
SOILS OF THE MACKENZIE
RIVER AREA

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by

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ACKNOWLEDGEMENTS

The project was initiated at the request of the Geological Survey of Canada and was carried out in conjunction with surficial mapping under the direction of Dr. N.W. Rutter. The Geological Survey of Canada provided the helicopter time and living facilities for most of the season.

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1. SUMMARY

Soils were examined in three areas of the Mackenzie River basin: the Upper Mackenzie River and the Norman Wells and Inuvik areas. The soils were first described and classified according to the System of Soil Classification for Canada and then, the soils of the Upper Mackenzie River area were related to the Geological Survey of Canada landform based mapping units. The associated vegetation, parent materials, drainage and permafrost were also described. Physical and chemical properties and ice content were determined on representative soil profiles. Special attention was paid to organic soils, which are widespread in the area, and to perennially frozen soils, especially those which are affected by cryoturbation.

It was found that, because of the large area involved, the climate was not uniform and thus it was necessary to subdivide the Upper Mackenzie River area into climatically significant ecological zones which were based on the distribution of soils, vegetation and permafrost. In each of these zones the soils were identified and related to the Geological Survey of Canada mapping units.

2. INTRODUCTION

The project was carried out at the request of the Geological Survey of Canada. The objectives were: to identify and characterize soils according to the S.S.C.C.; to include them in mapping units developed by the Geological Survey of Canada (G.S.C.); to accommodate their inclusion in the G.S.C. map legend; and to provide a description of these soils in the report. The area involved is the Upper Mackenzie River Basin, N.W.T., around Fort Simpson, Nahanni Butte and Wrigley and is shown in Figure 1. The field work was carried out between June 5 and August 12, 1972. Four map areas were studied by the Geological Survey of Canada during the summer of 1971 and, thus, some of these areas along the Mackenzie and Liard Highways were briefly visited and checked or else were interpreted by means of work done in adjacent areas.

The second part of August was spent attending a correlation tour organized by S.C. Zoltai of the Canadian Forestry Service. This tour involved visits to areas both around Norman Wells and north of Inuvik (Figure 1). The legend relates strictly to the southern area but, in the section "Description of Soils", the analysis of samples and other data collected both in Norman Wells and Inuvik areas are also included. This was done both because of the lack of soil information available concerning the Mackenzie River area and to show the distribution of soils in the entire Mackenzie River Valley.

Special attention was given to peatlands, which are among the most common surface deposits in the area. Ground checking was carried out along transects crossing the most common peatland types and organic soils. Soils were classified according to the System of Soil Classification for Canada (1970). The classification of perennially frozen cryoturbed soils was difficult because these soils are not adequately accommodated in the present Canadian classification system. The above system was, however, adapted to classify these cryoturbed soils using an asterisk (*) to indicate that, while they deviate greatly from the name assigned to them, they do have the basic characteristics of this group of soils.

3. LITERATURE REVIEW

Leahey (1947) studied some of the soils along the Mackenzie River and provided a brief analysis and description of soil samples from several locations along the route. Wright et al (1959) discussed the chemical, morphological and mineralogical characteristics of soils developed on alluvial deposits near the mouth of the Hay River, N.W.T. Day (1962) and Day and Rice (1964) provided some information concerning the characteristics of perennially frozen soils occurring along the Mackenzie River. Jeffrey (1964) provided valuable soil information relating to vegetation types occurring along the lower Liard River. A reconnaissance soil survey was carried out by Day (1966, 1968) along the Upper Mackenzie River and the Liard River Valley. These two reports provided detailed descriptions of soils and a soil map of an approximately 6,540,700 acre area along these two rivers. In the summer of 1971 Lavkulich (1971) carried out soil, vegetation and landform studies in the Fort Simpson area in cooperation with Dr. J.S. Rowe of the University of Saskatchewan, Dr. D.S. Lacate of the University of British Columbia and Dr. N.W. Rutter of the Geological Survey of Canada. Some soil information was provided by Janz (1971) for the eastern part of the Mackenzie Delta along with a vegetation study on selected sites. For the interpretation of organic soils the work of Zoltai and Tarnocai (1971) and Tarnocai (1970, 1972) was used. For the interpretation of cryoturbed subarctic and arctic soils, Mackay's work (1958) and papers published in the book "Soils of Eastern Siberia" edited by E.N. Ivanova, were found to be most useful.

4. STUDY AREA

4.1. Location

The soil study was carried out at three locations along the Mackenzie River during the 1972 field season (see Figure 1).

During the G.S.C. helicopter survey the following map areas were covered: The Fort Liard Sheet (N.T.S. 95B), Sibbeston Lake Sheet (N.T.S. 95G), Kakisa River Sheet (N.T.S. 85D), Bulmer Lake Sheet (N.T.S. 95I), Wrigley Sheet (N.T.S. 95O) and Dahadinni River Sheet (N.T.S. 95N). The Fort Simpson (N.T.S. 95H) and Mills Lake (N.T.S. 85F) sheets along the Mackenzie and Liard Highways were checked and the Trout Lake Sheet (N.T.S. 95A), Camsell Bend Sheet (N.T.S. 95J) and Root River Sheet (N.T.S. 95K) were interpreted by means of work done in adjacent areas.

During the investigations with Canadian Forestry Service personnel, areas around both Norman Wells and north of Inuvik were covered. The former included the area from Fort Norman north to Sans Sault Rapids and west to the Mackenzie Mountains, and the latter extended to Richards Island, Tuktoyaktuk and the Eskimo Lakes.

4.2. Climate

Available climatic data indicates that the Mackenzie River Valley has low precipitation, long cold winters and short, but moderately warm, summers. A summary of the climatic data is shown in Tables 1 and 2.

	Hay River			Yellowknife			Fort Providence			Fort Simpson		
	Mean temp. °F	Total pptn. Inches	Snow Inches	Mean temp. °F	Total pptn. Inches	Snow Inches	Mean temp. °F	Total pptn. Inches	Snow Inches	Mean temp. °F	Total pptn. Inches	Snow Inches
Jan.	-13	0.7	6.6	-19	0.6	5.8	-16	0.7	6.5	-16	0.7	7.4
Feb.	- 9	0.7	6.7	-15	0.5	5.0	-11	0.5	5.3	-12	0.5	5.4
March	5	0.6	6.1	0	0.5	5.2	5	0.6	5.9	5	0.7	6.7
April	22	0.6	4.8	17	0.4	2.8	23	0.6	4.7	24	0.8	5.4
May	40	0.7	1.4	39	0.6	0.8	44	0.6	1.2	45	0.9	1.6
June	52	1.0	0.1	54	0.6	0.0	55	0.9	0.0	58	1.5	0.0
July	60	2.0	0.0	61	1.5	0.0	61	1.4	0.0	62	2.1	0.0
Aug.	58	1.6	0.0	58	1.4	0.0	58	1.4	0.0	58	2.1	0.0
Sept.	47	1.6	0.9	45	1.2	1.2	47	1.1	0.7	46	1.5	0.7
Oct.	34	1.4	7.6	29	1.1	7.6	31	0.9	4.2	29	1.1	6.2
Nov.	12	1.7	16.3	6	1.0	9.6	9	1.0	9.5	7	0.9	8.8
Dec.	- 7	1.1	10.8	-12	0.9	9.0	-10	0.8	8.3	-12	0.9	8.8
Year	25	13.7	61.4	22	10.2	47.0	25	10.4	44.9	25	13.7	51.0

Data obtained from Dept. of Transport, 1954 and 1959.

Table 1. Mean Monthly Temperatures, Total Precipitation and Snowfall at Selected Stations.

	Jan.	Feb.	Mar.	Apr.	May.	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
Inuvik													
Mean daily maximum temperature	-11	- 7	2	19	41	63	68	61	46	25	3	- 7	25
Mean daily minimum temperature	-30	-26	-20	- 6	22	39	45	40	30	13	-13	-26	6
Total precipitation	0.51	0.43	0.35	0.49	0.44	0.85	1.19	1.35	0.96	0.78	0.65	0.45	8.45
Snowfall	5.4	4.6	3.6	5.1	2.4	1.5	T	0.7	2.9	7.5	6.9	4.5	45.1
Norman Wells													
Mean daily maximum temperature	-11	- 7	10	31	53	68	72	65	50	32	9	- 6	31
Mean daily minimum temperature	-26	-23	-12	7	32	46	50	45	35	20	- 4	-21	12
Total precipitation	0.65	0.58	0.34	0.54	0.67	1.40	2.02	2.65	1.66	0.77	0.84	0.67	12.79
Snowfall	6.5	5.8	3.4	4.6	1.8	0.2	0.0	T	2.8	6.5	8.4	6.7	46.7
Fort Norman													
Mean temperature													19.5
Mean precipitation													11.2
Fort Good Hope													
Mean temperature													18.7
Mean precipitation													10.6
Aklavik													
Mean temperature													15.3
Mean precipitation													10.3

Data obtained from Dept. of Transport, 1954 and 1959.

Table 2. Monthly and annual averages of daily maximum and minimum temperature (°F), monthly and annual averages of total precipitation and snowfall (inches)

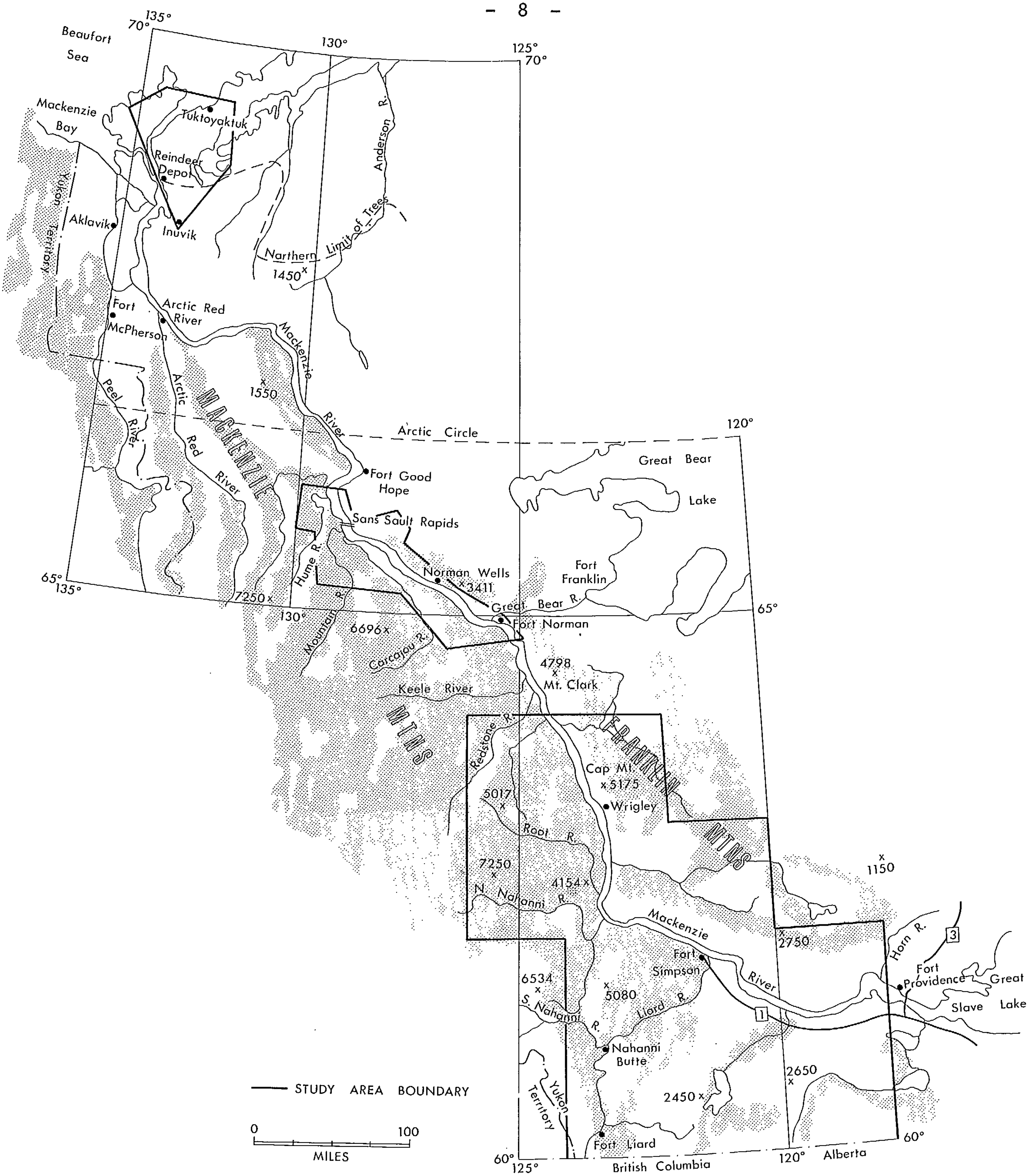


Figure 1. Map indicating the three areas where soil studies were carried out in the Mackenzie River basin during the 1972 field season.

5. METHODS

5.1. Field Methods

In the southern area around Nahanni Butte, Fort Simpson and Wrigley the objective of the study was to characterize the soils according to landforms, surface deposits and drainage. This was carried out in two steps:

(1) Traverses were made with the G.S.C. mapper along selected routes to collect as much information as possible about terrain and the distribution of soils, drainage and vegétation. During the stops, soils were examined and described and the vegetation, drainage and permafrost conditions were also noted. Some of the soils were sampled and described at this time.

(2) While on traverse, representative areas were selected and, at these sites, detailed ground work was carried out.

Surficial mapping was carried out by the Geological Survey of Canada mapper and is based on landforms.

Most of the soil sampling was carried out along surveyed transects, with special emphasis given to peatlands and perennially frozen mineral soils. The locations of the transects were carefully selected so that they crossed representative areas and showed relationships of adjacent landforms. Cross-sections were then drawn and vegetation and drainage were described according to landforms. Sites for soil sampling were selected and their locations were indicated on the transect. Soils were identified and described and samples were collected for laboratory analyses. Unfrozen soils were examined in soil pits while perennially frozen organic and fine textured mineral soils were penetrated and sampled with a Hoffer probe

(Brown, 1965) having an inside diameter of 2.1 cm and an outside diameter of 2.6 cm. Unfrozen peat was sampled with a Hiller peat sampler (MacFarlane, 1969). Soil temperatures were taken at depths of 2.5, 5, 10, 20, 50 and 100 cm using a thermistor type YSI Model 42 SC Tele-Thermometer. Free water associated with poorly drained organic soils was also sampled for chemical analysis. In perennially frozen organic and fine-textured mineral soils frozen core samples were taken using the Hoffer probe for determination of the ice content on a volume basis. In coarse-textured soils and stony till materials the ice content was determined on a weight basis using approximately 100 gms. of frozen soil.

5.2. Laboratory Methods

The ice content was determined in the field laboratory using a propane gas oven for drying the samples. Ice content then was calculated by measuring the water content and using the density of pure ice ($0.9168\ g\ cm^{-3}$) at 0°C and a pressure of 1 atm. (Pounder, 1965). Soil and water samples were shipped to the Soil Survey Laboratory at Winnipeg for analysis.

The chemical analysis was carried out according to the method of Kilmer and Alexander (1949). The pH of organic soils was determined with KCl and that of mineral soils with $CaCl_2$. For both mineral and organic soils the organic carbon was determined by the modified method of Peech _et al._ (1947), the electrical conductivity by the method of the United States Salinity Laboratory (1954) and the nitrogen by the Kjeldahl procedure (Atkinson _et al._, 1958). The cation exchange capacity and the exchangeable cations were determined in organic soils using the method of Farnham (1970) and in mineral soils using the method of Atkinson (1958). Calcium carbonate was determined by the method of Skinner (1957), the fiber content by Lynn's method (1971) and the pyrophosphate solubility and ash content by Farnham's method (1970).

6. CLIMATICALLY SIGNIFICANT ECOLOGICAL ZONES IN THE UPPER MACKENZIE RIVER AREA

The small amount of climatic data available does not provide adequate information for delineating climatically significant ecological zones in the area. The physical and biological portions of the environment do, however, provide reliable information, making it possible to establish broad climatically significant ecological zonations. In the Upper Mackenzie River basin these Zones (Figure 2) were separated on the basis of soils, permafrost, parent materials, elevation and vegetation, and were designated by a number from 0 to 6. Above the treeline or timberline the area is designated 0. Areas below the timberline are simply numbered 1 to 6. The numbers do not provide quantitative data concerning the climate; they simply serve to separate into Zones the physical and biological portions of the environment showing different patterns. The description of these Zones in the area between the 60°th and 64°th parallels (top of N.T.S. Sheets 95O and 95N), the area which was covered by the southern party of the Geological Survey of Canada, is given in detail below and is summarized in Table 3.

