rolling hills. Sedge *(Carex bigelowii)* is responsible for the meadow physiognomy.

PLATE 3E: Netted willow *(Salix reticulata* ssp. *reticulata)*/ feathermoss *(Hylocomium splendens)* association with sedge *(Carex bigelowii)* and willow *(Salix glauca* var. *acutifolia)* on poorly drained hummocky slopes on subalpine colluvium.

PLATE 3F: Low willow *(Salix planifolia* ssp. *pulchra)* - sedge *(Carex bigelowii)* feathermoss *(Hylocomium splendens)* association with cotton grass *(Eriophorum vaginatum)* on a level poorly drained solifluction plateau.

PLATE 3G: Open mountain avens *(Dryas octopetala* ssp. *octopetala)* - Minuartia *(Minuartia rossii)* association with lichen *(Alectoria tenuis)* on a fellfield plateau.

of the province on rounded hills. Netted willow (*Salix reticulata reticulata*), mountain avens (*Dryas integrifolia integrifolia*), Lapland cassiope (*Cassiope tetragona*), horsetail (*Equisetum scirpoides*) and moss (*Dicranum acutifolium*) occur as important associates with the dominant species. White spruce density is relatively low with 240 stems/Ha, although a few trees are up to 30 cm d.b.h. Dwarf birch shrubs over 1 m in height have the highest density with 1120 stems/Ha (Appendix 4, stand 26).

.2 Low heath and willow shrub (Deciduous orthophyll scrub, 1B21 and microphyllous evergreen dwarf heath scrub, 1C12 (c)).

Four associations are included in this vegetation type which covers much of the interior valleys on old hummocky moraine and montane and submontane valley colluvium. A dwarf birch and alpine blueberry (*Betula nana exilis/Vaccinium uliginosum alpinum*) association typifies vegetation at higher elevations (850 m) (2590 ft.) on submontane colluvium of rounded moderate to steep slopes with north and northeast exposures (Plate 3B). More important associated species include netted willow (*Salix reticulata reticulata*), willow (*S. glauca glauca*) Lapland cassiope, Arctic bearberry (*Arctostaphylos rubra*) and sedge (*Carex amblyorhyncha*). Dwarf birch and willow over 1 m in height have densities of 2280 stems/Ha and 1320 stems/Ha respectively (Appendix 4, stand 23).

A closely related dwarf birch and feathermoss (*Betula nana exilis/Hylocomium splendens*) with cotton grass (*Eriophorum vaginatum vaginatum*) association represents the shrub vegetation on wetter sites (flat or depressional areas) again at about 850 m (2590 ft.). The abundance of cotton grass and sedge (*Carex bigelowii*) is indicative of the increase in soil moisture. Other important species include willow (*Salix glauca acutifolia, S. glauca glauca*) and Lapland cassiope.

An association of netted willow, mountain avens and moss (*Salix reticulata reticulata/Dryas integrifolia integrifolia/Tomenthypnum nitens*) represents shrub vegetation on the knolls and slopes of gently rolling hills on old hummocky moraine terrain. This association also occurs on the fossil floodplains. Tall willow (*Salix planifolia pulchra*) occurs in clumps on slightly raised hummocks and has a density of only 840 stems/Ha. Much of the dwarf birch and willow are below 1 m in height and are not included in density measurements. Horsetail (*Equisetum scirpoides*) and moss, including *Hylocomium splendens* are more abundant in depressions between hummocks. Other important species include willow (*Salix glauca glauca*) and sedge (*Carex bigelowii*).

An association of low willow and sweet coltsfoot (*Salix planifolia pulchra/Petasites frigidus*) represents a denser vegetation of the higher (1000 - 1500 m) (3300 - 4800 ft.) intermountain valleys (Plate 3C). Gently rolling hills having cross drainage from surrounding slopes with various exposures support this association. Sedge (*Carex bigelowii*), Jacob's ladder (*Polemonium acutiflorum*) and feathermoss (*Hylocomium splendens*) are also abundant.

.3 Low shrub - moss meadow (Deciduous orthophyll dwarf scrub, 1C21 (a)).

An association of netted willow and feathermoss (*Salix reticulata reticulata/Hylocomium splendens*) represents typical alpine meadow tundra (Plate 3D). Other species include a low willow (*Salix glauca acutifolia* and *S. arctica*), sedge (*Carex bigelowii*), lousewort (*Pedicularis capitata*), sweet coltsfoot (*Petasites frigidus*) and bistort (*Polygonum bistorta plumosum*). This vegetation type covers much of the montane valley colluvium between the islands of bedrock outcropping on the gentle rolling hills between 1200 and 1350 m (3900 - 4500 ft.). The type is more widely distributed on north and east exposures and extends to a lower elevation on the gentler topography.

.4 Dwarf shrub-sedge meadow (Deciduous orthophyll dwqrf scrub, 1C241 (a)).

A similar type of alpine to subalpine vegetation is found at slightly lower elevations (1150 - 1200 m) (3700 - 3900 ft.) or on more level and, hence in this case, poorly drained areas. An association of netted willow and feathermoss (*Salix reticulata reticulata/Hylocomium splendens*) with high prominence of sedge (*Carex bigelowii*) exemplifies the vegetation type (Plate 3E). Other important species include low willow (*Salix glauca acutifolia*), cordate-leaved saxifrage (*Saxifraga punctata nelsoniana*), common horsetail (*Equisetum arvense*), cotton grass (*Eriophorum vaginatum vaginatum*) and mosses (*Aulocomnium turgidum, Tomenthypnum nitens*).

.5 Wet sedge meadow with scattered shrubs (Seasonal short grass meadows, 1M21 and deciduous orthophyll shrub savanna, 1K21).

The vegetation type is composed of two associations, both with an abundance of sedge. An association of low willow, sedge and feathermoss (*Salix planifolia pulchra/Carex bigelowii/Hylocomium splendens*) occurs on plateaus at 1200 - 1280 m (3900 - 4200 ft.) (Plate 3F). These areas are adjacent to higher ridges and bedrock outcroppings containing snowbeds from which water is supplied at least through June. Other dominant species include cotton grass (*Eriophorum vaginatum vaginatum*) netted willow (*Salix reticulata reticulata*), mountain sorrel (*Oxyria digyna*), cordate-leaved saxifrage (*Saxifraga punctata nelsoniana*) and moss (*Aulocomium turgidum*).

The other association of Lapland cassiope and sedge (*Cassiope tetragona - Carex bigelowii*) occupies similar sites at slightly lower elevations (1150 - 1250 m) (3700 - 4100 ft.) and gentler slopes which are not as well drained. Other important species include willow (*Salix glauca acutifolia*), bistort (*Polygonum viviparum*), lousewort (*Pedicularis capitata*), mountain avens (*Dryas octopetala octopetala*) and mosses (*Aulocomnium turgidum, Hylocomium splendens*).

.6 Alpine open dwarf shrub - sedge (Microphyllous deciduous desert scrub, 3B21).

Rocky ridges and plateaus exhibit open, poorly developed blockfield and fellfield areas (Plate 3G). Two associations of mountain avens and dwarf willow are embodied by the vegetation type. A mountain avens and minuartia (*Dryas octopetala octopetala - Minuartia rossii*) association represents frost shattered rock ridges, saddles and slopes at 1300 - 1350 m. This association is especially prominent on south aspects. Other major species include netted willow (*Salix reticulata reticulata*), holy grass (*Hierochloe pauciflora*), loco-weed (*Oxytropis nigrescens pygmaea*), mustard (*Braya humilus*) and lichen (*Alectoria tenuis*).

The other association of netted willow and sedge (*Salix reticulata reticulata - Carex saxitilus laxa*) occurs on similar sites, but may be a better developed entitiy with more plant cover, especially on small plateaus below ridges and slight depressions which are apparently protected from high winds by adjacent ridges. Holy grass (*Hierochloe alpina*), minuartia (*Minuartia rossii*), mosses (*Polytrichum piliferum, Rhizocarpon geographicum*) and lichen (*Umbilicara proboscidea*) are also prominent.

5.3.3 Brooks Range Physiographic Province

The Brooks Range encompasses the largest portion of the study area and contains the most topographic diversity. Sample location elevations range from 430 to 1680 m (1400 - 5500 ft.) and only a few plant species extended beyond 2050 m (6700 ft.). A typical area of the province is illustrated in Plate 4A. Bedrock and montane and submontane colluvium are the most abundant terrain types. Other types include talus slopes, alluvial fan deposits, alpine glacial moraine deposits and active and fossil floodplains all of which are most abundant along the lower side slopes and floors of the valleys and basins (Fig. 6). Stability ranges from very unstable on talus slopes to fairly stable on gentle slopes of some alluvial fan deposits. A number of the steeper (15%) mountain slopes show active solifluction processes and hence are placed in the unstable category with wet, ice-rich depressional areas of alluvial fan deposits. Slope failures are noticeable in much of the area, especially where colluvium is overlain by silts, or where cross-drainage occurs from above (Fig. 6).

Eleven major vegetation types are identified for the physiographic province and include 25 associations. Low and dwarf willow shrub tundra and alpine heath - Dryas meadows are the most widespread vegetation types. Many of the major types are composed of samples from a variety of sites with elevational or latitudinal difference, but equatibility of the environment is usually reflected by compensating differences in factors such as aspect, slope and substrate, and similarity of species composition.

.1 Riparian willow shrub (Mesophyllous deciduous orthophyll scrub, 1B21 (a)).

Four associations with a tall shrub strata are grouped in this vegetation type which occurs frequently on active and fossil floodplains between 430 and 750 m (1400 - 2460 ft.). A felt-leaf willow,

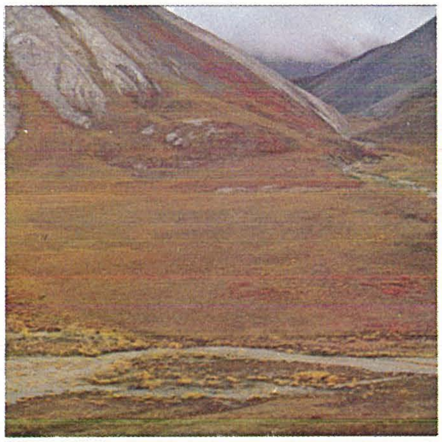


PLATE 4A: Typical landscape of the wider valleys in the Brooks Range with floodplains, deformed lateral moraine and colluvial slopes with some evidence of slope failures.

PLATE 4B: Felt-leaf willow *(Salix alaxensis* ssp. *alaxensis)* feathermoss/ *(Hylocomium splendens)* association on active and fossil floodplains near Cache Creek.

PLATE 4C: Felt-leaf willow *(Salix alaxensis* ssp. *alaxensis)*/ Arctic bearberry *(Arctostaphylos rubra)* - wintergreen *(Pyrola rotundifolia* ssp. *grandiflora)* association on older stream terrace on fossil floodplain near the Marshfork of the Canning River.

PLATE 4D: Mixed willow *(Salix alaxensis* ssp. *alaxensis — S. planifolia* ssp. *pulchra)*/ mountain avens *(Dryas integrifolia* var. *integrifolia)* association on young river terrace of Marshfork of the Canning River.

PLATE 4E: Low willow *(Salix planifolia* ssp. *pulchra — S. reticulata* ssp. *reticulata)*/ moss *(Tomenthypnum nitens)* association on high stable river terrace of Okerokovik River.

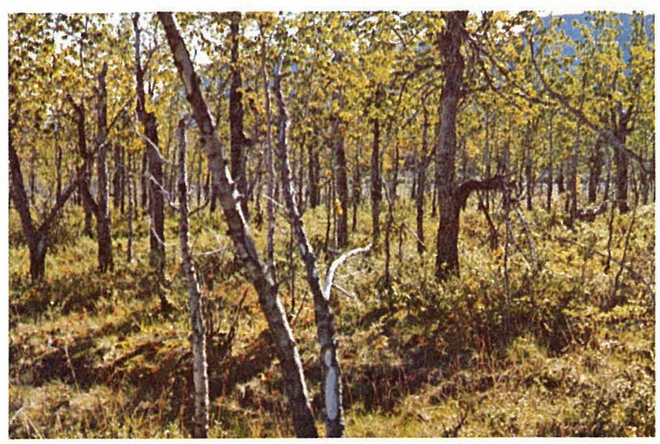


PLATE 4F: Arctic bearberry *(Arctostaphylos rubra)* — wintergreen *(Pyrola rotundifolia* ssp. *grandiflora)* association with open balsam poplar *(Populus balsamifera)* on topographically protected river terrace near Cache Creek.

PLATE 5A: White spruce *(Picea glauca)*/ feathermoss *(Hylocomium splendens)* association on high terrace near the Chandalar River and Cane Creek junction.

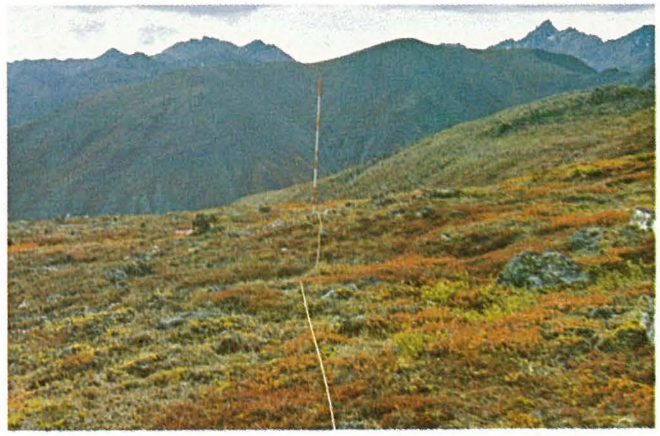


PLATE 5B: Dwarf birch *(Betula nana* ssp. *exilis)* - alpine blueberry *(Vaccinium uliginosum* ssp. *alpinum)* and dwarf birch *(Betula nana* ssp. *exilis)*/feathermoss *(Hylocomium splendens)* form the two associations found on bedrock and colluvium terrain types with south exposures at high elevations (1300 m).

PLATE 5C: Mountain avens *(Dryas integrifolia* ssp. *integrifolia)* - sedge *(Carex bigelowii)* association with scattered white spruce *(Picea glauca)* on alpine moraine above the Chandalar R.

PLATE 5D: Netted willow *(Salix reticulata* ssp. *reticulata)* - mountain avens *(Dryas integrifolia* ssp. *integrifolia)*/moss *(Tomenthypnum nitens)* association on depressional area between active floodplains and adjacent mountain slopes of the Romanzof Mtns. (Okerokovik River).

PLATE 5E: Willow *(Salix planifolia* ssp. *pulchra)* - netted willow *(Salix reticulata* ssp. *reticulata)*/moss *(Tomenthypnum nitens)* association on colluvium of mountain slopes in the Romanzof Mtns.

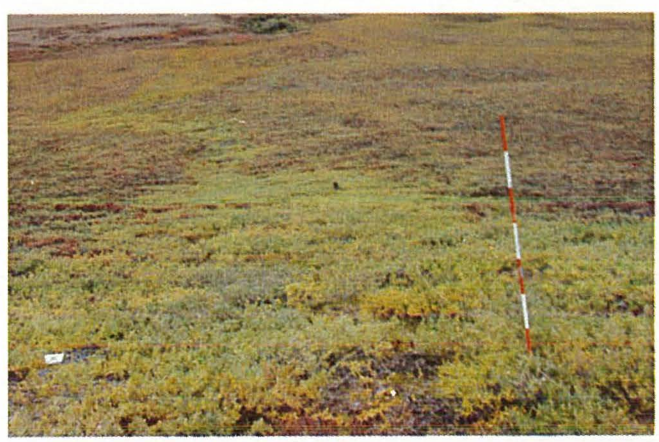


PLATE 5F: Willow *(Salix glauca* var. *acutifolia)* - Arctic bearberry *(Arctostaphylos rubra)* - alpine blueberry *(Vaccinium uliginosum* ssp. *alpinum)* association on an old slope failure near the Marshfork of the Canning River.

PLATE 6A: Mountain avens *(Dryas integrifolia* ssp *integrifolia)* /moss *(Tomenthypnum nitens)* association with willow *(Salix glauca* var. *acutifolia* and *S. rotundifolia* ssp. *dodgeneana)* on stable backswamp depressions along the Canning R.

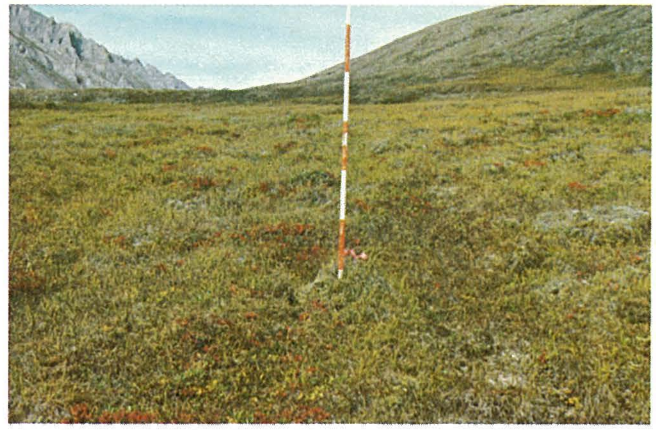


PLATE 6B: Sedge *(Carex membranacea)* – Arctic bearberry *(Arctostaphylos rubra)*/ moss *(Tomenthypnum nitens)* association on imperfectly drained sites on plateaus above the floodplains of the Ivishak R.

PLATE 6C: Mountain avens *(Dryas integrifolia* ssp. *integrifolia)* – Lapland cassiope *(Cassiope tetragona)* association on the more stable well drained morainic slopes above the Marshfork of the Canning R.

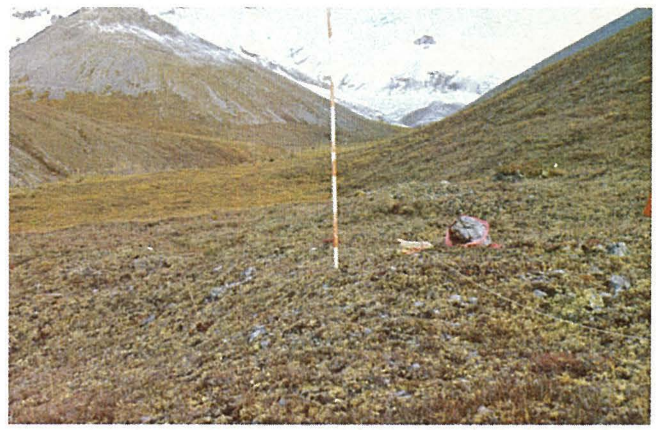


PLATE 6D: Mountain avens *(Dryas integrifolia* ssp. *integrifolia)* / moss *(Rhytidium rugosum)* association with Lapland cassiope *(Cassiope tetragona)* on rocky upland slopes on colluvium terrain above Cane Creek.

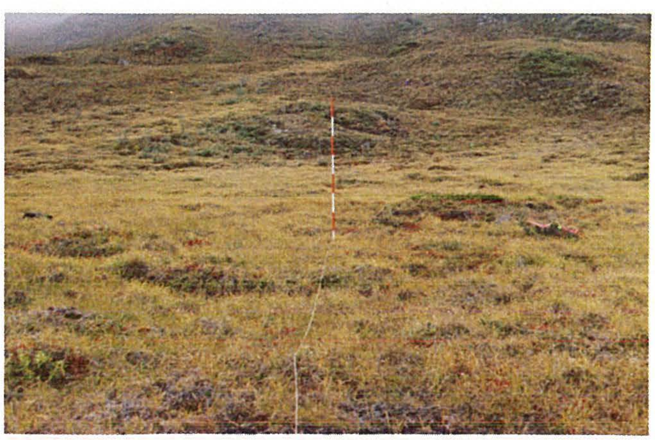


PLATE 6E: Mountain avens *(Dryas integrifolia* ssp. *integrifolia)* – sedge *(Carex scirpoidea)* and mountain avens *(Dryas integrifolia* ssp. *integrifolia)*/moss *(Tomenthypnum nitens)* associations on well drained upland meadows on colluvium terrain near the Marshfork of the Canning R.

PLATE 6F: Mountain avens *(Dryas integrifolia* ssp. *integrifolia)* – sedge *(Carex misandra)* association on alpine moraine next to the fossil floodplain in the Canning R. area.

PLATE 7A

PLATE 7B

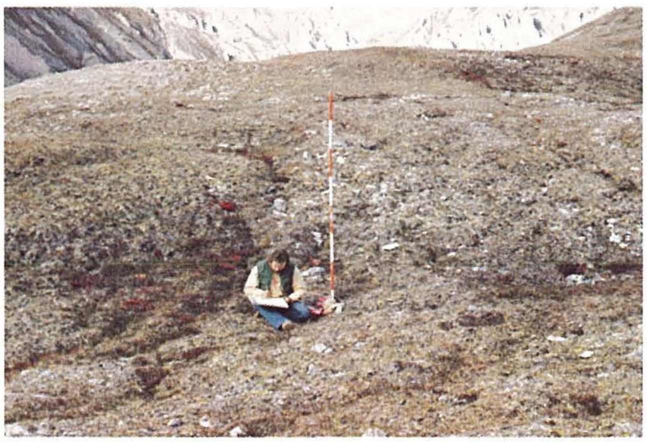


PLATE 7C

PLATE 7D

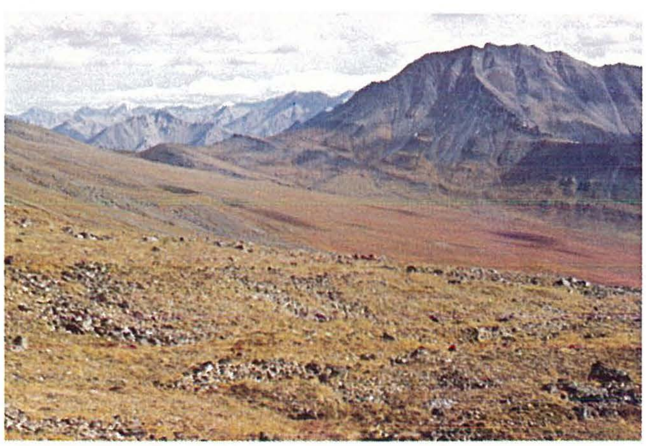


PLATE 7E

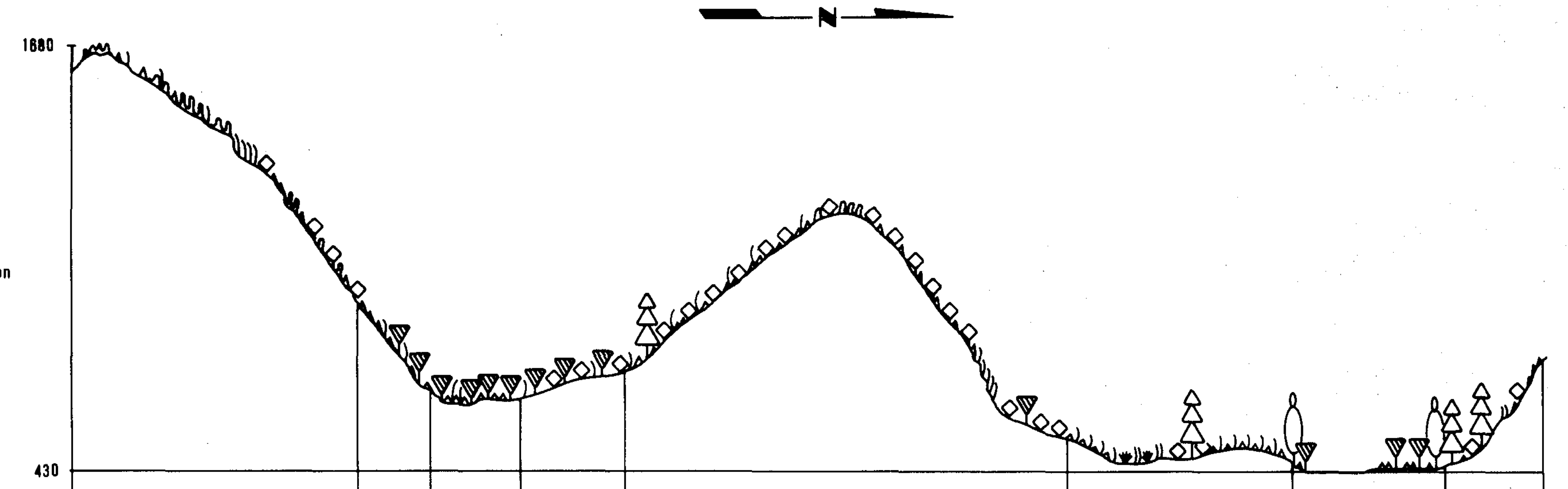
PLATE 7A: Mountain avens *(Dryas integrifolia* ssp. *integrifolia)* - Lapland cassiope *(Cassiope tetragona)* association with felt-leaf willow *(Salix alaxensis* ssp. *alaxensis)* on lower well drained sites on the fossil floodplain near the Marshfork of the Canning R.

PLATE 7B: Mountain avens *(Dryas integrifolia* ssp. *integrifolia)*/ moss *(Rhytidium rugosum)* association on rocky substrate of alpine moraine, old alluvial deposits from side valleys and colluvial slopes near the Marshfork of the Canning R.

PLATE 7C: Mountain avens *(Dryas integrifolia* ssp. *integrifolia)* /moss *(Rhytidium rugosum)* association with lichens *(Cetraria nivalis, C. commixtra* and *Icmadophila ericetorum)* on rocky substrate on high colluvial slopes above the Ivishak R.

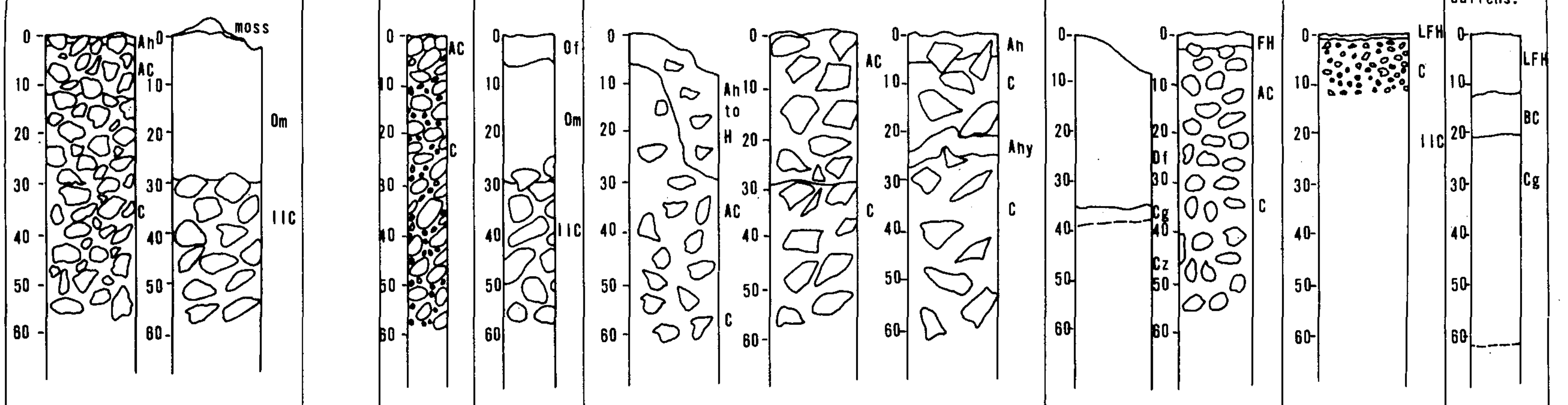
PLATE 7D: Mountain avens *(Dryas integrifolia* ssp. *integrifolia)* - moss campion *(Silene acaulis* ssp. *acaulis)* association on gentle and deformed lateral moraine above Cane Creek.

PLATE 7E: Netted willow *(Salix reticulata* ssp. *reticulata)* - sedge *(Carex microchaeta)*/moss *(Rhacomitrium lanuginosum)* association on high rocky solifluction slopes above the Canning R.



Terrain Type:	BR & MTV	TS	F & AFP	AFD	BR & MTV	AMX/AFD	F & AFP	MTV
Sub-type:	rock ridges, terraces and colluvium		river terraces	convex slope	rock outcrops, solifluction terraces and colluvial slopes	irregular hills and depressions	river terraces	solifl. terraces & colluvial slopes
Topography:	hilly	steeply sloping	nearly level	gently sloping	strongly rolling	gently rolling	nearly level	strongly rolling
Average % slope:	28	35	2	6	28	7	2	20
General vegetation type:	Alpine heath – Dryas Meadow, low & dwarf willow shrub tundra, low birch shrub, alpine Dryas sedge meadows and alpine dwarf shrub lichen fellfields	Willow shrub & sedge meadow	Willow shrub	Low & dwarf willow shrub & low & dwarf willow shrub tundra	Subalpine Dryas - shrub, alpine sedge meadows, alpine heath - Dryas meadows, low and dwarf willow shrub, low birch shrub & alpine Dryas - sedge meadows.	Alpine sedge meadows, low birch shrub and alpine Dryas meadows and barrens	Riparian willow and bearberry - herb & balsam poplar	White spruce, alpine heath - Dryas & alpine Dryas meadows & barrens.

General soil profile:



Soil texture:								
Drainage class:	Rapid / Very Poor	Well	Well	Poor	Well / Rapid / Well	Poor / Well	Well	Imperfect
Terrain stability class:	3	1	3 - 4	4	2 - 3	2 - 3	3 - 4	3

LEGEND

Vegetation

White spruce

Balsam poplar

Willow

Low & dwarf shrubs (heath, birch, willow)

cottongrass

Sedge & grass

Herbs

Moss & lichens

Terrain Types

BR: Bedrock outcroppings
MTV: montane & submontane
TS: talus slope
F & AFP: fossil and active flood plain
AFD: alluvial fan deposit
AMX: alpine glacial moraine deposits

Terrain Stability

1. Very unstable
2. Unstable
3. Unstable with disturbance
4. Fairly stable
5. Stable

FIGURE 6. Stylized landscape profile with terrain vegetation and soil types in the Brooks Range Physiographic Province.

feathermoss (*Salix alaxensis alaxensis/Hylocomium splendens*) association represents vegetation from older river terraces which have been stable long enough for the development of a dense tall shrub stratum (Plate 4B). Other prominent species include soapberry (*Shepherdia canadensis*) and Arctic bearberry (*Arctostaphylos rubra*) mostly below 700 m (2300 ft.), and common horsetail (*Equisetum arvense*), brome grass (*Bromus pumpellianus arcticus*), and mosses (*Brachythecium turgidum, Onocophorum wahlenbergii, Distichium capillaceum*). Widely scattered balsam poplar may occur at some sites, especially below 760 m (2500 ft.). An association of Arctic bearberry and wintergreen with felt-leaf willow (*Salix alaxensis alaxensis/Arctostaphylos rubra-Pyrola rotundifolia grandiflora*) occupies older stream terrace sites at elevations from 760 to 1040 m (Plate 4C). The vegetation is typified by a dense mat of Arctic bearberry, but other typical species include soapberry, willow (*Salix arbusculoides*) brome grass and mosses (*Hylocomium splendens, Thuidium abietinum*). Balsam poplar occurs at sites representing the more southern portion of the province at the lower elevations (760 m).

Younger terraces are represented by a mixed willow and mountain avens (*Salix alaxensis alaxensis - S. planifolia pulchra/Dryas integrifolia integrifolia*) association (Plate 4D). Bare gravelly areas were still in evidence at these sites and ground cover was heavier beneath the taller willows. Species with high prominence also include Arctic bearberry, hedysarum (*Hedysarum alpinum americanum*), loco-weed (*Oxytropis borealis*) and moss (*Ditrichum flexicaule*). Willow of up to 10 cm d.b.h. has a density of 5000 to 7500 stems/Ha in these sites and gives an indication of the closed nature of tall shrub stratum (Appendix 4, stands 63 and 66).

Stable river terraces in the northern portion of the province contains a low willow and moss (*Salix planifolia pulchra - S. reticulata reticulata/Tomenthypnum nitens*) association (Plate 4E). Examples of the vegetation occur in the Arctic Foothills and Arctic Coastal Plain. However, the prominence of some species, including bistort (*Polygonum bistorta plumosum*) and a dwarf willow (*Salix arctophila*), usually increases at the higher elevations. None of the shrubs are over 1 m in height.

The greater age of these more stable terraces is reflected by an increase in the amount of ground cover of such species as alpine bearberry and wintergreen at higher elevations, and feathermoss (*Hylocomium splendens*) at low elevations or more southernly exposures.

.2 Arctic bearberry - herb with open balsam poplar (Deciduous dwarf scrub with trees, 1F21).

An association of Arctic bearberry and wintergreen (*Arctostaphylos rubra - Pyrola rotundifolia grandiflora*) with balsam poplar represents a restricted vegetation type found only on protected river terraces (Plate 4F). The vegetation in many instances indicates the presence of a nearby perennial spring or underground water flow. Other associated species include soapberry (*Shepherdia canadensis*), brome grass (*Bromus pumpellianus*), river beauty (*Epilobium latifolium*), larkspur (*Delphinium brachycentrum*) and groundsel (*Senecio resedifolius*). These four species are indicative of a relatively early stage of the successional sere even though balsam poplar has formed a forest physiognomy. Balsam poplar has an average density of 1016 stems/Ha with a d.b.h. range of 2.5 to 30 cm. The lowest category found was in the tree category of 2.5 to 5 cm (Appendix 4, stand 77).

.3 White spruce forest (woodland terrace) (Resinous evergreen narrow sclerophyll forest, 1A17 (a)).

A white spruce and feathermoss (*Picea glauca/Hylocomium splendens*) association is prevalent on high terraces on most of the river systems to about 850 m (2800 ft.) elevation in the southern portion of the Brooks Range (to about Red Sheep Creek on the Chandalar River) (Plate 5A). The vegetation probably represents the end of a successional sere and hence a stable state (within a relative time period). Other prominent species include Arctic bearberry, sedge (*Carex bigelowii*), crowberry (*Empetrum nigrum hermaphroditum*), horsetail (*Equisetum scirpoides*) and moss (*Aulocomnium turgidum*). White spruce has a density of 2480 stems/Ha, mostly below 10 cm d.b.h., although a few trees have diameters of 35 cm. A few willow (*Salix glauca acutifolia*) have d.b.h.s up to 5 cm (Appendix 4, stand 96).

.4 Low birch shrub (Microphyllous deciduous orthophyll scrub, 1B21 (b) and microphyllous evergreen dwarf heath, 1C12 (c)).

Two associations of low birch, alpine blueberry and feathermoss (*Betula nana exilis - Vaccinium uliginosum alpine* and *Betula nana exilis/Hylocomium splendens*) represent a widespread low shrub vegetation.

The birch - heath vegetation is best developed and most extensive on bedrock and colluvium terrain types, especially on south exposures between 950 and 1300 m (3100 - 4300 ft.) elevation (Plate 5B). The birch and feathermoss association represents a more mesic site on an old river terrace. Associated species include netted willow (*Salix reticulata reticulata*), Lapland cassiope, sedge (*Carex macrochaeta*) and moss (*Rhytidium rugosum*) in the heath community, and willow (*Salix planifolia pulchra*), river beauty (*Epilobium latifolium*), horsetail (*Equisetum scirpoides*), polar grass (*Arctagrostis latifolia*) and groundsel (*Senecio resedifolius*) in the birch - feathermoss community on the river terrace. Willow, mostly 2.5 cm d.b.h. or less has a density of 1640 stems/Ha. Many of the latter species are pioneers in disturbed areas and indicate that the area, although a high river terrace, has still not reached a stable, long-lasting community type.

.5 Subalpine Dryas shrub w/scattered white spruce (Evergreen narrow-sclerphyll low savanna, 1J13).

Low shrub vegetation occurs on well drained conditions usually associated with the alpine moraine complex. A mountain avens and Lapland cassiope (*Dryas integrifolia integrifolia* - *Cassiope tetragona*) association represents vegetation on rounded moraine but below adjacent slopes. Other characteristic species consist of netted willow (*Salix reticulata reticulata*), sedge (*Carex scirpoidea*), Lapland rosebay (*Rhododendron lapponicum*), moss (*Rhytidium rugosum*) and lichen (*Stereocaulon grande*).

A mountain avens and sedge (*Dryas integrifolia integrifolia* - *Carex bigelowii*) association also occurs on deformed alpine moraine (Plate 5C). Associated species include scattered clumps of willow (*Salix glauca acutifolia*), sedge (*Carex limosa*), horsetail (*Equisetum scirpoides*), kobresia (*Kobresia simpliciuscula*) and mosses (*Rhytidium rugosum, Drepanocladus unciniatus*). White spruce has a density of 240 to 360 stems/Ha with most of the trees below 10 cm d.b.h. Willow densities (240 to 560 stems/Ha) increase with elevation whereas white spruce densities decrease.

.6 Low and dwarf willow shrub tundra (Deciduous orthophyll dwarf shrub, 1C21 (a)).

Five associations from a number of sites across the physiographic province (450 to 1100 m) (1500 - 3600 ft.) are placed within this tundra vegetation type. Sites include wet sedge areas from the Romanzof Mountains, a vegetated slope failure in the Marshfork of the Canning River, an old terrace in the fossil floodplain of the Chandalar River and an old alluvial fan on a side slope of the Cane Creek valley. All of these sites are fairly wet since they are below adjacent upslope water sources.

A netted willow, mountain avens and moss (*Salix reticulata reticulata - Dryas integrifolia integrifolia/Tomenthypnum nitens*) association represents a depressional habitat between active floodplains and adjacent mountain slopes (debris slope) and is most predominant in the northern part of the province (Plate 5D). Other important species are sedges (*Carex aquatilis, C. bigelowii, C. misandra*), horsetail (*Equisetum palustre*) and willow (*Salix rotundifolia dodgeana*).

The association of willow, netted willow and moss (*Salix planifolia pulchra/S. reticulata reticulata/Tomenthypnum nitens*) represents a more upland area on the colluvium of mountain slopes, again best developed in the northern section of the province (Romanzof Mountains) (Plate 5E). These sites are provided with surface water from snowbeds throughout much of the summer. Other abundant characteristic species include alpine blueberry, horsetail (*Equisetum arvense*), low willow (*Salix phlebophylla*), and bistort (*Polygonum bistorta plumosum*).

A willow, Arctic bearberry and alpine blueberry (*Salix glauca acutifolia/Arctostaphylos rubra - Vaccinium uliginosum alpinum*) association represents a somewhat more open vegetation on an old (20 yrs.) slope failure (35% slope) (Plate 5F). This particular site contained a water saturated loose shale substrate. Other species with high prominence values are Lapland cassiope, horsetail (*Equisetum arvense*), polar grass (*Arctagrostis latifolia latifolia*) and mosses (*Bryum pseudotriquestrum, Tomenthypnum nitens*).

Two similar associations of netted willow, sedge and moss (*Salix reticulata reticulata - Carex vaginata/Hylocomium splendens - Tomenthypnum nitens*) occurs on a low river terrace and old fossil floodplain near the Cane Creek - Chandalar River junction. Felt-leaf willow (*Salix alaxensis alaxensis*) forms a dense overstory as a part of most river terrace vegetation types. Other important understory species include sedge (*Carex vaginata*), horsetail (*Equisetum variegatum variegatum*), bistort and dwarf Arctic willow (*Salix arctica*). The floodplain community contains sedges (*Carex vaginata, C. scirpoidea*), mountain avens, Lapland cassiope and willow (*Salix lanata richardsonii*) as the associated, more prominent species. This community is fairly common in the southern portion of the Brooks Range since it occurs on the alluvial fans of side valleys which drain two or three adjacent peaks. Some white spruce (density = 320/Ha) and balsam poplar (density = 1240/Ha) (Appendix 4, stand 98) are usually associated with the river terrace vegetation, but willow was co-dominant, having an average density of 9520 stems/Ha on sites at least 40 years old.

.7 Alpine sedge meadows (Seasonal short grass meadows, 1M21). Four associations comprise the sedge meadow vegetation type. Sites represented include old backswamps (strangmoors) and old drainage systems, including alluvial fans with elevations ranging from 750 to 1400 m (2500 - 4600 ft.).

A mountain avens and moss (*Dryas integrifolia integrifolia/Tomenthypnum nitens*) association represents stable backswamp depressions along the Canning River (Plate 6A). Water actively drains into these areas and some ponding is noticeable throughout the summer. Important associates include shrubby cinquefoil (*Potentilla fruticosa*) sedges (*Carex aquatilis, C. scirpoidea*), netted willow (*Salix reticulata reticulata*), willow (*S. lanata richardsonii*), horsetail (*Equisetum palustre*) and Lapland rosebay (*Rhododendron lapponicum*).

The association of sedge, Arctic bearberry and moss (*Carex membranaces - Arctostaphylos rubra/Tomenthypnum nitens*) represents better drained sites on plateaus above the river floodplains (Plate 6B). This community is common throughout the Brooks Range, but is best developed along the Cane Creek, Chandalar River and Canning River corridor at 800 to 900 m (2600 - 2950 ft.) elevation which included solifluction plateaus. Abundant associated species include willow (*Salix glauca acutifolia*), Lapland cassiope, low willow (*Salix rotundifolia dodgeana*), false asphodel (*Tofieldia pusilla*), horsetail (*Equisetum scirpoides*) and Lapland rosebay (*Rhododendron lapponicum*).

