GEOLOGICAL SURVEY OF CANADA
COMMISSION GÉOLOGIQUE DU CANADA

PAPER 80-33

This document was produced by scanning the original publication.

Ce document est le produit d'une numérisation par balayage de la publication originale.

PLANT COMMUNITIES ON THE SURFICIAL MATERIALS OF NORTH-CENTRAL DISTRICT OF KEEWATIN, NORTHWEST TERRITORIES

S.A. EDLUND

GEOLOGICAL INFORMATION DIVISION
OCT 14 1982
DIVISION DE L'INFORMATION GÉOLOGIQUE

Canada

1982

GEOLOGICAL SURVEY
PAPER 80-33

PLANT COMMUNITIES ON THE SURFICIAL MATERIALS OF NORTH-CENTRAL DISTRICT OF KEEWATIN, NORTHWEST TERRITORIES

S.A. EDLUND

1982

© Minister of Supply and Services Canada 1981

Available in Canada through

authorized bookstore agents
and other bookstores

or by mail from

Canadian Government Publishing Centre
Supply and Services Canada
Hull, Québec, Canada K1A 0S9

and from

Geological Survey of Canada
601 Booth Street
Ottawa, Canada K1A 0E8

A deposit copy of this publication is also available
for reference in public libraries across Canada

Cat. No. M44-80/33E Canada: $6.50
ISBN 0-660-10929-8 Other countries: $7.80

Price subject to change without notice

Critical Readers

A.S. Dyke
A.N. Rencz

Original manuscript submitted: 1979 - 05 - 10
Approved for publication: 1980 - 11 - 21

CONTENTS

iv Abstract/Résumé
1 Introduction
1 Purpose
1 Field work
1 Previous botanical work
1 Topography
1 Climate
2 Tundra fires
2 Acknowledgments
2 Surficial materials
3 Bedrock
3 Glacial deposits
4 Marine deposits
4 "Active" deposits
4 Soils
5 Low Arctic ecosystem
6 Zone I: Shrub tundra
6 Zone III: Cryptogam tundra
6 Zone II: Cryptogam/shrub tundra
6 Relationships between plant communities and surficial materials
6 Bedrock: cryptogam communities
7 Glacial deposits
8 Dry glacial deposits: **Alectoria-Hierochloe** tundra
8 Moderately to well drained deposits: **Alectoria**-heath tundra
9 Imperfectly drained deposits: cryptogam-monocot tundra
10 Poorly drained and saturated deposits: wet sedge meadows and marsh emergents
10 Patterned ground
12 Marine deposits
12 Well drained silt and clay: grass barrens
12 Moderately to imperfectly drained silt: cottongrass tussock meadows
14 Poorly drained silt and clay: wet sedge meadows
14 Well drained sand and gravel: shrub-monocot barrens
14 Moderately drained sand and gravel: shrub-monocot tundra
14 Poorly drained sand and gravel: wet sedge meadows
14 Nonmarine sand caps: lichen-grass tundra
15 "Active" deposits: patterns of plant succession
15 Fluvial fine sand and silt: grass colonizers
15 Sand and sand with lag gravel: herb colonizers
16 Vegetation and sensitivity
16 Disruption of plant communities
17 Vegetation and geomorphic processes
17 Vegetation and wildlife
18 Summary
19 References

Tables

2 1. Mean temperatures and precipitation, Baker Lake and Pelly Bay
7 2. Cryptogams associated with bedrock
9 3. Vascular plants on glacial deposits
9 4. Cryptogams on glacial deposits
11 5. Vascular plants on marine deposits
13 6. Cryptogams on marine deposits
15 7. Colonizing species on recently active materials
16 8. Sensitivity of plant communities
18 9. Summary of plant communities

Figures

in pocket Map 1548A Vegetation of north-central District of Keewatin
1 1. Study area
3 2. Generalized distribution of surficial materials in the study area
4 3. Eroding bluffs of marine silt along Hayes River
5 4. Bioclimatic zonation of northern District of Keewatin
7 5. Diagrammatic sketch showing major plant communities on bedrock, bouldery till, and sandy till in zone III
8 6. Diagrammatic sketch showing major plant communities on glacial deposits in zone III
10 7. Plant communities on ice-contact and glaciolacustrine deposits
13 8. Diagrammatic sketch showing major plant communities on sandy and silty marine deposits
14 9. **Eriophorum vaginatum** tussock meadow community

PLANT COMMUNITIES ON THE SURFICIAL MATERIALS OF NORTH-CENTRAL DISTRICT OF KEEWATIN, NORTHWEST TERRITORIES

Abstract

A reconnaissance study of the vegetation of north-central District of Keewatin was undertaken in order to gain a better understanding of the relationships between the nature and distribution of plant communities and the surficial materials on which they grow. The four types of surficial materials studied – bedrock, glacial deposits, marine deposits, and actively aggrading and eroding deposits – each support a suite of plant communities that naturally segregate on the basis of moisture regime.

*Bedrock supports solely cryptogamic communities. Glacial deposits, commonly moderately to well drained, have lichen-heath and lichen-**Hierochloe** tundra; imperfectly and poorly drained glacial deposits have cryptogam-monocot tundra and wet sedge meadows. Marine silts and clays, generally moderately to poorly drained, support cottongrass tusscock tundra and wet sedge meadows. The driest aspects are unvegetated or have sparse grass barrens. Marine sand and gravel are generally moderately to well drained and have shrub-monocot tundra or shrub-monocot barrens. Locally where poorly drained, wet sedge meadows occur. Communities growing on actively aggrading and eroding postglacial fluvial and eolian deposits are generally in early stages of succession.*

Differences in species occurrence, abundance, and diversity, related to altitudinal and to some extent latitudinal changes, allow a bioclimatic subdivision of the Low Arctic ecosystem in the map area. This zonation is most obvious in the changes from Zone I where there is a variety of heath species, a dominance of dwarf shrubs, and the regular occurrence of erect shrubs, to Zone III where lichens and mosses are dominant and the importance of shrub species is reduced, particularly the absence of erect shrubs and the reduction of heath species to two major ones.

The removal or disruption of plant communities due to man's activities can lead to destruction of unique or botanically significant communities or species, alteration of drainage, accelerated geomorphic processes, and erosion. Such activities can also lead to the destruction of important feeding and breeding habitats for dependent fauna. Communities on imperfectly and poorly drained materials are the most vulnerable to disruption.

Résumé

Un relevé général de la flore du centre-nord du district de Keewatin a été entrepris dans le but de mieux comprendre les rapports existant entre la nature et la distribution des communautés végétales et les matériaux de surface sur lesquels elles poussent. Les quatre types de matériaux superficiels étudiés étaient: la roche en place, les dépôts glaciaires, les sédiments marins et les sédiments subissant un alluvionnement et une érosion actifs. Chacun sert de support à une série de communautés végétales qui se séparent naturellement en fonction des conditions d'humidité.

*La roche en place n'est exclusivement utilisée que par des communautés cryptogames. Les dépôts glaciaires, généralement modérément ou bien drainés, présentent des toundras de lichens-éricacées et de lichens-**Hierochloe**. tandis que les dépôts dont le drainage est mauvais ou imparfait présentent des toundras de type cryptogames-monocotylédones et des prairies humides à carex. Les silts et les argiles marins, généralement modérément ou bien drainés, présentent des toundras à coussins d'ériophorums et des prairies humides à carex. Les zones les plus sèches sont dénudées ou présentent une végétation herbeuses éparses. Les sables et graviers marins sont généralement modérément ou bien drainés et présentent des toundras de types arbustes-monocotylédones ou des zones dénudées de même végétation. On trouve localement des prairies humides à carex dans les zones mal drainées. Les communautés poussant sur les dépôts éoliens en sont généralement aux premiers stades de succession.*

Les différences entre la présence, l'abondance et la diversité des espèces présentent une corrélation avec les variations d'altitude et, dans une certaine mesure, de latitude, ce qui permet d'effectuer une subdivision bioclimatique de l'écosystème du Bas-Arctique de la région cartographiée. Cette distribution par zones est plus apparente dans le passage de la Zone 1, où l'on trouve diverses espèces d'éricacées, une dominance des arbustes nains et des arbustes dressés, à la Zone III, où les lichens et les mousses dominent où l'importance des arbustes est réduite et, particulièrement, où les arbustes dressés sont absents et les éricacées sont réduites à deux espèces principales.

L'élimination ou la perturbation des communautés végétales par l'activité humaine pourrait se traduire par la disparition de communautés ou d'espèces uniques ou importantes du point de vue botanique, une modification du drainage, et une accélération des processus géomorphologiques et de l'érosion. Une telle activité pourrait aussi provoquer la destruction d'aires d'alimentation ou de reproduction dont dépend la faune. Les communautés vivant sur des sols mal ou imparfaitement drainés sont les plus vulnérables aux perturbations.

INTRODUCTION

Purpose

The objectives of this project are to describe the vegetation and to determine plant communities and map their distribution in order to determine the relationships between vegetation and surficial materials in an area of north-central District of Keewatin (Fig. 1). This study (1) provides a regional plant geography of an undeveloped area and, therefore, can be used to assess future environmental impact and land use and (2) gives a preliminary understanding of the present phytogeography in order to provide the necessary information for interpreting past (Holocene) changes in vegetation. An understanding of the present relationships between plant distribution and climate allows pollen records, which reflect vegetational changes, to be used to infer climatic history. This particular area was chosen for study because it included the route of a proposed gas pipeline.

This study, carried out in July and August 1976, was based on a helicopter reconnaissance survey conducted with a concurrent surficial geology mapping program (Thomas, 1977; Thomas et al., 1979a, b).

Field Work

Field work was confined to that part of the map area between 65° and 68°N and 92° and 96°W (Fig. 1). Base camp was near Snow Bunting Lake with an auxiliary camp on Hayes River; access was through Baker Lake, which has regular commercial aircraft service. The field camps were serviced by float plane and helicopter.

At nearly 200 sites within the study area, plant species lists, estimates of frequency of occurrence, and per cent cover were made. When time allowed, more detailed measurements of per cent cover were made by line intercept and linear pin frame methods (Brown, 1954). All collections were identified using the keys of Porsild (1964) and Hultén (1968) for vascular plants, Conard (1956) for mosses, and Hale (1969) for lichens; vascular plant nomenclature follows that of Hultén (1968).

Landsat II imagery and airphotos were used to map vegetation distribution. Ground truth from the field area was extrapolated to surrounding areas, hence the map area is larger than the field area (Fig. 1).

Previous Botanical Work

Prior to the mid-1950's botanical work was confined to casual observations and small collections of plant specimens by early explorers travelling along the Back River drainage system and coastal waters. More recent work in the coastal areas to the west includes general observations on the flora of Adelaide Peninsula (Manning and Macpherson, 1959); botanical observations of the Perry River region (Hanson et al., 1956) and goose habitat mapping in the same area by Ryder (1967). Krebs (1964) made phenological observations at Baker Lake. Vegetation and soils have been studied in detail in northern District of Keewatin (Zoltai and Johnson, 1977) and on southern Boothia Peninsula and northern Keewatin just to the north of the map area, where a Low/Mid Arctic climatic boundary was established (Tarnocai and Boydell, 1975; Tarnocai et al., 1976). Palynological and bioclimatological studies in the vicinity of treeline by Larsen (1965, 1967, 1972), Nichols (1970, 1975, 1976), and Sorenson et al. (1971) greatly enhanced both current and historical knowledge of Low Arctic tundra vegetation.

Within the map area, Larsen (1972) described plant communities at a site on Wager Plateau near Snow Bunting Lake, and Zoltai and Johnson (1977) made detailed observations along a section of Hayes River.

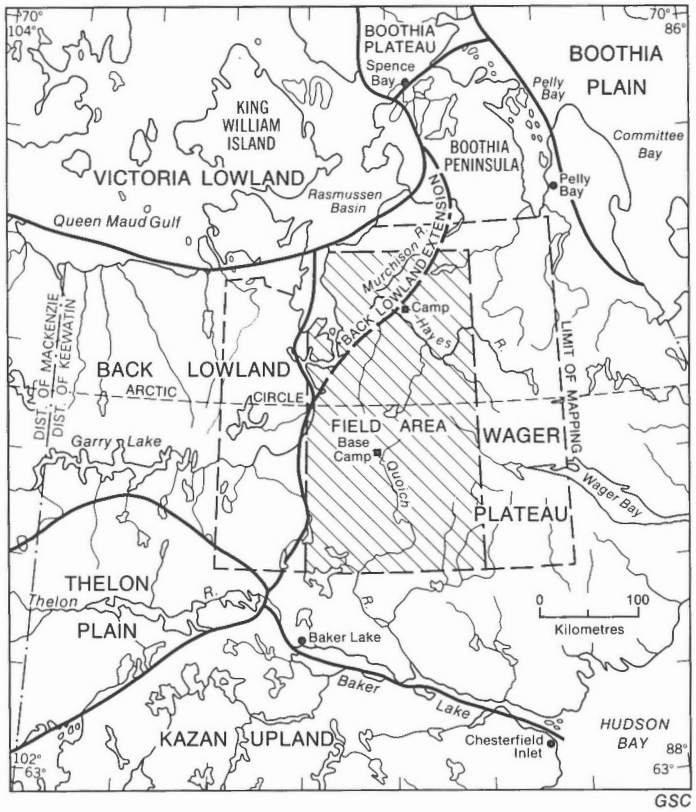

Figure 1. Study area in north-central District of Keewatin showing broad physiographic regions (modified from Bostock, 1970).

Floristic lists for vascular plants of the region are found in Porsild (1964) and Zoltai and Johnson (1977); the latter also includes comprehensive coverage of lichens and bryophytes.

Topography

Northern District of Keewatin has been divided into two broad physiographic units (Bostock, 1970; Fig. 1). Wager Plateau, ranging from 150 m to more than 300 m a.s.l., is a gently rolling upland with numerous lakes. In the south-central part of the study area, particularly around Quoich River and its tributaries, local relief is greater and the terrain is more dissected.

The land immediately east of Chantrey Inlet has been included within the Back Lowland of Bostock (designated here as the Back Lowland Extension) because, like the lowland itself, it is at low elevation and has little relief. The lack of relief is partly due to the presence of extensive, flat-lying marine deposits which mute the terrain.

Regional topography is of importance to this study because an altitudinal climatic zonation occurs which affects distribution and composition of plant communities.

