ARCTIC INSTITUTE OF NORTH AMERICA

TECHNICAL PAPER NO. 3

THE VEGETATION OF NORTHERN MANITOBA. III. STUDIES IN THE SUBARCTIC

By

J. C. Ritchie

Published January 1959

THE ARCTIC INSTITUTE OF NORTH AMERICA

The Arctic Institute of North America was formed to further the scientific study and exploration of the Arctic. The Institute provides information on the Arctic through its three Offices, awards research grants, and publishes scientific papers and other contributions in its journal *Arctic* and other publications. Those interested in this work are invited to become Associate Members. Associates receive all numbers of the journal. The Library and Map Collection at the Montreal Office are principally for their use, and they are welcome there and at the other Institute Offices. Dues are \$5.00 annually and may be paid in Canadian currency and forwarded to the Montreal Office, or in United States currency and forwarded to the New York Office. Registered students under the age of 25 years may pay a reduced subscription of \$3.00.

ARCTIC INSTITUTE OF NORTH AMERICA

TECHNICAL PAPER NO. 3

THE VEGETATION OF NORTHERN MANITOBA
III
STUDIES IN THE SUBARCTIC

By

J. C. Ritchie

Published January 1959

CONTENTS

Figures

THE VEGETATION OF NORTHERN MANITOBA. III.[1] STUDIES IN THE SUBARCTIC

J. C. Ritchie[2]

Introduction

THE primary object of this study is to describe and interpret the vegetation of northern Manitoba. Secondarily, it is designed to contribute to the knowledge of the flora of the region. That is, this work is in the first instance geographical in that it is concerned with the arrangement in space of the plants, as they occur in communities and individually; and secondly it aims to unfold the rudimentary relationships between the plants and their environment, which is the necessary beginning of ecological work. As the area of the present report is unknown botanically, the following account includes data on the composition, structure, dynamics, and ecology of the vegetation. No attempt is made to classify the vegetation, and the plant communities are described according to landform types. The vegetation of subarctic Canada is among the most poorly known in the northern hemisphere, and it would greatly simplify and accelerate understanding if future descriptions also related vegetation to landform, rather than attempted to erect systems of classification in terms of the plant cover itself. "Classification is logically the last step in the full investigation of any subject matter, attempted only when the subject matter is comprehended from all other points of view" (Egler, 1942).

The area of this study lies to the immediate north and east of the confluence of Big Spruce River and Seal River, at 59° 00N., 96° 45W. (Fig. 1). There is little information in literature on any geographical aspect of the region, and the only detailed botanical work from this entire northeast corner of the province, excluding the Churchill vicinity, was that of Scoggan (1952) who made a short visit in 1950 to the Baralzon and Nejanilini lake areas to collect plants. There have been no vegetation studies in this entire area, and one must cull scattered details on vegetation from the geological reports of J. B. Tyrrell (in particular, Tyrrell, 1896 and 1897). Even now some of the most pertinent and astute observations on the vegetation of subarctic Canada to the west of Hudson Bay are to be found in the writings of this celebrated geologist. Samuel Hearne traversed this general area on his journeys, successful and unsuccessful, to the mouth of the Coppermine River in the 18th century (Hearne, 1796), but he left no record of any botanical observations which he might have made in the region. Finally, a report is available (Russell, 1953) on the geology of the region, in which are included remarks on the topography and vegetation.

1Parts I and II are published in the *Canadian Journal of Botany* and *Ecology* respectively.

2Department of Botany, University of Manitoba, Winnipeg, Manitoba, Canada.

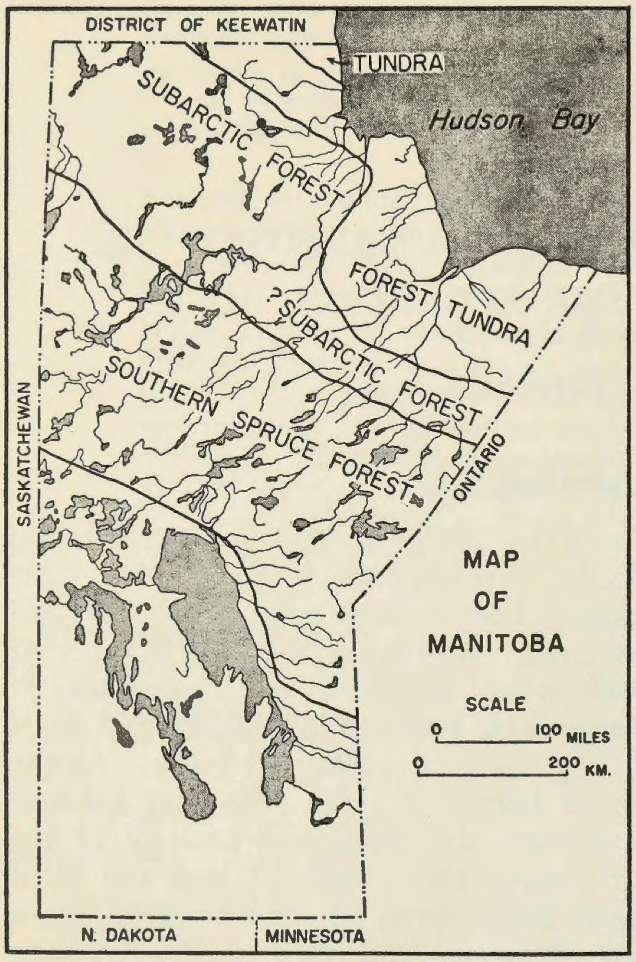

Fig. 1. Tentative vegetation zones of northern Manitoba. The black dot indicates the region of the present investigations. The term Subarctic Forest is used here to describe a vegetation zone, the boundaries of which are not well known for Manitoba. It corresponds with "taiga" in the sense of Hustich (1951).

The bedrock of the area is seldom exposed and consists entirely of Precambrian formations. Overlying the bedrock are glacial deposits of various types. As Russell (1953, p. 2) indicates, "The most prominent features are broad, rolling hills of boulder till which are believed to have cores of solid bedrock. Superimposed on the drift hills are eskers and crevasse fillings composed of pure sand, a mixture of sand and gravel, or entirely of gravel. . . . Some short, discontinuous ridges of angular to sub-rounded boulders occur in the lee of outcrop hills". The area of the present study includes a large floodplain on Big Spruce River with numerous meanders and oxbow lakes (Fig. 2). A landform of botanical interest, noted in certain parts of the area, consists of deep, extensive areas of peat. These occur, with one exception, at the periphery of glacial lakes and they occupy shallow basins, bounded on one side by the lake where they form an eroding, vertical peat surface. These formations are mapped in Fig. 2.

A single large esker crosses the area. This particular ridge extends northwards from Seal River for a distance of about 80 km., and it continues south from the southwest corner of Great Island for about 30 km. Considerable time was spent in the field studying the vegetation of this esker, since there are available no descriptions in literature of the vegetation of eskers in northern parts of North America. There is a fairly large body of literature on the vegetation of northern European eskers (cf. Jalas, 1950). General accounts of esker structure in subarctic Canada have been published by Wilson (1939, 1945), Bird (1953, 1955), and Taylor (1956), but the most informative botanically are those of Tyrrell (1897) and Low (1896).

Fig. 2. The main landforms in the area of study. This sketch-map was prepared from vertical air photographs.

There are no records of climate for the area, but data are available for Churchill, about 160 km. to the east, and for Brochet, about 300 km. to the west. From the maps and summaries of Sanderson (1948) a general account of the climate of this area might be constructed. It is drier than the climate of Churchill which is influenced by the immediate proximity of Hudson Bay, and it lies in the moist subhumid transition zone between the humid zones adjacent to Hudson Bay and the dry subhumid belt of the plains to the west (Fig. 6 of Sanderson, 1948). The climatic type is probably $C_2\ C_1'\ r\ c_1'$; that is, it has a moist, subhumid, microthermal climate with slight water deficiency and about 80 per cent summer concentration of thermal efficiency. Permafrost occurs in boulder till substrata at 1.5–2 m. in mid-summer and closer to the surface in peat deposits; it was not detected in esker and floodplain deposits.

This report is based on the field work of a single season; the area of study was examined by travelling through it on foot and by canoe, from the air, and by the subsequent scrutiny with stereoscope of vertical air photographs. The field procedure was simple. After a preliminary survey to determine the approximate range of landforms, major habitats, and community types, particular areas were selected for intensive study. Where possible quantitative data of community structure were obtained, but it should be noted that in all cases the areas which were sampled were selected as the most "typical" available. In a preliminary survey of this nature there is no feasible way of eliminating this element of subjectivity. Nevertheless, particular attention was paid to minor communities, since, as is well known to a bryologist for example, it is in the local, usually non-mesic habitat that those small aggregates of species occur which often reveal the essential geographical character of a region. Preoccupation with "climax" communities, or "most mesic" habitats, may result in incomplete comprehension, particularly since these local, discontinuous habitats harbour "atypical" units of vegetation which are seldom susceptible of quantitative analysis.

In all quadrat studies cover was recorded by visual estimate, using the following modification of the cover scale of Braun-Blanquet (1932):

5 = occupying 76–100%	2 = occupying 11–25%
4 = occupying 51–75%	1 = occupying less than 10%
3 = occupying 26–50%	+ = single plant, or small group

Tree heights were measured with an Abney level, trunk diameters with a diameter-tape, and the number of growth rings in the secondary xylem of the trunk was determined by microscopical examination of cores taken at breast height with an increment borer. A complete, replicate collection of vascular plants, mosses, and lichens was made, one set of which is available at the Herbarium of the Department of Botany, University of Manitoba. There is an authoritatively identified specimen of all mosses, lichens, and critical higher plants recorded in the vegetation studies.

I wish to record my thanks to Dr. H. A. Crum and Dr. J. W. Thomson who named the mosses and lichens respectively; to Dr. C. R. Ball, l'Abbé Ernest Lepage, Drs. Askell and Doris Löve, Marcel Raymond, Dr. C. F. Reed, and Dr. H. J. Scoggan, who undertook to revise my naming of certain vascular plants; and to Mr. E. Kronlund of Churchill who extended every kindness and help during the fieldwork. This work was made possible by a generous grant from the Arctic Institute of North America. Part of the expenses incurred were met by a grant which accompanied a post-doctorate fellowship awarded by the National Research Council of Canada.

PART I—VEGETATION STUDIES

1. The Vegetation of Boulder Till

The plant communities occupying the extensive low hills of coarse boulder till can be placed, for convenience, into four categories: black spruce lichen forest, which varies in structure and composition, depending upon whether it occurs on slopes or summits, and upon its seral status; black spruce muskeg and peat bog which occur in hollows; local communities associated with streams; and a rare, treeless vegetation which is confined to a local area of patterned ground.

Black spruce lichen forest

Slope community

In areas which have not been disturbed by fire, an open black spruce community occupies the middle slopes of low drift hills and ridges. It is composed of open stands of well-grown trees of *Picea mariana* with a density of approximately 7 trees per 100 square metres. The larger spruces show layering of the lower branches, rarely they are of a multiple-trunk form, but there is often slight asymmetry of the upper branches, due to the restriction of growth by the wind on the north side. In Table 1 data of height, diameter at breast height, and age are given; the maximum values for mature trees in this community are 9 m. in height, 18 cm. d.b.h., and 187 years of age. A discontinuous tall shrub layer is represented by occasional individuals of *Betula glandulosa*. The ground vegetation consists of a carpet of lichens, with which is associated a small number of shrubs, herbs, and bryophytes. Of the low shrubs, *Vaccinium uliginosum* is the most abundant, *V. vitis-idaea* ssp. *minus* is common at the bases of spruce trees, and *Salix anglorum* var. *antiplasta*, *Empetrum hermaphroditum*, *Ledum groenlandicum*, and *L. decumbens* are frequent. *Geocaulon lividum*, *Carex deflexa*, *Calamagrostis canadensis*, and *Lycopodium complanatum* are constant components of the ground vegetation, the first being the most common. The dominant lichen is *Stereocaulon*

Table 1. The heights, diameters at breast height, and ages of trees of *Picea mariana* from the summit and slope communities of mature lichen forest.

a. Slope community				*b. Summit community*			
Specimen	*Height*	*d.b.h.*	*Age*	*Specimen*	*Height*	*d.b.h.*	*Age*
1797	8 m.	16 cm.	184	1750	4 m.	7 cm.	176
1798	9 m.	15 cm.	180	1815	4.5 m.	7 cm.	142
1799	9 m	14 cm.	180	1816	4 m.	7 cm.	156
1800	8 m.	15 cm.	187	1817	6 m.	8 cm.	171
1801	8.5 m.	18 cm.	173	1818	4 m.	6.5 cm.	135
1805	7 m.	13 cm.	167	1820	5 m.	7 cm.	184

Table 2. A cover analysis of the ground vegetation of the black spruce lichen forest on boulder till — slope community.

Quadrats (1 m. sq.)

Species	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	% *frequency*
Vaccinium uliginosum	3	1	3	2	3	1	2	–	3	–	2	1	1	3	3	–	2	3	–	1	1	3	2	2	1	84
Geocaulon lividum	1	1	1	–	–	+	–	–	1	+	+	–	–	+	–	+	+	1	+	–	–	+	+	–	–	56
Vaccinium vitis-idaea ssp. *minus*	+	1	1	+	1	1	–	+	–	–	+	–	1	+	1	–	+	–	+	+	2	–	+	1	+	72
Ledum groenlandicum	–	+	1	–	–	1	+	–	+	–	+	1	–	–	2	+	–	–	+	–	+	–	+	–	+	52
Empetrum hermaphroditum	–	+	–	1	–	1	+	2	–	2	–	+	+	–	–	2	–	+	–	1	–	1	–	–	2	52
Lycopodium complanatum	–	–	–	–	–	+	–	–	–	+	–	–	–	–	–	–	–	–	+	–	+	–	–	–	–	16
Ledum decumbens	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	+	+	–	–	–	–	12
Carex deflexa	–	–	+	–	+	–	–	–	–	–	+	–	–	+	–	–	+	–	–	–	+	–	–	–	–	24
Salix anglorum	–	–	+	–	1	–	–	–	–	+	–	1	1	–	–	–	+	–	1	+	–	–	–	–	–	32
Stereocaulon paschale ssp. *evolutoides*	4	4	4	4	3	4	2	3	4	4	3	4	4	3	2	4	4	4	4	2	3	2	4	3	3	100
Cladonia pleurota	1	1	+	1	1	+	1	1	–	+	1	+	1	1	1	+	+	1	+	+	+	1	+	+	1	96
C. alpestris	1	1	1	–	–	+	1	1	1	+	1	1	1	+	+	1	+	1	1	+	1	1	+	1	1	92
Cetraria nivalis	1	1	+	1	1	1	+	+	–	–	+	–	–	–	+	1	1	1	+	–	1	+	1	–	–	68
C. nigricascens	+	–	–	+	–	+	+	–	–	–	+	1	1	+	–	1	+	–	–	+	+	–	1	1	+	64
Alectoria altaica	+	–	–	+	–	–	+	–	–	–	–	+	–	–	–	+	–	–	–	–	+	–	–	+	–	28
Dicranum fuscescens	–	+	–	+	–	–	+	–	–	+	+	–	–	+	–	–	–	1	–	+	1	–	+	1	1	48
Pleurozium schreberi	–	+	–	+	–	–	1	–	–	1	–	–	–	+	–	+	–	–	–	–	+	–	–	+	+	36
Polytrichum juniperinum	+	–	–	–	–	–	–	1	1	+	–	–	–	–	+	–	1	–	–	+	–	+	–	–	–	32

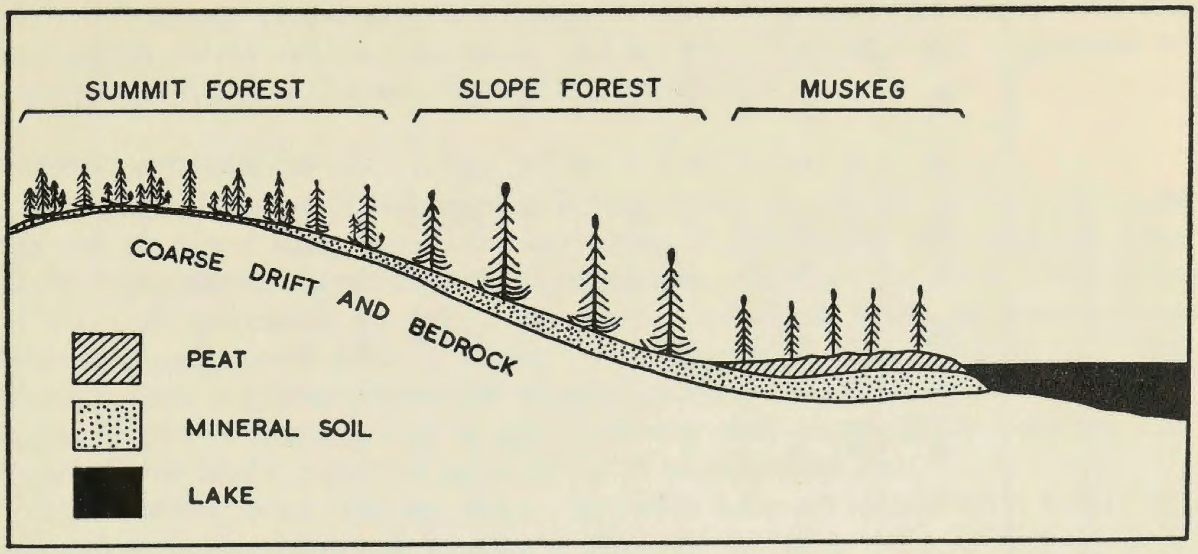

Fig. 3. A diagrammatic representation of the relationships of the communities on drift hills.

paschale ssp. *evolutoides* with which are associated *Cladonia pleurota*, *C. alpestris*, *Cetraria nivalis*, *C. nigricascens*, *Alectoria altaica*, and the mosses *Dicranum fuscescens*, *Pleurozium schreberi*, and *Polytrichum juniperinum*. The lichen carpet is replaced at the base of the spruces by a bryophyte carpet, dominated by *Pleurozium schreberi*, *Hylocomium splendens*, *Dicranum fuscescens*, and *Ptilidium ciliare*. An analysis of the ground vegetation of a particular stand of this community is given in Table 2.

The soil of these slope sites is a shallow podzol. There is a litter layer of 1–2 cm. in depth, composed largely of spruce needles and cryptogam remains; below this is a layer of black, fibrous humus, 5–7 cm. in depth. This layer overlies a shallow leached horizon, 5–8 cm. in depth, consisting of coarse, partly bleached mineral particles which give the horizon a grey-brown colour. At 15–20 cm. below the surface there is a narrow layer of deposition, consisting of 20–25 cm. of red-brown, coarse, sandy gravel. The subsoil is composed of coarse gravel with many granite boulders. In August, the permafrost level in these substrata was 1.5 m. from the surface.

Summit community

On the summits and ridges of these drift deposits the trees are smaller than on the slopes, they are more dense (approximately 20 per 100 square metres), and they show more evidence of the inimical effects of exposure and a shallow substratum. Many are of the candelabrum or multiple-trunk habit, and there is considerable evidence of trimming of the upper branches by the wind. A comparison of the values for height and diameter of trees of approximately the same age from the flank and summit communities is given in Table 1 and the gradient in stature of black spruce between the slope and the summit is shown diagrammatically in Fig. 3.

The ground vegetation of this summit forest also shows certain differences from that of the slopes. *Loiseleuria procumbens* appears on the summit, to which it is confined, and where it forms large prostrate mats. Of the common slope community plants, *Geocaulon lividum*, *Lycopodium complanatum*, and *Carex deflexa* are absent from the summit vegetation. *Betula glandulosa* and

Table 3. A cover analysis of the ground vegetation of the black spruce lichen forest on boulder till — summit community.

Quadrats (1 m. sq.)

Species	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	% *fre-quency*
Vaccinium uliginosum	2	1	–	–	1	+	+	–	1	–	+	1	2	+	–	1	–	1	+	–	–	1	+	1	1	68
Loiseleuria procumbens	2	1	3	2	3	2	–	3	1	3	1	2	+	2	+	2	1	2	1	+	+	2	3	2	2	96
Bare ground	3	–	2	2	1	1	3	1	2	–	2	–	–	+	2	–	2	+	2	2	1	+	–	–	–	68
Vaccinium vitis-idaea ssp. *minus*	+	1	+	+	–	1	+	+	–	1	–	–	+	1	+	1	+	–	–	–	+	+	1	1	+	72
Empetrum hermaphroditum	+	–	1	+	+	–	1	+	–	+	1	–	–	+	+	1	+	–	1	–	1	1	–	+	1	68
Ledum decumbens	–	–	+	–	+	–	+	–	–	1	+	–	–	1	–	+	+	–	1	+	–	–	+	–	+	48
Salix anglorum	–	–	+	–	–	+	–	–	+	–	–	+	+	–	+	–	–	–	+	–	+	–	–	+	+	40
Stereocaulon paschale ssp. *evolutoides*	2	3	4	3	2	3	4	2	3	2	4	1	2	4	4	4	3	+	4	3	1	2	1	3	3	100
Cladonia pleurota	+	1	1	+	+	+	–	+	+	1	+	+	1	1	+	–	+	+	1	+	+	–	–	+	+	84
C. coccifera	+	–	1	–	–	1	–	+	1	–	–	+	–	–	+	–	+	+	–	–	–	+	+	–	–	44
C. rangiferina	–	–	+	+	–	–	+	–	–	+	–	–	–	+	–	–	–	–	+	–	+	–	–	+	+	36
Cetraria nigricascens	1	+	+	–	+	–	+	–	–	+	–	+	–	+	–	–	+	+	–	–	+	–	+	–	–	48
C. nivalis	–	–	–	+	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	+	+	–	–	–	–	16
Ptilidium ciliare	–	–	–	–	+	–	–	–	–	–	–	–	–	–	+	–	–	–	+	–	–	–	–	–	–	12

the small, erect, ericoid shrubs are less widespread than on the slopes, and the bryophyte carpet is absent or rare. An analysis of the ground vegetation of a particular stand of this community is given in Table 3.