An association of mountain avens and moss (*Tomenthypnum nitens*) is a representative of depressional plateaus and old drainage systems at high elevations (1400 m)(4600 ft.). Other characteristic species include sedge (*Carex misandra*), wood rush (*Luzula confusa*), Lapland rosebay, bog saxifrage (*Saxifraga hirculus*) and moss (*Catoscopium nigritum*). The vegetation is dependent upon a reduction in slope and hence impediment of drainage from surrounding snowfields.

.8 Alpine heath - Dryas meadows (Evergreen narrow sclerophyll dwarf shrub steppe savanna, 2F12).

Upland sites on montane and submontane colluvium and alpine moraine are characterized by an open, xeric meadow vegetation type. Sites range from 850 to 1100 m (2790 - 3600 ft.) in elevation. The vegetation type is made up of three similar associations.

A mountain avens - Lapland cassiope association represents rock sorted and the more stable morainic slopes (Plate 6C). Alpine blueberry, lousewort (*Pedicularis oederi*), groundsel (*Senecio lugens*), bistort (*Polygonum bistorta plumosum*) and moss (*Dicranum acutifolium*) are prominent on well drained rocky sites, and sedge (*Carex lugens*), willow (*Salix glauca acutifolia, S. rotundifolia dodgeana*) and mosses (*Rhytidium rugosum, Tomenthypnum nitens*) occur on a poorer drained site.

A mountain avens and moss (*Rhytidium rugosum*) association with abundant Lapland cassiope is characteristic of rocky upland colluvial slopes (Plate 6D). Other prominent and representative species include netted willow, bellflower (*Campanula uniflora*), and a number of lichens (*Cetraria nivalis, Petusaria dactylina, Alectoria nitidula, A. ochroleuca*). The abundance of lichens is indicative of the rocky, and well drained conditions of these sites.

.9 Alpine Dryas - sedge meadows (Seasonal short grass meadows 1M21).

Lush well drained upland meadows on colluvium terrain are represented by this major type of vegetation. Topography consists of gentle slopes, swales and piedmont plateaus with north and northwest exposures at 750 to 850 m (2500 - 2800 ft.). The vegetation type is similar in physiognomy to alpine sedge meadow and alpine Dryas meadows and barrens, but species composition and abundance (e.g. high $\overline{x}$ cover % of mountain avens) is quite different. This vegetation type probably represents a fairly stable unit in terms of successional seres on colluvial material.

Mountain avens, sedge and moss combine to form two associations which represent the vegetation type (*Dryas integrifolia integrifolia - Carex scirpoidea; D. integrifolia integrifolia/Tomenthypnum nitens*) (Plate 6E). Other important characteristic species include Arctic bearberry, netted willow, willow (*Salix glauca glauca*), Lapland rosebay, alpine foxtail (*Alopecurus alpinus alpinus*), sedge (*Carex petricosa*), horsetail (*Equisetum palustre*) and cotton grass (*Eriophorum angustifolium subarcticum*). The last three species are common only on the less well drained plateaus and depressions on slopes and at the base of slopes.

.10 Alpine Dryas meadows and barrens (Seasonal grass steppe, 2G21 and evergreen narrow sclerophyll dwarf shrub steppe savanna, 2F12).

A large number of xeric sites on alpine moraine, stable frost shattered colluvium and deformed alluvial fan terrain support this vegetation type.

Five mountain avens associations are grouped into this category which is similar in physiognomy to the alpine Dryas - sedge - meadow vegetation, but usually has less vegetative cover. The associations include mountain avens (*Dryas integrifolia integrifolia*) - sedge (*Carex misandra*)/moss (*Rhytidium rugosum*), mountain avens - sedge (*Carex scirpoidea*), mountain avens - Lapland cassiope, mountain avens/moss (*Rhytidium rugosum*) and mountain avens - moss campion (*Silene acaulis acaulis*).

The first association with *Carex misandra* represents alpine lateral and end moraine next to the fossil floodplain in the Canning River area at 700 to 850 m (2300 - 2800 ft.) (Plate 6F). Important associated species include willow (*Salix brachycarpa niphoclada*), polar grass (*Arctagrostis latifolia latifolia*), milk vetch (*Astragalus arcticus*) and feathermoss (*Hylocomium splendens*). A similar association with *Carex scirpoidea* also occupies alpine moraine, but at slightly higher elevations and usually has more southerly exposures. Important associated species in this community include alpine blueberry, blue grass (*Poa alpina*), bistort (*Polygonum viviparum*), Arctic bearberry, Lapland rosebay and moss (*Rhytidium rugosum*).

The association with Lapland cassiope represents lower, well drained sites on the fossil floodplain, and is usually near and below the alpine moraine complex (Plate 7A). Well spaced felt-leaf willow (*Salix alaxensis alaxensis*), Arctic bearberry, large yellow loco-weed (*Oxytropis campestris gracilis*), wood rush (*Luzula confusa*) and moss (*Ditrichum flexicaule*) are characteristically associated species.

The mountain avens/moss (*Rhytidium rugosum*) association represents a number of sites, all of which were on rocky substrate (Plate 7B). Terrain includes alpine moraine, old alluvial deposits from side valleys and colluvial slopes from 780 to 1350 m (2600 - 4400 ft.). Other prominent species are netted willow, willow (*Salix glauca acutifolia*), sedge (*Carex scirpoidea*), hedysarum (*Hedysarum alpinum americanum*), loco-weed (*Oxytropis borealis*), alpine blueberry, bearberry (*Arctostaphylos alpinus*), lichens (*Cetraria nivalis, C. richardsonii, Lecanora coilocarpa*) and moss (*Polytrichum strictum*) at the lower sites within the valleys. The high colluvial slopes have greater percentage lichen cover of *Cetraria nivalis, C. commixta* and *Icmadophila ericetorum* with dwarf willow (*Salix phlebophylla*) and sedge (*Carex misandra*) (Plate 7C).

The mountain avens - moss campion association represents another community on gentle intermediate (900 - 1100 m) (3000 - 3600 ft.) well drained slopes of lateral moraine (Plate 7D). Other prominent species include low willow (*Salix glauca acutifolia*), sedge (*Carex concinna*), wood rush (*Luzula multiflora fridiga*), loco-weed (*Oxytropis nigrescens pygmaea*), lichen (*Cetraria nivalis*) and moss (*Rhytidium rugosum*). The lower abundance of lichens indicates the more stable and mesic condition of the sites as compared to habitats represented by the former associations.

.11 Alpine dwarf shrub - lichen fellfield (Microphyllous deciduous desert scrub, 3B21).

An association of netted willow, sedge and moss (*Salix reticulata reticulata - Carex macrochaeta/Rhacomitrium lanuginosum*) represents communities on high (1500 - 1600 m) (4900 - 5200 ft.) rocky solifluction slopes near the upper limit of a continuous plant cover (Plate 7E). Prominent species also include mountain avens (*Dryas octopetala octopetala*), moss (*Dicranum acutifolium*) and a host of lichens (*Parmelia panniformis, Rhizocarpon geographicum, R. concentricum, Umbilicara proboscidea*). The occurrence of lingonberry (*Vaccinium vitis-idaea minus*) on some protected surfaces with south exposures may indicate the potential for this community type to develop toward the low birch shrub type which occurs at 1300 m (4260 ft.) on south slopes usually directly below these sites (i.e. 5.1.5.2.4).

5.3.4 Arctic Foothills Physiographic Province

The foothills on the northern edge of the Brooks Range are mostly composed of rolling hills from 200 to 600 m (650 - 2000 ft.) which are dissected by numerous north flowing rivers (Fig. 7). Terrain types include rounded silt-mantled slopes, montane and submontane colluvium, active and fossil floodplains and meander floodplains (AAGSC, 1974). A major part of the province is composed of silt-mantled slopes of moderately to steeply sloping topography which usually shows evidence of solifluction. The general landscape of the province is illustrated in Plate 8A.

Terrain stability is assessed as very unstable to unstable on the steeper portions of the silt-mantled slopes. Many areas giving an indication of instability were placed in unstable with disturbance and very unstable classes (Fig. 7). These areas include silt-mantled slopes and meander floodplains with thin active layers. Floodplain areas were defined as fairly stable except where underlain by permafrost with a high silt content.

Six major vegetation types are distinguished in the physiographic province. Sedge meadows and tussock tundra cover the largest part of the area, with the latter being best developed on the higher rounded hills. Dwarf shrub-sedge meadows also cover a large portion of the province.

.1 Tussock tundra (Seasonal short grass meadows, 1M21).

Cotton grass, sedge and willow with a high moss cover form a major vegetation type which is especially well developed on the silt-mantled rolling hills adjacent to the northern Brooks Range (400 - 550 m) (1300 - 1800 ft.). An association of willow, cotton grass, sedge and feathermoss (*Salix planifolia pulchra/Eriophorum vaginatum vaginatum* and/or *Carex bigelowii/Hylcomium splendens*) represents the vegetation type (Plate 8B). Prominent associated species include cordate - leaved saxifrage (*Saxifraga punctata nelsoniana*), holy grass (*Hierochloe alpina*), bistort (*Polygonum bistorta plumosum*), sweet coltsfoot (*Petasites frigidus*) and valerian (*Valeriana capitata*) which are more abundant at the higher elevations (300 - 500 m),

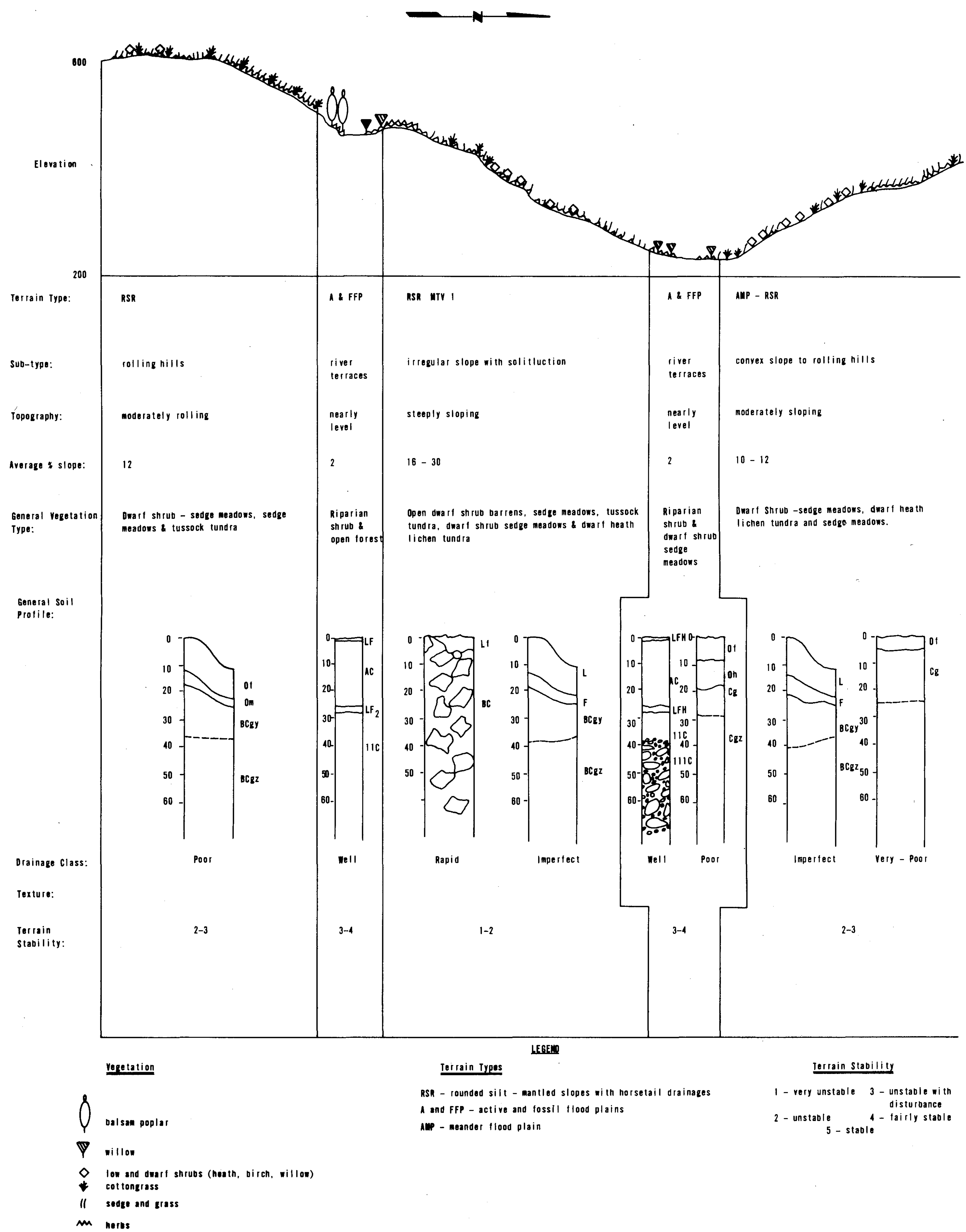


FIGURE 7. Stylized landscape profile with terrain, vegetation and soil types in the Arctic Foothills Physiographic Province.

PLATE 8A: Typical landscape of Arctic Foothills Physiographic Province with rounded silt-mantled slopes and rolling hills.

PLATE 8B: Well developed tussock tundra of willow *(Salix planifolia* ssp. *pulchra)* - cotton grass *(Eriophorum vaginatum)* and / or sedge *(Carex bigelowii)* / feathermoss *(Hylocomium splendens)* association on the silt mantled rolling hills above the Kongakut R.

PLATE 8C: Wet sedge meadow of dwarf willow *(Salix planifolia* ssp. *pulchra* or *S. glauca* var. *glauca)* - sedge *(Carex aquatilis)* association on old stream bed near the Kongakut R.

PLATE 8D: Felt-leaf willow *(Salix alaxensis* ssp. *alaxensis)* /feathermoss *(Hylocomium splendens)* association along Gilead Creek on a high river terrace of the fossil floodplain.

PLATE 9A: Felt-leaf willow *(Salix alaxensis* ssp. *alaxensis)* - willow *(Salix planifolia* ssp. *pulchra)* /mountain avens *(Dryas integrifolia* ssp. *integrifolia)* association in an open forest of balsam poplar *(Populus balsamifera)* on coarse alluvium.

PLATE 9B: Alpine blueberry *(Vaccinium uliginosum* ssp. *alpinum)* - lingonberry *(V. vitis-idaea* ssp. *minus)* association on gently rounded moraine near Gilead Creek.

PLATE 9C: Dwarf willow *(Salix reticulata* ssp. *reticulata)* mountain avens *(Dryas integrifolia* ssp. *integrifolia)* / moss *(Tomenthypnum nitens)* association on gentle to steep slopes and old river terraces.

PLATE 9D: Scattered mounds of vegetation of dwarf willow *(Salix reticulata* ssp. *reticulata)* - Labrador tea *(Ledum palustre* ssp. *decumbens)* - bluegrass *(Poa alpina)* association on gravelly area of rounded silt-mantled slope terrain with south exposure.

(1000 - 1600 ft.), and northern Labrador tea, wintergreen (*Pyrola rotundifolia grandiflora*) and moss (*Aulocomnium turgidum, Dicranum acutifolium*) which are more common throughout. Although cotton grass has often been identified as the dominant species of the vegetation type, sedge and low or dwarf willow may actually have a higher prominence value. However, cotton grass and sedge give the vegetation type the characteristic tussock physiognomy.

.2 Wet sedge meadows (Seasonal short grass meadows, 1M21).

Gently sloping areas, solifluction plateaus and depressional areas contain sedge meadows which are wet for most of the summer. The vegetation is represented by a dwarf or low willow (*Salix planifolia pulchra* or *S. glauca glauca*), sedge (*Carex aquatilis*) association which may also include sweet coltsfoot as one of the dominant species (Plate 8C). Other important species include cotton grass (*Eriophorum vaginatum vaginatum*), netted and dwarf willow (*Salix reticulata reticulata, S. rotundifolia dodgeana*), common horsetail (*Equisetum arvense*), valerian and mosses (*Tomenthypnum nitens, Aulocomnium turgidum, Hylocomium splendens*).

.3 Riparian shrub and open forest (Mesophyllous deciduous orthyophyll scrub, 1B21(a) and open deciduous orthophyll forest, 1D21).

Dense tall willow vegetation occurs along many of the stream courses, especially areas nearer the Brooks Range. The vegetation is represented by a felt-leaf willow and feathermoss association (*Salix alaxensis alaxensis/Hylocomium splendens*) with other willow species (*Salix* *glauca glauca, S. Planifolia pulchra*) and Arctic bearberry, soapberry and larkspur as important associates (Plate 8D). The vegetation type is similar to that found on older river terraces throughout the Brooks Range at the lower elevations. *Salix planifolia pulchra* has densities of 5080 stems/Ha most of which are below 5 cm d.b.h., but some have diameters up to 10 cm. *Salix glauca* with diameters of up to 5 cm had a density of 3680 stems/Ha.

An open forest vegetation type formed by balsam poplar, occupies restricted sites near permanent springs or underground water sources on coarse alluvium. The vegetation type is represented by an association of willow species (*Salix alaxensis alaxensis - S. planifolia pulchra*) and mountain avens (*Dryas integrifolia integrifolia*) (Plate 9A). Other important species include Arctic bearberry, balsam poplar, bluejoint (*Calamagrostis canadensis*), dwarf raspberry (*Rubus arcticus acaulis*), aster (*Aster sibiricus*), river beauty (*Epilobium latifolium*) and Jacob's ladder (*Polemonium acutiflorum*). This vegetation type is similar to the balsam poplar forest of the lower elevation river terraces of the Brooks Range. Understory species vary somewhat with latitude as well as length of time since stabilization of the terrace. Balsam poplar has a density of 1280 stems/Ha with some trees at 20 cm d.b.h., but the majority were between 10 to 15 cm d.b.h. No trees between 2.5 and 10 cm d.b.h. were found. Willows, mostly less than 3.5 cm diameter, have a density of 960 stems/Ha (Appendix 4, stand 50).

.4 Dwarf heath - lichen tundra (Deciduous orthophyll dwarf heath, 1C2(b).

Gravelly rounded slopes and bluffs above river systems contain sparse xeric communities. The vegetation type is represented by an alpine blueberry and lingonberry (*Vaccinium uliginosum alpinium - V. vitis-idaea minus*) association which is also characterized by the abundance of northern Labrador tea, crowberry, bearberry (*Arctostaphylos alpina*), moss (*Dicranum acutifolium*) and lichens (*Cetraria richardsonii, Sterocaulon grande*) (Plate 9B).

.5 Dwarf shrub-sedge meadow (Seasonal short grass meadows, 1M21).

Arctic tundra grassland and meadow vegetation occurs on gentle to steep hillsides and old river terraces and is best developed at the higher elevations (450 - 550 m) (1500 - 1800 ft.) of the physiographic province, but also occurs at elevations as low as 30 m (100 ft.) on the coastal plain. A dwarf willow, mountain avens and moss (*Salix reticulata reticulata - Dryas integrifolia integrifolia/Tomenthypnum nitens*) association typifies vegetation on the imperfectly drained, gentle slopes (Plate 9C). Important associated species include sedges (*Carex membranacea*), saxifrage (*Saxifraga punctata nelsoniana*), boykinia (*Boykinia richardsonii*), horsetail (*Equisetum scirpoides*) and mountain avens. The mountain avens and sedge (*Carex bigelowii*) association which represents old, stable river terraces at elevations above the tall riparian shrub zone. Other prominent species include dwarf willow (*Salix brachycarpa niphoclada, S. sphenophylla*), milkvetch (*Astragalus *arcticus*); bistort (*Polygonum viviparum*) and mosses (*Districhum capillaceum, Tomenthypnum nitens, Tortula ruralis*). The milkvetch had an aspect dominance during anthesis, but was not as prominent as the mountain avens or sedge. The abundance of several moss species reflects the stability and fossil floodplain status of these sites.

.6 Open dwarf shrub-heath barrens (Seasonal dwarf shrub steppe savanna, 2F21).

Gravelly areas with southern exposures on rounded silt-mantled slope terrain contain an open meadow and shrub vegetation with a hummocky appearance. An association of dwarf willow, Labrador tea and bluegrass (*Salix reticulata reticulata - Ledum palustre decumbens - Poa alpina*) typifies the sites (Plate 9D). Although the area is somewhat drier than the previous vegetation type, drainage from higher surrounding areas accounts for the moisture found at the sites on the sides or bases of hills. Other important species include mountain heather, crowberry, and lichens (*Alectoria nitidula, Pertusaria dactylina*).

5.3.5 Arctic Coastal Plain Physiographic Province

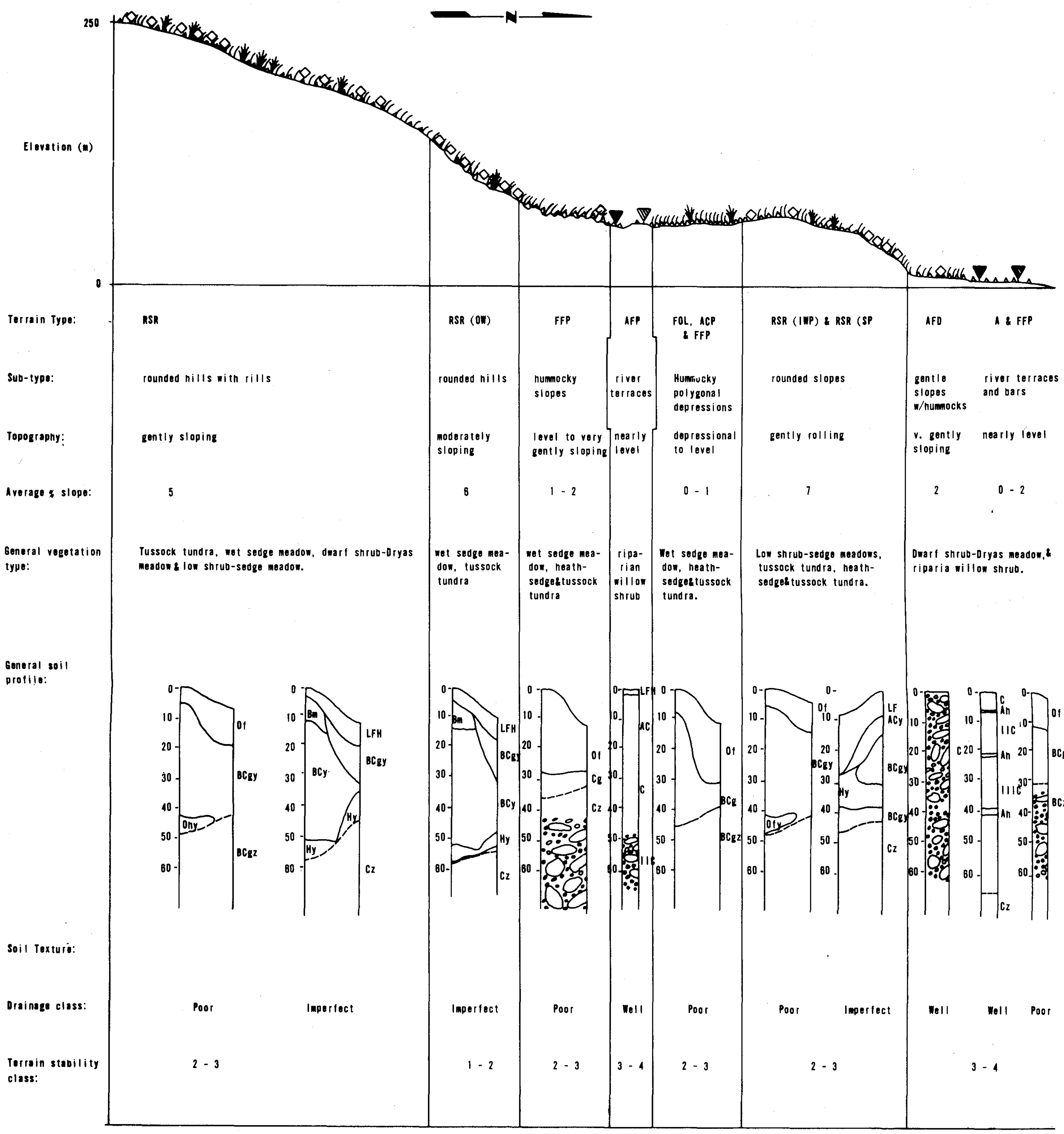
Terrain types within the Arctic Coastal Plain Province include Rounded Silt-Mantled Slopes, some with coarse outwash speckled pits, thaw ponds and ice wedges, fossil and active floodplains, former oriented lakes and Arctic Coastal Plain (AAGSC, 1974). rounded silt-mantled slopes comprise the largest portion of the province. The flat or very gently sloping Arctic Coastal Plain terrain type is also common nearer the coast (Fig. 8). Much of the coastal plain is underlain by ice-rich permafrost and hence is fairly unstable, as indicated by thaw pockets, solifluction lobes and various hummocky surface features associated with frost action. The flat, wet portion of the coastal plain with thaw pockets and polygonal features is illustrated in Plate 10A and 10B. The steeper silt-mantled slopes are assessed as very unstable to stable and those with less of a slope as unstable with disturbance (Fig. 8). Probably the most stable areas are the floodplains and alluvial fan deposits which have coarse material near the surface.

Six major vegetation types are identified for the coastal plain. Wet sedge meadows cover the largest portion of the area occurring at all elevations (Fig. 8). Low shrub sedge meadows and hummocky tundra and heath-sedge tussock tundra are also frequently encountered and occur throughout the elevational range (0 - 250 m) (0 - 820 ft.) of the physiographic province.

.1 Wet sedge meadows (Seasonal short grass meadows, 1M21).
Sedge and low or dwarf willow combine to form a matrix of vegetation on gently sloping, level and depressional areas which are inundated by water for most of the growing season. Five associations which differ in composition form the components of this matrix.

An association of dwarf willow, mountain avens and sedge (*Salix ovalifolia ovalifolia - Dryas integrifolia integrifolia - Carex bigelowii*) represents wet sedge meadows on rounded silt-mantled slopes which contain thaw ponds on ice wedge polygons (Plate 10C). The association is best developed on the rolling hill area of the Kongakut and Okerokovik rivers of the eastern part of the coastal plain. Other characteristic species include dwarf Arctic willow (*Salix arctica*), cotton grass (*Eriophorum scheuchzeri scheuchzeri*), marsh marigold (*Caltha palustris arctica*), polar grass (*Arctagrostis latifolia latifolia*), bistort (*Polygonum viiparum*) and feathermoss (*Thuidium abietinum*). Grass species are more abundant on the top of hummocks and polygonal ridges. A similar association of dwarf willow and sedge (*Salix planifolia pulchra - Carex bigelowii*) represents level areas near the coast where polygonal features are absent. Other characteristic species include sedge (*Carex aquatilis*), mountain avens, wintergreen (*Pyrola rotundifolia grandiflora*), valerian (*Valeriana capitata*) and mosses (*Aulocomnium turgidum, Mesoptychia sahlgergii*).

Another netted willow, sedge and moss (*Salix reticulata reticulata - Carex bigelowii/Tomenthypnumnitens*) association represents low center polygon areas on former oriented lakes in the western coastal plain area (Sagavanirktok to Canning rivers) and more interior portion of the coastal plain (30 - 100 m) (100 - 330 ft.).



LEGEND

Vegetation

- Willow
- Low dwarf shrubs (heath, birch, willows)
- Cottongrass
- Sedge and grass
- Herbs
- Moss & lichens

Terrain Types

RSR: rounded silt mantled slopes with horsetail drainages
(OW): with outwash of gravel and sand
(IWP): ice wedge polygons
(SP): speckled pattern of pits and thaw ponds
ACP: Arctic coastal plain
FOL: former oriented lake
A & FFP: active and fossil flood plain
AFD: alluvial fan deposit

Terrain Stability

1. Very unstable
2. Unstable
3. Unstable with disturbance
4. Fairly stable
5. Stable

FIGURE 8. . Stylized landscape profile with terrain, vegetation and soil types in the Arctic Coastal Plain Physiographic Province.

PLATE 10A

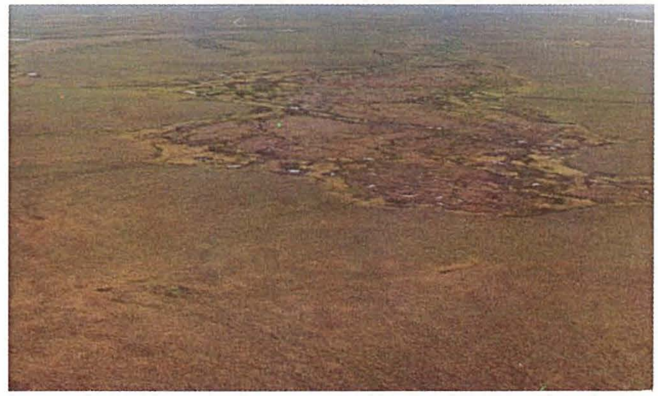


PLATE 10B

PLATE 10C

PLATE 10D

PLATE 10E

PLATE 10A: Outwash Plain and Floodplain terrain of the Arctic Coastal Plain near the Sagavanirktok R.

PLATE 10B: Flat Arctic Coastal Plain terrain with inclusions of fossil lake beds and polygonal features east of the Canning R.

PLATE 10C: Dwarf willow *(Salix ovalifolia* ssp. *ovalifolia)* – mountain avens *(Dryas integrifolia* ssp. *integrifolia)* – sedge *(Carex bigelowii)* association on rounded silt-mantled slope with thaw ponds on ice wedge polygons near the Kongakut R.

PLATE 10D: Willow *(Salix planifolia* ssp. *pulchra)* – sedge *(Carex aquatilis)* association on fossil lake bed. Wet sedge meadow is a dominant feature of the physiographic province.

PLATE 10E: Sedge *(Carex bigelowii-C. rariflora-C. saxitilus* ssp. *laxa)* association on former oriented lake terrain near the Sagavanirktok R.

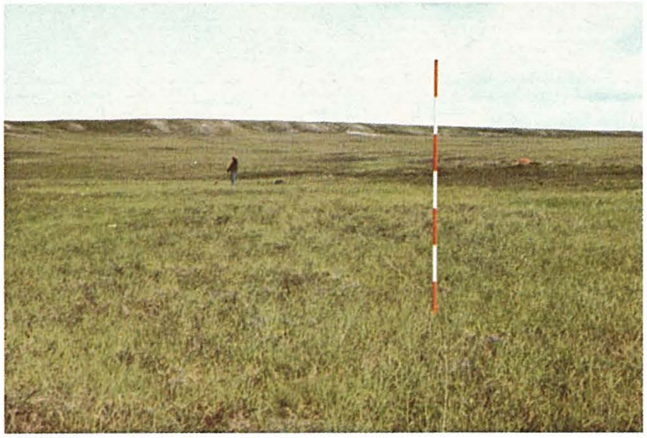


PLATE 11A

PLATE 11B

PLATE 11C

PLATE 11D

PLATE 11E

PLATE 11A: Dwarf birch *(Betula nana* ssp. *exilis)* - sedge *(Carex aquatilis* and *C. bigelowii)* association on level area of fossil floodplain in the interior portion of the coastal plain.

PLATE 11B: Willow *(Salix lanata* ssp. *richardsonii)* - sedge *(Carex vaginata)*/ feathermoss *(Hylocomium splendens)* association on silt-mantled terrain with thaw and ice mounds near the Kongakut R.

PLATE 11C: Netted willow *(Salix reticulata* ssp. *reticulata)* - sedge *(Carex bigelowii)*/ moss *(Tomenthypnum nitens)* association on rolling hills of the eastern coastal plain.

PLATE 11D: Dwarf willow *(Salix planifolia* ssp. *pulchra)* - sedge *(Carex bigelowii)* - cotton grass *(Eriophorum vaginatum)* association on higher areas between former oriented lake terrain forming a wet sedge meadow with some tussock development.

PLATE 11E: Willow *(Salix planifolia* ssp. *pulchra)* sweet coltsfoot *(Petasites frigidus)* on middle terraces and old oxbow areas of fossil floodplains on the upper elevations of the coastal plain.

PLATE 12A: Dwarf willow *(Salix ovalifolia* ssp. *ovalifolia)* - mountain avens *(Dryas integrifolia* ssp. *integrifolia)* - polar grass *(Arctogrostis latifolia* ssp. *latifolia)* association on an old terrace of the Canning R.

PLATE 12B: Netted willow *(Salix reticulata* ssp. *reticulata)* - mountain avens *(Dryas integrifolia* ssp. *integrifolia)*/ moss *(Tomenthypnum nitens* association on deformed alluvial fan deposits on lower portion of the coastal plain.

PLATE 12C: Mountain avens *(Dryas integrifolia* ssp. *integrifolia)* - Lapland cassiope *(Cassiope tetragona)* - sedge *(Carex scirpoidea)* - alpine blueberry *(Vaccinium uliginosum* ssp. *alpinum)* association on well drained alluvial fan deposits.

PLATE 12D: Lapland cassiope *(Cassiope tetragona)* - sedge *(Carex bigelowii)* - northern Labrador tea *(Ledum palustre* ssp. *decumbens)* association on old alluvial fan deposits and fossil floodplains above the Sagavanirktok R. Tussocks have developed on the slightly raised areas.

Other important species include a number of sedges (*Carex aquatilis*, *C. vaginata*, *C. misandra*), dwarf willow (*Salix planifolia pulchra*), mountain avens, lousewort (*Pedicularis sudetica*), bistort (*Polygonum viviparum*) and an increase of cotton grass (*Eriophorum vaginatum vaginatum*), sweet coltsfoot (*Petasites frigidus*) and mosses (*Aulocomnium turgidum*, *Scorpidium turgescens*) at the slightly better drained sites.

A similar association of willow and sedge (*Salix planifolia pulchra* - *Carex aquatilis*) represents fossil lake bed vegetation on the more inland areas. The sites are saturated by water throughout the growing season and although some hummocks due to frost action are evident, few polygons have developed (Plate 10D). Other important species include netted willow, lousewort (*Pedicularis oederi*), horsetail (*Equisetum scirpoides*), cinquefoil (*Potentilla biflora*), bistort (*Polygonum viviparum*), and moss (*Dicranum pallidisetum*).

Very wet areas on the flat coastal plain are represented by a sedge (*Carex bigelowii* - *C. rariflora* - *C. saxitilus laxa*) association which was found to be best developed on infilled lake beds (former oriented lake terrain) (Plate 10E). Subdominant species include cotton grass (*Eriophorum vaginatum vaginatum*), lousewort (*Pedicularis sudetica*) and moss (*Campylium stellatum*) which are much less abundant than the dominant species. The low number of species on these sites and the abundance of water is probably an indication of a shorter time period since completion of the infilling process of the lake. Some long frost ridges and low centre polygonal features are usually associated with the vegetation type.

Meadow areas with hummocky topography are represented by a dwarf birch and sedge (*Betula nana exilis - Carex aquatilis - C. bigelowii*) association (Plate 11A). These sites typically occur below hills on the level areas of fossil floodplains and hence are found most often in the more interior portions of the coastal plain. Important associated species include dwarf willow (*Salix planifolia pulchra*), wintergreen (*Pyrola rotundifolia grandiflora*) and mosses (*Aulocomnium turgidum, Tomenthypnum nitens, Sphagnum girgensohnii*). Dwarf birch, willow and wintergreen occur mostly on the hummocks.

.2 Low shrub - sedge meadow and hummocky tundra (Microphyllous deciduous orthophyll scrub, 1B21 (b)).

A predominance of low shrubs and a rugged micro-topography characterizes a number of sites on the more level portion of the coastal plain on rounded silt-mantled terrain. Several willow and sedge associations typify the vegetation type.

An association of willow, sedge and feathermoss (*Salix lanata richardsonii - Carex vaginata/Hylocomium splendens*) represents vegetation on silt-mantled terrain with thaw pockets and ice mounds (Plate 11B). The sites are characterized by numerous frost hummocks with micro-relief of up to 60 cm which provide habitats for a diverse group of species. Dwarf Arctic willow (*Salix arctica*), bistort (*Polygonum bistorta plumosum, P. viviparum*), meadow rue (*Thalictrum alpinum*) and mosses (*Tomenthypnum nitens, Oncophorus wahlenbergii*) are important associates.

Similar, but slightly better drained sites are represented by a low willow and sedge (*Salix planifolia pulchra/Carex bigelowii*) association with dwarf willow (*Salix phlebophylla*), mountain avens, alpine blueberry, common horsetail (*Equisetum arvense*), Lapland cassiope, lousewort (*Pedicularis sudetica*) and moss (*Tomenthypnum nitens*) as associates. The drier conditions are probably due to coarse material from old alluvial fan deposits which underlie most of the communities, along with an increase in slope.

Another association of low willow, sedge and mosses (*Salix planifolia pulchra/Carex bigelowii/Aulocomnium turgidum - Hylocomium splendens*) represents gentle slopes on silt in the more interior portion of the coastal plain (150 m). Alpine blueberry, sweet coltsfoot, bluegrass (*Poa glauca, P. arctica*), chickweed (*Stellaria monantha*) and mosses (*Aulocomnium turgidium, Dicranum acutifolium*) are also prominent. Although the active layer is thin, the slope provides some drainage and a similar community to that described previously.

.3 Tussock tundra (Seasonal short grass meadows, 1M21).
Tussock communities of cotton grass and sedge have traditionally been portrayed as the typical vegetation of the Arctic north slope of Alaska and Canada. The vegetation type seems to be best developed

on silt-mantled rolling hills at higher elevations (150 - 250 m), but it is also found on the Arctic Coastal Plain terrain type near the coast. Three associations with willow and sedges compose the vegetation type.

A netted willow, sedge and moss (*Salix reticulata reticulata - Carex bigelowii/Tomenthypnum nitens*) association with cotton grass (*Eriophorum vaginatum vaginatum*) and mountain avens as co-dominants typifies tussock vegetation on rolling hills of the eastern portion of the coastal plain (Plate 11C). Other species include dwarf willow (*Salix rotundifolia dodgeana*), cotton grass (*Eriophorum angustifolium subarcticum*), polar grass, bistort and Arctic bearberry.

A similar community on the higher rolling hills of the western coastal plain area is represented by a dwarf willow and sedge (*Salix planifolia pulchra - Carex bigelowii - C. misandra*) association. Important associated species include dwarf birch (*Betula nana exilis*), northern Labrador tea, lingonberry, Lapland cassiope, bistort and mosses (*Aulocomnium turgidum, Dicranum acutifolium*). The increased abundance of dwarf birch and heath in relation to the previous community reflects an increase in slope and surface drainage.

Slightly higher areas of the Arctic Coastal Plain terrain between former oriented lakes and wet sedge meadows also contain tussock tundra communities. The sites are represented by a dwarf willow, sedge and cotton grass (*Salix planifolia pulchra - Carex bigelowii - Eriophorum vaginatum vaginatum*) association (Plate 11D). Other important associates include netted willow, mountain avens, sawwort (*Sausserea angustifolia*), wintergreen, sedge (*Carex aquatilis*) and mosses (*Dicranum acutifolium, Tomenthypnum nitens*). This association probably represents the developmental potential for most of the wet sedge and sedge communities on the coastal plain.

.4 Riparian willow shrub (Mesophyllous deciduous orthophyll scrub, 1B21 (a)).

Middle terraces and old oxbow areas of fossil floodplains in the upper elevations (50 - 250 m) (160 - 820 ft.) of the coastal plain contain a dense willow shrub vegetation which is represented by an association of willow and sweet coltsfoot (*Salix planifolia pulchra/Petasites frigidus*) (Plate 11E). Felt-leaf willow (*Salix alaxensis alaxensis*) is a co-dominant with the other tall willow in most of the vegetation type. Other prominent species include loco-weed (*Oxytropis borealis*), groundsel (*Senecio atropurpureus frigidus*), alpine blueberry, lupine, lousewort (*Pedicularis capitata*), fescue grass (*Festuca brachyphylla*) and chickweed (*Stellaria monantha*). A high density of 12,040 stems/Ha was recorded for *Salix planfolia pulchra*, while *Salix alaxensis alaxensis* had 3720 stems/Ha. Most of these are below 2.5 cm d.b.h. but there are some up to 10 cm. Willow-dominated vegetation on fossil floodplains becomes less common with increase in latitude and is found only in restricted areas on the fossil floodplains and sand dunes within 10 - 15 km (6 - 9 mi.) of the coast.

.5 Dwarf shrub - Dryas meadow (Deciduous orthophyll dwarf scrub, 1.C21 (a)).

River terraces on active and fossil floodplains below 125 m elevation contained an open to closed meadow type vegetation. These sites are mostly north of well developed tall willow vegetation which occupies similar habitats further inland. An association of dwarf willow, mountain avens and polar grass (*Salix ovalifolia ovalifolia - Dryas integrifolia integrifolia - Arctagrostis latifolia latifolia*) occupies gravelly and cobbly surfaces on older terraces of many of the coastal plain rivers (Plate 12A). Other prominent species include milkvetch (*Astragalus alpinus*), brome grass, and minuartia (*Minuartia arctica*).