Climate

The map area straddles the Arctic Circle and falls within the Low Arctic climatic zone of Zoltai et al. (1978). The area lies at least 500 km north of the -7°C annual isotherm, which closely corresponds to treeline, the southern boundary of continuous permafrost (Bird, 1967), and the mean summer position of the arctic front (Bryson, 1966). Winters are long and severely cold, with snowfall most common in April through June and in September through November.

Rainfall in the general area is low and usually falls during June through early September (Table 1). Thunderstorms may occur during the summer as a result of the interaction of moist pacific air and cool, dry arctic air. Summers are short and temperatures low, with above freezing temperatures occurring during June through early September; temperatures may reach 25°C for a few days. Coastal fog is common in July and August after breakup of sea ice.

Tundra Fires

Vegetation in the boreal forest – tundra ecotone and adjacent Low Arctic ecosystem is susceptible to fire caused by lightning during thunderstorms. Although fires in southern and central District of Keewatin have been documented (Cochrane and Rowe, 1969; Wein and Bliss, 1973; Shilts, 1975; Wein and Shilts, 1976), none has been reported in the study area. The northernmost fire documented occurred just to the south at Lunan Lake (Shilts, 1975), and during the course of field work in 1976 several fires were observed near the southern shore of Tehek Lake. No smoke plumes appear on summer Landsat II imagery north of these areas, and no burn scars were seen in the field area.

During the middle and late Holocene, fires probably occurred within the study area. During two warmer climatic periods the forest-tundra ecotone extended farther north, as did the margin of the arctic front, where lightning activity is most common (Nichols, 1976). Nichols speculated that subsequent cooling, following redomination of cold dry arctic frontal air during summers resulted in desiccation of vegetation making it more vulnerable to fire.

Tundra fires are not currently an important influence on plant communities in the area, but adjacent areas to the south that have similar communities to those found in the map area can be significantly affected. With minor northward fluctuations of the summer arctic front, the map area could be within the zone influenced by tundra fires.

Acknowledgments

Appreciation is expressed to A.S. Dyke, R.D. Thomas (Geological Survey of Canada), and C. Tarnocai (Agriculture Canada) who provided useful discussion and criticism both during field and office phases of the project; to I.V. MacDonald, who assisted in plant identification; to G. Argus, (National Herbarium) who identified the willows; and to A.S. Dyke and A. Rencz (Geological Survey of Canada) for their critical review of the manuscript.

SURFICIAL MATERIALS

To facilitate an understanding of the relationship between surficial materials and plant communities rooted in them, it is necessary first to discuss the types of surficial materials found in the area.

With the exception of bedrock, all surficial materials, regardless of origin, are unlithified and acidic, being derived from Precambrian bedrock. Although carbonates do occur in adjacent areas, surficial materials in the map area contain little or no carbonates; pH values range from 3.8 to 7.1 with the majority of samples in a pH range of 4 to 5 (C. Tarnocai, personal communication, 1976).

The surficial materials in the study area (Thomas et al., 1979a, b) have been grouped as follows: (1) bedrock; (2) glacial deposits including till, ice-contact, glacio-lacustrine, and glaciofluvial deposits; (3) marine deposits including deep water, foreshore, and beach deposits; and (4) materials of actively eroding and aggrading surfaces, that is, modern fluvial and eolian deposits (Fig. 2). These groups serve as the framework on which the relationships between plant communities and surficial materials are examined. The properties of the materials that have particular importance to plants are discussed first.

Table 1. Mean Temperatures and Precipitation, Baker Lake and Pelly Bay, District of Keewatin

	Temperature (°C)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Annual
Baker Lake	Mean daily	-33.6	-32.8	-27.0	-17.6	-7.2	3.2	10.7	9.8	2.4	-7.5	-20.2	-27.5	-12.3
	Mean daily maximum	-30.1	-29.7	-23.0	-13.0	-3.4	6.8	15.7	14.1	5.5	-4.0	-16.0	-23.9	-8.4
	Mean daily minimum	-37.0	-36.1	-31.1	-22.3	-10.9	-0.4	5.6	5.6	-0.4	-10.7	-24.0	-31.1	-16.1
Pelly Bay	Mean daily	-33.1	-33.2	-28.9	-20.0	-9.7	-0.6	6.9	5.2	-2.9	-12.2	-22.6	-28.1	-14.9
	Mean daily maximum	-30.1	-29.8	-26.0	-16.6	-7.4	1.8	10.5	8.5	-0.9	-9.6	-19.3	-24.9	-12.0
	Mean daily minimum	-36.2	-36.6	-31.8	-23.4	-12.1	-2.9	3.4	1.9	-5.0	-14.8	-25.8	-31.3	-17.9
	Precipitation (mm)													
Baker Lake	Mean rainfall	-	-	-	0.3	2.8	14.0	35.6	34.3	29.0	7.9	Tr	-	123.9
	Mean snowfall (cm)	7.1	5.6	9.7	12.7	6.6	2.0	-	0.3	4.8	17.8	16.3	6.1	89.0
	Mean total	7.1	5.6	9.7	13.0	9.4	16.0	35.6	34.6	33.8	25.7	16.3	6.1	212.9
Pelly Bay	Mean rainfall	-	-	-	-	-	5.1	33.3	49.5	15.5	1.3	-	-	104.7
	Mean snowfall (cm)	2.5	1.8	2.8	11.2	12.7	6.1	0.5	3.3	15.7	18.5	8.9	3.3	87.3
	Mean total	2.5	1.8	2.8	11.2	12.7	11.2	33.8	52.8	31.2	19.8	8.9	3.3	192.0

Source: Environment Canada, 1975a, b

Bedrock

The study area is underlain by Precambrian bedrock (Heywood, 1961). Below marine limit, bedrock is generally masked by blankets and veneers of marine sediment, although bedrock outcrops near marine limit (ca. 150 to 210 m a.s.l.) and in areas close to Chantrey Inlet. On the Wager Plateau, above marine limit, bedrock is generally masked by glacial deposits but outcrops locally, especially where streams have incised glacial deposits to bedrock as in the Quoich River system and on domed hilltops where surficial materials have been eroded. Small quartzite outcrops occur locally.

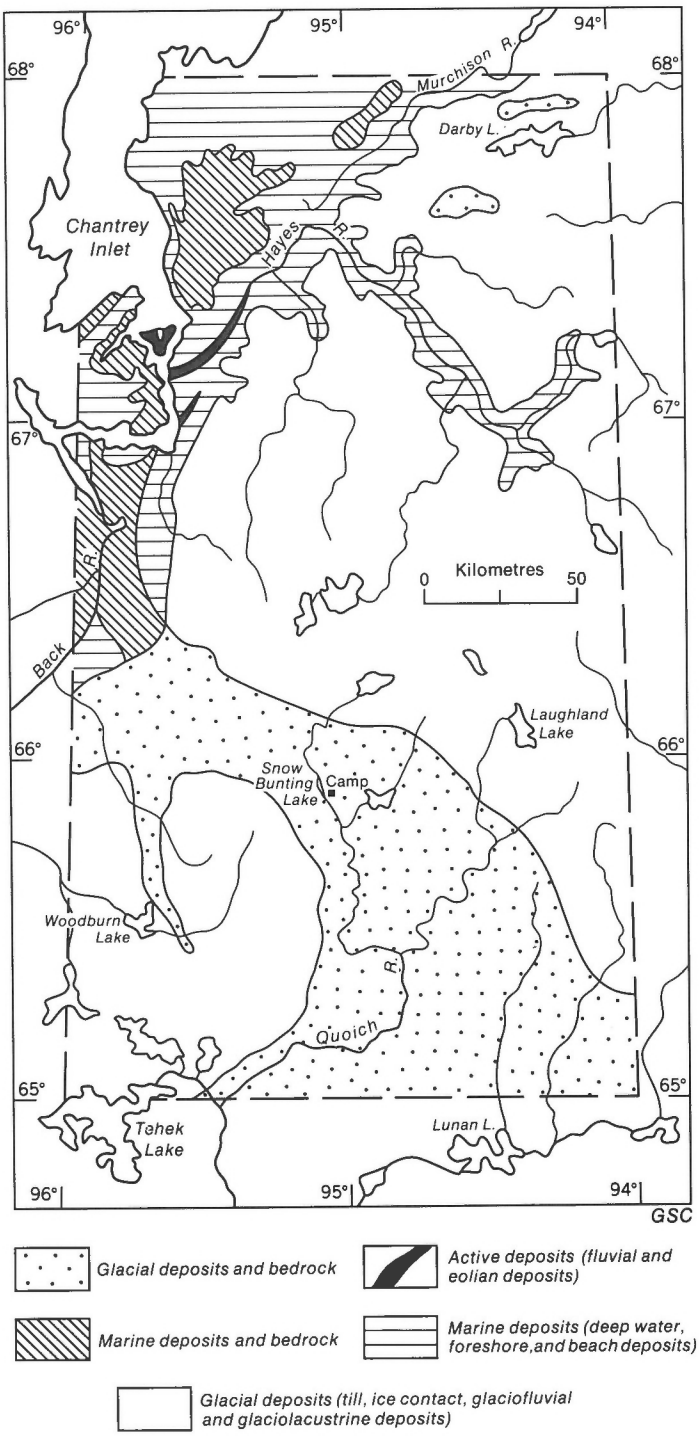

Figure 2. *Distribution of surficial materials in the study area.*

Frost shattering of bedrock commonly occurs on the sides of outcrops where late-lying snowbeds are found or where there is contact with saturated materials. The degree of fracturing varies from minor cracks and crevasses to the separation of slabs of rock from the main body. Most rock surfaces are smooth, with little evidence of weathering. Striae are preserved on many exposures and under vegetation mats.

Glacial Deposits

Glacial deposits are the most widespread surficial materials in the map area (Fig. 2) and include till, ice-contact, glaciofluvial, and glaciolacustrine deposits. Till was formed by the glacial erosion of bedrock, and the remainder are the result of reworking and redeposition of englacial debris by meltwater and waves. Thus glacial materials are closely related mineralogically and differ primarily in texture and degree of sorting. Textures range from fine sand and silt to gravels, cobbles, and boulders. Grain size distribution vary with the different deposits.

Till. Till is the most extensive surficial material of north-central District of Keewatin. Thicknesses vary from blankets, tens of metres thick, to veneers, less than 1 m thick through which bedrock knobs protrude. Landforms on the irregular till surfaces commonly include undulating plains with abundant lakes, major and minor moraine features, drumlins, and crag-and-tail features. Patterned ground is common: coarse materials are sorted into nets, stripes, and circles by frost action, and materials with a relatively high sand and silty sand matrix contain mudboils.

Three types of tills have been identified.

Bouldery Till. Bouldery till makes up a small proportion (less than 5 per cent) of till in the study area. It has a sandy matrix and a large boulder component, commonly between 50 and 80 per cent boulders (based on visual surface estimate), distributed throughout the deposit. In places boulders pave the surface, giving it a highly irregular appearance.

Sandy Till. Sandy till, with a silty coarse to fine sand matrix and about 20 to 30 per cent boulders (visual surface estimate), is the most common till in the study area (covering about 90 per cent of areas with till).

Modified Silty Till. In the Hayes, Murchison, Mistake valleys just below marine limit the till matrix has a fine grained component of silt and fine sand. Boulder cover is generally less than 20 per cent (visual surface estimate).

Ice-Contact Deposits. Stratified ice-contact materials, generally sandy gravel with a significant boulder component, are found in eskers, kames, kame terraces, and complexes of these. Terraces and ridges are commonly patterned by a network of high centre ice-wedge polygons, with an average diameter of about 15 m, separated by shallow (less than 50 cm) troughs.

Glaciofluvial Deposits. Glaciofluvial deposits consist of sand and gravel transported and deposited by proglacial meltwater. They form outwash plains, terraces, and fans – features of low relief along bedrock-controlled valleys or plains. The greatest relief commonly is only the few metres from the terrace edge to the stream bed.

Glaciolacustrine Deposits. On the Wager Plateau are areas of poorly sorted, sandy tills and ice-contact materials reworked by water from ice dammed lakes. In places, sand or coarse gravel and boulder beaches mark the upper limit of former water bodies. It is possible that high-level littoral marine deposits are included in this category in places because marine limit is locally difficult to identify.

Marine Deposits

Marine transgression, which immediately followed deglaciation, left substantial marine deposits on the Back and Victoria lowlands and reworked and washed materials 150 to 210 m a.s.l. These deposits mask bedrock and glacial deposits and mute the lowland topography. Marine waters most likely covered the region north of Baker Lake and Chesterfield Inlet, but the evidence is not as apparent as it is in the northern part of the map area around Chantrey Inlet and Committee Bay.

The main deposits associated with this transgression are (1) deep water facies composed primarily of silt and clay and (2) foreshore and beach gravel and sand.

Small nonmarine sand deposits of fluvial origin are found on the lowlands. Because these deposits are too small to be mapped, they have been included with marine deposits. They are typically well drained and are patterned by networks of high-centre polygons surrounded by shallow troughs. Eolian activity may once have been extensive on some of these areas for lag gravel paves the surface in many places.

Deep Water Deposits. Deep water laminated silt and clay vary in thickness from extensive blankets tens of metres thick to veneers less than 1 m thick. Isolated pockets of silt may cover bedrock and glacial deposits near marine limit. Deep water deposits are found in Murchison valley and parts of Hayes and Back valleys. Along Hayes and Arrowsmith rivers, thick sediments have been eroded into steep, highly dissected bluffs and currently are undergoing wind and water erosion (Fig. 3). These bluffs are extremely well drained and are virtually unvegetated.

Foreshore and Beach Deposits. This category includes sand and gravel veneers and remnants of sand and gravel beaches removed from present sea level. Such deposits are found on flanks of hills and bedrock knobs up to 190 m a.s.l. They are commony patterned by a network of high centre ice-wedge polygons. Discontinuous veneers of sand and gravel also occur in places on the plains.

"Active" Deposits

Erosion and aggradation, mainly by wind and water, currently occur but on a much smaller scale than during deglaciation.

Fluvial Deposits. Fluvial deposits large enough to be mapped are present in the Back Lowland Extension associated with Hayes and Back rivers and their tributaries. These sand and silt deposits containing minor gravel are found in braided streams, low terraces adjacent to channels, and deltas.

Erosion and aggradation by water is seasonal, related to periods of snowmelt and active layer thaw. Peak activity occurs at breakup of river ice, when streams are at their maximum and streambanks are actively eroded. Sheetwash also provides a sediment supply into streams and rivers to be deposited downstream along the floodplain.