Zone 2. This Zone covers the Dahadinni, Johnson and North Nahanni River areas on the west side of the Mackenzie River Valley. The mineral soils are dominantly Cryic (frozen) Brunisols and Cryic (frozen) Gleysols developed on the fine-textured glacial till which is typical of this zone. Some of the well-drained Cryic Brunisols have a hummocky micro-topography, but without a great deal of cryoturbation. Cryic Gleysols also exhibit a hummocky microtopography and very weak cryoturbation. Cryic Fibrisols and Cryic Mesisols

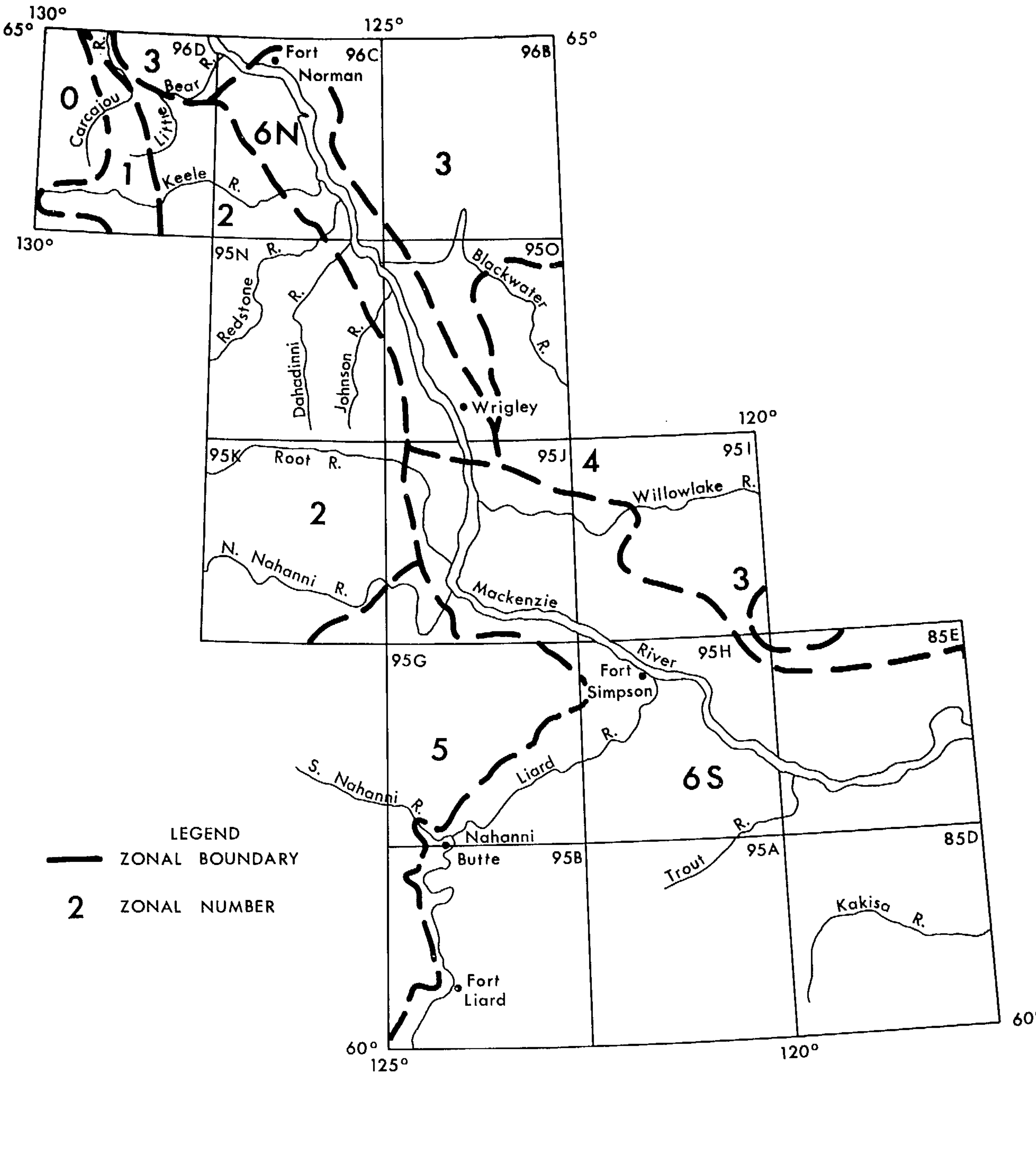


Figure 2. The distribution of Climatically Significant Ecological Zones in the Upper Mackenzie River area.

dominate the peatlands. Alpine Brunisols, which are affected by cryoturbation, are found at higher elevations and are associated with patterned ground. The vegetation cover is dominantly open black spruce-lichen type with some aspen, jack pine and white spruce being found in valleys. The timberline is at approximately 3,300 feet. The vegetation that occurs above the timberline is typical of the alpine tundra type.

Permafrost is widespread in the well and imperfectly drained sites and continuous under peatlands and poorly drained soils because of the fine-textured till material and the higher elevation, Some of the sands and gravels are also frozen. The fine-textured glacial till has a high ice content. Patterned ground above the timberline takes the form of hummocks, nonsorted circles, nonsorted stripes and nonsorted steps (Washburn, 1956). Flowslides and soil slumping are common in this area and occur mainly along the rivers and on mountain slopes.

Zone 3. This area is dominated by the Franklin Mountains, Horn Plateau and peatlands in the low lying areas of the northeastern portion of the Wrigley Sheet. The organic soils are dominantly Cryic Fibrisols and the mineral soils are Cryic Brunisols and Cryic Gleysols. At higher elevations in the Franklin Mountains Alpine Brunisols are found in association with patterned ground. The vegetation cover is dominantly of the open black spruce-lichen type. Aspen and jack pine are also found, mainly on recently burned areas. White spruce is found in valleys, along the rivers and creeks. The timberline is at approximately 3,300 to 3,400 feet and white spruce forms the timberline.

Except under shallow lakes and ponds, permafrost is continuous on peatlands and is associated with peat plateaus, palsas and peat polygons.

All frozen peat landforms have a high ice content, especially the peat polygons. Patterned ground takes the form of nonsorted circles, nonsorted stripes and nonsorted steps found in the Franklin Mountains and peat polygons in the lowland area. Some hummocks are found on well to poorly drained materials and show weak cryoturbation.

Zone 4. This Zone covers the northern portion of the Mills Lake map area and the eastern portion of Bulmer Lake and Wrigley map areas. Soils are dominantly Luvisols on glacial till and Brunisols on sand and gravel deposits and on some of the high lime till materials. Cryic Gleysols are found on the poorly drained sites. The organic soils are mainly Cryic Fibrisols and Mesisols in association with bogs and Typic Mesisols in association with fens.

Permafrost is widespread on poorly drained fine-textured soils and bog types of peatlands. Some permafrost is also found on well to imperfectly drained fine-textured deposits, especially at higher elevations. Perennially frozen peatlands take the form of peat plateaus and palsas and are composed dominantly of high ice content materials. Very little collapsing was noted on these peat plateaus and palsas.

Zone 5. This Zone covers the Liard Range, the lower South Nahanni River, the Nahanni Range and the Martin Hills areas. The soils are dominantly Luvisols on well to imperfectly drained materials and

Brunisols on coarser deposits and at higher elevations. Cryic Gleysols are found on poorly drained areas. The organic soils are mainly Cryic Fibrisols. Alpine soils are found associated with nonsorted circles above the timberline. Black spruce is the dominant species of vegetation but aspen is very common as a result of repeated forest fires. White spruce is found in the valleys on better drained sites. Alpine fir forms the timberline at elevations of approximately 3,600 feet.

Permafrost is discontinuous on poorly drained fine-textured mineral soils and widespread on peatlands. The perennially frozen peatlands take the form of peat plateaus and palsas composed dominantly of high ice content peat materials. Very little active collapsing is found on the peatlands. In old collapse areas, however, active palsa development was noted.

Zone 6. This Zone covers the plains of the Mackenzie and Liard Rivers. This area is divided into two subzones, 6S (south) and 6N (north).

Subzone 6S spans the Upper Mackenzie River from Mills Lake to approximately Willowlake River and the Liard River Plain. The Trout Lake and Kakisa River area is also included in this subzone in spite of the fact that it is somewhat higher in elevation. Based on information collected during the 1972 season, no great differences were found in soils and permafrost as compared to other areas of 6S. The soils are dominantly Luvisols developed on well to imperfectly drained till and glaciolacustrine deposits. Brunisols dominate the sandy aeolian deposits and the older alluvial terraces. Regosolic soils are associated with the recent alluvial deposits. Gleysolic soils are found on all poorly drained deposits and most of them are perennially frozen.

Organic soils are very common in this area and they are dominantly Mesisols and Cryic Fibrisols. The vegetation consists of good white spruce and balsam poplar forests along the Mackenzie and Liard River flood plains and along the other river valleys. Aspen, lodgepole pine and jack pine are found on well to imperfectly drained till and sand, mainly as a result of repeated forest fires. Black spruce is found on poorly drained mineral soils and peatlands. These black spruce stands are of the fairly dense feathermoss-Ledum type as compared to Zones 2 and 3 where black spruce-lichen-Ledum is the dominant cover type.

Permafrost is found in bog type peatlands and peaty gleysols. On peatlands the peat plateaus and palsas indicate the presence of permafrost. Along the rivers the poorly drained peaty soils are also frozen. Here the permafrost, however, is sporadic. The collapsing (melting) of permafrost on peat plateaus and palsas is moderately active. Build-up of permafrost was noted in the older collapse scars on peatlands and on alluvial deposits covered by thin peat.

Subzone 6N spans the area along the Mackenzie River from approximately Willowlake River to Fort Norman. The soils are Brunisols on well to imperfectly drained glaciolacustrine till and sandy and gravelly deposits.

Regosolic soils are associated with recent alluvial deposits. Gleysolic soils are very common and are found in all of the above-mentioned poorly drained deposits. These Gleysols are perennially frozen. The organic soils are mainly Cryic Fibrisols. The vegetation is also white spruce and balsam poplar but somewhat poorer than in Subzone 6S. Aspen and jack pine are found on well to imperfectly drained till and sandy and gravelly deposits. Black spruce occupies poorly drained mineral soils and peatlands. Permafrost was found on bog-type peatlands and in peaty gleysols. On peatland, peat plateaus and palsas are indicators of the presence of permafrost. Some of these peat landforms, especially the palsas, contain very high amounts of ice or layers of pure ice. The fine-textured mineral deposits (lacustrine and till) also contain high amounts of ice, especially in poorly drained peaty areas. On steep slopes and river banks slumping and flowslides result from the melting of this high ice content permafrost. Very little collapsing was noted on peatlands in this area.

Table 3

Summary of Description of Zones in the Upper Mackenzie Area

Zone	Dominant Soil	Dominant Vegetation	Permafrost and Associated Landforms
2	Cryic Brunisols and Cryic Gleysols on till and sandy and gravelly deposits. Alpine Brunisols above the timber-line. These soils are slightly affected by cryoturbation. Cryic Fibrisols and Cryic Mesisols dominate the peat-lands.	Open black spruce-lichen-Ledum type on all drainage situations. Aspen and jack pine on recently burned areas. Some white spruce is found in valleys. Above the timber-line (3,300 feet a.s.1.) alpine tundra type of vegetation.	Because of the fine-textured till material and higher elevation, permafrost is widespread. Fine-textured materials have a typical hummocky micro-topography with little cryoturbation. On coarser materials above the timberline nonsorted circles, nonsorted stripes and non-sorted steps are found. Sand and gravel are also frozen, but with no indication of micro-topography. Almost continuous perma-frost on peatlands and peaty gleysols. Peat plateaus and palsas are indicators of perma-frost on peatland.
3	Cryic Brunisols and Cryic Gleysols on till deposits. Alpine Brunisols above the timberline. These soils, especially in the alpine areas, are affected by cryoturbation. Cryic Fibrisols dominate the peatlands.	Open black spruce-lichen-Ledum type on all drainage situations in the lowland except for peat poly-gons which are treeless and covered with lichens. Some aspen and jack pine is found on recent burns. White spruce is found in valleys and on mountain slopes where it forms the timberline at approximately 3,300 to 3,400 feet a.s.1.	Widespread permafrost on well to imperfectly drained fine-textured deposits. Some of the soils have a typical hummocky topography with little cryoturbation. Almost continuous permafrost on peatland and peaty gleysols. Peat plateaus, peat polygons and palsas are indicators of permafrost on peatlands.
4.	Luvisols and Brunisols on well to imperfectly drained and Cryic Gleysols on poorly drained mineral deposits. Cryic Fibrisols and Cryic Mesisols are associated with bogs and Mesisols are associated with fen types of peatland.	Dominantly black spruce type of vegetation on all sites. Aspen and jack pine common on burned areas. White spruce found in valleys. Open black spruce-lichen-Ledum type on perennially frozen peatlands. Sedge and tamarack type on fens.	Discontinuous permafrost on poorly drained fine-textured mineral soils. Widespread permafrost on peatland, especially on bogs, in the form of peat plateaus and palsas.

Table 3 (cont'd)

Zone	Dominant Soil	Dominant Vegetation	Permafrost and Associated Landforms
5	Luvisols and Brunisols on well to imperfectly drained and Cryic Gleysols on poorly drained mineral deposits. Alpine Brunisols, slightly affected by cryoturbation, above the timberline. Cryic Fibrisols on peatlands.	Lower elevations are dominated by black spruce forests. Aspen and lodgepole pine are common on burned areas. White spruce found in valleys, on better drained soils. Alpine fir forms the timberline at 3,600 feet a.s.l.	Discontinuous permafrost on poorly drained fine-textured soils. In alpine areas active cryoturbation was noted in association with nonsorted circles. Widespread permafrost on peatland, especially on bogs, in the form of peat plateaus and palsas.
6S	Luvisols and Brunisols on well to imperfectly drained deposits, except on recent alluvium where Regosols occur. Gleysols on poorly drained mineral deposits. A large portion of these Gleysols are perennially frozen. Cryic Fibrisols and Cryic Mesisols are associated with bogs and Mesisols are associated with fens.	Good white spruce and balsam poplar on floodplains and valleys. Aspen and pine on well to imperfectly drained till and sands. Dense black spruce-feathermoss-Ledum type of vegetation on peatlands and poorly drained mineral soils.	Discontinuous permafrost on peatlands and poorly drained mineral soils. On peatlands, peat plateaus and palsas are the permafrost landforms.
6N	Brunisols on well to imperfectly drained mineral deposits, except on recent alluvium where Regosols occur. Cryic Gleysols on poorly drained mineral deposits and Cryic Fibrisols on peatlands.	White spruce and balsam poplar on floodplains and valleys. Aspen and jack pine on well to imperfectly drained tills, sandy and gravelly deposits. Somewhat open black spruce-lichen-Ledum type of vegetation on peatlands and poorly drained mineral soils.	Widespread permafrost on peatlands and poorly drained mineral soils. On peatlands, peat plateaus and palsas are the permafrost landforms.

7. DISTRIBUTION OF SOILS

The distribution of soils is designated according to Geological Survey of Canada map units as outlined in Table 4. Soil information is interpreted as illustrated by the following example.

The mapping unit, Moraine Plain, is indicated on the surficial map as tMp, tMpv and tMv. The distribution of dominant soils in Zone 6S on this mapping unit is as follows: well drained portions, 40 percent Brunisolic Gray Luvisol and Orthic Gray Luvisol; imperfectly drained portions, 20 percent Gleyed Gray Luvisol and Gleyed Brunisolic Gray Luvisol; and poorly drained portions, 40 percent Rego Gleysol and Cryic Rego Gleysol.

The soils denoted by an asterisk (*) are those influenced by cryoturbation.

The dominant vegetation types are also included and species are abbreviated and grouped according to the moisture condition and the zones.

Table 4. Distribution of Soils in the Upper Mackenzie River Area according to the Geological Survey of Canada map units.

Map Symbol+	Name	Parent Material	Topography	Drainage	Soils++ Dominant Soil	Zone (deciles) 6S	6N	5	4	3	2	Dominant Vegetation+++
fO	Organic (fen)	Dominantly moderately decomposed fen peat derived from sedge, tamarack and mosses (greater than 4 feet thick).	Flat to very gently sloping, some with reticulate network of low (<1m) ridges (patterned fen).	Poor to very poor	Typic Mesisol	10	10	10	10	10	-	Sedge-Bi or Sedge-Bi-tL in all Zones.
pO	Organic (bog)	Dominantly moderately decomposed forest and/ or undecomposed sphagnum peat, derived from black spruce, cladonia, feathermosses, Ericaceous and/or Sphagnum vegetation (greater than 4 feet thick).	Flat to gently sloping areas with occasional mounds (average relief 1m rarely to 6m); numerous steep-sided depressions and trenches.	Well to Imperfect	Cryic Mesisol Cryic Fibrisol	5	7	7	7	10	10	bS-Fm-Er in Zones 6S and 6N; bS-lichen-Er in Zones 4 and 5; Lichen-bS-Er in Zones 2 and 3.
				Poor	Typic Fibrisol Typic Mesisol	5	3	3	3	-	-	Sphagnum or Sphagnum-bS in Zones 4, 5, 6S and 6N.
(g, s, si) AP	Alluvial flood-plain	Calcareous gravel and/ or sand and silt; textures vary with the dominant material indicated first.	Floodplain and low bordering terraces; floodplains within mountains commonly scarred by braided channels; floodplains within plains region commonly with meander scars.	Well	Cumulic Regosol	4	-	4	4	-	-	wS-wB, bPo-wS-Equisetum, wS-bPo in Zones 4, 5 and 6S.
				Imperfect	Gleyed Cumulic Regosol	3	-	3	3	-	-	
				Poor	Rego Gleysol	3	-	-	-	-	-	Wi, Wi-Al, bPo-Al in Zones 4, 5 and 6S.
					Cryic Rego Gleysol		-	3	3	-	-	
(g, si) At	Alluvial terrace	Calcareous gravel and/or sand and silt; textures vary with the dominant material indicated first.	Terraces with relief intermediate between terraces associated with Ap and Gp; level to slightly sloping surfaces, some interrupted with shallow channels and low terraces.	Well	Degraded Eutric Brunisol Orthic Eutric Brunisol	6	6	6	6	-	-	wS-wB, wS-bPo, tA-wB, bPo, tA in Zones 4, 5, 6N and 6S;
					Cryic Orthic Eutric Brunisol	-	-	-	-	-	6	wS-wB, bS-bPo, tA-bS in Zone 2.
				Imperfect	Gleyed Eutric Brunisol	1	1	1	1	-	-	bPo-wS, wS-bPo-Wi, tA-wS in Zones 4, 5, 6N and 6S;
					Cryic Gleyed Eutric Brunisol	-	-	-	-	-	1	bS-bPo, wS-bPo in Zone 2.
				Poor	Rego Gleysol	3	-	-	-	-	-	bS-Fm, bS-Fm-Er, bS-Sphagnum in Zones 4, 5 6N and 6S;
					Cryic Rego Gleysol		3	3	3	-	3	bS-Lichen-Er in Zone 2
gAf	Alluvial fan	Mostly calcareous gravel and some sand.	Gently to moderately (1°-8°) sloping fans and coalescent fans.	Well	Cumulic Regosol	-	-	6	6	-	6	Mainly wB, tA, Wi and Al in Zones 2, 3, 4, 5, 6N and 6S.
				Imperfect	Gleyed Cumulic Regosol	-	-	2	2	-	2	
				Poor	Rego Gleysol Cryic Rego Gleysol	-	-	2	2	-	2	
Cx^1 Cx^2 Cx	Colluvial Complex	Colluvium derived from entire range of surficial deposits, and bedrock.	Gently to steeply sloping irregular surfaces; $Cx \leq 5°$ $Cx^2 > 5° \leq 15°$ $Cx > 15°$	Well	Lithic Orthic Regosol Lithic Alpine Brunisol*	-	-	5	-	5	5	tA, wS, wB at low elevations and stunted Alpine fir or wS, Er, lichen at high elevations in Zone 5. bS, wB at low elevations and Er, Lichen at high elevations; cryoturbed surfaces are unvegetated in Zones 2 and 3.
				Imperfect	Gleyed Lithic Orthic Regosol Gleyed Alpine Brunisol*	-	-	2	-	2	2	
				Poor	Rego Gleysol Cryic Rego Gleysol	-	-	3	-	3	3	Sphagnum, bS-Sphagnum-Er in Zones 2, 3 and 5.