A similar association of mountain avens and sedge (*Dryas integrifolia integrifolia - Carex bigelowii*) occurs on higher and older terraces, again north of the range of tall willow vegetation development. These sites have a more complete vegetative ground cover of dwarf willow (*Salix brachycarpa niphoclada, S. sphenophylla*), bistort (*Polygonum viviparum*), milkvetch (*Astragalus alpinus arcticus*), moss (*Tomenthypnum nitens*) and lichen (*Cetraria nivalis*). The trend of community development seems to be toward a sedge meadow with low or dwarf willow shrubs.

Old alluvial fan deposits on the lower (10 - 30 m) portion of the coastal plain are represented by an association of netted willow, mountain avens and moss (*Salix reticulata reticulata - Dryas integrifolia integrifolia/Tomenthypnum nitens*) (Plate 12B).

The sites represented have the most continuous vegetative cover and are the oldest since deposition of the land surface within the vegetation type. Other prominent species include dwarf willow (*Salix glauca glauca*), cotton grass (*Eriophorum vaginatum vaginatum*), sedge (*Carex begelowii*), horsetail (*Equisetum scirpoides*) and mosses (*Bryum pseudotriquetrum, Distichum capillaceum, Cinclidium arcticum*).

.6 Heath-sedge tussock tundra (Microphyllous evergreen dwarf heath, 1C12 (c)).

The combination of sedge and heath species forms a vegetation type which occurs on many of the slightly better drained sites on Arctic Coastal Plain, alluvial fan deposit and fossil floodplain terrain.

A mountain avens, Lapland cassiope, sedge and alpine blueberry (*Dryas integrifolia integrifolia - Cassiope tetragona - Carex scirpoidea - Vaccinium uliginosum alpinum*) association typifies fairly well drained youthful sites on alluvial fan deposits where the vegetation cover is not complete. (Plate 12C). Other prominent species include dwarf willow (*Salix phlebophylla*), lupine, saxifrage (*Saxifraga tricuspidata*), avens (*Geum glaciale*) and moss (*Onocophorus wahlenbergii*).

Some old alluvial fan deposits and fossil floodplains are typified by an association of Lapland cassiope, sedge and northern Labrador tea (*Cassiope tetragona - Carex bigelowii - Ledum palustre decumbens*). These sites have been established long enough so that permafrost is quite near the surface and some low ponding with a predominance of sedge is evident (Plate 12D). On the slightly raised and hence drier areas, sedges have formed tussocks. The vegetation represents sites from various areas along the Kavik, Canning and Sagavanirktok rivers which include elevations of 30 to 100 m (100 - 330 ft.). Certain prominent species including lingonberry, sedge (*Carex misandra*), dwarf willow (*Salix planifolia pulchra*) and moss (*Aulocomnium turgidum, Hylocomium splendens*) are common at all the sites. Dwarf willow (*Salix phlebophylla*), bistort and mosses (*Calypogeia neesiana, Dicranum acutifolium*) are more common at the lower elevational range of the association and dwarf birch (*Betula nana exilis*), cotton grass (*Eriophorum vaginatum vaginatum*), and moss (*Blepharostoma tricophyllum*) are more common at the upper limit.

5.3.6 Summary

Thirty major vegetation types have been identified for the five physiographic regions (Table 2). Wet sedge meadow, dwarf or low shrub sedge meadow, riparian willow shrub and white spruce forest types occur in three of the physiographic provinces and had the highest presence. Vegetation types made up of low and dwarf heath, sedges and low willow were found to be the most common. Mountain avens (*Dryas integrifolia integrifolia*) also is dominant in a number of types, especially in alpine areas of the Porcupine Plateau, Southern Foothills and the Brooks Range. Low heath shrub and dwarf heath with open white spruce types are the most common in the Porcupine Plateau, but tall willow-heath shrub is also common

Table 2 . Distribution of the major vegetaion types in the northeastern Alaska physiographic provinces.

Major Vegetation Type	Physiographic Provinces: Porcupine Plateau	Southern Foothills	Brooks Range	Arctic Foothills	Arctic Coastal Plain
Tussock tundra				X	X
Wet sedge meadows	X			X	X
Wet sedge meadows w/ scattered shrubs		X			
Alpine sedge meadows			X		
Dwarf or low shrub -sedge meadows	X			X	X
Alpine open dwarf shrub sedge meadows		X			
Alpine Dryas-sedge meadows			X		
Alpine-subalpine Dryas meadows	X				
Alpine Dryas meadows & barrens			X		
Dwarf shrub-Dryas meadows					X
Alpine heath-Dryas meadows			X		
Dwarf heath-sedge wetland	X				
Heath-sedge tussock tundra					X
Low heath shrub	X	X			
Low heath-willow shrub		X			
Dwarf heath-lichen tundra				X	
Open dwarf shrub-heath barrens				X	
Dwarf heath w/ open white spruce	X		X		
Subalpine Dryas shrub w/ white spruce			X		
Tall willow-heath shrub	X				
Low shrub-herb & moss meadow	X	X			
Low & dwarf willow shrub tundra			X		
Alpine dwarf shrub -lichen fellfield			X		
Low birch shrub			X		
Riparian willow shrub			X	X	X
Arctic bearberry-herb w/ balsam poplar			X		
Riparian shrub & open forest				X	
Balsam poplar forest	X				
White birch forest	X				
White spruce forest	X	X	X		

(Table 2). Low heath shrub, low heath-willow shrub and low shrub-herb and moss meadows are the most abundant types in the Southern Foothills. Alpine heath-Dryas meadows and alpine Dryas-sedge meadow types cover a major portion of the Brooks Range. Wet sedge meadows and dwarf or low shrub sedge tussock tundra are the most common types of the Arctic Foothills and Coastal Plain. Tussock tundra is more common on the rolling hills of the Foothills than on the Coastal Plain.

Forest types cover a small portion of the study area as they are restricted mostly to the lower riparian sites and south exposures only as far north as the Brooks Range. A few balsam poplar stands (Arctic bearberry with balsam poplar) extend into the Arctic Foothills. Riparian vegetation is composed of mixed shrub and forest species into the Brooks Range, but willows become more dominant through the Brooks Range and into the coastal plain. Other restricted types include alpine dwarf shrub-lichen fellfields near snow line in the Brooks Range, dwarf heath-lichen tundra which occurs only on well drained ridges in the Arctic Foothills and alpine sedge meadows which, although frequently found in the Brooks Range, cover a small percentage of the area.

5.4 Soils of the Physiographic Regions

5.4.1 Porcupine Plateau

.1 Valleys

Cumulic Regosols occur on level rapidly drained active floodplains (Plate 13A). They are characterized by alternating layers of varying texture (usually sand and silt), and also by the presence of buried former surface horizons. Cobbles may be encountered within the control section (within 1 m of the surface). These soils are found under various successional stages within seres along valley streams, including willow, balsam poplar, and mature white spruce (described in 5.1.1.1). The surface LFH horizon of 2 to 5 cm is often covered by feathermosses under the white spruce forest stage.

Gleyed Static Cryosols, which are sometimes vegetated by stunted and very scattered white spruce at 396 m (1300 ft.) with sedges, heaths and cotton grass forming the understory (see 5.1.1.1), are often associated with level poorly drained fossil floodplains (Plate 13B). These soils are characterized by the presence of permafrost within the control section (30 to 40 cm in August), and by silty loam textured gleyed mineral horizons under thick (10 - 20 cm) surface organic horizons. Horizon displacement is absent due to the lack of frost heaving.

Outwash plains which are common in these broad valleys, are composed of rounded cobbles mixed with sands. Permafrost is probably present within the control section through late summer, and widely spaced (5 - 10 m) organic ridged circles or strings are present, either due to the action of frost or downslope movement. Regosolic Turbic Cryosols with a 20 to 30 cm fibric surface horizon occur on moderately well to imperfectly drained sites under open white spruce vegetation (Plate 13C), and Organic soils with fibric surface horizons occur under poorly drained sedge vegetation at 488 m (1600 ft.).

.2 Slopes

All soils on colluvial slopes are characterized by having buried or rolled under horizons.

On gentle to moderate slopes, where drainage is imperfect, cryoturbation and slope movement combine to form Regosolic Turbic Cryosols (Plate 13C). These are characterized by having a high micro-topographic relief (20 - 40 cm) and associated ice wedges surrounding earth hummocks. Fibric surface horizons vary in thickness from 10 cm on hummocks, to 20 cm between hummocks. Silty loam textures are responsible for high ice contents and active frost heaving.

Steep south facing slopes vegetated by white birch at 427 m (1400 ft.) are moderately well drained and clay loam textured and containing soils with dislocated horizons. These soils are unfrozen within 1 m of the surface in late summer so that horizon displacement is probably due primarily to slope movement. Charcoal is present

PLATE 13A: Cumulic Regosol on a level well drained active floodplain near Monument Creek.

PLATE 13B: Gleyed Static Cryosol on a level poorly drained fossil floodplain of the Koness R.

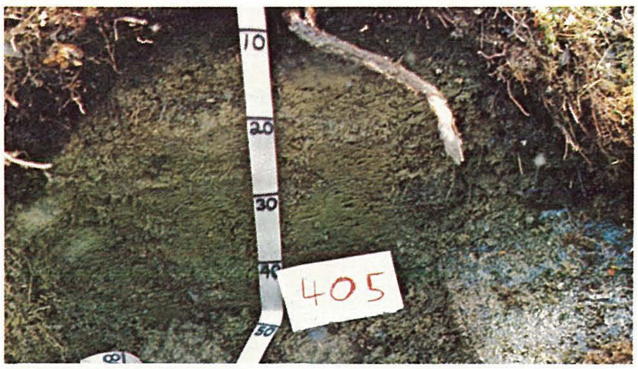


PLATE 13C: Regosolic Turbic Cryosol under earth hummocks near Grayling Lake.

PLATE 13D: Cumulic Regosol on a steep slope above the Koness R.

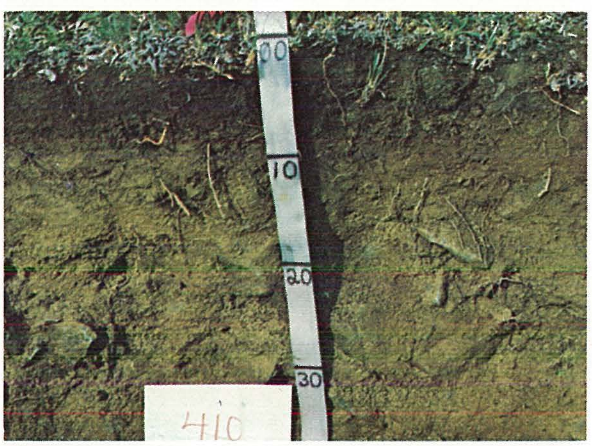


PLATE 13E: Lithic Alpine Eutric Brunisol on a level well drained ridge of the Porcupine Plateau.

PLATE 13F: Lithic Degraded Eutric Brunisol under white spruce on bedrock near Grayling Lake.

occasionally (Plate 13D). These soils which are characterized by having fibric surface horizons (5 - 10 cm) over BCg mineral horizons with buried charcoal and former surface horizons, are classed as Orthic, Cumulic or Gleyed Regosols.

At higher elevations (762 m; 2500 ft.) under mountain avens vegetation, the turfy surface horizon which may be buried, is designated as Ah (>30% organic matter by weight). This Ah is non-chernozemic (moder), and is derived from the mechanical incorporation of humus into the mineral soil. Permafrost was usually absent within 1 m of the surface in late summer, but a lithic contact is usually present at 10 to 50 cm so these soils are then classed as Lithic Regosols.

.3 Bedrock

In alpine regions at 762 m (2500 ft.) on level, rapidly drained ridges vegetated by alpine Dryas meadows, soils consist of mixed broken rock and sandy loam material. They may be designated as Lithic Alpine Eutric Brunisols and are characterized by having a turfy Ah surface horizon of 3 to 5 cm underlain by a weak brownish Bm (a mineral horizon of moderate iron and organic acid accumulation) (Plate 13E). A lithic contact was encountered at 10 to 15 cm.

At lower elevations (610 m) (2000 ft.) under white spruce vegetation but under similar conditions of drainage and parent materials, soils were very similar to those described above, except that the surface horizon is an LFH at 5 to 10 cm (> 30% organic matter by weight) instead of an Ah, and a discontinuous Aej of 1 to 3 cm (horizon of iron and organic matter eluviation, whitish grey in color). Such soils could be described as Lithic Degraded Eutric Brunisols (Plate 13F).

5.4.2 Southern Foothills

.1 Valleys

Soils in these high (915 m) (3000 ft.) valleys have developed on active and fossil floodplains, which occur on old moraine and colluvium.

Soils on active or recently active floodplains are undeveloped except for some gleying and mottling throughout the lower profile on more mature sites under well established sedge and low shrub tundra vegetation. These soils are classified as (Cumulic) Gleysolic Static Cryosols (Plate 14A) and may have active layers of 50 to 60 cm thick. Soils on the older surfaces of the fossil floodplains are similar, but have a shallower active layer and a thicker organic mat on the surface (Plate 14B).

.2 Colluvium Slopes and Terraces (915 - 1220 m) (3000 - 4000 ft.)

Most of these mountain slopes are poorly drained because of water movement from higher slopes or ridges. Therefore soils with silty clay textures are characterized by mottled and gleyed conditions

PLATE 14A: Cumulic Gleysolic Static Cryosol on a floodplain near Index Mtn.

PLATE 14B: Gleysolic Static Cryosol on a fossil floodplain near Index Mtn.

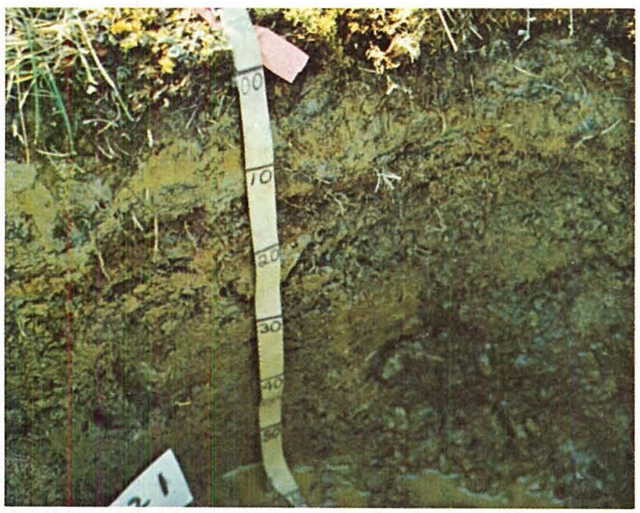


PLATE 14C: Gleysolic Turbic Cryosol on poorly drained solifluction slopes of Index Mtn.

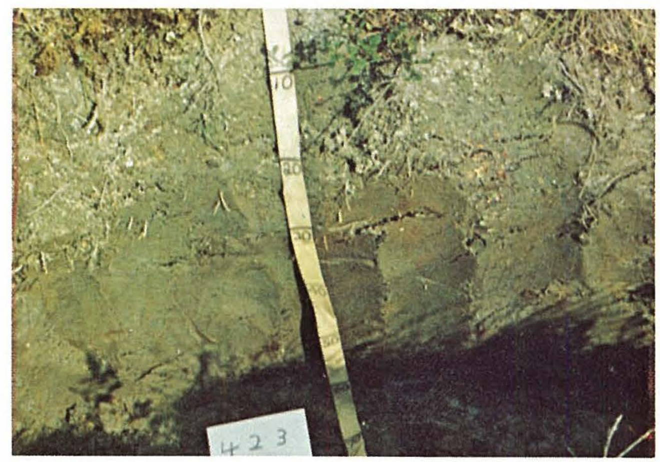


PLATE 14D: Gleysolic Turbic Cryosol on a poorly drained colluvial terrace of Index Mtn.

throughout the profile, with disruption of the profile occurring on solifluction slopes. Surface fibric horizons are 5 to 20 cm thick. These soils may be classified as Gleysolic Turbic Cryosols (Plate 14C). High moisture contents may be responsible for the thick active layers which may extend to 1 m in late summer. Willow is common in the low shrub tundra vegetation.

Slopes with relatively little drainage from above have shallow active layers (40 cm) with accompanying frost heaved topography. These soils which support low willow shrub vegetation may be classified as Regosolic Turbic Cryosols.

At higher elevations (1220 m), level to gently sloping and poorly drained colluvial terraces occur under wet sedge meadow vegetation. Soils here are characterized by having silt textures and are very amorphous in structure. Strongly gleyed conditions occur under thin (5 - 10 cm) surface fibric horizons. These soils may be classified as Gleysolic Turbic Cryosols (Plate 14D).

Bedrock on fellfield ridges at or above 1525 m (5000 ft.) had a very sparse and low plant cover, and no soil development was detected.

5.4.3 Brooks Range

Sampling areas included active and fossil floodplains, alluvial fan deposits entering valleys, lateral and other moraines left by Pleistocene Valley glaciers, and colluvial slopes at higher elevations.

.1 Active Floodplains

Permafrost is absent or undiscernable in these active floodplains. Unconsolidated rounded gravels and sands predominate in very young floodplains, where tall willow are common, and scattered mosses, herbs and shrubs make up the ground cover. Soils are Regosols and are similar to Plate 15A, except that the surface organic horizon is absent or very thin. On slightly older sites, the organic horizon may be 5 to 10 cm thick (Plate 15A). Development and differences of the youthful soils are probably not influenced as much by different vegetation type as by site age.

.2 Fossil Floodplains

The majority of fossil floodplain in the Brooks Range valleys are rapidly drained because of the lack of deep silt deposition over cobbles. As a result, terraces above present river courses are level to gently sloping, with alpine meadow vegetation consisting of mountain avens, grasses, sedges, some heaths and shrubs, and a ground cover of lichens and mosses. Soils are characterized by having a thick turfy Ah surface horizon which grades into the C horizon (Plate 15B) in the cases where there has been an accumulation of silts and sands among the upper (0 to 30 cm) cobbles and gravels. These soils would be classified as Lithic Regosols according to the Canadian classification system, but might be better categorized as Lithic Alpine Regosols because of the turfy Ah surface horizons.

PLATE 15A

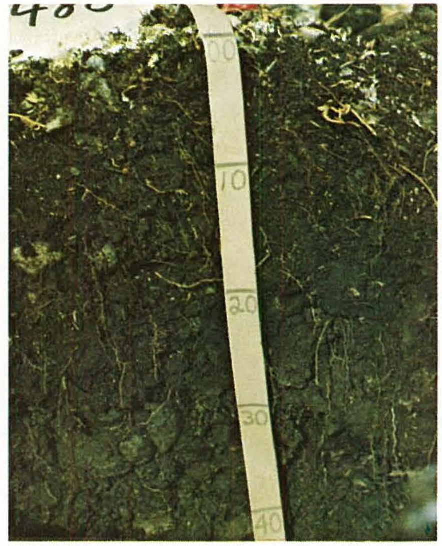


PLATE 15B

PLATE 15C

PLATE 15D

PLATE 15A: Regosol with a very thin surface organic horizon on an active floodplain of the Chandalar R.

PLATE 15B: Lithic Alpine Regosol or Lithic Regosol on a fossil floodplain near the Canning R.

PLATE 15C: Lithic Alpine Eutric Brunisol on a fossil floodplain terrace near Cane Creek.

PLATE 15D: Lithic Regosol on fossil floodplain of Cane Creek.

PLATE 15E: Cumulic Gleysolic Static Cryosol on fossil floodplain of the Chandalar R.

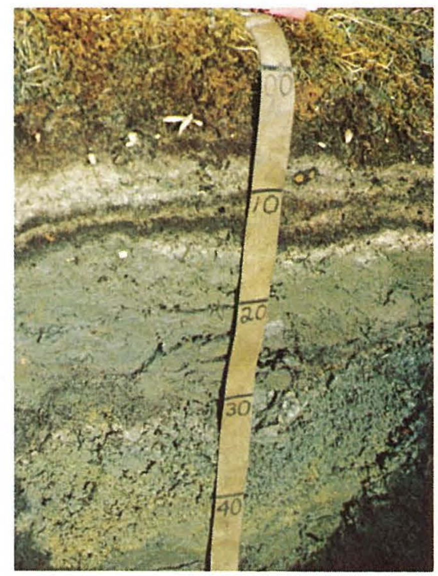


PLATE 15E

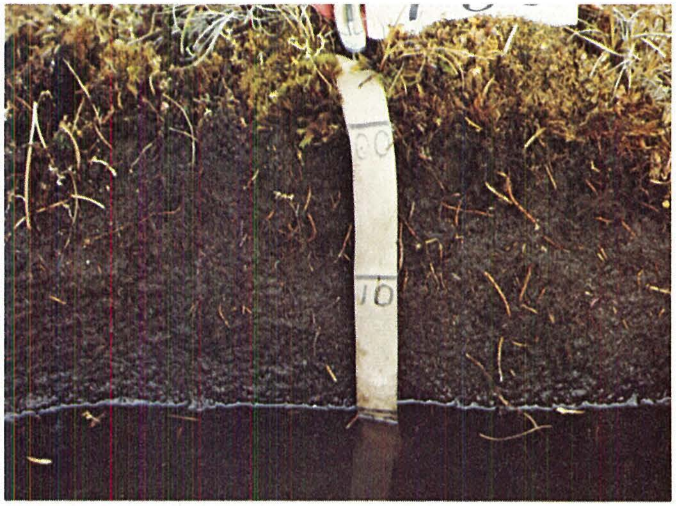


PLATE 16A: Mesic or Humic Organo Cryosol on an alluvial fan deposit in the Cane Creek Pass area.

PLATE 16B: Brunisolic Turbic Cryosol on a lateral moraine near the Chandalar R.

PLATE 16C: Lithic (Alpine) Regosol on a colluvial slope near Cane Creek Pass.

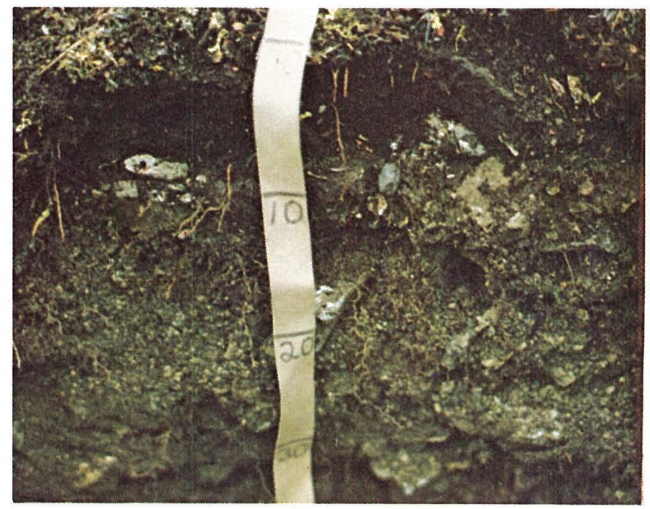


PLATE 16D: Lithic Cumulic Regosol on a colluvial slope near Cane Creek Pass.

Better developed soils occur on fossil floodplain terraces where a greater deposition of windblown or water carried silts and sands has taken place over porous gravels (Plate 15C). Here a turfy Ah horizon occurs over a 5 - 10 cm Bm horizon. Vegetation provides a heavier cover than on Lithic Alpine Regosols. The soil is classified as a Lithic Alpine Eutric Brunisol.

Fossil floodplains with 30 cm of silt loams over former river gravels support an even heavier vegetation cover and are moderately well drained. These soils may be classified as Lithic Regosols (Plate 15D). The soil illustrated supports scattered white spruce vegetation, which is near its latitudinal limit here at 850 m (2800 ft.).

A greater depth of fine textured materials on level topography promotes the development of a Cumulic Gleysolic Static Cryosol (Plate 15E). This particular soil is characterized by having buried organic horizons, alternating layers of marl (deposited in standing water) and mesic material (forming under present conditions) which occurs at 790 m (2600 ft.). Active layer thickness is 70 cm. Not far from this soil profile, a backswamp or strangmoor terrain sub-type has developed where predominately sedge vegetation exists over a Fibric Organo Cryosol. The active layer thickness here averages 50 cm.

.3 Alluvial Fan Deposits

These landforms are rapidly drained except near present drainage channels. On the well drained sites, soils and vegetation are similar to those found on well drained fossil floodplains (Plate 16A). Drainage patterns over these alluvial fan deposits are responsible for the development of Mesic or Humic Organo Cryosols.

.4 Valley Moraines

Lateral moraines deposited by Pleistocene valley glaciers are composed of slightly worn angular limestone rocks in a sandy clay loam matrix. Frost heaving is prevalent, but not dramatic because of well to moderately well drained conditions. Alpine Dryas meadows occur on these moraines at 915 m (3000 ft.) and Subalpine Dryas shrub and open white spruce occur at 762 m (2500 ft.). Soils are characterized by having a discontinuous Ah (0 to 10 cm) or H horizon over a Bm with variable (0 to 10 cm) thickness. Horizons are not buried but vary in depth and continuity because of frost heaving (Plate 16B). Slightly gleyed and mixed BCg horizons occur under the Bm. Structure of this lower region is generally amorphous and the soil is best classified as a Brunisolic Turbic Cryosol. Permafrost was encountered at 70 cm in late August.

.5 Colluvial Slopes

Colluvial slopes consist of mixed angular shale or limestone rocks and silty loam materials. Well and rapidly drained slopes with an abundance of fine textured materials among predominantly limestone rocks are conducive for the development of a deep, humified surface horizon which may extend to bedrock (40 cm). The Canadian classification system is inadequate to describe this profile though it may be placed into the Lithic Regosol Subgroup. According to Ugolini and Tedrow (1963) this soil could possibly fit into the Rendzina subgroup, which is characterized by having some of its organic carbon derived from the limestone itself, thus not being an inherent product of development. This soil is illustrated in Plate 16C.

Colluvial slopes with an absence of fine textured materials, but an abundance of fine shales surrounding larger limestone rocks, have soils with only a 5 to 10 cm surface Ah over the parent material. This soil would be classified as a Lithic Cumulic Regosol (Plate 16D) and in areas where bedrock is exposed, it would be called a "non-soil". Alpine heath and Dryas meadows occur on these colluvial slopes.

5.4.4 Arctic Foothills

Sampling in the Arctic Foothills section was confined to rounded silt-mantled slopes (AAGSC, 1974), originally deposited as lateral moraines in outer mountain valleys and terminal and end moraines some distance north of the mountains.

On these slopes, drainage is generally poor to very poor because of the silty clay textures of the parent materials. Near the tops of these morainal hills on gentle to strong slopes, and under tussock tundra vegetation, drainage is imperfect to poor. Surface organic horizons which are mainly fibric are 10 to 15 cm thick in a 20 to 30 cm active layer. A thin (2 - 3 cm) Ah may be present just under the Of. The saturated 10 to 15 cm mineral ACg is strongly gleyed. The soil is a Gleysolic Static or Turbic Cryosol (see Plate 17B for similar profile).

On strong to steep slopes with poor drainage, soil movement appears to be continuous and the 50 cm active layer is composed of a heterogenous organic - mineral mix. Solifluction is an important process for the maintenance of this Regosolic or Gleysolic Turbic Cryosol under dwarf shrub - sedge meadows. Near the bottom of solifluction slopes, where accumulation of materials from the slopes occurring for a long time, Mesic Organo Cryosols have developed under dwarf shrub - sedge meadows (see Plate 16A for a similar type profile).

5.4.5 Arctic Coastal Plain

.1 Active Floodplains

Several floodplains were sampled near the Canning and Sagavanirktok rivers. Alternating layers of silts and organic materials identify this particular soil as a Cumulic Regosolic Static Cryosol on the assumption that permafrost is absent within 1 m of the surface by late summer (Plate 17A). Other soils in the area on the same landfrom may have cobbles near the surface. Vegetation on this particular soil is classified as a Dryas shrub-sedge meadow which contains an abundance of leguminous species (*Oxytropis, Astragalus* spp.).

PLATE 17A

PLATE 17B

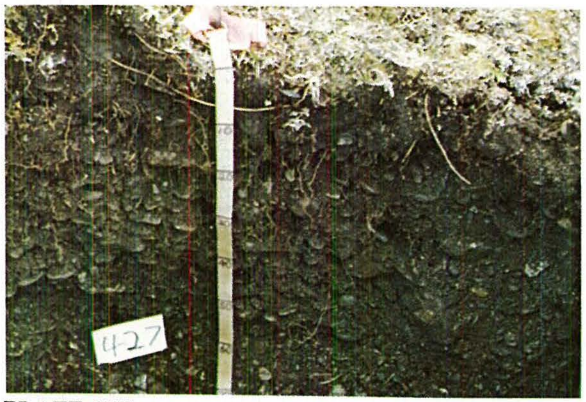


PLATE 17C


PLATE 17D

PLATE 17E

PLATE 17A: Cumulic Regosolic Static Cryosol on an active floodplain near the Canning R.

PLATE 17B: Gleysolic Turbic or Static Cryosol on a fossil floodplain near the Sagavanirktok R.

PLATE 17C: Lithic Static Cryosol on a fossil floodplain near the Kongakuk R.

PLATE 17D: Gleysolic Static Cryosol on a fossil lake basin near the Okerokovik R.

PLATE 17E: Gleysolic Turbic Cryosol on a silt mantled slope near the Okerokovik R.

.2 Fossil Floodplains

These terrain units occupy fairly extensive areas along streams flowing north across the flat coastal plain. Soil and vegetation development seem to depend more on the thickness of silt deposition over cobbles than on the distance from the present stream, or time since initial deposition.

Areas of silt deposition are very poorly drained and have thin active layers (30 to 40 cm). Frost heaved features are present, though not prominent. Mineral horizons are strongly gleyed with some mottles. The fibric organic horizon varies in depth (5 - 20 cm) because of frost heaving. It is usually underlain by a thin Ah or AB (1 to 2 cm) which is bron in color. These soils may be classified as Gleysolic Turbic (or Static) Cryosols (Plate 17B). With age these regions may develop into high centre polygon terrain in which case Fibric Organo Cryosols may occur on the high centres with low shrub-heath vegetation.

In areas where silt deposition over cobbles is absent, or where cobbles occur at the surface, moderately well to well drained conditions exist in the top 30 cm, but imperfect to poorly drained conditions can exist just above permafrost. Under less well drained conditions (i.e. cobbles and silt mixture), a 10 to 15 cm surface organic horizon occurs, while in well to rapidly drained conditions (sand and cobble mixture) Lithic Static Cryosols occur under heath-sedge vegetation (Plate 17C).

.3 Fossil Lake Basins

Plate 17D illustrates a Gleysolic Static Cryosol under wet sedge meadow vegetation and under the influence of poorly drained conditions with the water table just above permafrost. Organo Cryosols occur under very poorly drained conditions where the water table is at the surface.

.4 Silt-Mantled Slopes and Moraine Sediments

These terrain units occur between river systems, and are generally poorly drained due to fine textured parent materials. Under tussock tundra vegetation on silt-mantled slopes, active layers vary in depth (30 to 60 cm) and soil profiles contain a mixture of horizons which are commonly gleyed. These soils are classified as Gleysolic Turbic Cryosols (Plate 17E).

5.5 Successional Trends

An estimate of the time necessary to develop a vegetation type is important in predicting the rate of vegetation change for various habitat and land surface types after disturbance. Therefore variously aged communities within the same successional sere need to be identified in order to ascertain structural sequences of vegetation leading to stable or longer lasting community types.

Forested stands are simplest to place within a sere since ages can be estimated by tree ring counts. Shrub vegetation is difficult to age since parts of the crown of the larger shrubs were usually decayed. However the sequence of a sere can usually be established if enough samples are taken from the right vegetation types. If plant communities contain no trees or shrubs, placement into a sere is difficult. The practical stand ages (mean age of oldest 25% of the population) (Table 3) are used to rank the sites according to the age of either a continuously occurring population or a series of populations that overlap in age structure. Since woody tissue is needed to age the populations the occurrence of herbaceous stages in the sere can cause errors in the estimate of time since disturbance or colonization. Subsequent unmonitored disturbances which retard the successional sequence may also increase errors in time estimation. The number of stands utilized to characterize a sere varies from 6 to 12 and included some herbaceous vegetation types.

Table 3 . Practical stand age (PSA) and mean and maximum ages by species of the stands with trees and shrubs > 1m.

LOCATION	STAND	PSA	wS[1]		A		dB		wB		W		Sg		Sa		Sp		Bo		bPo		Sc	
			$\bar{x}$	Max.	$\bar{x}$	Max.	$\bar{x}$	Max.	$\bar{x}$	Max.	$\bar{x}$	Max.	$\bar{x}$	Mar.	$\bar{x}$	Mar.	$\bar{x}$	Max	$\bar{x}$	Max.	$\bar{x}$	Max.	$\bar{x}$	Max.
Western Porcupine Plateau	2	162	110	191																				
	4	130	83	156	58	72	45	45	107	107														
	6	71	42	48	18	22			56	74			18	29					68	68				
	7	223	143	241																				
	8	152	87	220	31	34					13	15												
	9	112	76	135	44	45			100	115	50	59												
	10	100	47	54	61	81			83	109					38	38								
	13	164	144	166																				
	14	56	34	41							34	44									45	67		
Southern Foothills	23	29					20	36			24	30	15	19										
	25	26					22	26					20	26	22	26								
	26	181	126	242			36	39					27	32										
Brooks Range — Southern	88	32											36	75	18	33	13	16					13	14
	89	24											20	26										
	93	260	134	286																				
	96	98	98	193									15	25										
	98	45													45	45								
	99	250	146	267																				
Brooks Range — Central and Northern	34	19					18	24					14	20			14	24						
	63	44													31	42	38	46						
	64	26											20	28										
	66	28													32	32								
	67	34													23	42								
	72	14											11	16										
	77	100													23	29					78	145		
	78	39					18	29							32	40	30	45						
Arctic Foothills and Coastal Plain	27	32											25	35										
	29	25											22	25										
	30	34											28	36										
	42	20											13	25										
	43	20											13	23										
	50	86													44	48			65	96				
	51	46											20	24	32	52								

[1] TREE SPECIES LEGEND:

wS = white spruce (<u>Picea glauca</u>)
A = alder (<u>Alnus crispa</u>)
dB = dwarf birch (<u>Betula glandulosa</u>)
wB = white birch (<u>Betula papyrifera</u>)
W = willow (<u>Salix spp.</u>)
Sg = willow (<u>Salix glauca</u>)
Sa = willow (<u>Salix alaxensis</u>)
Sp = willow (<u>Salix planifolia pulchra</u>)
Bo = shrub birch (<u>Betula occidentalis</u>)
bPo = balsam poplar (<u>Populus balsamifera</u>)
Sc = soapberry (<u>Shepherdia canadensis</u>)

Most of the herb and grass vegetation of the Arctic Coastal Plain, the Arctic Foothills and Brooks Range Physiographic Provinces is difficult to place within a traditional successional sequence since definite stand ages are unknown. In this case the best estimte of successional relationships is ascertained by placing the stands from related habitats and terrain units into a sequence within a sere by evaluating soil maturity and ground cover composed of fewer and fewer species known to colonize disturbed areas. Some species may also assume roles in both disturbed and stable communities which also increases the complexity of sere identification.

5.5.1 Porcupine Plateau

Stands are divided into riparian or upland seres on the basis of location and species composition. Upland succession occurs most usually after fires and/or slope failure. The sere toward white spruce forest climax on alluvium is identified by balsam poplar and white spruce forest types on river terraces. Balsam poplar occurs as a well developed forest species at 65 years on the youngest sites sampled (Fig. 9A). White spruce is already prominent in the low or tall shrub strata at this time. The evidence indicates that white spruce replaces balsam poplar as a dominant species after about 125 years of balsam poplar colonization.

A high cover of the low shrub, herb and grass category is represented at 65 years by Arctic bearberry (*Arctostaphylos rubra*), wintergreen (*Pyrola rotundifolia grandiflora*), river beauty (*Epilobium latifolium*) and polar grass (*Arctagrostis latifolia latifolia*). The latter two species are probably remnants of the earlier stages of the sere and can be found abundantly on open gravel bars. White spruce forests were well developed 150 years after initial establishment. By this time balsam poplar occurs only as old, widely scattered trees and the ground cover has changed from predominantly vascular species to mosses. Wintergreen remains a dominant understory species with moss (*Hylocomium splendens, Rhytidium rugosum*) and willow (*Salix glauca acutifolia*) being more abundant than at the younger sites (Fig. 9A). The white spruce community probably represents a traditional temperate climax state. However, an increasing surface organic layer thickness in combination with increased shading by the tree canopy appears to result in a decrease in the active layer thickness. Older (> 200 years) sites reflect the colder, wetter soil environment by a reduction in the forest canopy and increase in vascular ground cover as mosses decrease in importance. Therefore, the white spruce forest type may not be an acceptable example of a climax community, but this is relative to the time scale used and the type of climax concept. Important lower stratum species include lingonberry, alpine blueberry, sedges (*Carex bigelowii, C. rariflora*), Labrador tea and mosses (*Dicranum acutifolium, Tomenthypnum nitens*) which reached a mean cover of 50% at 250 year old sites (Fig. 9A). Age estimates of widely scattered white spruce indicate that the length of time necessary to attain this heath-sedge community from newly deposited river gravels is greater than 300 years. The assumption, however, that alluvium ultimately supports a heath-sedge vegetation type may not be true in all situations.

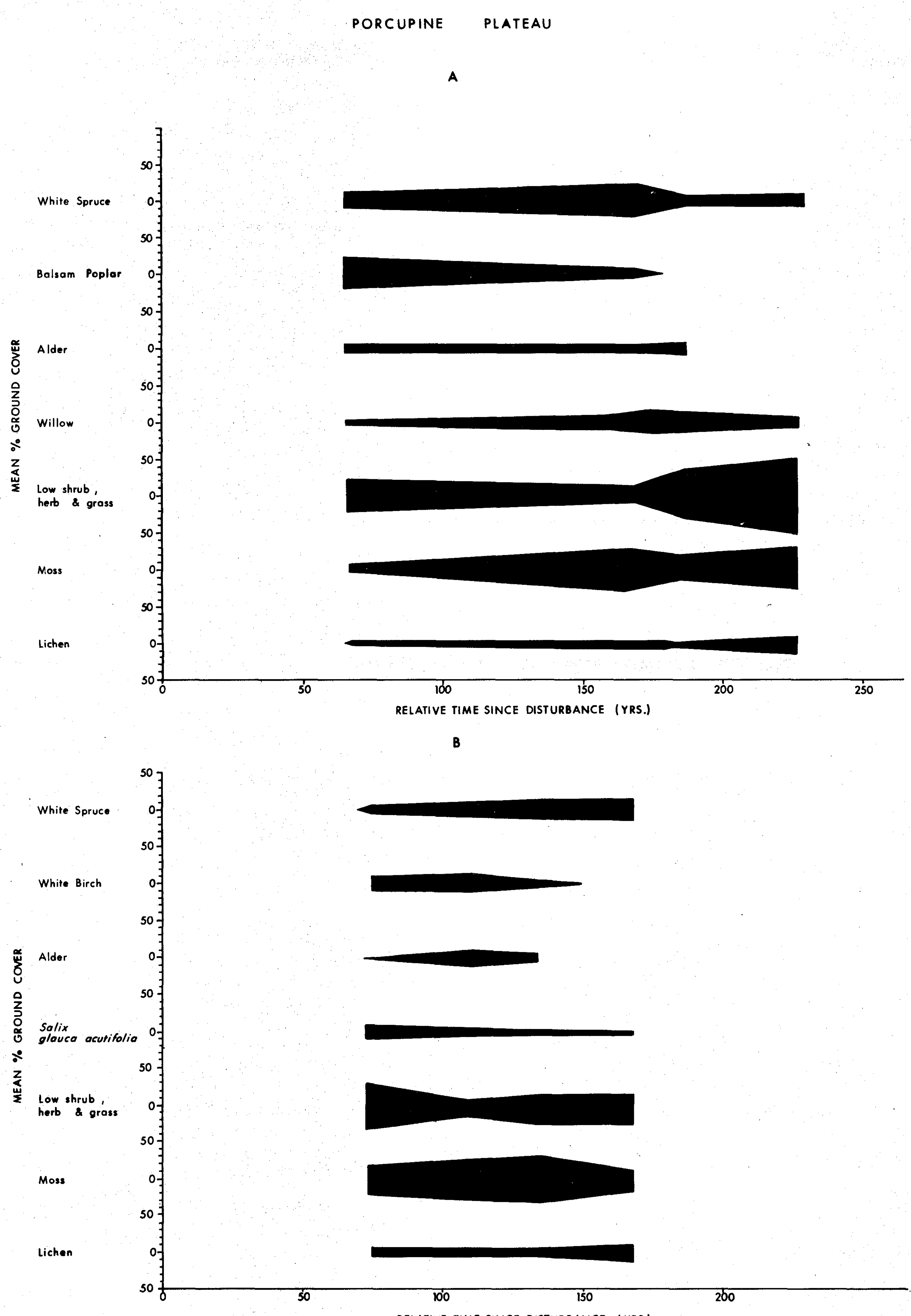


FIGURE 9. SUCCESSIONAL TRENDS AS MEASURED BY STRATA GROUND COVER PERCENTAGE ON RIPARIAN (A) AND UPLAND (B) COMMUNITIES

Upland slopes that have had fires or surface failures and populated by paper birch eventually establishes a forest type vegetation (at about 50 years). Again a white spruce forest community is given climax status in terms of more temperate monoclimatic concepts. Upland disturbance by fire or land slides has not been frequent in the area and no sites younger than 70 years were identified. By this time a well developed forest of paper birch with smaller and younger white spruce is evident, especially on south slopes. The ground cover includes mainly reed bent grass and bluejoint (*Calamagrostis purpurascens, C. canadensis*), lingonberry, mosses (*Aulocomnium turgidum, Hylocomium splendens*) and lichen (*Parmelia sulcata*) which constitute a major portion of the total vegetation cover (Fig. 9B). Moss and lingonberry probably represent a more mature portion of the sere. White spruce begins to dominate the sere about 110 years after establishment, at which time the percent cover of white birch decreases sharply (Fig. 9B).