Subseral communities

Stands of mature black spruce lichen forest on till are not extensive in the area as forest fires, started by both natural and human agencies, are relatively common throughout northern Manitoba. In this area, three main types of subseral vegetation on drift were noted: a treeless heath on certain hills with shallow, rocky soils; a young forest in which trees of tamarack and black spruce are associated with various tall and short shrubs; and an older forest which is intermediate in physiognomy and composition between the young forest and the mature community of undisturbed sites.

Subseral heaths. Certain ridges and low hills are completely devoid of trees, the coarse, stony soil bearing a heath community. On several of these sites old stumps and upturned roots from a previous forest were present, indicating probable destruction by fire in the past. The vegetation of an example of these treeless areas yielded the following list:

Vaccinium vitis-idaea ssp. *minus*	f
Empetrum hermaphroditum	f
Arctous rubra	o
Betula papyrifera var. *neoalaskana*	o (small, shrub-like)
Loiseleuria procumbens	o, la
Ledum decumbens	o
Carex deflexa	o
Luzula confusa	r
Salix anglorum	r
Polytrichum piliferum	f
Cetraria nivalis	f
Alectoria altaica	f
Cladonia rangiferina	o
C. coccifera	o

On the lower slopes of certain of these low hills there is some evidence of colonization by young trees of *Picea mariana.*

Young subseral communities. Considerable areas of the boulder till are dominated by mixed stands of trees and shrubs. The following description of a stand near Spruce Lake is typical of this community. On the ridges and flanks there are considerable areas which are dominated by trees of *Picea mariana* and *Larix laricina*; this is an uneven-aged stand, the tallest trees being 3–4 m. in height and the smallest 0.5–1 m. The spruce and larch occur in roughly equal numbers, and the size and age of older individuals is indicated in Table 4.

Table 4. Dimensions and ages of larch and black spruce of a subseral community on boulder till.

Picea mariana				*Larix laricina*			
Specimen	*Height*	*d.b.h.*	*Age*	*Specimen*	*Height*	*d.b.h.*	*Age*
2029	4–5 m.	8 cm.	26	2028	4 m.	7 cm.	20
2031	4 m.	7.5 cm.	17	2030	5 m.	8 cm.	25
2033	5 m.	8 cm.	28	2032	5 m.	8 cm.	28
2035	5 m.	8 cm.	29	2034	5 m.	8.5 cm.	25

Associated with the spruce and larch there is a discontinuous shrub layer at 1–1.5 m., made up of *Alnus crispa* and *Betula glandulosa.* A short shrub stratum at 30–60 cm. is represented by *Ledum groenlandicum,* which is locally dominant and abundant on all sites. No willows take part in this subsere.

The ground vegetation of these communities consists of the following species:

Vaccinium uliginosum	a – ld	*Dicranum bergeri*	o
V. vitis-idaea ssp. *minus*	o – f	*Polytrichum juniperinum* var. *alpestre*	o
Equisetum arvense var. *boreale*	o	*Pleurozium schreberi*	o
Empetrum hermaphroditum	o – r	*Cladonia rangiferina*	o
Lycopodium complanatum	r	*C. coccifera*	r

Extensive areas are dominated by this type of community, in which the relative abundance of the trees and shrubs varies between localities. In older subseral stands there is evidence of the gradual elimination of *Alnus, Betula,* and *Larix* and the assumption of complete dominance by *Picea mariana.*

Muskeg and bog

Between the ridges and hills of boulder till there are hollows in which drainage is impeded. Under these edaphic conditions two main types of vegetation develop—muskeg and bog. These terms are used in the sense indicated in an earlier paper (Ritchie, 1956b, p. 528).

Muskeg

Considerable areas of these hollows are occupied by a black spruce community on a peat substratum overlying the drift, with the ground vegetation dominated by species of *Sphagnum,* associated with various mosses, lichens, and vascular plants. The peat is seldom deeper than 2 m., more usually about 1 m., and in late summer the active layer extends for 1–1.5 m.

Here, as is general in muskeg, the trees of *Picea mariana* are poorly grown, though fairly dense (roughly 45 per 100 square metres). In Table 5 data of height, diameter at breast height, and age are given.

Table 5. Dimensions and ages of *Picea mariana* from muskeg at Spruce Lake.

Specimen	*Height*	*d.b.h.*	*Age*
1854	3 m.	5 cm.	143
1855	3 m.	5 cm.	136
1856	4 m.	6 cm.	152
1857	4 m.	6 cm.	145
1858	7.5 m.	10 cm.	173

A scattered tall shrub stratum is represented by individuals of *Salix anglorum* and, less commonly, *Betula glandulosa.* The ground vegetation is dominated by hummock-forming moss species, of which *Sphagnum fuscum* and

S. warnstorfianum are the most abundant. *Dicranum groenlandicum* is a characteristic species of the ground vegetation, forming small, dense tussocks. A conspicuous early summer feature of the vegetation consists of the fertile shoots of *Equisetum sylvaticum* var. *pauciramosum* growing through moss hummocks. There it is associated with *Rubus chamaemorus, Oxycoccus microcarpus, Ledum groenlandicum,* and *L. decumbens.* Less common, but constant members of the community, are the low shrubs *Vaccinium vitis-idaea* ssp. *minus, V. uliginosum, Empetrum hermaphroditum,* and *Andromeda polifolia.* The mosses *Polytrichum juniperinum* var. *alpestre, Aulacomnium palustre, Pleurozium schreberi,* and *Dicranum fuscescens* are common, assuming local dominance. Associated with these species are certain characteristic lichens: *Icmadophila ericetorum,* which colonizes disturbed peat on the *Sphagnum* hummocks, and *Cladonia rangiferina, C. subrangiformis,* and *Peltigera aphthosa* which are common in the surfaces of the moss hummocks and larger tufts.

In this area the mosses *Tetraplodon mnioides* and *T. angustatus* are constant members of the muskeg flora, although neither is common in any one locality. They form small, compact tufts, consistently associated with accumulations of animal remains, such as hawk casts.

Scattered throughout the muskeg are certain vascular plants, of which *Lycopodium annotinum, Carex canescens, C. paupercula* var. *irrigua, Eriophorum spissum* (a tussock-forming species), *Smilacina trifolia, Kalmia polifolia,* and *Pedicularis labradorica* are of frequent occurrence. A quantitative analysis of a single typical stand of muskeg is given in Table 6.

In many muskeg areas there are small depressions, seldom exceeding 2 m. in diameter, filled with wet peat and dominated by a small number of characteristic species. Of these, the following are the most common and often form pure stands in individual depressions: *Drepanocladus fluitans, D. badius, D. intermedius, Calliergon sarmentosum, Sphagnum lindbergii, S. recurvum, Aulacomnium palustre,* and *Mnium andrewsianum.*

Bog

Somewhat arbitrarily, communities on shallow peat which lack a tree stratum are designated bog, but it should be noted that there are many transitions between muskeg and bog which occur along gradients of soil moisture conditions.

The wettest areas, where water collects in small pools, are colonized by a group of bog pioneer species: these are, in order of approximate abundance, *Carex stans, Comarum palustre, Drepanocladus fluitans, Sphagnum riparium, S. teres, S. lindbergii,* and *Eriophorum angustifolium.* When a closed peat layer has developed the following species appear: *Polytrichum commune, Carex paupercula* var. *irrigua, C. canescens, C. rotundata, Sphagnum fuscum,* and *S. recurvum.* The *Sphagnum* species form large hummocks which are colonized by various ericaceous shrubs, and this mature bog phase is dominated by *Ledum groenlandicum, Chamaedaphne calyculata* var. *angustifolia, Oxycoccus microcarpus, Rubus chamaemorus, Kalmia polifolia, Andromeda polifolia,* and *Ledum decumbens;* the hummocks are composed of *Sphagnum fuscum, S. recurvum, Aulacomnium palustre,* and *Polytrichum commune.* This consolidated bog phase merges into typical muskeg vegetation from which the *Chamaedaphne* is usually absent, in which the *Sphagnum* hummocks are

Table 6. An analysis of the ground vegetation of muskeg.

Species	*Quadrats* (1 m. sq.) 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	% frequency
Rubus chamaemorus	1	+	2	+	–	+	1	1	+	–	+	1	2	1	1	+	–	–	+	–	+	1	–	–	1	72
Equisetum sylvaticum var. *pauciramosum*	+	1	–	–	1	–	+	–	+	–	1	+	+	–	–	+	–	+	–	–	–	+	–	–	–	44
Ledum groenlandicum	1	2	–	2	3	+	–	–	1	–	2	–	–	3	–	2	2	1	3	–	–	3	–	–	1	56
L. decumbens	+	–	+	–	1	1	–	+	1	–	–	+	–	+	–	+	–	1	1	+	1	–	–	–	+	56
Andromeda polifolia	1	–	–	+	–	–	+	+	+	+	–	+	+	+	–	–	+	–	+	–	–	–	+	–	–	44
Oxycoccus microcarpus	+	–	–	–	+	–	–	–	–	–	–	–	+	+	–	–	+	–	–	+	–	–	–	–	–	24
Lycopodium annotinum	–	–	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
Smilacina trifolia	–	–	–	–	–	1	–	–	+	–	–	–	–	–	–	–	+	+	1	+	–	–	–	–	–	24
Carex paupercula var. *irrigua*	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	+	–	–	–	–	–	–	–	–	–	8
C. canescens	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
Pedicularis labradorica	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
Vaccinium vitis-idaea ssp. *minus*	1	+	–	+	1	–	–	+	–	+	–	–	+	+	–	1	2	–	2	+	–	–	–	+	+	14
V. uliginosum	1	+	–	–	2	–	–	–	–	1	+	–	–	2	–	–	–	+	–	2	–	–	–	–	–	8
Empetrum hermaphroditum	+	–	+	2	–	2	–	–	2	+	–	+	–	+	–	–	2	+	–	–	–	+	–	–	–	44
Eriophorum spissum	–	–	–	–	–	–	–	+	–	–	+	–	–	–	–	–	–	+	–	–	1	–	–	–	–	16
Sphagnum fuscum	4	4	3	1	3	+	1	4	+	–	+	4	+	–	+	1	4	+	+	1	2	+	1	3	1	92
S. warnstorfianum	1	2	4	4	+	4	3	+	2	3	3	2	3	3	4	2	+	2	+	2	3	1	+	2	1	100
S. recurvum	+	–	–	–	+	–	+	–	–	–	–	–	–	+	–	–	–	–	–	–	+	–	–	–	–	20
Pleurozium schreberi	2	1	1	+	–	–	2	–	–	–	–	–	3	2	+	–	–	3	3	–	–	–	+	–	–	11
Polytrichum juniperinum var. *alpestre*	3	1	1	+	1	–	–	+	–	1	1	+	–	–	–	–	–	2	3	1	+	–	–	+	1	60
Aulacomnium palustre	–	–	–	2	–	–	–	3	–	1	–	–	–	–	–	2	–	–	1	–	–	–	+	+	1	32
Dicranum bergeri	+	–	+	–	–	+	–	–	+	+	–	–	+	+	–	+	–	–	+	–	–	–	+	+	+	48
D. groenlandicum	+	–	+	–	–	+	–	–	–	–	+	–	+	+	+	–	+	–	1	+	–	–	1	–	–	40
Tetraplodon mnioides	–	–	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	+	–	–	–	–	–	8
T. angustatus	–	–	+	–	–	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
Drepanocladus intermedius	2	+	–	+	1	–	–	2	+	–	–	–	–	+	2	+	–	+	–	–	1	–	+	–	–	48
Cladonia rangiferina	+	–	–	–	+	–	+	–	+	–	–	+	–	–	+	–	+	–	–	–	–	+	–	–	–	32
C. subrangiformis	–	–	–	–	–	–	–	+	–	+	1	–	–	–	+	–	–	–	+	–	–	–	–	+	–	24
Icmadophila ericetorum	–	–	–	–	+	–	–	–	–	–	–	–	–	–	–	–	–	–	+	–	+	–	–	–	–	12
Peltigera aphthosa	–	–	–	1	–	–	+	–	–	–	–	–	1	+	–	–	–	+	+	–	–	–	+	–	+	32

more conspicuous, and in which black spruce appears. In these bog communities, individuals of *Larix laricina* are common, but persist only locally in muskeg.

Stream vegetation

Associated with small streams flowing through drift material, linking small lakes at different levels, there is a distinct and consistently occurring assemblage of plants. Local communities of this kind lack the spatial continuity which is necessary for standard quantitative analysis of structure and composition; accordingly, the following brief, descriptive account is offered, being a composite survey culled from the examination of several different streams.

Along the banks of the streams, and almost completely confined to this habitat, trees of *Betula papyrifera* var. *neoalaskana* are common, associated with *Picea mariana.* Locally, where the drainage of the banks is impeded, small stands of *Salix planifolia* var. *nelsoni* replace the spruce/birch stands. Under the canopy of spruce/birch, the following plants are common components of the field and ground layers:

Carex disperma	a	*Ribes glandulosum*	o, lf
Calamagrostis canadensis	f	*Galium trifidum*	o
Dryopteris disjuncta	r	*Lycopodium annotinum*	r
Viola palustris	o, la	*Smilacina trifolia*	r
Petasites sagittatus	o, lf	*Sphagnum teres*	la
Comarum palustre	f, lf	*Calliergon cordifolium*	f
Rubus acaulis	lf	*Campylium hispidulum*	lf
Ribes triste	o, lf	*Mnium stellatum*	lf

On the bases of the willows the following local community of mosses was noted: *Pohlia cruda*, *Plagiothecium denticulatum*, *Campylium hispidulum*, *Leptobryum pyriforme*, and *Ceratodon purpureus.* In peaty substrata, the following emergent aquatics are locally frequent: *Calla palustris*, *Caltha natans*, and *Sparganium hyperboreum. Dichelyma falcatum* is locally common on wet rocks in streams, and *Hygrohypnum alpestre* and *Fontinalis nitida* are locally abundant on submerged rocks in fast running water.

Stone rings

At a single locality near the east bank of Big Spruce River, a small area (100 $\times$ 200 m.) was discovered with distinct, patterned ground. This consists of continuous sorted rings. The peculiar characteristics of the area are that it is devoid of trees, that it has a high water table, and that there is considerable surface evidence of iron deposition.

These ground patterns consist of local accumulations of coarse pebbles and stones, arranged in irregular rings, with an average diameter of 4 m. The central part of the polygons is occupied by a small dome, raised about 20 cm. above the level of the peripheral stone boundary, and consisting of a fine-grained, wet mineral soil. The larger rocks of the polygons are 30–50 cm. in diameter. No other example of this phenomenon was recorded from this area. It occurs in a region of muskeg, and it forms a treeless "island", surrounded by black spruce muskeg and drift ridges bearing subseral communities.

Indicating considerable instability of soil surface, these sorted rings vary widely in their vegetation cover, from bare exposed surfaces almost totally lacking plants to well-vegetated surfaces with a closed community. It is possible, arbitrarily, to distinguish three vegetation types on the basis of the extent of the plant cover. The first type consists of a central region of bare soil with a few pioneer plants of *Juncus albescens*, which occurs consistently as the first colonizer. (This was the only locality in the region for which this arctic rush was recorded). Associated with *J. albescens*, on certain polygon surfaces, was the small tuft-form moss *Oncophorus wahlenbergii*. Scoggan (1952, p. 224) describes *Juncus albescens* as a characteristic plant of "stony, disturbed ground within frost polygons" in the forest-tundra zone of Manitoba.

The second type of plant cover consists of an open community of colonizers, of which the following species, arranged in order of relative abundance, were recorded: *Juncus alpinus*, *Vaccinium uliginosum*, *Triglochin maritima*, *Carex tenuiflora*, *Ledum decumbens*, *Polytrichum juniperinum*, *Mnium punctatum*, *Tofieldia pusilla*, *Salix uva-ursi*, *Vaccinium vitis-idaea* ssp. *minus*, *Loiseleuria procumbens*, and *Betula glandulosa*.

The third general type occurs in wetter and probably older rings, in which a shallow (4–8 cm.) layer of amorphous peat accumulates. These centres are occupied by the following species, arranged in approximate order of relative abundance: *Andromeda polifolia*, *Scirpus caespitosus* ssp. *austriacus*, *Eriophorum angustifolium*, *Oncophorus wahlenbergii*, *Drepanocladus revolvens*, *Betula glandulosa*, *Scirpus hudsonianus*, and *Tofieldia pusilla*. Locally these peaty centres are of considerable depth, forming raised hummocks almost 1 m. above the level of the surrounding polygons.

It is possible to identify these surface features with those which have been described by numerous authors for other parts of the Arctic and Subarctic (recently summarized by Washburn, 1956). It would seem likely that the explanation of their formation is concerned with soil frost phenomena. However, the limited observations made here preclude any contribution to the already cumbersome, varied, and rather hypothetical body of literature which exists on the nature and origin of these patterns. Nevertheless, a few generalizations might be suggested about the plant cover which is associated with these surfaces. The instability of the soil surfaces maintains a treeless, poorly developed community which consists of a mosaic of plant assemblages showing various stages in the processes of colonization of bare areas. After a few early pioneer species become established on bare areas (*Juncus albescens* and *Oncophorus wahlenbergii*) various herbs and shrubs invade to form an open community. In the absence of further disturbance a layer of humus or peat develops and a distinct group of plants dominates the vegetation of the surfaces. Many intermediate stages exist between the three main types described here, and it would appear that an irregular cycle of colonization and destruction is maintained by the instability of the substratum. The three main stages which have been described are summarized diagrammatically in Fig. 4.

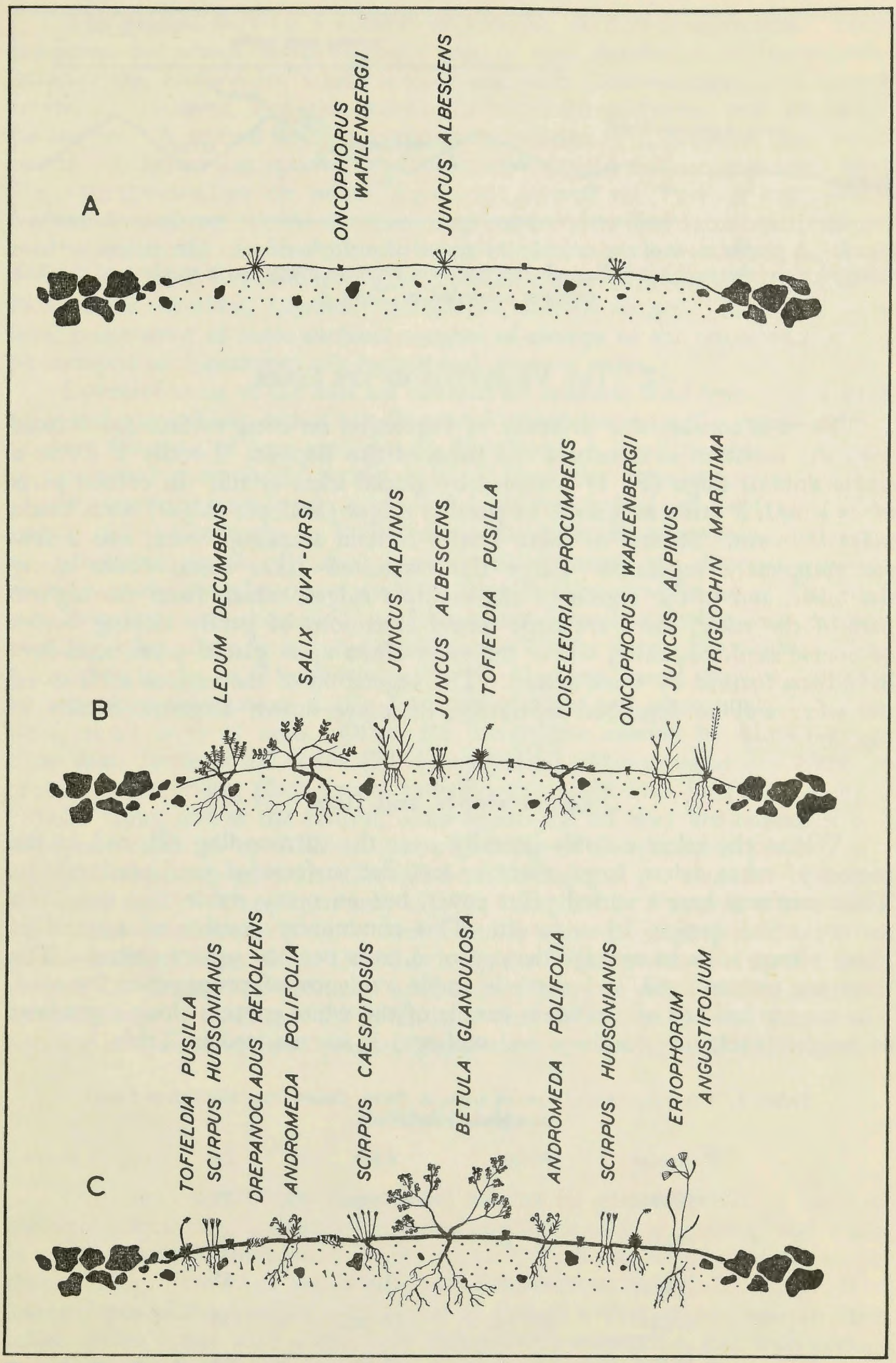

Fig. 4. Profile diagrams of stone rings, showing three stages in the sequence of plant colonization.

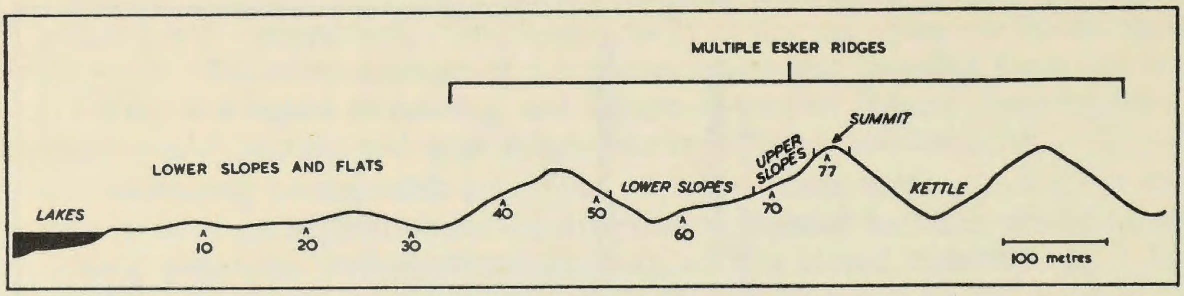

Fig. 5. A profile view of the esker in the region of multiple ridges. The various surfaces referred to in the text are indicated; the numbers refer to every tenth quadrat of the belt transect recorded in Table 8.