Table 4 (cont'd)

Map Symbol+	Name	Parent Material	Topography	Drainage	Soils++ Dominant Soil	Zone (deciles) 6S	6N	5	4	3	2	Dominant Vegetation+++
sEr SEh	Aeolian deposits	Fine to medium sand.	sEr, dune ridges, usually parallel to subparallel; sEh, irregularily shaped dunes, no apparent pattern.	Well	Degraded Eutric Brunisol	5	–	5	–	–	–	P, tA-wB in Zones 5 and 6S.
				Imperfect	Gleyed Degraded Eutric Brunisol	2	–	2	–	–	–	tA-bS-Wi in Zones 5 and 6S.
				Poor	Rego Gleysol	3	–	3	–	–	–	bS-Fm, bS-Sphagnum-Er in Zones 5 and 6S.
					Cryic Rego Gleysol		–		–	–	–	
si, sLp si, sLpv	Glacio-lacustrine Plain	Calcareous silt and fine sand; if gravel and/or sand and/or clay is present map symbol prefixed by g, c; dominant material indicated first.	Flat to gently sloping.	Well	Brunisolic Gray Luvisol	3	–	3	–	–	–	wS, wS-tA in Zones 5 and 6S; wS-tA, bS-wB-tA in Zone 6N.
					Orthic Gray Luvisol	–	2	–	–	–	–	
				Imperfect	Gleyed Gray Luvisol	2	–	2	–	–	–	bS-wB-tA, bS-Wi-Al in Zones 5, 6S and 6N.
					Cryic Gleyed Gray Luvisol	–	2	–	–	–	–	
				Poor	Rego Gleysol	5	–	–	–	–	–	bS-Fm-Er, bS-tL-wB in Zones 5, 6S and 6N.
					Cryic Rego Gleysol		6	5	–	–	–	
si, sLpk	Glacio-lacustrine thermo-karst plain	Mainly silt and fine sand; discontinuous organic cover.	Flat to gently sloping; numerous shallow thermo-karst lakes and ponds.	Well	Cryic Eutric Brunisol Cryic Eutric Brunisol*	–	3	–	–	3	–	wS-wB, bS-Fm-Er in Zones 3 and 6N.
				Imperfect	Cryic Gleyed Eutric Brunisol Cryic Gleyed Eutric Brunisol*	–	2	–	–	2	–	bS-wB-Er in Zones 3 and 6N.
				Poor	Cryic Rego Gleysol*	–	5	–	–	5	–	bS-Fm-Er in Zone 6N; bS-Lichen-Er in Zone 3.
gLpbx gLpbxv gLpbv	Glacio-lacustrine beaches	Mainly sand and/or gravel; if silt is present map symbol prefixed by si; dominant material indicated first.	gLpbx and gLpbv, parallel to sub-parallel beach ridges arranged in belts; up to 6° slopes; gLpbv, beach material without distinct ridges forming belts up to 4± miles wide.	Well	Degraded Eutric Brunisol Orthic Eutric Brunisol	5	–	–	–	–	–	P, P-wB-tA
				Imperfect	Gleyed Eutric Brunisol	2	–	–	–	–	–	P-wB-Wi, bS-wB-Wi, tA-bS-Wi
				Poor	Rego Gleysol	3	–	–	–	–	–	bS-Fm-Er
(g,s,si)Gp (g,s,si)Gpv (g,s,si)Gt	Glacio-fluvial plain Glacio-fluvial terrace	Gravel and/or sand, sand and silt; textures vary with the dominant material indicated first.	Flat to gently sloping	Well	Degraded Eutric Brunisol Orthic Eutric Brunisol	5	5	–	–	–	–	P-wB-tA, P in Zones 6S and 6N.
				Imperfect	Gleyed Eutric Brunisol	2	2	–	–	–	–	bS-wB-Wi, P-wB-Wi, tA-bS-Wi in Zones 6S and 6N.
				Poor	Rego Gleysol	3	–	–	–	–	–	bS-Fm-Er in Zones 6S and 6N.
					Cryic Rego Gleysol	–	3	–	–	–	–	
gGh gGr	Hummocky glacio-fluvial deposits Ridged glacio-fluvial deposits; includes eskers & esker complexes	Mainly gravel and/or sand.	Hummocks and ridges to 10m.	Well	Degraded Eutric Brunisol Orthic Eutric Brunisol	–	–	–	5	–	–	tA-bS-wB wS-tA-wB
				Imperfect	Gleyed Eutric Brunisol	–	–	–	2	–	–	bS-tA-wB
				Poor	Cryic Rego Gleysol	–	–	–	3	–	–	bS-Fm-Er bS-Lichen-Er

Table 4 (cont'd)

Map Symbol+	Name	Parent Material	Topography	Drainage	Soils++ Dominant Soil	Zone (deciles) 6S	6N	5	4	3	2	Dominant Vegetation+++
tMp tMpv tMv	Moraine Plain	Moderately to strongly calcareous glacial till, typically clay, silt and minor sand with 5% pebbles and boulders; prefixes g, si or c, indicate lenses of gravel and/or sand, silt, or clay within the till.	Flat to gently sloping (0-2°); map symbol may be suffixed by one or more r, m, s, d, or h (see description below) indicating the mapped area in part consists of one or more of these landform units.	Well	Brunisolic Gray Luvisol	4	–	3	–	–	–	wS-tA-wB, tA-P-wB in Zones 4, 5, 6S and 6N; wS-wB, bS-wB in Zones 2 and 3.
					Orthic Gray Luvisol		3		3	–	–	
					Cryic Orthic Eutric Brunisol	–		–	–	4	5	
					Cryic Orthic Eutric Brunisol*	–	–	–	–			
				Imperfect	Gleyed Gray Luvisol	2	–	3	2	–	–	wS-tA-wB, wS-tA-Wi in Zones 4, 5, 6S and 6N; bS-Wi-Al, bS-wB in Zones 2 and 3.
					Gleyed Brunisolic Gray Luvisol		–		–	–	–	
					Cryic Gleyed Orthic Eutric Brunisol*	–	2	–	–	1	1	
					Cryic Gleyed Orthic Eutric Brunisol	–	–	–	–			
				Poor	Rego Gleysol	4	–	–	–	–	–	bS-Fm-Er in Zone 6S; bS-Fm-Lichen-Er in Zones 4, 5 and 6N; bS-Lichen-Er in Zones 2 and 3.
					Cryic Rego Gleysol		5	4	5	5	4	
					Cryic Rego Gleysol*	–		–	–			
tMp[1] tMpc[1]	Moraine Plain	Moderately to strongly calcareous glacial till.	Slope ± 2°-5°.	Well	Brunisolic Gray Luvisol	6	–	4	–	–	–	wS-tA-wB, tA-P-wB in Zones 4, 5, 6S and 6N; wS-wB, bS-wB in Zones 2 and 3.
					Orthic Gray Luvisol		3		3	–	–	
					Cryic Orthic Eutric Brunisol	–		–	–	4	5	
					Cryic Eutric Brunisol*	–	–	–	–			
				Imperfect	Gleyed Gray Luvisol	2	–	2	2	–	–	wS-tA-wB, wS-tA-Wi in Zones 4, 5, 6S and 6N; bS-Wi-Al, bS-wB in Zones 2 and 3.
					Gleyed Brunisolic Gray Luvisol		2		–	–	–	
					Cryic Gleyed Eutric Brunisol	–		–	–	1	1	
					Cryic Gleyed Eutric Brunisol*	–	–	–	–			
				Poor	Rego Gleysol	2	–	–	–	–	–	bS-Fm-Er in Zone 6S; bS-Fm-Lichen-Er in Zones 4, 5 and 6N; bS-Lichen-Er in Zones 2 and 3.
					Cryic Rego Gleysol		5	4	5	5	4	
					Cryic Rego Gleysol*	–		–	–			
tMd tMsd tMs	Drumlins Flutings drumlins Flutings	Moderately to strongly calcareous glacial till; prefix g indicates lenses of gravel and/or sand within the till.	Parallel drumlins and/or flutings within a moraine plain.	Well	Brunisolic Gray Luvisol	4	–	4	–	–	–	P-tA, tA-P-wB, wS-tA-wB in Zones 4, 5 and 6S; wS-wB, bS-wB-Wi in Zones 2 and 3.
					Orthic Gray Luvisol		–		3	–	–	
					Cryic Orthic Eutric Brunisol	–	–	–	–	4	4	
					Cryic Eutric Brunisol*	–	–	–	–			
				Imperfect	Gleyed Gray Luvisol	2	–	2	2	–	–	wS-tA-wB, wS-tA-Wi in Zones 4, 5 and 6S; bS-Wi-Al, bS-wB in Zones 2 and 3.
					Gleyed Brunisolic Gray Luvisol		–		–	–	–	
					Cryic Gleyed Eutric Brunisol	–	–	–	–	2	2	
					Cryic Gleyed Eutric Brunisol*	–	–	–	–			
				Poor	Rego Gleysol	4	–	–	–	–	–	bS-Fm-Er in Zone 6S; bS-Fm-Lichen-Er in Zones 4 and 5; bS-Lichen-Er in Zones 2 and 3.
					Cryic Rego Gleysol		–	4	5	4	4	
					Cryic Rego Gleysol*	–	–	–	–			

Table 4 (cont'd)

Map Symbol+	Name	Parent Material	Topography	Drainage	Soils++ Dominant Soil	Zone (deciles) 6S	6N	5	4	3	2	Dominant Vegetation+++
tMr	Ridge moraine	Moderately to strongly calcareous glacial till; prefix g indicates lenses of gravel and/or sand within the till.	Individual, parallel to subparallel straight to sinuous ridges within a moraine plain; 0.5 to 5m relief; slopes 5° to 30°.	Well	Brunisolic Gray Luvisol	6	–	6	–	–	–	P-tA, tA-P-wB, wS-tA-wB in Zones 4, 5 and 6S; wS-wB, bS-wB in Zones 2 and 3.
					Orthic Gray Luvisol		–		6	–	–	
					Cryic Orthic Eutric Brunisol	–	–	–	–	6	6	
					Cryic Eutric Brunisol*	–	–	–	–			
				Poor	Rego Gleysol	4	–	–	–	–	–	bS-Fm-Er in Zone 6S; bS-Fm-Lichen-Er in Zones 4 and 5; bS-Lichen-Er in Zones 2 and 3.
					Cryic Rego Gleysol		–	4	4	4	4	
					Cryic Rego Gleysol*	–	–	–	–			
tMh	Hummocky moraine	Moderately to strongly calcareous glacial till.	Individual to coalescent hummocks; to 10m relief; slopes to 20°.	Well	Brunisolic Gray Luvisol	6	–	6	–	–	–	P-tA, tA-P-wB, wS-tA-wB in Zones 4, 5 and 6S; wS-wB, bS-wB in Zones 2 and 3.
					Orthic Gray Luvisol		–		6	–	–	
					Cryic Orthic Eutric Brunisol	–	–	–	–	6	6	
					Cryic Eutric Brunisol*	–	–	–	–			
				Poor	Rego Gleysol	4	–	–	–	–	–	bS-Fm-Er in Zone 6S; bS-Fm-Lichen-Er in Zones 4 and 5; bS-Lichen-Er in Zones 2 and 3.
					Cryic Rego Gleysol		–	4	4	4	4	
					Cryic Rego Gleysol*	–	–	–	–			
tMm	Subdued hummocky & rolling moraine	Moderately to strongly calcareous glacial till.	Subdued hummocks and rolling terrain; 5 to 30m relief; slopes 5-30°.	Well	Brunisolic Gray Luvisol	6	–	6	–	–	–	P-tA, tA-P-wB, wS-tA-wB in Zones 4, 5 and 6S; wS-wB, bS-wB in Zones 2, and 3.
					Orthic Gray Luvisol		–		6	–	–	
					Cryic Orthic Eutric Brunisol	–	–	–	–	6	6	
					Cryic Eutric Brunisol*	–	–	–	–			
				Poor	Rego Gleysol	4	–	–	–	–	–	bS-Fm-Er in Zone 6S; bS-Fm-Lichen-Er in Zones 4 and 5; bS-Lichen-Er in Zones 2 and 3.
					Cryic Rego Gleysol		–	4	4	4	4	
					Cryic Rego Gleysol*	–	–	–	–			
S	Debris avalanche; earthflow, mudflow flowslide and slumps deposits.	Material derived mainly from glaciolacustrine silts and clays, till and shale bedrock.	Debris avalanches commonly occur as thin narrow tongues; earth and mudflows as bulbous masses, and slump deposits as blocks.	Well	Cumulic Regosol	–	–	4	–	4	4	bS-wB-Wi-Fireweed or unvegetated in Zones 2, 3 and 5.
				Imperfect	Gleyed Cumulic Regosol	–	–	2	–	1	1	
				Poor	Rego Gleysol	–	–	4	–	5	5	Wi, bS-Wi in Zones 2, 3 and 5.
					Cryic Rego Gleysol	–	–	–	–			
R	Bedrock	Mainly Cretaceous shale, sandstone and silt-stone; and Paleozoic carbonate, shale and sandstone.	The bedrock crops out as ridges in Mackenzie and Franklin Mountains and as scarps along major rivers and plateaus.	Well	Lithic Orthic Regosol Lithic Eutric Brunisol	–	–	5	–	5	5	wS-Er, Er, Ws-Wi in Zones 2, 3 and 5.
				Imperfect	Gleyed Lithic Regosol Gleyed Lithic Eutric Brunisol	–	–	2	–	2	2	
				Poor	Lithic Rego Gleysol	–	–	3	–	3	3	bS-Sphagnum, Sphagnum-Er in Zones 2, 3 and 5.

Table 4 (cont'd)

+Map Symbol

Genetic

M - morainal
G - glaciofluvial
L - lacustrine
A - alluvial
C - colluvial
E - eolian
R - bedrock
F - earthflow
S - slump
O - organic

Morphologic Modifier
(placed behind genetic category)

p - plain
b - beach
r - ridged
v - veneer ($\leq$1.5m thick)
t - terraced
x - complex
s - striated (i.e., flutings)
d - drumlinoid
c - channelled
h - hummocky
k - kettled thermokarst

e - eroded
f - fan
m - rolling
j - jointed
g - ice gouged

Superscripts

shallow slope ($\leq 5°$)	1
steep slope ($>5° \leq 15°$)	2

Textural Modifier
(placed in front of genetic category)

g - gravel and/or sand
s - sand
si - silt
c - clay
r - rocks and rubble
b - boulders
t - till
p - peat
f - fen

N.B. - commas used between textural modifiers for distinct lithologies: e.g. t, g, siMp - mostly till with some minor sand and/or gravel and silt lenses.
- one textural modifier signifies the dominant material.
- slope is normally $>15°$ in Cx units.

Description of mapping units, parent material and topography compiled by Geological Survey of Canada.

++ Soils:

* soils influenced by cryoturbation

N.B.- all Gleysols have a peaty surface layer and are associated with a small amount of organic soils.
- soils developed on bedrock areas have the lithic contact from 10 to 50 cm below the mineral surface.

+++ Vegetation: species abbreviation

bS - black spruce (*Picea mariana*)
wS - white spruce (*Picea glauca*)
wB - white birch (*Betula neoalaskana*)
Bi - dwarf birch (*Betula glandulosa*)
tL - tamarack (*Larix laricina*)
Wi - willow (*Salix* sp.)
Al - alder (*Alnus* sp.)
tA - trembling aspen (*Populus tremuloides*)
bPo - balsam poplar (*Populus balsamifera*)
Sedge - *Carex* sp.
Cottongrass - *Eriophorum* sp.
Lichen - *Cladonia* sp., *Cetraria* sp.
Sphagnum - *Sphagnum* sp.
Er - *Ericaceae* (*Ledum*, *Chamaedaphne*, *Kalmia*, etc.)
Fm - Feathermosses
P - Pine - *Pinus banksiana* and *Pinus contorta* var. *latifolia*

8. DESCRIPTION OF SOILS

8.1. Organic Soils

8.11. Peat Materials

In the Mackenzie River area organic soils are associated with two peatland types: fens and bogs. A further subdivision of these peatlands was worked out by Tarnocai (1970) and Lavkulich (1972). The peat materials constituting these two peatlands show differences in their botanical origin, physical and chemical characteristics and ice content. The following peat materials were identified during the study:

A. Forest Peat

This type of peat material usually develops on slightly better drained sites of transitional bogs and well to imperfectly drained bogs (Tarnocai, 1970). This peat is derived primarily from black spruce-feathermoss-*Ledum*, black spruce-*Cladonia*-*Ledum*, and black spruce-tamarack-*Carex* types of vegetation. The forest peat is usually moderately decomposed (mesic), has a very dark brown to dark reddish-brown matrix, has an amorphous to very fine-fibered structure and may have a somewhat layered macro-structure. The material is non-sticky to slightly sticky and is interspersed with a random distribution of coarse to medium-sized woody fragments or particles of black spruce, tamarack and *Ledum* or other ericaceous shrubs, roots, stems and needles or leaves. The moss component is also important and is derived from the feathermoss group (*Ptilium crista-castrensis*, *Dicranum rugosum*, *Pleurozium shrebery*, and *Hylocomium splendens*). On the dryer, perennially frozen peatland types, lichens (*Cladonia* sp.) become dominant and the resultant peat material is dark brown to black in color and moderately well decomposed with the fibers being composed mainly of the woody materials of stems and very fine roots. The unrubbed fiber content (particles less than 0.15 mm thick) of the forest peat material is about 60 percent and is usually base saturated, medium acid to neutral (pH 5.9 to 7.3). The matrix is fairly dense; the bulk density is usually greater than 0.1 gm/cm^3 and becomes greater with increasing depth. Three subtypes of forest peats were separated, based on the dominance of the plant material, and these are:

A.1: Woody-Forest Peat

A.2: Feather Moss-Forest Peat

A.3: Cladonia-Forest Peat

B. Sphagnum Peat

This type of peat material develops on very wet to wet bogs (Tarnocai, 1970). This peat material is primarily derived from stunted black spruce-*Sphagnum*-*Ledum*, *Sphagnum*-*Ledum* and *Sphagnum* types of vegetation. The dominant peat-former among these vegetation types is *Sphagnum* with minor components of feathermosses and stems and leaves of ericaceous shrubs. This peat material may contain woody intrusive materials such as roots and stems of black spruce. Sphagnum peat is usually undecomposed (fibric), light yellowish-brown to very pale brown in color and loose and spongy in consistency with the entire *Sphagnum* plant being readily identified. The unrubbed fiber content is approximately 95 percent and the peat is extremely acid (pH $<$ 4.5). The bulk density is usually less than 0.1 gm/cm^3. Two subtypes of sphagnum peat were separated, based on the dominant species, and these are:

B.1: Sphagnum (*riparium*) Peat

B.2: Sphagnum (*fuscum*) Peat

C. Fen Peat

This type of peat material occurs on very wet fens (Tarnocai, 1970). The peat material is derived primarily from Carex, Carex-Drepanocladus, Carex-Betula or Salix and Carex-tamarack types of vegetation. The dominant peat-formers among these vegetation types are Carex sp., Drepanocladus moss and tamarack. Fen peat is usually moderately well decomposed (mesic), dark brown to very dark brown, and the fibers are fine to medium with a horizontally matted or layered structure. Fen peat is non-sticky to slightly sticky; the unrubbed fiber content is approximately 40 to 60 percent; and the peat is medium acid to neutral (pH 5.6 to 7.3). The moderately well decomposed material is fairly dense (bulk density greater than 0.1 gm/cm^3). Three subtypes of fen peat were separated, based on the dominance of the plant material, and these are:

C.1: Carex - Fen Peat

C.2: Drepanocladus - Fen Peat

C.3: Woody - Fen Peat

D. Aquatic Peat

This type of peat material usually develops on very wet sites in shallow lakes and ponds. The peat is primarily derived from various aquatic mosses, plants and algae. The material is slightly sticky, dark brown to black in color and is usually well decomposed (humic) (unrubbed fiber content less than 30 percent). Aquatic peat is usually found at the bottom of the peat deposits.