An increase in the abundance of heaths is apparent after about 130 years of white spruce establishment. The increase follows a low in the vascular ground cover category which occurred before the heaths were well established at a time of high tall shrub (alder) cover. The increase in abundance of crowberry, lingonberry, Labrador tea, alpine blueberry and lichens (*Cetraria pinastri, Sereocaulon grande, Cladonia* spp.) continues until 135 years after white spruce establishment and is relatively high to about 165 years (Fig. 9B). The abundance of *Hylocomium splendens* decreases at about 130 years at which time other moss species (*Aulocomnium* *turgidum, Rhytidium rugosum*) become more dominant. The general trend of the sere is towards a more open xeric vegetation type with a predominant low shrub-heath ground cover and open white spruce and some willow (*Salix glauca acutifolia*) as taller shrubs. This vegetation type may be near a climax status, although the reduction of white spruce may continue to occur. The sites represented by this vegetation type still have some small solifluction activity, but generally the surface appears to be relatively stable and fires may be necessary to initiate further slumping and the re-establishment of white birch.

No definitive sere is identified for the alpine and subalpine areas since no reliable age data were available. However, sites in the alpine areas can be positioned into a hypothetical sequence on the basis of increased plant cover and soil development. The divergence of the successional trend into different seres is related to elevation, exposure and drainage conditions. Open communities of mountain avens and dwarf netted willow (*Salix reticulata reticulata*) with holy grass and lichen (*Alectoria tenuis*) are used to represent the younger sites both in the Porcupine Plateau and adjacent Southern Foothills. Low willow and mountain avens with some heaths and sedges represent more mature areas on slopes having a continuous vegetative cover. The abundance of heaths increases on slopes with south exposures, and sedges with some heaths represent mature portions of seres on top of large solifluction slopes that have adequate moisture. The trend at these sites is for a decrease in active layer depths and soil aeration accompanying an increase in the depth of the organic mat on the surface.

5.5.2 Southern Foothills

Riparian sites with low or tall shrubs and white spruce are the only areas with enough age data for placement into a successional sequence toward white spruce climax. The low shrub and alpine meadow communities are assessed on a more subjective basis and successional aspects are similar to those given for the Porcupine Plateau.

Shrub and heath vegetation on a high stream terrace contain a number of 23 year old willow (*Salix glauca glauca*), but judging from the high amount of ground cover of lingonberry, alpine blueberry and bearberry, the vegetation is from a relatively mature portion of the sere. Fescue grass (*Festuca altaica*) and horsetail (*Equisetum arvense*) are the only prominent species from earlier successional seres and are more abundant on younger alluvium. The high average moss cover (28%) is represented by *Hylcomium splendens*, *Meesia uliginosa*, and *Rhytidium rugosum*. Dwarf birch (*Betula nana exilis*) abundance is higher on sites with less slope and white spruce abundance is higher on southern exposures on sites at least 50 years old. The absence of white spruce and hence continuous age records in the earlier portion of the sere probably results in an underestimate of the time for development (Fig. 10). In general, the trend is for an increase in white spruce, dwarf birch and heaths and a slight decrease in moss cover even though additional species (e.g. *Catascopium nigritum*) occur with *Hylocomium splendens*

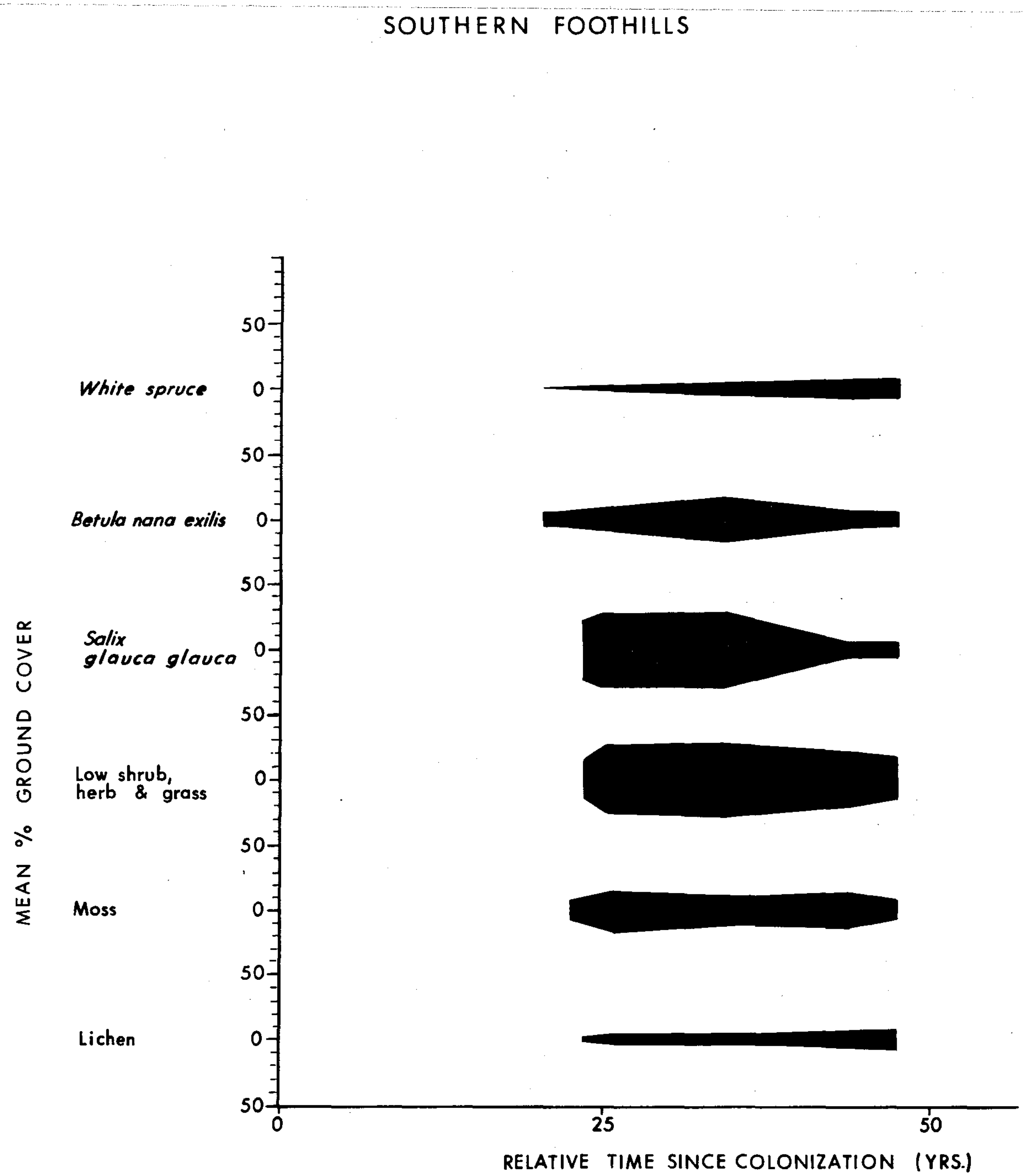


FIGURE 10. SUCCESSIONAL TRENDS AS MEASURED BY STRATA GROUND COVER PERCENTAGE ON RIPARIAN COMMUNITIES.

and *Rhytidium rugosum*. The widespread low heath and willow shrub communities also represent a fairly stable portion of a sere. Dwarf birch and willow (*Salix glauca* var. *acutifolia*) were a maximum of 30 years old, but this age probably does not include previously discussed vegetation types (mountain avens and lichen or wet sedge). A change from this community to wet sedge, cotton grass and moss types with an increase in insulative cover and decrease in active layer depth is probable. The length of time necessary for this transition is greater than 200 years, however.

5.5.3 Brooks Range

The Brooks Range is divided into two sections, southern and northern on the basis of sere similarily, the last taking in most of the central area of the range as well. Riparian areas again are the only sites with definite age structure, providing the best evidence of a successional sequence.

.1 Southern Section

The lower elevations of the valleys (760 m) (2500 ft.) contain a riparian pioneer community that is dominated by balsam poplar and willow (*Salix alaxensis alaxensis*, *S. planifolia pulchra*). The youngest of these communities sampled was 35 years old. A high ground cover of vascular species (*Arctagrostis latifolia latifolia*, *Calamagrostis purpurascens*, *Hedysarum alpinum*, *Claytonia acutifolia*) and mosses (*Oncophorus wahlenbergii*, *Thuidium abietinum*) occurs at these sites (Fig. 11).

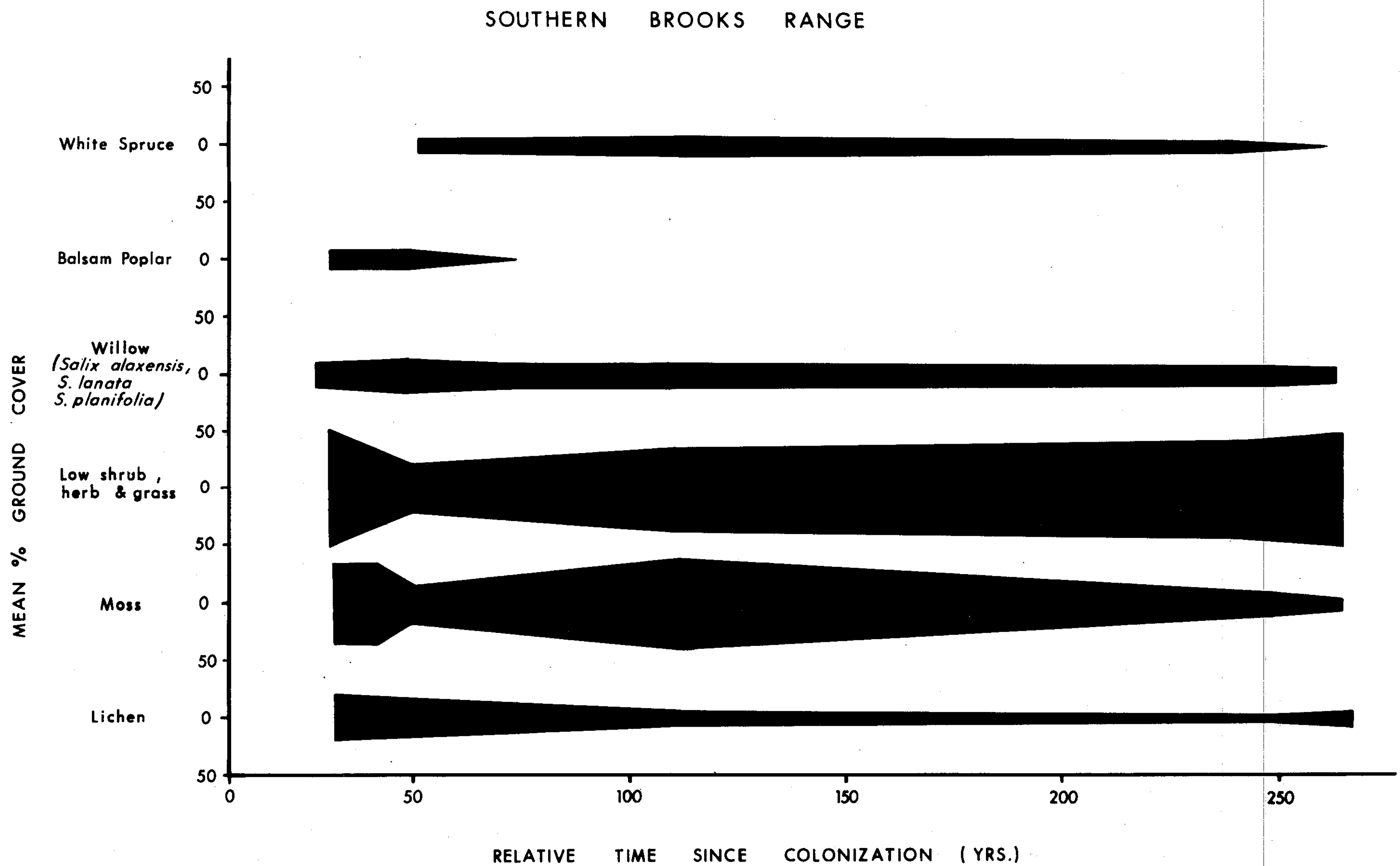


FIGURE 11. SUCCESSIONAL TRENDS AS MEASURED BY STRATA GROUND COVER PERCENTAGE ON RIPARIAN COMMUNITIES.

Felt-leaf willow forms a dense tall shrub strata at this time and has a wider distribution than balsam poplar, which is usually no longer dominant after 75 years. A gradual shift to other willow (*Salix planifolia pulchra, S. lanata richardsonii*) occurs at about 100 years after felt-leaf willow establishment. High lichen cover, mainly of *Cetraria richardsonii* and *Parmelia panniformis* is evident early in the sere. A reduction in low shrub, herb, grass and moss cover occurs at about 50 years at which time pioneer species become less frequent, probably due to an increase in shrub and tree shading. Cover values of low shrubs begin to increase again as mountain avens, crowberry, lingonberry, bearberry and blueberry become more abundant with white spruce which appears after about 55 years of balsam poplar dominance (Fig. 11). Later trends (200 - 270 years) are toward a xeric low shrub savanna as the heath species increase and white spruce decreases in abundance.

A split in the sere is also possible at this time if side slope drainage is impeded by an accumulation of the surface organic mat and a resulting shallower active layer. The end point for this trend appears to be a wet sedge (*Carex limosa, C. bigelowii*) meadow with some low willow shrubs (*Salix planifolia pulchra*). Although the total moss cover decreases in the later stages, *Aulocomnium turgidum, Rhytidium rugosum* and *Hylocomium splendens* are still prominent.

The successional trends on the more upland sites proceed from open gravelly or rocky colluvium to a closed meadow type of community. However, low and dwarf shrub vegetation may be a relatively stable type on southern exposures. Mountain avens and moss campion were found to be present on relatively young, rocky substratum. Sites with an increase in vegetative cover and soil development contain mountain avens, sedges (*Carex scirpoidea, C. misandra*), Lapland cassiope and moss (*Rhytidium rugosum*). Areas with less slope contain a higher cover of sedges (*Carex bigelowii, C. vaginata*) and lingonberry with willow (*Salix glauca acutifolia*) which probably becomes less dominant with development of the sere.

.2 Northern Brooks Range

Successional trends for riparian sites are similar for a large portion of the Brooks Range, but some species of willow (*Salix arctica, S. arctophila, S. reticulata reticulata*) are more common in the section near the northern foothills. A wide enough range of sites was sampled to ascertain seral characteristics from about 10 to 90 years of vascular plant colonization (Fig. 12). The increase in the number of vascular species after colonization is the most dramatic change and remains high throughout the sere. Felt-leaf willow (*Salix alaxensis alaxensis*) appears early in the sere and is usually a dominant feature of the communities ten years after its initial establishment. Other important species at this time are aster (*Aster sibiricus*), horsetail (*Equisetum arvense*), polar grass, loco-weed (*Oxytropis borealis*) and mosses (*Oncophorus wahlenbergii, Bryum pseudotriquestrum, Brachythecium turgidum, Drepanocladus revolvens*). A change in the shrub dominance from felt-leaf willow to *Salix planifolia pulchra* and *S. glauca acutifolia* appears to occur at about 30 years after deposition (Fig. 12). Increaser

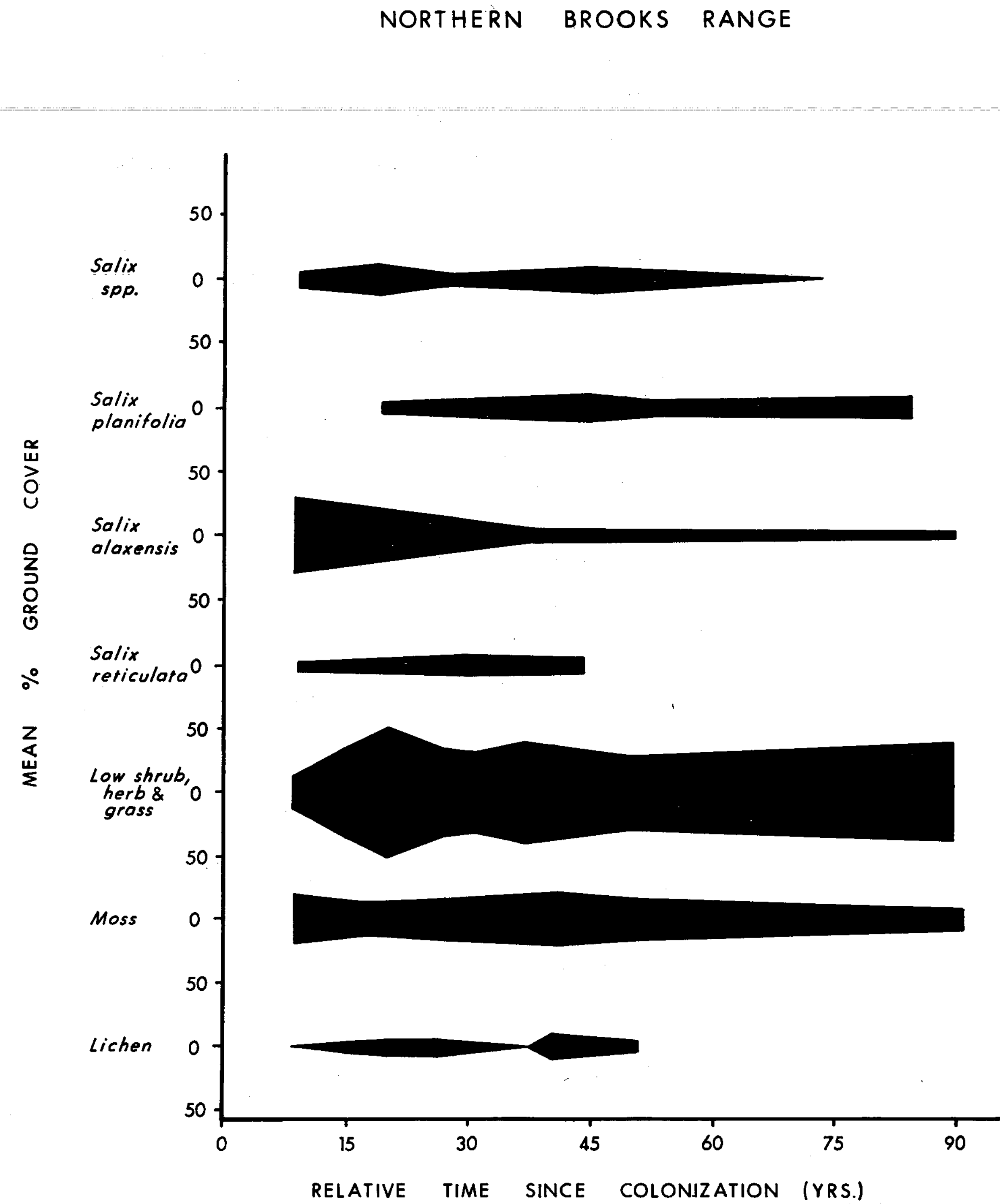


FIGURE 12. SUCCESSIONAL TRENDS AS MEASURED BY STRATA GROUND COVER PERCENTAGE ON RIPARIAN COMMUNITIES.

species in the middle portion (45 years) of the sere include hedysarum (*Hedysarum mackenzii*), Arctic bearberry, loco-weed (*Oxytropis campestris gracilis*), yarrow (*Achillea borealis*), river beauty (*Epilobium latifolium*), groundsel (*Senecio residifolius*) and soapberry. Mosses (*Rhytidium rugosum, Hylocomium splendens, Aulocomnium turgidum*) become more abundant during this stage of the sere and continue to increase in ground cover with further sere development. Willows (*Salix hastata, S. planifolia pulchra*) and soapberry remain as the dominant shrubs for at least 90 years, but there are some changes in ground cover species with dwarf birch, brome grass (*Bromus pumpellianus*), mountain avens, Lapland cassiope, alpine blueberry and mosses (*Thuidium abietinum, Eurhynchium pulchellum*) becoming more dominant. Some of the irregularity in the low shrub, herb and grass category was attributed to compositional changes in the sere progression. The direction of the sere after 90 years may be toward an alpine heath-Dryas meadow if the site is not affected by drainage from the surrounding slopes. If drainage becomes increasing poor, a wet sedge meadow (*Carex membranacea, C. bigelowii*) community may develop. The amount of time necessary for such development is probably greater than 150 years.

Some riparian sites near perennial springs and underground water flow may support a long lasting sub-climax balsam poplar forest type. Understory species of Arctic bearberry, wintergreen and lingonberry indicate a trend toward a heath shrub community. However soapberry, groundsel, river beauty, brome grass and larkspur

(*Delphinium brachycentrum*) are still common and may be evidence of a relatively early (70 years since colonization) part of the sere. This community is widely disjunct in the northern part of the mountains where balsam poplar is at the limit of its range. Other environmental factors probably important in determining the location of this community, other than ground water and coarse substrata, include the accumulation of deep snow and topographic protection from winter winds. The low density of the lower balsam poplar size classes may indicate a transition toward low shrub vegetation types, however the smaller trees are browsed quite heavily by moose.

Successional trends on upland areas are again not well defined, but the development of stable, continuously vegetated meadows from rocky substrata is indicated. Open rocky and xeric communities of sedge (*Carex macrochaeta, C. misandra*), netted willow, mosses (*Rhacomitrium lanuginosum, Rhizocarpon geographicum*) and lichens (*Parmelia panniformis, Alectoria nitidula*) are given colonizer status. The developmental trend is generally toward alpine tundra vegetation with dwarf heath shrubs (Lapland cassiope, alpine blueberry), sedges, mountain avens and moss (*Tomenthypnum nitens*). Stable communities of dwarf birch and heaths are common on drier southern exposures and are probably a stable, long lasting vegetation type. Areas with less slope (solifluction plateaus and flat ridge tops) usually contained wet sedge meadows (*Carex membranacea, Dryas integrifolia integrifolia, Tomenthypnum nitens*). These sites are poorly drained with thin active layers (30 - 40 cm) and thick surface organic layers due to their proximity to streams or snow banks. Slope failure on wet areas are colonized by willow (*Salix glauca acutifolia*), Arctic bearberry, polar grass and horsetail (*Equisetum arvense*). More xeric sites on slopes and alluvial gravels at high elevations (1200 m) (3900 ft.) contain a longer lasting sparse vegetation of willow (*Salix glauca acutifolia*), hedysarum, loco-weed (*Oxytropis borealis, O. campestris gracilis*) and cinquefoil (*Potentilla biflora*).

5.5.4 Arctic Foothills and Coastal Plain

Most vegetation types of the foothills and coastal plain are difficult to place into a successional sequence. Stands with ascertainable population age structures include mainly those from riparian sites and those in more upland sites with willow and birch shrubs.
Most of the information in Figure 13 is from stands in the foothills, but similar coastal plain riparian stands are also included.
Species of the early (20 - 30 years) stages on river alluvium include aster (*Aster sibiricus*), river beauty, groundsel (*Senecio atropurpureus frigidus*), horsetail (*Equisetum arvense*), reed bent grass, moss (*Eurhynchium pulchellum*) and felt-leaf willow (*Salix alaxensis alaxensis*). Other species of willow (*Salix planifolia pulchra, S. lanata richardsonii, S. glauca*) eventually replace felt-leaf willow and are the dominant shrub at 45 - 50 years.
An increase in the abundance of larkspur (*Delphinium glaucum*),

ARCTIC FOOTHILLS AND COASTAL PLAIN

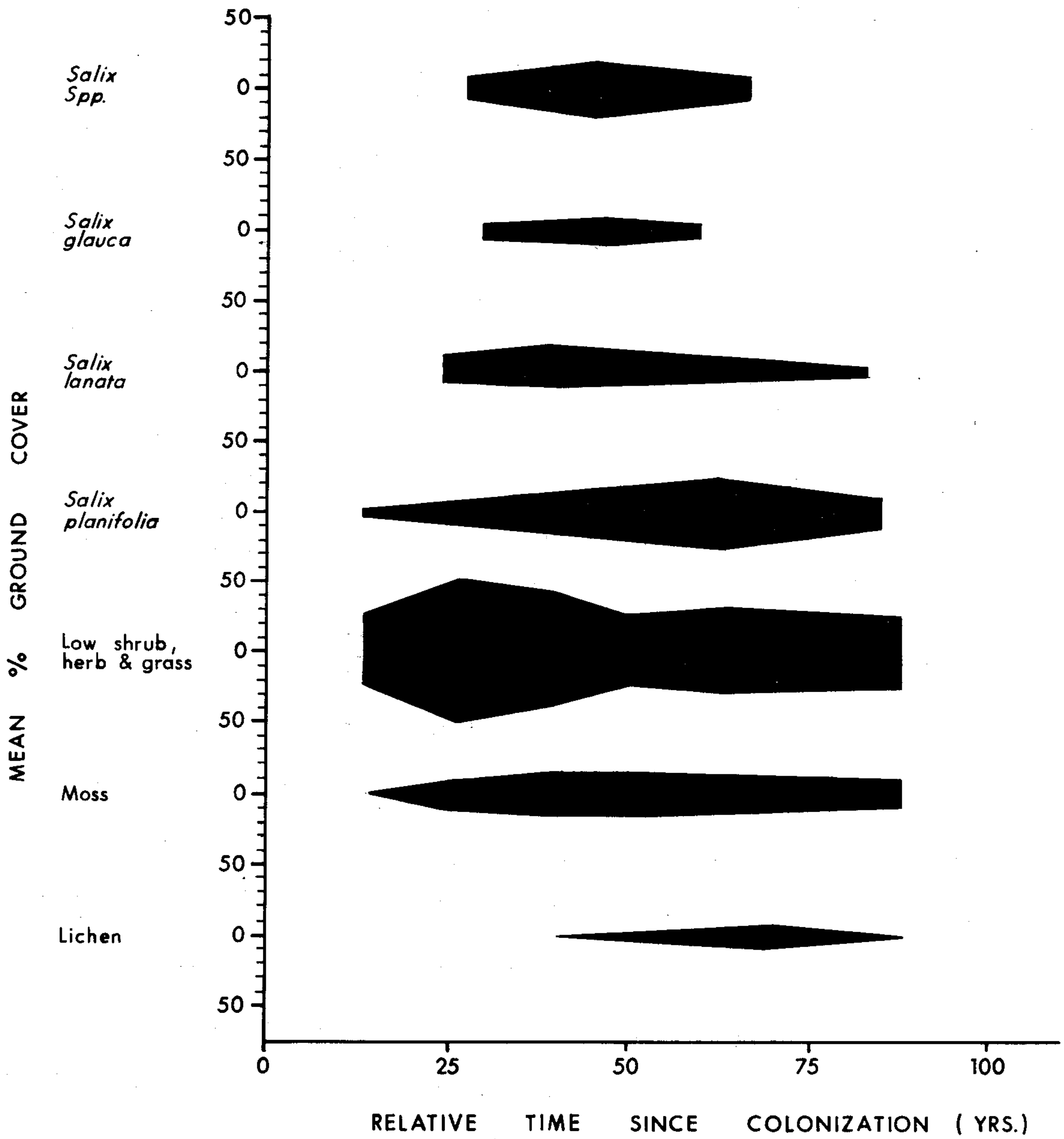


FIGURE 13. SUCCESSIONAL TRENDS AS MEASURED BY STRATA GROUND COVER PERCENTAGE ON RIPARIAN COMMUNITIES.

Jacob's ladder, lupine and Arctic bearberry also occur at this time, but there was a general decrease in total vascular ground cover (Fig. 13). Older (about 90 years) portions of the sere contain elements of a trend toward low willow sedge communities as indicated by an increase in the amount of sedges (*Carex bigelowii*, *C. rariflora*) cotton grass (*Eriophorum vaginatum*), dwarf willow (*Salix arctica*, *S. phlebophylla*), alpine blueberry and louseworts (*Pedicularis langsdorfii*, *P. verticillata*). A more mature portion of the sere was also indicated by an increase in moss cover mainly of *Scorpidium turgescens*, *Hylocomium splendens* and *Onocophorus wahlenbergii*.

The younger surfaces on the coastal plain beyond well developed tall shrub distribution contain fairly open, gravelly areas with milkvetch (*Astragalus alpinus arcticus*, *A. alpinus alpinus*), mountain avens, brome grass, minuarta (*Minuartia arctica*) and low willow (*Salix sphenophylla*, *S. brachycarpa niphoclada*, *S. ovalifolia ovalifolia*). Sites with a better developed vegetative cover and soil contain sedge (*Carex scirpoidea*), Lapland cassiope and alpine blueberry. Mountain avens and dwarf willow (*Salix sphenophylla*) are well represented throughout the proposed sere. Total moss cover increases with site age with a shift in dominance from *Bryum* spp. and *Tortula ruralis* to *Polytricum strictum*, *Rhytidium rugosum* and *Onocophorus wahlenbergii*.

Stable climax communities on upland sites are more difficult to ascertain, but trends towards wet sedge, tussock tundra and dwarf shrub heath communities are indicated. Species showing inclination to populate disturbed areas include mountain avens, polar grass, bluegrass (*Poa arctica*) and cloudberry (*Rubus chamaemorus*), but cotton grass and sedges may also assume an increaser role in this area. The length of time necessary for the development of these communities may be much longer than most traditional temperate seres. The establishment of fairly continuous vegetative cover on river terraces takes at least 40 years and this community is still relatively immature.

5.5.5 Summarization

A general trend in all of the physiographic provinces is for an increase in vegetation cover on new or disturbed areas accompanied by an increased surface organic layer thickness, and a resultant decrease in the active layer depth, soil drainage, soil temperature, and hence biological activity. An increase in the number of species accompanied the increase in plant cover throughout most of the successional stages, but a decrease in the number of species occur at some of the sites which are given climax status (white spruce forest). The high frequency of natural disturbance due to frost action may inhibit the formation of stable climax communities. However, long-lasting types of vegetation are indicated for all physiographic provinces and a relatively long time period is required for their development when comparing seres to more temperate examples.

Evidence of natural disturbance is common in all of the physiographic provinces. Fires have occurred in the Porcupine Plateau and Southern Foothills areas, but a complex and recent fire history is not evident. Low heath shrub, tall willow heath shrub and low heath willow shrub vegetation types are probably the most susceptible to burning. This assessment is made on the basis of the dense, continuous vegetation cover of which there is a major portion including heaths and dwarf birch having resinous leaves. Slope failures are commonly evident, although recent ones are infrequent. Solifluction is the most common type of disturbance found. The most active slope movement is associated with silty textures, drainage from higher, adjacent areas and high ice content permafrost. Areas with thicker active layers (> 80 cm) on south exposures also contains solifluction lobes, but these are usually more stable, and contain older communities.

Solifluction is also common in the Brooks Range being found on most slopes. Unstable scree is also a common feature of the area as is the undercutting of slopes by rivers. Frost-associated processes are common in some areas of the Brooks Range, but became more abundant rock as well as the more typical low and high centre polygons, sorted and non-sorted nets, frost stripes, sorted circles and earth hummocks. Solifluction lobes are common in both provinces, but are most frequent on the hilly terrain of the foothills. Evidence of fire was not found north of the southern Brooks Range. A number of species are consistently found to be pioneers in disturbed areas or on newly deposited rock or soil and are listed in Table 4.

Table 4. Pioneer species on riparian and upland sites in the physiographic provinces

Physiographic Province	Habitat	
	Riparian	Upland
Porcupine Plateau	*Arctagrostis latifolia* ssp. *latifolia*, *Epilobium latifolium*, *Populus balsamifera*	*Calamagrostis purpurascens*, *C. canadensis*, *Rosa acicularis*, *Parmelia sulcata*, *Dryas integrifolia* ssp. *integrifolia*, *Hierochloe alpina*, *Alectoria tenuis*
Southern Foothills	*Festuca altaica*, *Equisetum arvense*	*Dryas integrifolia* ssp. *integrifolia*, *Hierochloe alpina*
Brooks Range	*Salix alaxensis* var. *alaxensis*, *Arctagrostis latifolia* var. *latifolia*, *Calamagrostis purpurascens*, *Hedysarum alpinum*, *Claytonia acutifolia*, *Aster sibiricus*, *Equisetum arvense*, *Oxytropis borealis*, *Bromus pumpellianus* ssp. *arcticus*, *Cetraria richardsonii*, *Parmelia panniformis*, *Onocophorus wahlenbergii*, *Bryum pseudotriquestrum*, *Brachythecium turgidum*, *Drepanocladus revolvens*	*Dryas integrifolia* ssp. *integrifolia*, *Silene acaulis*, *Carex microchaeta*, *C. misandra*, *Salix reticulata* ssp. *reticulata*, *Rhacomitrium lanuginosum*, *Rhizocarpon geographicum*, *Parmelia panniformis*, *Alectoria nitidula*
Arctic Foothills & Arctic Coastal Plain	*Aster sibiricus*, *Epilobium latifolium*, *Senecio atropurpureus* ssp. *frigidus*, *Calamagrostis purpurascens*, *Astragalus arcticus*, *A. alpinus*, *Bromus pumpellianus*, *Minuartia arctica*, *Salix* spp., *Eurhynchium pulchellum*	*Dryas integrifolia* var. *integrifolia*, *Arctagrostis latifolia* var. *latifolia*, *Poa arctica*, *Rubus chamaemorus*, *Salix reticulata* ssp. *reticulata*

5.6 Biotic and Abiotic Relationships

Several significant relationships between environmental variables are indicated by simple correlation. However, a screening of the results is necessary in order to discard correlations which have minimal ecological value (e.g. positive relationship between distance from the coast and elevation) (Table 5).

Microrelief is greater on the steeper slopes than on the level low-lying areas. Solifluction lobes tend to increase in size as the slopes steepen, whereas frost action on the more level areas of the coastal plain did not cause microrelief greater than 1 m. The increase in micro-habitat diversity with microrelief is indicated by an increase in the number of species per area sampled. This is most evident in communities of dwarf shrub-sedge meadows in the foothills and alpine Dryas-sedge meadows in the Brooks Range and in some wet sedge meadows and low shrub-sedge meadows and hummocky tundra on the coastal plain. There is a percent increase of moss and low shrubs and herb cover with microrelief. The increase of plant cover on slopes with more northerly aspects may in part reflect a more amenable environment of east and west exposures. In some cases, south exposures present a fairly xeric environment and hence low plant cover.

Negative relationships occur between vascular ground cover and lichen cover, and also between tree cover and species number and between tree cover and low shrub and herb cover. Lichen cover is usually higher in the earlier stages of successional seres, especially in alpine areas,

Table 5. Simple correlation between the physical and biotic factors measured at each stand. Significance is indicated for probability >.05 as either + or -. Number of observations ranged from 17 to 99.

		Variables										
		1	2	3	4	5	6	7	8	9	10	11
Km from coast	1											
Elevation ASL	2	+										
% slope	3	.	+									
Cm microrelief	4	.	.	+								
Degrees from south	5	.	.	.	.							
Simpson species diversity	6	.	.	.	.	.						
No. species per stand	7	.	.	.	+	+	-					
% cover trees	8	.	.	.	-	.	-	-				
% cover med. & tall shrubs	9	.	.	.	.	.	.	.	-			
% cover low shrubs & herbs	10	.	.	.	.	+	.	+	-	.		
% cover mosses	11	.	.	.	.	+	-	.	.	.	.	
% cover lichens	12	.	.	.	.	.	.	.	.	-	.	.

and decreases in the later stages as the vascular cover increases. In forest habitats low shrub and herb cover and species number decreases due to an increased tree canopy and shading which was evident in more mature portions of some seres.

An inverse relationship also occurs between the Simpson Species Diversity Index and moss and tree cover. High moss cover is often associated with wet, poorly drained sites which usually have a low species diversity as well as low species richness. However, species diversity and species richness are not positively related since diversity is a measure of spatial density as well as the species number per unit area.

Sites containing tree and medium tall shrub strata are analyzed separately for relationships between biotic variables and physical characteristics (Appendix 5). Since forested and medium (> 1 m) and tall (> 2 m) shrub sites occur mainly in the southern portion of the study area, the maximum number of observations (stands) with forest characteristics is 25. The reduction of variables is due to the restrictions of forest and tall shrub species to a few sites. Again only the more meaningful relationships are discussed.

Alders are more abundant on steeper slopes and on older riparian sites which are indicated by stands with taller balsam poplar and greater balsam poplar and willow (*Salix planifolia pulchra*) ages all of which are positively correlated. Average age increase of balsam poplar is also correlated with an increase in microrelief and probably the amount of frost action with site maturity. A negative relationship is found between slope steepness and dwarf birch growth increment.

Felt-leaf willow and other willow species have greater densities and heights on more northerly exposed slopes. Simpson species diversity and white spruce, balsam poplar and willow growth increment are positively correlated which may indicate better soil nutrient conditions at some of the riparian sites or at least an environment more amenable to the growth of a greater number of species in the earlier part of the seres. A negative relationship was indicated between balsam poplar growth increment and tree age.

Species richness increases with white birch and balsam poplar age and is a normal trend during succession after disturbance on upland and riparian sites. There is a decrease in species richness which is associated with the more mature portion of these seres as measured by white spruce density and percent tree cover.

White spruce growth increment is higher at sites with a higher canopy cover which is usually produced by either white birch or balsam poplar. Medium and tall shrub cover increases with ages of white birch and balsam poplar, whereas low shrub, herb, and grass cover is higher at sites with older white spruce and lower at sites with high cover of balsam poplar and white birch (Appendix 5). It should be noted that white spruce often appeared in the shrub strata in balsam poplar and white birch forests, but there was also an increase in alder and willow densities with stand age. An inverse relationship is found between low shrub, herb and grass and lichen cover and between percent lichen cover and white birch height, balsam poplar height and white birch maximum age (Appendix 5). Negative relationships are indicated between white spruce average age and dwarf birch growth increment, the inference being that white spruce growth rate decreases with age.

Changes in riparian communities in and north of the Brooks Range are indicated by an increase in willow (*Salix glauca*) growth increment with increase in felt-leaf willow density and age. Generally, willow (*Salix* spp., *S. glauca*) growth increment is inversely related to stand age as indicated by maximum and average ages of white birch, balsam poplar and white spruce.

Changes in composition through time is noted by negative correlations between densities (number of stems/area) of white spruce and balsam poplar, and between felt-leaf willow and willow (*Salix planifolia pulchra*) (Appendix 5), which usually had higher densities during the earlier portions of riparian seres. Inverse relationships between willow density and balsam poplar and white birch height and age as well as dwarf birch average age may also be due to changes during succession.

5.7 Land Use and Disturbance Implications

Several soil categories and vegetation associations have been identified within topographic and terrain units as indicators of unstable landscapes. Only those units assessed as unstable or potentially unstable are discussed. Absence or presence of permafrost within the control section (1 m depth) of the soil is an important first criteria in making an assessment of instability on the assumption that terrain with thicker active layers is more stable than terrain with thin active layers (Table 6). Other criteria include soil texture (amount of silt), degree of horizon displacement, soil drainage, steepness of slope and presence of plant associations which indicate past disturbances.

Outwash plain terrain offers the greatest potential for problems in valleys of the Porcupine Plateau. Although the soils were usually coarse textured, thin active layers, and areas with sedge - Arctic bearberry vegetation had standing water through June. Some of the vegetation is associated with a varied microrelief as indicated by the "drunken forest" aspect of white spruce, and hence the turbic soil classification. Problems of this terrain include frost heaving and thermokarst degradation with a subsequent increase in surface water. The potential for instability problems may decrease in late summer with increased dryness. Similar problems should be expected on depressional backswamps where thin active layers and poor drainage is indicated by sedge communities (Table 6). Colluvial slopes were also found to be unstable, especially if the soil texture is silty and poorly drained or has an abundant upslope water supply. The instability is usually indicated by solifluction and slope failure evidence.