Eolian Deposits. Eolian erosion and deposition occur at any time of year where bare ground is exposed. Eolian activity can occur locally on small areas, such as esker ridges and terrace edges, or over a large area several kilometres square, such as an outwash plain. Eolian deposits are primarily medium to fine grained sand; in places lag gravel lines the surface.

Soils

Surficial materials of north-central District of Keewatin show little classical soil development. Soils have been classified by Tarnocai (1977) as Cryosols (developed over permafrost). Active layer thicknesses vary from a maximum of just less than 1 m on coarse, well drained materials to 30 to 40 cm on fine grained, saturated materials with a shallow peat cover. Organic debris collects at the surface on many plant communities but is slow to decompose. Weak leaching occurs in the southern part of the map area (Tarnocai, 1977).

Cryoturbation is common in many surficial materials. This process strongly influences plant community patterns because cryoturbation places stress on the root systems, creates bare surfaces, and locally disrupts plant communities. Cryoturbation produces mudboils, circles, nets, and stripes in till and earth hummocks in marine silt. Such soils are classified as Turbic Cryosols. In some poorly drained areas, particularly on marine sediments, gleying and peat formation occur (Gleyosolic Turbic Cryosols).

Sandy marine, ice-contact, glaciofluvial, fluvial, and eolian deposits are not as susceptible to cryoturbation. The soils that form on such materials are known as Static Cryosols. Geomorphological processes active on these material include contraction cracking and ice-wedge formation.

Figure 3

Eroding bluffs of marine silt along Hayes River. Deeply dissected silts are unvegetated. Shrub-monocot tundra is found on the sandy cap over the silt in the foreground. Wet sedge meadows occur in depressions and around lakes. GSC 203642

Tarnocai (1977) shows that the soils of northern District of Keewatin have little buffering capacity and are quick to respond to air temperature change.

LOW ARCTIC ECOSYSTEM

Arctic Canada, the area north of treeline, has been divided into three major ecosystems: Low Arctic, Mid Arctic, and High Arctic by Polunin (1951).

Since deglaciation, the District of Keewatin has been under the influence of two major ecosystems – the boreal forest and treeless Low Arctic tundra. The demarcation between these two systems is treeline, which roughly follows the -7°C annual isotherm (Bird, 1967).

Treeline passes through the southern part of the District of Keewatin, with an outlier extending northward up Thelon River to western Aberdeen Lake immediately southwest of the map area (Fig. 4). Treeline is not a static boundary; it has fluctuated several hundred kilometres since deglaciation. During the middle and late Holocene, there were two periods of consistently warmer summers that caused treeline to extend northward into the map area, beyond its present position (Sorsenen et al., 1971; Nichols, 1976). current outliers of spruce, such as those along Thelon River, are thought to be relicts of these warmer periods.

Rowe (1972) described the vegetation of the area south of treeline and divided it into two zones (Fig. 4): the forest-tundra ecotone, a zone with stunted spruce forest and willow and alder shrub tundra, and farther south the boreal forest with muskeg and open stands of spruce, tamarack, birch, and balsam poplar. A carpet of lichens commonly occurs under the open stands of trees.

The Low Arctic ecosystem, which lies directly north of treeline encompasses the study area. Plant communities in this ecosystem have a continuous vegetation cover, broken only where bedrock is exposed or where surfaces are being actively aggraded or eroded. The "lower stratum" of vegetation is made up of a cryptogamic carpet of foliose, squamulose, and fruiticose lichens and substantial moss blankets that cover most surficial materials. The "upper stratum", which varies from a few centimetres to 80 cm in height, is composed of a variety of shrubs and herbs. Erect shrubs include willos **(Salix** species), dwarf birch **(Betula glandulosa)**, dwarf shrubs: **Salix**, mountain avens **(Dryas intergrifolia)**, crowberry **(Empetrum nigrum)**, and the heaths: commonly Labrador tea **(Ledum palustre** spp. **decumbens)**, arctic white heather **(Cassiope tetragona)**, bilberry, and mountain cranberry **(Vaccinium** species). Communities with a shrub component occur on all but the wettest sites. Well developed cottongrass **(Eriophorum vaginatum)** tussock meadows are common. Species diversity is at its maximum for areas above treeline.

The Low Arctic/Mid Arctic boundary has been refined north of the map area in northernmost District of Keewatin – southern Boothia Peninsula (Fig. 4; Tarnocai et al., 1976). Mid-Arctic vegetation is marked by an absence of erect and semi-erect shrubs, an absence of **Eriophorum vaginatum** tussock communities, and a diminution of the heath component, which regularly consists of eight species in low altitude areas of the Low Arctic (Zoltai and Johnson, 1977), to the single species, **Cassiope tetragona.** In addition, continuous vegetation cover appears only on hillsides and in valleys. While treeline was fluctuating during warmer periods, it is likely that the Low/Mid Arctic ecosystem boundary fluctuated northward as well.

Although the study area lies entirely within the Low Arctic ecosystem, vegetation patterns are not uniform throughout. Three subdivisions (zones) of the Low Arctic ecosystem are recognized (Edlund, 1977) within the map area (Fig. 4). These zones are complicated by the preferential selection of plant communities of certain types of materials. Glacial deposits are the only friable materials (for root systems) that consisently occur in all parts and at various elevations of the map area; therefore a vascular plant zonation is recognized mainly on these deposits. Although bedrock outcrops throughout the map area, it supports only cryptogamic communities, which do not show obvious zonation. Because the distribution of most marine sediments is limited to the north and north-central part of the map area (Fig. 2) and to low elevations, the spatial distribution of plant community types, and therefore vegetation zonation, is limited. Plants associated with early stages of succession, such as those colonizing recent fluvial deposits and active eolian surfaces, did not show evidence of bioclimatic zonation. Therefore, the following discussion of vascular plant zonation of the Low Arctic ecosystem will be in terms of communities found on glacial deposits (mainly till) and marine deposits.

The land surface within the map area rises to 400 m, with most of Wager Plateau at more than 200 m a.s.l. There is also a latitudinal change of about 3°. Although all plant communities in the study area fit the basic defintion of Low Arctic vegetation, changes in diversity and abundance of species and changes in stratum dominance are evident through the area. These trends change with elevation from

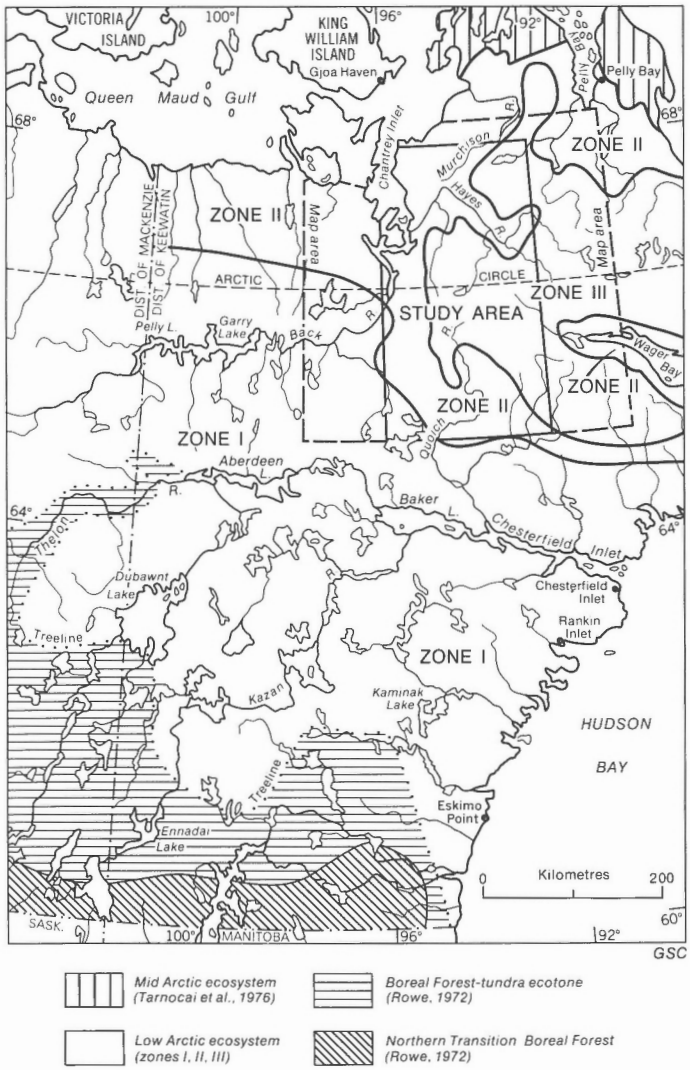

Figure 4. *Bioclimatic zonation of northern District of Keewatin.*

sea level to the uplands of Wager Plateau and, to a lesser extent, from south to north when comparing areas of similar elevations.

Based on reconnaissance field work, the Low Arctic ecosystem in the map area has been divided into three bioclimatic zones (Fig. 4): shrub tundra (zone I), cryptogam tundra (zone III), and a transition zone of cryptogam/shrub tundra (zone II).

Zone I: Shrub Tundra

Zone I is found at low elevations (less than 150 m a.s.l.) in the southwestern part of the map area. The diversity of plant species is greatest, and the shrub component of plant communities is dominant (greater than 50 per cent) on all but the wettest ground. Plant cover is continuous, composed primarily of shrubs, monocots, mosses, and lichens. Erect shrub thickets, reaching heights of up to 80 cm, are abundant on sheltered valleysides and river terraces.

Glacial deposits have the greatest diversity of ericaceous (heath) species, including lapland rosebay **(Rhododendron lapponicum)**, arctic white heather **(Cassiope tetragona)**, Labrador tea **(Ledum palustre** ssp. **decumbens)**, mountain cranberry **(Vaccinium vitis-idaea)**, bilberry **(V. uliginosum)**, alpine bear berry **(Artostaphylos alpina)**, **Andromeda polifolia**, and alpine azalea **(Loiseluria procumbens)**. Shrubs include the willows **Salix alaxensis**, **S. arctica**, **S. glauca**, **S. herbacea**, **S. phylicifolia** ssp. **planifolia**, **S. reticulata**, crowberry **(Empetrum nigrum)**, **Diapensia lapponica**, and dwarf birch **(Betula glandulosa)**. Cottongrass **(Eriophorum vaginatum)** tussocks are a common component of meadow communities on imperfectly drained fine grained deposits. Imperfectly drained meadow communities have the greatest diversity for moss and monocot tussocks with microrelief of up to 25 cm create microhabitats that accommodate species preferring drier habitats.

On marine deposits non-ericaceous erect, semi-erect, and dwarf shrubs, including willows and dwarf birch, dominate moderately to well drained sites; although ericaceous species are present and in diversity similar to that on glacial deposits, these species do not make up a substantial component of the communities. Moncots such as **Eriophorum vaginatum** dominate moderately to imperfectly drained sites and are accompanied by a substantial semi-erect willow and birch component. Dense sedge meadows are common on wetlands.

Zone III: Cryptogam Tundra

Zone III is the harshest bioclimatic zone in the map area and includes most of the plateau over 200 m a.s.l. Plant cover is continuous: lichens and mosses are typically dominant (at least 75 per cent cover), and vascular plants are much reduced in numbers and diversity compared to those in zone I.

On glacial deposits, ericaceous species still dominate the vascular component of the plant communities on moderately to well drained sites, but the species are limited to **Cassiope tetragona** and **Ledum palustre**, with **Vaccinium vitis-idaea** present locally. Erect and semi-erect shrubs are absent, as is **Eriophorum vaginatum**.

No marine deposits occur at these elevations, so comparisons with Zone 1 vegetation cannot be made.

Zone II: Cryptogam/Shrub Tundra

Between zones I and III is an intermediate zone (Fig. 4) which is similar to zone III in that the cryptogam component is the dominant plant cover; however, semi-erect shrubs grow to 0.5 m high in sheltered sites and can be a significant part of the plant community. The herbaceous component of the communities is more diverse than in zone III but is less so than in zone I.

On glaical deposits the heath species **Cassiope** and **Ledum**, which dominante zone III communities, are also dominant here; however, other ericaceous species – bear berry, blueberry, and mountain cranberry, **Andromeda**, and lapland rosebay – also grow. Erect shrubs include dwarf birch, **Salix alaxensis**, and **Salix phylicifolia**. On wet, sandy areas, **Eriophorium vaginatum** is a small but regular component of the community.

On marine deposits, which cover a substantial part of zone II, non-ericaceous dwarf shrubs, **Salix** species, and to a lesser extent **Dryas integrifolia** and monocots dominate the vascular component. Erect shrubs and the ericaceous species listed above for this zone are generally restricted to sheltered sites. **Eriophorum vaginatum** tussock meadows are common, and there is still a small semi-erect willow and birch component to this community. Sedges and grass species dominate the wetlands.

RELATIONSHIPS BETWEEN PLANT COMMUNITIES AND SURFICIAL MATERIALS

In the map area, bedrock and glacial deposits occur in all three bioclimatic zones; marine deposits are restricted to zones I and II; and mappable, actively aggrading and eroding surfaces are found primarily in zones II and III (cf. Fig. 2, 4). For each material type in each zone, a suite of plant communities can be recognized, reflecting moisture differences in the surficial materials. Factors that influence moisture regime include topography, soil texture, and depth of active layer. Dominant plant communities are shown on the vegetation map (Map 1548A).

Soil moisture can be uniform over large areas, such as well drained hilltops and ridges or imperfectly drained gentle slopes. Changes in soil moisture, however, can occur within a small (1 m or less) distance, such as variations seen on sorted materials, where the fine fraction is poorly drained, or on hummocky terrain, where moisture regime varies vertically as well as horizontally. Such local variations are reflected in changes in vegetation, which in turn give the terrain a patchy, striped, or mosaic appearance.

Moisture regimes of the various types of surficial materials and their accompanying plant communities are discussed below, as well as comparisons of the plant communities growing on a given surficial material throughout the three bioclimatic zones. Two of the materials, bedrock and modern deposits, show no zonal variation; on glacial deposits descriptions of plant communities will be made initially for zone III, with reference to how these communities change in the other two zones; on marine deposits, zone II vegetation will be described with reference to vegetation in zone I.