2. The Vegetation of the Esker

There is considerable diversity of vegetation on esker surfaces, associated with the variation in structure and form of this deposit. Locally it forms a single sinuous ridge (Pl. 1) bounded by glacial lakes or till. In certain parts of its length it exists as a series of parallel ridges (multiple ridges) with kettle holes between. Several of these kettles contain standing water, and a few are completely vegetated. Large flat extensions—esker deltas—occur along the esker, and in the region of the multiple ridges, which form the highest part of the esker, there are large lateral extensions of gently sloping bodies of coarse sand. Locally, where the esker abuts upon glacial lakes, sand-bars have been formed by wave action. The vegetation of the various surfaces of the esker will be described separately; these are shown diagrammatically in Fig. 5.

Lower slopes and flats

Where the esker extends laterally over the surrounding till, and in the region of esker deltas, large, more or less, flat surfaces of sand predominate. These surfaces bear a varied plant cover, but on many stable sites there is a mature white spruce lichen forest. This community consists of a stand of *Picea glauca* with an average density of 6 trees per 100 square metres. The trees are uneven-aged, and there is ample evidence of propagation by seed. The stature and age of a random sample of the white spruces along a gradient of height (excluding seedlings and saplings) is summarized in Table 7.

Table 7. Dimensions and ages of trees of *Picea glauca* from the lichen forest of a lower esker slope.

Specimen	*Height*	*d.b.h.*	*Age*
1920	3.5 m.	7 cm.	29
1921	6 m.	10 cm.	64
1922	10 m.	21 cm.	58
1923	17 m.	28 cm.	158
1924	18 m.	26 cm.	164
1925	18.5 m.	29 cm.	171

The ground vegetation consists of a mosaic of four components. There is a lichen mat which covers extensive areas of sand, dominated by *Stereocaulon paschale* ssp. *evolutoides*, which is associated with *Cladonia alpestris*, *C. rangiferina*, *C. pleurota*, and the mosses *Polytrichum piliferum* and *Dicranum fuscescens*. A second discrete community consists of a prostrate mat, intermixed wih lichen-mat species, of *Empetrum hermaphroditum* associated with *Vaccinium vitis-idaea* ssp. *minus*, *Equisetum arvense* var. *boreale*, and, locally, *Ledum decumbens*. A third community can be identified at the bases of the spruces, consisting of a low mat of *Vaccinium vitis-idaea* ssp. *minus*, *Empetrum hermaphroditum*, *Geocaulon lividum*, *Ptilidium ciliare*, *Hylocomium splendens*, *Pleurozium schreberi*, *Dicranum fuscescens*, and *D. bergeri*. A fourth, very local component of these surfaces consists of clumps of the ericaceous microphanerophytes *Vaccinium uliginosum* and *Arctous rubra*.

Extensive areas of the flats are covered by unstable sand from which both trees and ground vegetation are absent. Various stages in the recolonization of these flat areas of bare sand can be discerned. A small number of pioneer species occur sporadically in the area; of these the most prevalent are *Poa glauca*, *Artemisia canadensis*, *Arabis arenicola* var. *pubescens*, *Saxifraga tricuspidata*, and the cryptogams *Polytrichum piliferum*, *Rhacomitrium canescens*, and *Alectoria altaica*. By their capacity to withstand the dry and unstable conditions—the vascular plants are either extensively rhizomatous or furnished with deep tap roots—these species are important fixers of unstable sand surfaces, enabling other plants to become established. Of the latter, *Empetrum hermaphroditum* is the most important. By its vigorous lateral growth, effected by spreading rhizomes, it forms extensive circular and crescent-shaped mats, fixing small areas of sand. Often the incomplete erosion by blow-outs of these mats forms small dunes (Pl. 4). Cyclical phenomena are common in crowberry; a young plant grows radially, extending into bare sand along a circular front, and as the central, older shoots die off they are colonized and ultimately replaced by a lichen mat, consisting of *Stereocaulon paschale* ssp. *evolutoides*, associated with *Cladonia rangiferina* and the moss *Polytrichum piliferum* (Pl.3). These mats may then be colonized by *Vaccinium vitis-idaea* ssp. *minus* which forms a stable sward, and it is at this stage that invasion by spruce seedlings takes place. In other cases the lichen mat breaks up and fresh growth by *Empetrum* produces a closed carpet. In other areas, after the central shoots of an *Empetrum* patch have died off, the peripheral shoots may advance in crescent-shaped patches; these are common in small dune areas.

Multiple ridges

Lower slopes

The large esker which was studied reaches its greatest width in areas of multiple ridges, which, along with lateral extensions of sand, form a band 1 km. in width. Also in these areas the greatest elevation was noted, and the ridges shown in Fig. 5 are 80 m. above the level of the surrounding glacial lakes. The lower slopes of these ridges, with either an east or a west aspect, bear an open white spruce forest with a relatively rich ground vegetation, and with certain subsidiary shrub and tree associates. The angle of slope of these surfaces is 28–35°. The trees occur with a density of 6–8 per 100 square metres, and

Table 8. A cover analysis of the vegetation on the esker.

Quadrats (10 m. sq.)

Species	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Alnus crispa	4	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Equisetum sylvaticum var. *pauciramosum*	2	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calamagrostis canadensis	3	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Sphagnum robustum	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aulacomnium palustre	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vaccinium uliginosum	1	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—
Picea glauca	—	1	5	4	5	4	1	2	1	1	—	—	—	—	—	—	—	1
Vaccinium vitis-idaea ssp. *minus*	—	4	4	2	3	4	—	1	1	1	+	—	—	—	—	—	+	1
Stereocaulon paschale ssp. *evolutoides*	—	3	3	4	2	2	4	1	+	—	—	—	—	—	—	—	—	2
Empetrum hermaphroditum	—	1	2	—	1	1	+	5	4	5	2	—	—	—	2	2	3	3
Cladonia alpestris	—	1	2	2	1	—	1	—	—	+	—	—	—	—	—	—	—	1
C. pleurota	—	+	—	1	—	+	—	+	—	—	—	—	—	—	—	—	—	—
C. rangiferina	—	+	—	—	+	—	+	—	+	+	—	—	—	—	—	—	—	+
Geocaulon lividum	—	1	1	+	+	1	+	+	—	—	—	—	—	—	—	—	—	—
Pleurozium schreberi	—	1	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dicranum bergeri	—	+	+	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—
D. fuscescens	—	+	+	—	+	1	+	—	—	—	—	—	—	—	—	—	—	—
Ptilidium ciliare	—	+	—	—	+	+	—	—	—	—	—	—	—	—	—	—	—	—
Tetraplodon mnioides	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Polytrichum piliferum	—	+	—	+	+	+	1	—	+	—	+	—	+	—	—	—	—	1
Hylocomium splendens	—	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bare sand	—	—	1	—	—	—	—	3	3	3	5	5	5	5	5	5	4	3
Cetraria nivalis	—	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	—	—
Rhacomitrium canescens	—	—	—	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—
Poa glauca	—	—	—	—	—	—	—	—	—	—	—	+	—	+	—	+	—	—
Alectoria altaica	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—
Arabis arenicola var. *pubescens*	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—
Artemisia canadensis	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—
Saxifraga tricuspidata	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—
Ledum decumbens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Equisetum arvense var. *boreale*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Betula papyrifera var. *neoalaskana*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Lycopodium complanatum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arctostaphylos uva-ursi var. *coactilis*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chamaenerion angustifolium	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Betula glandulosa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Linnaea borealis ssp. *americana*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex glacialis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C. deflexa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Potentilla tridentata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex stans	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Polytrichum commune	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Peltigera pulverulenta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nephroma arcticum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ledum groenlandicum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oxytropis campestris var. *varians*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calamagrostis purpurascens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ptilium crista-castrensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhytidium rugosum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ceratodon purpureus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Stable Flats									Unstable Flats								

Species	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37
Alnus crispa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Equisetum sylvaticum var. *pauciramosum*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calamagrostis canadensis	—	—	—	—	—	—	—	+	+	—	+	—	+	—	1	—	+	+	+
Sphagnum robustum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aulacomnium palustre	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vaccinium uliginosum	—	+	1	—	—	—	—	2	—	1	—	—	3	+	1	—	—	—	2
Picea glauca	3	2	1	2	1	3	3	2	1	2	—	2	3	5	—	3	3	2	4
Vaccinium vitis-idaea ssp. *minus*	2	2	1	2	1	2	1	1	—	—	1	2	+	—	—	—	+	—	+
Stereocaulon paschale ssp. *evolutoides*	2	3	1	2	4	3	3	2	4	3	3	3	2	3	2	4	2	4	—
Empetrum hermaphroditum	2	3	4	2	1	2	2	3	3	3	2	2	—	1	—	—	2	3	1
Cladonia alpestris	+	+	—	1	+	+	1	—	+	—	+	+	+	+	+	+	—	1	—
C. pleurota	+	+	+	—	+	+	+	+	—	—	—	+	—	+	—	+	+	+	—
C. rangiferina	—	—	+	—	+	—	+	+	+	—	—	—	+	+	+	—	+	—	—
Geocaulon lividum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	+
Pleurozium schreberi	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—
Dicranum bergeri	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
D. fuscescens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ptilidium ciliare	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tetraplodon mnioides	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Polytrichum piliferum	—	—	—	—	—	—	—	—	—	1	—	—	+	+	—	1	—	2	—
Hylocomium splendens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bare sand	3	2	—	—	—	—	—	3	—	—	—	—	3	—	—	2	—	—	—
Cetraria nivalis	1	—	1	+	—	—	+	—	—	—	+	—	—	+	—	—	—	—	—
Rhacomitrium canescens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Poa glauca	—	—	—	—	—	—	—	—	—	—	—	—	—	+	1	+	—	—	+
Alectoria altaica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arabis arenicola var. *pubescens*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Artemisia canadensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Saxifraga tricuspidata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ledum decumbens	—	—	+	—	+	—	+	—	—	—	—	+	—	—	—	—	—	+	+
Equisetum arvense var. *boreale*	—	—	—	—	—	—	—	+	+	—	—	—	—	—	—	—	—	—	—
Betula papyrifera var. *neoalaskana*	—	—	—	—	—	—	—	—	—	1	—	—	—	—	—	—	—	—	—
Lycopodium complanatum	—	—	—	—	—	—	—	—	—	—	+	—	—	1	—	+	+	+	—
Arctostaphylos uva-ursi var. *coactilis*	—	—	—	—	—	—	—	—	—	—	+	2	1	—	—	2	3	2	3
Chamaenerion angustifolium	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	+	—	—
Betula glandulosa	—	—	—	—	—	—	—	—	—	—	—	—	+	—	+	4	1	+	—
Linnaea borealis ssp. *americana*	—	—	—	—	—	—	—	—	—	—	—	—	+	+	—	—	—	—	—
Carex glacialis	—	—	—	—	—	—	—	—	—	—	—	—	+	+	—	+	—	—	—
C. deflexa	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+	—	—	—	—
Potentilla tridentata	—	—	—	—	—	—	—	—	—	—	—	—	+	—	+	—	—	—	—
Carex stans	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—
Polytrichum commune	—	—	—	—	—	—	—	—	—	—	—	—	—	—	3	—	—	—	—
Peltigera pulverulenta	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	+
Nephroma arcticum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+
Ledum groenlandicum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oxytropis campestris var. *varians*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calamagrostis purpurascens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ptilium crista-castrensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhytidium rugosum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ceratodon purpureus	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Stable Flats									Lower slope — Stable									

Species	38	39	40	41	42	43	44	45	46	47	48	49	50	51
Alnus crispa	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Equisetum sylvaticum var. *pauciramosum*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calamagrostis canadensis	+	+	+	+	—	+	+	—	—	—	—	—	—	—
Sphagnum robustum	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aulacomnium palustre	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vaccinium uliginosum	—	—	—	—	—	—	—	—	—	—	—	1	—	—
Picea glauca	—	3	2	1	2	1	3	—	—	—	1	—	—	—
Vaccinium vitis-idaea ssp. *minus*	3	+	1	2	2	2	2	—	—	+	+	+	+	+
Stereocaulon paschale ssp. *evolutoides*	1	+	1	1	1	+	1	—	—	—	—	—	—	—
Empetrum hermaphroditum	1	+	1	2	3	2	2	—	—	+	+	+	+	2
Cladonia alpestris	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C. pleurota	+	—	—	—	+	—	+	—	—	—	—	—	—	—
C. rangiferina	—	—	+	—	—	+	—	—	—	—	—	—	—	—
Geocaulon lividum	+	+	—	1	1	+	1	—	—	—	—	—	—	—
Pleurozium schreberi	1	+	+	—	—	—	—	—	—	—	—	—	—	—
Dicranum bergeri	+	+	—	—	—	—	—	—	—	—	—	—	—	—
D. fuscescens	—	+	+	—	—	—	—	—	—	—	—	—	—	—
Ptilidium ciliare	—	—	+	—	—	—	—	—	—	—	—	—	—	—
Tetraplodon mnioides	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Polytrichum piliferum	—	+	—	—	—	+	+	—	—	—	—	—	—	+
Hylocomium splendens	+	—	—	—	—	—	—	—	—	—	—	—	—	—
Bare sand	—	3	1	1	2	2	+	5	5	5	5	5	5	5
Cetraria nivalis	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhacomitrium canescens	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Poa glauca	—	+	—	—	—	+	—	—	—	—	—	—	—	—
Alectoria altaica	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arabis arenicola var. *pubescens*	—	—	—	—	—	—	—	—	+	—	—	—	—	—
Artemisia canadensis	—	—	—	—	—	—	—	+	+	—	—	—	—	—
Saxifraga tricuspidata	—	—	—	—	+	—	—	—	—	—	—	—	—	—
Ledum decumbens	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Equisetum arvense var. *boreale*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Betula papyrifera var. *neoalaskana*	5	1	—	—	—	—	—	—	—	—	—	—	—	—
Lycopodium complanatum	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arctostaphylos uva-ursi var. *coactilis*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Chamaenerion angustifolium	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Betula glandulosa	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Linnaea borealis ssp. *americana*	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex glacialis	—	—	—	—	—	—	—	—	+	—	—	—	—	—
C. deflexa	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Potentilla tridentata	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex stans	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Polytrichum commune	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Peltigera pulverulenta	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nephroma arcticum	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ledum groenlandicum	1	—	—	—	—	—	—	—	—	—	—	—	—	—
Oxytropis campestris var. *varians*	—	—	—	—	—	—	—	1	2	1	1	—	—	—
Calamagrostis purpurascens	—	—	—	—	—	—	—	—	+	—	—	—	—	—
Ptilium crista-castrensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhytidium rugosum	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ceratodon purpureus	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Upper slope — Stable							Summit ridge — Unstable						

Species	52	53	54	55	56	57	58	59	60	61	62	63	64	65	66	67	68	69	70	71	72	73	74	75	76	77
Alnus crispa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Equisetum sylvaticum var. *pauciramosum*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calamagrostis canadensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	+	—	+	+	—	—	—
Sphagnum robustum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Aulacomnium palustre	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Vaccinium uliginosum	—	—	—	—	—	—	1	—	—	—	—	1	—	—	+	—	—	—	+	—	—	—	—	+	—	—
Picea glauca	1	4	4	2	1	5	1	2	3	4	5	2	3	4	4	3	3	2	3	4	4	2	3	4	2	3
Vaccinium vitis-idaea ssp. *minus*	3	4	3	2	2	1	1	2	1	2	1	1	2	2	+	—	—	—	—	—	—	—	—	—	—	—
Stereocaulon paschale ssp. *evolutoides*	3	1	3	3	3	4	2	3	4	3	4	4	2	3	4	4	4	4	3	3	4	4	4	4	3	—
Empetrum hermaphroditum	2	2	+	—	—	+	—	—	+	1	+	—	+	+	+	—	2	—	2	—	+	+	—	—	+	—
Cladonia alpestris	—	1	2	1	1	1	2	1	1	+	1	+	2	+	1	+	1	+	+	1	1	1	+	1	1	—
C. pleurota	—	+	—	—	+	—	—	—	+	—	—	—	—	—	—	+	—	—	+	—	—	+	—	—	—	—
C. rangiferina	—	1	1	1	1	1	+	1	1	+	+	+	+	+	+	+	+	1	+	+	+	1	+	+	+	—
Geocaulon lividum	1	+	+	1	+	—	1	+	+	+	—	1	+	+	+	—	1	—	—	+	—	—	+	—	+	—
Pleurozium schreberi	1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Dicranum bergeri	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
D. fuscescens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ptilidium ciliare	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Tetraplodon mnioides	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Polytrichum piliferum	+	+	+	+	+	+	—	+	+	+	—	+	+	+	+	+	1	—	+	1	1	+	—	+	1	—
Hylocomium splendens	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Bare sand	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Cetraria nivalis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	1	—	—	—
Rhacomitrium canescens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Poa glauca	—	+	—	—	—	—	—	—	—	—	+	—	—	—	—	+	—	—	—	+	—	1	—	—	—	—
Alectoria altaica	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Arabis arenicola var. *pubescens*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Artemisia canadensis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Saxifraga tricuspidata	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ledum decumbens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	+	—	—	—
Equisetum arvense var. *boreale*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Betula papyrifera var. *neoalaskana*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	1	—	2	1	—
Lycopodium complanatum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	+	—	+	—	+	+	—	—	+	—
Arctostaphylos uva-ursi var. *coactilis*	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	1	2	+	—	2	—	+	1	+	—	1
Chamaenerion angustifolium	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Betula glandulosa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	1	—	—	1	—	—	—
Linnaea borealis ssp. *americana*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	+	—	—	—	—	—	—	—	—	—	—
Carex glacialis	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
C. deflexa	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Potentilla tridentata	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Carex stans	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Polytrichum commune	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Peltigera pulverulenta	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Nephroma arcticum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ledum groenlandicum	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Oxytropis campestris var. *varians*	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Calamagrostis purpurascens	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ptilium crista-castrensis	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Rhytidium rugosum	+	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Ceratodon purpureus	—	+	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	Lower slope — Stable															Upper slope — Stable										

they form an uneven-aged community with the most mature trees reaching 20 m. in height, 50 cm. diameter at breast height, and an age of 180–200 years. Associated with the spruce there are a few trees of *Betula papyrifera* var. *neoalaskana* and a discontinuous shrub layer composed of *B. glandulosa.* The chief component of the ground layer is the lichen-moss mat, of which *Stereocaulon paschale* ssp. *evolutoides, Cladonia pleurota, C. rangiferina, Pleurozium schreberi,* and *Hylocomium splendens* are common. A dwarf shrub component is present, represented by *Empetrum hermaphroditum, Vaccinium uliginosum, V. vitis-idaea* ssp. *minus,* and *Arctostaphylos uva-ursi* var. *coactilis.* Consistently occurring members of the field layer are *Calamagrostis canadensis, Carex deflexa, C. glacialis, Linnaea borealis* ssp. *americana, Chamaenerion angustifolia, Potentilla tridentata, Lycopodium complanatum, Poa glauca,* and *Geocaulon lividum.* The relative position and structure of this stable community is illustrated in Fig. 5, Pl. 2, and in Table 8.

Upper slopes

The structure and composition of the minor plant communities of the upper slopes of these multiple ridges differ in certain aspects from those of the lower slopes. Several of the herbs and shrubs—*Linnaea, Arctostaphylos, Lycopodium, Carex deflexa, Chamaenerion, Betula glandulosa,* and *Potentilla tridentata*—are absent from these upper slopes, where the lichen-moss mat, associated with *Vaccinium vitis-idaea* ssp. *minus, Empetrum,* and *Geocaulon,* predominates. A cover analysis of the vegetation of one of these upper slopes is included in Table 8 under "upper slope—stable".

Kettles

In the depressions, or kettles, between the multiple ridges of the esker there are various plant communities. Under an open canopy of mature white spruce, confined to south-facing slopes, the ground vegetation is made up of the weft-form moss *Rhytidium rugosum,* associated with *Ptilium crista-castrensis, Arctostaphylos uva-ursi* var. *coactilis,* and *Linnaea borealis* ssp. *americana.* On north-facing slopes *Ledum decumbens* forms a major part of the ground vegetation, being associated with a lichen-moss mat, *Empetrum, Vaccinium vitis-idaea* ssp. *minus, V. uliginosum,* and *Calamagrostis canadensis.*

In the bottom of these kettles various local communities are present, the precise structure and composition being determined by the drainage. Some (Pl. 6) show little local variation and bear a plant community which is identical with that of the slopes. In one kettle, there was a small pool, with distinct vegetation zones. The shallow peaty pool was dominated by *Drepanocladus fluitans.* Immediately contiguous with the pool and confined to the north-facing side, there is a small patch of muskeg, consisting of a carpet of *Sphagnum girgensohnii* associated with *Carex stans, Drepanocladus uncinatus, Salix pyrifolia, Ledum groenlandicum, Calamagrostis canadensis, Calliergon stramineum, Rubus chamaemorus, Polytrichum commune, Pohlia nutans,* and a number of small trees of *Picea mariana.* On the south-facing slope there is a narrow zone of *Salix pyrifolia* under which *Linnaea borealis* ssp. *americana, Rhytidium rugosum, Arctostaphylos uva-ursi* var. *coactilis, Saxifraga tricuspidata,* and *Calamagrostis canadensis* form the ground vegetation. This narrow zone is immediately contiguous with the closed ground vegetation of the stable esker slope, bearing white spruce.