Thin active layers were also found on gentle to moderate colluvial slopes. Most of these slopes show signs of instability via solifluction and were found to be wet through most of the summer if they were north exposed. North exposure and an increase in slope tends to increase the frequency and severeness of solifluction until slope failures occur. Unstable slopes with south exposures more often support white birch vegetation with some white spruce, and had deeper active layers. Fires have increased the frequency of slope failure especially on steep (30%) topography, or where slopes have been undercut by rivers.

Problems associated with thin, wet active layers can also be predicted for some active and fossil floodplain terraces in the Southern Foothills. Most of the dwarf birch and willow vegetation of the valleys occurs on thin gleysolic soils and precautions against thermokarst will be necessary in land use planning. The dwarf birch vegetation on the higher slopes is usually associated with solifluction and thin active layers (Table 6). Any outside disturbance on these slopes during summer would probably cause accelerated downslope movement and stabilization techniques would probably be necessary to curtail slumping. The dwarf birch and heath vegetation on south exposures are assessed as being well able to sustain fire which may complicate stability problems.

Table 6 . Integration of landscape and terrain features with soil and vegetation type according to physiographic province. Active layer depths are used to help centre information towards impact assessment.

MAJOR LANDSCAPE FEATURE	TERRAIN TYPE	TERRAIN SUB-TYPE & TOPOGRAPHY	SOIL	VEGETATION	ACTIVE LAYER DEPTH
PORCUPINE PLATEAU Valleys	Active Floodplain	Terraces and Pointbars	Cumulic Regosol	Populus balsamifera/Arctostaphylos rubra - Pyrola rotundifolia Picea glauca/Hylocomium splendens	>1 m
	Fossil Floodplain	Depressional Backswamps	Gleyed Static Cryosol	Carex bigelowii - Carex rariflora - Carex saxitilus laxa	<1 m
	Outwash Plain	Gentle Slopes to Level	Regosolic Turbic Cryosol	Dryas integrifolia integrifolia/Tomenthypnum nitens w/Picea glauca Carex membranacea - Arctostaphylos rubra/Tomenthypnum nitens	<1 m
Slopes	Alpine & Subalpine Colluvium	Gentle to Moderate Slopes	Regosolic Turbic Cryosol	Salix glauca acutifolia - Ledum groenlandicum - Vaccinium vitis-idaea minus Betula nana exilis/Hylocomium splendens	<1 m
		Steep Slopes (with old slope failures)	Regosolic Turbic Cryosol	Betula papyrifera/Hylocomium splendens	>1 m
		Steep Slopes	Regosolic Turbic Cryosol	Salix glauca acutifolia/Dryas octopetala octopetala	>1 m
Ridges & Peaks	Bedrock	Sharp Ridges & Peaks	Lithic Degraded Eutric Brunisol	Vaccinium vitis-idaea minus - Vaccinium uliginosum alpinum w/Picea glauca	>1 m
SOUTHERN FOOTHILLS Valleys	Active Floodplain	Terraces	Gleysolic Static Cumulic Cryosol	Salix glauca acutifolia/Betula nana exilis - Carex vaginata	<1 m
	Fossil Floodplain	Terraces	Gleysolic Static Cryosol	Betula nana exilis/Hylocomium splendens w/Eriophorum vaginatum	<1 m
	Lateral & End Moraines	Gentle Slopes	Gleysolic Static Cryosol	Betula nana exilis - Vaccinium uliginosum alpinum	<1 m
Slopes	Alpine - Subalpine Colluvium	Gentle Slopes	Gleysolic Turbic Cryosol	Betula nana exilis - Vaccinium uliginosum Salix reticulata/Hylocomium splendens	<1 m
		Steep Slopes	Regosolic Turbic Cryosol	Betula nana exilis - Vaccinium uliginosum/Hylocomium splendens	<1 m
	Hummocky Moraine	Solifluction Terraces	Gleysolic Turbic Cryosol	Salix planifolia pulchra /Carex bigelowii/Hylocomium splendens Betula nana exilis/Hylocomium splendens Cassiope tetragona - Carex bigelowii	<1 m
Ridges & Peaks	Bedrock	Blockfields & Fellfields	Regosol	Dryas octopetala octopetala - Minuartia rossii Salix reticulata reticulata - Carex saxitilus laxa	>1 m
BROOKS RANGE Valleys	Active Floodplains	Low Terraces	Regosol	Salix alaxensis alaxensis - Salix planifolia pulchra/Dryas integrifolia integrifolia	>1 m
	Fossil Floodplains	Middle Terraces	Lithic Regosol - Lithic Alpine Regosol	Salix alaxensis alaxensis/Hylocomium splendens Salix reticulata reticulata - Carex vaginata/Hylocomium splendens	>1 m
		Middle Terraces with Silt Deposition	Lithic Alpine Eutric Brunisol	Salix alaxensis alaxensis/Arctostaphylos rubra - Pyrola rotundifolia grandiflora	>1 m
		High Terraces	Lithic Regosol	Arctostaphylos rubra - Pyrola rotundifolia grandiflora w/Populus balsamifera	$\lessgtr$1 m
		Depressional Backswamps	Gleyed Static Cryosol	Salix reticulata reticulata - Dryas integrifolia integrifolia/Tomenthypnum nitens Dryas integrifolia integrifolia/Tomenthypnum nitens	<1 m
	Alluvial Fan Deposits	Moderate Slopes	Mesic & Humic Organo Cryosols	Dryas integrifolia integrifolia - Carex misandra/Rhytidium rugosum Dryas integrifolia - Cassiope tetragona	<1 m
	Lateral Moraine Complex	Gentle Slopes	Brunisolic Turbic Cryosol	Dryas integrifolia - Carex bigelowii	
Slopes & Ridges	Alpine and Subalpine Colluvium	Solifluction Terraces	Gleysolic Turbic Cryosol	Dryas integrifolia integrifolia/Tomenthypnum nitens	<1 m
		Moderate - Steep Slopes with Fine Material	Redzina	Betula nana exilis - Vaccinium uliginosum alpinum Dryas integrifolia - Cassiope tetragona Dryas integrifolia - Carex scirpoidea/Tomenthypnum nitens	>1 m
		Rocky Slopes	Lithic Regosol	Salix reticulata/Carex macrochaeta/Rhacomitrium lanuginosum	>1 m
		Slope Failure	Regosol	Salix planifolia pulchra/S.reticulata reticulata/Tomenthypnum nitens Salix glauca acutifolia/Arctostaphylos rubra - Vaccinium uliginosum	>1 m
ARCTIC FOOTHILLS Rolling Hills (waxing and constant slopes)	Rounded Silt-Mantled Slopes	Gentle to Moderate Slope	Gleysolic Static Cryosol	Salix planifolia pulchra/Eriophorum vaginatum Carex bigelowii/Hylocomium splendens Salix reticulata - Dryas integrifolia	<1 m
	Rounded Silt-Mantled Slopes	Steep Slopes	Regosolic Turbic Cryosol	Vaccinium uliginosum alpinum - Vaccinium vitis-idaea minus Carex membranacea /Hylocomium splendens Salix reticulata reticulata - Ledum palustre decumbens - Poa alpina	<1 m
	Rounded Silt-Mantled Slopes	Slope Base (lower debris slope)	Mesic Organo Cryosol	Salix planifolia pulchra - S.glauca glauca/Carex aquatilis	<1 m
Valleys	Fossil Floodplain	High Stream Terrace	Gleysolic Turbic Cryosol	Salix alaxensis alaxensis - Hylocomium splendens S.alaxensis alaxensis - S.planifolia pulchra/Dryas integrifolia	>1 m
ARCTIC COASTAL PLAIN Peidmont Plateau	Active Floodplain	Middle Terrace	Cumulic Regosol	Salix planifolia pulchra/Petasites frigidus Salix ovalifolia ovalifolia - Dryas integrifolia - Arctagrostis latifolia	>1 m
	Fossil Floodplain	High Terrace	Gleysolic Turbic or Static Cryosol	Dryas integrifolia - Carex bigelowii	<1 m
		Slope Base (lower debris slope)	Fibric Organo Cryosol	Betula nana exilis - Carex aquatilis - C. bigelowii	$\lessgtr$1 m
		Backswamp	Lithic Static Cryosol	Cassiope tetragona - Carex bigelowii - Ledum palustre decumbens	<1 m
	Fossil Lake Basin	Level to Depressional (with frost featured topography)	Gleysolic Static Cryosol	Salix reticulata - Carex bigelowii/Tomenthypnum nitens	<1 m
		Level to Depressional	Organo Cryosols	Salix planifolia pulchra - Carex aquatilis Salix planifolia pulchra - Carex bigelowii	<1 m
	Arctic Coastal Plain	Level to Slight Slopes	Organo Cryosols	Carex bigelowii - C. rariflora - C. saxitilus laxa Salix planifolia pulchra - Carex bigelowii - Eriophorum vaginatum	<1 m
	Silt-Mantled Slopes & Moraine Sediment	Gentle Slopes	Gleysolic Turbic Cryosols	Salix planifolia pulchra/Carex bigelowii/Hylocomium splendens - Aulocomnium turgidum Salix reticulata reticulata/Carex bigelowii/Tomenthypnum nitens Salix planifolia pulchra - Carex bigelowii - Carex misandra	<1 m
		Polygonal or Frost Hummocked	Organo Cryosols	Salix ovalifolia ovalifolia - Dryas integrifolia - Carex bigelowii Salix lanata richardsonii - Carex vaginata/Hylocomium splendens Salix planifolia pulchra - Carex bigelowii	<1 m
	Alluvial Fan Deposits	Level to Gently Sloping	Cumulic Regosol	Salix reticulata - Dryas integrifolia/ Tomenthypnum nitens Dryas integrifolia - Cassiope tetragona Carex scirpoidea - Vaccinium uliginosum Cassiope tetragona - Carex bigelowii - Ledum palustre decumbens	$\lessgtr$1 m

Some high terraces with continuous vegetation (*Pyrola rotundifolia grandiflora* dominance) and backswamps in the Brooks Range contained permafrost within 1 m of the surface. Problems associated here are similar to those discussed earlier for similar terrain types and include surface degradation (thermokarst) and subsequent ponding. Alluvial fan terrain may occur on slopes, which with thin active layers may increase the potential for instability. The Dryas, sedge and moss association usually occurs on the most unstable portion of the terrain that was sampled with thinnest active layers and wettest conditions (Table 6). Steeper slopes (> 15%) with fine textured soils are naturally unstable as indicated by solifluction lobes. These slopes are associated with dwarf birch shrub vegetation on south exposures and Dryas alpine meadows with Lapland cassiope or sedge on north exposures.

Slope failures of various magnitude are also common on the steeper slopes, especially those with shale substrata which receive downslope drainage from snow fields. Steep side canyons also exhibit unstable conditions and during intensive rain storms carry a high boulder and silt load into the main valleys. Both slope failure and recent alluvial depositions contain open willow (*Salix planifolia pulchra* or *S. alaxensis alaxensis*) vegetation and are found on Regosol or Lithic Regosol soils (Table 6). The amount of plant cover usually varied directly with severity and time since disturbance.

Thin active layers are more evident in the Arctic Foothills and rounded silt-mantled slope terrain is judged to be generally unstable, especially on the steeper (> 10%) north exposures where large solifluction lobes were common. The instability of the soil is indicated by the turbic description, but high percent ground cover of the vegetation suggests that soil movement is relatively slow. Some slumping is present however, where areas are undercut by streams and failures have occurred on steep (20%) slopes nearer the mountains. Solifluction lobed topography is also thought to be increased by the passage of caribou on steep slopes. Wet slope bases are also given potential problem status because of thin active layers, frost hummock micro-topography and wet organic soils. Fossil and active floodplains are assessed as the most stable portions of the foothills with regards to permafrost problems. However permafrost was found within some of the fossil floodplains, and both of those areas can be unstable during intensive rain storms.

Only active floodplain terrain was found to have active layers > 1 m within the Arctic Coastal Plain. Hence, the potential problems of degradation and slumping due to the melting of permafrost are widespread. This results in the establishment of ponds which increase in size with melt-out of the perimeters. The length of time necessary for natural restoration to original conditions is not known.

The churning of soil, due to frost action, is also common in silt-mantled areas as indicated by frost hummocks and polygonal topography and turbic soil type (Table 5). Areas with relatively rapid turnover contained more Dryas - dwarf willow communities. Slower soil movement is reflected by more continuous and dense ground cover with more willow (*Salix reticulata, S. planifolia pulchra, S. lanata richardsonii*) on the raised areas and sedges and moss in the depressions with Dryas fairly abundant on both (Table 6). Disturbance problems may become more severe where there are slopes. Changes in stream direction as reflected by slumping and exposure of ice-rich permafrost are fairly common on the Arctic Coastal Plain and stream and river banks (fossil floodplain interface) which are therefore classed as unstable or potentially unstable especially where there has been deep incision. Although most areas of the coastal plain are wet and poorly drained during summer, certain deformed till areas on river bluffs and hilltops exhibited xeric conditions with open *Dryas integrifolia - Carex misandra - Salix reticulata* associations. The extremes of water availability (hydric and xeric conditions) on the Arctic Coastal Plain may cause problems with vegetative reclamation programs after land use.

6.0 DISCUSSION

The completeness of the vegetation description is dependent on sampling intensity since only quantitative data are used in establishing the vegetation associations. It is believed on the basis of air and ground reconnaissance that most of the major types of vegetation and soils within the study area are represented. However the range of vegetation and soils could possibly be increased by sampling areas outside the study site locations (Fig. 1). Additional associations could no doubt be identified within the study area, but hopefully these would fit into the classification framework of major types presented here.

The major vegetation types are easier to use than associations to make comparisons with other studies since they represent a more general category. Vegetation type, as it has been most often used, is equivalent to the formation, or alliance classes of the more formal phytosociological classification systems (Shimwell, 1971). Nomenclature of these units by other workers varies considerably, since generic epithets, common names and topographic and physiographic characteristics have been used (Britton, 1957; Johnson *et al.*, 1966). Part of the problem in Arctic areas apparently results from the broad connotation of tundra, which has been used to describe a vast portion of the vegetation (Beschel, 1969). Shacklett (1963) recognized the difficulty of relating vegetation to the more traditional controlling environmental factors which seem to have credence for temperate areas. The flora of Arctic areas has been recognized as being relatively low in diversity (species numbers), but this does not mean that the vegetation mosaic is not complex, especially when the range of types and the combinations of species, including cryptogams are considered (Bliss, 1962; Beschel, 1969).

6.1 Vegetation

The 309 vascular, 68 moss and 56 lichen species do not appear to be an excessive number considering the size of the area. Spetzman (1959) found 439 vascular species and subspecies during a six year field study in the coastal plain, foothills and small section of the Brooks Range. Johnson *et al.* (1966) found about 300 species of vascular plants in the Ogotoruk Creek - Cape Thompson area of Alaska, while Britton (1957) listed 250 species near Umiat. Rastorfer *et al.* (1973) compiled a list of 81 bryophyte taxa at Prudhoe Bay. A similar study in the northern Yukon and adjacent portion of the Northwest Territories recorded more than 320 vascular and about 70 each of moss and lichen species (Hettinger *et al.*, 1973). Lambert (1968) identified 183 vascular, 136 mosses and 99 lichens in an intensive study at Canoe and Trout Lakes, Northwest Territories. Welsh and Rigby (1971) listed about 280 vascular plants during an extensive survey in the northern Yukon Territory. The number of species per stand (averages of 40 to 43) appears typical for low Arctic regions. Hanson (1953) found 32 vascular species in dwarf birch type vegetation and 26 in dwarf birch - heath lichen types. Areas in the northern Yukon were also comparable, with a maximum of 60 species, including cryptogams, per stand (Hettinger *et al.*, 1973).

The *Salix ovalifolia ovalifolia/Dryas integrifolia integrifolia - Arctagrostis latifolia latifolia* and *Dryas integrifolia integrifolia - Carex bigelowii* associations from fossil floodplains of the Canning and Sagavanirktok rivers of the Arctic Coastal Plain represent two botanically unique stands which are within 1 km (0.6 mi.) of the pipeline route. The *Salix ovalifolia*

ovalifolia/Dryas integrifolia integrifolia - Carex bigelowii association on rounded silt-mantled slope terrain near the Kongakut River is about 5 km from the routing. However, a collection of *Salix reptans* which previously has only been described in Eurasia (Argus, 1973), was made in this vicinity which may increase the botanical significance of the area.

Elsewhere, two botanically unique communities include a *Dryas integrifolia integrifolia/Tomenthypnum nitens* association on a stable backswamp depression about 2 km from the present routing in the Marshfork of the Canning River, and a well developed white spruce forest (*Picea glauca/Hylocomium splendens* association) in the lower portion of Monument Creek within 3 km (1.8 mi.) of the present route alignment. It is possible that the status of the stands within the botanically unique category may change as more intensive sampling is done near these sites.

Wet Sedge Meadows (Spetzman, 1959) have been variously described as Marsh and Wet Tundra (Porsild, 1951), Wet Sedge community (Bliss, 1956), *Carex aquatilis* Marsh (Britton, 1957) and *Eriophorum - Carex* Wet Meadow (Johnson *et al.*, 1966). Sedges are the character species, both in physiognomy and abundance in the associations within this type, but dwarf willow occurs as a co-dominant in a number of communities in the Coastal Plain and adjacent foothills. Although the vegetation type is easy to identify and appears homogeneous, eight different associations were delineated. The dominance of *Carex aquatalis* and *C. bigelowii* in these communities on the coastal plain and foothills of Alaska appears to be well established

(Britton, 1957), but other sedges are also important. The co-dominance of cotton grass and other sedges has also been noted for the vegetation type (Johnson *et al.*, 1966), but these seem to appear more frequently in the foothills and where tussock tundra vegetation type was more frequent. Britton (1957) noted that cotton grass appears with other sedges and grasses without prominent tussock formation along the coast. There appears to be a tendency to overestimate the cover and dominance of cotton grass when it has a tussock physiognomy (Corns, 1972; Hettinger *et al.*, 1973). The wet sedge (*Carex bigelowii - C. saxitilus laxa - C. rariflora*) association in the Porcupine Plateau of Alaska is similar to vegetation on Fossil Lake Bed terrain in the Old Crow Flats and depressional terraces in the Richardson Mountains. *Carex microchaeta* was apparently more prominent in the Yukon (Hettinger *et al.*, 1973).

Associations with dwarf willow (*Salix planifolia pulchra, S. ovalifolia ovalifolia, S. reticulata reticulata*) are similar to the *Carex aquatilis* marsh type although cotton grass (*Eriophorum angustifolium*) and dwarf birch (*Betula nana exilis*) were also dominant. Other studies with similar wet sedge phases include the Calcareous Bog Meadow of Drew and Shanks (1965) in the Firth River area of the Yukon, and *Carex microcheata - Salix pulchra* vegetation in the Arctic Foothills area of the northern Yukon (Hettinger *et al.*, 1973).

Tussock tundra has been widely used to describe vegetation formed by the physiognomic dominance of cotton grass. Other descriptive terms applied to the vegetation type include niggerhead tundra (Porsild, 1951), Heath Tussock (Bliss, 1956) and *Eriophorum* Tussock (Johnson *et al.*, 1966). The three associations identified for the Arctic Foothills also contained low willows (*Salix planifolia pulchra*, *S. reticulata reticulata*) as dominant species with cotton grass (*Eriophorum vaginatum vaginatum*), and in this respect were similar to the vegetation of the Arctic Foothills in the northern Yukon (Hettinger *et al.*, 1973). The results are also comparable to those discussed by Britton (1957) for the Brooks Range and Arctic Foothills as a number of sedges, including *Carex bigelowii*, were found to be prominent. The cotton grass was sometimes listed as *Eriophorum vaginatum spissum* however, but in the present study was not always identified to subspecies. A comparable Upland Tussock Tundra type was described by Drew and Shanks (1965), but dwarf birch, Labrador tea and netted willow were dominant and hence the type is probably more similar to that described by Britton (1957) as a Dwarf Shrub Heath type. The variation in associated species in tussock types has probably caused the diversity of nomenclature for the vegetation (Johnson *et al.*, 1966). The heath sedge-tussock tundra associations of the coastal plain are similar to the Tussock Tundra type but cotton grass is much less abundant while heaths (lingonberry, Lapland cassiope and alpine blueberry) are more prominent than found in the previous study. Similarities exist between this type and Corns' (1972) Sedge-Heath sub-group and the *Cassiope tetragona* group of Lambert (1968). The dwarf shrub heath type was found to incorporate Cotton grass Tussock types of Britton (1957), but they probably would fit into this major type since heaths and dwarf birch were also found to be characteristic species.

Sedge (*Carex bigelowii*) meadows with scattered willow (*Salix planifolia pulchra*) vegetation are deemed a separate type due to the taller nature of willow and hence different physiognomy. A type similar in physiognomy was identified in wet flat areas of the Peel Plateau, but heaths (crowberry and lingonberry) replaced willow as the shrub and *Sphagnum girgensohnii* instead of *Hylocomium splendens* formed a dense ground cover (Hettinger *et al.*, 1973).

Alpine sedge meadows of *Carex membranacea, C. scirpoides, C. misandra* and *Dryas integrifolia integrifolia* are differentiated from wet sedge meadows on the basis of species composition as well as elevational distribution. The type appears similar to Hanson's (1953) Alpine-Sedge - Alpine Dryas type but contrasts are apparent with different dominant species (*Carex lugens* and *Dryas octopetala*). Alpine Sedge communities of *Carex microchaeta* with *Eriophorum vaginatum vaginatum* and *Sphagnum girgensohnii* (Hettinger *et al.*, 1973), and *Carex montanensis* and *Salix pulchra* (Lambert, 1968) have also been described for the Richardson mountains, which have some affinities with the Alpine Tundra (*Kobresia* spp., *Carex kravsei*) types described by Drew and Shanks (1965) in the British mountains.

The increase in shrub (*Salix* spp.) abundance is the major criterion in distinguishing the dwarf or low shrub sedge meadow type which describe vegetation from both the Arctic Foothills and the Arctic Coastal Plain. A similar vegetation was described for the Richardson and British Mountains and coastal plain areas of the Yukon, but *Betula glandulosa* and *Sphagnum girgensohnii* were used to characterize one of the associations (Hettinger *et al.*, 1973). The Peaty High Centre Polygon vegetation class described by Drew and Shanks (1965) also appears to be similar and is comparable to the *Salicetosum reticulatae* association designated by Lambert (1968). Related vegetation in the higher portions of the Southern Foothills was placed within the alpine open dwarf shrub sedge meadow type. A similar community was described by Lambert (1968) as a *Salicetosum phlebophyllae* association with *Hierochloe alpina* and *Dryas octopetala* as common dominant species.

Several vegetation types are distinguished by mountain avens dominance, but since *Dryas integrifolia* is quite ubiquitus the vegetation types are separated on the basis of co-dominance components and physiognomic conditions. Similar vegetation to Alpine Dryas - Sedge Meadows was discussed by Britton (1957) for the Brooks Range and by Drew and Shanks (1965) in the British mountains. Vegetation with less sedge but with a grassland type physiognomy is placed in alpine-subalpine Dryas meadows and barrens categories, depending on the amount of ground cover. A number of associations described for the British Mountains with *Dryas octopetala* appear similar (Hettinger *et al.*, 1973), as does Drew and Shanks' (1965) Dryas - Lichen Gravel Terrace type which was characterized by a dominance of *Dryas integrifolia* and *Carex scirpoidea*.

The combination of mountain avens and shrubs as dominant species is the distinguishing feature of several vegetation types. The dwarf shrub - Dryas meadow vegetation appears related to a number of associations which were described mostly in the British Mountains, Arctic Foothills and Arctic Coastal Plain provinces (Hettinger *et al.*, 1973). *Dryas integrifolia integrifolia* and low willows are common to both studies but *Salix ovalifolia ovalifolia* and *S. glauca glauca* were found to be dominant in Alaska and *S. phlebophylla* was more abundant at the Yukon sites with *S. integrifolia integrifolia* common to both. Similar types of vegetation are discussed by Britton (1957) for the Arctic Foothills Province of Alaska but heaths appear to have been more prominent. The *Lupino-Dryadetum alaskanensis* association described by Lambert (1968) for the norther Richardson Mountains also appears to have similar characteristics. The alpine heath Dryas meadow type of the Brooks Range has affinities with vegetation described for the Arctic Foothills by Britton (1957) and Hettinger *et al.* (1973).

The occurrence and dominance of heath shrubs distinguishes a large unit of vegetation which names the major types according to various combinations. Low heath shrub vegetation with *Betula nana exilis* of the Porcupine Plateau and Southern Foothills is similar to types found in the Peel Plateau, Porcupine Plateau and Old Crow Flats in the Yukon (Hettinger *et al.*, 1973). *Rubus chamaemorus* and *Betula glandulosa* were apparently more abundant in the Yukon communities, however. Similar vegetation, but with taller willows (*Salix glauca acutifolia*) characterizes the low heath-willow shrub type which appears most similar to medium Shrub and Dwarf Shrub-Heath types described by Corns (1972), although *Alnus crispa* was not important in the Alaskan vegetation type. Lambert (1968) makes reference to a *Vaccinio-Betuletum glandulosae* association which appears to have compositional affinities. This association was given a probable climax status for the vegetation on slopes in the northern Richardson mountains. The dwarf heath lichen tundra type is most similar to some of the vegetation in Churchill's (1955) Frost-Scar Collective Type, but more open vegetation occurs in the open dwarf shrub-heath barrens of the Arctic Foothills which appears to have affinities with coastal plain vegetation in the Yukon (Hettinger *et al.*, 1973). However, heaths are apparently not as dominant in this type further east. The dwarf heath type with white spruce appears to be a common community in areas across the Yukon and Alaska and extends northward into the lower portion of the mountains. Identifications of similar types were made in the Richardson Mountains which correlate with White Spruce Woodland Terrace and Solifluction Fan with Scattered Spruce types of Drew and Shanks (1965), although sedges appear to have been more dominant in the latter study. Vegetation with a similar physiognomy and a heath understory was described for wet areas of the Peel Plateau with black spruce (*Picea mariana*) instead of white spruce (Hettinger *et al.*, 1973). A similar type is illustrated for an upland treeline area in the Yukon - Tanana area of Alaska (Johnson and Vogel, 1966).

Taller willow (*Salix glauca acutifolia*) with heaths in the lower areas of the Porcupine Plateau is most similar to a type described by Lambert (1968) with *Salix pulchra, Betula glandulosa* and *Vaccinium uliginosum* in the northern Richardsons. Lower willow (*Salix glauca acutifolia*) of the Porcupine Plateau and Southern Foothills shows similarities towards

Salix glauca callicarpaea and Moss Frost Scar communities of the Yukon Arctic Coastal Plain (Hettinger *et al.*, 1973) and *Salix chamissonis* communities in the Richardson mountains (Lambert, 1968) which were associated with late-melting snow banks.

The low and dwarf willow shrub vegetation type of the Brooks Range is quite varied with associations characterized by *Salix reticulata reticulata*, *S. glauca acutifolia* and *S. planifolia pulchra*. Similar types were described in the Old Crow Range, Richardson Mountains and Arctic Foothills of the Yukon, but *Salix phlebophylla* was also found to be a dominant of some communities (Hettinger *et al.*, 1973). Alpine dwarf shrub-lichen fellfields with *Salix reticulata* are most similar to a *Salix phlebophylla* community that was found on hilltops in the Coastal Plain of the Yukon. The low birch shrub vegetation which is well distributed through the lower valleys of the Brooks Range is comparable to Chruchill's (1955) Heath Sub-type of the Arctic Foothills although heaths appear to be less common in the Brooks Range.

Riparian willow shrub embodies a large group of vegetation types. Either *Salix alaxensis alaxensis* or *Salix planifolia pulchra* is the dominant species even though sites ranged from the southern Brooks Range to the coastal plain. Similar communities have been reported in the Northern Yukon where *Salix glauca acutifolia* and *Salix planifolia pulchra* were dominant in the mountainous areas, whereas co-dominance of both alder and willow was more frequent in riparian sites from the eastern coastal plain (Hettinger *et al.*, 1973). Various *Salix* and *Alnus* types are discussed by Britton (1957) and affinities appear possible with his *Salix glauca* and *S. pulchra* dominated vegetation. Similar types were identified in the Mackenzie Delta Region, but *Salix lanata richardsonii* was a frequent dominant and alder also appears fairly common (Corns, 1972). Bliss and Cantlon (1957) describe alluvial communities near the Colville River of Alaska which appear very similar to the *Salix alaxensis alaxensis* associations in the Brooks Range. Some variation in understory species probably relates to the stage of the succession, although different types of habitats may be included. Riparian sites beyond or above tall shrub distribution were described by Spetzman (1959) as "grassy stream margin" vegetation and occur frequently in the coastal plain where an abundance horsetail and herbs (*Saxifraga* ssp., *Aconitum delphinifolium*, *Dodecatheon frigidum*) reflect a similarity to the low shrub - sedge meadow type from the present study.

The riparian shrub and open forest type with balsam poplar shows some affinities to vegetation at upper elevations of the Porcupine Plateau in the Northern Yukon. Both communities contained a co-dominance of tall shrubs (*Salix* spp.) and balsam poplar. Alder was not associated with the Alaskan types except in the Porcupine Plateau. Other common important species include *Calamagrostis canadensis* and *Epilobium latifolium*. The Arctic bearberry-herb with balsam poplar type is less similar since few tall shrubs were found to be abundant. The open character of the stand and dominance of *Arctostaphylos rubra* and *Pyrola rotundifolia* may indicate an older phase of riparian succession.

The last two vegetation types reflect the northern limit of balsam poplar in the sparseness of the community within the Northern Foothills. The formation of this community only in certain confined habitats may make it botanically unique. Balsam poplar (cottonwood) communities are listed for the Yukon Flats of Alaska, but appear to be very minor communities and were usually found mixed with white spruce on alluvium (Johnson and Vogel, 1966). This vegetation is probably similar to the more closed balsam poplar forest type from the Porcupine Plateau in Alaska and Balsam Poplar - Alder vegetation class of riparian areas of the Peel and Porcupine Plateaus in the Northwest Territories and Yukon (Hettinger *et al.*, 1973).

The white birch forest type shows a close relationship to a White Birch - Alder association that was described for the Peel Plateau with lingonberry and smaller white spruce as other common species. Some similarities also exist with vegetation form the Porcupine Plateau but *Salix glauca acutifolia* was a co-dominant species and *Hylocomium splendens* and *Rosa acicularis* were more abundant (Hettinger *et al.*, 1973). Similar white birch stands were described in the Yukon Flats on upland areas, but only some of the stands contained alder, as willow appeared to be more constant. Again white spruce was usually represented in the lower d.b.h. size classes, and the vegetation type was often associated with slope failure (Johnson and Vogel, 1966). Aspen (*Populus tremuloides*) was also found within some of the white birch forests in the Yukon Flats, but occur only as occasional trees in restricted habitats further north.

The white spruce forest type encompasses a common association (*Picea glauca/Hylocomium splendens*) that has affinities with types found in the Porcupine and Peel plateaus (Hettinger *et al.*, 1973) and the Yukon Flats in Alaska (Johnson and Vogel, 1966). The latter study listed willow as a dominant for some of the stands, but an illustration with white spruce on alluvium has a similar physiognomy. Variation in associated species was noted for alluvial sites with latitudinal increase with Arctic bearberry and sedge (*Carex bigelowii*) being more dominant in the southern Brooks Range than in the Porcupine Plateau. The *Populus/Salix Shepherdia* association within the White spruce - Fir type of LaRoi (1967) also exhibits similarities to this vegetation type since willow (*Salix glauca acutifolia*) and balsam poplar were important species in the more southern portions of the study area. The Spruce Forest Terrace category of Drew and Shanks (1965) with white spruce, felt-leaf willow, balsam poplar and feathermoss vegetation has some affinities to the type, but may be more similar to more open phases of white spruce near ridge tops or on moraine since there was a high number of associated heaths. Variation composition in the vegetation type increases with distance between the areas, but differences also occur between upland slope and alluvium site locations with *Pyrola rotundifolia*, *Linnaea borealis* and grasses (*Calamagrostis* spp.), and *Salix* spp. being more common at the two different landscape positions. Similar associations with black spruce and *Hylocomium splendens* were found as far east as the western portion of the Porcupine Plateau near the Old Crow Range in the Yukon, but these were not found in Alaska. White spruce appeared to assume the ecological role of black spruce in the southern portion of the study area where it was found in wet muskeg areas.

The forest and open forest vegetation types fit into the forest and barren section of the Boreal Forest Region as presented for Canada by Rowe (1959). This includes a fairly abundant distribution of *Picea glauca* and *Betula papyrifera* and only local abundance of *Populus balsamifera* and *P. tremuloides*. Forest vegetation extends into the lower and southern valleys of the Brooks Range, but becomes very disjunct further north as tundra vegetation becomes more widespread. This transition between vegetation types is characterized by the dominance of medium tall and low shrub vegetation (Beschel, 1969).

6.2 Soils

Soil development is weak or generally retarded in the surveyed area. Best development occurs on rapidly drained alpine and forested ridges in the southern part of the study area where Eutric Brunisols occur on calcareous bedrock ridges. Similar developmental conditions occur on similar terrain units in the northern Yukon (Hettinger *et al.*, 1973). The characteristic brown colored Bm of these Alpine Brunisols may develop under acidic or calcareous conditions, but was usually found on calcareous materials. In northern Alaska the Arctic Brown is the dominant well drained soil (Tedrow and Hills, 1955). In this study, few well drained sites were sampled in the foothills and coastal plain so that the Arctic Brown soils (Brunisols) were not encountered and comparisons cannot be made with results of Tedrow and Hill (1955) or Brown (1969a). Brown (1969a) found several podzol-like profiles in the Okpilak and Anaktuvik valleys which may be similar to Canadian Degraded or Dystric Brunisols. Other comparable soils may be the Alpine Rendzina (Drew and Shanks, 1965), Rendzina (Lambert, 1968; Ugolini and Tedrow, 1963) and Cryumbrepts (Soil Survey Staff, 1960) all of which have developed on calcareous materials.

Cryosols are the most extensive soils, occurring on all types except some well and rapidly drained areas. They are widespread on the Arctic Coastal Plain and Arctic Foothills and are common in the Southern Foothills region as well. The Gleyosolic Turbic Cryosol subgroups predominate in all these regions, indicating that the dominant soil forming process is that of frost action and gleization in an imperfect to poorly drained substrate.

The Gleysolic Turbic Cryosols are similar to the Meadow and Upland Tundra soils of Tedrow and Cantlon (1958) in northern Alaska. These soils are commonly found in combination with non-sorted stripes (solifluction slopes) with low shrub tundra vegetation and non-sorted circles (earth hummocks) with low shrub sedge meadows. Drew and Shanks (1965) have described similar soils from the Upper Firth River Valley and classified them as Low Humic Gley, Upland and Meadow Tundra. These soils may also be similar to the Tundra Moss and Tundra Ranker soils of Lambert (1968) in the Yukon and to the Orthic or Cryaqueptic Cryaquent of the Soil Survey Staff (1960) or Pergelic Cryaquepts (Soil Survey Staff, 1967) in the 7th Approximation System. Pergelic Cryaquepts have also been described by Allan *et al.* (1968) in Alaska.

Organo Cryosols are common in the Arctic Coastal Plain region under poorly drained conditions and wet sedge meadow vegetation. These soils are saturated throughout the growing season so that decomposition of dying vegetation is retarded to the point when accumulation rates exceed decomposition rates. These soils compare to the Bog and Half Bog of Tedrow and Cantlon (1958), Bog meadow and Strangmoor of Drew and Shanks (1965), Sub-Aquatic peat forming and Semi-terrestrial Peat Soils of Lambert (1968) and Histobols of the Soil Survey Staff (1960). Those soils with mineral horizons under more then 40 cm of organic may be compared to the Histic Dergelic Cryaquetps descibed by Allan *et al.* (1968).

The Static Cryosol Great Group is most common on imperfectly to poorly drained fossil floodplains, where the organic horizon is not thick enough to meet the 40 cm requirement of Organo Cryosols. The Gleysolic Subgroup is the most common one associated with fossil floodplains. Again, the comparable soils elsewhere are the Meadow and Upland Tundra (Tedrow and Cantlon, 1958 and Drew and Shanks, 1965), Tundra Moss and Tundra Ranker (Lambert, 1968) and Histic Pergelic Cryaquepts (Allan *et al.*, 1968).

Regosols are most common in the Brooks Range and on active floodplains where rapid drainage in coarse materials retards development. Some of these soils may integrade into weak Brunisols (Arctic Brown).

6.3 Successional Trends

Development of stable self-perpetuating or climax communities from either open water or bare land has been traditionally accepted as a conventional process for more temperate ecosystems. Events leading to climax communities, as well as the identification of climax in the tradional sense, have been questioned for the northern boreal forest and especially for regions of arctic tundra (Churchill and Hanson, 1958). Drury (1956) was of the opinion that traditional concepts could be applied to at least the forested portion of the forest-tundra transition zone although some seres were indicated as multi-directional.

Disturbances, including slumping, fire, alluvial aggradation and degradation along with environmental differences, contribute to the vegetation heterogeneity of the Boreal forest (Rowe and Scotter, 1973). Fire has apparently been a widespread and frequent feature in the northern forested areas of both Canada and Alaska (Lutz, 1956; Barney, 1971; Rowe and Scotter, 1973). Successional trends after fire have been discussed in terms of black or white spruce seres which have been further differentiated on the basis of site characteristics. Black spruce seres usually occur in wetter sites of the lower valleys, and fire history plus moisture gradients usually have increased the vegetation mosaic (Quirk and Sykes, 1971).

White spruce appears to assume the role of black spruce in the poorly drained areas of the Porcupine Plateau and was the only conifer tree species found in the study area.

Seres involving white birch and white spruce on upland slopes in the Porcupine Plateau appear similar to those found in a number of areas in the Northwest Territories (Reid, 1974; Zoltai and Pettapiece, 1973). White birch may establish more quickly after fire further south but establishment varies with site conditions (Hettinger *et al.*, 1973). Aspen and white birch appear to have similar successional roles in the interior portion of Alaska as both tend to decrease in abundance at about 100 years (Lutz, 1956). Canada bluestem, prickly rose, twinflower and a number of wintergreen species appear as common ground cover components throughout much of the sere. The establishment of white spruce with a dense feathermoss understory has been given climax status. Willow and alder are also reported as associates in the sere, but are probably more common in more mesic (northerly exposured) sites. The decrease in tree canopy may continue on south exposures or on ridges with an increase in Arctic bearberry and lichen species, but these sites may be of a different sere with reduced white birch importance.

Stability of the climax stands seems to increase with age, and fires may be necessary to initiate slope failures. Undercutting of slope bases by rivers was also observed be an important factor in instigating slumps in certain areas. The development of nearly pure conifer forests at about 150 years after establishment appears to be a common feature of this sere (Hettinger *et al.*, 1973; Zoltai and Pettapiece, 1973). Unpublished fire statistics for Northeastern Alaska indicate that only an average of 2315 acres/year have burned near or within the study area since 1957 (U.S. Bureau of Land Management, Anchorage). All of the fires were started by lightning except for small fires near Arctic Village and the Arctic Foothills. Most of the fires have been in the forested portions of the study area (Sheenjek and Coleen rivers) but two 5 acre fires were reported north of the Brooks Range. The largest fire burned 25,000 acres in the upper drainages of the Yukon Flats in 1958.

Succession after alluvial degradation or aggradation was similar along rivers of the Porcupine Plateau and the southern Brooks Range, having a stage dominated by balsam poplar with associated willows. Alder was common with balsam poplar in the more southern section of the study area. White spruce forest with a dense moss ground cover, usually of feathermoss, was identified as the climax community. Similar communities of the sere have been identified in a number of areas of the Boreal forest of Alaska (Lutz, 1956; Johnson and Vogel, 1966). However, the later study did not include balsam poplar as a component of the vegetation but there were some similarities in ground cover species (*Rosa* and *Equisetum*) and in the importance of willows. Viereck (1970) presented a sere on alluvium near Fairbanks where white spruce is eventually replaced by black spruce with a *sphagnum* dominated understory which was given climax status. The most mature white spruce forests were found along the rivers where they are apparently protected by fires. Similar communities in the Northwest Territories have been reported to have white spruce over 250 years old (Reid, 1974; Rowe and Scotter, 1973).

A question has arisen as to whether spruce communities actually represent an end point in succession, (Hettinger *et al.*, 1973; Strang, 1973). Zach (1950) designated muskeg as the physiognomic climax in southeastern Alaska. Indications are that conditions become less favorable for white spruce as the active layer becomes shallower, cooler and less well drained. These conditions are especially evident on fossil meander plans and backswamps in the Porcupine Plateau where sedges and heaths are more dominant, and white spruce reproduction and the ratio of living to dead was reduced. Strang (1973) related this trend to the absence of fire with a moss/lichen association as the climax type. Development of a sere and identification of the climax community is relative to the time scale used and this can be a problem in interpreting succession in northern areas. The change in dominance from spruce to species of lower strata takes at least 300 years after initial white spruce establishment at the site.