Bedrock: Cryptogam Communities

Bedrock outcrops are generally local in extent and are commonly associated with glacial deposits (Fig. 5). Bedrock is subject to sudden extremes of moisture and temperatures and to severe desiccation, resulting in an extremely harsh environment for vegetation. Because outcrops commonly occur on the tops of knolls and ridges, snow frequently blows clear in winter, exposing the rock.

The vegetation on outcrops is entirely cryptogamic in composition (Table 2); vascular plants, which require soil for rooting, are absent. No zonal variation in cryptogamic communities was seen, and only local differences occur. Coverage of lichen communities varies from less than 10 per cent to nearly complete cover. This seems to be

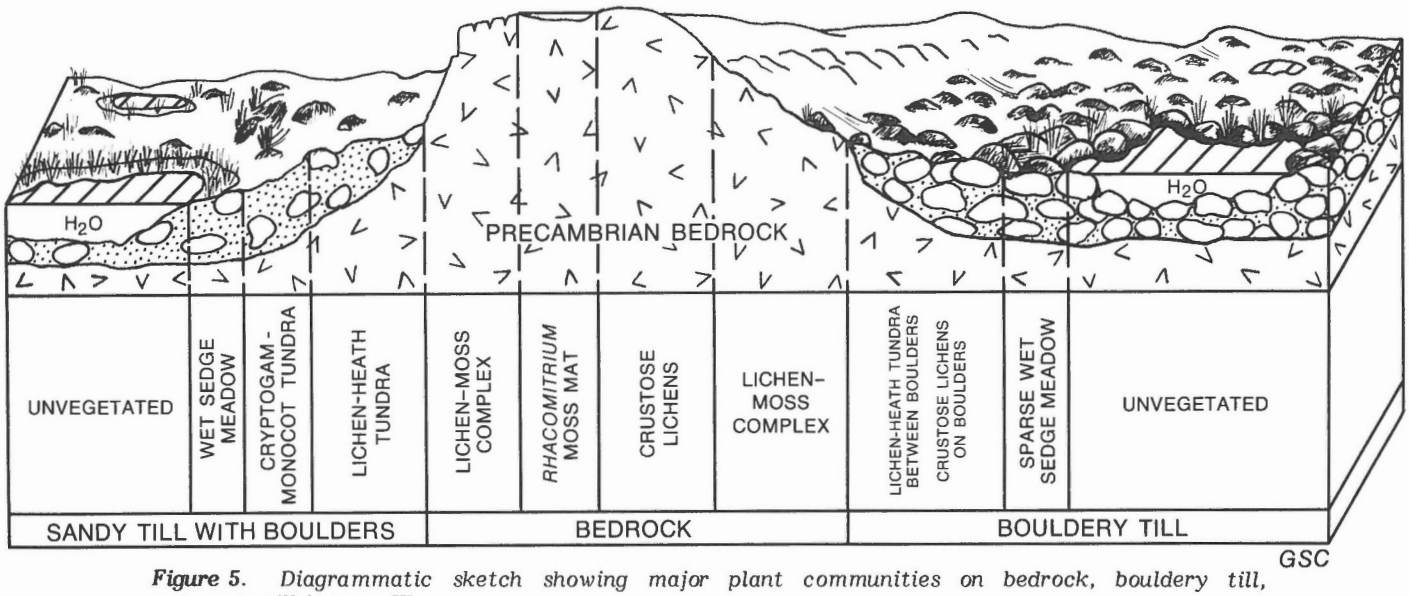

Figure 5. *Diagrammatic sketch showing major plant communities on bedrock, bouldery till, and sandy till in zone III.*

related to the amount of available moisture and protection from wind abrasion, for density is greatest on the sheltered parts of rock where snow accumulates and where protection exists from desiccation and from wind blasting by snow.

Dry, smooth bedrock exposures and large boulders are vegetated by tightly adhering lichens, primarily crustose species. These are mainly **Rhizocarpon, Lecanora,** and **Lecidea** species. Foliose lichens also occur in places. Dense thalli of orange nitrophilous **Xanthoria elegans** are found on some prominent rock knobs and boulders that probably have been used as bird perches.

Frost-shattered bedrock provides sheltered cracks and zones of snow and water accumulation. Common lichens on more protected surfaces are **Parmelia, Umbilicaria, Physcia, Cornicularia, Alectoria nigricans,** and **Stereocaulon** species. In crevices, tufts of the mosses **Rhacomitrium lanuginosum, Grimmia affinis,** and **Polytrichum piliferum** also are established.

In large crevices and depressions such as shallow concavities in the rock surface, thick **Rhacomitrium** moss mats grow directly on the bedrock in the absence of soil or humus. The mat may contain lichens such as **Alectoria nigricans, A. ochroleuca, Cetraria nivalis, C. cucullata,** and **Thamnolia** species. The moss mat can have a vascular component rooted within it (usually less than 1 per cent cover), which includes common colonizing monocots such as **Luzula confusa, Hierochloe alpina, Festuca brachyphylla, Poa arctica,** and in places herbs such as **Papaver lapponicum** and **Cerastium alpinum.** The fern **Dryopteris fragrans** is locally found in sheltered nooks and crevices.

Glacial Deposits

Glacial deposits are the most widespread surficial materials in the map area (Fig. 2). The deposits are similar in mineral composition, since they are derived from Precambrian bedrock. The materials differ in texture: some tills and ice-contact materials may have a sandy gravel matrix with a large percentage of boulders; some tills and glaciofluvial and ice-contact deposits are predominantly sand and gravel; glaciolacustrine deposits are primarily sandy with few boulders.

Table 2. Cryptogams associated with bedrock in the study area

	Exposed Rock Surfaces	Cracks and Sheltered Zones	Moss Mats
LICHENS			
Alectoria nigricans	-	x	x
Alectoria nitidula	-	x	x
Alectoria ochroleuca	-	-	x
Cetraris islandica	-	-	x
Cetraria nivalis	-	-	x
Cetraria cucullata	-	-	x
Cladonia multiformis	-	-	x
Cladonia pyxidata	-	-	x
Cornicularia divergens	-	x	x
Lecanora sp.	*	x	-
Lecidea sp.	*	x	-
Parmelia alpicola	x	x	-
Parmelia centrifuga	*	x	-
Parmelia ophaloides	x	x	-
Parmelia saxatilis	*	x	-
Peltigera sp.	-	-	x
Physcia sp.	x	x	-
Rhizocarpon geographicum	*	-	-
Rhizocarpon sp.	x	x	-
Rinodina sp.	-	x	-
Stereocaulon paschale	-	x	x
Sphaeroporus sp.	-	-	x
Thamnolia vermicularis	-	-	x
Umbilicaria hyperborea	-	x	-
Umbilicaria proboscidea	-	x	-
Xanthoria elegans	x	-	-
MOSSES			
Rhacomitrium lanuginosum	-	x	*
Grimmia affinis	-	x	-
Polytrichum piliferum	-	x	x

Species dominant(*), present(x), absent(-)

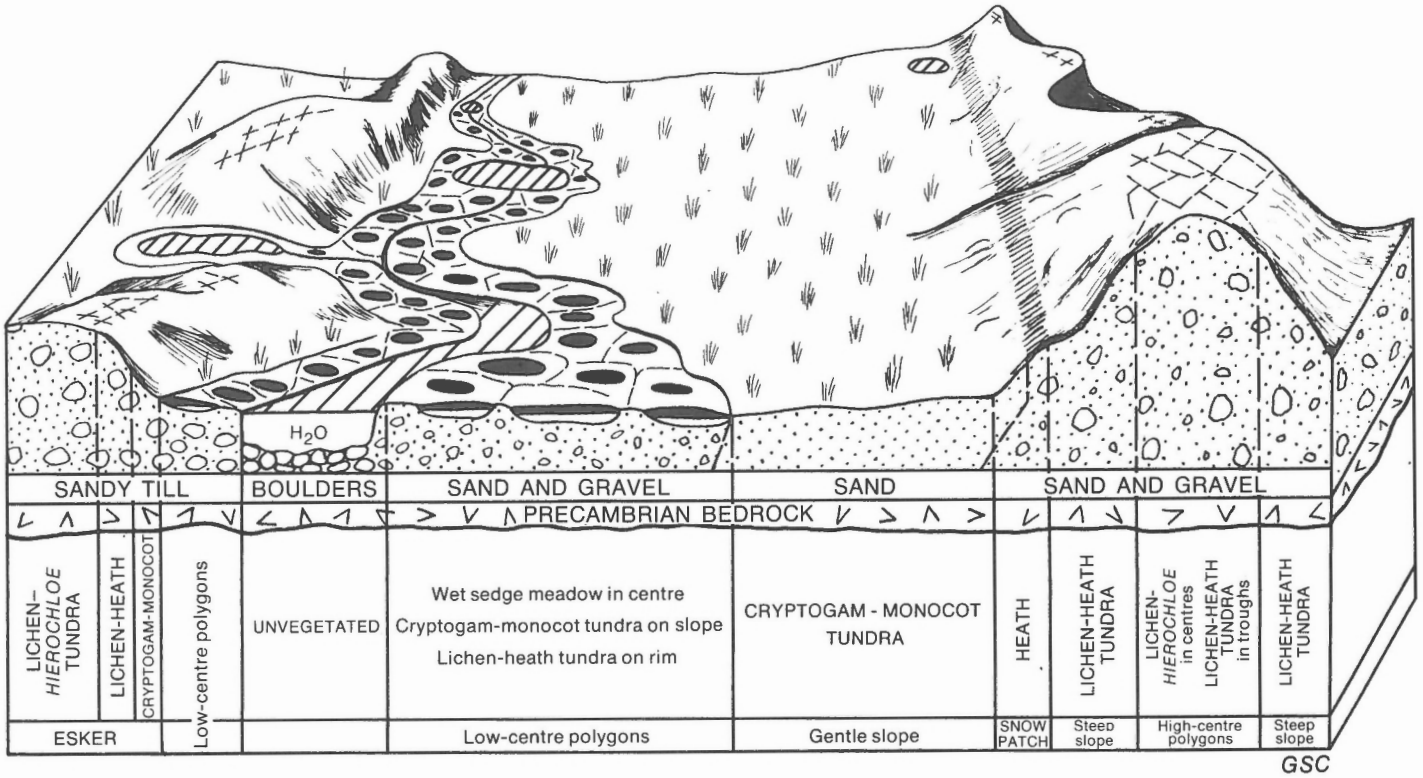

Figure 6. *Diagrammatic sketch showing major plant communities on glacial deposits in zone III.*

Texture and topographic configurations of the deposits influence moisture regime. Ridge crests, hilltops, upper slopes, high centres of polygons, and terrace edges are the best drained materials; upper till slopes are moderately to well drained; lower slopes and valley bottoms and areas directly below late-lying snowbeds are imperfectly to poorly drained; centres of low-centre polygons and some terraces and areas adjacent to water bodies are usually saturated. Generally coarse textured materials are the best drained, whereas fine textured materials are poorly drained.

At snowmelt all materials are saturated, but only glacial deposits with a fine grained matrix or those adjacent to water bodies remain saturated throughout the growing season. Ridge crests and upper slopes on all glacial deposits dry out rapidly. Lower slopes are seasonally variable, with an adequate water supply for most of the season.

Figure 6 and Tables 3 and 4 summarize the distribution of vegetation on glacial deposits.

Dry Glacial Deposits: ***Alectoria-Hierochloe*** *Tundra.* Well drained, sandy glacial deposits, such as esker crests, ridge tops, and terrace edges, support an **Alectoria-Hierochloe** tundra community which has an extensive lower stratum (at least 90 per cent cover) of **Alectoria nigricans** and **Alectoria ochroleuca. Rhacomitrium lanuginosum** is also present in most places and is locally co-dominant. **Hierochloe alpina** is the most common, and in many places the only, vascular plant (1 to 5 per cent cover). Heath species are generally absent from this community but may be present locally in depressions and in the lee of boulders. This community has a characteristic dark appearance on photographs (Fig. 7).

A similar **Alectoria-Hierochloe** tundra also exists in zone II and the driest areas of zone I; however, in zone I the dwarf shrubs **Arctostaphylos alpina, Empetrum nigrum, Vaccinium uliginosum,** and **Salix arctica** may be locally present as well.

Moderately to Well Drained Deposits: ***Alectoria****-heath tundra.* Moderately to well drained bouldery glacial deposits, the most common surficial material in the map area, are vegetated in zone III by a complex of **Alectoria**-heath tundra rooted in the matrix of the diamicton and crustose lichen communities on the boulders.

Alectoria-heath tundra consists of a lower stratum of about 75 per cent **Alectoria** lichens, with **A. ochroleuca** commonly dominant, and **Rhacomitrium lanuginosum** moss, similar to that of the **Alectoria-Hierochloe** tundra lower stratum; however, **Cladonia** and **Cetraria** lichens are also associated with the cryptogamic mat (Table 4). The combination of **Alectoria ochroleuca, Cladonia,** and **Cetraria** gives this lichen community a characteristic grey-green appearance.

Shrub heath species are the dominant vascular plants (5 to 25 per cent) with **Cassiope tetragona** and **Ledum palustre** ssp. **decumbens** being co-dominant. Heath forms dense dwarf thickets in places in the shelter of boulders. **Alectoria**-heath tundra is also found on midslopes where substantial snow cover has accumulated in winter; here **Cassiope** and **Ledum** may form 25 to 75 per cent of the cover.

In zone II this community is similar in composition to **Alectoria**-heath tundra of zone III, except that the heath component can be more abundant (15 to 25 per cent). In parts of zone I the shrub component is greater than 50 per cent, forming a shrub-heath-lichen tundra community.