In certain kettles water has accumulated as larger, shallow ponds, which show a distinct peripheral zonation of vegetation. The outer zones are dominated by *Carex stans* and *Comarum palustre;* adjacent to the pond margin there is a zone of *Carex stans* associated with *C. canescens, Drepanocladus fluitans, Sphagnum robustum,* and *S. recurvum.* On shallow, peaty soil at the pond margin there is a local fringe of black spruce muskeg, confined to the south and west sides of the pool; it consists of hummocks of *S. robustum* with *Kalmia polifolia, Rubus chamaemorus, Hylocomium splendens, Ptilium crista-castrensis, Peltigera aphthosa, Ledum groenlandicum, Polytrichum commune, Pinguicula villosa,* and *Ptilidium ciliare.*

Certain of the esker hollows are relatively dry and bear an interesting, local community. The soil is a fine, sandy clay, very different from the coarse-grained highly porous soil of other esker sites. Most abundant in drier parts of these kettles are the grasses *Agrostis borealis, Festuca brachyphylla,* and *Oryzopsis pungens,* associated with *Carex praticola, Potentilla tridentata,* and *Antennaria rosea.* In damper parts *Petasites palmatus, Viola labradorica,* and *Polytrichum commune* are locally dominant. Sporadic clumps of *Vaccinium uliginosum,* associated with *Pleurozium schreberi* and *Chamaenerion augustifolium,* were recorded. An analysis of the vegetation of one of these kettle bottoms is given in Table 9.

Table 9. A cover analysis of the vegetation of the bottom of an esker kettle.

Species	*Quadrats* (1 m. sq.)							
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*
Oryzopsis pungens	2	1	+	–	2	3	1	–
Festuca brachyphylla	1	1	+	+	+	–	+	–
Carex praticola	2	–	2	+	1	2	–	–
Agrostis borealis	1	1	+	–	1	+	–	+
Viola labradorica	+	–	–	2	–	–	2	–
Petasites palmatus	1	–	1	+	+	1	+	+
Betula glandulosa	+	–	–	–	1	–	–	–
Chamaenerion angustifolium	+	–	–	+	+	+	–	+
Pleurozium schreberi	+	1	1	+	1	1	+	+
Polytrichum commune	+	1	–	+	2	+	1	1

On south-facing slopes, adjacent to these kettle bottoms, there is a distinctive assemblage of plants, of which the following are characteristic: *Linnaea borealis* ssp. *americana, Lycopodium complanatum, Pyrola grandiflora, Arnica lonchophylla, Oryzopsis pungens,* and *Arctostaphylos uva-ursi* var. *coactilis.*

In all cases, *Picea glauca* is absent from these bottoms and only *Betula glandulosa* and a few small trees of *Picea mariana* form a discontinuous chamaephytic stratum. It has been noted elsewhere in this report that white spruce tends to be replaced by black spruce on heavier soils, and the operative factor here might be edaphic.

Summit communities

There is a characteristic pattern of communities on the summits of multiple ridges. Locally, and very rarely, the ridges are completely covered by vegetation which conforms to the description given above for the white spruce lichen forest on esker upper slopes. That is, it consists of well-spaced

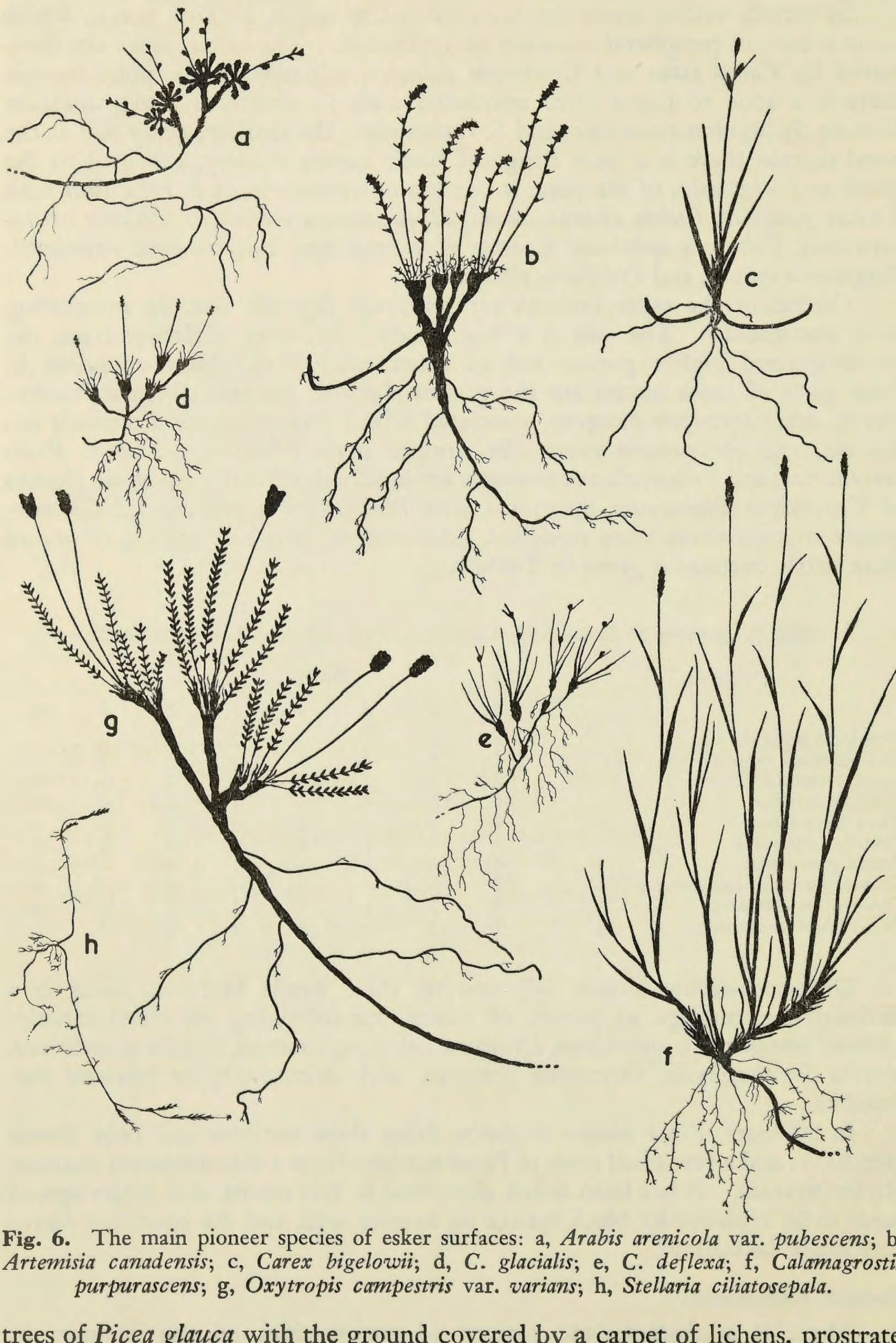

Fig. 6. The main pioneer species of esker surfaces: a, *Arabis arenicola* var. *pubescens*; b, *Artemisia canadensis*; c, *Carex bigelowii*; d, *C. glacialis*; e, *C. deflexa*; f, *Calamagrostis purpurascens*; g, *Oxytropis campestris* var. *varians*; h, *Stellaria ciliatosepala*.

trees of *Picea glauca* with the ground covered by a carpet of lichens, prostrate shrubs, and mosses.

More commonly the ridges are unstable, being devoid of trees and showing signs of recent erosion—numerous old, upturned stumps of white spruce and remains of buried and eroded humus layers. Certain pioneer species are actively colonizing parts of these steep-sided ridges. A common association of pioneers is made up of the following species: *Calamagrostis purpurascens*, *Oxytropis campestris* var. *varians*, *Artemisia canadensis*, *Arabis arenicola* var. *pubescens*, and *Carex glacialis*. These species are all furnished with extensive subterranean parts—tap roots and/or rhizomes (Fig. 6)—and they are able to withstand the conditions of instability and low soil moisture of the summit sites. Less commonly, *Stellaria ciliatosepala*, here extensively rhizomatous, and *Carex bigelowii* f. *anguillata* take part in the fixation and colonization of these esker surfaces. The lichens *Alectoria altaica* and *Sphaerophorus fragilis* are of some significance in the stabilizing of the ridge surfaces. These small fruticose species grow between coarse sand and gravel particles which they bind together into small aggregates. Probably of less importance ecologically, *Parmelia incurva* and *Rhizocarpon geographicum* are common on pebbles and coarse sand particles. Often at this stage of local stabilization of a sand surface, the pioneer mosses *Polytrichum piliferum* and, in finer sand, *Rhacomitrium canescens* advance the stabilization process.

Ridge sites which are successfully colonized by these pioneer species are invaded by various secondary colonizers—particularly *Empetrum hermaphroditum*, *Vaccinium vitis-idaea* ssp. *minus*, and *Stereocaulon paschale* ssp. *evolutoides*. Ultimately a stable mat of lichens and prostrate shrubs is formed which is then invaded by white spruce.

The contemporary surfaces of these ridges are occupied by a mosaic of communities at various stages of colonization, stabilization, and degeneration. It is hardly possible from a single short season in the field to determine the precise factor or factor complex which initiates erosion on the esker surfaces. Undoubtedly wind is the chief accelerator of erosion after the mat of ground vegetation has been broken, and several living spruce trees were examined whose root system was being exposed rapidly by wind erosion of an unstable surface. The trapper-prospector whose cabin is situated near this esker, described the spring and autumn migrations of large herds of Barren Ground Caribou (*Rangifer arcticus arcticus*) in this area, which cross and travel along the esker at many points. It seems probable that these animals contribute to the disturbance of the sward of lichens and prostrate shrubs. It would be of value to have information about the winter conditions on the esker; it is possible that the lack of snow cover of summit sites might account in part for the absence of vegetation from many areas.

Careful scrutiny of Table 8 will indicate the structure and composition of certain of the communities on multiple ridge slopes.

Single ridge communities

Locally the esker is a single ridge which either slopes on both sides directly and abruptly on to till substrata, or is bounded by shallow glacial lakes. On these exposed ridges there are several distinct communities which differ from those of the "multiple ridge" areas in certain respects. On the stable summits of these ridges there is a white spruce lichen forest community, similar in many ways to that of the lower slopes and deltas (Pl. 5). On certain of the steep flanks (angle of slope 30–38°), a treeless heath or tundra community is locally dominant, consisting of a dense, closed sward of lichens and heath plants. A conspicuous component is the mat of cryptogams, dominated by *Cetraria nivalis*, *Cladonia uncialis*, *C. subrangiformis*, *C. alpestris*, *Stereocaulon paschale* ssp. *evolutoides*, *Polytrichum piliferum*, and *Ceratodon purpureus*. The dominant prostrate shrubs are *Ledum decumbens*, *Empetrum hermaphroditum*, *Vaccinium vitis-idaea* ssp. *minus*, and *Arctous rubra*. Herbaceous perennials in the community are represented by *Luzula confusa*, *Poa glauca*, *Calamagrostis purpurascens* (rare in closed communities), *Carex glacialis*, and *C. bigelowii* f. *anguillata*. The relative abundance of these species is summarized in Table 10.

Table 10. A cover analysis of the heath community on a single esker ridge.

Species	*Quadrats* (1 m. sq.)					
	1	*2*	*3*	*4*	*5*	*6*
Ledum decumbens	3	2	2	+	1	1
Empetrum hermaphroditum	1	+	–	+	+	1
Vaccinium vitis-idaea ssp. *minus*	2	+	+	1	+	–
Arctous rubra	+	–	2	–	–	–
Luzula confusa	+	–	+	+	+	–
Carex glacialis	+	–	–	+	+	–
Chamaenerion angustifolium	–	–	1	–	–	–
Poa glauca	+	–	+	–	–	–
Cladonia uncialis	1	–	1	+	2	–
C. alpestris	+	+	+	+	+	–
C. subrangiformis	+	+	–	–	1	1
C. rangiferina	+	+	–	+	–	+
Cetraria nivalis	1	+	+	1	1	1
C. nigricascens	–	–	+	–	+	+
Alectoria altaica	+	–	+	–	–	+
Stereocaulon paschale ssp. *evolutoides*	1	1	2	+	1	2
Polytrichum piliferum	1	+	1	1	+	1
Ceratodon purpureus	–	–	1	–	+	–
Cetraria crispa	–	+	–	–	+	–

Along the lower margin of the esker where it abuts directly upon lakes, there is a fringe community dominated by *Alnus crispa* and *Picea glauca*. This shrub is associated with *Equisetum sylvaticum* var. *pauciramosum*, *Calamagrostis canadensis*, *Vaccinium uliginosum*, and, at the bank, a moss carpet of *Sphagnum robustum*, *Aulacomnium palustre*, and *Dicranum fuscescens*.

Locally, small sand-bars have developed at the lake margin where esker sand forms the lake bottom. Here there is a small series of 10–15 bars with intervening swales. The older swales and ridges are being colonized by a local assemblage of plants. The damp sand of the ridges is occupied by an open colony of *Eriophorum scheuchzeri* var. *tenuifolium*, which is associated with *Carex stans*. The wetter sand surfaces of the swales bear an open community of which *Colpodium fulvum* and *Eleocharis acicularis* var. *submersa* are dominant. Subsequently, *Polytrichum commune* var. *jensenii*, *Calliergon stramineum*, *Sphagnum recurvum*, *Carex rariflora*, *Myrica gale*, and *Epilobium palustre* colonize the older swales.

Black spruce on the esker

Picea glauca is generally the dominant tree of the esker, but in some areas it shares dominance with *P. mariana* which replaces it entirely on certain local sites. Where the esker consists of a narrow, single ridge, bounded at least on one side by a body of water, *P. glauca* is the sole conifer. But in areas where it slopes gradually on to drift areas, always dominated by black spruce lichen forest, there is considerable encroachment on to the esker by *P. mariana*, which forms stands similar in every respect to those dominated by white spruce. In these situations the growth of black spruce was the best for the area. The trees are tall, symmetrical, and bushy-based due to "layering" of the lower branches. In these black spruce lichen woodland stands, trees of 180–200 years in age reach 12–15 m. in height and 15–20 cm. in diameter at breast height.

In the area of multiple ridges, on the west side of the esker, an unusual black spruce community was observed on a sand-covered ridge in a flat sandy area otherwise dominated by white spruce lichen woodland. This small ridge extends along the esker flank for about 200 m., and it rises 5–6 m. above the level of the surrounding surface. The subsidiary vegetation is a discontinuous stratum of *Alnus crispa*, with occasional individuals of *Betula glandulosa*. The ground vegetation consists of a mosaic of prostrate shrubs, lichen mat with mosses, and various herbs. The details of the composition of the ground vegetation are summarized in Table 11.

Table 11. A cover analysis of the ground vegetation of a stand of black spruce forest on the esker.

Species	*Quadrats* (1 m. sq.)					
	1	*2*	*3*	*4*	*5*	*6*
Ledum groenlandicum	3	2	4	4	3	2
Empetrum hermaphroditum	1	+	2	+	+	1
Vaccinium uliginosum	2	–	–	1	–	–
Lycopodium complanatum	+	–	+	–	–	+
L. annotinum	–	–	+	–	–	–
Equisetum arvense var. *boreale*	–	+	+	–	+	–
Cladonia alpestris	1	+	1	+	1	1
Stereocaulon paschale ssp. *evolutoides*	2	2	1	1	2	1
Cladonia rangiferina	+	+	+	–	–	+
Cetraria nivalis	–	–	–	+	–	+
Dicranum fuscescens	+	+	1	+	+	1
Pleurozium schreberi	+	–	+	+	–	+
Drepanocladus uncinatus	–	–	–	+	–	–

Associated with this conspicuous and unexpected difference in the tree cover on the ridge there is a marked difference in the substrata. In a soil pit dug under the black spruces the following horizons were exposed:

0–6 cm., compact black fibrous humus

7–27 cm., grey-white sand in which the grains are bleached

28–45 cm., reddish-brown coarse sand.

The lower horizons are the layers of leaching and deposition respectively. At 45 cm., and extending as far down the pit as could be seen (2½ m.), there is a distinct layer of compacted, uniform, clayey sand of a dull brown colour. This lower layer was wet, but it was possible to locate neither a water table nor evidence of permafrost. By contrast, a soil pit on the adjacent sand surface under white spruce revealed a continuous deposit of uniform coarse sand, with no evidence of profile development or of an underlying clay layer.

It would appear that this local dominance of *Picea mariana*, associated with a relatively mesophytic ground vegetation, can be correlated with the existence of the ridge of heavy clay, and that local dominance of black spruce elsewhere on this esker can be accounted for in this way. It is possible that this clay ridge has originated as a glacial crevasse-filling at the margin of the esker (cf. Lobeck, 1939, p. 313). Elsewhere, black spruce competes well with the dominant white spruce, in local kettles on north-facing slopes, and often in areas where there is a local substratum of heavy, fine grained, sorted material.

Pine communities on the esker

One large stand of *Pinus banksiana* was noted on the esker, growing on a large flat summit area. Locally old trees of jackpine are present, but the greater proportion of the trees is made up of young individuals (average, 30 years, 6 m. in height, and 15 cm. d.b.h.) which form a closed stand. There is evidence that the area has been burned over in the past and that the jackpine is a subseral community. Old stumps and fallen trunks of spruce occur on the ground between the pines. Associated with the pine there is a discontinuous shrub stratum of *Alnus crispa* and *Betula glandulosa.* The ground vegetation is poor in species, being composed of patches of *Vaccinium uliginosum*, *Ledum groenlandicum*, and *V. vitis-idaea* ssp. *minus* alternating with patches of lichen-moss mat, dominated by *Stereocaulon paschale* ssp. *evolutoides*, *Cladonia alpestris*, *C. rangiferina*, *Dicranum fuscescens*, *Pleurozium schreberi*, and *Ceratodon purpureus.*

Jackpine was absent from all other parts of the esker which were examined, and it was noted in only one other locality in the entire area.

3. Peat Deposits

As indicated above, considerable areas of the particular region of this investigation are occupied by deep deposits of peat. The greater number of these deposits are situated at the edges of small lakes, occupying shallow basins between the low ridges of drift. A feature of the deposits, common to all, is the presence of an eroding surface at the lake margin, consisting of a vertical wall of unstable peat, 3–6 m. above the level of the lake. As shown in Fig. 2, with few exceptions, these deposits occur at the periphery of lakes. Two exceptions are conspicuous high islands of peat in the largest lake of the area (Fig. 2); they are about 300 m. in length, 100 m. in breadth, and rise 8–10 m. above the level of the lake.

It is possible to recognize two main community types on the surface layer of these peat deposits. The greater number are covered by a heath vegetation, while in certain areas of poor surface drainage a *Scirpus-Eriophorum* community dominates the deposits. These deposits are devoid of trees and for this reason they are loosely referred to here—merely for convenience—as "peat tundra". As these deposits appear to be confined to the subarctic region (cf. Tyrrell, 1897; Raup, 1941) there might be some justification for using this term, rather than "low tundra" which has been used to describe separate, arctic communities.

The surface of the heaths is marked by small mounds, 0.5—1 m. above the surface level and 1–2 m. in diameter. The centre of the mounds consists of disturbed peat lacking vegetation, being colonized locally by certain lichens—particularly the crustose *Icmadophila ericetorum.* Throughout the deposits the lower level of the active layer in late summer is 30–45 cm. below the surface. It is suggested that these mounds are the result of frost action, by which swelling and heaving disturbs and locally erodes the peat surface, resulting in a typical hummocked topography.

A second frost phenomenon is present on the surface of these deposits—large polygonal patterns. These unsorted polygons are 4—5 sided, 20—30 m. in breadth, and bounded by fissures in the peat which vary from 50 cm. in depth and 20 cm. in width to 1 m. in depth. and 60 cm. in width. The peat surfaces of the fissure are unstable, being colonized only by certain pioneer species.

Several of these deposits showed slight convexity of the surface.

The stable surfaces of the heath type are dominated by ericaceous and ericoid shrubs, associated with a small number of lichens and mosses. The vegetation is very uniform and is composed of a few species. *Ledum decumbens* dominates the microphanerophytic layer, associated with *Vaccinium vitis-idaea* ssp. *minus*, *Empetrum hermaphroditum*, and *V. uliginosum. Rubus chamaemorus* and *Andromeda polifolia* are constant members of the community, never occurring in local abundance. Exposed peat surfaces are colonized by various lichens and mosses. Raw peat on peat mounds is first colonized by *Icmadophila ericetorum*, and various fruticose species appear subsequently: *Cladonia digitata*, *C. coccifera*, *C. alpestris*, *C. uncialis*, *Cetraria nivalis*, and *C. crispa*. A conspicuous moss which colonizes the peat is *Dicranum elongatum*, which forms compact tussocks raised 10–20 cm. above the surface level. Scattered throughout the lichen ground carpet are plants of *Polytrichum juniperinum* var. *alpestre*.

In the polygon fissures there is a small number of species, predominantly mosses, which colonize the wet, unstable peat surfaces. In the bottoms *Sphagnum recurvum* and *Drepanocladus vernicosus* are abundant, often associated with *Rubus chamaemorus* and *Eriophorum chamissonis* f. *turneri.* Common colonizers of the drier peat of the fissure sides are *Dicranum muhlenbergii*, *Polytrichum juniperinum*, and *Rubus chamaemorus.*

The eroding wall of the deposits, which abuts upon the lake, is too unstable to support much vegetation. Only mosses grow on these walls, in particular colonies of the tuft-form *Dicranella cerviculata* and *Tetraphis pellucida.*

A cover analysis of the vegetation of a particular deposit bearing the heath type community is given in Table 12.

Locally, where drainage is poor a different vegetation covers the surfaces of these deposits. This consists of an association of *Scirpus caespitosus* ssp. *austriacus*, *Eriophorum spissum*, and *Carex rotundata;* also present are *Andromeda polifolia*, *Rubus chamaemorus*, *Carex stans*, *C. rariflora*, *Ledum decumbens*, *Sphagnum recurvum*, *S. lindbergii*, *Pleurozium schreberi*, *Dicranum elongatum*, *Cladonia alpestris*, *C. uncialis*, *Cetraria nivalis*, and *Polytrichum juniperinum* var. *alpestre.*

Only at the boundary between the heath community of these peat deposits and typical muskeg is there any tree cover, and here black spruce is present as

Table 12. A cover analysis of the tundra vegetation of peat deposits.