Succession after alluvial deposition in the northern Brooks Range to the Coastal Plain involves a number of tall willows (*Salix alaxensis alaxensis*, *S. planifolia pulchra*, *S. lanata richardsonii* and *S. glauca acutifolia*). Comparisons of these areas to a more detailed analysis near Umiat indicate a number of similarities between the proposed seres (Bliss and Cantlon, 1957). Felt-leaf willow is an important species following heraceous colonization which includes horsetail, river beauty, legume and graminoid species.

Felt-leaf willow appears to be more frequent in Alaska than in the Yukon where *Salix glauca acutifolia* and *S. pulchra* were usually associated with riparian succession (Hettinger *et al.*, 1973). The trend toward sedge dominance and a decrease in tall willows is comparable to the transition from decadent felt-leaf willow communities toward sedge and shrub-heath as discussed by Bliss and Cantlon (1957). Again the changes with sere maturity include decreased active layer depth, drainage and vegetation height as wet sedge meadows and cotton grass tussock communities assume the role of the stable community. The best evidence for ascribing climax status to these graminoid communities occurred in the Brooks Range on fossil meander plains and backswamps adjacent to present floodplains. The length of time from initial colonization to heath or graminoid communities is not known since willows could not be dated past 90 years. Shrub age estimates may not give an accurate indication of the time necessary for seral development since the maturity and death of stems is a short-term process in relation to the total population age. The abundance of legumes (*Oxytropis* spp., *Astragalus* spp.) in the earlier portion of the sere appears to increase with latitude and *Artemesia tilesii* and *A. alaskana* were not found to be important as identified in the other similar plant communities (Bliss and Cantlon, 1957; Hettinger *et al.*, 1973).

Succession in alpine regions of Alaska has not been well defined. Lambert (1972) has described *Betula glandulosa - Vaccinium vuliginosum* and *Betula glandulosa - Eriophorum vaginatum* vegetation as the climax communities in the northern Richardson Mountains. Pioneer species inlcuded *Eriophorum* *scheuchzeri*, *Calamagrostis canadensis* and *Arctagrostis latifolia*. Mountain avens, netted willow and holy grass represent relatively young areas in alpine areas of the Porcupine Plateau to the Southern Brooks Range which is similar to seres discussed for the British and Richardson mountains in the Yukon (Hettinger *et al.*, 1973). Sedges, netted willow and lichens (*Parmelia panniformis*, *Alectoria nitidula*) appear on rocky and gravelly areas of the northern Brooks Range. Graminoid species (*Poa*, *Bromus*, *Hierochloe* and *Festuca*) also act as pioneer species in some alpine areas, but are usually associated with the more nutrient rich ground squirrel burrows. *Minuartia rossii* and *Carex macrochaeta* - *C. misandra* communities are comparable to young *Poa glauca*, *Minuartia biflora* scree vegetation in the Richardson Mountains (Hettinger *et al.*, 1973).

The difficulty of interpreting succession in low shrub and other tundra types of vegetation has been discussed by Churchill and Hanson (1958). Part of the problem is ascribed to the instability of frost churned soils in the Arctic and hence the short time available for sere development (Sigafoos, 1952). Tussock tundra communities were given climax status at least in the foothills (Spetzman, 1959), and may develop through hydric seres with various wet sedge communities on fossil lake beds occurring as stages of the succession. Development of tussock tundra from bedrock ridges was also thought possible although *Dryas* - lichen meadows were thought to be climax vegetation of well drained ridges and slopes (Spetzman, 1959). Mountain avens, polar grass, bluegrass (*Poa arctica*) and cloudberry were given pioneer status for disturbed areas on the coastal plain and foothills here. However, cotton grass and sedges have the ability to withstand some disturbance and their re-establishment may be stimulated by fire (Bliss and Wein, 1972). Other communities including low shrub and heath types contain species which also may survive disturbance and regenerate from rootstocks (Drury, 1956). It is believed that low and dwarf birch, heath and willow shrub vegeation of the study area are able to reestablish quickly after fire. Bliss and Wein (1972) found that dwarf heath recovery was rapid after tundra fires. Severe disturbance on wet areas of the coastal plain contained only *Rubus chamaemorus* as a dominant pioneer species (Hernandez, 1972; Kerfoot, 1972), but sedge (*Carex bigelowii, C. aquatilis*) may also be important in similar circumstances in northeastern Alaska.

Better drained sites with mineral soil exposure after disturbance may be initially revegetated by grasses (*Calamagrostis canadensis, Arctagrostis latifolia* and *Poa lanata*), *Senecio congestus* and *Epilobium angustifolium* (Bliss and Wein, 1972; Hernandez, 1972). Other species exhibiting similar potential from the present study include *Bromus pumpellianus, Calamagrostis purpurascens, Poa arctica, Senecio atropurpureus* ssp. *frigidus* and *Epilobium latifolium*.

6.4 Application of Biotic and Abiotic Relationships

Analyzing a number of environmental factors by a simple correlation is a first step in understanding some of the relationships involved in biological systems. However, cause and effect relationships are not necessarily indicated by simple correlation since plant distribution and growth is a function of all environmental factors.

A number of relationships between factors was associated with changes during succession. The increase in species diversity was associated with plant community development on alluvium except under mature white spruce. Increase in micro-relief is also associated with community maturity which offers a more diverse habitat for species establishment. Species diversity is also higher at mid-slope positions which usually represents a median between the environmental extremes of the dry rocky ridge-tops and wet slope bases. Lichens decrease in importance with more vascular cover and are assessed as important colonizers in gravelly, rocky areas especially common in the mountains. Moss species, on the other hand, are more common in wet areas and high cover is frequently common in wet sedge, tussock tundra and sedge-low shrub vegetation types. Both moss and lichen diversity is lower when vascular species diversity is high and hence appears to be partially limited by competition.

Sites, including those with young balsam poplar and white birch, which are favorable to greater growth rates and species diversity probably have more available nutrients (Hettinger *et al.*, 1973). The possibility of nutrients becoming less available with successional maturity has been discussed by Bliss and Cantlon (1957) and Heilman (1966, 1968). Rejuvenation of the available nutrient pool appears to occur after fires and is related to increase in available nutrients partly through an increase in the active layer depth (Bliss and Wein, 1972). Indications from this and past studies are that disturbance and perturbation are continual processes in the Low Arctic and northern boreal ecosystems and fluctuations of population numbers are inherently associated with these changes. Unless disturbances are severe, a trend toward original conditions is rapidly established. Severe disturbance on permafrost is of concern however since subsidence of the surface and additional slumping may take a relatively long time to stablize. This feature and the simplistic structure of the ecosystems are mostly responsible for the widespread concept of fragility in the Arctic (Bliss *et al.*, 1973). However Dunbar (1973) discusses the concept that instability is a naturally occurring phenomenon of most Arctic systems which are therefore adapted to perturbation. The amount of disturbance that northern ecosystems can tolerate before irreversible change is initiated is the questionable entity and caution is the best policy in land use. Heginbottom (1973) indicates that slope failure is a common result of a number of disturbances including fire and ground vegetation removal. A number of guidelines have been developed and are discussed by Wein and Bliss (1973a,c) with regard to potential problem areas. The presence of silty soil over high ice-content permafrost is probably the extreme of instability which is compounded where slopes are involved. Most problem areas are indicated by a high frequency of natural instability which could be increased by usage of the area by man.

7.0 SUMMARY AND CONCLUSIONS

Fourteen clusters with 41 component associations are categorized for the study area from the cluster analysis. Ubiquitous species are a dominant character for several groups, but combinations of dominant species are used for the association nomenclature.

Stands from widely separated areas are often placed in the same association as a result of similar composition. However, the association is used as an indication of some environmental equivalency and therefore it is possible to have, for instance, stands from a xeric site in the Arctic Coastal Plain and a more mesic site in the Porcupine Plateau within the same association.

Thirty basic vegetation categories are utilized to classify the associations in relation to terrain types. Wet sedge meadow, dwarf or low shrub sedge and white spruce forest types occur most frequently in the physiographic regions. However, sedge, herb-sedge, lichen meadows and heath shrub vegetation cover the greatest amount of area.

Successional trends toward white spruce climax are identified in the Porcupine Plateau, Southern Foothills and Brooks Range. The riparian sere established after alluvial disturbance with balsam poplar, willow and sometimes alder vegetation typifying much of the vegetation. Secondary succession after fire or slope failures is characterized by white spruce or mixed stands of white birch and white spruce. The white spruce/feather-moss community which are here recognized as a climax type require at least 125 years to develop on alluvium and about 110 years on upland sites. Heath and sedge vegetation types may eventually replace white spruce vegetation if the active layer becomes thin and cold enough, but the replacement takes at least 300 years and hence climax status depends on the time scale used in making comparisons with seres in other areas.

Alpine vegetation develops mostly on frost shattered rock and colluvial surfaces. Lichens, sedges, mountain avens and dwarf willow are important in the early portion of upland seres. An increase in heaths including Lapland cassiope, and moss is associated with the more mature portion of the sere. Mature vegetation in the Arctic Foothills and Arctic Coastal Plain is represented by heath, sedge, and cotton grass communities which occupy a median between xeric and hydric habitat extremes. Species of the early portion of the sere are varied since hydric to xeric conditions are involved. Felt-leaved willow is important as a colonizer in most riparian seres, but is usually succeeded by other willow species which in turn are replaced by species with a lower stature.

A trend from medium tall and tall shrub types toward low shrub and graminoid communities is frequently indicated for most riparian and upland sites within the study area throughout most of the coastal plain. A decrease in the active layer depth, and associated decrease in aeration, soil temperatures and possibly nutrient turnover rate is related to sere maturity. Most of the tree species have higher growth rates in the earlier portions of the sere when active layer depths are relatively deep and soils are still well-drained. Communities with greater microtopographic relief are associated with mature communities, with the exception of white spruce types. Increase in micro-relief is also related to an increase in species diversity. Both lichen and moss species diversity appears to be limited by the presence of vascular species. Most of the soils were found to be immature. The Eutric Brunisol soils of well drained slopes and ridges are the best developed and support relatively diverse communities. Cryosols and Regosols which represent two extremes in soil environment, are common, with Cryosols predominating in all of the areas except the Brooks Range. The predominance of the Gleysolic Turbic Cryosol Subgroup gives an indication of the high frequency of instability due to frost action and associated drainage. No consistent relationships between soil sub-groups and vegetation types are indicated. Regosols are usually associated with early vegetation successional phases, especially on alluvium and bedrock. Mountain avens and willow communities are often associated with Turbic Great Groups and hence an increased micro-relief.

A number of terrain types with silt textured Turbic Cryosol soils are identified as potential land-use problem areas. The combination of slope angle and silt over ice-rich permafrost increases the amount of instability of the land surface as is indicated by patterned ground, slope failures and thermokarst slumping after natural disturbance.

Instability and perturbation are inherent components of low Arctic ecosystems. However, the organisms and communities are adapted to cope with these disruptive forces, and some populations require cyclic environmental fluctuations for survival. The threshold whereby disturbance becomes intolerable to existing ecosystems is conjectural and hence of concern since most are structurally simple and closely inter-related. Therefore, all the populations of the area must be respected with regard to their functional importance in maintaining certain ecosystems.

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Appendix 1. Monthly temperature and precipitation values for six stations nearest the study area in Alaska and Canada.

Element and Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Stokes Point	Lat. 69° 20' N		Long. 130° 46' W			El. 3m							
Mean Daily Temp. (°C)	-26.7	-26.7	-25.6	-17.8	- 4.4	2.2	7.8	6.7	1.1	- 8.3	-20.0	-24.4	-11.1
Mean Daily Max. Temp.	-22.2	-22.8	-22.2	-13.3	- 1.1	5.0	11.7	10.0	3.9	- 5.6	-16.7	-21.7	- 7.8
Mean Daily Min. Temp.	-30.6	-30.6	-28.9	-21.7	- 7.8	- 0.6	3.9	3.3	- 1.7	-11.1	-22.8	-27.2	-14.4
Max. Temp.	2.8	0	- 2.8	8.9	16.1	24.4	27.8	23.3	18.3	7.8	- 3.9	3.3	27.8
Min. Temp.	-49.4	-41.1	-42.2	-40.6	-26.1	- 7.2	- 2.8	- 2.8	- 9.4	-30.0	-38.3	-40.0	-49.4
Komakuk Beach	Lat. 69° 35' N		Long. 140° 11' W			El. 3m							
Mean Daily Temp. (°C)	-26.7	-26.7	-26.7	-18.3	- 5.6	2.8	7.2	6.1	0.6	- 8.9	-18.9	-23.3	-23.9
Mean Daily	-22.2	-22.2	-22.8	-13.9	- 2.2	5.6	11.7	9.4	3.3	- 5.6	-15.0	-18.9	- 7.8
Mean Daily Min. Temp.	-31.1	-30.0	-30.6	-22.8	- 8.3	- 0.6	2.8	2.2	- 2.2	-12.2	-23.3	-27.2	-15.6
Max. Temp.	8.3	- 0.6	0	7.8	15	25.6	27.2	25.6	13.9	6.7	7.2	7.2	27.2
Min. Temp.	-46.7	-42.2	-47.8	-35.6	-25.0	- 8.9	- 5.0	- 2.8	-11.1	-23.9	-38.9	-44.4	-47.8
Mean Total Precip. (cm)	0.86	0.30	0.15	0.30	0.36	1.78	4.09	3.28	1.57	2.11	0.51	0.08	15.4
No. Days With Meas. Rain	1	0	0	0	0	2	6	4	3	*	0	0	16
No. Days With Meas. Precip.	3	3	1	1	2	3	7	5	5	6	2	*	38
Shingle Point	Lat. 68° 57' N		Long. 137° 12' W			El. 9m							
Mean Daily Temp (°C)	-26.1	-26.1	-26.1	-17.8	- 3.9	5.0	10.0	8.9	1.7	- 7.8	-20.0	-23.9	-10.6
Mean Daily Max. Temp.	-21.7	-22.2	-22.2	-13.3	- 0.6	8.9	15.6	12.8	4.4	- 4.4	-16.1	-19.4	- 6.7
Mean Daily Min. Temp.	-30.6	-30.0	-30.0	-21.7	- 7.8	1.1	5.0	5.0	- 1.1	-11.1	-11.1	-27.8	-14.4

continued........	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Max. Temp.	3.3	1.7	0	7.8	17.8	28.3	27.8	28.9	20.0	10.0	6.7	1.7	28.9
Min. Temp.	-51.1	-43.9	-42.2	-38.9	-27.2	- 8.9	- 6.7	- 3.9	-13.3	-27.8	-42.2	-47.2	-51.1
Mean Total Precip. (cm)	0.64	0.18	0.15	0.66	0.51	2.49	4.65	3.25	1.37	3.81	0.71	0.18	18.6
No. Days With Meas. Rain	0	0	0	0	1	7	10	8	3	1	0	0	30
No. Days With Meas. Presip.	1	1	1	2	3	7	10	8	6	9	3	1	52
<u>Old Crow</u>	Lat. 67° 58' N		Long. 139° 38' W		El. 243m								
Mean Total Precip. (cm)	0.74	0.38	0.84	0.91	0.74	5.36	2.60	1.78	1.20	1.45	1.35	1.83	19.15
No. Days With Meas. Rain	0	0	0	0	1	5	3	3	1	1	0	0	14
No. Days With Meas. Precip.	2	2	3	2	2	5	3	3	2	5	4	2	35
<u>Barrow, Alaska</u>	Lat. 71° 18' N		Long. 156° 47' W		El. 9m								
Mean Daily Temp. (°C)	-26.7	-27.8	-26.1	-17.8	- 7.8	0.6	3.9	3.3	- 1.1	- 8.3	-18.3	-23.9	-12.2
Mean Daily Max. Temp.	-22.8	-24.4	-22.2	-13.9	- 4.4	3.3	7.2	6.1	1.1	- 6.1	-15.0	-20.6	- 9.4
Mean Daily Min. Temp.	-30.6	-31.1	-29.4	-21.7	-10.6	- 1.7	0.6	0.6	- 2.8	-11.1	-21.7	-27.2	-15.6
Max. Temp.	1.7	0	0.6	5.6	7.2	21.1	25.6	22.8	16.7	6.1	3.9	1.1	25.6
Min. Temp.	-47.2	-48.9	-46.7	-41.1	-27.8	-13.3	- 5.6	- 6.7	-17.2	-29.4	-40.0	-48.3	-48.9
Mean Total Precip. (cm)	0.46	0.43	0.28	0.28	0.30	0.91	1.96	2.29	1.62	1.27	0.58	0.43	10.82
<u>Barter Island, Alaska</u>	Lat. 70° 08' N		Long. 143° 38' W		El. 12m								
Mean Daily Temp. (°C)	-27.2	-28.9	-26.1	-17.2	- 6.1	1.1	5.0	4.4	0	- 8.3	-17.8	-23.3	-12.2
Mean Daily Max. Temp.	-23.3	-25.0	-22.2	-12.8	- 3.3	3.9	8.9	7.2	2.2	- 5.0	-14.4	-20.0	- 8.9
Mean Daily Min. Temp.	-31.1	-32.2	-30.0	-21.7	- 8.9	- 1.7	1.7	1.7	- 2.2	-11.1	-21.1	-27.2	-15.6

continued........	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Max. Temp.	3.9	1.1	2.2	6.1	11.1	19.4	23.9	22.2	17.8	6.1	2.8	1.7	23.9
Min. Temp.	-46.1	-50.6	-45.6	-38.3	-26.7	- 9.4	- 4.4	- 4.4	-13.9	-29.4	-46.1	-46.1	-50.6
Mean Total Precip. (cm)	1.02	0.89	0.51	0.43	0.64	1.30	2.24	2.67	2.40	0.56	0.27	0.19	4.22

Appendix 2. Annotated species list with common names collected or identified from the study area.

VASCULARS

Trees

Betula papyrifera Marsh.	paper birch
Picea glauca (Moench)	white spruce
Populus balsamifera L.	balsam poplar, cottonwood
P. tremuloides Michx.	quaking aspen

Tall and Low Shrubs

Alnus crispa (Ait.) Pursh ssp. *crispa*	mountain alder
Betula glandulosa Michx.	dwarf birch
B. glandulosa x *nana* [1]	dwarf birch
B. nana L. ssp. *exilis* (Sukatsch.) Hult.	dwarf birch
B. occidentalis Hook.	shrub birch
Chamaedaphne calyculata (L.) Moench	cassandra
Juniperis communis L.	common mountain juniper
J. communis L. ssp. *nana* (Willd.) Syme	common mountain juniper
Ledum palustre L. ssp. *decumbens* (Ait.) Hult.	northern Labrador tea
L. palustre L. ssp. *groenlandicum* (Oeder) Hult.	Labrador tea
Ribes triste Pall.	northern red currant
Rosa acicularis Lindl.	prickly rose
Salix alaxensis (Anderss.) Cov. ssp. *alaxensis*	felt leaf willow
S. alaxensis (Anderss.) Cov. ssp. *longistylis* (Rydb.) Hult.	felt leaf willow
S. arbusculoides Anderss.	willow
S. glauca L.	willow
S. glauca L. var. *acutifolia* (Hook.) Hult	willow
S. glauca L. var. *glauca*	willow
S. hastata L.	willow
S. lanata L. ssp. *richardsonii* (Hook.) A. Skvortz	willow
S. planifolia ssp. *pulchra* (Cham.) Argus	willow
S. reptans Rupr.	willow
S. reticulata L. ssp. *reticulata*	netted willow
S. sphenophylla A. Skvortz	willow
Shepherdia canadensis (L.) Nutt.	soapberry
Vaccinium uliginosum L. ssp. *alpinum* (Bigel.) Hult.	alpine blueberry

Herbs, Dwarf Shrubs and Grasses

Achillea borealis Bong.	yarrow
Aconitum delphinifolium DC.	monkshood
A. delphinifolium DC. ssp. *delphinifolium*	monkshood
A. violaceum (Hornem.) Lange ssp. *andinum* (Scribn. & Sm.) Mekderis	wheatgrass
A. yukonense Scribn. & Merr.	wheatgrass
Alopecurus alpinus Sm. ssp. *alpinus*	alpine foxtail
Andromeda polifolia L.	bog rosemary
Androsace chamaejasme Host ssp. *lehmanniana* (Spreng.) Hult.	sweet-flowered androsace
A. septentrionalis L.	fairy candelabra
Anemone drummondii S. Wats.	cut-leaved anemone
A. parviflora Michx.	anemone
A. richardsonii Hook.	anemone
Antennaria alaskana Malte	pussytoe
A. friesiana (Trautv.) Ekman ssp. *alaskana* (Malte) Hult.	pussytoe
A. friesiana (Trautv.) Ekman ssp. *compacta* (Malte) Hult.	pussytoe
Arctagrostis latifolia (R. Br.) Griseb. var. *latifolia*	polar grass
Arctostaphylos alpina (L.) Spreng.	bearberry
A. rubra (Rehd. & Wilson) Fern.	Arctic bearberry
A. uva-ursi (L.) Spreng.	kinnikinnick
Arnica alpina (L.) Olin	maguire
A. frigida C.A. Mey.	arnica
Artemesia alaskana Rydb.	wormwood
A. arctica Less. ssp. *comata* (Rydb.) Hult.	wormwood
A. frigida Willd.	prairie sagewort
A. tilesii Ledeb. ssp. *elatior* (Torr. & Gray) Hult.	wormwood
Aster ciliatus (Ledeb.) Fedsch.	aster
A. sibiricus L.	aster
Astragalus aboriginum Richards.	milk vetch
A. alpinus L.	milk vetch
A. alpinus L. ssp. *arcticus* (Bunge) Hult.	milk vetch
A. umbellatus Bunge	milk vetch
Boschniakia rossica (Cham. & Schlecht.) Fedtsh.	
Boykinia richardsonii (Hook.) Gray	Alaska boykinia
Braya humilis (C.A. Mey.) Robins.	mustard
B. purpurascens (R. Br.) Bunge	mustard
Bromus pumpellianus Scribn.	brome grass
B. pumpellianus Scribn. ssp. *arcticus* (Shear Pors.	brome grass
Bupleurum triradiatum Adams	thoroughwax
B. triradiatum Adams ssp. *arcticum* (Regel) Hult.	thoroughwax
Calamagrostis canadensis (Michx.) Beauv.	bluejoint
C. purpurascens R. Br.	reed bent grass

Caltha palustris L. ssp. *arctica* (R. Br.) Hult.	marsh marigold
Campanula unifolora L.	bellflower
Cardamine bellidifolia L.	bitter cress
C. hyperborea O.E. Schulz	bitter cress
C. microphylla Adams	bitter cress
C. pratensis L. ssp. *angustifolia* (Hook.) O.E. Schulz	cuckoo flower
Carex amblyorhyncha Krecz.	sedge
C. aquatilis Wahlenb.	sedge
C. atrofusca Schkuhr	sedge
C. bigelowii Torr.	sedge
C. capillaris L.	sedge
C. capitata Soland. in L.	sedge
C. concinna R. Br.	sedge
C. glacialis Mack.	sedge
C. gynocrates Wormsk.	sedge
C. limosa L.	sedge
C. livida (Wahlenb.) Willd.	sedge
C. lugens Holm	sedge
C. macrochaeta C.A. Mey	sedge
C. maritima Gunn.	sedge
C. media R. Br.	sedge
C. membranacea Hook.	sedge
C. microchaeta Holm	sedge
C. misandra R. Br.	sedge
C. nardina E. Fries	sedge
C. petricosa Dew.	sedge
C. rariflora (Wahlenb.) J.E. Sm.	sedge
C. rupestris All.	sedge
C. saxatilis L. ssp. *laxa* (Trauv.) Kalela	sedge
C. scirpoidea Michx.	sedge
C. spp.	sedge
C. vaginata Tausch	sedge
Cassiope tetragona (L.) D. Don	Lapland cassiope
C. tetragona (L.) D. Don ssp. *tetragona*	Lapland cassiope
Castilleja caudata (Pennell) Rebr.	Indian paintbrush
Cerastium beeringianum Cham. & Schlecht. var. *grandiflorum* (Fenzl) Hult.	mouse-ear chickweed
C. maximum L.	mouse-ear chickweed
Chrysanthemum integrifolium Richards.	chrysanthemum
Claytonia acutifolia Pakk. ssp. *graminifolia* Hult.	spring beauty
C. sarmentosa E.A. Mey.	spring beauty
Corydalis aurea Willd.	golden corydalis
Crepis nana Richards.	hawk's-beard
Cystopteris fragilis (L.) Bernh.	fragile fern
Delphinium brachycentrum Ledeb.	larkspur
D. glaucum S. wats.	larkspur
Deschampsia brevifolia R. Br.	grass
D. caespitosa L. Beauv. var. *caespitosa*	grass

D. caespitosa L. Beauv. var. *glauca* (Hartm.) Sam.	grass
Diapensia lapponica L.	
Dodecatheon frigidum Cham. & Schlecht.	shooting star
Draba alpina L.[3]	mustard
D. corymbosa[3]	mustard
D. fladnizensis Wulf.[3]	mustard
D. lactea Adams[3]	mustard
Draba palouderiana[1]	mustard
Dryas drummondii Richards.	yellow dryas
D. integrifolia M. Vahl. ssp. *integrifolia*	mountain avens
D. octopetala L. ssp. *octopetala*	mountain avens
D. ssp.	avens
Dryopteris fragrans (L.) Schott	shield fern
Dupontia fischeri R. Br. ssp. *psilosantha* (Rupr.) Hult.	grass
Elymus arenarius L. ssp. *mollis* (Trin.) Hult var. *villosissimus* (Scribn.) Hult.	lyme grass
Empetrum nigrum L. ssp. *hermaphroditum* (Lange) Bocher	crowberry
Epilobium latifolium L.	river beauty
Equisetum arvense L.	common horsetail
E. multiflora[1]	horsetail
E. palustre L.	horsetail
E. pratense L.	horsetail
E. scirpoides Michx.	horsetail, scouring rush
E. silvaticum L.	horsetail
E. variegatum Schleich. ssp. *variegatum*	horsetail
Erigeron eriocephalus J. Vahl	fleabane, wild daisy
E. hyperboreus Greene	
Eriophorum angustifolium Honck. ssp. *subarcticum* (Vassil jev.) Hult.	cotton grass
E. angustifolium Honck. ssp. *triste* (T. Fries) Hult.	cotton grass
E. brachyantherum Trautv. & Mey.	cotton grass
E. callitrix Cham.	cotton grass
E. scheuchzeri Hoppe var. *scheuchzeri*	cotton grass
E. scheuchzeri Hoppe var. *tenuifolium*	cotton grass
E. vaginatum ssp. *spissum* (Fern.) Hult	cotton grass
E. vaginatum L. ssp. *vaginatum*	cotton grass
Eritrichium aretioides (Cham.) DC.	Arctic forget-me-not
Erysimum pallasii (Pursh) Fern	mustard
Eutrema edwardsii R. Br.	mustard
Fustuca altaica Trin.	fescue grass
F. brachyphylla Schult.	fescus grass
F. ovina L. ssp. *alaskensis* Holmen	fescue grass
F. rubra L. coll. ssp. *richardsonii* (R. Br.) Hult.	fescue grass
Gentiana glauca Pall.	gentian
G. propinqua Richards.	gentian

G. propinqua Richards. ssp. *propinqua*	gentian
Geum glaciale Adams	avens
G. rossii (R. Br.) Ser.	avens
Hedysarum alpinum L. ssp. *americanum* (Michx.) Fedtsch	hedysarum
H. mackenzii Richards.	hedysarum
Hierochloe alpina (Sw.) Roem. & Schult.	holy grass
H. pauciflora R. Br.	holy grass
Hippuris vulgaris L.	mare's tail
Juncus arcticus Willd.	rush
J. arcticus Willd. ssp. *alaskanus* Hult.	rush
J. balticus Willd.	rush
J. biglumis L.	rush
J. castaneus Sm.	rush
J. triglumis L.	rush
J. triglumis L. ssp. *triglumis*	rush
Kobresia myosuroides (Vill.) Fiori & Paol.	sedge
K. sibirica Turcz.	sedge
K. simpliciuscula (Wahlenb.)	sedge
Lagotis glauca Gaertn.	figwort
L. glauca Gaertn. ssp. *minor* (Willd.) Hult.	figwort
Lesquerella arctica (Wormsk.) S. Wats.	bladder-pod
Linnaea borealis L.	twinflower
Lupinus arcticus S. Wats.	lupine
Luzula arctica Blytt	wood rush
L. arcuata (Wahlenb.)	wood rush
L. confusa Lindeb.	wood rush
L. multiflora (Retz.) Lej. var. *frigida* (Buchenau) Sam.	wood rush
L. multiflora (Retz.) Lej. ssp. *multiflora*	wood rush
L. parviflora (Ehrh.) Desv.	wood rush
L. tundricola Goroodk	wood rush
Lycopodium calavatum L. ssp. *monostachyon* (Grev. & Hook.) Sel.	common club moss
L. complanatum L.	Christmas green, creeping Jenny
L. selago L.	fir club moss
L. selago L. ssp. *appressum* (Desv.) Hult.	club moss
Melandrium affine J. Vahl	bladder-campion
M. apetalum (L.) Fenzl. ssp. *arcticum* (E. Fries) Hult.	bladder-campion
Menyanthes trifoliata L.	buckbean
Mertensia paniculata (Ait.) G. Don ssp. *paniculata*	bluebell
Minuartia arctica (Stev.) Aschers. & Graebn.	minuartia
M. rossii (R. Br.) Graebn.	minuartia
M. rubella (Wahlenb.) Grabn.	minuartia
Myosotis alpestris F. W. Schmidt ssp. *asiatica* Vestergr.	forget-me-not
Orchis rotundifolia Banks.	orchid
Oxyria digyna (L.) Hill	mountain sorrel

Oxytropis arctica R. Br.	loco-weed
O. borealis DC.	loco-weed
O. campestris (L.) DC. ssp. *gracilis* (Nels.) Hult.	late yellow loco-weed
O. koyukukensis Pors.	loco-weed
O. maydelliana Trautv.	loco-weed
O. nigrescens (Pall.) Fisch. ssp. *pygmaea* (Pall.) Hult.	loco-weed
O. scammaniana Hult.	loco-weed
O. spp.	loco-weed
O. viscida Nutt.	loco-weed
Papaver macounii Greene	poppy
P. spp.	poppy
Parnassia kotzebuei Cham. & Schlecht.	grass-of-parnassus
P. palustris L. ssp. *neogaea* (Fern.) Hult.	northern-grass-of-parnassus
Parrya nudicaulis (L.) Regel ssp. *septentrionalis* Hult.	mustard
Pedicularis capitata Adams	lousewort
P. kanei Durand ssp. *kanei*	lousewort
P. labradorica Wirsing	lousewort
P. langsdorffii Fisch. ssp. *arctica* (R. Br.) Pennell	lousewort
P. oederi M. Vahl	lousewort
P. spp.	lousewort
P. sudetica Willd.	lousewort
P. verticillata L.	lousewort
Petasites frigidus (L.) Franch.	sweet coltsfoot
Phlox sibirica L.	phlox
Pinguicula vulgaris L.	bitterwort
Poa abbreviata R. Br.	blue grass
P. alpigena (E. Fries) Lindm.	blue grass
P. alpina L.	blue grass
P. arctica R. Br.	blue grass
P. glauca M. Vahl	blue grass
P. lanata Scribn. & Merr.	blue grass
P. pratensis L.	blue grass
P. pseudoabbreviata Roshev.	blue grass
P. spp.	blue grass
Polemonium acutiflorum Willd.	Jacob's ladder
P. boreale Adams	Jacob's ladder
Polygonum bistora L. ssp. *plumosum* (Small) Hult.	bistort
P. viviparum L.	bistort
Potentilla biflora Willd.	conquefoil
P. fruticosa L.	shrubby cinquefoil
P. hookeriana Lehm.	cinguefoil
P. multifida L.	cinquefoil
P. nivea L.	cinquefoil
P. palustris (L.) Scop.	marsh fivefinger
Primula sibirica Jacq.	primrose

Pyrola secunda (L.) House [2]	wintergreen
P. secunda L. ssp. *obtusata* (Turcz.) Hult.	one-sided wintergreen
P. rotundifolia ssp. *grandiflora* (Radius) Andres [2]	
Ranunculus hyperboreus Robbt.	buttercup, crowfoot
R. nivalis L.	snow buttercup
R. pedatifidus Sm. ssp. *affinis* (R. Br.) Hult.	buttercup
Rhododendron lapponicum (L.) Wahlenb.	Lapland roesbay
Rubus articus L. ssp. *acaulis* (Michx.) Focke	dwarf raspberry
R. chamaemorus L.	cloudberry
Salix arctica Pall.	Arctic willow
S. arctophila Cockerell	dwarf willow
S. barrattiana Hook.	willow
S. brachycarpa ssp. *niphoclada* (Rydb.) Argus	willow
S. brachycarpa ssp. *niphoclada* x *S. glauca* [2]	willow
S. chamissonis Anderss.	willow
S. fuscescens anderss.	willow
S. ovalifolia Trautv. *ovalifolia* [1]	dwarf willow
Salix phleborphylla Anderss.	willow
S. rotundifolia ssp. *dodgeana* (Rydb.) Argus	willow
Saussurea angustifolia (Willd.) DC.	sawwort
S. nuda Ledb. var. *densa* (Hook.) Hult.	sawwort
S. viscida Hult. var. *yukonensis* (Pors.) Hult.	sawwort
Saxifraga bronchialis L. spp. *funstonii* (Small) Hult.	spotted saxifrage
S. cernua L.	bulblet saxifrage
S. davurica Willd. ssp. *grandipetala* (Engler & Irmsch.) Hult.	saxifrage
S. foliolosa R. Br.	grained saxifrage
S. foliolosa R. Br. var. *multiflora* Hult.	grained saxifrage
S. hieracifolia Waldst. & Kit.	stiff-stemmed saxifrage
S. hirculus L.	bog saxifrage
S. oppositifolia L.	purple mountain saxifrage
S. punctata L. ssp. *nelsoniana* (D. Don) Hult.	cordate-leaved saxifrage
S. tricuspidata Rottb.	prickly saxifrage
Sedum rosea (L.) Scop. ssp. *integrifolium* (Raf.) Hult.	roseroot
Senecio atropurpureus (Ledeb.) Fedtsch. ssp. *frigidus* (Richards.) Hult.	groundsel
S. congestus (R. Br.) DC.	march fleabane
S. fuscatus (Jord. & Fourr.) Hayek	groundsel
S. lugens Richards.	groundsel
S. residifolius Less.	groundsel
S. spp.	groundsel
Silene acaulis L. spp. *acaulis*	moss campion
Stellaria edwardsii R. Br.	chickweed
S. laeta Richards.	chickweed
S. longpipes Goldie	chickweed
S. monantha Hult.	chickweed

Thalitricum alpinum L.	meadow rue
Tofieldia alpine[1]	false asphodel
T. coccinea Richards.	false asphodel
T. pusilla (Michx.) Pers.	false asphodel
Trichophorum caespitosum (L.) Hartm. ssp. *austriacum* (Pall.) Hegi	rush
Triglochin maritimum L.	arrow grass
T. palustris L.	arrow grass
Trisetum spicatum (L.) Richter	grass
Vaccinium vitis-idaea L. ssp. *minus* (Lodd.) Hult.	lingonberry
Valeriana capitata Pall.	valerian
Wilhelmsia physodes (Fisch.) McNeil	
Woodsia ilvensis (L.) R. Br.	lady fern
Zygadenus elegans Pursh	white camass

1 Nomenclature according to G. W. Argus
2 Nomenclature according to G. Mulligan
3 Nomenclature according to E. Haber

MOSSES

Andreaea rupestris Hedw.
Aulacomnium palustre (Hedw.) Schwaegr.
A. turgidum (Wahlenb.) Schwaegr.
Brachythecium turgidum (Hartm.) Kindb.
B. spp.
Bryoerythrophyllum recurvirostrum (Hedw.) Chen
Bryum argenteum Hedw.
B. cryophilum Mart.
B. pseudotriquetrum (Hedw.) Gaertn., Meyer & Schreb.
B. spp.
B. wrightii Sull. & Lesq.
Calliergon giganteum (Schimp.) Kindb.
C. spp
Campylium stellatum (Hedw.) C. Jens.
Catoscopium nigritum (Hedw.) Brid.
Cinclidium arcticum (B.S.G.) Schimp.
Cirriphyllum cirrosum (Schwaegr.ex Schultes) Grout
Cyrtomnium hymenophylliodes (Heub.) Kop.
Dicranoweisia crispula (Hedw.) Linab.ex Milde
Dicranum acutifolium (Lindb. & Arn.) C. Jens. ex Weinm
D. elongatum Schleich ex. Schwaegr.
D. muehlenbeckii B.S.G.
D. scoparium Hedw.
D. spp.
Distichium capillaceum (Hedw.) B.S.G.
Ditrichum flexicaule (Schwaegr.) Hampe
Drepanocladus revolvens (Sw.) Warnst.
D. uncinatus (Hedw.) Warnst.
Eurhynchium pulchellum (Hedw.) Jenn.
Fissidens osmundoides Hedw.
Grimmia alpicola Hedw.
Hylocomium splendens (Hedw.) B.S.G.
Isopterygium pulchellum (Hedw.) Jaeg. & Sauerb.
Meesia triquetra (Richt.) Angstr.
M. uliginosa Hedw.
Oncophorus wahlenbergii Brid
Orthothecium chryseum (Schwaegr. ex Schultes) B.S.G.
Orthotrichum speciosum Nees ex Sturm
Philonotis fontana (Hedw.) Brid. var. *pumila* (Turn.) Brid.
Plagiomnium medium (B.S.G.) Kop.
Pleurozium schreberi (Brid.) Mitt.
Pohlia cruda (Hedw.) Lindb.
Polytrichum commune Hedw.
P. juniperinum Hedw.
P. piliferum Hedw.
P. strictum Brid.
Rhacomitrium lanuginosum (Hedw.) Brid.
Rhytidium rugosum (Hedw.) Kindb.
Scorpidium turgescens (T. Jens.) Loeske

Sphagnum capillaceum (Weiss) Schrank
S. girgensohnii Russ.
S. spp.
S. squarrosum Crome
Tetraplodon mnioides (Hedw.) B.S.G.
Thuidium abietinum (Hedw.) B.S.G.
Timmia austriaca Hedw.
Tomenthypnum nitens (Hedw.) Loeske
Tortula norvegica (Web.) Wahlenb ex Lindb.
T. ruralis (Hedw.) Gaertn., Meyer & Scherb.

LIVERWORTS

Barbilophozia barbata (Schmid.)
Blepharostoma trichophyllum (L.) Dumort.
Calypogeia neesiana (M.&C.) K. Muell.
Chandonanthos setiformis (Ehrh.) Lindb.
Mesoptchia sahlgergii
Ptilidium ciliate (L.) Hampe
Riccardia pinguis (L.) S.F. Gray
Scapania simmonsii
Sphenolobus spp.

LICHENS

Alectoria nitidula (Th. Fr.) Vain
A. ochroleuca (Hoffm.) Mass.
A. subdivergens Dahl
A. tenius Dahl
Asahinea chrysantha (Tuck.) W. Culb & C. Culb.
Caloplaca splendens (Darb.) Zahlbr.
Cetraria commixta (Nyl.) Th. Fr.
C. cucullata (Bell.) Ach.
C. islandica (L.) Ach.
C. laevigata Rass.
C. nivalis (L.) Ach.
C. pinastri (Scop.) S. Gray
C. richardsonii Hook
C. tilesii Ach.
Cladina alpestris (L.) Harm.
C. mitis (Sandst) Hale & W. Culb
Cladonia amaurocraea (Florke) Schaer.
C. phyllophora Hoffm.
C. pyxidata (L.) Hoffm.
C. spp.
Cornicularia aculeata (Schreb.) Ach.
C. normoerica (Gunn.) Du Rietz
Dactylina arctica (Hook.) Nyl.
Evernia mesomorpha Nyl.
E. perfragilis Llano
Haematomma lapponicum Ras.
Hypogymnia physodes (L.) W. Wats.
H. subobscura (Vain.) Poelt
Icmadophila ericetorum (L.) Zahlbr.
Lecanora coilocarpa (Ach.) Nyl.
L. subfusca (L.) Ach.
Lecidea spp.
Leptogium saturninum (Dicks.) Nyl.
Nephroma arcticum (L.) Torss.
Ochrolechia upsaliensis (L.) Mass.
Parmelia panniformis (Nyl.) Vain.
P. separata Th. Fr.
P. sulcata Tayl.
Parmeliopsis ambigua (Wulf.) Nyl.
Peltigera aphthosa (L.) Willd.
P. canina (L.) Willd.
Pertusaria dactylina (Ach.) Nyl.
Physconia muscigena (Ach.) Poelt
Polyblastia cupularis Mass.
Polyblastiopsis inductula (Nyl.) Fink
Ramalina minuscula (Nyl.) Nyl.
Rhizocarpon concentricum (Dav.) Beltr.
R. geographicum (L.) DC.