E. Mixed Peat

This type of peat material is found in collapsed areas where, due to the melting of permafrost, the peat banks are eroding and slumping into a water saturated area. During this process extensive mixing of the different peat layers takes place resulting in a peat deposit where two or more peat types are usually intermixed.

8.12. Accumulation of Peat Materials

A deposit of White River volcanic ash ranging in thickness from a few millimeters to several centimeters was found in the peat materials in the Upper Mackenzie River Basin. The eastern lobe of this volcanic ash, which occurred in the Upper Mackenzie River Basin, was dated 1460 ± 70 and 1390 ± 70 by Stuiver et al (1964) for peat samples taken immediately above and immediately below the ash, respectively, and 1200 ± 140 by Lowdon and Blake (1968) for peat just beneath the ash deposit.

For calculation of the accumulation of different peat materials an age of 1500 years B.P. was assumed for the ash, as suggested by Lerbekmo and Campbell (1969). The peat material was identified and the depth measured above the ash layer in several locations. The rate of accumulation, according to different peat materials, is shown in Table 5.

Table 5. Rate of Accumulation of Peat Materials

Peat Materials	No. of observations	Range Depth to Ash cm.	Mean Depth cm.	Accumulation per 100 years cm.
Forest Peat				
Cladonia forest peat	3	2 - 5	3.6	0.24
Feathermoss forest peat	9	35 - 40	38.1	2.54
Ericaceous woody forest peat	1		13	0.87
Sphagnum Peat				
Sphagnum (f) peat	7	30.5-61	44.1	2.94
Sphagnum (r) peat	1		104	6.93
Fen Peat				
Carex fen peat	5	19 - 24	22	1.47

8.13. Chemical Composition of Water

Water samples were collected mainly from wetlands to determine the relationship between the chemical composition of water and the peatland types (see Appendix II).

The fens (spring fen, patterned fen, flat fen) show the highest amounts of cations and anions and the highest pH of all the peatland types. This is especially so for the sample collected from a spring fen (discharge area, sample 101) which shows total cations of 96.6 ppm and total anions of 406.6 ppm. This peatland type is rich in nutrients and is minerotrophic, receiving almost all of its water from neighboring mineral soils. On the other hand, water samples from bog types of peatlands (bog plateau, peat polygon, collapse scar) show much lower amounts of cations and a lower pH than do the waters from fens.

Here, water samples from a polygonal trench (sample 102) provided the lowest amounts of cations, 1.5 ppm, and only a trace of anions. The associated pH (pH 3.9) was the lowest of all the peatlands, thus indicating a highly ombrotrophic environment receiving most of its water from precipitation.

The other wetland types (water tracks, swamps and small lakes and streams) show minerótrophic conditions, except for the small lakes and streams. These two waters received most of their water supply as a result of run-off from surrounding peat plateaus and thus their nutrient content is relatively lower than that of lakes and streams supplied by waters from mineral soils.

Two mineral springs were also sampled: the hot spring is located on the west side of Roche-qui-Trempe-a-l'Eau Mountain (sample 106) and the cool mineral spring (sample 117) is located in the Canyon Range, Dahadinni River map sheet. Both waters show high amounts of cations and anions when compared to waters from other wetland types with waters from the hot spring being by far the highest of all samples.

8.14. Description of Organic Soils

Organic soils have developed from the foregoing peat types. The classification of these organic soils is based on the use of one of the following two control sections: either from the surface to 130 cm when the surface materials are moderately decomposed (mesic) or shallow undecomposed peat (less than 60 cm) or to 160 cm when the surface peat is undecomposed (fibric) peat greater than 60 cm deep. The control section is divided into three tiers: the surface, middle, and bottom tiers (see The System of Soil Classification for Canada, 1970). If the mineral contact lies below the middle tier the classification is based on the peat material found in the middle tier or, if the mineral contact occurs in the middle tier, the classification is based on the dominant peat material in the middle and surface tiers. Using this classification system, two dominant Great Groups of organic soils were found in the study area: the Mesisols and the Fibrisols.

8.141. Mesisols

These organic soils have developed dominantly from mesic fen and/or forest peat materials. They are dominated by a mesic middle tier or middle and surface tiers if the mineral contact occurs in the middle tier. Three groups of Mesisolic soils were separated in the study area, based on the type of peat parent materials and the associated peat landforms. The descriptions of these groups are as follows:

Mesisols developed dominantly from fen peat material. These soils are associated with fens (Plate 1A) as mapped in the area.

Profile T 15B   Typic Mesisol (Figure 3 & Appendix I: Table 1)

Om- 0 to 130 cm, black (10YR 2/1, moist), moderately decomposed carex fen peat; layered; medium acid; unrubbed fiber content 60 percent; clear, wavy boundary.

IICg- 130+ cm, greenish-gray (5GY 5/1, moist), clay loam; amorphous; firm when moist, hard when dry; very sticky and plastic.

Profile T 36B   Typic Mesisol (Figure 3 & Appendix I: Table 1)

Of-   0 to 40 cm, dark brown (10YR 3/3, moist), undecomposed Drepanocladus fen peat; loose; mildly alkaline; unrubbed fiber content 92 percent; gradual, wavy boundary.

Om-   40 to 220 cm, black (10YR 2/1, moist), moderately decomposed carex and woody fen peat; layered; medium acid; unrubbed fiber content 50 percent; clear, wavy boundary.

IICg-   220 to 250 cm, medium to fine sand.

Profile T 44   Terric Humic Mesisol (Appendix I: Table 1)

Om-   0 to 22 cm, black (10YR 2/1, moist), moderately well decomposed carex fen peat; matted; neutral; unrubbed fiber content 34 percent; 20 mm thick layer of volcanic ash at the bottom of this layer; clear, wavy boundary.

Oh-   22 to 42 cm, black (10YR 2/1, moist), well decomposed carex fen peat; somewhat layered; slightly acid; unrubbed fiber content 28 percent; clear, wavy boundary.

IICg-   42+ cm, gravelly till.

Mesisols developed from fen and/or forest peat materials. These soils are associated with perennially frozen bogs (wooded peat plateaus, palsas and peat polygons) and are mapped as bogs in the area (see Plate 1A).

Profile T 36C   Cryic Mesisol (Figure 3 & Appendix I: Table 2)

Of-   0 to 56 cm, dark grayish-brown (10YR 4/2, moist), undecomposed sphagnum peat (dominantly _Sphagnum fuscum_); loose; extremely acid; unrubbed fiber content 92 percent; clear, wavy boundary.

Omz-   56 to 255 cm, black (10YR 2/1, moist), frozen, moderately well decomposed carex fen peat; layered; strongly acid; unrubbed fiber content 34 percent; vein ice and ice lenses are common; ice content approximately 65%; clear, wavy boundary.

IICgz-   255 to 280 cm, frozen sand.

Profile T5A Cryic Mesisol (Figure 8, Appendix I: Table 2 & Plate 1B)

Om- 0 to 22 cm, dark red (2.5YR 2/4, moist), moderately decomposed Cladonia forest peat with a significant amount of sphagnum peat; loose; extremely acid; unrubbed fiber content 56 percent; clear, wavy boundary.

Of- 22 to 45 cm, dark yellowish-brown (10YR 4/4, moist), partly frozen (seasonal frost), undecomposed sphagnum peat; extremely acid; unrubbed fiber content 92 percent; gradual, wavy boundary.

Omz_1- 45 to 256 cm, dark yellowish-brown (10YR 4/4, moist), frozen, moderately decomposed Carex fen peat mixed with sphagnum peat; extremely acid; unrubbed fiber content 56 percent; segregated ice crystals and some vein ice; ice content approximately 60 percent; gradual, wavy boundary.

Omz_2- 256 to 265 cm, very dark brown (10YR 2/2, moist), frozen, moderately decomposed carex fen peat; very strongly acid; unrubbed fiber content 54 percent; ice lenses 4 to 5 mm thick; ice content approximately 75 percent; clear, wavy boundary.

IICgz- 265 to 300 cm, dark grayish-brown (2Y 4/2, moist), frozen, silt loam; amorphous; firm when moist, hard when dry; sticky and plastic; very strongly acid; ice lenses 5 to 10 mm thick in the upper portion and 60 to 100 mm thick in the lower portion of this layer; ice content approximately 40 percent in the upper portion and 80 percent in the lower portion.

Profile T 35B Cryic Mesisol (Figure 4 & Appendix I: Table 3)

Of- 0 to 18 cm, very dark gray (5Y 3/1, moist), undecomposed sphagnum peat; loose; extremely acid; unrubbed fiber content 88 percent; clear, wavy boundary.

Omz- 18 to 57 cm, black (5Y 2/2, moist), frozen, moderately decomposed fen peat with layers of sphagnum peat; matted; extremely acid; unrubbed fiber content 48 percent; medium to coarse disseminated ice; ice veins up to 10 mm thick; ice content approximately 75 percent; clear, wavy boundary.

Ice- 57 to 164 cm, pure ice from the buried ice wedge.

IICgz- 164 to 170 cm, frozen, silty clay till.

A. Patterned fen and string fen surrounded by peat plateaus in the north-east portion of the Bulmer map sheet. The string fen area (middle of the photograph) is unfrozen and dominated by Typic Mesisol. On the peat plateaus (lower and upper portions of the photograph) Cryic Mesisol and Cryic Fibrisol occur.

B. Young palsa developed in a collapse scar area surrounded by peat plateaus, site T5B, Sibbeston Lake map sheet.

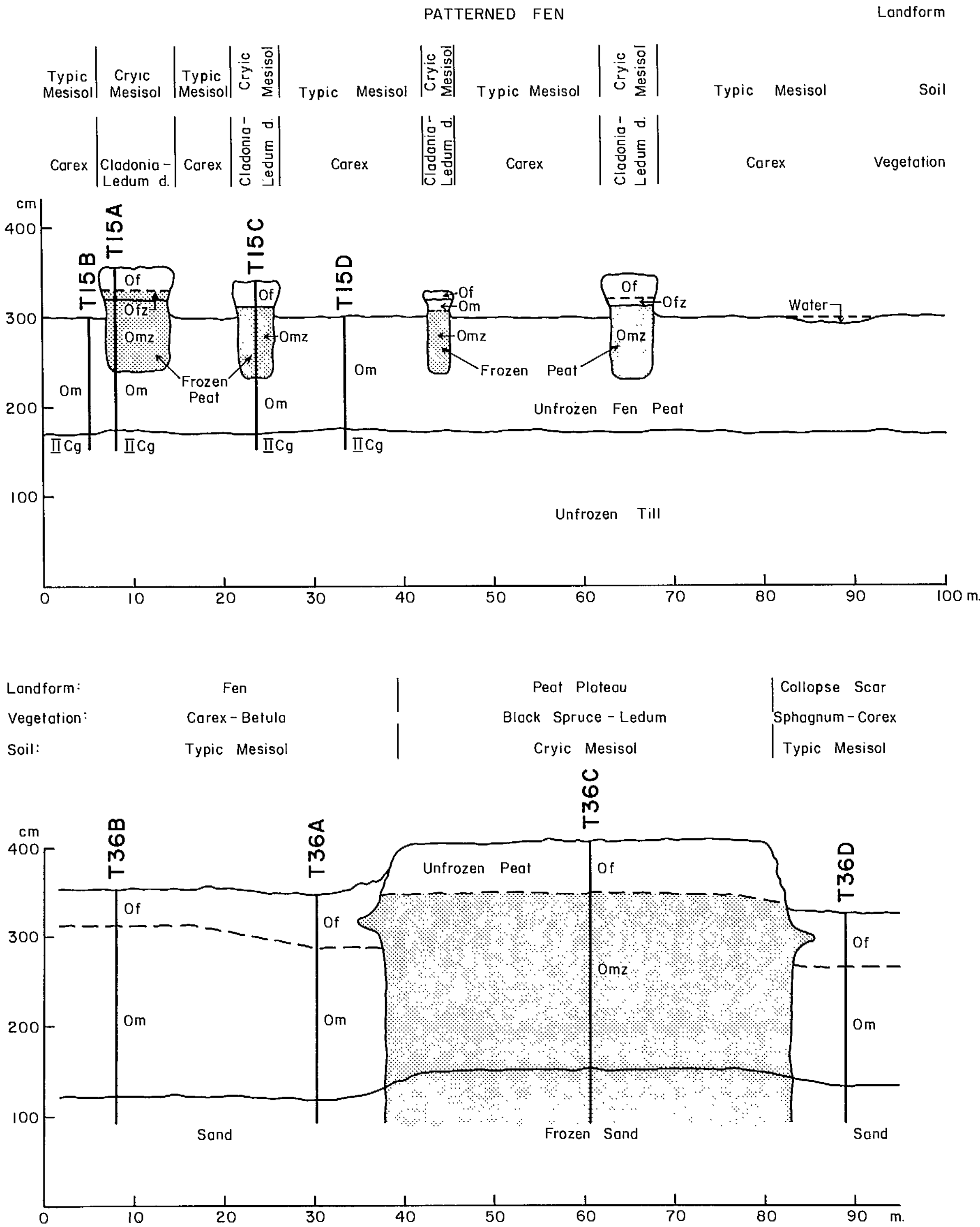


Figure 3. Cross-section of a patterned fen (site T15) and a peat plateau-fen area (site T36).

Mesisols developed dominantly from sphagnum (_riparium_) peat which is usually underlain by mixed peat materials. These soils are associated with collapse scar areas and are mapped as bog and fen complexes.

Profile T 36D Typic Mesisol (Figure 3 & Appendix I: Table 3)

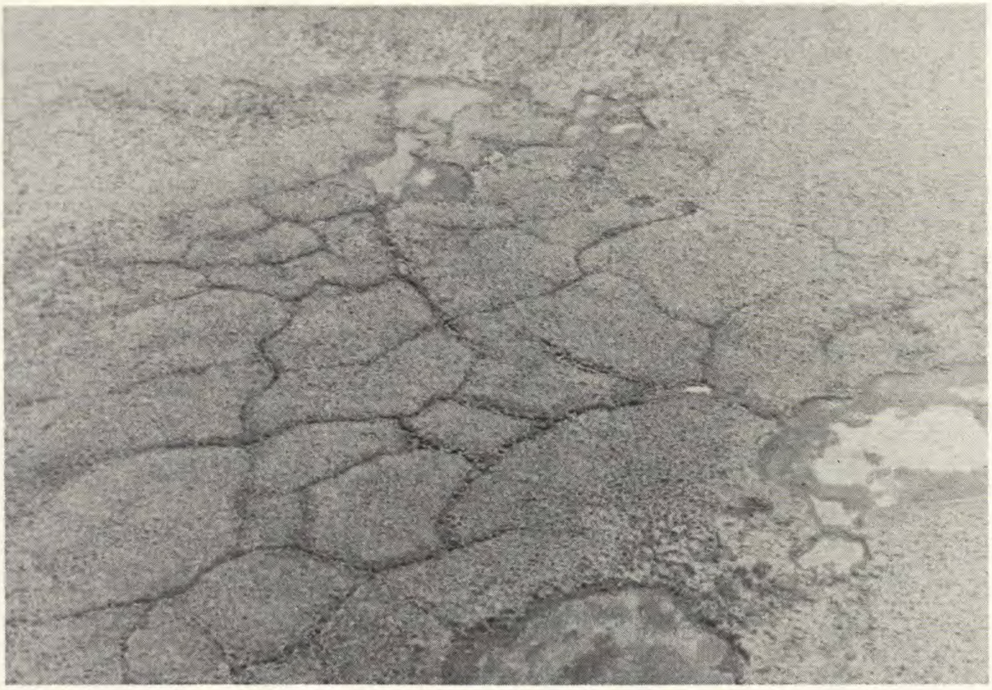
Of- 0 to 60 cm, yellowish-brown (10YR 5/4, moist), undecomposed sphagnum peat; loose; extremely acid; unrubbed fiber content 92 percent; clear, wavy boundary.

Om- 60 to 185 cm, black (10YR 2/1, moist), moderately well decomposed mixed peat; amorphous; strongly acid; unrubbed fiber content 34 percent; clear, wavy boundary.

IICg- 185+ cm, medium to fine sand.

Vegetation: Mesisols associated with fen type peatlands (see Figure 3) are either covered with very open stands of stunted tamarack or are completely devoid of tree cover. The shrub layer is dominated by _Betula glandulosa_, _Chamaedaphne calyculata_ while smaller amounts of _Salix_ sp. and _Potentilla fruticosa_, are also present. The herb layer is dominated by _Carex_ sp. and _Eriophorum spissum_ and the moss layer is dominated by _Drepanocladus_ sp. with _Sphagnum_ spp. also being present occasionally.