Species	*Quadrats* (1 sq. m.)																									% fre-quency
	1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*	*21*	*22*	*23*	*24*	*25*	
Ledum decumbens	2	2	2	2	3	2	2	2	4	3	1	2	4	3	3	3	1	2	4	2	1	4	2	3	3	100
Vaccinium vitis-idaea ssp. *minus*	2	3	3	2	2	2	2	+	3	–	2	2	2	1	3	1	+	2	+	3	4	+	2	1	1	96
Empetrum hermaphroditum	1	4	1	1	2	3	1	2	+	1	2	1	+	+	1	+	3	+	1	1	2	1	+	1	1	100
Vaccinium uliginosum	1	+	1	2	+	1	+	+	1	+	1	1	+	+	–	+	–	+	1	1	+	1	+	1	1	92
Andromeda polifolia	+	1	+	+	+	1	–	+	1	+	+	1	+	1	+	+	–	1	+	+	1	+	+	+	1	92
Rubus chamaemorus	–	–	+	+	–	+	+	–	–	–	+	–	–	–	–	+	+	+	–	–	+	–	+	–	–	40
Bare peat	1	+	2	2	1	+	1	+	2	1	1	+	1	+	–	+	1	2	1	+	1	+	2	1	1	96
Cetraria nivalis	+	+	+	+	+	–	+	–	–	+	–	–	+	+	+	–	+	+	–	–	+	+	–	–	–	56
Cladonia alpestris	+	+	+	–	+	–	+	–	–	+	–	–	+	+	–	+	–	–	–	+	–	+	–	+	+	52
C. digitata	+	–	–	+	–	–	–	–	+	–	–	+	+	–	+	+	–	–	–	+	–	–	–	–	+	36
C. coccifera	+	–	–	–	–	–	+	–	+	+	+	+	+	–	–	+	–	–	+	–	+	–	–	–	+	44
C. uncialis	+	–	+	–	–	+	+	–	+	–	–	+	+	1	–	–	+	–	1	+	+	–	–	–	+	52
Cetraria crispa	+	–	+	–	+	+	+	+	–	+	–	–	+	–	–	+	+	–	+	+	1	+	+	–	+	64
Icmadophila ericetorum	1	1	+	–	1	+	1	1	+	–	+	2	+	–	+	+	–	+	1	1	+	+	–	–	+	76
Dicranum elongatum	+	–	–	+	–	–	+	+	–	–	+	+	1	+	–	–	+	–	–	–	+	+	+	–	+	52
Polytrichum juniperinum var. *alpestre*	+	–	+	+	–	+	1	+	1	+	+	–	+	–	+	+	+	–	+	+	–	–	+	+	–	68

stunted, shrubby individuals. It is likely that the high permafrost layer throughout the deposits, due to the insulating influence of the deep blanket of drying peat, inhibits tree growth.

Locally, small streams cut back into the peat deposits, exposing channels bounded by vertical, usually terraced surfaces of peat. On these irregular terraces there are consistent vegetation zones. At the stream margin there is a zone dominated by *Salix planifolia* var. *nelsoni* which is associated with ground vegetation consisting of *Carex stans*, *Comarum palustre*, *Sphagnum recurvum*, *Drepanocladus fluitans*, *Eriophorum angustifolium*, and *Galium trifidum*. Adjacent, on drier peat, there is a zone dominated by *Carex paupercula* var. *irrigua* and *Scirpus caespitosus* ssp. *austriacus* associated with the following species, arranged in approximate order of abundance: *Carex canescens*, *C. rariflora*, *Rubus chamaemorus*, *Sphagnum recurvum*, *Eriophorum spissum*, *E. angustifolium*, *Andromeda polifolia*, *Polytrichum commune*, *Drepanocladus fluitans*, and *Eriophorum chamissonis* f. *turneri*.

On higher, better drained terraces a heath vegetation is prevalent, made up of the following species:

Vaccinium uliginosum	d	*Rubus chamaemorus*	o
Betula glandulosa	f	*Andromeda polifolia*	o
Kalmia polifolia	f	*Carex canescens*	o
Chamaedaphne calyculata var. *angustifolia*	f	*Sphagnum fuscum*	lf, a
Vaccinium vitis-idaea ssp. *minus*	f	*Polytrichum juniperinum* var. *alpestre*	o
Ledum groenlandicum	o		

Locally, accumulations of water on the surface of these peat deposits form small pools, associated with which there are usually vegetation zones. The open water of the pools at 10–40 cm. depth, is dominated by a loose mat of *Drepanocladus exannulatus* associated with *Menyanthes trifoliata* var. *minor*. The periphery of the pool consists of a closed community on wet peat, made up of a continuous carpet of *Sphagnum recurvum* and *S. lindbergii*, bearing local patches of *Eriophorum spissum*, *Carex rotundata*, and *Andromeda polifolia*. Between this zone, which is usually 10–15 m. wide, and the heath community, there is a transition zone made up of the following species:

Sphagnum lindbergii	a	*Rubus acaulis*	f
Carex rotundata	f	*Ledum decumbens*	o
C. rariflora	f	*Empetrum hermaphroditum*	o
Eriophorum spissum	f		

4. Lake Vegetation

For convenience of treatment, the vegetation associated with lakes is divided into: aquatic, shoreline, and island.

Aquatic

The number of aquatic plants in these lakes is small, and aquatic vegetation is seldom well developed. In lakes with sandy bottoms, particularly in the vicinity of the esker, *Eleocharis acicularis* var. *submersa*, *Hippuris vulgaris*, and *Ranunculus trichophyllus* var. *eradicatus* occur sporadically. In deeper water, forming a narrow zone between depths of 2 m. and 3 m., *Isoëtes muricata*, *I. macrospora*, and *I. echinospora* were recorded in considerable abundance. The last species was not recognized in the field and as a result no information is available about its relative abundance. Elsewhere in these lakes with sandy bottoms, little vegetation occurs.

Where there is an accumulation of organic matter on the lake bottom, very local colonies of *Nuphar variegatum* occur, associated in shallow water with *Hippuris vulgaris*, *Sparganium hyperboreum*, and *Potomageton gramineus*. In certain shallow peaty lakes, such as those adjoining the large peat deposits which have been described above, *Sparganium angustifolium* assumes local dominance.

Shoreline

Lake shorelines are low, being formed by rocky drift, outcrops or, locally, by esker deposits. Where the lake shore is rocky and shelves gradually into the lake, an outer zone of *Equisetum fluviatile* f. *linnaeanum* is often present, being replaced by *Carex stans* which extends to the limit of the water where a narrow zone of *Myrica gale* and *Alnus crispa* is common. This is replaced inland by muskeg vegetation. Various mosses occur on low, emergent shoreline rocks, in particular *Hedwigia ciliata*, *Dicranoweissia crispula*, *Grimmia alpicola* var. *rivularis*, *Hygrohypnum alpestre*, *Fissidens osmundioides*, and *Drepanocladus uncinatus*. On certain north-facing shorelines, *Parnassia kotzebuei*, *Pyrola minor*, *Petasites palmatus*, and *Lycopodium selago*, all rare in this area, form a local association in humus among rocks.

In many areas, particularly along northern shores, outcrops form the lake bank. They bear a varied assemblage of higher and lower plants which are seldom more than local facies. On thin humus over outcrops, the lichens *Cladonia subrangiformis*, *C. alpestris*, *and C. chlorophaea* are common, associated with *Pleurozium schreberi*, *Hylocomium splendens*, *Rhytidium rugosum*, and *Ptilidium ciliare*. On thin sand over outcrops there is a compact turf of *Mnium andrewsianum*, *Drepanocladus revolvens*, and *Oncophorus wahlenbergii*. On shaded, moist outcrops *Hypnum lindbergii* and *H. revolutum* are common, associated with patches of *Bryum pseudotriquetrum*.

The vertical faces of low sandy banks, formed by extensions of the esker, are characterized by a mosaic of species, the most common of which are *Sphagnum warnstorfianum*, *Aulacomnium palustre*, *Hypnum lindbergii*, *Tofieldia pusilla*, *Bryum pseudotriquetrum*, and *Drepanocladus uncinatus*. On narrow beaches below these faces the following plants are typical: *Luzula multiflora* ssp. *frigida* var. *contracta*, *L. parviflora*, *Equisetum sylvaticum* var. *pauciramosum*, *Aulacomnium palustre*, *Myrica gale*, *Alnus crispa*, *Agrostis borealis*, *Carex canescens*, *Polytrichum juniperinum*, *Vaccinium uliginosum*, *Calamagrostis canadensis*, and *Stellaria calycantha*.

Locally, where the shoreline consists of small peaty banks, exposed, vertical surfaces are colonized by *Mnium punctatum*, *Tetraphis pellucida*, and *Cladonia polydactyla*.

Island

Certain small islands in these glacial lakes are devoid of trees, bearing a varied community of shrubs and herbs. The following were recorded for a single small island in Spruce Lake:

Marginal community

Carex stans	a
Calamagrostis canadensis	a
Myrica gale	la
Stellaria calycantha	f
Parnassia kotzebuei	o
Luzula multiflora ssp. *frigida* var. *contracta*	o

Middle slopes

Betula glandulosa	lf
Alnus crispa	o
Petasites palmatus	r
Chamaenerion angustifolium	lf
Poa alpigena	o
Comarum palustre	o
Ledum groenlandicum	o

The summit of the island is dominated by a low heath community of which the following species are the chief components: *Empetrum hermaphroditum*, *Poa alpigena*, *Rubus idaeus* var. *canadensis*, *Vaccinium uliginosum*, and *V. vitis-idaea* ssp. *minus*.

5. River Vegetation

Floodplain and oxbow lakes

The vegetation of the extensive floodplain with meanders and oxbow lakes on Big Spruce River (Fig. 2) was studied in detail. The younger, stable stretches, composed of coarse sand deposits, are dominated by a white spruce lichen forest community (Pl. 8), similar in many respects to that of the lower esker slopes and deltas. The average age, height, and diameter at breast height of mature trees of this community are 180 years, 13 m., and 34 cm. respectively. The ground vegetation, which forms a discontinuous carpet alternating with bare sand, is dominated by mats of lichens and prostrate shrubs. The former are dominated by *Stereocaulon paschale* ssp. *evolutoides* associated with various *Cladonia* species and *Polytrichum piliferum*; the latter by *Empetrum hermaphroditum* which is accompanied by *Vaccinium vitis-idaea* ssp. *minus*, *V. uliginosum*, *Carex deflexa*, and *C. glacialis*.

In certain parts of the floodplain, this white spruce community abuts directly on to a black spruce lichen forest, and the boundary between the communities coincides with the limit of the floodplain at its junction with adjacent boulder till (Fig. 7).

Not all the floodplain terraces bear a white spruce forest. On the west side of the Big Spruce River floodplain, extensive areas of older terraces are dominated by black spruce lichen forests. The soil profile of these older sites shows some evidence of podzolization—there is a distinct leached horizon below which there is a local development of an orstein layer in the horizons of deposition. In these black spruce stands the ground vegetation is similar to that of the white spruce forests.

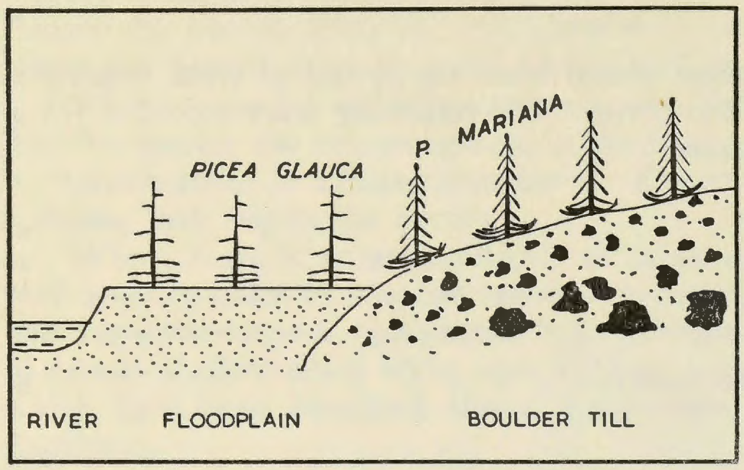

Fig. 7. Diagrammatic summary of the relationships of river floodplain and adjacent till, showing the tree dominants.

At the southwest tip of the floodplain a dense stand of young trees of *Pinus banksiana* was noted, in which there were a few very old trees. The ground vegetation of this stand is poor in species, being dominated by the ericoid shrubs *Vaccinium vitis-idaea* ssp. *minus*, *Empetrum hermaphroditum*, *Arctous rubra*, and *V. uliginosum*, associated with a carpet of lichens and mosses composed of *Cladonia rangiferina*, *Stereocaulon paschale* ssp. *evolutoides*, and *C. alpestris*. In this general area jackpine is very rare, being near its northern limit of distribution in Manitoba; the vegetation both of the area on the floodplain and of that on the esker indicates that its local spread from a few outliers has been favoured by fire.

A few small streams have cut back through the floodplain, approximately at right angles to the course of Big Spruce River, and there is a distinctive community on their banks. *Picea glauca* is the dominant tree along these streams, and the maximum values for vertical and radial growth of this tree were measured in these situations. Mature trees gave the following values for height, diameter at breast height, and age respectively: 21 m., 45 cm., and 183 years. These spruces, growing at the northern limit of continuous forest, show as vigorous vegetative and reproductive performance as average specimens from the southern boreal forest, ten degrees of latitude to the south (cf. Rowe, 1956). Part of this stand is shown in Pl. 7. (It would seem likely that the river takes its name from these local stands of white spruce on the floodplain). Associated with the conifers along the sides of the stream was a rare group of plants, typical both structurally and floristically of the white spruce forests on alluvial soils in southern parts of the boreal forest (cf. Ritchie, 1956b; Rowe, 1956). Occasional old trees of *Populus tremuloides* were recorded, and the ground vegetation consists of the following species, arranged in approximate order of relative abundance: *Vaccinium vitis-idaea* ssp. *minus*, *Chamaepericlymenum canadense**, *Viburnum edule**, *Alnus crispa*, *Linnaea borealis* ssp. *americana**, *Pyrola grandiflora**, *Calamagrostis canadensis*, *Geocaulon lividum*, *Empetrum hermaphroditum*, *Ledum decumbens*, *Hylocomium splendens*, *Pleurozium schreberi*, and *Peltigera aphthosa*. Those species marked with an asterisk are characteristic of the southern boreal forest and they are near their northern limit in Manitoba at this station.

The floodplain of Big Spruce River contains several oxbow lakes (Fig. 2), some of more recent origin than others. They show various stages of colonization by vegetation. In shallow lakes, *Menyanthes trifoliata* var. *minor* occurs as the pioneer aquatic. Adjacent to this discontinuous zone, *Carex stans* and

Comarum palustre form a narrow zone at the periphery of the oxbow. Exposed wet sand surfaces at the margins are colonized by the mosses *Drepanocladus exannulatus* (the type and f. *orthophyllus*) and *Sphagnum teres*, associated with *Carex paupercula* var. *irrigua*, *Rubus chamaemorus*, *Andromeda polifolia*, *Salix planifolia* var. *nelsoni*, and *Eriophorum angustifolium*. Subsequently *Betula glandulosa* and *Picea mariana* appear and the most mature oxbow lake vegetation is of the black spruce muskeg type. Likewise, the slip-off slopes associated with meanders usually bear a black spruce forest which is either of the muskeg type or the feather-moss type, depending on the soil moisture.

River bank communities

Locally, Big Spruce River and Seal River cut through rock formations, forming falls and chutes. The wet rocks and banks of these situations provide suitable niches for a small number of uncommon plants, in particular *Dryopteris fragrans*, *Potentilla tridentata*, *Poa glauca*, and *Andreaea rupestris*. Below the falls, wet sand surfaces between boulders in that part of the river bed which is inundated only at flood, bear a local moss community of the following species: *Grimmia alpicola* (on the rocks), *Bryum pseudotriquetrum*, *Isopterygium pulchellum*, *Dicranoweissia crispula*, *Campylium stellatum*, *Drepanocladus revolvens*, and *D. uncinatus*.

Along the low banks of boulder till, a consistent zonation of the vegetation was noted. At the edge of the river there is a marginal zone of *Carex stans*. On the low bank, which is within the zone submerged by spring floods, there is a poorly developed, seral community dominated by mosses. The chief mosses of this narrow zone are *Polytrichum commune*, *Climacium dendroides*, *Mnium affine*, *Atrichum undulatum*, and *Ceratodon purpureus*. Abutting on this zone is a belt of tall shrubs, dominated by *Salix planifolia*, *S. pyrifolia*, and *Alnus crispa*. In regions which have been unaffected in recent times by disturbance, this shrub zone is replaced by a white spruce community which never exceeds a few metres in width, being replaced by a black spruce forest. It is dominated by well-grown trees of *Picea glauca* which form a closed stand and which are associated locally with *Betula papyrifera* var. *neoalaskana*. The oldest tree noted in this situation was 204 years of age, 14 m. in height, and 30 cm. d.b.h. Associated with these fringe stands of white spruce there is a characteristic ground vegetation, consisting of the following species, arranged in order of approximate abundance: *Vaccinium vitis-idaea* ssp. *minus*, *Viburnum edule*, *Chamaepericlymenum canadense*, *Linnaea borealis* ssp. *americana*, *Empetrum hermaphroditum*, *Calamagrostis canadensis*, *Lycopodium annotinum*, *Hylocomium splendens*, *Pleurozium schreberi*, *Dicranum fuscescens*, and *Peltigera aphthosa*.

In the section of Big Spruce River above the floodplain (Fig. 2) the water is shallow and slow-flowing, passing between high banks of fine sandy loam. There is a constant zonation of the vegetation on these banks. At the edge of the water there is a fringe community dominated by *Carex stans*. On the steep slope of the bank there is an open community dominated by *Calamagrostis canadensis*, which is associated with *Carex canescens*, *Juncus filiformis*, *Polytrichum commune*, and *Atrichum undulatum*. On south-facing stretches of these banks a particular assemblage of plants appears, associated with this open, grass-dominated zone. These are: *Hierochloë odorata*, *Agrostis borealis*, *Rubus idaeus* var. *canadensis*, *Poa glauca*, *Achillea borealis*, *Solidago multiradiata*, and *Chamaepericlymenum canadense*. Behind this meadow zone, on the brow of the bank, there is a narrow zone (2–4 m.) of shrubs, dominated by *Alnus crispa*, *Salix pyrifolia*, and *Betula glandulosa*. Adjacent to this belt, in undisturbed areas, there is a narrow fringe of white spruce forest on the till surfaces farther from the river.

At that point where Big Spruce River enters the region, an unusual local community was observed. It occupies a low depression a few metres from the river bank, and it appeared to have been partly flooded in spring. This community consists of a central sedge-grass meadow, forming a roughly symmetrical area of about 100 m. in diameter, bounded by a narrow zone of shrubs. It is surrounded on one side by the river bank communities and on the others by black spruce forest. The meadow is dominated by *Calamagrostis canadensis*, *Carex miliaris*, and *C. arcta*, occurring in approximately equal abundance, and forming dense, tall tussocks. Scattered throughout this meadow are a few herbs—*Achillea borealis*, *Solidago multiradiata*, *Galium trifidum* (in the centre), and *Chamaenerion angustifolium*. Apparently encroaching on this sedge meadow, and forming a narrow peripheral zone, are shrubs of *Salix pyrifolia*, *Betula glandulosa*, and *Alnus crispa*. The soil under this community is a light brown sandy loam, apparently of alluvial origin.

6. Discussion

The area studied lies at the northern limit of continuous forest, which boundary also limits the so-called "taiga" zone (Fig. 1). Hare (1950), and more recently Hoffman (1958), have pointed out that the word "taiga" is used correctly when it refers to the entire northern coniferous forest zone. No attempt is made here to supply an alternative name for this zone. This report establishes its existence in northern Manitoba, and future work will reveal its extent and climatic characteristics. As Hustich (1949 and 1951) has made clear, this zone is characterized on mesic sites by an open coniferous forest with the ground vegetation dominated by lichens. In North America, the only available vegetation studies of the portion of this zone which lies to the west of Hudson Bay are those of Raup (1946). To the east, Hustich (1949, 1950, 1951, and 1954), Rousseau (1948), and Dutilly, Lepage, and Duman (1953) have made botanical field studies in this zone, while Hare (1950, 1954) and Hare and Taylor (1956) have provided geographical accounts.

A short distance to the north-northeast of the area studied, the coniferous forest zone is replaced by the forest-tundra. This zone is distinguished by the presence of tundra on the summits of till ridges and hills, and the restriction of the forest to discontinuous stands on sheltered slopes, river banks, and esker slopes (cf. Scoggan, 1952). The distribution of forest in the forest-tundra is probably an extreme development of the tendency noted here (*see* Fig. 3), for the performance of black spruce to be impaired on the summits of the ridges. The nature of the factors which control this progressive elimination of trees is still a matter for speculation.

The lichen forests described in this paper can be identified with those of Labrador which Hustich (1951) designates "dwarf shrub lichen forests".

They differ from the "pure lichen forests" in that the ground vegetation consists of a mosaic of lichen carpet and microphanerophytes. However, the nature of the lichen cover in all the stands described here differs from those of other North American accounts, and from certain stands which the writer has studied in other parts of Manitoba. Elsewhere this component of the ground vegetation is dominated by species of *Cladonia*. Here, the dominant lichen is *Stereocaulon paschale* ssp. *evolutoides*, while the chief species of *Cladonia* neither form continuous dominant carpets nor assume the typical stature and luxuriance found in other regions. The probable explanation of this is that the intensive local grazing and trampling by caribou repress the *Cladonia* and favour the more vigorous *Stereocaulon*. The latter grows more rapidly than the species of *Cladonia*, and Hustich (1951) suggests that this explains in part the more rapid invasion by *Stereocaulon* after habitat disturbance. The temporary dominance of *Stereocaulon* in the lichen forests of Finnish Lapland is a common phenomenon, and Du Rietz (1925) and Kalliola (1932) account for this in terms of intensive grazing by reindeer. It would appear from the comprehensive review of Harper (1955) that this grazing effect has not been reported previously for North America. As was noted above, the area of this study lies on the present migration route of the Barren Ground Caribou, and large herds have been seen passing through in spring and autumn.