Solorina bispora Nyl.
S. crocea (L.) Ach.
Stereocaulon grande (Magn.) Magn.
Thamnolia subuliformis (Ehrh.) W. Culb.
Umbilicaria hyperborea (Ach.) Ach.
U. proboscidea (L.) Schrad.
Usnea spp.

Appendix 3. Stand locations with general vegetation type and physical features in the study area. Site number refers to those placed on Figure 1.

PORCUPINE PLATEAU

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
Grayling lake	1	1	Low shrub - herb; *Salix glauca acutifolia/Dryas octopetala*	51	WNW	15	760
	1	2	Dwarf heath shrub w/ open white spruce; *Vaccinium vitis-idaea minus-V. uliginosum alpinum*	54	S	10	600
	1	3	Low shrub-heath; *Betula nana exilis/Hylocomium splendens*	38	NNE	8	550
	1	4	Low shrub-heath; *Betula nana exilis/Hylocomium splendens*	59	S	10	580
	1	5	Dwarf heath, wet sedge; *Carex membranacea-Arctostaphylos rubra/Tomenthypnum nitens*	41	-	0	490
	1	6	Tall willow-heath shrub; *Salix glauca acutifolia/Ledum groenlandicum-Vaccinium vitis-idaea minus*	35	NW	9	500

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	1	7	Dryas-moss-shrub w/open white spruce; *Dryas integrifolia integrifolia/ Tomenthypnum nitens*	43	-	0	490
Koness River	2	8	Wet sedge meadow (strangmoor); *Carex bigelowii-C. rariflora-C. saxitilus laxa*	38	NE	3	400
	2	9	White birch forest; *Betula papyrifera/ Hylocomium splendens*	34	W	25	430
	2	10	White birch forest; *Betula papyrifera/ Hylocomium splendens*	41	W	25	550
	2	11	Alpine and subalpine Dryas meadow; *Dryas octopetala octopetala/ Minuartia rossii, D. integrifolia integrifolia-Carex misandra/Rhytidium rugosum*	23	-	0	760
	2	12	Alpine and subalpine Dryas meadow; *Dryas octopetala octopetala/ Minuartia rossii, D. integrifolia integrifolia-Carex misandra/Rhytidium rugosum*	58	N	15	700

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
Monument Creek	1	13	White spruce forest (white spruce woodland terrace); *Picea glauca/Hylocomium splendens*	30	-	0	490
	1	14	Balsam poplar forest; *Populus balsamifera/ Arctostaphylos rubra/ Pyrola rotundifolia grandiflora*	26	-	0	490
Index Mountain	3	15	Wet sedge meadow w/ scattered shrubs; *Salix planifolia pulchra/Carex bigelowii/Hylocomium splendens*	45	E	8	1280
	3	16	Low shrub-moss meadow; *Salix reticulata reticulata/Hylocomium splendens*	50	E	15	1300
	3	17	Wet sedge meadow w/ scattered shrubs; *Cassiope tetragona-Carex bigelowii*	57	E	6	1270
	3	18	Alpine open dwarf shrub-sedge; *Salix reticulata reticulata/Carex saxitilus laxa*	28	SE	12	1510
	3	19	Alpine open dwarf shrub-sedge; *Salix reticulata reticulata/Carex saxitilus laxa*	36	NNW	8	1510

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	3	20	Alpine open dwarf shrub-sedge; *Dryas octopetala octopetala/Minuartia rossii*	44	SSE	15	1342
	3	21	Dwarf shrub-sedge meadow; *Salix reticulata reticulata/Hylocomium splendens*	43	E	10	1140
	3	22	Low heath & willow shrub; *Salix planifolia pulchra/Petasites frigidus*	52	ENE	12	1160
	3	23	Low heath & willow shrub; *Betula nana exilis/Vaccinium uliginosum alpinum*	58	NNE	7	850
	3	24	Low heath & willow shrub; *Betula nana exilis/Hylocomium splendens* w/cotton grass (*Eriophorum vaginatum vaginatum*)	46	NNE	2	850
	3	25	Low heath & willow shrub; *Salix reticulata reticulata/Dryas integrifolia integrifolia/Tomenthypnum nitens* w/open willow (*Salix planifolia pulchra*)	49	NNE	7	860
	3	26	Low shrub heath; *Betula nana exilis* w/open white spruce	57	WSW	13	760

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
Kongakut River	11	27	Wet sedge meadow; *Salix ovalifolia ovalifolia/ Dryas integrifolia integrifolia-Arctagrostis latifolia latifolia-Carex bigelowii*	48	ENE	1	60
	11	28	Heath-sedge tussock tundra; *Dryas integrifolia integrifolia-Cassiope tetragona-Carex scirpoidea-Vaccinium uliginosum alpinum*	56	NNW	2	70
	11	29	Low shrub-sedge meadow & hummocky tundra; *Salix lanata richardsonii-Carex vaginata/Hylocomium splendens*	57	NNE	3	70
	11	30	Low shrub-sedge meadow & hummocky tundra; *Salix planifolia pulchra/Carex bigelowii*	66	N	1	85
Okerokovik River	10	37	Tussock tundra; *Salix reticulata reticulata-Dryas integrifolia integrifolia-Eriophorum vaginatum vaginatum/Tomenthypnum nitens*	62	NE	9	213
	10	38	Wet sedge meadow; *Salix planifolia pulchra/Carex bigelowii*	36	ENE	1	210

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
Canning River	8a	39	Dwarf shrub-Dryas meadow; *Salix ovalifolia ovalifolia/ Dryas integrifolia integrifolia/Arctagrostis latifolia latifolia*	20	ENE	1	122
Sagavanirktok River	9	40	Dwarf shrub-Dryas meadow; *Dryas integrifolia integrifolia-Carex bigelowii*	26	-	0	20
	9	41	Dwarf shrub-Dryas meadow; *Salix reticulata reticulata-Dryas integrifolia integrifolia/ Tomenthypnum nitens*	26	-	0	18
	9	42	Tussock tundra; *Salix planifolia pulchra/Carex bigelowii-Eriophorum vaginatum vaginatum*	60	NNW	1	20
	9	43	Wet sedge meadow; *Carex bigelowii-C. rariflora-C. saxitilus laxa*	22	E	1	100
	9	44	Wet sedge meadow; *Salix reticulata reticulata-Carex bigelowii/Tomenthypnum nitens*	50	-	0	30

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	9	45	Heath-sedge tussock tundra; *Cassiope tetragona/Carex bigelowii-Ledum palustre decumbens*	62	-	0	50
Kadleroshilik River	8	53	Wet sedge meadow; *Salix reticulata reticulata-Carex bigelowii/ Tomenthypnum nitens*	42	SSE	6	80
	8	54	Heath-sedge tussock tundra; *Cassiope tetragona/Carex bigelowii/Ledum palustre decumbens*	54	ESE	1	70
Weir Creek	7	57	Low shrub-sedge meadow & hummocky tundra; *Salix planifolia pulchra-Carex misandra/Aulocomnium turgidum-Hylocomium splendens*	52	WSW	2	150
	7	58	Riparian willow shrub; *Salix planifolia pulchra/ Petasites frigidus*	25	N	2	130
Hill 659	8	59	Wet sedge meadow; *Betula nana exilis/Carex aquatilis-C. bigelowii*	39	SW	7	130
	8	60	Tussock tundra; *Salix planifolia pulchra/Carex bigelowii-C. misandra*	46	SW	7	140
Lake 188	8	61	Wet sedge meadow; *Salix planifolia pulchra/Carex aquatilis*	22	-	0	60

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	8	62	Wet sedge meadow; *Salix reticulata reticulata/Carex bigelowii/Tomenthypnum nitens*	44	-	0	60
Kongakut River	11	31	Tussock tundra; *Salix planifolia pulchra/ Eriophorum vaginatum vaginatum/Hylocomium splendens*	54	N	8	250
	11	32	Sedge meadow; *Salix glauca glauca/Carex aquatilis-Petasites frigidus*	40	NNE	7	210
	11	33	Sedge meadow; *Salix planifolia/pulchra/Carex aquatilis*	38	NNE	4	160
Red Hill	7a	46	Tussock tundra; *Salix planifolia pulchra/Carex bigelowii/Hylocomium splendens*	42	NW	13	550
	7a	47	Dwarf shrub-sedge; *Salix reticulata reticulata-Dryas integrifolia integrifolia/Tomenthypnum nitens*	43	NNW	20	520
	7a	48	Dwarf shrub-sedge meadow; *Carex membranacea/Hylocomium splendens-Tomenthypnum nitens*	47	N	40	470

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	7a	49	Dwarf shrub-sedge meadow; *Salix reticulata reticulata Dryas integrifolia integrifolia-Carex bigelowii*	45	N	13	450
Gilead Creek	6a	50	Riparian shrub & open forest; *Salix alaxensis alaxensis-S. planifolia pulchra/Dryas integrifolia integrifolia* w/balsam poplar	41	NNW	4	460
	6a	51	Riparian shrub & open forest; *Salix alaxensis alaxensis/Hylocomium splendens*	32	NNW	1	460
	6a	52	Dwarf heath lichen tundra; *Vaccinium uliginosum alpinum-V. vitis-idaea minus*	44	NNW	35	470
Red Hill	7a	55	Open dwarf shrub heath barrens; *Salix reticulata reticulata-Ledum palustre decumbens/Poa alpina*	24	SSE	9	430
	7a	56	Open dwarf shrub heath barrens; *Salix reticulata reticulata-Ledum palustre decumbens/Poa alpina*	25	S	15	420
Okerokovik River	10	34	Riparian willow shrub; *Salix reticulata reticulata/Tomenthypnum nitens*	59	N	3	430

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	10	35	Low & dwarf willow shrub tundra; *Salix reticulata reticulata-Dryas integrifolia integrifolia/Tomenthypnum nitens*	62	ENE	6	440
	10	36	Low & dwarf willow shrub tundra; *Salix planifolia pulchra-Salix reticulata reticulata/Tomenthypnum nitens*	50	ESE	21	490
Marshfork of Canning River	5	63	Riparian willow shrub; *Arctostaphylos rubra-Pyrola rotundifolia grandiflora* w/*Salix alaxensis alaxensis*	30	NW	3	750
	5	64	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia - Carex misandra/Rhytidium rugosum*	47	NW	7	780
	5	65	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia-Carex scirpoidea*	44	ENE	3	780
	5	66	Riparian willow shrub; *Salix alaxensis alaxensis - S. planifolia pulchra/Dryas integrifolia integrifolia*	26	NNW	3	750

6.4 Application of Biotic and Abiotic Relationships

Analyzing a number of environmental factors by a simple correlation is a first step in understanding some of the relationships involved in biological systems. However, cause and effect relationships are not necessarily indicated by simple correlation since plant distribution and growth is a function of all environmental factors.

A number of relationships between factors was associated with changes during succession. The increase in species diversity was associated with plant community development on alluvium except under mature white spruce. Increase in micro-relief is also associated with community maturity which offers a more diverse habitat for species establishment. Species diversity is also higher at mid-slope positions which usually represents a median between the environmental extremes of the dry rocky ridge-tops and wet slope bases. Lichens decrease in importance with more vascular cover and are assessed as important colonizers in gravelly, rocky areas especially common in the mountains. Moss species, on the other hand, are more common in wet areas and high cover is frequently common in wet sedge, tussock tundra and sedge-low shrub vegetation types. Both moss and lichen diversity is lower when vascular species diversity is high and hence appears to be partially limited by competition.

Sites, including those with young balsam poplar and white birch, which are favorable to greater growth rates and species diversity probably have more available nutrients (Hettinger *et al.*, 1973). The possibility of nutrients becoming less available with successional maturity has been discussed by Bliss and Cantlon (1957) and Heilman (1966, 1968). Rejuvenation of the available nutrient pool appears to occur after fires and is related to increase in available nutrients partly through an increase in the active layer depth (Bliss and Wein, 1972). Indications from this and past studies are that disturbance and perturbation are continual processes in the Low Arctic and northern boreal ecosystems and fluctuations of population numbers are inherently associated with these changes. Unless disturbances are severe, a trend toward original conditions is rapidly established. Severe disturbance on permafrost is of concern however since subsidence of the surface and additional slumping may take a relatively long time to stablize. This feature and the simplistic structure of the ecosystems are mostly responsible for the widespread concept of fragility in the Arctic (Bliss *et al.*, 1973). However Dunbar (1973) discusses the concept that instability is a naturally occurring phenomenon of most Arctic systems which are therefore adapted to perturbation. The amount of disturbance that northern ecosystems can tolerate before irreversible change is initiated is the questionable entity and caution is the best policy in land use. Heginbottom (1973) indicates that slope failure is a common result of a number of disturbances including fire and ground vegetation removal. A number of guidelines have been developed and are discussed by Wein and Bliss (1973a,c) with regard to potential problem areas. The presence of silty soil over high ice-content permafrost is probably the extreme of instability which is compounded where slopes are involved. Most problem areas are indicated by a high frequency of natural instability which could be increased by usage of the area by man.

7.0 SUMMARY AND CONCLUSIONS

Fourteen clusters with 41 component associations are categorized for the study area from the cluster analysis. Ubiquitous species are a dominant character for several groups, but combinations of dominant species are used for the association nomenclature.

Stands from widely separated areas are often placed in the same association as a result of similar composition. However, the association is used as an indication of some environmental equivalency and therefore it is possible to have, for instance, stands from a xeric site in the Arctic Coastal Plain and a more mesic site in the Porcupine Plateau within the same association.

Thirty basic vegetation categories are utilized to classify the associations in relation to terrain types. Wet sedge meadow, dwarf or low shrub sedge and white spruce forest types occur most frequently in the physiographic regions. However, sedge, herb-sedge, lichen meadows and heath shrub vegetation cover the greatest amount of area.

Successional trends toward white spruce climax are identified in the Porcupine Plateau, Southern Foothills and Brooks Range. The riparian sere established after alluvial disturbance with balsam poplar, willow and sometimes alder vegetation typifying much of the vegetation. Secondary succession after fire or slope failures is characterized by white spruce or mixed stands of white birch and white spruce. The white spruce/feather-moss community which are here recognized as a climax type require at least 125 years to develop on alluvium and about 110 years on upland sites. Heath and sedge vegetation types may eventually replace white spruce vegetation if the active layer becomes thin and cold enough, but the replacement takes at least 300 years and hence climax status depends on the time scale used in making comparisons with seres in other areas.

Alpine vegetation develops mostly on frost shattered rock and colluvial surfaces. Lichens, sedges, mountain avens and dwarf willow are important in the early portion of upland seres. An increase in heaths including Lapland cassiope, and moss is associated with the more mature portion of the sere. Mature vegetation in the Arctic Foothills and Arctic Coastal Plain is represented by heath, sedge, and cotton grass communities which occupy a median between xeric and hydric habitat extremes. Species of the early portion of the sere are varied since hydric to xeric conditions are involved. Felt-leaved willow is important as a colonizer in most riparian seres, but is usually succeeded by other willow species which in turn are replaced by species with a lower stature.

A trend from medium tall and tall shrub types toward low shrub and graminoid communities is frequently indicated for most riparian and upland sites within the study area throughout most of the coastal plain. A decrease in the active layer depth, and associated decrease in aeration, soil temperatures and possibly nutrient turnover rate is related to sere maturity. Most of the tree species have higher growth rates in the earlier portions of the sere when active layer depths are relatively deep and soils are still well-drained. Communities with greater microtopographic relief are associated with mature communities, with the exception of white spruce types. Increase in micro-relief is also related to an increase in species diversity. Both lichen and moss species diversity appears to be limited by the presence of vascular species. Most of the soils were found to be immature. The Eutric Brunisol soils of well drained slopes and ridges are the best developed and support relatively diverse communities. Cryosols and Regosols which represent two extremes in soil environment, are common, with Cryosols predominating in all of the areas except the Brooks Range. The predominance of the Gleysolic Turbic Cryosol Subgroup gives an indication of the high frequency of instability due to frost action and associated drainage. No consistent relationships between soil sub-groups and vegetation types are indicated. Regosols are usually associated with early vegetation successional phases, especially on alluvium and bedrock. Mountain avens and willow communities are often associated with Turbic Great Groups and hence an increased micro-relief.

A number of terrain types with silt textured Turbic Cryosol soils are identified as potential land-use problem areas. The combination of slope angle and silt over ice-rich permafrost increases the amount of instability of the land surface as is indicated by patterned ground, slope failures and thermokarst slumping after natural disturbance.

Instability and perturbation are inherent components of low Arctic ecosystems. However, the organisms and communities are adapted to cope with these disruptive forces, and some populations require cyclic environmental fluctuations for survival. The threshold whereby disturbance becomes intolerable to existing ecosystems is conjectural and hence of concern since most are structurally simple and closely inter-related. Therefore, all the populations of the area must be respected with regard to their functional importance in maintaining certain ecosystems.

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Appendix 1. Monthly temperature and precipitation values for six stations nearest the study area in Alaska and Canada.

Element and Station	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Stokes Point	Lat. 69° 20' N		Long. 130° 46' W		El. 3m								
Mean Daily Temp. (°C)	-26.7	-26.7	-25.6	-17.8	- 4.4	2.2	7.8	6.7	1.1	- 8.3	-20.0	-24.4	-11.1
Mean Daily Max. Temp.	-22.2	-22.8	-22.2	-13.3	- 1.1	5.0	11.7	10.0	3.9	- 5.6	-16.7	-21.7	- 7.8
Mean Daily Min. Temp.	-30.6	-30.6	-28.9	-21.7	- 7.8	- 0.6	3.9	3.3	- 1.7	-11.1	-22.8	-27.2	-14.4
Max. Temp.	2.8	0	- 2.8	8.9	16.1	24.4	27.8	23.3	18.3	7.8	- 3.9	3.3	27.8
Min. Temp.	-49.4	-41.1	-42.2	-40.6	-26.1	- 7.2	- 2.8	- 2.8	- 9.4	-30.0	-38.3	-40.0	-49.4
Komakuk Beach	Lat. 69° 35' N		Long. 140° 11' W		El. 3m								
Mean Daily Temp. (°C)	-26.7	-26.7	-26.7	-18.3	- 5.6	2.8	7.2	6.1	0.6	- 8.9	-18.9	-23.3	-23.9
Mean Daily	-22.2	-22.2	-22.8	-13.9	- 2.2	5.6	11.7	9.4	3.3	- 5.6	-15.0	-18.9	- 7.8
Mean Daily Min. Temp.	-31.1	-30.0	-30.6	-22.8	- 8.3	- 0.6	2.8	2.2	- 2.2	-12.2	-23.3	-27.2	-15.6
Max. Temp.	8.3	- 0.6	0	7.8	15	25.6	27.2	25.6	13.9	6.7	7.2	7.2	27.2
Min. Temp.	-46.7	-42.2	-47.8	-35.6	-25.0	- 8.9	- 5.0	- 2.8	-11.1	-23.9	-38.9	-44.4	-47.8
Mean Total Precip. (cm)	0.86	0.30	0.15	0.30	0.36	1.78	4.09	3.28	1.57	2.11	0.51	0.08	15.4
No. Days With Meas. Rain	1	0	0	0	0	2	6	4	3	*	0	0	16
No. Days With Meas. Precip.	3	3	1	1	2	3	7	5	5	6	2	*	38
Shingle Point	Lat. 68° 57' N		Long. 137° 12' W		El. 9m								
Mean Daily Temp (°C)	-26.1	-26.1	-26.1	-17.8	- 3.9	5.0	10.0	8.9	1.7	- 7.8	-20.0	-23.9	-10.6
Mean Daily Max. Temp.	-21.7	-22.2	-22.2	-13.3	- 0.6	8.9	15.6	12.8	4.4	- 4.4	-16.1	-19.4	- 6.7
Mean Daily Min. Temp.	-30.6	-30.0	-30.0	-21.7	- 7.8	1.1	5.0	5.0	- 1.1	-11.1	-11.1	-27.8	-14.4

continued........	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Max. Temp.	3.3	1.7	0	7.8	17.8	28.3	27.8	28.9	20.0	10.0	6.7	1.7	28.9
Min. Temp.	-51.1	-43.9	-42.2	-38.9	-27.2	- 8.9	- 6.7	- 3.9	-13.3	-27.8	-42.2	-47.2	-51.1
Mean Total Precip. (cm)	0.64	0.18	0.15	0.66	0.51	2.49	4.65	3.25	1.37	3.81	0.71	0.18	18.6
No. Days With Meas. Rain	0	0	0	0	1	7	10	8	3	1	0	0	30
No. Days With Meas. Presip.	1	1	1	2	3	7	10	8	6	9	3	1	52
<u>Old Crow</u>	Lat. 67° 58' N		Long. 139° 38' W		El. 243m								
Mean Total Precip. (cm)	0.74	0.38	0.84	0.91	0.74	5.36	2.60	1.78	1.20	1.45	1.35	1.83	19.15
No. Days With Meas. Rain	0	0	0	0	1	5	3	3	1	1	0	0	14
No. Days With Meas. Precip.	2	2	3	2	2	5	3	3	2	5	4	2	35
<u>Barrow, Alaska</u>	Lat. 71° 18' N		Long. 156° 47' W		El. 9m								
Mean Daily Temp. (°C)	-26.7	-27.8	-26.1	-17.8	- 7.8	0.6	3.9	3.3	- 1.1	- 8.3	-18.3	-23.9	-12.2
Mean Daily Max. Temp.	-22.8	-24.4	-22.2	-13.9	- 4.4	3.3	7.2	6.1	1.1	- 6.1	-15.0	-20.6	- 9.4
Mean Daily Min. Temp.	-30.6	-31.1	-29.4	-21.7	-10.6	- 1.7	0.6	0.6	- 2.8	-11.1	-21.7	-27.2	-15.6
Max. Temp.	1.7	0	0.6	5.6	7.2	21.1	25.6	22.8	16.7	6.1	3.9	1.1	25.6
Min. Temp.	-47.2	-48.9	-46.7	-41.1	-27.8	-13.3	- 5.6	- 6.7	-17.2	-29.4	-40.0	-48.3	-48.9
Mean Total Precip. (cm)	0.46	0.43	0.28	0.28	0.30	0.91	1.96	2.29	1.62	1.27	0.58	0.43	10.82
<u>Barter Island, Alaska</u>	Lat. 70° 08' N		Long. 143° 38' W		El. 12m								
Mean Daily Temp. (°C)	-27.2	-28.9	-26.1	-17.2	- 6.1	1.1	5.0	4.4	0	- 8.3	-17.8	-23.3	-12.2
Mean Daily Max. Temp.	-23.3	-25.0	-22.2	-12.8	- 3.3	3.9	8.9	7.2	2.2	- 5.0	-14.4	-20.0	- 8.9
Mean Daily Min. Temp.	-31.1	-32.2	-30.0	-21.7	- 8.9	- 1.7	1.7	1.7	- 2.2	-11.1	-21.1	-27.2	-15.6

continued........	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Max. Temp.	3.9	1.1	2.2	6.1	11.1	19.4	23.9	22.2	17.8	6.1	2.8	1.7	23.9
Min. Temp.	-46.1	-50.6	-45.6	-38.3	-26.7	- 9.4	- 4.4	- 4.4	-13.9	-29.4	-46.1	-46.1	-50.6
Mean Total Precip. (cm)	1.02	0.89	0.51	0.43	0.64	1.30	2.24	2.67	2.40	0.56	0.27	0.19	4.22

Appendix 2. Annotated species list with common names collected or identified from the study area.

VASCULARS

Trees

Betula papyrifera Marsh.	paper birch
Picea glauca (Moench)	white spruce
Populus balsamifera L.	balsam poplar, cottonwood
P. tremuloides Michx.	quaking aspen

Tall and Low Shrubs

Alnus crispa (Ait.) Pursh ssp. *crispa*	mountain alder
Betula glandulosa Michx.	dwarf birch
B. glandulosa x *nana* [1]	dwarf birch
B. nana L. ssp. *exilis* (Sukatsch.) Hult.	dwarf birch
B. occidentalis Hook.	shrub birch
Chamaedaphne calyculata (L.) Moench	cassandra
Juniperis communis L.	common mountain juniper
J. communis L. ssp. *nana* (Willd.) Syme	common mountain juniper
Ledum palustre L. ssp. *decumbens* (Ait.) Hult.	northern Labrador tea
L. palustre L. ssp. *groenlandicum* (Oeder) Hult.	Labrador tea
Ribes triste Pall.	northern red currant
Rosa acicularis Lindl.	prickly rose
Salix alaxensis (Anderss.) Cov. ssp. *alaxensis*	felt leaf willow
S. alaxensis (Anderss.) Cov. ssp. *longistylis* (Rydb.) Hult.	felt leaf willow
S. arbusculoides Anderss.	willow
S. glauca L.	willow
S. glauca L. var. *acutifolia* (Hook.) Hult	willow
S. glauca L. var. *glauca*	willow
S. hastata L.	willow
S. lanata L. ssp. *richardsonii* (Hook.) A. Skvortz	willow
S. planifolia ssp. *pulchra* (Cham.) Argus	willow
S. reptans Rupr.	willow
S. reticulata L. ssp. *reticulata*	netted willow
S. sphenophylla A. Skvortz	willow
Shepherdia canadensis (L.) Nutt.	soapberry
Vaccinium uliginosum L. ssp. *alpinum* (Bigel.) Hult.	alpine blueberry

Herbs, Dwarf Shrubs and Grasses

Achillea borealis Bong.	yarrow
Aconitum delphinifolium DC.	monkshood
A. delphinifolium DC. ssp. *delphinifolium*	monkshood
A. violaceum (Hornem.) Lange ssp. *andinum* (Scribn. & Sm.) Mekderis	wheatgrass
A. yukonense Scribn. & Merr.	wheatgrass
Alopecurus alpinus Sm. ssp. *alpinus*	alpine foxtail
Andromeda polifolia L.	bog rosemary
Androsace chamaejasme Host ssp. *lehmanniana* (Spreng.) Hult.	sweet-flowered androsace
A. septentrionalis L.	fairy candelabra
Anemone drummondii S. Wats.	cut-leaved anemone
A. parviflora Michx.	anemone
A. richardsonii Hook.	anemone
Antennaria alaskana Malte	pussytoe
A. friesiana (Trautv.) Ekman ssp. *alaskana* (Malte) Hult.	pussytoe
A. friesiana (Trautv.) Ekman ssp. *compacta* (Malte) Hult.	pussytoe
Arctagrostis latifolia (R. Br.) Griseb. var. *latifolia*	polar grass
Arctostaphylos alpina (L.) Spreng.	bearberry
A. rubra (Rehd. & Wilson) Fern.	Arctic bearberry
A. uva-ursi (L.) Spreng.	kinnikinnick
Arnica alpina (L.) Olin	maguire
A. frigida C.A. Mey.	arnica
Artemesia alaskana Rydb.	wormwood
A. arctica Less. ssp. *comata* (Rydb.) Hult.	wormwood
A. frigida Willd.	prairie sagewort
A. tilesii Ledeb. ssp. *elatior* (Torr. & Gray) Hult.	wormwood
Aster ciliatus (Ledeb.) Fedsch.	aster
A. sibiricus L.	aster
Astragalus aboriginum Richards.	milk vetch
A. alpinus L.	milk vetch
A. alpinus L. ssp. *arcticus* (Bunge) Hult.	milk vetch
A. umbellatus Bunge	milk vetch
Boschniakia rossica (Cham. & Schlecht.) Fedtsh.	
Boykinia richardsonii (Hook.) Gray	Alaska boykinia
Braya humilis (C.A. Mey.) Robins.	mustard
B. purpurascens (R. Br.) Bunge	mustard
Bromus pumpellianus Scribn.	brome grass
B. pumpellianus Scribn. ssp. *arcticus* (Shear Pors.	brome grass
Bupleurum triradiatum Adams	thoroughwax
B. triradiatum Adams ssp. *arcticum* (Regel) Hult.	thoroughwax
Calamagrostis canadensis (Michx.) Beauv.	bluejoint
C. purpurascens R. Br.	reed bent grass

Caltha palustris L. ssp. *arctica* (R. Br.) Hult.	marsh marigold
Campanula unifolora L.	bellflower
Cardamine bellidifolia L.	bitter cress
C. hyperborea O.E. Schulz	bitter cress
C. microphylla Adams	bitter cress
C. pratensis L. ssp. *angustifolia* (Hook.) O.E. Schulz	cuckoo flower
Carex amblyorhyncha Krecz.	sedge
C. aquatilis Wahlenb.	sedge
C. atrofusca Schkuhr	sedge
C. bigelowii Torr.	sedge
C. capillaris L.	sedge
C. capitata Soland. in L.	sedge
C. concinna R. Br.	sedge
C. glacialis Mack.	sedge
C. gynocrates Wormsk.	sedge
C. limosa L.	sedge
C. livida (Wahlenb.) Willd.	sedge
C. lugens Holm	sedge
C. macrochaeta C.A. Mey	sedge
C. maritima Gunn.	sedge
C. media R. Br.	sedge
C. membranacea Hook.	sedge
C. microchaeta Holm	sedge
C. misandra R. Br.	sedge
C. nardina E. Fries	sedge
C. petricosa Dew.	sedge
C. rariflora (Wahlenb.) J.E. Sm.	sedge
C. rupestris All.	sedge
C. saxatilis L. ssp. *laxa* (Trauv.) Kalela	sedge
C. scirpoidea Michx.	sedge
C. spp.	sedge
C. vaginata Tausch	sedge
Cassiope tetragona (L.) D. Don	Lapland cassiope
C. tetragona (L.) D. Don ssp. *tetragona*	Lapland cassiope
Castilleja caudata (Pennell) Rebr.	Indian paintbrush
Cerastium beeringianum Cham. & Schlecht. var. *grandiflorum* (Fenzl) Hult.	mouse-ear chickweed
C. maximum L.	mouse-ear chickweed
Chrysanthemum integrifolium Richards.	chrysanthemum
Claytonia acutifolia Pakk. ssp. *graminifolia* Hult.	spring beauty
C. sarmentosa E.A. Mey.	spring beauty
Corydalis aurea Willd.	golden corydalis
Crepis nana Richards.	hawk's-beard
Cystopteris fragilis (L.) Bernh.	fragile fern
Delphinium brachycentrum Ledeb.	larkspur
D. glaucum S. wats.	larkspur
Deschampsia brevifolia R. Br.	grass
D. caespitosa L. Beauv. var. *caespitosa*	grass

D. caespitosa L. Beauv. var. *glauca* (Hartm.) Sam.	grass
Diapensia lapponica L.	
Dodecatheon frigidum Cham. & Schlecht.	shooting star
Draba alpina L. [3]	mustard
D. corymbosa [3]	mustard
D. fladnizensis Wulf. [3]	mustard
D. lactea Adams [3]	mustard
Draba palouderiana [1]	mustard
Dryas drummondii Richards.	yellow dryas
D. integrifolia M. Vahl. ssp. *integrifolia*	mountain avens
D. octopetala L. ssp. *octopetala*	mountain avens
D. ssp.	avens
Dryopteris fragrans (L.) Schott	shield fern
Dupontia fischeri R. Br. ssp. *psilosantha* (Rupr.) Hult.	grass
Elymus arenarius L. ssp. *mollis* (Trin.) Hult var. *villosissimus* (Scribn.) Hult.	lyme grass
Empetrum nigrum L. ssp. *hermaphroditum* (Lange) Bocher	crowberry
Epilobium latifolium L.	river beauty
Equisetum arvense L.	common horsetail
E. multiflora [1]	horsetail
E. palustre L.	horsetail
E. pratense L.	horsetail
E. scirpoides Michx.	horsetail, scouring rush
E. silvaticum L.	horsetail
E. variegatum Schleich. ssp. *variegatum*	horsetail
Erigeron eriocephalus J. Vahl	fleabane, wild daisy
E. hyperboreus Greene	
Eriophorum angustifolium Honck. ssp. *subarcticum* (Vassil jev.) Hult.	cotton grass
E. angustifolium Honck. ssp. *triste* (T. Fries) Hult.	cotton grass
E. brachyantherum Trautv. & Mey.	cotton grass
E. callitrix Cham.	cotton grass
E. scheuchzeri Hoppe var. *scheuchzeri*	cotton grass
E. scheuchzeri Hoppe var. *tenuifolium*	cotton grass
E. vaginatum ssp. *spissum* (Fern.) Hult	cotton grass
E. vaginatum L. ssp. *vaginatum*	cotton grass
Eritrichium aretioides (Cham.) DC.	Arctic forget-me-not
Erysimum pallasii (Pursh) Fern	mustard
Eutrema edwardsii R. Br.	mustard
Fustuca altaica Trin.	fescue grass
F. brachyphylla Schult.	fescus grass
F. ovina L. ssp. *alaskensis* Holmen	fescue grass
F. rubra L. coll. ssp. *richardsonii* (R. Br.) Hult.	fescue grass
Gentiana glauca Pall.	gentian
G. propinqua Richards.	gentian

G. propinqua Richards. ssp. *propinqua*	gentian
Geum glaciale Adams	avens
G. rossii (R. Br.) Ser.	avens
Hedysarum alpinum L. ssp. *americanum* (Michx.) Fedtsch	hedysarum
H. mackenzii Richards.	hedysarum
Hierochloe alpina (Sw.) Roem. & Schult.	holy grass
H. pauciflora R. Br.	holy grass
Hippuris vulgaris L.	mare's tail
Juncus arcticus Willd.	rush
J. arcticus Willd. ssp. *alaskanus* Hult.	rush
J. balticus Willd.	rush
J. biglumis L.	rush
J. castaneus Sm.	rush
J. triglumis L.	rush
J. triglumis L. ssp. *triglumis*	rush
Kobresia myosuroides (Vill.) Fiori & Paol.	sedge
K. sibirica Turcz.	sedge
K. simpliciuscula (Wahlenb.)	sedge
Lagotis glauca Gaertn.	figwort
L. glauca Gaertn. ssp. *minor* (Willd.) Hult.	figwort
Lesquerella arctica (Wormsk.) S. Wats.	bladder-pod
Linnaea borealis L.	twinflower
Lupinus arcticus S. Wats.	lupine
Luzula arctica Blytt	wood rush
L. arcuata (Wahlenb.)	wood rush
L. confusa Lindeb.	wood rush
L. multiflora (Retz.) Lej. var. *frigida* (Buchenau) Sam.	wood rush
L. multiflora (Retz.) Lej. ssp. *multiflora*	wood rush
L. parviflora (Ehrh.) Desv.	wood rush
L. tundricola Goroodk	wood rush
Lycopodium calavatum L. ssp. *monostachyon* (Grev. & Hook.) Sel.	common club moss
L. complanatum L.	Christmas green, creeping Jenny
L. selago L.	fir club moss
L. selago L. ssp. *appressum* (Desv.) Hult.	club moss
Melandrium affine J. Vahl	bladder-campion
M. apetalum (L.) Fenzl. ssp. *arcticum* (E. Fries) Hult.	bladder-campion
Menyanthes trifoliata L.	buckbean
Mertensia paniculata (Ait.) G. Don ssp. *paniculata*	bluebell
Minuartia arctica (Stev.) Aschers. & Graebn.	minuartia
M. rossii (R. Br.) Graebn.	minuartia
M. rubella (Wahlenb.) Grabn.	minuartia
Myosotis alpestris F. W. Schmidt ssp. *asiatica* Vestergr.	forget-me-not
Orchis rotundifolia Banks.	orchid
Oxyria digyna (L.) Hill	mountain sorrel

Oxytropis arctica R. Br.	loco-weed
O. borealis DC.	loco-weed
O. campestris (L.) DC. ssp. *gracilis* (Nels.) Hult.	late yellow loco-weed
O. koyukukensis Pors.	loco-weed
O. maydelliana Trautv.	loco-weed
O. nigrescens (Pall.) Fisch. ssp. *pygmaea* (Pall.) Hult.	loco-weed
O. scammaniana Hult.	loco-weed
O. spp.	loco-weed
O. viscida Nutt.	loco-weed
Papaver macounii Greene	poppy
P. spp.	poppy
Parnassia kotzebuei Cham. & Schlecht.	grass-of-parnassus
P. palustris L. ssp. *neogaea* (Fern.) Hult.	northern-grass-of-parnassus
Parrya nudicaulis (L.) Regel ssp. *septentrionalis* Hult.	mustard
Pedicularis capitata Adams	lousewort
P. kanei Durand ssp. *kanei*	lousewort
P. labradorica Wirsing	lousewort
P. langsdorffii Fisch. ssp. *arctica* (R. Br.) Pennell	lousewort
P. oederi M. Vahl	lousewort
P. spp.	lousewort
P. sudetica Willd.	lousewort
P. verticillata L.	lousewort
Petasites frigidus (L.) Franch.	sweet coltsfoot
Phlox sibirica L.	phlox
Pinguicula vulgaris L.	bitterwort
Poa abbreviata R. Br.	blue grass
P. alpigena (E. Fries) Lindm.	blue grass
P. alpina L.	blue grass
P. arctica R. Br.	blue grass
P. glauca M. Vahl	blue grass
P. lanata Scribn. & Merr.	blue grass
P. pratensis L.	blue grass
P. pseudoabbreviata Roshev.	blue grass
P. spp.	blue grass
Polemonium acutiflorum Willd.	Jacob's ladder
P. boreale Adams	Jacob's ladder
Polygonum bistora L. ssp. *plumosum* (Small) Hult.	bistort
P. viviparum L.	bistort
Potentilla biflora Willd.	conquefoil
P. fruticosa L.	shrubby cinquefoil
P. hookeriana Lehm.	cinguefoil
P. multifida L.	cinquefoil
P. nivea L.	cinquefoil
P. palustris (L.) Scop.	marsh fivefinger
Primula sibirica Jacq.	primrose

Pyrola secunda (L.) House [2]	wintergreen
P. secunda L. ssp. *obtusata* (Turcz.) Hult.	one-sided wintergreen
P. rotundifolia ssp. *grandiflora* (Radius) Andres [2]	
Ranunculus hyperboreus Robbt.	buttercup, crowfoot
R. nivalis L.	snow buttercup
R. pedatifidus Sm. ssp. *affinis* (R. Br.) Hult.	buttercup
Rhododendron lapponicum (L.) Wahlenb.	Lapland roesbay
Rubus articus L. ssp. *acaulis* (Michx.) Focke	dwarf raspberry
R. chamaemorus L.	cloudberry
Salix arctica Pall.	Arctic willow
S. arctophila Cockerell	dwarf willow
S. barrattiana Hook.	willow
S. brachycarpa ssp. *niphoclada* (Rydb.) Argus [2]	willow
S. brachycarpa ssp. *niphoclada* x *S. glauca* [2]	willow
S. chamissonis Anderss.	willow
S. fuscescens anderss.	willow
S. ovalifolia Trautv. *ovalifolia* [1]	dwarf willow
Salix phleborphylla Anderss.	willow
S. rotundifolia ssp. *dodgeana* (Rydb.) Argus	willow
Saussurea angustifolia (Willd.) DC.	sawwort
S. nuda Ledb. var. *densa* (Hook.) Hult.	sawwort
S. viscida Hult. var. *yukonensis* (Pors.) Hult.	sawwort
Saxifraga bronchialis L. spp. *funstonii* (Small) Hult.	spotted saxifrage
S. cernua L.	bulblet saxifrage
S. davurica Willd. ssp. *grandipetala* (Engler & Irmsch.) Hult.	saxifrage
S. foliolosa R. Br.	grained saxifrage
S. foliolosa R. Br. var. *multiflora* Hult.	grained saxifrage
S. hieracifolia Waldst. & Kit.	stiff-stemmed saxifrage
S. hirculus L.	bog saxifrage
S. oppositifolia L.	purple mountain saxifrage
S. punctata L. ssp. *nelsoniana* (D. Don) Hult.	cordate-leaved saxifrage
S. tricuspidata Rottb.	prickly saxifrage
Sedum rosea (L.) Scop. ssp. *integrifolium* (Raf.) Hult.	roseroot
Senecio atropurpureus (Ledeb.) Fedtsch. ssp. *frigidus* (Richards.) Hult.	groundsel
S. congestus (R. Br.) DC.	march fleabane
S. fuscatus (Jord. & Fourr.) Hayek	groundsel
S. lugens Richards.	groundsel
S. residifolius Less.	groundsel
S. spp.	groundsel
Silene acaulis L. spp. *acaulis*	moss campion
Stellaria edwardsii R. Br.	chickweed
S. laeta Richards.	chickweed
S. longpipes Goldie	chickweed
S. monantha Hult.	chickweed

Thalitricum alpinum L.	meadow rue
Tofieldia alpine [1]	false asphodel
T. coccinea Richards.	false asphodel
T. pusilla (Michx.) Pers.	false asphodel
Trichophorum caespitosum (L.) Hartm. ssp. *austriacum* (Pall.) Hegi	rush
Triglochin maritimum L.	arrow grass
T. palustris L.	arrow grass
Trisetum spicatum (L.) Richter	grass
Vaccinium vitis-idaea L. ssp. *minus* (Lodd.) Hult.	lingonberry
Valeriana capitata Pall.	valerian
Wilhelmsia physodes (Fisch.) McNeil	
Woodsia ilvensis (L.) R. Br.	lady fern
Zygadenus elegans Pursh	white camass

1 Nomenclature according to G. W. Argus
2 Nomenclature according to G. Mulligan
3 Nomenclature according to E. Haber

MOSSES

Andreaea rupestris Hedw.
Aulacomnium palustre (Hedw.) Schwaegr.
A. turgidum (Wahlenb.) Schwaegr.
Brachythecium turgidum (Hartm.) Kindb.
B. spp.
Bryoerythrophyllum recurvirostrum (Hedw.) Chen
Bryum argenteum Hedw.
B. cryophilum Mart.
B. pseudotriquetrum (Hedw.) Gaertn., Meyer & Schreb.
B. spp.
B. wrightii Sull. & Lesq.
Calliergon giganteum (Schimp.) Kindb.
C. spp
Campylium stellatum (Hedw.) C. Jens.
Catoscopium nigritum (Hedw.) Brid.
Cinclidium arcticum (B.S.G.) Schimp.
Cirriphyllum cirrosum (Schwaegr.ex Schultes) Grout
Cyrtomnium hymenophylliodes (Heub.) Kop.
Dicranoweisia crispula (Hedw.) Linab.ex Milde
Dicranum acutifolium (Lindb. & Arn.) C. Jens. ex Weinm
D. elongatum Schleich ex. Schwaegr.
D. muehlenbeckii B.S.G.
D. scoparium Hedw.
D. spp.
Distichium capillaceum (Hedw.) B.S.G.
Ditrichum flexicaule (Schwaegr.) Hampe
Drepanocladus revolvens (Sw.) Warnst.
D. uncinatus (Hedw.) Warnst.
Eurhynchium pulchellum (Hedw.) Jenn.
Fissidens osmundoides Hedw.
Grimmia alpicola Hedw.
Hylocomium splendens (Hedw.) B.S.G.
Isopterygium pulchellum (Hedw.) Jaeg. & Sauerb.
Meesia triquetra (Richt.) Angstr.
M. uliginosa Hedw.
Oncophorus wahlenbergii Brid
Orthothecium chryseum (Schwaegr. ex Schultes) B.S.G.
Orthotrichum speciosum Nees ex Sturm
Philonotis fontana (Hedw.) Brid. var. *pumila* (Turn.) Brid.
Plagiomnium medium (B.S.G.) Kop.
Pleurozium schreberi (Brid.) Mitt.
Pohlia cruda (Hedw.) Lindb.
Polytrichum commune Hedw.
P. juniperinum Hedw.
P. piliferum Hedw.
P. strictum Brid.
Rhacomitrium lanuginosum (Hedw.) Brid.
Rhytidium rugosum (Hedw.) Kindb.
Scorpidium turgescens (T. Jens.) Loeske

Sphagnum capillaceum (Weiss) Schrank
S. girgensohnii Russ.
S. spp.
S. squarrosum Crome
Tetraplodon mnioides (Hedw.) B.S.G.
Thuidium abietinum (Hedw.) B.S.G.
Timmia austriaca Hedw.
Tomenthypnum nitens (Hedw.) Loeske
Tortula norvegica (Web.) Wahlenb ex Lindb.
T. ruralis (Hedw.) Gaertn., Meyer & Scherb.