Table 3. Vascular plants on glacial deposits in the study area

	Lichen-Heath and Lichen-**Hierochloe** Tundra	Cryptogam-Monocot Tundra	Wet Sedge Meadow
Dryopteris fragrans	-	1	-
Lycopodium selago	-	1,2	-
Equisetum arvense	-	1,2	-
Hierochloe alpina	*1,2,3	1,2,3	-
Alopecurus alpinus	-	1,2,3	-
Arctagrostis latifolia	-	1,2,3	-
Arctophila fulva	-	-	1,2,E
Poa arctica	1,2,3	-	-
Poa glauca	1,2,3	-	-
Festuca brachyphylla	1,2,3	-	-
Dupontia Fisheri	-	-	1,2
Pleuropogon Sabinei	-	-	1,2,E
Eriophorum angustifolium	-	-	*1,2,3
Eriophorum russeolum	-	-	1,2
Eriophorum Scheuchzeri	-	1,2	-
Eriophorum vaginatum	-	-	1,2
Carex aquatilis var. **stans**	-	-	*1,2,3
Carex Bigelowii	-	1,2,3	-
Carex chordorhiza	-	-	1
Carex capillaris	-	-	1,2
Carex membranacea	-	-	1,2
Carex misandra	-	1,2	-
Carex rariflora	-	-	1,2
Carex saxatilis	-	-	1
Juncus arcticus	-	-	1,2
Juncus biglumis	-	-	1,2,3
Luzula confusa	1,2,3	1,2,3,	-
Luzula Wahlenbergii	-	1,2	-
Tofieldia pusilla	-	-	1,2
Salix alaxensis	-	1,2	-
Salix arctophila	-	1,2	-
Salix niphoclada	-	1,2	-
Salix phylicifolia ssp. **planifolia**	-	1,2	-
Salix herbacea	-	1,2,3	-
Salix reticulata	-	1,2,3	-
Betula glandulosa	-	1,2	-
Polygonum viviparum	-	1,2,3	-
Stellaria monantha	-	1,2,3	-
Cerastium alpinum	1,2,3	-	-
Silene acaulis ssp. **acaulis**	1,2,3	-	-
Melandrium apetalum	-	1,2	-
Caltha palustris	-	-	1,2
Ranunculus pedatifidus	-	1,2	-
Papaver lapponicum	1,2,3	1,2,3	-
Eutrema Edwardsii	-	1,2	-
Draba sp.	1,2,3	1,2,3	-
Saxifraga cernua	-	1,2,3	-
Saxifraga foliolosa	-	1,2,3	-
Saxifraga hirculis	-	-	1,2
Saxifraga nivalis	-	1,2,3	-
Saxifraga oppositifolia	1,2,3	1,2,3	-
Rubus chamaemorus	-	1	-
Potentilla hyparctica	1,2,3	1,2,3	-
Dryas integrifolia	-	1,2,3	-
Astragalus alpinus	-	1,2,3	-
Oxytropis Maydelliana	-	1,2	-
Empetrum nigrum	1,2	1,2	-
Epilobium latifolium	1,2	1,2	-
Hippuris vulgaris	-	-	1,2,E
Pyrola grandiflora	-	1,2	-
Ledum palustre ssp. **decumbens**	*1,2,3	-	
Loiseleuria procumbens	-	1,2	-
Cassiope tetragona	*1,2,3	-	-
Rhododendron lapponicum	-	1,2	-
Arctostaphylos alpina	1,2	1,2	-
Vaccinium vitis-idaea	1,2,3	1,2,3	-
Vaccinium uliginosum	1,2	1,2	-
Diapensia lapponica	-	1,2	-
Andromeda polifolia	-	1,2	-
Pedicularis sudetica	-	1,2,3	-
Arnica alpina	-	1,2	-
Taraxacum lacerum	-	1,2	-

Species dominant (*); present in zones I, II, III (1,2,3), emergent (E); absent (-)

Table 4. Cryptogams on glacial deposits in the study area

	Lichen-Heath and Lichen-**Hierochloe** Tundra	Cryptogam-Monocot Tundra	Wet Sedge Meadow
MOSSES			
Aulacomnium sp.	-	*	x
Bryum sp.	-	x	x
Calliergon sp.	-	x	*
Dicranum sp.	-	x	x
Drepanocladus sp.	-	x	*
Grimmia sp.	x	-	-
Hylocomnium sp.	-	*	x
Pleurozium schreberi	-	x	-
Polytrichum piliferum	x	x	-
Rhacomitrium lanuginosum	x	x	-
Sphagnum sp.	-	-	x
Tomenthypnum nitens	-	*	-
LICHENS			
Alectoria nigricans	*	x	-
Alectoria nitidula	x	-	-
Alectoria ochroleuca	*	x	-
Cetraria cucullata	x	x	-
Cetraria delisei	x	x	-
Cetraria islandica	-	x	-
Cladonia alpestris	-	*	-
Cladonia amaurocraea	-	x	-
Cladonia coccifera	-	x	-
Cladonia mitis	x	*	-
Cladonia multiformis	-	x	-
Cladonia rangiferina	x	*	-
Cladonia pixidata	x	x	-
Cladonia unciatis	x	x	-
Cornicularia divergens	x	-	-
Dactylina arctica	-	x	-
Dactylina ramulosa	-	x	-
Nephroma arctica	-	x	-
Parmelia omphalodes	x	x	-
Peltigera sp.	-	x	x
Sphaerophorus sp.	-	x	-
Stereocaulon paschale	x	x	-
Thamnolia vermicularis	x	x	-

Species dominant (*), present (x), absent (-)

Erect and prostrate willow species, dwarf birch, **Arctostaphylos alpina**, and **Empetrum nigrum** occur, in addition to abundant **Cassiope** and **Ledum**. The cryptogamic lower stratum species are similar in composition to those in zones II and III but are no longer the dominant plant cover. In the driest areas **Alectoria**-heath tundra, similar to that of zone III, still occurs.

The lichen communities on boulders are similar to those on bedrock described above.

Imperfectly Drained Deposits: Cryptogam-Monocot Tundra. Imperfectly drained, seasonally saturated, sandy deposits are vegetated by cryptogam-monocot tundra. This is the most common community seen on the lower slopes of eskers and long gentle slopes (Fig. 6) and, in fact, on most glacio-lacustrine deposits. The lower stratum is dense and extensive (greater than 90 per cent cover), with dominant bryophytes including **Rhacomitrium, Aulacomnium,** and **Tomenthypnum** species, which give the community a distinctive yellow. **Dicranum, Hylocomnium, Polytrichum,** and **Pleurozium** mosses are common associates. Within this moss mat are numerous lichens, the most abundant include **Cladonia rangiferina, C. mitis, C. alpestris,** with regular occurrences of **Cetraria nivalis** and **C. cucullata.** Other cryptogamic species are listed in Table 4. Imperfectly drained glacial deposits with a high boulder component frequently have a mosaic of cryptogam-monocot tundra on the matrix and crustose lichens on boulders.

Table 5. Vascular plants on marine deposits in zone II

	SILTS			SANDS		
	Dry Barrens	Tussock Meadow	Wet Sedge Meadow	Dry Barrens	Shrub Monocot Tundra	Wet Sedge Meadow
Equisetum arvense	-	-	-	-	x	-
Lycopodium selago	-	-	-	-	x	-
Hierochloe alpina	-	x	-	x	x	-
Alopecurus alpinus	*	x	x	x	x	x
Arctagrostis latifolia	-	x	-	-	x	-
Trisetum spicatum	-	-	-	x	-	-
Poa arctica	-	-	-	x	-	-
Poa glauca	-	-	-	x	-	-
Pleuropogon Sabinei	-	-	x, E	-	-	x, E
Arctophila fulva	-	-	x, E	-	-	x, E
Puccinellia phryganodes	x	-	-	-	-	-
Colpodium Vahlianum	*	-	-	-	-	-
Dupontia Fisheri	-	-	x	-	-	x
Festuca brachyphylla	x	-	-	x	-	-
Agropyron boreale	-	-	-	x	-	-
Agrostis borealis	-	-	-	x	-	-
Calamagrostis neglecta	-	-	x	-	-	x
Elymus arenarius ssp. mollis	x	-	-	-	-	-
Eriophorum angustifolium	-	-	*	-	x	*
Eriophorum russeolum	-	x	x	-	x	x
Eriophorum Scheuchzeri	-	-	-	-	x	-
Eriophorum vaginatum ssp. spissum	-	*	x	-	x	x
Kobresia myosuroides	-	-	-	-	x	-
Carex aquatilis var. stans	-	-	*	-	-	*
Carex atrofusca	-	-	x	-	-	x
Carex bicolor	-	-	-	-	-	x
Carex Bigelowii	-	x	-	-	x	-
Carex capillaris	-	-	x	-	-	x
Carex holostoma	-	-	x	-	-	x
Carex membranacea	-	-	-	-	x	-
Carex misandra	-	-	-	-	x	-
Carex nardina	-	-	-	-	x	-
Carex rariflora	-	-	-	-	-	x
Carex saxitilis	-	-	x	-	-	x
Carex scirpoidea	-	-	-	-	x	-
Carex vaginata	-	-	-	-	x	-
Juncus arcticus	-	-	x	-	-	x
Juncus biglumis	-	-	x	-	-	x
Juncus castaneus	-	-	x	-	-	x
Luzula arctica	-	x	-	x	x	-
Luzula confusa	-	x	-	*	x	-
Tofieldia pusilla	-	x	-	-	x	-
Salix arctica	-	x	-	-	x	-
Salix alaxensis	-	x	-	-	x	-
Salix herbacea	-	x	-	-	x	-
Salix phylicifolia ssp. planifolia	-	x	-	-	-	-
Salix reticulata	-	x	-	-	x	-
Betula glandulosa	-	x, S	-	-	x, S	-
Oxyria digyna	-	x	-	x	x	-
Polygonum viviparum	-	x	-	-	x	-
Stellaria laeta	-	x	-	-	x	-
Stellaria monantha	-	x	-	-	x	-
Stellaria crassipes	-	-	-	-	x	-
Cerastium alpinum	-	x	-	-	x	-
Cerastium beeringianum	-	-	-	-	x	-
Silene acaulis ssp. acaulis	-	-	-	x	x	-
Arenaria rubella	-	-	-	x	-	-
Melandrium apetalum	-	x	-	-	x	-
Ranunculus gmelini	-	-	x	-	-	x
Ranunculus hyperboreus	-	-	x	-	-	x
Ranunculus nivalis	-	x	-	-	x	-
Ranunculus Pallasii	-	-	x	-	-	x
Papaver lapponicum	-	x	-	x	x	-
Eutrema Edwardsii	-	x	-	-	x	-
Cardamine bellidifolia	-	-	x	-	-	x

Table 5 (cont.)

	SILTS			SANDS		
	Dry Barrens	Tussock Meadow	Wet Sedge Meadow	Dry Barrens	Shrub Monocot Tundra	Wet Sedge Meadow
Draba sp.	-	x	-	x	x	-
Saxifraga caespitosa	-	-	-	x	-	-
Saxifraga cernua	-	x	-	x	x	-
Saxifraga foliolosa	-	x	x	-	x	x
Saxifraga hieracifolia	-	-	x	-	-	x
Saxifraga hirculis	-	-	x	-	-	x
Saxifraga oppositifolia	-	-	-	x	-	-
Saxifraga tricuspidata	-	-	-	x	-	-
Potentilla hyparctica	-	x	-	x	x	-
Potentilla Vahliana	-	-	-	-	x	-
Dryas integrifolia	-	x	-	*	*	-
Astragalus alpinus	-	x	-	-	x	-
Oxytropis Maydelliana	-	-	-	-	x	-
Empertrum nigrum	-	x	-	x	x	-
Hippuris vulgaris	-	-	x, E	-	-	x, E
Pyrola gradiflora	-	-	-	-	x	-
Ledum palustre ssp. **decumbens**	-	x, S	-	-	x, S	-
Cassiope tetragona	-	x, S	-	-	x, S	-
Phyllodoce coerulea	-	-	-	-	x	-
Arctostaphylos alpina	-	x	-	x	x	-
Vaccinium uliginosum	-	x	-	-	x	-
Vaccinium vitis-idaea	-	x	-	-	x	-
Diapensia lapponica	-	-	-	x	-	-
Armeria maritima	-	-	-	x	-	-
Castilleja pallida	-	-	-	-	x	-
Pedicularis hirsuta	-	x	-	-	x	-
Pedicularis lapponica	-	x	-	-	x	-
Pedicularis sudetica	-	x	-	-	x	-
Erigeron eriocephalus	-	-	-	x	-	-
Antennaria Friesiana	-	-	-	-	x	-
Antennaria monocephela	-	-	-	-	x	-
Matricaria sp.	-	-	-	x	-	-
Artemesia borealis	-	-	-	x	-	-
Arnica alpina	-	x	-	-	x	-
Taraxacum lacerum	-	x	-	-	x	-

Species dominant(*); present(x); in sheltered location(S); emergent(E); absent(-)

Luzula confusa and **Carex Bigelowii** are the only regularly occurring vascular plants in zone III (Table 3). In zones I and II the monocots **Arctagrostis latifolia, Carex misandra, Luzula Wahlenbergii,** and **Juncus** species are common. The most obvious zonal difference is seen in the shrub component: In zone I erect shrubs **Salix alaxensis** and **S. phylicifolia** form up to 10 per cent cover compared to zone III where cover is only 1 to 2 per cent and shrubs are shorter (less than 30 cm), possibly indicating maximum depth of snow cover in winter. Also, the diversity of herbs increases in zones I and II (Table 3), especially dwarf willows, legumes, and ericaceous species.

Poorly Drained and Saturated Deposits: Wet Sedge Meadows and March Emergents. Only poorly drained sites, commonly bottomlands with ponds, depressions in terraces, and slopes beneath late-lying snowbeds, wet sedge meadows occur. This community commonly has a dense, nearly continuous bryophytic lower stratum of **Drepanocladus, Calliergon,** and **Aulacomnium** mosses (Table 4); lichens are generally absent. **Carex aquatilis** var. **stans** and **Eriophorum angustifolium** are characteristic of wet sedge meadows and commonly have a bright green appearance. On wet bouldery deposits these two diagnostic species are often the only vascular plants; and the bryophytic lower stratum is poorly developed.

In zone I and in some places in zone II, **Sphagnum** species are present. Other monocots such as **E. vaginatum, Dupontia Fisheri, Arctagrostis,** and a variety of Carices are common (Table 3). Hummocks in the cryptogamic layer support a variety of dwarf shrubs and herbs: **Ledum, Cassiope, Loiseleuria, Vaccinium, Salix arctica,** and **Salix herbacea.** Between moss hummocks and **Eriophorum vaginatum** tussocks, **Betula** and semi-erect **Salix** grow in places. Therefore in many wet meadow communities moisture regime varies vertically, and several different communities are found in close proximity.

At the edges of ponds, shallow marsh emergents such as **Hippuris vulgaris, Pleuropogon Sabinei,** and **Arctophila fulva** can be found in zones I and II but rarely in zone III. **Carex aquatilis** var. **stans** and **Eriophorum angustifolium** may also behave as emergents.

Patterned Ground. Glacial deposits in the study area are subjected to intense frost action which results in the formation of a variety of patterned ground features. Because the materials are nearly completely covered by vegetation, the patterned ground features are best seen in the preferential response of plant communities to local differences in grain size and moisture content. Other patterns reflect different stages of natural revegetation.