The vegetation on the perennially frozen peatlands (see Figures 3 and 4), with the exception of peat polygons, is composed of a black spruce dominated tree layer. In the shrub layer _Ledum groenlandicum_, _L. decumbens_, _Empetrum nigrum_, _Rubus chamaemorus_, _Oxycoccus microcarpus_ and _Kalmia polifolia_ are the most common species. The moss and the lichen layer is dominated by _Sphagnum fuscum_, _Dichranum undulatum_, _Polytrichum_ sp., _Cladonia alpestris_, _C. rangiferina_ and _C. cornuta_. The vegetation on the wooded peat plateaus and wooded palsas in



A. Peat polygons, site T35 east of the Cap Mountain area. The vegetation is dominantly lichens (75 percent cover) and Ericaceous shrubs.

B. Top of an active ice wedge in a peat polygon, site T35C. Note that the volcanic ash layer is continuous over the top of the ice wedge.

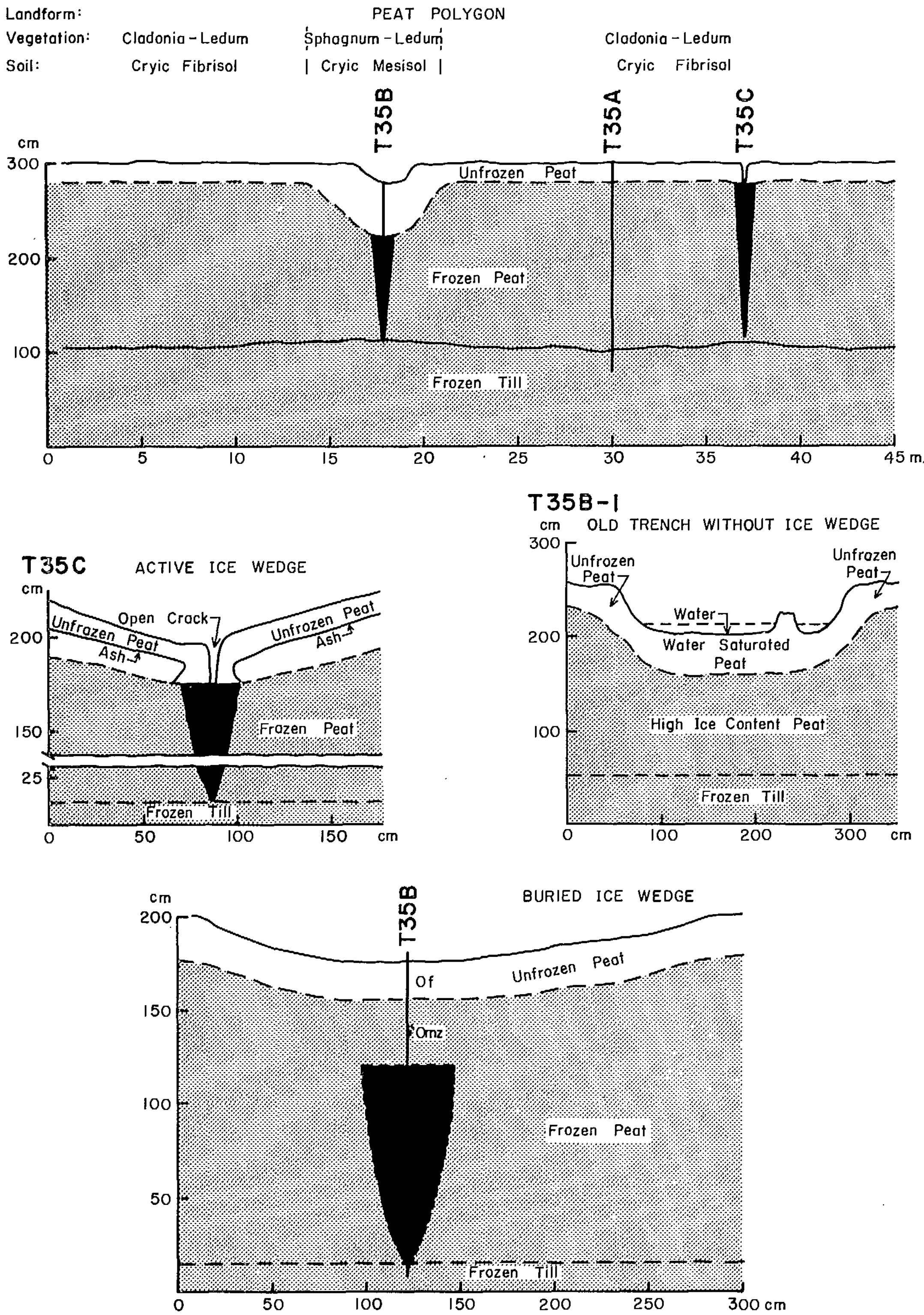


Figure 4. Cross-section of a peat polygon (site T36) showing the sample sites and detailed cross-section of them. Site T35B-1 is a detailed cross-section located 20 feet behind site T35B.

A. Vegetation on a peat polygon, site T35C (Cladonia alpestris, Ledum decumbens and Rubus chamaemorus). Note the crack in the lower middle of the photograph, indicating an active ice wedge below.

B. Close-up of the vertical cross-section of the ice wedge at site T35C. Note the bubbles and bubble trails fanning out from the centre of the wedge.

Zone 6S is typical of the black spruce-feathermoss-Ledum groenlandicum type. In Zones 4, 5 and 6N the black spruce is more open and the lichen cover becomes dominant with both _Ledum_ sp. being present. In Zones 2 and 3 these peatlands are covered with a very open black spruce-lichen-Ledum decumbens type of vegetation.

The vegetation on the Mesisols associated with peat polygons (see Figure 4) is dominantly _Cladonia_ _alpestris_ (approximately 75 percent cover) and _C. rangiferina_ with clumps of _Ledum_ _decumbens_ and _Empetrum_ _nigrum_ also being present. _Dichranum_ sp. and _Sphagnum_ sp. represent the mosses, the latter being dominant in the moist polygonal trenches (see Plate 2A and Plate 3A).

Physical and Chemical Characteristics: The fiber content of Mesisols (see Appendix I: Tables 1 to 3) developed from fen peat materials is moderately to moderately well decomposed with the exception of Drepanocladus fen peat which is undecomposed. Those developed from forest peat materials are moderately decomposed with various amounts of wood present. The pH of these soils varies greatly, reflecting the chemistry of the peat parent material. Mesisols developed from fen peats are medium acid to mildly alkaline (pH 5.6 to 7.5). The surface layer of the soil has a higher pH (neutral to mildly alkaline) and the pH decreases with depth to become medium to slightly acid. On the other hand, Mesisols developed from forest peat materials range from extremely acid to strongly acid. Here, the surface layer of the soil is more acid and the acidity decreases with depth. This is due partly to the thin sphagnum peat surface layer which has a low pH and partly to the fact that most of these soils are perennially frozen. Water migration into the frozen core increases the nutrient content, especially the Ca and Mg content, thus resulting in a slightly higher pH (Tarnocai, 1972).

Soil Temperature: Correlation of all of the soil temperatures is difficult because they were obtained at various times during the summer. Soil temperatures taken at one site, however, provide some information about the thermal properties of organic soils associated with certain peatland types.

In general, the surface (2.5 cm depth) temperature of organic soils is either the same as or just slightly lower than the air temperature (see Table 6). At two sites (T36B and T15A) the surface temperature of the organic soil was found to be slightly higher than the air temperature. Temperatures taken at site T36 (Kakisa Lake area) show that the soil temperatures of the collapsed peatland area (site T36D) were significantly lower than that of the fens. The soil temperature of the peat plateau (site T36C), below the 5 cm depth, was found to be the lowest of all sites of T36.

Table 6. Soil temperatures of sites T36 and T15.

Site No.	Date	Time of Day	Air Atmos. Temp. °C	Soil Temperature °C Depth (cm.)					
				2.5	5	10	20	50	100
T36A	Aug. 5	1250	19	20	14.5	13.5	13.0	11.5	8.5
T36B		1255	20	21	17	13.5	13.0	13	11
T36C		1225	22	20	14.5	8	5.5	2	0
T36D		1230	20	19.5	14.0	11.5	11.0	9.5	6
T15A	June 23	1200	24	30	16	13	8	0	0
T15B		1210	24	22	16	12	8	1	1

The soil temperature of the perennially frozen peat layers was found to be 0°C. This agrees with the results of soil temperatures taken in northern Manitoba under similar conditions.

Ice Content: Mesisols have developed in a wet environment and thus, in the perennially frozen state, they are always associated with high amounts of ice. The ice is generally found to be in the form of segregated ice crystals, vein ice, and small ice lenses (see Plate 4A). These soils, in areas of widespread permafrost, are sometimes associated with pure ice bodies in the form of ice layers or ice wedges.

The ice content usually ranges between 60 percent and 80 percent on a volume basis in Mesisols associated with peat plateaus and palsas (Figures 5 and 6). On the other hand, some peatlands around the Wrigley area (site T29B) are higher in ice and a layer or layers of pure ice are found (Figure 6). Mesisols associated with peat polygons are higher in ice content than those associated with palsas and peat plateaus. Here, large amounts of ice are found in the form of active and buried ice wedges (Figure 5 and Plates 2B and 3B).

The underlying fine-textured till material usually has the same amount of ice as the frozen peat layer (Figure 6, T29B). The ice here, however, is mainly of the thicker ice lens and vein ice types (see Plate 4B). This is reflected in the doming of these perennially frozen areas. The cross-section shows that the doming is mainly the result of the more extensive ice lens and vein ice formation in the underlying mineral material and to a lesser extent to the high ice content frozen peat whose ice is mainly in the form of ice

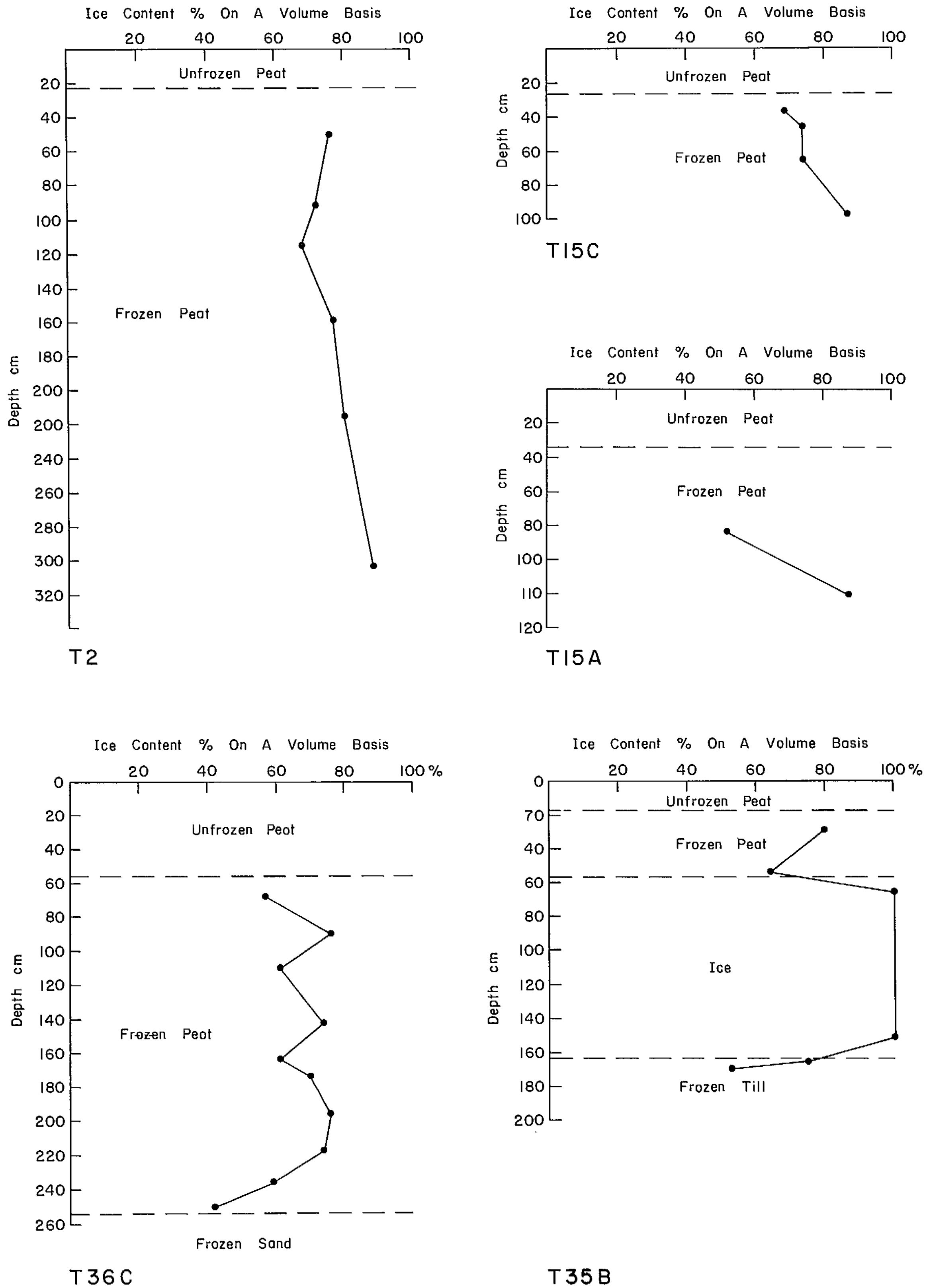


Figure 5. Ice content of Cryic Mesisols. Sites T2, T15A, T15C and T36C are located on a peat plateau while site T35B is located in a peat polygon trench.

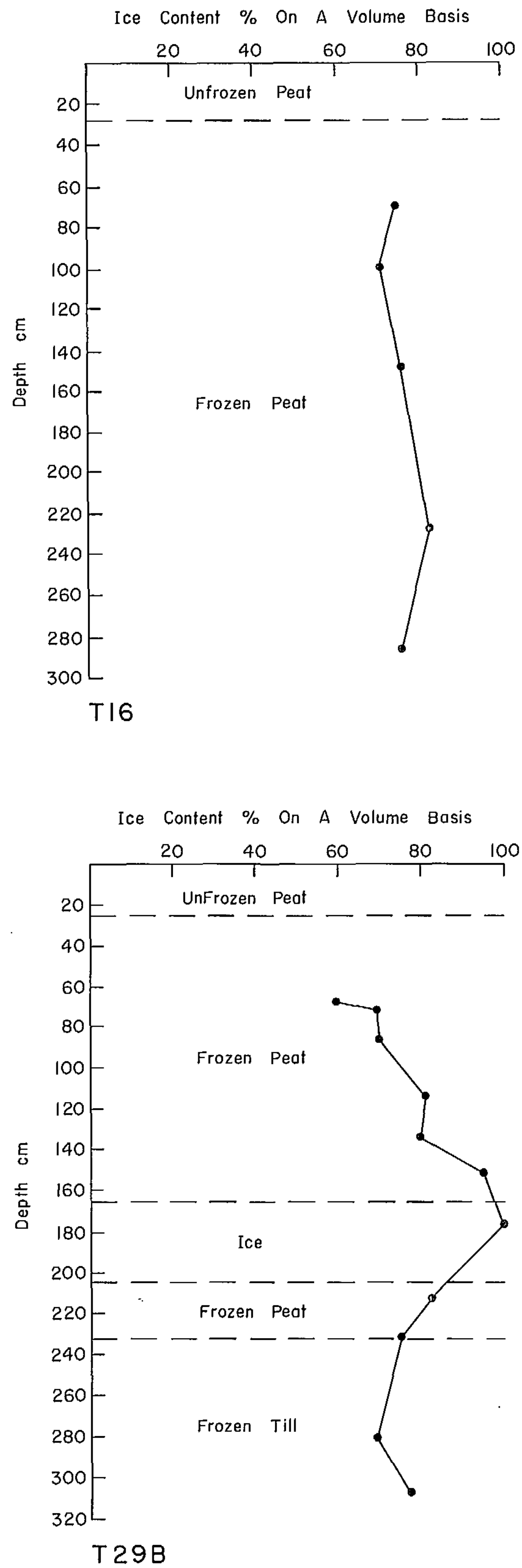


Figure 6. Ice content of Cryic Mesisols located on a peat plateau (T16) and on a wooded palsa (T29B).

crystals and thin vein ice. This has been discussed in the work by Zoltai and Tarnocai (1971) concerning palsas in northern Manitoba.

8.1.4.2. Fibrisols

These organic soils have developed dominantly from fibric sphagnum and forest peat materials. They are dominated by a fibric middle tier, or middle and surface tiers if the mineral contact occurs in the control section (above 160 cm).

Two groups of Fibrisols were separated in the study area, based on the type of parent peat materials and the associated peat landforms. The descriptions of these groups are as follows:

Fibrisols developed from sphagnum peat materials. These soils are associated with perennially frozen bogs (wooded peat plateaus, palsas and peat polygons) and are mapped as bogs in the area (Plate 2A and Plate 1B).

Profile T28A   Cryic Fibrisol (Figure 7 & Appendix I: Table 4)

Of- 0 to 31 cm, grayish-brown (10YR 5/2, moist), undecomposed sphagnum peat (dominantly Sphagnum fuscum); loose; extremely acid; unrubbed fiber content 98 percent; clear, wavy boundary.

Ofz_1- 31 to 83 cm, very dark grayish-brown (10YR 3/2, moist), undecomposed, frozen, sphagnum peat; layer of charcoal at 57 cm depth; 2 cm thick volcanic ash layer at 61 cm depth; extremely acid; unrubbed fiber content 76 percent; segregated ice crystals; ice content approximately 65 percent; clear, wavy boundary.

Ofz_2- 83 to 112 cm, black (10YR 2/1, moist), undecomposed, frozen Drepanocladus fen peat; extremely acid; unrubbed fiber content 64 percent; segregated ice crystals and vein ice; ice content approximately 70 percent; clear, wavy boundary.

IICgz- 112 to 123 cm, dark gray (5Y 4/1, moist), frozen clay till; amorphous; firm when moist, hard when dry; sticky and plastic; very strongly acid; ice lenses and vein ice; ice content approximately 45 percent.