It is pointed out above that extensive areas of boulder till bear a subseral forest type of variable structure and composition. At this latitude, on mesic sites, *Larix laricina* is the most important tree of these subseral communities, forming stands in association with black spruce, alder, and willows. In mature communities, larch is very rare, occurring sporadically in muskeg and bog. In the Southern Spruce Forest Zone, white birch, and to a lesser extent aspen and jackpine are the chief dominants of subseral communities on mesic sites (Ritchie, 1956b), but in this area these trees are very scarce and are almost completely absent from boulder till soils. Larch seldom persists in maturing black spruce lichen forest communities, being eliminated when the spruces reach a height of 7–10 m. Larch has been noted in southern areas on mesic sites and the present studies amplify the conclusion of an earlier report (Ritchie, 1956b, pp. 558–9) that it appears to show little edaphic restriction and that it survives in the absence of competition from seedlings of other trees. The summits of certain low hills of coarse till bear a tundra vegetation and show evidence of the removal of forest in the past by fire. Locally, these summit tundras appear to be persisting, and it seems likely that this phenomenon is similar to the persistence of montane treeless balds, which Billings and Mark (1957) describe, in areas within the forest margin.

Surface frost phenomena are rare in the area, being more typical of truly arctic regions (Washburn, 1956), but the presence of a single area with sorted stone rings indicates that this locality is within the southern limit of these features. Scoggan (1952) indicates that frost phenomena are common near Baralzon Lake, 160 km. north of the present locality, in the forest-tundra zone.

This report, together with a diversity of comments in the reports of Tyrrell (1896 and 1897) and Low (1896), suggest that the chief tree species of eskers in the Subarctic is *Picea glauca*. Only at points where a continuous black spruce forest on till is contiguous with the esker is there any evidence of encroachment of black spruce on to esker surfaces. This appears to be related to the proximity of large numbers of seed parents. In parts of the esker which do not abut upon boulder till, the only conifer is white spruce. The esker presents a range of varied habitats and the prevalence of erosion maintains a constant set of vegetation cycles. Certain mosses and rhizomatous vascular plants are important in the colonization and stabilization of esker surfaces. In the most stable conditions, on freely drained sand surfaces, the most mature community is probably a white spruce lichen forest. The possible sequences of development and degeneration of this forest are shown in Fig. 8.

There are references in North American literature to large subarctic peat deposits, similar to those described above, but neither detailed vegetation studies nor palaeobotanical work has been attempted. The only description of these is by Tyrrell (1897, pp. 43F–44F) who described deposits at Daly Lake (Wholdaia Lake) in southeastern District of Mackenzie. He notes that "In July, at a depth of a foot, the moss was found to be frozen . . . ", and his comments concerning their position and structure indicate clearly that they are identical with the deposits which are described here. Tyrrell (1910) comments further on these deposits, and Raup (1941, p. 232) remarks that he has observed large islands of peat in the western part of Great Slave Lake; they seem to resemble the peat islands described in the present report. Raup points out that knowledge of the origin of these deposits must await detailed physiographic studies. Tyrrell (1897) suggests that they have arisen as follows: "The drainage from the higher land accumulated at the bases of the hills on soil which was either impervious in itself or was rendered impervious by being permanently frozen". He envisages a sequence of winter freezing and summer thaw with an increase in the moss carpet until a depth of peat accumulates in which the summer thaw is inadequate to permit tree growth. Hansen (1953) provides evidence that certain peat deposits in subarctic regions of the northwest have developed in this way, "without the initial stages of hydrarch succession" (p. 509). On the other hand, Raup (1941) suggests that these deposits might have formed at a time when the lake level was considerably higher than it is at present, and that subsequent lowering of the level had caused considerable destruction and erosion of the bog peat, leaving certain peripheral and island masses. These are eroding at present, but the rate of erosion is retarded by the presence of perennially frozen peat in all but the upper layers. The solution to the problem lies in an investigation of the nature of macroscopic and microscopic plant remains in the deposits, and in an understanding of the postglacial physiographic processes of the area. Large peat deposits, associated with bodies of water, have been described from the Southern Spruce Forest Zone of Manitoba (Ritchie, 1956b), but there more rapid erosion appears to have reduced the size of the deposits. Also, the absence of permafrost from the upper few metres permits the entry and dominance of white birch. However, it is possible that both deposits are of the same nature, and that the differences in vegetation and extent are due to differences in climate. Further studies of these deposits are being currently pursued in an attempt to clarify their nature and origin.

The single sedge-grass meadow on alluvial soil near Big Spruce River is of some interest, since it provides another example of a phenomenon which has been recorded in the Canadian Subarctic in both the northwest and the east. Porsild (1951, p. 108) describes certain sedge meadows in the Yukon which

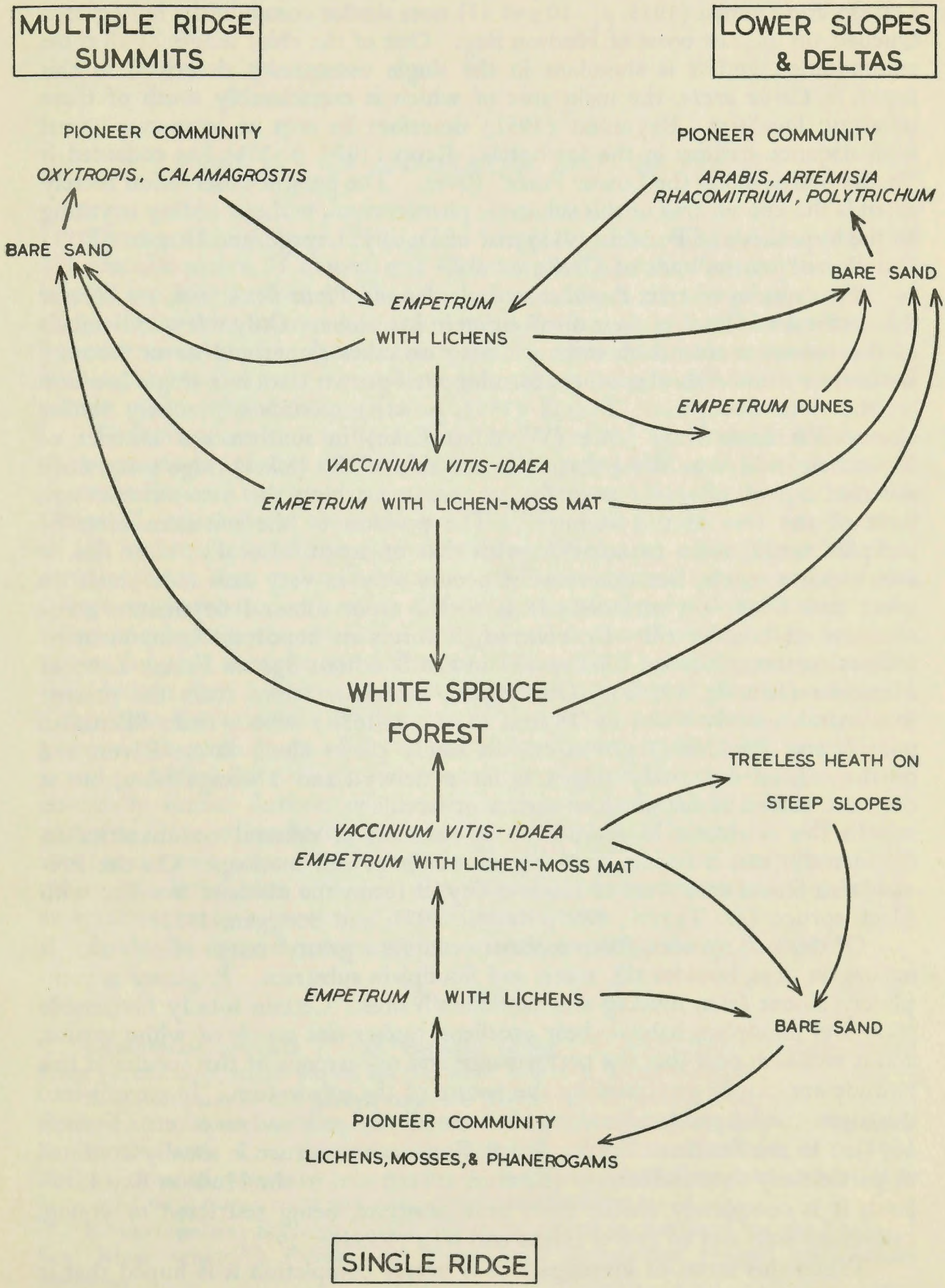

Fig. 8. A summary of the more common trends of community degeneration and recolonization on the three main esker surfaces.

appear to be outliers of the temperate zone prairie vegetation, and Dutilly, Lepage, and Duman (1953, pp. 10 and 43) note similar communities in northern Quebec, on the east coast of Hudson Bay. One of the chief sedges of all these communities, and it is abundant in the single community described in this paper, is *Carex arcta*, the main area of which is considerably south of these subarctic localities. Raymond (1951) describes its area as temperate-boreal with disjunct stations in the far north. Raup (1930, p. 201) has collected it "in the prairie along the Lower Peace" River. The present observation merely extends the known area of this subarctic phenomenon, without adding anything to the hypothesis of Porsild (1951) and of Dutilly, Lepage, and Duman (1953) that these "prairies" are of a relic nature.

Two species of tree, *Populus tremuloides* and *Pinus banksiana*, are here at the northeastern limit of their distribution in Manitoba. Only a few individuals of the former were noted, some growing on esker slopes and never forming more than stunted shrubs, others forming well-grown trees in a single location on the river floodplain. Tyrrell (1897, p. 42F) records a precisely similar observation from Daly Lake (Wholdaia Lake) in southeastern District of Mackenzie, where he notes that: "On the side of this [esker] ridge some small dwarfed aspens (*Populus tremuloides*) grow, marking the extreme northern limit of the tree in this vicinity". The position of the northern limit of jackpine would seem to coincide with that of aspen. Locally, after fire, it forms dense stands, but otherwise it occurs only as very rare individuals on esker and floodplain surfaces. It is absent from subseral or mature communities on boulder till. By contrast, it forms an important component of subseral communities on till deposits in the Southern Spruce Forest Zone of Manitoba (Ritchie, 1956b). Once again, the observations from the present area match exactly those of Tyrrell (1897, p. 163F) who writes: "Banksian pine (*Pinus Banksiana*) grows on the sandy plains along Stone River, and northward, on dry sandy ridges, as far as Selwyn and Theitaga lakes, but it does not extend as far north as spruce or larch".

In this subarctic locality, larch is common in subseral communities on boulder till, and it occurs sparingly in wet bogs and muskegs. On the Precambrian Shield area west of Hudson Bay, it forms the ultimate tree-line with black spruce (cf. Tyrrell, 1897; Russell, 1953; and Scoggan, 1952).

Of the two spruces, *Picea mariana* occupies a greater range of habitat. It occurs on peat, boulder till, esker, and floodplain substrata. *P. glauca* is completely absent from muskeg and boulder till sites. Certain locally favourable esker and floodplain habitats bear excellent, timber-size stands of white spruce, and it would appear that the performance and occurrence of this species at this latitude are closely governed by the nature of the substratum. It extends into the forest-tundra and tundra along rivers on alluvial soils and on eskers (Tyrrell, 1897). In the Southern Spruce Forest Zone, white spruce is usually confined to particularly favourable sites (Ritchie, 1956b) and in the Hudson Bay Lowlands it is completely absent from peat substrata, being restricted to young, calcareous soils and to gravel ridges and hills (Ritchie, 1957).

When this series of investigations is nearer completion it is hoped that it will be possible to provide a comprehensive, comparative review of the habitat ranges, performance, and relative abundance of the tree species of northern Manitoba.

PART II. AN ANNOTATED LIST OF PLANTS

During the fieldwork, 257 species of plants were collected, consisting of 135 vascular plants, 75 mosses, and 47 lichens. The following list summarizes briefly the information which was gathered about the range of habitat of each, and includes reference to any notable floristic records. The list includes five new vascular plant records for Manitoba, all considerable range extensions in North America, and several records which extend the known areas of certain plants within the province.

The area is not rich in flora, being typical of the Precambrian Shield area of the province (cf. lists of Baldwin, 1953, Scoggan, 1952, and Ritchie, 1956c). A comparison of the present list with a preliminary list (Ritchie, 1956a) for Churchill—which lies at about the same latitude as the present area, at a distance of 160 km. to the southeast—reveals striking differences. The Churchill flora contains more than twice the number of vascular plant species and includes a large arctic-subarctic element. Of the present list, only 25 species are truly arctic or subarctic, the remainder being boreal or boreal-arctic. The probable reason for this conspicuous difference is that the Churchill area lies within the Hudson Bay Lowlands, which consist of calcareous glacio-fluvial soils, richer than the acid soils of the present area which are derived mainly from granites. A wide range of open, base-rich substrata at Churchill is available, bearing a varied flora which includes a large element of arctic calcicoles. An essentially similar floristic relationship between Lowland and Shield areas in northern Ontario has been established by Hustich (1957a and b). The moss lists for the two areas would almost certainly yield a similar comparison. Of the mosses listed here only one, *Cinclidium arcticum*, has an arctic-subarctic area, the others being boreal or boreal-arctic species.

In the list the collection number of each species is shown in italics.

VASCULARES

Equisetum arvense L. var. **boreale** (Bong.) Ledeb. *1903*. Recorded only from certain dry, stable slopes on the esker where it is not common.

E. sylvaticum L. var. **pauciramosum** Milde *1717*. Locally common, it grows in the surface layers of *Sphagnum* hummocks in black spruce muskeg communities.

E. fluviatile L. f. **linnaeanum** (Döll.) Broun *1937*. Common, it forms a distinct zone of vegetation along certain shorelines of shallow lakes where it is associated with *Carex stans* and various species of willow.

E. variegatum Schleich. *2022*. Rare, recorded in wet sand on the banks of Seal River where it forms local facies with *Ranunculus reptans* and *Juncus filiformis*.

E. scirpoides Michx. *1823*. Locally common, this species occurs in muskeg where it is associated with *Sphagnum fuscum* and *Aulacomnium palustre*.

Lycopodium selago L. *1941*. Rare in this area, it was found only on a north-facing steep outcrop surface on a lake shoreline.

L. annotinum L. *1846.* Local, found only in shaded situations on boulder till under black spruce and white birch along a small stream.

L. annotinum L. var. **pungens** (LaPylaie) Desv. *2005.* This species is locally common in peaty substrata of muskegs and along streams.

L. complanatum L. *1874.* Local, recorded only from certain favourable esker slopes under white spruce and white birch.

Isoëtes muricata Dur. *1942.* Locally common, growing on sandy lake bottoms at a depth of 1–2 m.

I. echinospora Dur. *1774.* This species was collected with the previous one, and no clear information is available about its relative abundance. Its identity is not certain[1] but it is probably an addition to the flora of the province.

I. macrospora Dur. *1868.* Apparently common, this species grows in similar situations to those of *I. muricata.* This is the first record for this species for Manitoba.

Woodsia ilvensis (L.) R. Br. *1996.* Rare, recorded only in crevices and cliffs of a few large granite outcrops.

Dryopteris disjuncta (Ledeb.) C. V. Mort. *1840, 1936.* Very local, occurring in shaded, damp situations along streams on boulder till, and in shaded habitats on the north-facing side of a large granite outcrop.

D. fragrans (L.) Shott var. **remotiuscula** Kom. *1935.* Local and rare, this fern was recorded in exposed crevices of a large granite outcrop ridge.

Picea glauca (Moench) Voss *2088.* The habitat ranges of this and the following three species are outlined in the vegetation studies above.

P. mariana (Mill.) BSP. *2196.*

Larix laricina (DuRoi) K. Koch *1896.*

Pinus banksiana Lamb. *1766.*

Sparganium angustifolium Michx. *2094.* Common in shallow peaty lakes at 1–1.5 m., occasionally associated with *Nuphar variegatum.*

S. hyperboreum Laestad. *2008.* Local, found in a slow-running stream where it is associated with *Caltha natans.*

Potamogeton gramineus L. *1943.* Locally common in shallow (0.5 m.) water of glacial lakes adjacent to the esker.

Triglochin maritima L. *2053.* Rare, found only in wet mineral soil associated with a single area of sorted stone rings.

Vallisneria americana Michx. *2076.* Of local abundance, it was noted in the shallow marginal water of slow-flowing parts of Big Spruce River.

Festuca brachyphylla Schultes *2086.* Rare, occurring in certain damp kettle bottoms in the esker.

Colpodium fulvum (Trin.) Griseb. *1928.* Recorded only from certain lake sand-bars which extended from the flank of the esker; it forms small colonies in wet sand. This is the second record of this arctic grass in the province; it was first collected at Baralzon Lake (60° N.) (Scoggan, 1957).

Poa alpigena (Fries) Lindm. f. *2017.* Local, occurring in heathy, treeless vegetation of a small island in a glacial lake.

P. palustris L. *2024.* Rare, found in shaded, north-facing crevices of a high cliff on Seal River.

P. glauca Vahl *1787, 2073.* Common, occurring on sunny river bank sites, on outcrop ledges and as a pioneer species on certain unstable surfaces of esker ridges.

Trisetum spicatum (L.) Richter var. **molle** (Michx.) Beal *2090.* Recorded only on certain south-facing banks of Big Spruce River, where it grows in a sandy loam.

[1]Dr. C. F. Reed has examined the material of *Isoëtes* and he indicates that possibly five species are involved. The naming here is tentative, and further collections are being made before final identification is suggested.

Calamagrostis purpurascens R. Br. *1872, 2089.* Locally common on steep slopes of esker ridges where it is an important colonizer of unstable surfaces.

C. canadensis (Michx.) Nutt. *2069.* Common in many habitats, it assumes dominance in certain rare sedge-grass meadows where it is concomitant with *Carex arcta* and *C. miliaris.*

Agrostis borealis Hartm. *2072.* Local, recorded only on south-facing, open habitats on the banks of Big Spruce River.

Oryzopsis pungens (Torr.) Hitchc. *2085.* This grass assumes local dominance in certain kettles between mutiple esker ridges where it forms dense clumps.

Hierochlöe odorata (L.) Beauv. *2071.* Locally common, but never widespread, it was recorded on a well-drained loam on high, south-facing banks of Big Spruce River.

Eleocharis acicularis (L.) R. & S. var. **submersa** (Hj. Nilss.) Svenson *2018.* Local, forming a dense mat at 30 cm. depth on a sandy lake bottom abutting on the esker. It also colonizes freshly exposed sand-bars which extend from the esker in certain localities.

Scirpus caespitosus L. ssp. **austriacus** (Palla) Aschers. & Graebn. *2003.* Locally common, forming dense tussocks in wetter parts of the tundra vegetation on certain deep peat deposits.

S. hudsonianus (Michx.) Fern. *1982.* Rare, occurring in a small number of peat bogs where it is consistently associated with *Tofieldia pusilla.*

Eriophorum scheuchzeri Hoppe var. **tenuifolium** Ohwi. *1927.* Rare, occurring in wet open parts of sand-bars which extend, locally, from the esker flanks; growing there with *Colpodium fulvum.*

E. chamissonis C. A. Mey. f. **turneri** Raymond *2014.* Locally common in open wet situations in peat bogs.

E. spissum Fern. *1865, 2013.* Common in bogs and wet tundra areas over deep peats, it forms conspicuous tussocks (the so-called "nigger-heads").

E. angustifolium Honckeny *2050.* Common in the wetter parts of peat bogs and muskegs, and in various minor communities.

Carex capitata L. ssp. **arctogena** (Sm.) Böcher *2001.* Of very local occurrence, it is found in certain peat tundra types, associated with *C. paupercula, Aulacomnium turgidum,* and *Scirpus caespitosus* ssp. *austriacus.*

C. disperma Dew. *1889.* Locally common along shaded, mossy stream banks, where it is concomitant with *Rubus acaulis* and *Ribes glandulosum.*

C. tenuiflora Wahlenb. *2055.* Rare, recorded only from open wet soil in an area of sorted stone rings.

C. canescens L. *2040.* Locally common in wet bogs with *Sphagnum recurvum* and *Chamaedaphne calyculata* var. *angustifolia.*

C. brunnescens (Pers.) Poir. *2046.* Forming dense tussocks, this species is locally common in wet parts of muskeg, usually concomitant with *Sphagnum fuscum* and *Carex paupercula* var. *irrigua.*

C. arcta Boott *2068.* Very local, recorded only from a sedge swamp where it was abundant, forming large tussocks in association with *C. miliaris* and *Calamagrostis canadensis.* This is the second record in Manitoba for this temperate boreal sedge, and it extends the range northwards by 800 km. from Sasaginnigak Lake (collected there by Breitung in 1949, DAO). A similar areal pattern exists for this species in Quebec (Raymond, 1951, p. 15) where there are northern outliers of a main temperate-boreal distribution.

C. praticola Rydb. *2082.* Very local, recorded only from certain esker ridges where it grows under *Betula glandulosa* and shrub plants of *B. papyrifera* var. *neoalaskana.*

C. deflexa Hornem. *1765.* Of local occurrence on the esker, it grows in dry sandy soils in both the white spruce forest and the heaths of exposed slopes.

C. glacialis Mackenz. *1786.* A common pioneer of open sand surfaces on the esker, and less commonly on certain unstable sand surfaces of the Big Spruce River floodplain.

C. stans Drej. *2075.* Common in the entire area, it forms a marginal fringe zone along river banks and on certain lake shorelines.

C. bigelowii Torr. f. **anguillata** (Drej.) Fern. *2083.* Locally common, this sedge occurs as an early colonizer of certain esker slopes, where it forms a stable mat in association with *Polytrichum piliferum.*

C. rariflora (Wahlenb.) Sm. *1926.* Not common in this region, it was recorded in local abundance from a few wet peat bogs.

C. paupercula Michx. var. **irrigua** (Wahlenb.) Fern. *2002.* One of the common sedges in the area, it occurs in wet peat of bogs and muskeg, and in certain peat tundra communities.