Figure 7

Plant communities on ice-contact and glaciolacustrine deposits. Well drained ridges and slopes support the dark-appearing ***Alectoria-Hierochloe*** *and* ***Alectoria****-heath tundra, whereas on the lowland grows the light-toned cryptogam-monocto tundra. Also not areas of eolian activity on the esker. GSC 203642-A*

Glaciofluvial outwash terraces and some ice-contact deposits are commonly patterned with a network of ice-wedge polygons. High-centre polygons are associated with moderately well drained materials and low-centre polygons with imperfectly to poorly drained materials. Small ponds may be found in the central depressions of low-centre polygons or where troughs intersect around high-central polygons. In such patterned ground features, moisture regimes change drastically within a metre, producing a mosaic of plant communities reflecting differences in moisture content.

In zone III the driest materials, such as those forming the centre of high-centre polygons, have **Alectoria-Hierochloe** tundra communities with **Alectoria**-heath tundra in shallow polygon troughs. Deep troughs with ponds in the nodes may have small, poorly developed wet sedge meadow communities. Low-centre polygons are dominated by wet sedge meadows and cryptogamic monocot tundra, with berms of **Alectoria**-heath tundra.

Mudboils commonly develop on till that has a substantial component of fine grained material in the matrix. Active mudboils have bare, fine grained centres (up to about 1 m in diameter) and commonly have coarse material at the edge. A cryptogamic berm composed of **Rhacomitrium lanuginosum, Alectoria nigricans, A. ochroleuca,** and **Cladonia** and **Cetraria** species commonly surrounds the bare centre. Heath species and herbs may root in this berm, making it a type of lichen-heath tundra. Colonization of the bare centre begins with the invasion of scattered herbs, primarily grasses, followed by dwarf shrubs. At this time a thin skin of dark lichen thalli nearly covers the boil and **Alectoria, Cetraria,** and **Stereocaulon** lichen species appear; the development of this skin of thalli indicates that the boil is no longer active. Inactive mudboils have **Alectoria**-heath tundra on dry areas and cryptogam-monocot tundra and wet sedge meadows on wet areas.

Sorted stripes, found on some gentle slopes, have alternating bands of fine and coarse sand and gravel, with the coarse fraction being drier than the fine fraction. The parallel alignment of **Alectoria**-heath and cryptogam-monocot tundra reflects the moisture differences. Vegetation striping can also occur on material of uniform texture where alternating light and dark bands of vegetation grow on sediments where minor parallel rills have developed.

The coarsest materials, cobbles and boulders, may also be sorted into nets and stripes having diapirs of fines among the boulders. The boulders support the usual crustose lichen communities and between boulders grows **Alectoria**-heath.

Marine Deposits

Marine deposits are made up of fine grained silt and clay of deep water deposits, with seawater salts incorporated in them, and sand and gravel of nearshore and beach deposits from which most salts have been leached. Marine deposits are generally less acidic than glacial deposits. The silt and clay are usually moderately to poorly drained; in only a few cases are they dry. Sand and gravel deposits are much better drained, and most communities are associated with moderately to well drained sand and gravel. Marine deposits occur within zones I and II (cf. Fig. 2, 4); descriptions will be made of plant communities in zones II (Tables 5, 6), with references to differences in zone I. Figure 8 shows a schematic distribution of communities on sandy and silty marine deposits.

Well Drained Silt and Clay: Grass Barrens. Extremely dry silt and clay deposits are found along the eroding silt bluffs adjacent to Hayes River and in a few local areas where silt has been recently eroded. The bluffs are unvegetated; at the base, where an apron of eroded marien silt accumulates, a sparse (less than 5 per cent) halophytic community of isolated plants of **Elymus arenarius** ssp. **mollis** and **Puccinellia phryganodes** occurs. **Alopecurus alpinus** and **Colpodium Vahlianum** are part of this community in places. This halophytic community also occurs sporadically in the present day tidal zone.

Redposited clay and soils are found in terraces along Hayes River. On some terraces the materials are extremely dry and covered by a dense network of desiccation cracks. These materials are sparsely vegetated (less than 20 per cent cover) in zones I and II by tufts of **Colpodium Vahlianum** and **Alopecurus alpinus; Puccinellia phryganodes** and **Festuca brachyphylla** occur sporadically.

Moderately to Imperfectly Drained Silt: Cottongrass Tussock Meadows. Moderately to imperfectly drained silt supports dense cottongrass tussock meadow communities, common in Murchison River valley and on the silty plains of the Back

Table 6. Cryptogams on Marine Deposits in zone II

	SILTS		SANDS		
	Tussock Meadow	Wet Sedge Meadow	Dry Barrens	Shrub Monocot Tundra	Wet Sedge Meadow
MOSSES					
Aulacomnium sp. / **Aulacomnium palustre** / **Aulacomnium turgidum**	*	x	-	x	x
Bryum sp.	x	-	-	x	-
Calliergon sp.	-	x	-	-	x
Campylium stellatum	-	x	-	-	x
Ceratodon purpureus	-	-	x	-	-
Dicranum sp.	x	x	-	x	-
Drepanocladus sp. / **Drepanocladus revolvens**	-	*	-	x	*
Hylocomnium sp.	*	-	-	x	-
Pohlia nutans	x	-	-	x	-
Polytrichum piliferum	-	-	x	-	-
Rhacomitrium lanuginosum	x	-	x	x	-
Rhytidium rugosum	x	-	-	x	-
Scorpidium sp.	x	-	-	x	-
Sphagnum sp.	x	x	-	x	x
Tomenthypnum nitens	*	x	-	x	x
LICHENS					
Alectoria nitidula	-	-	x	-	-
Alectoria ochroleuca	-	-	x	-	-
Cetraria cucullata	x	-	x	-	-
Cetraria delisei	-	-	x	-	-
Cetraria islandica	x	-	-	x	-
Cetraria nivalis	x	-	-	x	-
Cladonia multiformis	-	-	-	x	-
Cladonia pyxidata	-	-	x	-	-
Cladonia uncialis	-	-	-	x	-
Cornicularia divergens	-	-	x	-	-
Dactylina arctica	x	-	-	x	-
Peltigera sp.	x	x	-	x	x
Sphaerophorus globosus	x	-	-	x	-
Stereocaulon sp.	x	-	-	x	-
Thamnolia sp.	x	-	-	x	-
Xanthoria elegans	-	-	x	-	-

Species dominant(*), present(x), absent(-)

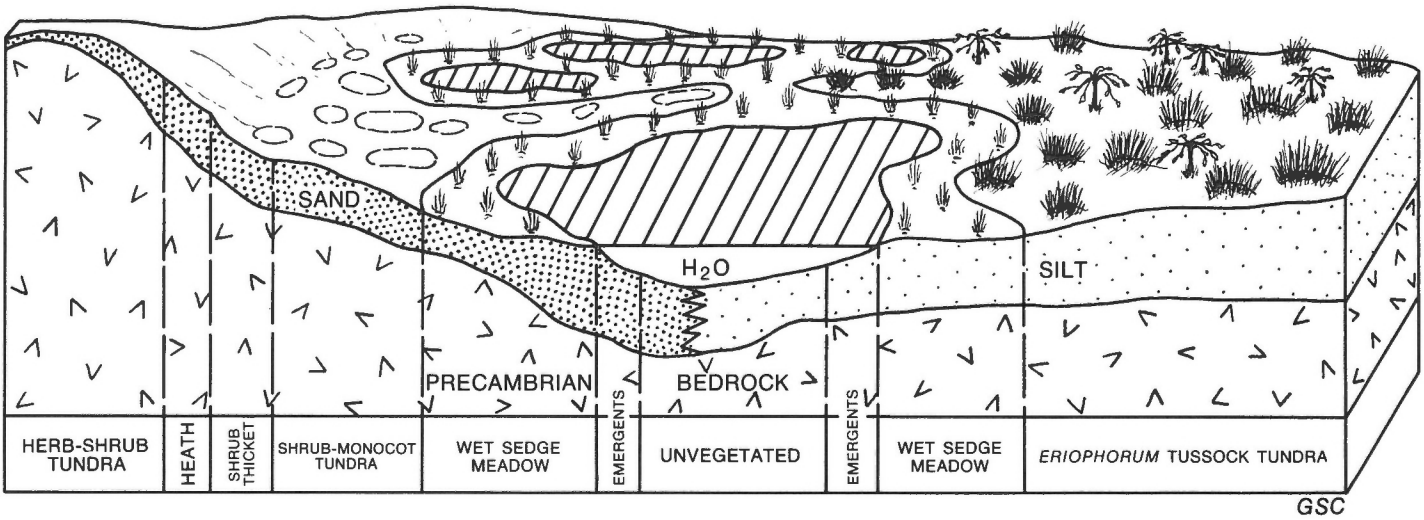

Figure 8. Diagrammatic sketch showing major plant communities on sandy and silty marine deposits.

Lowland extension. **Eriophorum vaginatum** ssp. **spissum** is clearly dominant (averaging 50 to 75 per cent cover), and these tussocks are responsible for the hummocky appearance (Fig. 9). The tussocks are 20 to 30 cm in diameter and up to 30 cm high. When flowering, the inflorescences commonly reach another 30 to 40 cm. An erect shrub component, **Salix phylicifolia** ssp. **planifolia** and **S. alaxensis,** is present in many places. The shrubs reach a height of 50 cm, which indicates the height of snow cover on the plains, for at this height the shrub develops lateral branching in krummholz fashion.

The hummocky terrain offers a variety of microhabitats on which dwarf shrubs, monocots, forbs, and cryptogams grow. Dense thickets of **Betula glandulosa** and **Salix alaxensis** grow in protected locations such as streambanks and gullies. The cryptogamic lower stratum is best developed between the hummocks but is also intermingled with tussocks. The most abundant species include **Rhacomitrium, Dicranum, Bryum, Hylocomnium,** and **Tomenthypnum; Drepanocladus** grows locally on wet aspects. The lichen component is much reduced in amount and diversity from that found on glacial deposits. There is a general absence of **Alectoria** species, except on **Rhacomitrium** mats in sheltered areas; colonial **Cladonia** species are absent; and **Cetraria** and **Dactylina** species are less abundant. **Peltigera, Cetraria, Thamnolia,** and **Dactylina** are the most common lichens.

In zone I there is a further increase in species diversity and in per cent cover (10 to 25 per cent) of the erect and semi-erect shrub component.

Poorly Drained Silt and Clay: Wet Sedge Meadows. The water table is commonly at or near the surface and ponds are abundant on poorly drained marine silt. Wet sedge meadow communities grow around the margins of ponds; many wet meadow species also grow on slopes where water seeps throughout the summer. Dense (20 to 50 per cent cover) **Carex aquatilis** var. **stans** is dominant and **Eriophorum angustifolium** is commonly co-dominant. These sedges appear in pure stands and in mixtures with other less abundant monocots, such as other carices and cottongrasses, **Dupontia Fisheri, Arctagrostis latifolia,** and **Juncus biglumis.** Shrubs are absent from this community. The species composition is similar to that on glacial deposits, but plants are generally more numerous on marine deposits.

Well Drained Sand and Gravel: Shrub-Monocot Barrens. Dry sand and gravel are commonly vegetated by shrub-monocot barrens. Dwarf **Salix** species are dominant, but generally with less than 10 per cent cover; they are commonly found in depressions and shallow polygon troughs. Some heath species may also be present. The herbaceous component (usually 2 to 5 per cent) is dominated by monocots, chiefly **Alopecurus alpinus, Carex Bigelowii, Hierochloe alpina,** and **Festuca brachyphylla;** forbs are present but not in significant amount. A cryptogamic lower stratum is poorly developed or discontinuous at best.

Moderately Drained Sand and Gravel: Shrub-monocot Tundra. Moderately well drained sand and gravel support a shrub-monocot tundra. Dwarf shrubs, including **Salix arctica, Dryas integrifolia,** and **Empetrum nigrum** are present to 25 per cent cover. Heath species are confined mostly to sheltered habitats.

Monocots include **Eriophorum Scheuchzeri,** Carices, **Arctagrostis,** and **Alopecurus,** totalling between 4 and 15 per cent cover. Monocots are even more abundant locally on wet sites; forbs are diverse (Table 5).

The lower stratum consists of **Aulacomnium** and **Tomenthypnum,** with **Drepanocladus** and **Sphagnum** species in places. Lichens are uncommon, **Peltigera** species are the only regularly appearing types (Table 6).

In zone I species are more diverse and shrubs are even more dominant, with a greater representation of erect and semi-erect shrubs.

Poorly Drained Sand and Gravel: Wet Sedge Meadows. Wetlands occur locally on sand and gravel and support wet sedge meadow communities similar to those on marine silt and clay (see above). Seepage slopes also have this wetland assemblage and may have a terraced appearance with dykes of bryophytic species occurring at regular intervals in a fashion resembling string bogs. Mosaics of wet and moderately drained communities are common on these deposits, reflecting microhabitats with different moisture regimes in close proximity.

Nonmarine Sand Caps: Lichen-Grass Tundra. Local nonmarine sand caps, which are found over some marine deposits in the lowlands, are typically well drained and are patterned by networks of high-centre polygons with shallows

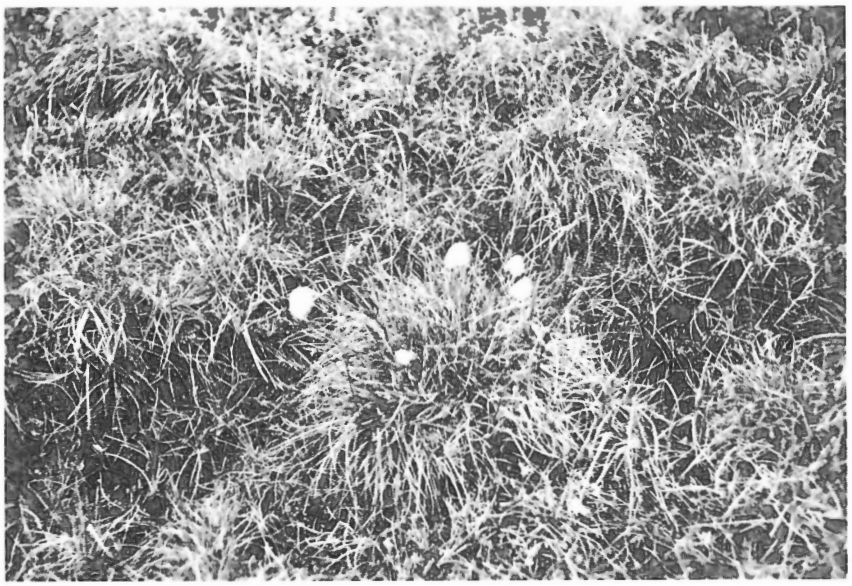

Figure 9

Eriophorum vaginatum *tussock meadow community. Note the close spacing of tussocks. GSC 203642-B*

troughs. Vegetation is typically **Alectoria-Hierochloe** tundra, as described for glacial deposits. Heath species are concentrated in the shallow troughs.