LIVERWORTS

Barbilophozia barbata (Schmid.)
Blepharostoma trichophyllum (L.) Dumort.
Calypogeia neesiana (M.&C.) K. Muell.
Chandonanthos setiformis (Ehrh.) Lindb.
Mesoptchia sahlgergii
Ptilidium ciliate (L.) Hampe
Riccardia pinguis (L.) S.F. Gray
Scapania simmonsii
Sphenolobus spp.

LICHENS

Alectoria nitidula (Th. Fr.) Vain
A. ochroleuca (Hoffm.) Mass.
A. subdivergens Dahl
A. tenius Dahl
Asahinea chrysantha (Tuck.) W. Culb & C. Culb.
Caloplaca splendens (Darb.) Zahlbr.
Cetraria commixta (Nyl.) Th. Fr.
C. cucullata (Bell.) Ach.
C. islandica (L.) Ach.
C. laevigata Rass.
C. nivalis (L.) Ach.
C. pinastri (Scop.) S. Gray
C. richardsonii Hook
C. tilesii Ach.
Cladina alpestris (L.) Harm.
C. mitis (Sandst) Hale & W. Culb
Cladonia amaurocraea (Florke) Schaer.
C. phyllophora Hoffm.
C. pyxidata (L.) Hoffm.
C. spp.
Cornicularia aculeata (Schreb.) Ach.
C. normoerica (Gunn.) Du Rietz
Dactylina arctica (Hook.) Nyl.
Evernia mesomorpha Nyl.
E. perfragilis Llano
Haematomma lapponicum Ras.
Hypogymnia physodes (L.) W. Wats.
H. subobscura (Vain.) Poelt
Icmadophila ericetorum (L.) Zahlbr.
Lecanora coilocarpa (Ach.) Nyl.
L. subfusca (L.) Ach.
Lecidea spp.
Leptogium saturninum (Dicks.) Nyl.
Nephroma arcticum (L.) Torss.
Ochrolechia upsaliensis (L.) Mass.
Parmelia panniformis (Nyl.) Vain.
P. separata Th. Fr.
P. sulcata Tayl.
Parmeliopsis ambigua (Wulf.) Nyl.
Peltigera aphthosa (L.) Willd.
P. canina (L.) Willd.
Pertusaria dactylina (Ach.) Nyl.
Physconia muscigena (Ach.) Poelt
Polyblastia cupularis Mass.
Polyblastiopsis inductula (Nyl.) Fink
Ramalina minuscula (Nyl.) Nyl.
Rhizocarpon concentricum (Dav.) Beltr.
R. geographicum (L.) DC.

Solorina bispora Nyl.
S. crocea (L.) Ach.
Stereocaulon grande (Magn.) Magn.
Thamnolia subuliformis (Ehrh.) W. Culb.
Umbilicaria hyperborea (Ach.) Ach.
U. proboscidea (L.) Schrad.
Usnea spp.

Appendix 3. Stand locations with general vegetation type and physical features in the study area. Site number refers to those placed on Figure 1.

PORCUPINE PLATEAU

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
Grayling lake	1	1	Low shrub - herb; *Salix glauca acutifolia/Dryas octopetala*	51	WNW	15	760
	1	2	Dwarf heath shrub w/ open white spruce; *Vaccinium vitis-idaea minus-V. uliginosum alpinum*	54	S	10	600
	1	3	Low shrub-heath; *Betula nana exilis/Hylocomium splendens*	38	NNE	8	550
	1	4	Low shrub-heath; *Betula nana exilis/Hylocomium splendens*	59	S	10	580
	1	5	Dwarf heath, wet sedge; *Carex membranacea-Arctostaphylos rubra/Tomenthypnum nitens*	41	-	0	490
	1	6	Tall willow-heath shrub; *Salix glauca acutifolia/Ledum groenlandicum-Vaccinium vitis-idaea minus*	35	NW	9	500

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	1	7	Dryas-moss-shrub w/open white spruce; *Dryas integrifolia integrifolia/ Tomenthypnum nitens*	43	-	0	490
Koness River	2	8	Wet sedge meadow (strangmoor); *Carex bigelowii-C. rariflora-C. saxitilus laxa*	38	NE	3	400
	2	9	White birch forest; *Betula papyrifera/ Hylocomium splendens*	34	W	25	430
	2	10	White birch forest; *Betula papyrifera/ Hylocomium splendens*	41	W	25	550
	2	11	Alpine and subalpine Dryas meadow; *Dryas octopetala octopetala/ Minuartia rossii, D. integrifolia integrifolia-Carex misandra/Rhytidium rugosum*	23	-	0	760
	2	12	Alpine and subalpine Dryas meadow; *Dryas octopetala octopetala/ Minuartia rossii, D. integrifolia integrifolia-Carex misandra/Rhytidium rugosum*	58	N	15	700

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
Monument Creek	1	13	White spruce forest (white spruce woodland terrace); *Picea glauca/Hylocomium splendens*	30	-	0	490
	1	14	Balsam poplar forest; *Populus balsamifera/ Arctostaphylos rubra/ Pyrola rotundifolia grandiflora*	26	-	0	490
Index Mountain	3	15	Wet sedge meadow w/ scattered shrubs; *Salix planifolia pulchra/Carex bigelowii/Hylocomium splendens*	45	E	8	1280
	3	16	Low shrub-moss meadow; *Salix reticulata reticulata/Hylocomium splendens*	50	E	15	1300
	3	17	Wet sedge meadow w/ scattered shrubs; *Cassiope tetragona-Carex bigelowii*	57	E	6	1270
	3	18	Alpine open dwarf shrub-sedge; *Salix reticulata reticulata/Carex saxitilus laxa*	28	SE	12	1510
	3	19	Alpine open dwarf shrub-sedge; *Salix reticulata reticulata/Carex saxitilus laxa*	36	NNW	8	1510

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	3	20	Alpine open dwarf shrub-sedge; *Dryas octopetala octopetala/Minuartia rossii*	44	SSE	15	1342
	3	21	Dwarf shrub-sedge meadow; *Salix reticulata reticulata/ Hylocomium splendens*	43	E	10	1140
	3	22	Low heath & willow shrub; *Salix planifolia pulchra/ Petasites frigidus*	52	ENE	12	1160
	3	23	Low heath & willow shrub; *Betula nana exilis/Vaccinium uliginosum alpinum*	58	NNE	7	850
	3	24	Low heath & willow shrub; *Betula nana exilis/Hylocomium splendens* w/cotton grass (*Eriophorum vaginatum vaginatum*)	46	NNE	2	850
	3	25	Low heath & willow shrub; *Salix reticulata reticulata/Dryas integrifolia integrifolia/ Tomenthypnum nitens* w/open willow (*Salix planifolia pulchra*)	49	NNE	7	860
	3	26	Low shrub heath; *Betula nana exilis* w/open white spruce	57	WSW	13	760

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
Kongakut River	11	27	Wet sedge meadow; *Salix ovalifolia ovalifolia/ Dryas integrifolia integrifolia-Arctagrostis latifolia latifolia-Carex bigelowii*	48	ENE	1	60
	11	28	Heath-sedge tussock tundra; *Dryas integrifolia integrifolia-Cassiope tetragona-Carex scirpoidea-Vaccinium uliginosum alpinum*	56	NNW	2	70
	11	29	Low shrub-sedge meadow & hummocky tundra; *Salix lanata richardsonii-Carex vaginata/Hylocomium splendens*	57	NNE	3	70
	11	30	Low shrub-sedge meadow & hummocky tundra; *Salix planifolia pulchra/Carex bigelowii*	66	N	1	85
Okerokovik River	10	37	Tussock tundra; *Salix reticulata reticulata-Dryas integrifolia integrifolia-Eriophorum vaginatum vaginatum/Tomenthypnum nitens*	62	NE	9	213
	10	38	Wet sedge meadow; *Salix planifolia pulchra/Carex bigelowii*	36	ENE	1	210

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
Canning River	8a	39	Dwarf shrub-Dryas meadow; *Salix ovalifolia ovalifolia/ Dryas integrifolia integrifolia/Arctagrostis latifolia latifolia*	20	ENE	1	122
Sagavanirktok River	9	40	Dwarf shrub-Dryas meadow; *Dryas integrifolia integrifolia-Carex bigelowii*	26	-	0	20
	9	41	Dwarf shrub-Dryas meadow; *Salix reticulata reticulata-Dryas integrifolia integrifolia/ Tomenthypnum nitens*	26	-	0	18
	9	42	Tussock tundra; *Salix planifolia pulchra/Carex bigelowii-Eriophorum vaginatum vaginatum*	60	NNW	1	20
	9	43	Wet sedge meadow; *Carex bigelowii-C. rariflora-C. saxitilus laxa*	22	E	1	100
	9	44	Wet sedge meadow; *Salix reticulata reticulata-Carex bigelowii/Tomenthypnum nitens*	50	-	0	30

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	9	45	Heath-sedge tussock tundra; *Cassiope tetragona/Carex bigelowii-Ledum palustre decumbens*	62	-	0	50
Kadleroshilik River	8	53	Wet sedge meadow; *Salix reticulata reticulata-Carex bigelowii/Tomenthypnum nitens*	42	SSE	6	80
	8	54	Heath-sedge tussock tundra; *Cassiope tetragona/Carex bigelowii/Ledum palustre decumbens*	54	ESE	1	70
Weir Creek	7	57	Low shrub-sedge meadow & hummocky tundra; *Salix planifolia pulchra-Carex misandra/Aulocomnium turgidum-Hylocomium splendens*	52	WSW	2	150
	7	58	Riparian willow shrub; *Salix planifolia pulchra/Petasites frigidus*	25	N	2	130
Hill 659	8	59	Wet sedge meadow; *Betula nana exilis/Carex aquatilis-C. bigelowii*	39	SW	7	130
	8	60	Tussock tundra; *Salix planifolia pulchra/Carex bigelowii-C. misandra*	46	SW	7	140
Lake 188	8	61	Wet sedge meadow; *Salix planifolia pulchra/Carex aquatilis*	22	-	0	60

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	8	62	Wet sedge meadow; *Salix reticulata reticulata/Carex bigelowii/Tomenthypnum nitens*	44	-	0	60
Kongakut River	11	31	Tussock tundra; *Salix planifolia pulchra/Eriophorum vaginatum vaginatum/Hylocomium splendens*	54	N	8	250
	11	32	Sedge meadow; *Salix glauca glauca/Carex aquatilis-Petasites frigidus*	40	NNE	7	210
	11	33	Sedge meadow; *Salix planifolia/pulchra/Carex aquatilis*	38	NNE	4	160
Red Hill	7a	46	Tussock tundra; *Salix planifolia pulchra/Carex bigelowii/Hylocomium splendens*	42	NW	13	550
	7a	47	Dwarf shrub-sedge; *Salix reticulata reticulata-Dryas integrifolia integrifolia/Tomenthypnum nitens*	43	NNW	20	520
	7a	48	Dwarf shrub-sedge meadow; *Carex membranacea/Hylocomium splendens-Tomenthypnum nitens*	47	N	40	470

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	7a	49	Dwarf shrub-sedge meadow; *Salix reticulata reticulata Dryas integrifolia integrifolia-Carex bigelowii*	45	N	13	450
Gilead Creek	6a	50	Riparian shrub & open forest; *Salix alaxensis alaxensis-S. planifolia pulchra/Dryas integrifolia integrifolia* w/balsam poplar	41	NNW	4	460
	6a	51	Riparian shrub & open forest; *Salix alaxensis alaxensis/Hylocomium splendens*	32	NNW	1	460
	6a	52	Dwarf heath lichen tundra; *Vaccinium uliginosum alpinum-V. vitis-idaea minus*	44	NNW	35	470
Red Hill	7a	55	Open dwarf shrub heath barrens; *Salix reticulata reticulata-Ledum palustre decumbens/Poa alpina*	24	SSE	9	430
	7a	56	Open dwarf shrub heath barrens; *Salix reticulata reticulata-Ledum palustre decumbens/Poa alpina*	25	S	15	420
Okerokovik River	10	34	Riparian willow shrub; *Salix reticulata reticulata/Tomenthypnum nitens*	59	N	3	430

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	10	35	Low & dwarf willow shrub tundra; *Salix reticulata reticulata-Dryas integrifolia integrifolia/Tomenthypnum nitens*	62	ENE	6	440
	10	36	Low & dwarf willow shrub tundra; *Salix planifolia pulchra-Salix reticulata reticulata/Tomenthypnum nitens*	50	ESE	21	490
Marshfork of Canning River	5	63	Riparian willow shrub; *Arctostaphylos rubra-Pyrola rotundifolia grandiflora* w/*Salix alaxensis alaxensis*	30	NW	3	750
	5	64	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia - Carex misandra/Rhytidium rugosum*	47	NW	7	780
	5	65	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia-Carex scirpoidea*	44	ENE	3	780
	5	66	Riparian willow shrub; *Salix alaxensis alaxensis - S. planifolia pulchra/Dryas integrifolia integrifolia*	26	NNW	3	750

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	5	67	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia-Cassiope tetragona* w/willow (*Salix alaxensis alaxensis*)	25	NW	4	750
	5	68	Alpine sedge meadow (strangmoors); *Dryas integrifolia integrifolia Tomenthypnum nitens*	44	W	2	750
	5	69	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia/ Rhytidium rugosum*	45	W	30	990
	5	70	Alpine Dryas-sedge meadow; *Dryas integrifolia integrifolia/Carex scirpoidea*	53	W	15	860
	5	71	Alpine Dryas-sedge meadow; *Dryas integrifolia integrifolia/ Carex scirpoidea*	45	WNW	10	860
	5	72	Low & dwarf willow shrub tundra; *Salix glauca acutifolia/ Arctostaphylos rubra-Vaccinium uliginosum alpinum*	51	NW	30	860
	5	73	Alpine heath-Dryas meadows; *Dryas integrifolia integrifolia-Cassiope tetragona*	52	NNW	50	870

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
f	5	74	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia-Carex scirpoidea*	41	WNW	2	810
Marshfork-Eastfork confluence	5	75	Alpine dwarf shrub-lichen fellfield; *Salix reticulata reticulata/ Carex macrochaeta/Rhacomitrium lanuginosum*	26	SE	30	1530
	5	76	Low birch shrub; *Betula nana exilis-Vaccinium uliginosum alpinum*	57	SSE	20	1310
Cache Creek	6	77	Bearberry-herb w/open balsam poplar; *Arctostaphylos rubra-Pyrola rotundifolia grandiflora*	36	SW	2	490
	6	78	Low birch shrub; *Betula nana exilis/Hylocomium splendens*	40	SW	2	490
	6	79	Riparian willow shrub; *Salix alaxensis alaxensis/Hylocomium splendens*	28	SW	2	500
Ivishak River	5	80	Riparian willow shrub; *Salix alaxensis alaxensis/ Hylocomium splendens*	21	SW	1	720
	5	81	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia/Rhytidium rugosum*	41	NW	9	760

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
	5	82	Alpine heath-Dryas meadow; *Dryas integrifolia integrifolia -Cassiope tetragona*	29	WNW	11	780
	5	83	Alpine sedge meadows (strangmoors); *Carex membranacea-Arctostaphylos rubra/Tomenthypnum nitens*	39	SSE	33	840
	5	84	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia/Rhytidium rugosum*	48	SW	20	820
Cane Creek Pass	5	85	Alpine sedge meadow (strangmoors); *Dryas integrifolia integrifolia/ Tomenthypnum nitens* w/ *Carex*	37	W	6	1400
	5	86	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia/Rhytidium rugosum*	38	S	35	1360
	5	87	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia-Silene acaulis acaulis*	33	SW	7	1040
	5	88	Riparian willow shrub; *Arctostaphylos rubra-Pyrola rotundifolia grandiflora* w/*Salix alaxensis alaxensis*	35	NW	3	1040

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
Cane Creek	4	89	Alpine heath-Dryas meadow; *Dryas integrifolia integrifolia-Cassiope tetragona*	48	N	10	920
	4	90	Alpine sedge meadow (strangmoors); *Carex membranacea-Arctostaphylos rubra/Tomenthypnum nitens*	46	NNE	9	900
	4	91	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia-Silene acaulis acaulis*	49	NNE	10	900
	4	92	Alpine Dryas meadow & barren; *Dryas integrifolia integrifolia/Rhytidium rugosum*	45	NNE	1	880
	4	93	Subalpine Dryas shrub; *Dryas integrifolia integrifolia-Cassiope tetragona*	52	NNW	0	870
	4	94	Low & dwarf willow shrub tundra; *Salix reticulata reticulata/Hylocomium splendens*	45	NNW	22	1100
	4	95	Alpine heath-Dryas meadow; *Dryas integrifolia integrifolia/Rhytidium rugosum* w/ *Cassiope tetragona*	53	NNE	18	1080

AREA	SITE NUMBER	STAND NUMBER	MAJOR VEGETATION TYPES AND ASSOCIATIONS	NUMBER OF SPECIES	EXPOSURE	% SLOPE	ELEVATION (m)
Chandalar River	4	96	White spruce forest (woodland terrace); *Picea glauca/Hylocomium splendens*	41	NW	6	790
	4	97	Alpine-Dryas sedge meadows; *Dryas integrifolia integrifolia/Tomenthypnum nitens*	37	N	3	790
	4	98	Low & dwarf willow shrub tundra; *Salix reticulata reticulata-Carex vaginata/Hylocomium splendens-Tomenthypnum nitens*	34	N	4	800
	4	99	Subalpine Dryas shrub; *Dryas integrifolia integrifolia-Carex bigelowii*	49	WNW	5	810

Appendix 4 . Tree and shrub structure (density/Ha by size class) of stands in the various physiographic provinces and divisions. Stands only with trees and shrubs over 1 m are listed. Average density of 1 Hectare = 2.47 acres and DBH = diameter breast height.

		Shrubs & Saplings	Tall shrubs & Trees															
		1 m tall-	DBH(cm)															
Stand	Species	2.5	-5	-10	-15	-20	-25	-30	-35	-40	-45	Total Density/Ha	% Composition	Avg. Height(m)	Avg. DBH(cm)	Avg. Age	Max. Age	Practical Stand Age
				WESTERN PORCUPINE PLATEAU														
2	wS	40	360	320	120	80	40	-	-	-	-	960	100.0	5.5	11.3	100	191	162
4	wS	1360	600	520	120	360	120	-	-	-	-	3080	61.6	5.6	10.2	83.3	156	130
	A	600	120	-	-	-	-	-	-	-	-	720	14.4	4.5	2.2	58	72	
	dB	800	80	-	-	-	-	-	-	-	-	880	17.6	0.4	1.7	45+	45+	
	W	240	-	-	-	-	-	-	-	-	-	240	4.8	-	1.0	-	-	
	wB	-	40	40	-	-	-	-	-	-	-	80	1.6	-	7.7	107+	107+	
6	wS	-	72	-	-	-	-	-	-	-	-	72	1.4	1.6	4.0	42.3	48	71
	wB	2254	762	108	-	-	-	-	-	-	-	3124	58.9	3.2	3.1	56.5	74	
	dB	760	-	-	-	-	-	-	-	-	-	760	14.3	2.5	1.5	-	-	
	A	144	-	-	-	-	-	-	-	-	-	144	2.7	2.1	1.6	18.5	22	
	Sg	1092	108	-	-	-	-	-	-	-	-	1200	22.6	1.5	1.5	18.5	20	
	Bo	-	-	-	-	-	-	-	-	-	-	-	-	-	-	68+	68+	
7	wS	1320	440	400	40	-	-	-	-	-	-	2200	100.0	3.7	5.7	143	241	233
8	wS	720	-	-	-	-	-	-	-	-	-	720	90.0	2	1.0	86.8	220	152
	A	80	-	-	-	-	-	-	-	-	-	80	10.0	1.6	1.6	31	34	
	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13	15	
9	wS	200	280	440	40	-	-	-	-	-	-	960	13.3	7.2	7.9	75.6*	135*	112
	wB	40	360	2600	200	-	-	-	-	-	-	3200	44.2	7.6	9.7	99.8	115	
	A	760	1160	-	-	-	-	-	-	-	-	1920	26.5	4.6	3.9	43.6	45	
	W	560	520	80	-	-	-	-	-	-	-	1160	16.0	5.9	4.7	49.5	59	
10	wS	280	120	-	-	-	-	-	-	-	-	400	7.9	4.0	2.9	46.6	54	100
	wB	-	120	1040	160	-	-	-	-	-	-	1320	26.2	7.9	10.8	83.3	109	
	A	1440	960	40	-	-	-	-	-	-	-	2440	48.4	4.2	3.4	61*	81	
	Sa	680	200	-	-	-	-	-	-	-	-	880	17.5	3.0	2.4	38+	38+	
13	wS	-	40	200	40	80	200	80	80	40	80	760	86.4	22.1	26.2	143.9*	166	164
	W	120	-	-	-	-	-	-	-	-	-	120	13.6	-	2.0	-	-	
14	wS	520	520	280	120	160	40	-	-	-	-	1640	38.0	14.0	9.6	33.7	41	56
	W	1160	520	80	-	-	-	-	-	-	-	1760	40.7	3.9	3.3	34.5	44	
	bPo	-	40	-	360	-	40	-	-	-	-	440	10.2	4.8	21.5	45.3	67	
	A	240	120	-	40	80	-	-	-	-	-	480	11.1	-	9.6	-	-	

Stand	Species	1m-2.5	-5	-10	-15	-20	-25	-30	-35	-40	-45	Total Density/Ha	% Composition	Avg. Height(m)	Avg. DBH(cm)	Avg. Age	Max. Age	Practical Stand Age
				SOUTHERN BROOKS FOOTHILLS														
23	W	280	-	-	-	-	-	-	-	-	-	280	7.2	.6	1.0	23.5	30	29
	dB	2280	-	-	-	-	-	-	-	-	-	2280	58.8	.7	1.0	20.3	36	
	Sg	1320	-	-	-	-	-	-	-	-	-	1320	34.0	1.4	1.0	14.8	19	
25	Sa	840	-	-	-	-	-	-	-	-	-	840	84.0	1.0	1.0	21.5	26	26
	dB	80	-	-	-	-	-	-	-	-	-	80	8.0	1.0	1.0	21.5	26	
	Sg	80	-	-	-	-	-	-	-	-	-	80	8.0	1.0	1.0	20.5	26	
26	wS	40	40	80	-	-	40	40	-	-	-	240	12.5	8.0	16.6	125.9*	242+*	181
	dB	1120	-	-	-	-	-	-	-	-	-	1120	58.3	1.5	1.0	36.0	39	
	Sg	560	-	-	-	-	-	-	-	-	-	560	29.2	2.5	1.0	27.0	32	
				ARCTIC FOOTHILLS														
50	W	280	-	80	80	-	-	-	-	-	-	440	16.4	-	7.5	-	-	86
	bPo	160	-	800	280	40	-	-	-	-	-	1280	47.8	8.8	11.6	65.1	96	
	Sa	280	-	-	-	-	-	-	-	-	-	280	10.4	1.4	1.4	44.0	48	
	Sg	680	-	-	-	-	-	-	-	-	-	680	25.4	.5	1.2	-	-	
51	Sa	2920	2080	80	-	-	-	-	-	-	-	5080	58.0	2.2	3.3	32.0	52	46
	Sg	3600	80	-	-	-	-	-	-	-	-	3680	42.0	1.2	1.4	19.6	24	
				BROOKS RANGE - FRANKLIN MTN. SECTION														
63	Sa	2100	1240	80	-	-	-	-	-	-	-	3480	46.0	3.9	3.3	31.0	42	44
	Sp	2360	1720	560	-	-	-	-	-	-	-	4080	54.0	4.5	3.3	37.8	46	
66	Sa	4240	560	-	-	-	-	-	-	-	-	4800	63.8	1.9	1.9	32.0	32	28
	Sp	560	40	-	-	-	-	-	-	-	-	600	7.9	-	1.8	-	-	
	W	2120	-	-	-	-	-	-	-	-	-	2120	28.2	-	1.0	-	-	
67	Sa	40	320	80	-	-	-	-	-	-	-	440	100.0	2.1	5.4	23.2	42	34
				BROOKS RANGE - SHUBLIK MOUNTAINS														
77	Sa	144	-	-	-	-	-	-	-	-	-	144	12.4	1.4	1.0	22.6*	29	100
	bPo	109	37	433	109	74	109	145	-	-	-	1016	87.6	6.6	16.8	78.3	145*	
78	Sa	480	120	-	-	-	-	-	-	-	-	600	26.8	-	2.4	32.0*	40	39
	Sp	1640	-	-	-	-	-	-	-	-	-	1640	73.2	-	1.2	30.2	29	
	dB	-	-	-	-	-	-	-	-	-	-	-	-	-	-	17.8	-	
80	Sa	4640	1940	-	-	-	-	-	-	-	-	6580	93.5	-	2.7	-	-	16
	Sp	240	220	-	-	-	-	-	-	-	-	460	6.5	-	2.9	-	-	
				BROOKS RANGE - FRANKLIN MOUNTAINS														
88	Sa	-	-	-	-	-	-	-	-	-	-	-	-	-	-	18.0	33	32
	Sg	-	-	-	-	-	-	-	-	-	-	-	-	-	-	36.0	75	
	Sp	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.0	16	
	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	13.0	14	
93	wS	-	160	200	-	-	-	-	-	-	-	360	52.9	6.5	5.8	133.7*	286*	260
	dB	80	-	-	-	-	-	-	-	-	-	80	11.8	-	1.0	-	-	
	Sp	240	-	-	-	-	-	-	-	-	-	240	35.3	-	1.3	-	-	
96	wS	920	800	480	160	40		40	40	-	-	2480	75.6	7.3	8.8	98.3	193	98
	Sg	640	160	-	-	-	-	-	-	-	-	800	24.4	-	2.7	14.8	25	

Stand	Species	1m-2.5	-5	-10	-15	-20	-25	-30	-35	-40	-45	Total Density/Ha	% Composition	Avg. Height(m)	Avg. DBG(cm)	Avg. Age	Max. Age	Practical Stand Age
98	wS	80	40	120	40	40		-	-	-	-	320	2.9	-	12.2	-	-	45
	bPo	40	720	400	80	-	-	-	-	-	-	1240	11.2	-	7.7	-	-	
	Sa	3160	4280	40	-	-	-	-	-	-	-	7480	67.5	-	3.7	45.0*	45	
	Sp	1120	920	-	-	-	-	-	-	-	-	2040	18.4	-	3.3	-	-	
99	wS	40	160	40	-	-	-	-	-	-	-	240	30.0	-	4.9	146.0*	267	250
	Sg	560	-	-	-	-	-	-	-	-	-	560	70.0	-	1.0	-	-	
			ARCTIC COASTAL PLAIN - WEIR CREEK															
58	Sa	2306	1373	41	-	-	-	-	-	-	-	3720	23.6	2.3	3.3	-	-	-
	Sg	8572	3288	180	-	-	-	-	-	-	-	12040	76.4	1.6	2.8	-	-	

TREES SPECIES LEGEND:
- wS = white spruce (Picea glauca)
- A = Alder (Alnus crispa)
- dB = dwarf birch (Betula galndulosa & B. nana ssp. exilis)
- W = willow (Salix ssp.)
- Sg = willow (Salix glauca)
- Sa = willow (Salix alaxensis)
- Sp = willow (Salix planifolia pulchra)
- Bo = shrub birch (Betula occidentalis)
- bPo = balsam poplar (Populus balsamifera)
- Sc = soapberry (Sheperdia canadensis)

NOTE:
- * = Estimated with heart rot
- + = Only 1 sample

APPENDIX 5. SIMPLE CORRELATION OF BIOTIC AND ENVIRONMENTAL FACTORS AT FORESTED AND TALL AND MEDIUM SHRUB SITES. SIGNIFICANCE IS GIVEN AS + OR − WHERE P > .05, AND o = NO SIGNIFICANCE. NUMBER OF OBSERVATIONS RANGED FROM 3 TO 25.

		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65
KM FROM COAST	1																																																																		
ELEVATION (ASL)	2	o																																																																
% SLOPE	3	+	o																																																														
MICRORELIEF (CM)	4	o	+	o																																																												
DEGREES FROM SOUTH	5	o	o	o	o																																																										
SIMPSON SPP. DIVERSITY	6	o	o	o	o	o																																																								
NO. OF SPECIES	7	o	+	o	+	o	−																																																						
% TREE COVER	8	o	o	o	−	o	+	−																																																				
% MED. & TALL SHRUB COVER	9	o	o	o	o	o	o	o	o																																																	
% LOW SHRUBS, HERBS & GRASS COVER	10	o	o	o	o	o	o	o	−	o																																															
% MOSS COVER	11	o	o	o	o	o	o	o	o	o	o																																														
% LICHEN COVER	12	o	o	o	o	o	o	o	o	o	o	o																																												
WHITE SPRUCE GROWTH INCREMENT (CM/YR)	13	o	o	o	o	o	+	o	+	o	−	o	o																																										
WHITE BIRCH GROWTH INCREMENT	14	o	o	o	o	o	o	o	o	−	o	o	o	o																																								
BALSAM POPLAR GROWTH INCREMENT	15	o	o	−	−	+	+	o	+	−	o	o	+	o	o																																						
ALDER GROWTH INCREMENT	16	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o																																				
DWARF BIRCH GROWTH INCREMENT	17	o	o	−	o	o	o	o	+	o	o	o	o	−	o	o	o																																		
WILLOW GROWTH INCREMENT	18	o	o	o	−	o	+	−	+	−	o	o	−	+	o	o	o	o																																
SALIX GLAUCA GROWTH INCREMENT	19	o	o	o	o	o	o	o	+	o	o	+	o	o	o	o	o	o	o																															
SALIX ALAXENSIS GROWTH INCREMENT	20	o	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o																													
SALIX PLANIFOLIA GROWTH INCREMENT	21	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o																												
WHITE SPRUCE DENSITY	22	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	+	o	o	o																										
WHITE BIRCH DENSITY	23	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o																								
BALSAM POPLAR DENSITY	24	o	o	o	o	o	o	o	−	o	o	o	o	o	o	o	o	o	o	o	o	o	−	o																						
ALDER DENSITY	25	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	−	o	o	o	o	o	o																					
DWARF BIRCH DENSITY	26	o	o	o	o	o	o	o	o	+	o	o	o	o	+	o	−	o	o	o	o	o	o	−	o	+																				
WILLOW DENSITY	27	o	o	o	o	o	+	−	o	o	o	o	o	o	o	+	o	+	o	o	o	o	o	o	−	o	+																			
SALIX GLAUCA DENSITY	28	+	−	o	o	o	+	−	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	−																		
SALIX ALAXENSIS DENSITY	29	+	o	o	o	+	o	o	o	o	o	o	o	o	o	−	o	o	o	+	o	o	−	o	o	o	o	o	o																	
SALIX PLANIFOLIA DENSITY	30	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	−	o	o	o	o	o	o	o																
WHITE SPRUCE AV. HEIGHT	31	o	o	o	o	o	+	o	+	o	o	o	o	+	o	o	o	−	+	o	o	o	o	o	o	o	o	o	o	o	o															
WHITE BIRCH AV. HEIGHT	32	+	o	+	−	o	o	o	+	−	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	−	o	o	o	o														
BALSAM POPLAR AV. HEIGHT	33	o	o	+	+	o	−	o	−	+	o	o	−	o	o	o	o	o	o	o	o	o	o	o	o	o	o	−	o	+	o	o	o													
ALDER AV. HEIGHT	34	o	o	o	−	o	−	o	+	o	−	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	+	o	o	o	o	+	o												
DWARF BIRCH AV. HEIGHT	35	o	−	o	o	o	o	o	+	o	o	o	+	−	o	o	o	o	o	o	o	o	−	o	o	o	o	o	o	o	o	−	o	o	o											
WILLOW AV. HEIGHT	36	+	−	−	−	+	+	−	o	−	−	−	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o										
SALIX GLAUCA AV. HEIGHT	37	o	o	o	o	o	o	o	−	o	o	o	o	+	o	o	o	o	o	o	o	o	+	o	o	o	o	−	o	+	o	+	o	o	o	o	o									
SALIX ALAXENSIS AV. HEIGHT	38	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o								
SALIX PLANIFOLIA AV. HEIGHT	39	o	o	o	o	o	o	o	o	o	o	o	−	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+							
WHITE SPRUCE AV. D.B.H.	40	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	−	+	o	o	o	o	o	+	o	o	o	o	+	+	+	o	o	o	−	o	+	o	o						
WHITE BIRCH AV. D.B.H.	41	o	o	o	o	o	o	o	+	+	o	o	−	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	+	o	o	o	o	o	o	o	o					
BALSAM POPLAR AV. D.B.H.	42	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	+	o	o	o	o	o	+	o	o	o	o	o	o	−	o				
ALDER AV. D.B.H.	43	o	o	o	o	o	+	−	+	o	o	o	o	+	o	o	o	o	+	o	o	o	o	o	o	o	+	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o			
SHRUB BIRCH AV. D.B.H.	44	+	−	o	o	o	+	−	−	o	o	o	o	o	+	o	−	o	o	o	o	o	o	−	o	+	o	−	o	o	o	o	o	o	+	o	o	o	o	o	o	+	o	+		
WILLOW AV. D.B.H.	45	o	−	o	o	o	o	o	o	o	o	o	o	o	+	−	+	o	o	o	−	o	o	+	+	o	o	o	−	−	o	o	o	+	o	o	+	−	−	o	o	+	−	o	o	
SALIX GLAUCA AV. D.B.H.	46	o	o	o	o	o	o	o	+	o	o	+	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	+	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	+
SALIX ALAXENSIS AV. D.B.H.	47	o	o	o	o	o	o	o	o	o	o	o	o	o	o	−	o	o	o	+	+	o	−	o	o	o	o	o	+	o	o	o	o	+	o	o	o	o	o	o	+	o	o	o	o	−	o																			
SALIX PLANIFOLIA AV. D.B.H.	48	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	−	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o																		
WHITE SPRUCE MAX. AGE	49	o	o	o	o	o	o	o	o	o	+	o	o	+	o	o	o	+	−	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o																	
WHITE BIRCH MAX. AGE	50	o	o	o	o	−	o	o	+	o	o	o	−	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	+	o	o	o	o																
BALSAM POPLAR MAX. AGE	51	o	o	+	+	o	−	o	−	+	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	−	o	−	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	−	o	o	o															
ALDER MAX. AGE	52	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	−	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	−	o	o	o	o	o	o														
DWARF BIRCH MAX. AGE	53	o	o	o	o	o	o	o	+	o	o	o	o	−	o	o	o	o	o	o	o	o	+	o	o	o	o	−	o	−	o	−	o	o	o	o	o	o	+	o	−	o	o	o	o	o	o	+	o	+	o	o	o													
WILLOW MAX. AGE	54	o	o	o	o	o	o	o	o	o	−	o	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o												
SALIX GLAUCA MAX. AGE	55	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	−	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o											
SALIX ALAXENSIS MAX. AGE	56	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o										
SALIX PLANIFOLIA MAX. AGE	57	o	o	o	o	o	o	o	o	o	o	−	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o									
WHITE SPRUCE AV. AGE	58	o	o	o	o	o	o	o	o	−	o	o	o	o	o	o	o	+	−	o	o	o	o	o	o	o	o	o	o	o	−	o	o	o	o	−	o	o	o	o	o	o	o	o	o	o	o	o	−	o	o	o	o	+	o	o	o	o								
WHITE BIRCH AV. AGE	59	−	o	o	+	o	o	+	o	o	o	o	o	o	o	o	o	−	o	−	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	−	o	o	+	o	o	o	o	o	o	o	o	+	o	o	o	o	o	−	o	+	−	o	o							
BALSAM POPLAR AV. AGE	60	o	o	o	o	o	o	o	o	o	o	o	−	+	o	−	o	o	o	o	o	o	+	o	+	o	o	o	o	o	o	+	o	+	o	o	o	o	o	o	−	o	−	o	o	o	o	o	o	−	o	+	o	o	o	−	−	o	−	o						
ALDER AV. AGE	61	o	o	o	−	o	o	o	+	o	o	+	o	o	o	o	o	+	o	+	+	o	o	o	o	o	o	−	+	o	o	o	o	o	o	+	o	−	o	o	o	o	o	o	o	−	+	o	o	o	o	o	o	+	+	−	o	o	o	o	o					
DWARF BIRCH AV. AGE	62	o	o	o	o	o	o	o	−	o	o	o	+	+	o	o	o	o	o	o	o	o	−	o	o	o	o	−	o	+	o	+	o	o	o	+	o	o	−	o	+	o	o	o	o	o	o	−	o	−	o	o	o	o	o	o	o	o	−	+	o	+				
WILLOW AV. AGE	63	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	−	o	−	−	o	o	o	o	o	−	o	−	o	o	o	o	o	o	+	+	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	+	+	o	o	o	+	−	o	+			
SALIX GLAUCA AV. AGE	64	o	o	o	o	−	o	o	−	o	o	o	o	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	−	o	o	o	o	o	o	o	o	−	o	o	o	o	o	o	o	o	−	o	o	o	o	o	o	o	o	o	o	o	+	o	−	o	+		
SALIX ALAXENSIS AV. AGE	65	o	o	o	+	o	o	o	o	o	o	o	+	+	o	−	o	−	o	o	o	o	o	o	o	o	+	o	o	o	o	+	o	+	o	+	o	o	o	−	o	o	o	o	o	+	o	o	o	+	o	−	o	o	o	o	o	o	+	+	−	−	o	o	o	
SALIX PLANIFOLIA AV. AGE	66	+	o	+	+	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	o	+	o	o	o	o	o	o	o	+	+	o	o	o	o	o	o	o	+	+	o	o	o	o	o	o	o	+	+	o	o	o	o	+	o	+	+	+	o	o	o	o	+	o	o	+
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38	39	40	41	42	43	44	45	46	47	48	49	50	51	52	53	54	55	56	57	58	59	60	61	62	63	64	65