C. capillaris L. *1906.* Only one patch of this sedge was collected, from a wet marl in a muskeg depression where it was associated with *Parnassia kotzebuei.*

C. rostrata Stokes *2096.* Locally abundant, recorded only in a sedge-grass swamp area near Big Spruce River where it forms conspicuous tussocks, concomitant with *C. arcta, C. miliaris,* and *Calamagrostis canadensis.*

C. rotundata Wahlenb. *1967, 2004.* Common, occurring in open, wet parts of muskeg and in peat bogs.

C. miliaris Michx. *2067.* Recorded from a single locality in the area, it forms tussocks in a grass-sedge swamp.

Calla palustris L. *1998, 2007.* Very local in this area, it occurs at the margin of certain slow-flowing peaty streams.

Juncus filiformis L. *2023, 2025.* Never abundant, this rush was collected in wet peaty habitats along the banks of Seal River, and in wet peat along a caribou trail in muskeg.

J. albescens (Lange) Fern. *2052.* Rare in this region, this arctic-subarctic species is confined to an area of open, sorted stone rings, where it forms the initial stage of colonization of the unstable, wet, fine mineral material of the ring centres.

J. alpinus Vill. *2051.* Like the previous species, this rare subarctic species was apparently confined to the central, unstable areas of sorted stone rings. This is the only record for Manitoba, and it extends the range of the typical form of this eastern species which previously was known only from areas east of Hudson Bay (cf. map in Dutilly, Lepage, and Duman, 1953, p. 53).

Luzula parviflora (Ehrh.) Desv. *1931.* Local, occurring on certain damp, sandy lake shorelines and on certain open esker sites.

L. confusa Lindeberg *1790.* Rare, growing in the heath vegetation which dominates certain steep, exposed esker slopes.

L. multiflora (Retz.) Lejeune ssp. **frigida** (Buch.) Krecz. var. **contracta** Sam. *1897.* Local, growing with *L. parviflora* on damp sand on certain shorelines.

Tofieldia pusilla (Michx.) Pers. *1987.* Local in occurrence, growing in wet peat bogs where there is evidence of seepage from adjacent mineral soil; also it is common in the early stages of colonization of certain unstable sorted stone rings.

Smilacina trifolia (L.) Desf. *1891.* Locally common, growing in *Sphagnum* of muskegs.

Salix uva-ursi Pursh *2062.* Rare, the only specimens seen were growing in wet, mineral soil of certain sorted stone rings near Big Spruce River. A new record for the province, this is the first collection of this eastern subarctic willow on the west side of Hudson Bay (cf. Raup, 1943, pp. 96–7 and Böcher, 1954, p. 31).

S. planifolia Pursh var. **nelsoni** (Ball) Ball *1832.* Locally common, this tall shrub grows along streams and rivers on boulder till.

S. pyrifolia Anderss. *2074.* This willow forms a zone of local dominance on certain steep banks of Big Spruce River where it is associated with *Betula glandulosa* and *Alnus crispa.*

S. anglorum Cham. *1822, 2084.* Common, this species occurs in muskeg as tall shrubs, seldom exceeding 2 m.; it also grows on boulder till in open black spruce forest stands.

S. anglorum Cham. var. **antiplasta** Schneider *1821.* Growing as a low shrub, 40–80 cm. tall, this variety appears to replace the species on drier, more exposed sites. It is common in the black spruce forest on boulder till.

S. drummondiana Barratt *2081.* The only localities which were established for this willow were certain dry esker slopes, dominated by heath vegetation in their upper regions, where it forms a discontinuous layer at 1–1.5 m. A new record for the province, this forms a considerable extension of this western willow from Alberta and British Columbia.

Populus tremuloides Michx. *1866.* (See vegetation studies for discussion).

Myrica gale L. *1746.* Common in the area, it grows along lake shores and on river banks.

Betula papyrifera Marsh. var. **neoalaskana** (Sarg.) Raup *1845.* (See vegetation studies for discussion).

B. glandulosa Michx. *1842.* A common shrub in the region, it occurs on drift soils in regeneration communities after fire; it is also a common member of river bank and lake shoreline communities.

Alnus crispa (Ait.) Pursh *1773.* Of local occurrence in mature black spruce forests on boulder till, this shrub is the dominant on similar sites which have been cleared of forest by fire, usually associated with young trees of *Larix laricina.*

Geocaulon lividum (Richards.) Fern. *2049.* Locally frequent, this species occurs in shaded parts of white spruce forest stands on the esker, and black spruce forest stands on boulder till.

Stellaria monantha Hult. *1995.* Of local occurrence, it was recorded on south-facing banks of a small meandering stream in the sand floodplain of Big Spruce River.

S. calycantha (Ledeb.) Bong. *1932.* Widespread in the area, never assuming local abundance, it was recorded in wet shoreline sand and in shallow wet peat.

S. ciliatosepala Trautv. *1871.* This species was found only in unstable, esker ridge habitats where it is a component of the pioneer vegetation of these areas. In these situations it forms extensive, fine rhizomes.

Nuphar variegatum Engelm. *2015.* Local, occurring in shallow lakes with sandy bottoms on which there is an accumulation of organic material.

Ranunculus reptans L. *2021, 2047.* Rare, it grows in wet humus over sand along Seal River, and on certain sandy lake shores abutting on the esker.

R. gmelini DC. var. **hookeri** (Don) Benson *1997.* Occurring in shallow peaty ponds in certain meanders of Big Spruce River, this species is very local.

R. trichophyllus Chaix var. **eradicatus** (Laestad.) W. B. Drew *2012.* Rare, submerged at 1 m. on a sandy lake bottom adjoining the esker.

Caltha natans Pall. *2009.* Recorded from a single locality in this area, it grows in a small peaty stream with *Calla palustris.*

Arabis arenicola (Richards.) Gelert var. **pubescens** (Wats.) Gelert *1727.* Confined to the esker, this plant is one of a group of pioneer species which colonize open, unstable sand surfaces on the ridges and slopes.

Saxifraga tricuspidata Rottb. *1867, 1796.* Also confined to the esker this species occurs sporadically in open sand of ridges and slopes and in stable slope communities under white spruce.

Parnassia kotzebuei Cham. *1905.* Found growing on a few shaded, often north-facing outcrops along shorelines.

Ribes glandulosum Grauer *1789, 1838.* Of local occurrence, it is most common along shaded streams on boulder till.

R. triste Pall. *1745.* Found only among wet mossy rocks at the margin of a stream under black spruce and white birch.

Comarum palustre L. *2048.* Common in the wettest parts of peat bogs where it is usually associated with *Carex stans* and *Sphagnum lindbergii.*

Potentilla tridentata Ait. *1751.* Locally common on exposed, sunny outcrop ridges where it grows in thin humus of crevices.

Rubus chamaemorus L. *1771.* Abundant in muskeg and peat tundra where it is typically associated with *Sphagnum* hummocks.

R. acaulis Michx. *1837.* Locally common, it is confined to wet mossy situations along small streams where it is associated with *Comarum palustre* and *Calamagrostis canadensis.*

R. idaeus L. var. **canadensis** Richards. *2066.* Very local, this plant was noted only on certain unshaded, south-facing parts of the bank of Big Spruce River.

Oxytropis campestris (L.) DC. var. **varians** (Rydb.) Barneby *1873.* Restricted to esker sites, this deeply rhizomatous species grows only on unstable, high ridges where it is an important pioneer species.

Callitriche palustris L. *2091.* Locally common in slow-flowing parts of Big Spruce River where it grows near the banks at a depth of 15–40 cm.

Empetrum hermaphroditum Lange *1843.* A common species in the area, reaching its best development on the esker and floodplain where it is an important component of the stable and unstable communities. It also occurs on coarse boulder till soils.

Viola labradorica Schrank (*V. adunca* Sm. var. *minor* (Hook.) Fern.) *1876.* Rare, found only on a few esker hollows between multiple ridges where it grows in damp, clayey sand.

V. palustris L. *1744.* Locally common in wet, mossy situations along small streams on boulder till.

Chamaenerion angustifolium (L.) Scop. *2016.* Locally common in a diversity of localities; most common on treeless, gravelly islands in various lakes.

Epilobium palustre L. *1985.* Locally common in muskeg and peat bog where it is usually associated with *Carex paupercula* var. *irrigua, Eriophorum angustifolium,* and *Scirpus caespitosus* ssp. *austriacus.*

Hippuris vulgaris L. *1940, 1960.* This aquatic is abundant in shallow (20–40 cm.) parts of peaty lakes and streams.

Chamaepericlymenum canadensis (L.) Schers. & Graebn. *1878.* Recorded only on sheltered, spruce-clad slopes of the esker and on certain alluvial soils with white spruce cover along Big Spruce River.

Pyrola minor L. *2095.* Rare, found in a single locality on the north-facing shoreline of a small island where it grows in a shaded habitat.

P. grandiflora Radius *1992.* Rare, but in local abundance, it was found only in the unusual ground vegetation associated with a stand of white spruce and aspen along a small stream in the Big Spruce River floodplain.

Ledum decumbens (Ait.) Lodd. *1770.* This low shrub occurs frequently in muskeg, and it is the dominant vascular plant of the tundra vegetation on the surface of certain deep peat deposits in the area. Also, it is common on the esker, particularly on north-facing steep slopes where it is a conspicuous member of the heath vegetation.

Ledum groenlandicum Oeder. *1890.* Common, this is the dominant shrub of muskeg communities, also occurring in peat bogs.

Loiseleuria procumbens (L.) Desv. *1772.* This prostrate shrub dominates the ground vegetation on the summits of well-drained drift hills and ridges where it is associated with poorly grown trees of *Picea mariana.*

Kalmia polifolia Wang. *1794.* Common in muskegs, this species also extends on to better drained mineral soils of drift ridges under black spruce open forest.

Phyllodoce caerulea (L.) Bab. *1747.* Only a single patch of this rare plant was found; it occurred under black spruce at the transition between open lichen forest and muskeg. This is the second record for Manitoba, the other being at MacLeod Lake (Cody, 1953).

Andromeda polifolia L. *1769.* Common in wet transition zones between bog and muskeg, usually associated with *Chamaedaphne*, *Ledum groenlandicum*, and *Rubus chamaemorus.* It also occurs in the tundra vegetation which dominates certain deep peat deposits.

Chamaedaphne calyculata (L.) Moench var. **angustifolia** (Ait.) Rehd. *1768.* Locally abundant, it occurs in the transitional zones between peat bog and muskeg. It is considerably less common here than in similar situations in southern regions.

Arctostaphylos uva-ursi (L.) Spreng. var. **coactilis** Fern. and Macbr. *1726.* Here confined to forested esker slopes (under white spruce and white birch) of a southern or southeastern aspect.

Arctous rubra (Redh. & Wils.) Fern. *1895.* This prostrate shrub is locally common on certain sunny esker slopes, and it occurs less frequently on boulder till of certain black spruce communities. It was also recorded on the floodplain sand of Big Spruce River.

Vaccinium uliginosum L. *1841.* One of the commonest shrubs in the region, it is a consistent member of the subsidiary vegetation of black spruce forests on boulder till and it occurs on the esker under open white spruce stands.

V. vitis-idaea L. ssp. **minus** (Lodd.) Hult. *1848.* Common in many habitats, this species is abundant in all lichen forest communities, on drift hills and ridges, on the esker and on river floodplain sites. It also occurs sporadically in muskeg.

Oxycoccus microcarpus Turcz. *1827, 2065.* Locally common in *Sphagnum* hummocks in muskeg and peat bog, usually concomitant with *Andromeda.*

Menyanthes trifoliata L. var. **minor** Raf. *1987.* Rare, a few patches were noted in shallow (0.5–1 m.) peaty pools in certain deep peat deposits.

Pedicularis labradorica Wirsing *1980.* Of local occurrence, it grows in open situations in the transition zone between certain peat bogs and muskeg communities.

Utricularia intermedia Hayne *2054.* Rare, the only locality was in an area of sorted stone rings where it grows in water accumulated round the borders of the ring.

Pinguicula villosa L. *1729, 1826.* Not common in this area, it occurs in wet *Sphagnum* hummocks of certain peat bogs and muskegs.

Galium trifidum L. *2006.* Local, recorded in shaded, damp substrata at the margins of small streams in boulder till; here it is associated with *Mnium punctatum.*

Linnaea borealis L. ssp. **americana** (Forbes) Hult. *2090.* Locally common on certain sunny, forested esker slopes; it was also noted in certain river bank communities under white spruce.

Viburnum edule (Michx.) Raf. *1907.* Very local, it occurs on certain outcrops along shorelines, and more typically in fragmentary river bank stands of white spruce.

Solidago multiradiata Ait. *2063.* Recorded here only on certain south-facing banks of Big Spruce River, growing in a well-drained sandy loam.

Antennaria rosea Greene *1875, 1939.* Rare, recorded in a few large esker hollows between multiple ridges where it occurs in damp clayey soil.

Achillea borealis Bong. *2064.* Locally common on the bank of Big Spruce River, growing in unshaded, well-drained sites.

Artemisia canadensis Michx. *1875.* Rare, this deeply rhizomatous species is confined to the esker where it is a member of a small group of pioneer species which occupy areas of unstable sand.

Petasites palmatus (Ait.) Gray *1938.* Very local, it occurs in damp sand of certain esker kettles.

P. sagittatus (Pursh) Gray *1844.* Recorded in relative abundance only from wet, shaded muck soils associated with small streams in boulder till areas.

Arnica lonchophylla Greene *1879.* Found only on the esker, it is locally frequent on well-drained, stable slopes under white spruce and white birch.

Musci

Andreaea rupestris Hedw. *1742.* A common saxicolous species, usually confined to relatively sheltered rock surfaces.

Tetraphis pellucida Hedw. *1732, 1853.* Common on vertical, peaty faces of lake and stream banks in shaded situations.

Atrichum undulatum (Hedw.) P.-B. *1762.* Local, recorded on thin sandy soil between river-bank rocks along Big Spruce River.

Polytrichum commune Hedw. *1761, 1901.* A common species, growing in damp sandy soil of the river banks and esker kettles.

P. commune Hedw. var. **jensenii** Mönk. *2044, 2061.* Apparently common, recorded from only two stations—a wet muskeg site, and along the bank of Big Spruce River on wet, mineral soil.

P. juniperinum Hedw. *1809, 2057.* Locally common in black spruce lichen forest stands.

P. juniperinum Hedw. var. **alpestre** (Hoppe) BSG. *1721, 1864, 1886, 1971.* More widespread than the type, it occurs throughout a range of sites which show evidence of impeded drainage—in muskeg and esker hollows, and is associated with sorted stone rings.

P. piliferum Hedw. *1724, 1893, 1900.* Most common on the esker where it is an important pioneer on open sand surfaces; it also occurs in esker heaths and in the ground vegetation of black spruce lichen forests on esker flats.

Fissidens osmundioides (Hedw.) Broth. *1759*a. Recorded only from the wet, shaded surface of an outcrop on the shoreline of a lake.

Saelania glaucescens (Hedw.) Broth. *1759*b. Recorded only from wet rocks at certain falls on Big Spruce River.

Ceratodon purpureus (Hedw.) Broth. *1764, 2079, 2085.* Common in a diversity of open habitats, usually growing on mineral soil.

Distichium capillaceum (Hedw.) BSG. *1910.* Locally common in wet hollows of muskeg.

Dicranella cerviculata (Hedw.) Schwaegr. *1963.* Confined to the wet, vertical, eroding faces of large peat deposits where it forms extensive fruiting tufts.

Dicranoweissia crispula (Hedw.) Lindb. *1731, 1756.* Locally common in wet situations, growing occasionally on boulders at the shoreline and on wet sand surfaces along Big Spruce River.

Dicranum elongatum Schleich. *1974.* Common, forming dense tufts in the peaty vegetation of peat tundra areas.

D. bergeri Bland. *1861, 1883.* Common in muskegs, forming extensive, dense tufts.

D. fuscescens Turn. *1806, 1902.* Common in the ground vegetation of black spruce lichen forest stands on boulder till and white spruce lichen forest on esker surfaces.

D. groenlandicum Brid. *1862.* Tuft-forming species, locally common in muskeg, usually associated with *D. bergeri.*

D. muhlenbergii BSG. *1973.* Recorded only from the fissures of large unsorted polygons in the surface of peat deposits.

Oncophorus wahlenbergii Brid. *1966, 2059.* Local, growing on shaded outcrops at the shoreline, and in wet unstable soil in the centres of certain sorted stone rings.

Grimmia affinis Hornsch. *1743.* Common on rock surfaces, particularly in sheltered situations.

G. alpicola Hedw. *1753.* Abundant on wet rocks at falls on Big Spruce River.

G. alpicola Hedw. var. **rivularis** (Brid.) Broth. *1731a.* The only record, it occurs on wet rock surfaces at the shoreline.

Hedwigia ciliata (Hedw.) P.-B. *1869.* Not common, it was recorded on the exposed surface of a rock in a lake.

Rhacomitrium canescens Brid. *1725.* Confined to unstable sand surfaces on the esker and river floodplain, this species is an important colonizer, forming extensive compact carpets. On the esker it appears to be absent from the coarser sands of higher ridges.

Tetraplodon angustatus (Hedw.) BSG. *1863.* Local, growing in muskeg where it forms small compact tufts, associated with various organic remains.

T. mnioides (Hedw.) BSG. *1880, 1881, 1899.* More common than the previous species, it occurs in both muskeg substrata and the drier soils of open forest over boulder till.

Ulota cirrata (Bernh.) Grout *1892.* Rare, growing in a shaded crevice in a granite outcrop.

Aulacomnium palustre (Web. & Mohr) Schwaegr. *1850, 1958, 1962.* A common moss, growing in wet, usually peaty situations in bogs, muskeg, and by rivers and streams.

A. turgidum (Wahlenb.) Schimp. *2000.* Local, occurring as compact cushions in the organic substratum of an open tundra area on a deep peat deposit.

Paludella squarrosa (Hedw.) Schwaegr. *1847.* Local, but in abundance where it occurs, this species is confined to wet hollows in peat bogs and muskeg where it is associated with *Calliergon stramineum.*

Leptobryum pyriforme (Hedw.) Schimp. *1830.* Recorded along a stream, it grows at the bases of small trees of *Salix planifolia* var. *nelsoni* where it forms a carpet with *Pohlia cruda, Plagiothecium denticulatum, Campylium hispidulum,* and *Ceratodon purpureus.*

Bryum pseudotriquetrum (Hedw.) Schwaegr. *1758.* Forming small dense tufts in wet open sand at falls on Big Spruce River and along Seal River.

Pohlia cruda (Hedw.) Lindb. *1829.* In the same locality as *Leptobryum* (above).

P. nutans (Hedw.) Lindb. *1736, 1814, 1852, 1915.* A common moss, it grows in damp humus of various habitat types in both open and shaded sites.

Cinclidium arcticum (BSG.) C.M. *1908.* Rare, recorded only from the wet, shaded surface of an outcrop along a shoreline.

Mnium affine Bland. *1763.* Common, usually associated with *Climacium dendroides,* occurring in shaded sites along river banks and lake shorelines.

M. cinclidioides Hub. *1833.* Occurring in local abundance, it was recorded frequently from shaded, moist situations under willows and birch along small streams.

M. andrewsianum Steere *1825, 1949, 1964.* Common, occurring in wet, shaded sites on outcrops at the shoreline and in muskeg depressions.

M. punctatum Hedw. *1730, 2056.* Local, recorded from wet shaded sites on lake shorelines and in open mineral soil of certain sorted stone rings.

Brachythecium flagellare (Hedw.) Jenn. *1948.* Rare, recorded on a shaded moist rock surface at the shoreline.

Calliergon cordifolium (Hedw.) Kindb. *1836.* A common species in shaded, wet sites under marginal willow and birch stands along streams.

C. sarmentosum (Wahlenb.) Kindb. *2060.* Recorded only from a wet rock crevice in an area of sorted stone rings.

C. stramineum (Brid.) Kindb. *1914.* Locally dominant, forming a central zone in peaty depressions in various communities, particularly in muskeg.

Campylium hispidulum (Brid.) Mitt. *1831.* Locally common at the base of small trees of *Salix planifolia* var. *nelsoni* along stream banks.

C. stellatum (Hedw.) Lange & Jens. *1757.* In shallow wet sand over rocks at falls on Big Spruce River; locally abundant.

Climacium dendroides (Hedw.) Web. & Mohr *1752.* Confined to damp shaded situations along river banks and lake shorelines.

Drepanocladus exannulatus (Gümb.) Warnst. *1775, 1986, 1994.* A common species of the wettest parts of bogs, forming a dense partly submerged layer in certain pools.

D. fluitans (Hedw.) Warnst. *1849, 1870, 1916, 2043.* Common, occurring with *Sphagnum* spp. in many wet depressions in muskeg and bog, where it forms a conspicuous central zone.

D. intermedius (Lindb.) Warnst. *1882.* Local, recorded in wet peaty areas of muskeg vegetation.

D. revolvens (C.M.) Warnst. *1754, 1965, 2058.* Common in wet situations, growing on mineral substrata – shoreline outcrops, river banks, and on certain rare sorted stone rings.

D. vernicosus (Turn.) Warnst. *1970.* Confined to the vertical surfaces of large polygonal fissures in the surface of certain deep peat deposits.

D. uncinatus (Hedw.) Warnst. *1734, 1755, 1810, 1913, 1947.* Common, growing on wet outcrops at the shoreline and in wet parts of muskeg vegetation.

D. badius (Hartm.) Roth. *1983.* Associated with *Sphagnum cuspidatum*, this species (occurring here in an extremely atypical form) occupies a central zone in certain small muskeg depressions and hollows.

Hygrohypnum alpestre (Hedw.) Loeske *1839, 1945, 1946.* Recorded on rock surfaces in moist shaded sites on lake shorelines and submerged on small rocks of shallow streams.

Isopterygium pulchellum (Hedw.) Jaeg. *1759.* Local, recorded on wet rocks at falls on Big Spruce River.

Plagiothecium denticulatum (Hedw.) BSG. *1829a, 1888.* Growing epiphytically on the bases of willow trunks, and on old spruce trunks, in moist, shaded sites near streams.

Ptilium crista-castrensis (Hedw.) DeNot. *1729.* Locally common, but not widespread, it was recorded from certain fragments of "feather moss" ground vegetation under a closed black spruce stand on damp esker sand.

Pleurozium schreberi (BSG.) Mitt. *1808.* Common, forming wefts in the ground vegetation of black spruce and white spruce stands on boulder till and esker substrata, usually confined to the shaded sites at the base of the trees.