"Active" Deposits: Patterns of Plant Succession

Observations made in this study indicate that the plants colonizing fluvial or eolian deposits with actively eroding or aggarading surfaces are not the same. Fluvial deposits, mapped along Hayes and Back rivers, are composed of fine sand and silt; colonizing species have slightly different assemblages than those on eolian sand. The majority of mapped fluvial deposits occur in zone II; unmapped, locally bare, fine sand and silt were observed in zone I. Eolian and bare sand and gravel deposits occur throughout all zones.

No zonal difference in colonizing species was evident within this part of the Low Arctic; variation was greater between the two types of deposits than among the three zones. Table 7 lists species involved in colonizing active materials.

Fluvial Fine Sand and Silt: Grass Colonizers. Most modern floodplains consist of unvegetated active bars and stream channels. On low terraces scattered vascular plants, with density rarely exceeding 5 per cent and more typically 1 to 2 per cent, colonize stabilizing surfaces.

The initial stages of primary succession on fine sand and silt are dominated by grasses, the most common ones are **Colpodium Vahlianum, Alopecurus alpinus,** and **Festuca brachyphylla.** Forbs are scarce in the early stages of succession and are restricted to a few Caryophyllaceae; shrubs and cryptogams are absent at this stage.

In intermediate stages of succession, grasses are still a major component, but forbs such as **Papaver lapponicum, Descurainia sophioides, Draba** species, and some composites do appear. Tiny, scattered shrubs, mainly **Salix** species and **Dryas integrifolia** occur locally. Cryptogams are absent; only in the final stages of succession is there a development of a cryptogamic layer and a diminishing significance of grasses. Climax on such materials seems to be cottongrass tussock tundra.

Sand and Sand with Lag Gravel: Herb Colonizers. Eolian sand deposits and sandy fluvial deposits generally have eroding and aggrading surfaces that are nearly unvegetated. Where materials have stabilized, colonizing plants appear, most of which are absent or rare in more mature communities. Species diversity is much greater on sand deposits than on finer grained materials.

Widely scattered monocots and forbs, in about equal amounts, are common on sand in the early stages of succession. Saxifrages, **Papaver lapponicum, Oxyria digyna, Epilobium,** and **Armeria** are typical forbs, and **Hierochloe, Poa** species, **Festuca, Agropyron, Trisetum spicatum, Alopecurus,** and **Luzula confusa** and typical monocots. **Hierochloe alpina** is one of the few grasses that regularly appears in the more mature communities. The mosses **Ceratodon purpureus, Polytrichum commune, P. piliferum,** and **Rhacomitrium lanuginosum** form small tufts in places.

Species diversity and coverage increase with increasing stability of the surface. Both monocots and forbs are well represented in the intermediate stages of succession. **Eriophorum angustifolium** and **Alopecurus alpinus** occur on wet deposits. A thin cryptogamic layer starts forming at this stage, and shrubs, though rare, may include sprigs of **Salix** and **Dryas integrifolia.**

Vascular plants on eolian deposits commonly adopt a tussock form due to wind erosion of fines that are not secured by root systems. Some accumulation of fines occurs on the lee side of plants. Both monocots and forbs, which are primarily solitary or rhizomatous forms, adopt this hummock form. In addition, abnormal nodal elongation is seen in some grasses that have had sand deposited on their apexes so that the growing tips do not remain buried.

Table 7. Colonizing species on recently active materials

	Silt	Sand	Sand & Gravel
VASCULAR PLANTS			
Equisetum arvense	-	m	-
Hierochloe alpina	-	e	e
Alopecurus alpinus	e	e	e
Trisetum spicatum	-	e	e
Poa arctica	-	e	e
Poa glauca	-	e	e
Colpodium Vahlianum	e	-	-
Puccinellia phryganodes	e	-	-
Festuca brachyphylla	e	e	e
Agropyron boreale	-	e	e
Elymus arenarius ssp. **mollis**	e	-	-
Carex Bigelowii	m	e	e
Eriophorum sp.	m	e	-
Luzula confusa	-	e	e
Salix arctica	m	m	m
Oxyria digyna	m	e	e
Stellaria sp.	e	e	e
Cerastium sp.	e	e	e
Silene acaulis	-	m	m
Papaver lapponicum	m	e	e
Descurainia sophioides	m	-	-
Draba sp.	m	e	e
Saxifraga cernua	-	e	e
Saxifraga caespitosa	m	m	m
Saxifraga oppositifolia	-	m	m
Saxifraga tricuspidata	-	m	m
Potentilla hyparctica	m	m	m
Dryas integrifolia	m	m	m
Astragalus alpinus	m	m	m
Oxytropis Maydelliana	-	m	m
Epilobium latifolium	-	e	e
Diapensia lapponicum	-	m	m
Armeria maritima	-	e	e
Casteleja elegans	-	m	-
Erigeron eriocephalus	-	m	m
Antennaria sp.	m	m	m
Matricaria sp.	-	m	-
Arnica alpina	m	m	m
Taraxacum lacerum	m	m	m
MOSSES			
Ceratodon purpureus	-	e	e
Polytrichum commune	-	e	e
Polytrichum piliferum	-	e	e
Rhacomitrium lanuginosum	-	e	e
Bryum sp.	-	m	m
Dicranum sp.	-	m	m
LICHENS			
Alectoria nitidula	-	-	e
Alectoria nigricans	-	-	e
Cornicularia divergens	-	-	e
Parmelia sp.	-	-	m
Thamnolia sp.	-	m	m

Species absent(-);
present during early stages of colonization (e);
present during mid stages of colonization(m)

Table 8. Sensitivity of plant communities in north-central District of Keewatin

Plant communities	Effects of disruption on materials	Effects of disruption on wildlife
Lichen-**Hierochloe** tundra	possible increase in eolian activity	little use by herbivores; no significant effects
Lichen-heath tundra	accelerated solifluction and gullying; activation of mudboils	destruction of local passerine and ptarmigan habitat
Cryptogam-monocot tundra	activation of mudboils; rilling, gullying, and ponding	destruction of seasonal caribou habitat
Wet Sedge meadows (plateau)	thermal erosion; slumping and ponding	destruction of caribou and waterfowl habitat that is seasonally used
Shrub-lichen tundra	accelerated solifluction and gullying; activation of mudboils; local ponding	destruction of possible caribou habitat and also passerine and ptarmigan habitat
Wet sedge meadows (lowland)	thermal erosion; slumping; ponding; siltation of lakes, ponds, and streams	destruction of critical nesting and staging areas for waterfowl and other birds and of winter habitat for caribou
Cottongrass tussock meadow	gullying; siltation of streams; slumping; ponding	destruction of year round habitat for caribou and seasonal bird habitat
Shrub-monocot tundra	gullying; some thermal erosion; ponding; solifluction; activation of mudboils	destruction of year round habitat for caribou and destruction of a number of bird habitats
Dwarf shrub-monocot barrens	increased eolian activity	destruction of some passerine habitats
Snowbed communities	accelerated slope erosion and solifluction	destruction of local passerine habitats
Rhacomitrium mats	thermal erosion where occurs on soil	destruction of local passerine habitats
Crustose lichen communities	no effect	no effect

On sandy materials with lag gravel, such as high level fluvial deposits, the initial stages of colonization are similar to those found on sands, with the exception of the early appearance of a few lichens on the lag gravel. These include **Alectoria nitidula, A. nigricans, Cornicularia divergens, Parmelia** sp., and **Thamnolia** sp.

The successional pattern described here for sandy materials having lag gravel also applies to tills with a sandy matrix which are undergoing cryoturbation.

Continuously vegetated eolian sand, in climax situation, has communities similar to those on glacial deposits, primarily lichen-heath and lichen-**Hierochloe** tundras.

VEGETATION AND SENSITIVITY

Increasing attention has been focused on the effects on arctic ecosystems of major construction operations that have been proposed for the area. There has been interest in developing the area as a pipeline corridor for natural gas from the Arctic Islands to southern Canada. Also, mining leases cover parts of the District of Keewatin, and exploration operations are underway. Little is known about the impact of man's activities on Low Arctic vegetation, but some problems resulting from disruption of the continuous vegetation cover can be predicted. In the Arctic natural revegetation is a long, slow process, taking a century or more to reinstate stable plant communities (Wein, 1974), so that disruption of vegetation has long-lasting effects. This study provides a "before impact" picture of the area so that future impacts may be assessed.

Exploration activities and road and base camp construction necessitate overland travel by tracked vehicles, quarrying, construction of raised roadbeds and building pads, trenching, and backfilling. These activities all affect vegetation either directly, by the compaction and crushing of plants and organic layers, by the removal of vegetation by low blading and stripping, and by the covering of plants with fill or by dust or sediment deposition, or indirectly by altering natural slope drainage.

Vegetation forms an interface between surficial materials on which plants grow and the herbivorous wildlife that depends on certain components of the vegetation. Disruption of vegetation, therefore, has significant impact on plant communities, the surficial deposits (by initiating or accelerating geomorphic processes), and on wildlife habitats. This interaction is summarized in Table 8.

Disruption of Plant Communities

Plant communities can be disrupted by a variety of surface activities, but some effects are not immediately obvious. The timing of activities, the alteration of moisture regimes, and the deposition of dust can all affect plants. Rare or unique species or communities could be adversely affected by man's activites.

Overland travel and construction during the summer has potentially damaging effects on nearly all habitats. At this time vegetation is most vulnerable to compaction, crushing, tearing, churning, and stripping. Travel in winter, when the ground is frozen and the mosses, lichens, monocots, and low shrubs are protected by snow, results in little damage to vegetation. In areas where there is little or no snow cover,however, winter activity can have deleterious effects on vegetation that will not show up until subsequent thaw periods; lichens and mosses can be churned and killed even when frozen, and stripping can still occur. With removal of or breaks in the vegetation cover, erosive processes can be initiated and accelerated. To minimize the effects of disturbance on plant communities, travel should be undertaken only when the ground is frozen and if sufficient snow cover exists to protect vegetation.

Man's activities can also alter moisture regimes. Elevated roads and buried pipelines with raised berms will disrupt natural slope drainage which can result in desiccation of areas downslope and ponding immediately upslope from the barrier. The effects of these changes can occur far downslope and can result in loss of plant cover and wildlife habitat either by the killing of plant species or the activation of geomorphic processes.

Dust plumes created by traffic on haul roads are deposited downwind and can cause suffocation of roadside vegetation or alteration of species composition. In the Low Arctic, areas with continuous vegetation, especially with a cryptogamic lower stratum which provides an insulating surface cover, are particularly vulnerable to this type of disruption.

It was not possible in this study to identify rare or unique communities or species, mainly because of the small scale of mapping and the heavy reliance on airphoto interpretation. In areas where activity is proposed, detailed studies should be undertaken to ensure that such communities and species are not destroyed.

Vegetation and Geomorphic Processes

Removal or disruption of vegetation can cause acceleration of geomorphic processes by altering the thermal and hydrological regimes in the surficial materials, resulting in accelerated erosion.

Vegetation is continuous over much of the Low Arctic, and well developed bryophytic mats and organic deposits are effective insulating materials. Under dense communities, such as wet sedge meadows, the active layer is shallower than on drier or unvegetated terrain. Removal of vegetation can lead to local deepening of the active layer. Where the underlying materials are ice rich, rapid melting of icy layers can lead to surface ponding, slumping, and gullying; this in turn can increase sediment loads in streams and lakes, blanket downslope vegetation, and alter the stability of adjacent materials.

A continuous vegetation cover also acts as a protective layer that prevents direct contact of surficial materials with water and slows surface flow. This buffering also affects the amount of water penetration into the soil. Cryptogams can absorb moderate amounts of surface water; on slopes excess water flows laterally over vegetation and less moisture penetrates these surficial materials than would bare materials. The vegetation cover, therefore, minimizes stripping and gullying of surface sediments.

Continuous vegetation cover also protects the surface from wind erosion. In areas of dry, fine grained materials, a break in the vegetation can expose surficial materials to eolian activity and hence lead to an expansion of areas prone to deflation.

Vegetation plays a role in the partial stabilization of relatively unstable materials such as marine sediments and tills with a fine grained matrix. If these materials have a high moisture content, they are prone to solifluction and frost churning. The root systems of plants, particularly monocots and shrubs, bind the materials and slow or prevent these disruptive processes; removal of vegetation, on the other hand, can accelerate them. Rootless plants such as mosses and lichens have little binding effect.

Vegetation and Wildlife

Wildlife on the Wager Plateau was scarce during the summer of 1976; in the lowlands, however, numbers and diversity increased. The most common mammal in the map area was the barren ground caribou **(Rangifer tarandus groenlandicus)**, usually seen in pairs or individually. Large groups of caribou (75 to 100) were observed at two locations on the Wager Plateau south and east of Hayes River, and several small herds (10 to 15 caribou) were sighted in upper Murchison Valley, Hayes Valley, and near the coast. A solitary muskox **(Ovibos moschatus)** was observed on a tributary of Hayes River. This sighting is unusual, because muskoxen are rare in the northeastern Arctic mainland, although prior to the 19th century they were a regular part of the fauna; decimation by explorers is probably the cause of their decline. Other animals sighted include the arctic fox **(Alopex lagopus)** along lower Hayes River, corresponding to areas with numerous arctic ground squirrels **(Spermophilus parryii)**; a solitary arctic hare **(Lepus arcticus)** on the plateau; and arctic ground squirrels, which are abundant on areas of silt and sand along Hayes and Back rivers. Fox dens, but no animals, were seen on the Wager Plateau. Also, a dead brown lemming **(Lemmus sibiricus)** was found.