Profile T35A Cryic Fibrisol (Figure 4 & Appendix I: Table 4)

Of- 0 to 23 cm, very dark gray (5Y 3/1, moist), undecomposed sphagnum peat (dominantly Sphagnum and Dichranum mosses); loose; extremely acid; unrubbed fiber content 76 percent; 1 cm thick volcanic ash at 23 cm depth; clear, wavy boundary.

Ofz_1- 23 to 79 cm, black (10YR 2/1, moist), moderately decomposed, frozen, sphagnum peat; extremely acid; ice crystals and some vein ice; ice content approximately 65 percent; unrubbed fiber content 67 percent; gradual, wavy boundary.

Ofz_2- 79 to 140 cm, black (10YR 2/1, moist), moderately decomposed, frozen sphagnum peat; extremely acid; ice crystals and vein ice; ice content approximately 70 percent; fiber content 65 percent; clear, wavy boundary.

Ofz_3- 140 to 200 cm, black (10YR 2/1, moist), moderately decomposed, frozen Drepanocladus fen peat; extremely acid; ice crystals and vein ice; ice content approximately 70 percent; unrubbed fiber content 68 percent; clear, wavy boundary.

IICgz- 200 to 257 cm, dark greenish-gray (5GY 4/1, moist), frozen, clay loam; neutral; 5 to 10 cm thick layers of vein ice; ice content approximately 75 percent.

Profile T27C Cryic Fibrisol (Appendix I: Table 5)

Of- 0 to 25 cm, dark brown (10YR 3/3, moist), undecomposed sphagnum peat (dominantly Sphagnum and Dichranum mosses); loose; extremely acid; unrubbed fiber content 84 percent; clear, wavy boundary.

Ofz_1- 25 to 119 cm, dark brown (10YR 3/3, moist), undecomposed frozen sphagnum peat; extremely acid; ice crystals; ice content approximately 65 percent; unrubbed fiber content 88 percent; gradual, wavy boundary.

Ofz_2- 119 to 212 cm, very dark grayish-brown (10YR 3/2, moist), undecomposed frozen sphagnum peat; ice crystals; ice content approximately 65 percent; unrubbed fiber content 78 percent; gradual, wavy boundary.

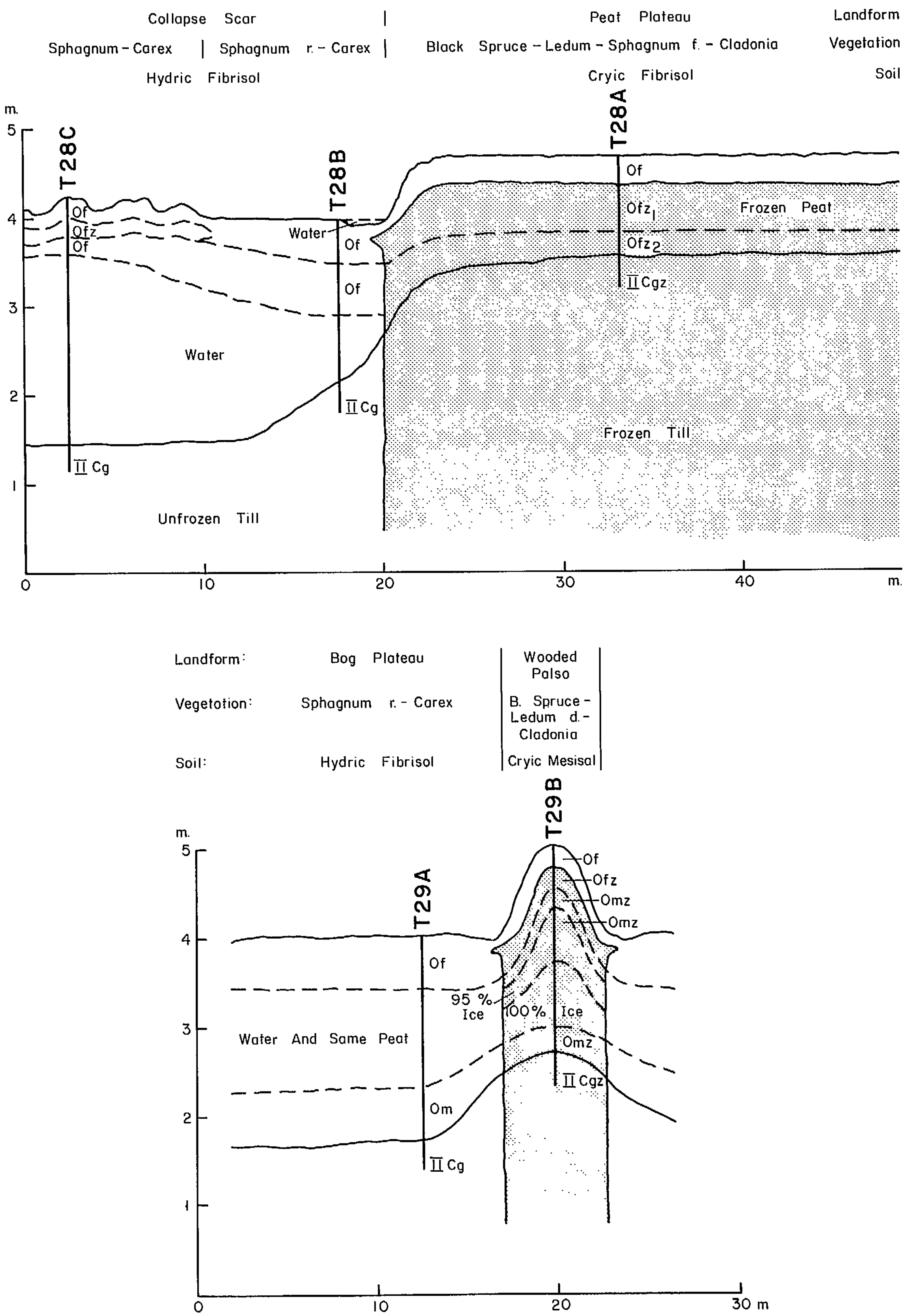


Figure 7. Cross-section of a peat plateau-collapse scar area (site T28) and of a high ice content wooded palsa-bog plateau area.

Ofz_3- 212 to 260 cm, black (10YR 2/1, moist), undecomposed frozen Drepanocladus fen peat; ice crystals and vein ice; ice content approximately 75 percent; unrubbed fiber content 72 percent; clear, wavy boundary.

IICgz- 260 to 290 cm, dark gray (5Y 4/1, moist); frozen, clay loam; medium acid; ice content approximately 75 percent.

Fibrisols developed from sphagnum peat or undecomposed Drepanocladus-fen peat materials. These soils are associated with unfrozen bogs and fens and are mapped as bogs or bog-fen complexes. The most common organic soil associated with these peatlands is Typic Fibrisol.

Vegetation: The vegetation on the perennially frozen Fibrisols, which are found on peat plateaus and palsas (Figures 7 and 8), is dominated by a stunted black spruce tree layer. The shrub layer is dominated by *Ledum groenlandicum*, *L. decumbens*, *Empetrum nigrum*, *Rubus chamaemorus* and *Oxycoccus microcarpus*. The moss layer is dominated by *Sphagnum fuscum* but some of the feathermoss species are also present. The most common lichen species are *Cladonia alpestris*, *C. rangiferina* and *C. cornuta*.

Here again, the tree cover on the peat plateaus and palsas found in Zone 6S is moderately dense black spruce. Further north, in Zones 4, 5 and 6N, the black spruce is more open and lichen cover becomes dominant. In the northern portions of the study area (Zones 2 and 3) these peatlands are covered with a very open black spruce-lichen type of vegetation.

The vegetation on Fibrisols associated with peat polygons is

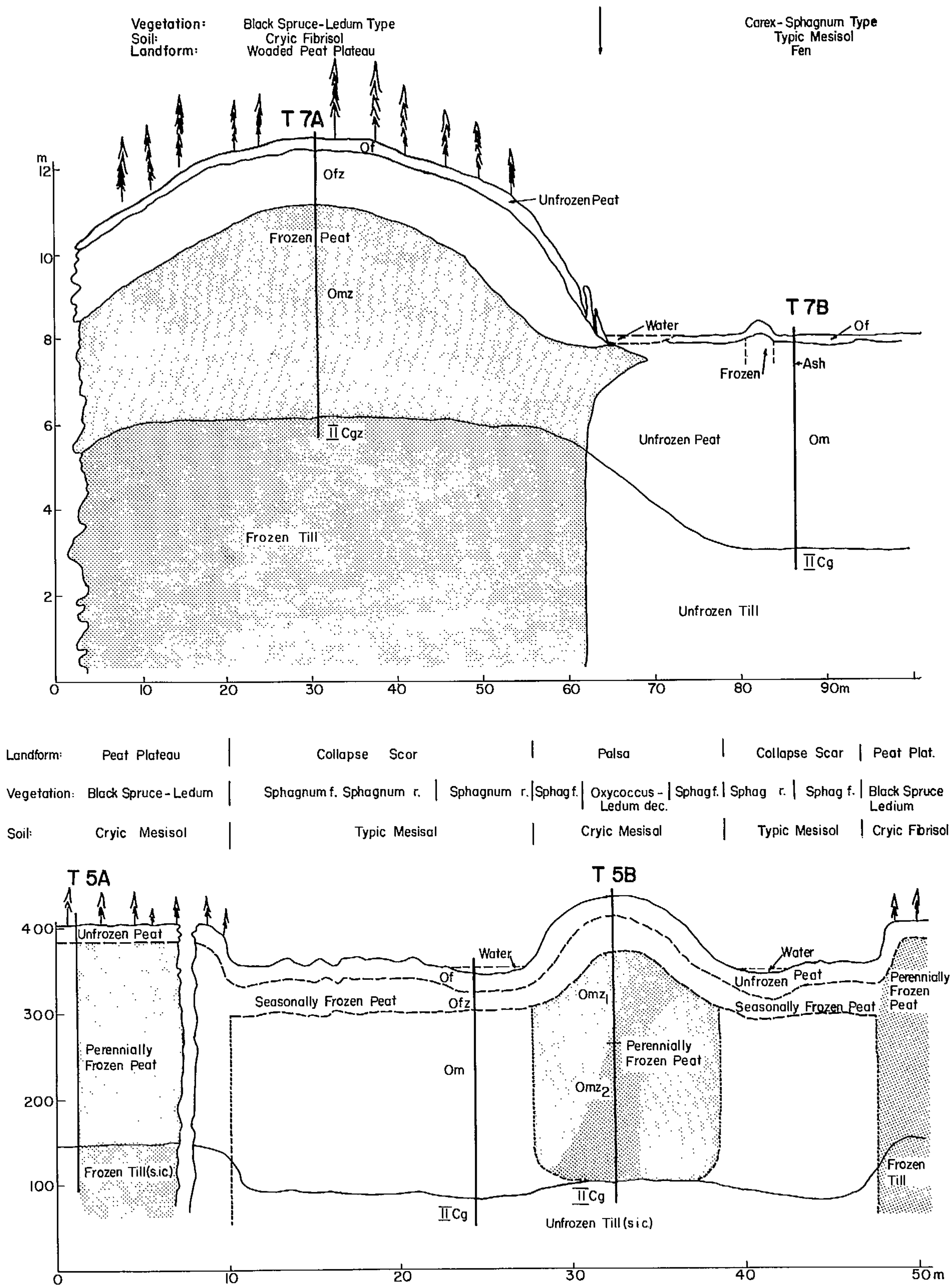


Figure 8. Cross-section of a wooded palsa-fen area (site T7) and of a peat plateau-collapse scar area with a young palsa (site T5).

dominantly the lichens Cladonia alpestris and C. rangiferina with clumps of Ledum decumbens and Rubus chamaemorus also being present (see Plate 2A and Plate 3A).

Physical and Chemical Characteristics: Fibrisols have developed mainly from undecomposed sphagnum peat, thus the fiber content is generally high. The pH of the unfrozen surface peat layer is extremely low (pH 2.5); the pH, however, increases in the frozen peat layer. This is partly due to water migration into the frozen peat increasing the nutrient content, especially the Ca and Mg content (see Appendix I: Tables 4 and 5).

Soil Temperature: The surface (2.5 cm depth) soil temperature was found to be the same as or slightly lower than the air temperature (Table 7). Temperatures were taken on peat polygons at two locations: T27 on the Horn Plateau and T35A in the Wrigley area on the east side of the Franklin Mountains. Site T35A was found to be cooler than site T27 in spite of the fact that the temperature at site T27 was measured fifteen days earlier than that at site T35A.

From a comparison of the two sites located in the Wrigley area it can be seen that the temperatures of the surface peat (0 to 10 cm) of T28A (peat plateau) and T28B (collapse scar) are very similar. The temperature of the surface layer of the peat plateau is slightly higher than that of the collapse scar. This is probably the result of the dryness of the surface layer of unfrozen peat on the slightly elevated plateaus (moisture content is 25 percent or less on a volume basis). On the other hand, the peat occurring on the collapse scar areas is water saturated. The temperature of the frozen peat was found to be 0°C and the soil in the collapse scar area was found to be a relatively cool 5°C at a depth of 100 cm.

Table 7. Soil temperatures at sites T27, T28 and T35A

Site No.	Date 1972	Time of Day	Air Atmos. Temp. °C	Soil Temperature °C Depth (cm.)					
				2.5	5	10	20	50	100
T27	June 28	1600	21	18	16	10	2	0	0
T28A	July 8	1150	18	18	16	14	10	0	0
T28B	July 8	1200	18	16	15	14.5	13.5	10	5
T35A	July 13	1515	28	28	15	6.5	0	0	0

Ice Content: The ice content of Fibrisols associated with peat plateaus varies from 60 percent to 80 percent approximately, on a volume basis (Figure 9). Fibrisols associated with peat polygons show a slightly higher ice content than do those associated with other perennially frozen peatlands. This is especially so at site T27C (Figure 9), a peat polygon located on the Horn Plateau, which has an ice content higher than 80 percent. Site T35A (Figure 9), also a peat polygon located on the east side of the Franklin Mountains, shows moderate amounts of ice in the profile but here large amounts of ice are found in the form of ice wedges. The ice content of the underlying mineral material varies greatly (45%-70%) with large amounts of

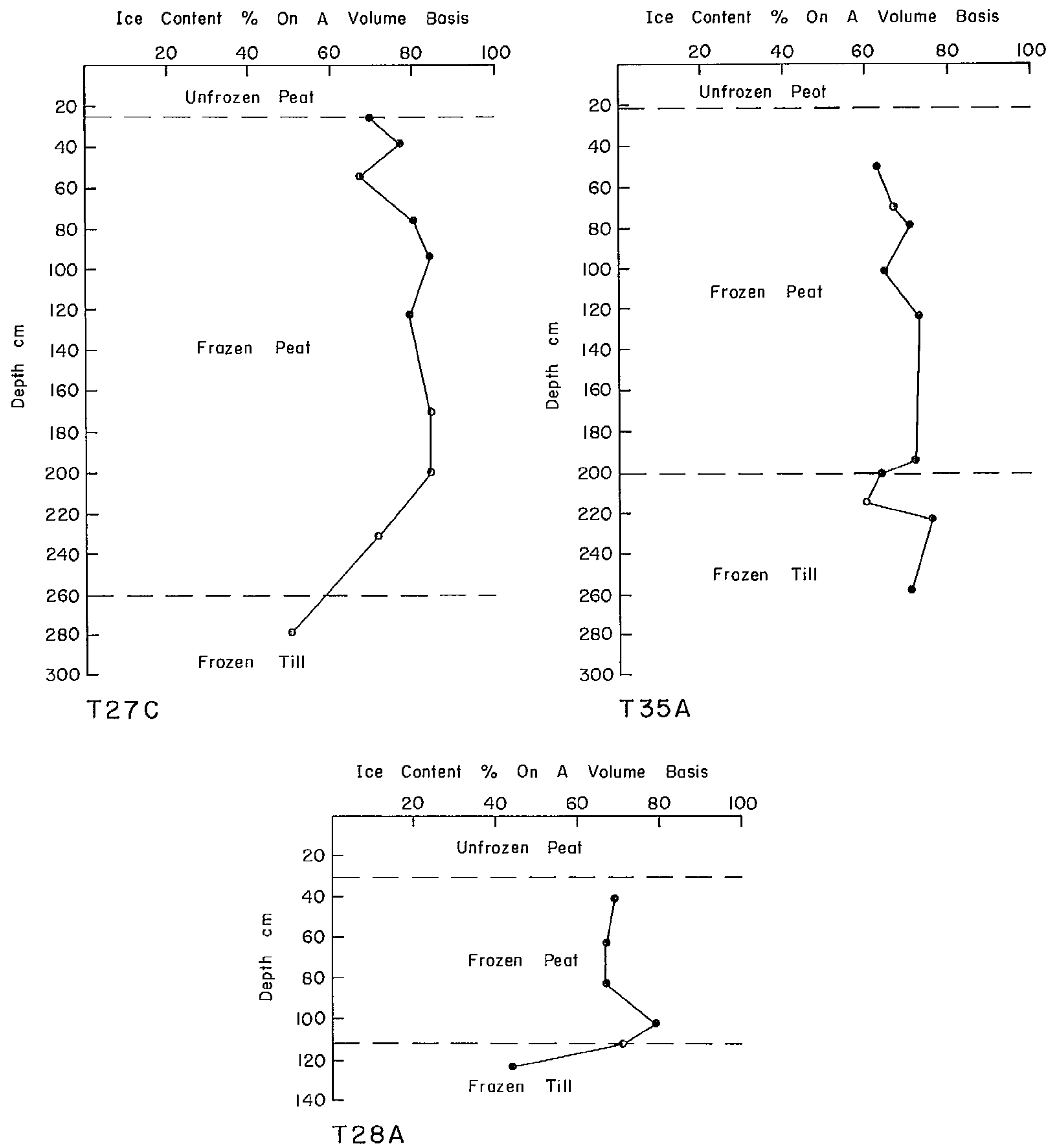
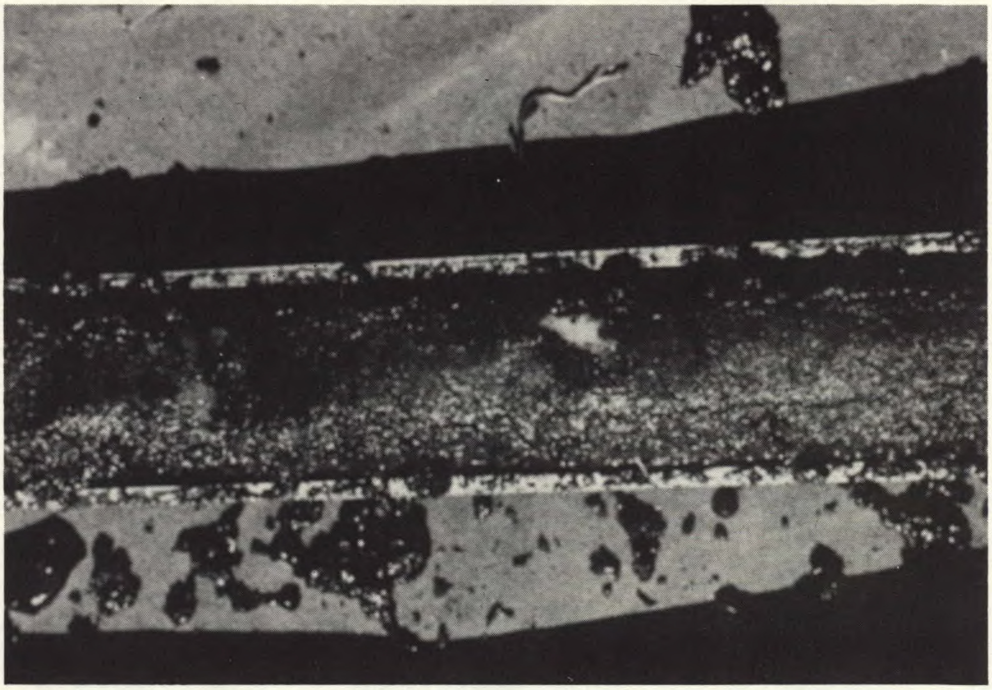
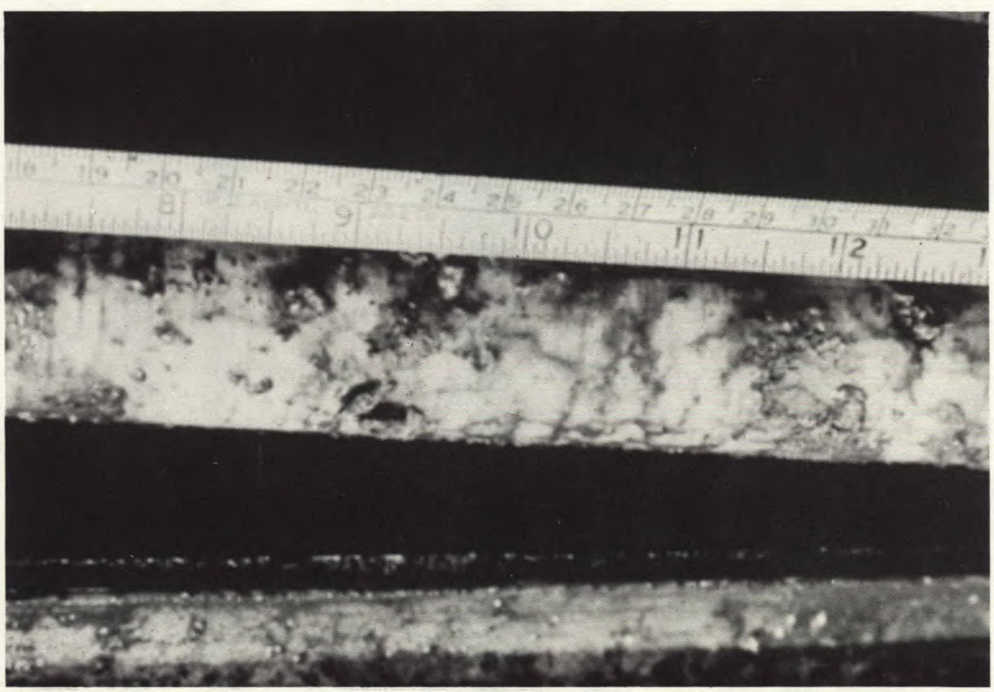