Hypnum lindbergii Mitt. *1851, 1950, 1951, 1957.* Common along shorelines and stream banks, it grows on low, wet, shaded rocks.

H. revolutum Lindb. *1952a.* The only record for the area, it occurred on a low wet rock at the shoreline.

Hylocomium splendens (Hedw.) BSG. *1729a, 1919.* Locally common in the ground vegetation of open lichen forest stands on the esker and on boulder till, it is usually restricted to the bases of large conifers where it is associated with *Pleurozium.*

Rhytidium rugosum (Hedw.) Kindb. *1911.* Recorded only on the esker under a stand of mature white spruce, it is confined to south-facing slopes. This habitat restriction of this species was noted elsewhere in northern Manitoba (Ritchie, 1956c).

Dichelyma falcatum (Hedw.) Myr. *1834.* Local, the only collection was made from a wet rock in a small stream over boulder till.

Fontinalis nitida Lindb. & Arn. *1828.* Locally abundant, it forms extensive submerged wefts in a rapid, shallow stream.

Sphagnum cuspidatum Ehrh. *1984.* Local, recorded in the central, wettest parts of small depressions in muskeg and bog.

S. girgensohnii Russ. *1912.* Forming a dominant peripheral zone round a small pool at the base of an esker kettle.

S. fuscum (Schimp.) Klinggr. *2045.* Common, forming dense hummocks in muskegs.

S. lindbergii Schimp. *1989.* Locally common in the sedge zone which surrounds a shallow pool in an area of peat tundra.

S. recurvum P.-B. *1972, 2042.* Common in wet hollows of peat bogs, it also occurs at the bottom of polygonal fissures in the surface of certain deep peat deposits.

S. robustum (Russ.) Röll *1728.* Recorded only from the peripheral zone of shallow pools in esker kettles, it forms dense hummocks associated with *Picea mariana.*

S. teres (Schimp.) Ångstr. *1835.* Recorded in wet sites along streams and as a colonizer of wet sandy surfaces in older oxbow lakes.

S. warnstorfianum Du Rietz *1959.* Local, occurring in muskeg and along shorelines, in shaded, damp sites.

S. balticum Russ. *1988.* Locally common with *Eriophorum angustifolium,* forming the marginal zone of an open shallow pond in an area of deep peat deposits.

S. riparium Ångstr. *2039.* Recorded from the wettest, central part of certain peat bogs, where it is concomitant with *Eriophorum angustifolium* and *Carex canescens.*

Lichenes

Sphaerophorus fragilis (L.) Pers. *1785.* Occurring commonly on bare sand surfaces of the esker, usually in coarse sand and gravel.

Nephroma arcticum (L.) Torss. *1718.* Local, growing in the ground layer of certain local black spruce stands on damp esker sand, associated with *Pleurozium schreberi* and *Peltigera aphthosa.*

N. bellum (Spreng.) Tuck *1956.* Rare, growing on an old root of black spruce in a shaded lake shoreline site.

Peltigera aphthosa (L.) Willd. *1720.* Locally common, occurring in shaded parts of ground vegetation of local black spruce stands on damp esker surfaces.

P. pulverulenta (Tayl.) Nyl. *1719.* Locally common in shaded ground layers of black and white spruce stands on the esker, associated with *Vaccinium uliginosum, Ptilidium ciliare,* and *Peltigera aphthosa.*

Lecidea cinereoatra Ach. *2196.* Common encrusting lichen of rocks at the shoreline.

L. dicksonii (Gmel.) Ach. *2201.* Local, encrusting rocks on lake shorelines.

L. flavocaerulescens (Hornem.) Ach. *2220.* Recorded on vertical surfaces of outcrops of granite at the shoreline.

L. subsorediza Lynge *2197.* Local, on outcrops at the shoreline.

Mycoblastus sanguinarius (L.) Norm. *1780.* A common epiphyte of young twigs of *Picea mariana.*

Rhizocarpon jemtlandicum Malme *1792a.* A common colonizer of pebbles on esker surfaces.

R. geographicum (L.) DC. *2202.* Common on rocks throughout the area.

R. grande (Flk.) Arn. *2199.* In similar habitats to the previous species.

Cladonia alpestris (L.) Rabh. *1779.* Common throughout the area, it never forms the dense, extensive carpets which are characteristic; it appears to have been suppressed by intensive caribou grazing.

C. rangiferina (L.) Web. *1887.* Common in the ground vegetation of lichen forest stands, muskeg, and esker communities; like the previous species it shows evidence of caribou grazing.

C. coccifera (L.) Willd. *1979.* Local, common in peat tundra heaths, and of occasional occurrence in the ground vegetation of subseral lichen forest communities.

C. uncialis (L.) Web. *2077.* Locally frequent on steep heath-clad slopes of the esker ridge.

C. cornuta (L.) Schaer. *2078a.* Recorded only from the heath community of the esker ridge summits.

C. digitata (L.) Schaer. *1979a.* Recorded only from the heath vegetation of large peat deposits where it is common.

C. pleurota (Flk.) Schaer. *1812.* Common in the lichen carpet of the black spruce lichen forest on coarse boulder till.

C. chlorophaea (Flk.) Schaer. *2011.* A local species here, recorded only from certain shoreline rocks.

C. polydactyla (Flk.) Spreng *1735.* Local, occurring in a damp, shaded site under a rocky bank along a lake shoreline. According to Dr. J. W. Thomson this record provides a considerable extension eastwards of the North American range of this species which is known from Washington, Oregon, British Columbia, and Alaska.

C. subrangiformis Asahina *1859, 1955, 2078.* Common in the area, it occurs typically in *Sphagnum* hummocks of muskeg and shoreline sites; also recorded from the summit ridge heath of the esker. This record brings some continuity to the known range of the species which has been reported from Alaska, Labrador, Quebec, and Michigan (Evans, 1955, p. 99).

Stereocaulon paschale (L.) Hoffm. ssp. **evolutoides** (Magn.) Lamb *1778.* This species dominates the ground vegetation of black and white spruce lichen forest stands; it appears that its relative abundance is controlled in part by the restriction of *Cladonia* species in these communities as a result of intensive caribou grazing.

Actinogyra mühlenbergii (Ach.) Schol. *1737.* A common saxicolous species, growing on large rocks and outcrops in sheltered situations.

Umbilicaria hyperborea (Ach.) Hoffm. *1737a.* In the same habitats as the previous species.

U. torrefacta (Lichtf.) Schrad. *1894.* Locally dominant on outcrops and drift rocks.

Lecanora arctica Lynge *2198.* Frequent on granite outcrops and drift.

L. polytropa (Ehrh.) Rabh. *2201a.* Local on outcrops along the shoreline.

L. pinastri (Schaer.) Magn. *1738a.* Epiphytic, occurring frequently on old dead branches of black spruce.

Icmadophila ericetorum (L.) Zahlbr. *1976.* Locally common, it occurs typically as a colonizer of open peat surfaces; it is common in the tundra on large peat deposits and in muskeg, and in both habitats it grows on the disturbed peat of hummocks.

Parmeliopsis ambigua (Wulf.) Nyl. *1780a.* A common epiphyte of black spruce trunks and old branches.

P. hyperopta (Ach.) Arn. *1780b.* Growing with the previous species.

Parmelia centrifuga (L.) Ach. *1740.* Common, forming extensive covering of rock surfaces on outcrops and drift rocks.

P. sulcata Tayl. *1738, 1739.* A common thalloid lichen, growing with the previous species on rock surfaces.

P. incurva (Pers.) T. Fr. *1792.* Common on the esker, growing among small pebbles and coarse sand grains as a pioneer colonizer of open, unstable surfaces.

P. disjuncta Erichs. *1741.* Local, recorded on outcrop and drift rock surfaces.

Cetraria nivalis (L.) Ach. *1788.* A common lichen, it occurs in esker and boulder till heath vegetation, and less commonly in lichen forest and peat tundra communities.

C. nigricascens Elenk. *1777.* A common pioneer of open esker sand surfaces, growing with *Polytrichum piliferum* and *Alectoria altaica.*

C. crispa (Ach.) Nyl. *1978.* Local, recorded only from the heath vegetation which dominates the surfaces of certain deep peat deposits.

C. pinastri (Scop.) Hoffm. *2019.* Common on old, dead twigs and branches of black spruce.

C. ciliaris Ach. *1781, 2038.* Common epiphyte of dead branches of black spruce and larch.

C. hepatizon (Ach.) Vainio *2020.* Locally common, occurring on rock surfaces.

Evernia mesomorpha Nyl. *1783.* Common epiphyte on old shoots of black spruce.

Alectoria altaica (Gyel.) Räs. *1776.* A local species, it occurs as a pioneer of open coarse sand on esker ridges.

A. jubata (L.) Ach. *1782.* Epiphytic on black spruce.

Rinodina annulata Magn. *2019a.* Recorded on old dead twigs of black spruce trees.

SUMMARY

1. Vegetation studies in a limited area at Seal River, in northeastern Manitoba, have shown that the predominant landform type—low hills and ridges of boulder till—bears a black spruce lichen forest. This community consists of well-spaced trees with the ground vegetation dominated by lichens and low shrubs. There is evidence that the precise structure and composition of the lichen carpet are influenced by the grazing and trampling activities of the Barren Ground Caribou. Many boulder till surfaces are dominated by subseral communities, in which larch plays an important role; in this the chief factor is the removal of forest by fire.

2. Within one kilometre of each other, single examples of "prairies" and of sorted stone rings were discovered, these phenomena being typical of temperate and arctic regions respectively.

3. Lichen forests dominated by *Picea glauca* are confined to eskers and alluvial deposits; on these deposits, local, favourable sites bear trees of white spruce which are as large as the average well-grown tree of this species in areas 500–800 km. south of the present locality. It is suggested that the main factor controlling the performance and occurrence of white spruce in this area concerns the nature of the substratum.

4. At this latitude, the dominant tree of eskers is *Picea glauca.* Considerable instability of the surface soil of these glacial deposits maintains the vegetation in a state of continuous change. The chief factors which influence the vegetation of esker surfaces are probably erosion and soil moisture. White spruce is absent from local deposits where there is a stratum of clay near the surface; in these stations black spruce is the dominant tree—it is rare elsewhere on the esker.

5. In this region, there are large deposits of peat, dominated by a treeless heath, and apparently restricted to the Subarctic in North America. Large polygonal fissures occur in the surface layers of these deposits.

6. Jackpine and aspen are rare in this area, the latter seldom forming more than stunted shrubs. Both are near their northern limit. White birch is locally common, along streams and on the esker.

7. The flora of the area is meagre, being typical of Precambrian regions. It is composed mainly of boreal species, often near the northern limit of their areas. Arctic species form only 19 per cent of the vascular plant flora, while only one of the 75 species of mosses recorded is exclusively arctic, the majority being arctic-boreal or boreal.

Plate 1. A view along the esker ridge, showing in the foreground the bare sand which is typical of many summit sites; elsewhere the surface bears an *Empetrum*-lichen mat which is being invaded by *Picea glauca*.

Plate 2. The lower slopes of the esker showing a mature stand of white spruce lichen forest. The oldest trees are about 200 years of age, and the stand is uneven-aged. Between the trees can be seen areas of bare sand and patches of lichen-heath.

Plate 3. A single plant of *Empetrum hermaphroditum* on a treeless lower slope of the esker. The oldest, central shoots are dying and being replaced by lichens, chiefly *Stereocaulon.* Surrounding the *Empetrum* patch is a mat of lichens with *Vaccinium vitis-idaea* ssp. *minus.*

Plate 4. *Empetrum* dunes near the margin of the esker. Here black spruce is encroaching on the esker along a small depression. Near the spade, the irregular cover on the sand surface consists of carpets of *Rhacomitrium canescens.*

Plate 5. A view of the esker summit. To the left is a continuous stand of white spruce lichen forest on the flanks. On the upper ridge surfaces there are patches of trees, bare sand, and lichen-heath cover. The darker patches in the middle foreground are *Arctous rubra.* The tallest trees are 180–200 years of age, 12 m. in height, and 35 cm. d.b.h.

Plate 6. A dry esker "kettle". It bears an open, uneven-aged stand of *Picea glauca.* The ground vegetation consists of a discontinuous lichen-heath carpet. (See text for description).

Plate 7. A stand of *Picea glauca* along a small stream cutting through the Big Spruce River floodplain. The tallest tree is 21 m. in height, 45 cm. d.b.h., and 183 years of age. The floodplain surface in the foreground is being recolonized by young spruces.

Plate 8. A meander on the Big Spruce River floodplain. The floodplain open forest is dominated here by *Picea glauca*.

REFERENCES

Baldwin, W. D. W. 1953. 'Botanical investigations in the Reindeer–Nueltin lakes area, Manitoba'. *Bull. Nat. Mus. Can.* No. 128, pp. 110–42.

Billings, W. D. and A. F. Mark. 1957. "Factors involved in the persistence of montane treeless balds". *Ecology,* Vol. 38, pp. 140–2.

Bird, J. B. 1953. "The glaciation of central Keewatin, Northwest Territories, Canada". *Amer. J. Sci.* Vol. 251, pp. 215–30.

1955. "Terrain conditions in the Central Canadian Arctic". *Geogr. Bull.* Vol. 7, pp. 1–16.

Böcher, T. W. 1954. 'Oceanic and continental vegetational complexes in southwest Greenland'. *Medd. om. Grønl.* Vol. 148, No. 1, 336 pp.

Braun-Blanquet, J. 1932. 'Plant sociology'. New York: 439 pp.

Cody, W. J. 1953. "*Phyllodoce caerulea* in North America". *Can. Field-Nat.* Vol. 67, pp. 131–4.

Du Rietz, G. E. 1925. "Zur Kenntnis der flechtenreichen Zwergstrauchheiden im kontinentalen Süd Norwegen". *Svenska Växtsociologiska Sällskapets Handlingar,* Vol. 4, pp. 1–80.

Dutilly, A., E. Lepage, and M. Duman. 1953. 'Contribution à la flore du bassin de la Baie D'Ungava'. *Contrib. Arctic Inst. Catholic Univ. North Amer.* Vol. 4F, 104 pp.

Egler, F. E. 1942. "Vegetation as an object of study". *Phil. Sci.* Vol. 9, pp. 245–60.

Evans, A. W. 1955. "Notes on North American Cladoniae". *Bryologist,* Vol. 58, 93–112.

Halliday, W. E. D. 1937. 'A forest classification for Canada'. *Dom. Forest Serv. Bull.* 89, 50 pp.

Hansen, H. P. 1953. "Postglacial forests in the Yukon Territory and Alaska". *Amer. J. Sci.* Vol. 251, pp. 505–42.

Hare, F. K. 1950. "Climate and zonal divisions of the Boreal Forest formation in eastern Canada". *Geogr. Rev.* Vol. 40, pp. 615–35.

1954. "The Boreal Conifer Zone". *Geogr. Studies,* Vol. 1, pp. 4–18.

Hare, F. K. and R. G. Taylor. 1956. "The position of certain forest boundaries in southern Labrador-Ungava". *Geogr. Bull.* Vol. 8, pp. 51–73.

Harper, F. 1955. 'The Barren Ground Caribou of Keewatin'. *Publ. Mus. Nat. Hist. Univ. Kans.* Misc. Publ. 6, 163 pp.

Hearne, S. 1796. 'A journey from Prince of Wales's Fort, in Hudson's Bay to the Northern Ocean'. Dublin: 459 pp.

Hoffman, R. S. 1958. "The meaning of the word 'taiga' ". *Ecology,* Vol. 39, pp. 540–1.

Hustich, I. 1949. 'On the forest geography of the Labrador Peninsula'. *Acta Geogr. Helsingf.* Vol. 10, No. 2, 63 pp.

1950. 'Notes on the forests on the east coast of Hudson Bay and James Bay'. *Acta Geogr. Helsingf.* Vol. 11, No. 1, 83 pp.

1951. 'The lichen woodlands in Labrador and their importance as winter pastures for domesticated reindeer'. *Acta Geogr. Helsingf.* Vol. 12, No. 1, 48 pp.

1953. "The boreal limits of conifers". *Arctic,* Vol. 6, pp. 149–62.

1954. 'On forests and tree growth in the Knob Lake area, Quebec-Labrador Peninsula'. *Acta Geogr. Helsingf.* Vol. 13, No. 1, 60 pp.

1957a. 'On the phytogeography of the subarctic Hudson Bay Lowland'. *Acta Geogr. Helsingf.* Vol. 16, No. 1, 48 pp.

1957b. "Comparison of the flora and vegetation in the Fort Severn and in the Big Trout Lake area". Unpublished report to the Arctic Inst. of North Amer. 1957, 44 pp. mimeo.

Jalas, J. 1950. 'Zur Kausalanalyse der Verbreitung einiger nordischen Os- und Sandpflanzen'. *Ann. Bot. Soc. Vanamo,* Vol. 24, No. 1, 345 pp.

Kalliola, R. 1932. 'Pflanzenosoziologische Untersuchungen in der alpinen Stufe Finnisch-Lapplands'. *Ann. Bot. Soc. Vanamo,* Vol. 13, No. 2, 321 pp.

Lobeck, A. K. 1939. 'Geomorphology'. New York: 731 pp.

Low, A. P. 1896. 'Report on explorations in the Labrador Peninsula along the East Main, Koksoak, Hamilton, Manicuagan and portions of other rivers in 1892–93–94–95'. *Geol. Surv. Can. Ann. Rept.* Vol. 8 (1895), Rept. L, 387 pp.

Marr, J. W. 1948. "Ecology of the forest-tundra ecotone on the east coast of Hudson Bay". *Ecol. Monogr.* Vol. 18, pp. 117–44.

Porsild, A. E. 1951. 'Botany of southeastern Yukon adjacent to the Canol Road'. *Bull. Nat. Mus. Can.* No. 121, 400 pp.

Raup, H. M. 1930. "The distribution and affinities of the vegetation of the Athabasca-Great Slave Lake region". *Rhodora,* Vol. 32, pp. 187–208.

——— 1941. "Botanical problems in boreal America". *Bot. Rev.* Vol. 7, pp. 148–248.

——— 1943. "The willows of the Hudson Bay region and the Labrador Peninsula". *Sargentia,* Vol. 4, pp. 81–127.

——— 1946. "Phytogeographic studies in the Athabaska–Great Slave region, II". *J. Arnold Arbor.* (Harvard), Vol. 27, pp. 1–85.

Raymond, M. 1951. "Sedges as material for phytogeographical studies". *Mém. Jardin Bot. Montréal,* No. 20, 23 pp.

Ritchie, J. C. 1956a. "The native plants of Churchill, Manitoba, Canada". *Can. J. Bot.* Vol. 34, pp. 269–320.

——— 1956b. "The vegetation of northern Manitoba. I. Studies in the Southern Spruce Forest Zone". *Can. J. Bot.* Vol. 34, pp. 523–61.

——— 1956c. "A plant collection from northwestern Manitoba". *Can. Field-Nat.* Vol. 70, pp. 171–81.

——— 1957. "The vegetation of northern Manitoba. II. A prisere on the Hudson Bay Lowlands". *Ecology,* Vol. 38, pp. 429–35.

Rousseau, J. 1948. "The vegetation and life zones of George River, eastern Ungava and the welfare of the natives". *Arctic,* Vol. 1, pp. 93–6.

Rowe, J. S. 1956. "Vegetation of the Southern Boreal Forest in Saskatchewan and Manitoba". Ph.D. Thesis, University of Manitoba, 305 pp.

Russell, G. A. 1953. "A geological reconnaissance of the Wolverine and Caribou rivers". *Manitoba Dept. of Mines and Nat. Resources, Mines Branch,* Publ. 52-2, 10 pp.

Sanderson, Marie. 1948. "The climates of Canada according to the new Thornthwaite Classification". *Sci. Agri.* Vol. 28, pp. 501–17.

Scoggan, H. J. 1952. 'Botanical investigations in Manitoba in 1950'. *Bull. Nat. Mus. Can.* No. 126, pp. 208–27.

——— 1957. 'Flora of Manitoba'. *Bull. Nat. Mus. Can.* No. 140, 619 pp.

Taylor, R. S. 1956. "Glacial geology of north-central Keewatin, Northwest Territories, Canada". *Bull. Geol. Soc. Amer.* Vol. 67, pp. 943–56.

Tyrrell, J. B. 1896. 'Report on the country between Athabasca Lake and Churchill River'. *Geol. Surv. Can. Ann. Rept.* Vol. 8 (1895) Rept. D, 120 pp.

——— 1897. 'Report on the Doobaunt, Kazan and Ferguson rivers and the north-west coast of Hudson Bay'. *Geol. Surv. Can. Ann. Rept.* Vol. 9 (1896) Rept. F, 218 pp.

——— 1910. "Changes of climate in north-western Canada since the glacial period" in 'Die Veränderungen des Klimas seit dem Maximum der letzten Eiszeit', pp. 389–91.

Washburn, A. L. 1956. "Classification of patterned ground and review of suggested origins". *Bull. Geol. Soc. Amer.* Vol. 67, pp. 823–66.

Wilson, J. T. 1939. "Eskers north-east of Great Slave Lake". *Trans. Roy. Soc. Can.* Vol. 33, Sect. 4, pp. 119–30.

——— 1945. "Further eskers north of Great Slave Lake". *Trans. Roy. Soc. Can.* Vol. 39, Sect. 4, pp. 151–3.

TECH … OF

Copies … eal Office
of the Insti…

Number 1 … AS OF THE
ARCTI… Johnson.
1956.

Number 2 … and A. H.
Macp… *to Mem-*
bers o…

Number 3 … ES IN THE
SUBAR… gures, and
8 plat… *bers $2.00.*

PUBLICATIONS COMMITTEE

CONTRIBUTIONS TO THE *TECHNICAL PAPERS*

Scientific papers on all aspects of arctic work which are either too technical or too long for publication in the Institute's journal *Arctic*, may be submitted for publication in the *Technical Papers*. Manuscripts should be complete with maps, diagrams, and good glossy enlargements of photographs. Proofs will be sent to authors for correction.

An allowance of free reprints will be made.

All manuscripts should be addressed to the Editor, The Arctic Institute, 3485 University Street, Montreal 2, Que., Canada.

PRINTED IN CANADA