Birds sighted include the red-throated loon **(Gavia stellata)**, which nests in the area; whistling swan **(Olor columbianus)** in lowland ponds; Canada geese **(Branta canadensis)**; old squaw **(Clangula hyemalis)**; rough legged hawk **(Buteo lagopus)** and peregrine falcon **(Falco peregrinus)**, which both nest on eroding bluffs along Hayes River; willow ptarmigan **(Lagopus lagopus)**; rock ptarmigan **(Lagopus mutus)**; sandhill crane **(Grus canadensis)** in the lowlands; golden plover **(Pluvialis dominica)**; red phalarope **(Phalaropus fulicarius)**; long-tailed jaeger **(Stercorarius longicaudus)**; common raven **(Corvus corax)**; lapland longspur **(Calcarius lapponicus)**; and snow bunting **(Plectrophenax nivalis)**.

The Back Lowland extension, with its blanket of marine sediments, is one of the richest wildlife habitats in the region, primarily due to the abundance of wet sedge meadows, tussock tundra, and shrub-monocot tundra. Wet sedge meadows around ponds and lakes are of great importance to a variety of nesting and staging waterfowl. Tussock and shrub-monocot tundras are used by nesting and feeding birds, including cranes, shorebirds and passerines. The concentration of monocots provides excellent forage for lemmings and arctic ground squirrels, which in turn are food for hawks, falcons, and snowy owls. The tussock tundra and shrub-monocot tundra are important caribou habitats. Observation of scats shows that these communities likely serve both as summer and winter grazing areas. The wet sedge meadows seem to be important to caribou in winter, as only winter scat was observed in such areas. Removal of vegetation or organic layers on the lowland can also be detrimental to fish populations for the accompanying erosion may release large quantities of silt into lakes and rivers.

The lowland area is thus a critical wildlife area for many species. Activities in this area should be discouraged or, if necessary, should be carefully routed to cause as little damage as possible.

On the Wager Plateau, the cryptogam-monocot tundra may be used seasonally by caribou. The small, sporadically distributed wet sedge meadows on the plateau also show seasonal use by caribou, but not to the extent as on the lowlands. Flocks of Canada geese, as well as other migrating waterfowl, inhabit the ponds and wet sedge meadows on the plateau in late summer, and likely in spring.

Lichen-heath and heath tundra on the plateau seem to be of little significance to wildlife, with the exception of small populations of passerines and ptarmigan. **Rhacomitrium** moss mats and crustose lichen communities do not appear to be used by wildlife. Disruption of these communities should have little impact on wildlife.

Table 9. Summary of plant communities on the surficial materials of north-central District of Keewatin

		PLANT COMMUNITIES		
		Zone I	Zone II	Zone III
BED-ROCK	Materials/Drainage	Cryptogam Communities	Cryptogam Communities	Cryptogam Communities
GLACIAL DEPOSITS	Dry sand	**Alectoria-Hierochloe** tundra (±shrubs)	**Alectoria-Hierochloe** tundra	Same as zone II
	Well drained bouldery material	Shrub-lichen tundra	Lichen-heath tundra	Lichen-heath tundra
	Imperfectly drained material	Cryptogam-shrub-monocot tundra	Cryptogam (±shrub) - monocot tundra	Cryptogam-monocot Monocot tundra
	Poorly drained material	Wet sedge meadow	Wet sedge meadow	Wet sedge meadow
MARINE DEPOSITS	Well drained silt and clay	Bald to sparse grass barrens	Same as zone I	Absent
	Moderately to imperfectly drained silt	Cottongrass-shrub tussock meadow	Cottongrass tussock meadow	Absent
	Poorly drained silt and sand	Wet Sedge meadow	Wet sedge meadow	Absent
	Well drained sand and gravel	Shrub-barrens	Shrub-monocot barrens	Absent
	Moderately drained sand and gravel	Shrub tundra	Shrub-monocot tundra	Absent
"ACTIVE" DEPOSITS	Fluvial fine sand and silt	Grass colonizers	Same as zone I	Same as zone I
	Sand, and sand with lag gravel	Monocot and forb colonizers	Same as zone I	Same as zone I

SUMMARY

The study area lies within the Low Arctic ecosystem which has been divided into three bioclimatic zones (see Map 1548A). The vegetation zones are strongly influenced by elevation change and to a lesser extent by latitude. Plant communities show reduction in numbers and abundance of species, a diminution and local disappearance of erect and semi-erect shrubs, and greater cover by cryptogamic species as one progresses northward from zone I to zone III and from sea level to the uplands of Wager Plateau.

Within each zone two major factors influence the diversity and abundance of plant communities – the type of surficial material (glacial or marine deposits) and the soil moisture regime; differences in these factors are reflected in changes in plant communities (Table 9).

Bedrock outcrop and large boulders are vegetated exclusively by cryptogamic communities that show little variation through the zones. Crustose lichens dominate exposed facets whereas foliose and fruiticose lichens, in addition to crustose lichens, grow in sheltered crevices and zones where snow accumulates. **Rhacomitrium** moss mats develop in shallow depressions on the bedrock surface and in deep crevices.

Lichen-heath tundra, found on moderately to well drained tills and other glacial deposits with a significant boulder component, is the most extensive plant community on the Wager Plateau in zone III, II, and locally in zone I.

On dry sands, such as esker crests and fluvial terrace edges, lichen-**Hierochloe** tundra occurs in all three zones.

Cryptogam-monocot tundra occurs on imperfectly drained materials, particularly low-lying sandy glacio-lacustrine deposits. A minor shrub component is found in this community in zone II and especially in zone I. In the few areas where glacial deposits are saturated, wet sedge meadow communities occur; they are best developed around ponds on glaciofluvial terraces. On the coarsest materials the bryophytic lower stratum is poorly developed.

In the extreme southwestern part of the map area shrub-lichen communities are found in habitats similar to those where lichen-heath occurs in zones II and III. This community is thought to be the northward extension of shrub communities commonly found in regions adjacent to treeline and is an expression of climatic control rather than soils control since the surficial materials are similar to those farther north vegetated by lichen-heath tundra.

Marine deposits support a different suite of plant communities. Dry silts are commonly unvegetated, but in places support sparse grass barrens. Cottongrass tussock tundra occurs on moderately drained silt blankets. Dwarf shrub-monocot barrens and tundra communities occur on moderately and well drained sands. Heath species play a lesser role in communities on marine deposits and are commonly restricted to snowpatch and sheltered locations. Extensive, well developed wet sedge meadows occur on both poorly drained silt and sand. Zonation of plant communities on marine deposits is reflected by an increase in diversity of vascular plants and in shrub coverage from zones II to I.

Vegetation on fluvial and eolian deposits gives clues to the forms that colonization and plant succession take in the Low Arctic ecosystem. Monocots and forbs are the major

component of the earliest stage of succession; even in these early stages the plant assemblages can be related to the type of material being colonized.

Trends in plant community and surficial material relationships and bioclimatic zonation likely apply to other Low Arctic areas, somewhat removed from treeline, particularly areas with acidic Precambrian bedrock and glacial and noncalcareous marine deposits. This survey did not include the tundra areas adjacent to treeline; further zonation of Low Arctic tundra is likely there.

Man's activities can have a major impact on the Low Arctic ecosystem. Botanically important or unique communities or species can be disrupted or destroyed. Plant communities serve as a buffer inhibiting thermal and physical erosion of surficial deposits and also provide important habitats for herbivores. Disruption of plant communities can destroy important nesting, staging, and feeding areas for waterfowl and forage areas for caribou; can accelerate geomorphic processes and erosion; and can alter drainage characteristics, which in turn affects plant growth and community stability. Wetland communities having dense bryophytic mats, which serve as an insulating material, and high concentrations of sedges, grasses, and in places shrubs, which provide food for herbivores, are the most vulnerable to disruption.

REFERENCES

Bird, J.B.
1967: The Physiography of Arctic Canada; Johns Hopkins Press, Baltimore, Maryland, 336 p.

Bostock, H.S.
1970: Physiographic subdivisions of Canada; in Geology and Economic Minerals of Canada, ed. R.J.W. Douglas; Geological Survey of Canada, Economic Geology Report Number 1, p. 11-30.

Brown, D.K.
1954: Methods of Surveying and Measuring Vegetation; Commonwealth Bureau of Pastures and Field Crops, Bulletin Number 42, 223 p.

Bryson, R.A.
1966: Air masses, streamlines and boreal forest; Geographical Bulletin, v. 8, no. 3, p. 228-269.

Cochrane, G.R. and Rowe, J.S.
1969: Fire in the tundra at Rankin Inlet, N.W.T.; in Tall Timbers Fire Ecology Conference, Proceedings; Tallahassee, Florida, p. 61-74.

Conard, H.S.
1956: How to Know the Mosses and Liverworts; Wm. C. Brown Co., Dubuque, Iowa, 226 p.

Edlund, S.A.
1977: Vegetation types of north-central District of Keewatin; in Report of Activities, Part A; Geological Survey of Canada, Paper 76-1A, p. 385-386.

Environment Canada
1975a: Canadian Normals: Precipitation 1941-1970; Environment Canada, Atmospheric Environment Service, Volume 2-SI.

1975b: Canadian Normals: Temperatures, 1941-1970; Environment Canada, Atmospheric Environment Service, Volume 1-SI.

Hale, M.E.
1969: How to Know the Lichens; Wm. C. Brown Co., Dubuque, Iowa, 226 p.

Hanson, H.C., Queneau, P., and Scott, P.
1956: The geography, birds and mammals of the Perry River region; Arctic Institute of North America, Special Publication Number 3, 96 p.

Heywood, W.W.
1961: Geological notes, northern District of Keewatin; Geological Survey of Canada, Paper 61-18, 9 p.

Hultén, E.
1968: Flora of Alaska and Neighboring Territories; Stanford University Press, Stanford, California, 1008 p.

Krebs, C.J.
1964: Spring and summer phenology at Baker Lake, Keewatin, N.W.T. during 1959-62; Canadian Field-Naturalist, v. 78, no. 1, p. 25-27.

Larsen, J.A.
1965: The vegetation of the Ennadai Lake area, N.W.T.: Studies in bioclimatology; Ecological Monographs, v. 35, p. 37-59.

1967: Ecotonal plant communities north of the forest border, Keewatin, N.W.T., central Canada; Meteorological Department, University of Wisconsin, Madison, Technical Report Number 13, 16 p.

1972: The vegetation of northern Keewatin; Canadian Field-Naturalist, v. 86, no. 1, p. 45-72.

Manning, T.H. and Macpherson, A.H.
1959: The birds and mammals of Adelaide Peninsula, N.W.T.; National Museum of Canada, Bulletin Number 161, 63 p.

Nichols, H.
1970: Late Quaternary pollen diagrams from the Canadian Arctic barren grounds at Pelly Lake, Northern Keewatin, N.W.T.; Arctic and Alpine Research, v. 2, no. 1, p. 43-61.

1975: Palynological and paleoclimatic studies of the Late Quaternary displacement of the boreal forest-tundra ecotone in Keewatin and Mackenzie, N.W.T., Canada; Institute for Arctic and Alpine Research, Occasional Paper Number 15, 75 p.

1976: Historical aspects of the northern Canadian treeline; Arctic, v. 29, no. 1, p. 38-47.

Polunin, N.
1951: The real Arctic: suggestions for its delimitation, subdivision and characterization; Journal of Ecology, v. 39, p. 308-315.

Porsild, A.E.
1964: Illustrated flora of the Canadian Arctic Archipelago; National Museum of Canada, Bulletin Number 146, 218 p.

Rowe, J.S.
1972: Forest Regions of Canada; Department of the Environment, Canadian Forestry Service, Publication Number 1300, 172 p.

Ryder, J.P.
1967: The breeding biology of Ross' goose in the Perry River region, northwest Territories; Canadian Wildlife Service, Report Series Number 3, 56 p.

Shilts, W.W.
1975: Tundra fires, southeast District of Keewatin; in Report of Activities, Part B; Geological Survey of Canada, Paper 75-1B, p. 187-195.

Sorenson, C.J., Knox, J.C., Larsen, J.A., and Bryson, R.A.
1971: Paleosols and the forest border in Keewatin, N.W.T.; Quaternary Research, v. 1, no. 4, p. 468-473.

Tarnocai, C.
1977: Soils of north-central Keewatin; in Report of Activities, Part A; Geological Survey of Canada, Paper 77-1A, p. 61-69.

Tarnocai, C. and Boydell, A.N.
1975: Biophysical study of the Boothia Peninsula and northern Keewatin; in Report of Activities, Part A; Geological Survey of Canada, Paper 75-1A, p. 423-424.

Tarnocai, C., Boydell, A.N., Netterville, J.A., and Drabinsky, K.
1976: Biophysical land classification of Boothia Peninsula and northeast Keewatin, N.W.T.; Geological Survey of Canada, Open File Number 390.

Thomas, R.D.
1977: A brief description of the surficial materials of north-central Keewatin, Northwest Territories; in Report of Activities, Part B; Geological Survey of Canada; Paper 77-1B, p. 314-317.

Thomas, R.D., Dyke, A.S., and Edlund, S.A.
1979a: Surficial geology and geomorphology, north-central Keewatin, N.W.T. (Part 1); Geological Survey of Canada, Open File Number 626, scale 1:125 000.

Thomas, R.D., Dyke, A.S., and Edlund, S.A. (cont.)
1979b: Surficial geology and geomorphology, north-central Keewatin, N.W.T. (Part 2); Geological Survey of Canada, Open File 642, scale 1:125 000.

Wein, R.W.
1974: Recovery of vegetation in Arctic regions after burning; Environmental-Social Program, Northern Pipelines, Task Force on Northern Oil Development, Ottawa, Report 74-6.

Wein, R.W. and Bliss, L.C.
1973: Changes in Arctic **Eriophorum** communities following fire; Ecology, v. 54, no. 4, p. 845-852.

Wein, R.W. and Shilts, W.W.
1976: Tundra fires in the District of Keewatin; in Report of Activities, Part A; Geological Survey of Canada, Paper 76-1A, p. 511-515.

Zoltai, S.C. and Johnson, J.D.
1977: Vegetation-soil studies; reference sites in northern Keewatin; Department of Indian and Northern Affairs, ESCOM Report Number A1-19, 29 p.

Zoltai, S.C., Tarnocai, C., and Pettapiece, W.W.
1978: Age of cryoturbated organic materials in earth hummocks from the Canadian Arctic; in Third International Conference on Permafrost (Edmonton), Proceedings; v. 1, p. 326-331.