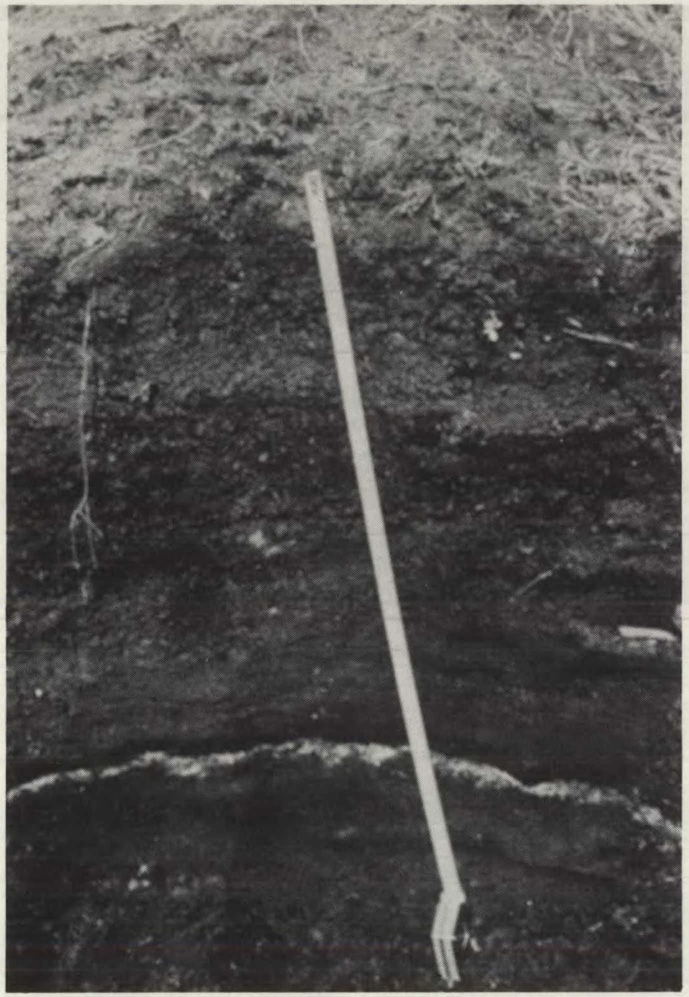
Figure 9. Ice content of Cryic Fibrisols located on a peat polygon (T27C, T35A) and on a peat plateau (T28A).



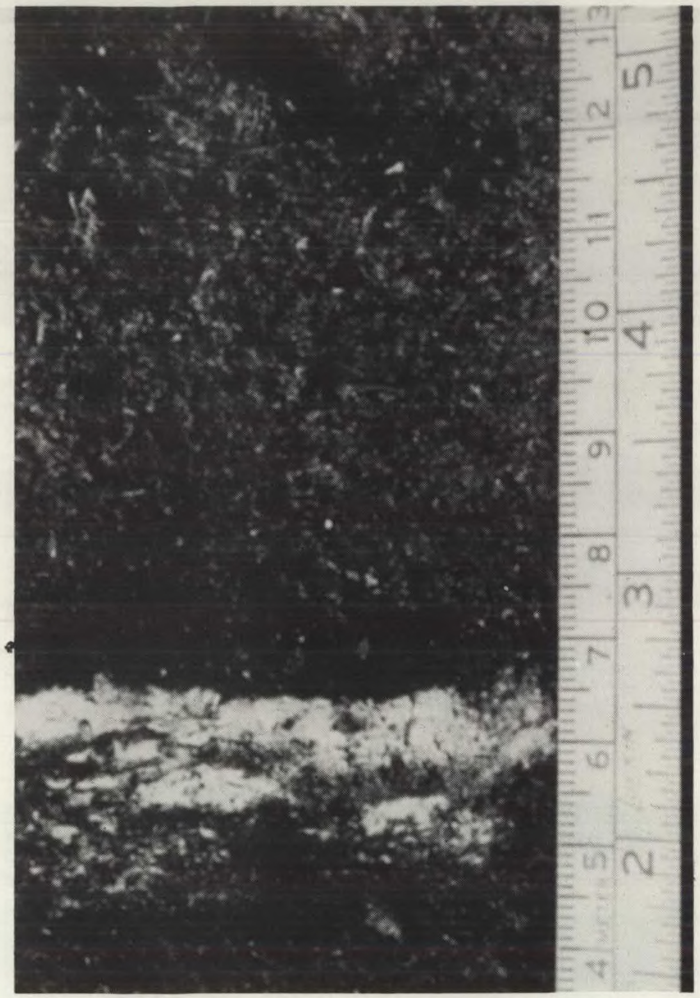
A. Core sample of perennially frozen peat material from profile T5A. Note the large amounts of ice crystals and some ice lenses indicated by the white color.



B. Core sample of the underlying perennially frozen mineral material of profile T5A. Note the large amount of ice with the mineral material represented by only thin veins between the ice.



A. 46 cm Sphagnum (fuscum) peat above the volcanic ash layer. Site T12, south-east side of Sibbeston Lake.



B. Close-up of the volcanic ash layer. Note the dark layer above the ash indicating that there was an intermediate vegetation type before the Sphagnum was re-established after the ash fall.

ice lenses and vein ice up to 10 cm thick being present. On the other hand, the type of ice occurring in the frozen peat is generally ice crystals and vein ice.

8.2. Mineral Soils

8.2.1. Description of Mineral Soils

8.2.1.1. Luvisols

Luvisols consist of well and imperfectly drained soils that have developed under deciduous, mixed deciduous-coniferous and coniferous forests.

These soils have an L-H surface horizon of forest litter overlying an eluvial (Ae) horizon and illuvial textural B horizons in which silicate clay is the main accumulation product and which meet the requirements of a Bt horizon. Slight accumulation of $CaCO_3$ may occur under the B horizon but it is seldom enough to meet the requirements of a Cca horizon.

Gray Luvisols

These are soils with an organic surface horizon (L-H), a light-colored eluvial horizon (Ae), and an illuvial horizon (Bt). They have developed on moderately to very strongly calcareous glacial till deposits and are mapped as moraine plains, drumlins, flutings, ridge moraines, hummocky moraines and subdued hummocky and rolling morainic landforms. They are also found on strongly calcareous lacustrine deposits which are mapped as glacio-lacustrine plains in the study area. The descriptions of Gray Luvisols are as follows:

Orthic Gray Luvisol

These soils have the general characteristics of the Gray Luvisols; i.e. they have organic surface horizons (L-H), light-colored Ae and Bt horizons. These soils have developed on either very strongly calcareous glacial till (profile T1) or strongly calcareous lacustrine deposits (profile T17). The profile descriptions of these soils are as follows:

Profile T1 Orthic Gray Luvisol (Appendix I: Table 6)

L-H- 4 to 0 cm, very dark brown (10YR 2/2, moist), forest litter of needles and twigs; strongly acid; abrupt, wavy boundary.

Ae- 0 to 3 cm, light gray (10YR 7/1, moist), silt loam; fine platy; non-sticky, non-plastic; loose when moist, loose when dry; extremely acid; abrupt, irregular boundary.

Bt- 3 to 19 cm, yellowish-brown (10YR 5/6, moist), clay loam; fine subangular blocky; slightly sticky, slightly plastic; firm when moist, hard when dry; extremely acid; abrupt, smooth boundary.

C- 19 to 54 cm, light brownish-gray (10YR 6/2, moist), silt loam; fine subangular blocky; slightly sticky, slightly plastic; firm when moist, hard when dry; mildly alkaline; very strongly calcareous.

Profile T17 Orthic Gray Luvisol (Appendix I: Table 7)

L-H- 3 to 0 cm, very dark grayish-brown (10YR 3/2, moist), forest litter of spruce needles, aspen leaves and twigs; medium acid; abrupt, smooth boundary.

Ae- 0 to 10 cm, very pale brown (10YR 3/2, moist), silt loam; very fine platy; non-sticky, non-plastic; very friable when moist, soft when dry; very strongly acid; abrupt, irregular boundary.

Bt- 10 to 23 cm, dark yellowish-brown (10YR 4/4, moist), silt loam; fine subangular blocky; slightly sticky, slightly plastic; firm when moist, hard when dry; very strongly acid; abrupt, smooth boundary.

BC- 23 to 45 cm, yellowish-brown (10YR 5/6, moist), loam; fine subangular blocky; slightly sticky, slightly plastic; friable when moist, slightly hard when dry; strongly acid; gradual, wavy boundary.

C- 45 to 80 cm, grayish-brown (2.5Y 5/2, moist), loam; fine subangular blocky; slightly sticky, slightly plastic; friable when moist, slightly hard when dry; moderately alkaline; strongly calcareous.

Gleyed Gray Luvisol

These soils are Orthic Gray Luvisols that have imperfect drainage, duller colors, mottled horizons and thicker L-H horizons than do the well drained Orthic Grey Luvisols.

Brunisolic Gray Luvisol

These soils have the general characteristics of the Gray Luvisols but have a brownish Bm horizon developing within the light gray Ae horizon. The Brunisolic Gray Luvisols (Plate 6A) have developed on moderately to strongly calcareous glacial till (profiles T3 and B68). The profile descriptions of these soils are as follows:

Profile T3 Brunisolic Gray Luvisol (Appendix I: Table 8)

L-H- 8 to 0 cm, very dark grayish-brown (10YR 3/2, moist), forest litter of aspen and alder leaves and twigs; strongly acid; abrupt, smooth boundary.

Aej- 0 to 2 cm, light brownish-gray (2.5Y 6/2, moist), silt; fine platy; non-sticky, non-plastic; loose when moist, loose when dry; very strongly acid; abrupt, smooth boundary.

Bm- 2 to 20 cm, yellowish-brown (10YR 5/6, moist), silt; very fine subangular blocky; non-sticky, non-plastic; very friable when moist, soft when dry; extremely acid; clear, wavy boundary.

Bt- 20 to 45 cm, yellowish-brown (10YR 5/4, moist), silt; fine subangular blocky; sticky and plastic; firm when moist, hard when dry; extremely acid; gradual, wavy boundary.

C- 45 to 70 cm, grayish-brown (2.5Y 5/2, moist), clay loam; fine subangular blocky; slightly sticky, slightly plastic; firm when moist, hard when dry; mildly alkaline; strongly calcareous.

Profile B68 Brunisolic Gray Luvisol (Appendix I: Table 9)

L-H- 3 to 0 cm, very dark grayish-brown (10YR 3/2, moist), forest litter of needles, twigs and mosses; neutral; abrupt, smooth boundary.

Bm- 0 to 5 cm, dark brown (7.5YR 4/4, moist), loam; very fine subangular blocky; non-sticky, non-plastic; very friable when moist, soft when dry; neutral; clear, wavy boundary.

Ae- 5 to 20 cm, pale brown (10YR 6/3, moist), silt loam; fine platy; non-sticky, non-plastic; loose when moist, loose when dry; slightly acid; abrupt, smooth boundary.

Bt- 20 to 45 cm, dark yellowish-brown (10YR 4/4, moist), clay loam; slightly sticky, slightly plastic; firm when moist, hard when dry; very strongly acid; clear, wavy boundary.

C- 45 to 70 cm, very dark grayish brown (2.5Y 3/2, moist), clay loam; slightly sticky, slightly plastic; firm when moist, hard when dry; mildly alkaline; moderately calcareous.

Gleyed Brunisolic Gray Luvisol

These soils are Brunisolic Gray Luvisols that have imperfect drainage, duller colors, mottled horizons and thicker L-H horizons than do the well drained Brunisolic Gray Luvisols.

Topography: Gray Luvisols developed on moraine plains have a flat to gently sloping topography; on drumlins and flutings a gently to moderately sloping topography; on ridge moraines a strongly to steeply sloping topography; on hummocky, subdued hummocky and rolling moraines a strongly to steeply sloping topography and; on glaciolacustrine plains a flat to gently sloping topography.

Vegetation: On well to imperfectly drained glacial till the tree layer is composed dominantly of aspen, lodgepole and/or jack pine, white spruce and white birch. Good growths of white spruce together with aspen stands were found on well to imperfectly drained glaciolacustrine deposits. The shrub layer is dominated by alder, *Rose* sp. and some willows. The herb and moss layer is composed dominantly of *Cornus canadensis*, *Pyrola* sp., *Cladonia* sp. and feather mosses.

Physical and Chemical Characteristics: The till material contains a very small amount of stones. The most common stone sizes are 1/8-inch to 1/4-inch and constitute only 6 to 10 percent of the total weight of the sample. The surface of the soil is relatively stone-free; areas of shallow till over bedrock, however, contain a greater amount of stones. The texture of the soils developed on glacial till varies from silt loam to clay loam (Appendix I: Tables 6 and 7) while, on lacustrine sediment, it is loam textured (Appendix I: Tables 8 and 9).

The parent material of Orthic Gray Luvisol soils was found to be the highest in calcium carbonate. These soils generally have shallower and weaker profile development than do the Brunisolic Gray Luvisols. On the other hand, the calcium carbonate equivalent of the parent materials of the Brunisolic Gray Luvisols is lower and these soils also have both deeper profiles and stronger profile development.

The solum of Luvisolic soils is generally very acid (pH 4.2 to 4.9) and contains high amounts of exchangeable hydrogen, indicating a strong leaching condition.

8.2.1.2 Brunisols

The Brunisols consist of well and imperfectly drained soils that have developed under mixed deciduous-coniferous and coniferous types of vegetation in the Boreal Forest Zone and under a heath type of vegetation in the Alpine and Tundra Zones.

These soils have organic surface horizons (L-H). They may also have an eluvial horizon (Ae) and all have a brownish Bm horizon, but none have a Bt or a podzolic B horizon. Brunisolic soils constitute one of the most common soil groups found in the Mackenzie River area, especially in the middle and northern portions of the area. Their descriptions are as follows:

Eutric Brunisols

These soils have the general characteristics of the Brunisols; they have organic surface horizons (L-H) and a brownish Bm horizon. They may also have an Ae or Aej horizon. In the middle and northern Boreal and Tundra Regions (Zones 3, 2, 1 and 0) these soils are associated with permafrost and are greatly affected by cryoturbation. They have developed on glacial till, alluvium, colluvium, sand, gravel and lacustrine sediment. They are mapped as moraine plains, drumlins, flutings, ridge moraines, hummocky moraines, subdued hummocky and rolling moraines, alluvial terraces, colluvial complexes, aeolian deposits, glaciolacustrine beaches, glaciolacustrine thermokarst plains, glacio-fluvial plains and terraces, and hummocky and ridged glacio-fluvial deposits.

Orthic Eutric Brunisol

These soils have the general characteristics of the Eutric Brunisols and they have developed on medium-textured alluvium, gravelly and sandy beaches, glacio-fluvial sand and gravel (profile C28) and glacio-lacustrine and glacial till deposits (profiles T6 and B172). On glacial till they are found in association with the Brunisolic Gray Luvisol and Orthic Gray Luvisol soils, the two dominant soil types found on well drained sites and on areas of shallow till over bedrock.

Orthic Eutric Brunisols developed on alluvial, lacustrine or beach deposits have been described by Day (1966, 1968), while those which have developed on glacial till and glacio-fluvial sand and gravel deposits are described as follows:

Profile C28 Orthic Eutric Brunisol (Appendix I: Table 10 & Plate 6B)

Ah- 0 to 8 cm, very dark gray (10YR 3/1, moist), sandy loam; single-grained; non-sticky, non-plastic; loose when moist, loose when dry; mildly alkaline; clear, smooth boundary.

Bm- 8 to 40 cm, dark yellowish brown (10YR 3/4, moist), sandy loam; single-grained; non-sticky, non-plastic; loose when moist, loose when dry; mildly alkaline; clear, smooth boundary.

C- 40 to 100 cm, light brownish gray (2.5Y 6/2, moist), sandy gravel; single-grained; non-sticky, non-plastic; loose when moist, loose when dry; moderately alkaline; moderately calcareous.

Profile B172 Orthic Eutric Brunisol (Appendix I: Table 11)

L-H- 8 to 0 cm, very dark grayish brown (10YR 3/2, moist), forest litter of needles, twigs and mosses; neutral; abrupt, smooth boundary.

Bm- 0 to 14 cm, brown (7.5YR 5/4, moist), clay; fine subangular blocky; slightly sticky, slightly plastic; firm when moist, hard when dry; neutral; gradual, wavy boundary.

BC- 14 to 55 cm, pale brown (10YR 6/3, moist), silty clay; fine subangular blocky; slightly sticky, slightly plastic; friable when moist, slightly hard when dry; mildly alkaline; very strongly calcareous; gradual, wavy boundary.

C- 55 to 100 cm, light gray (10YR 7/1, moist), silty clay; fine subangular blocky; slightly sticky, slightly plastic; friable when moist, slightly hard when dry; moderately alkaline; extremely calcareous.

Profile T6 Orthic Eutric Brunisol (Appendix I: Table 12)

L-H- 10 to 0 cm, dark reddish brown (5YR 2/2, moist), forest litter of balsam poplar, birch and shrubs; very strongly acid; abrupt, smooth boundary.

Bm- 0 to 45 cm, dark brown (7.5YR 4/4, moist), silt loam; fine subangular blocky; non-sticky, non-plastic; very friable when moist, soft when dry; extremely acid; clear, wavy boundary.

C- 45 to 70 cm, olive brown (2.5Y 4/4, moist), silt loam; weak fine subangular blocky; non-sticky, non-plastic; very friable when moist, soft when dry; neutral; moderately calcareous.

Cryic Orthic Eutric Brunisols

These soils have the general characteristics of Orthic Eutric Brunisols but have the permafrost table within the control section. Most of these soils have a hummocky micro-topography. The hummocks are usually 15 to 20 cm. high and 100 to 140 cm. in diameter. In the southern portions of Zones 2 and 3 these hummocks show no indication of cryoturbation and thus the soils associated with them are classified as Cryic Orthic Eutric Brunisol. A representative profile of a Cryic Orthic Eutric Brunisol developed on clay till (R 166) in the Dahadinni River area is described below:

Profile R 166   Cryic Orthic Eutric Brunisol (Fig. 10 & Appendix I: Table 13)

L-F- 3 to 0 cm, very dark brown (10YR 2/2, moist), forest litter of needles and twigs of jack pine and black spruce; extremely acid; clear, wavy boundary.

Bm- 0 to 12 cm, brown (10YR 5/3, moist), silty clay; medium granular to shotty; slightly sticky, slightly plastic; firm when moist, hard when dry; extremely acid; clear, wavy boundary.

BC- 12 to 28 cm, pale brown (10YR 6/3, moist), silty clay; medium subangular blocky; slightly sticky, slightly plastic; firm when moist, hard when dry; medium acid; clear, gradual boundary.

C- 28 to 85 cm, very dark gray (5Y 3/1, moist), clay; weak medium subangular blocky to amorphous; sticky and plastic; firm when moist, hard when dry; mildly alkaline; abrupt, wavy boundary.

Cz- 85 to 110 cm, very dark gray (5Y 3/1, moist), frozen clay.

Orthic Eutric Brunisols*

These Orthic Eutric Brunisols affected by cryoturbation are found in association with nonsorted circles, stone stripes and steps (Plate 7A). The Bmy horizon often contains blobs of Ah or C materials. The surface of the soil is always covered with various amounts of unsorted stones. A representative profile of cryoturbed Orthic Eutric Brunisol developed on mixed till and colluvial materials is described below:

Profile T30A   Orthic Eutric Brunisol* (Fig. 10 & Appendix I: Table 14)

Bmy- 0 to 48 cm, dark brown (10YR 4/3, moist), loam; cryoturbed; very fine subangular blocky to amorphous; slightly sticky, slightly plastic; friable when moist, slightly hard when dry; medium acid; nonsorted stones on surface; clear, wavy boundary.

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* Influenced by cryoturbation.

Bm- 48 to 76 cm, dark grayish brown (10YR 4/2, moist), loam; fine subangular blocky; slightly sticky, slightly plastic; friable when moist, slightly hard when dry; medium acid; abrupt, smooth boundary.

R- 76+ cm, quartzite bedrock.

Degraded Eutric Brunisol

These soils have the general characteristics of Eutric Brunisols that have an Ae and a Bm horizon. The Bm horizon may contain some illuvial clay or some sesquioxides but not enough to meet the requirements of a Bt or Bf horizon. These soils have developed on medium-textured alluvium, sandy aeolian deposits and glacio-fluvial and glacio-lacustrine beach deposits. A representative profile of Degraded Eutric Brunisol developed on a fine sandy aeolian deposit is described as follows:

Profile T50 Degraded Eutric Brunisol (Appendix I: Table 15; Plate 7B)

L-F- 2 to 0 cm, very dark brown (10YR 2/2, moist), forest litter of aspen leaves and twigs; neutral; abrupt, smooth boundary.

Ae- 0 to 12 cm, light gray (10YR 6/1, moist), silt loam; single grained; non-sticky, non-plastic; loose when moist, loose when dry; extremely acid; clear, wavy boundary.

Bm_1- 12 to 61 cm, brown (10YR 4/3, moist), loamy sand; single-grained; non-sticky, non-plastic; loose when moist, loose when dry; strongly acid; gradual, wavy boundary.

Bm_2- 61 to 107 cm, dark yellowish brown (10YR 4/4, moist), sand; single-grained; non-sticky, non-plastic; loose when moist, loose when dry; medium acid; clear, wavy boundary.

C- 107 to 150 cm, olive gray (5Y 4/2, moist), sand; single-grained; non-sticky, non-plastic; loose when moist, loose when dry; mildly alkaline; moderately calcareous.

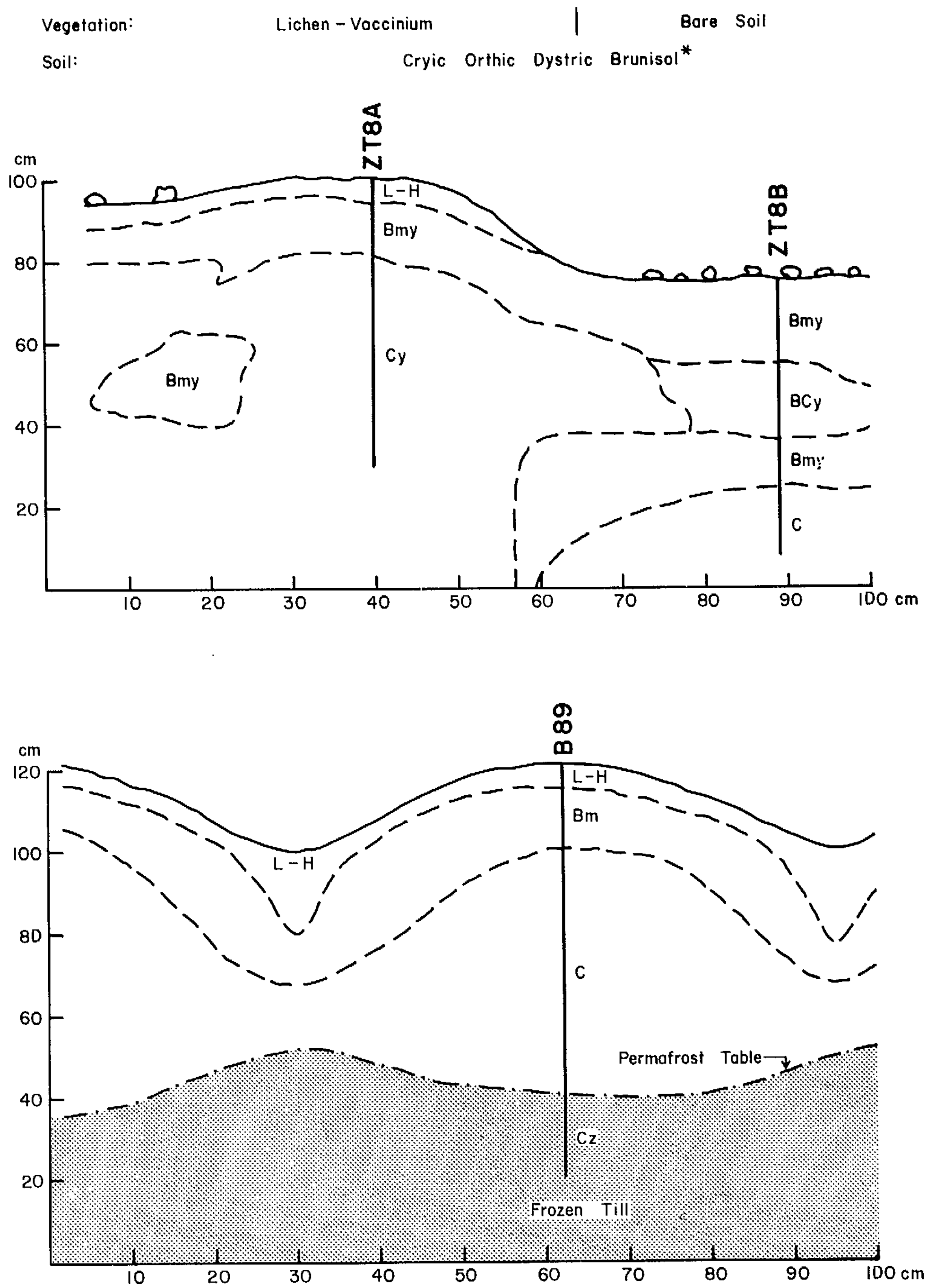

Figure 10. Cross-section of a non-sorted circle (site T30) and hummocks (site R166). Note that soils denoted by an asterisk (*) are affected by cryoturbation.

A. Nonsorted stripes on Cap Mountain. Alpine Eutric Brunisols in the stripes are affected by cryoturbation; under vegetation they are unaffected by frost action.

B. Degraded Eutric Brunisol developed on aeolian sand. Profile T50, Fort Simpson map area.

Alpine Eutric Brunisol

These soils have the general characteristics of Eutric Brunisols but they have a moder Ah horizon derived mainly from the mechanical incorporation of humus into the mineral soil.

Alpine Eutric Brunisol soils have developed on colluviated till or colluvial materials. A representative profile of Alpine Eutric Brunisol developed on mixed till and colluvial deposits is described as follows:

Profile T30B Alpine Eutric Brunisol (Fig. 10 & Appendix I: Table 16)

L-H- 3 to 0 cm, very dark gray (10YR 3/1, moist), litter of ericaceous shrubs, lichens and mosses; slightly acid; clear, smooth boundary.

Ah- 0 to 13 cm, black (10YR 2/1, moist), loam; fine granular; slightly sticky, slightly plastic; friable when moist, soft when dry; medium acid; clear, wavy boundary.

Bm_1- 13 to 41 cm, yellowish brown (10YR 5/4, moist), loam; fine subangular blocky; slightly sticky, slightly plastic; friable when moist, slightly hard when dry; strongly acid; clear, wavy boundary.

Bm_2- 41 to 78 cm, dark brown (10YR 3/3, moist), loam; fine subangular blocky; slightly sticky, slightly plastic; friable when moist, slightly hard when dry; medium acid; abrupt, smooth boundary.

R- 78+ cm, quartzite bedrock.

Alpine Eutric Brunisols*

These are Alpine Eutric Brunisols affected by cryoturbation. As a result of cryoturbation, the sequence of horizons is changed either to Bmy (where "y" indicates cryoturbation), Ah, Bm_1, Bm_2 and R or to Ah_1, Bmy, Ah_2, Bmy, Bm and R as is shown in Figure 10. In the first case, B materials were pushed over the Ah horizon and in

* Influenced by cryoturbation.

the second case B materials were squeezed into the Ah horizon by frost action. These soils are associated with nonsorted circles, stone stripes and steps in the alpine areas of the Mackenzie and Franklin Mountains (see Plate 7A).

Cryic Gleyed Orthic Eutric Brunisol

These soils have the general characteristics of Cryic Orthic Eutric Brunisols but with mottling and dull matrix colors in the B horizons. The Cryic Gleyed Orthic Eutric Brunisols have developed on fine-textured till materials and are found in Zones 2 and 3 (profile B89). A representative profile of Cryic Gleyed Orthic Eutric Brunisol developed on fine-textured glacial till is described as follows:

Profile B89   Cryic Gleyed Orthic Eutric Brunisol (Fig. 11 & Appendix I: Table 17)

L-H-   5 to 0 cm, dark brown (10YR 3/3, moist), forest litter of black spruce needles, branches, mosses and lichens; extremely acid; abrupt, smooth boundary.

Bmg-   0 to 15 cm, pale brown (10YR 6/3, moist), silty clay; medium granular; slightly sticky, slightly plastic; firm when moist, hard when dry; extremely acid; clear, wavy boundary.

Cg-   15 to 84 cm, gray (5Y 5/1, moist), silty clay loam; weak medium subangular blocky; slightly sticky, slightly plastic; firm when moist, hard when dry; mildly alkaline; abrupt, wavy boundary.

Cz-   84+ cm, frozen clay.

Cryic Gleyed Orthic Eutric Brunisol*

These Cryic Gleyed Orthic Eutric Brunisols are affected by

* Influenced by cryoturbation.

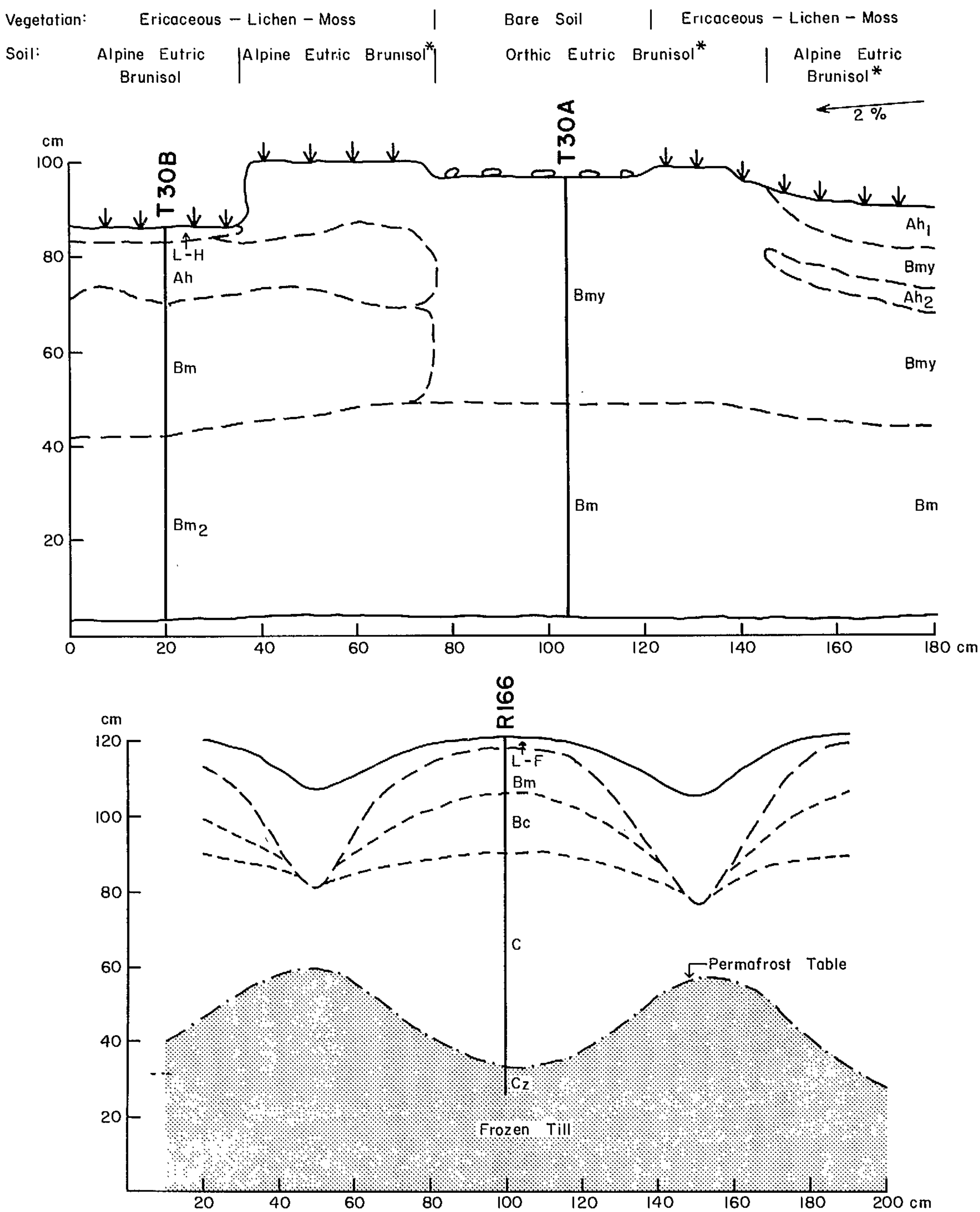

Figure 11. Cross-section of a non-sorted circle (site ZT8) and hummocks (site B89). Note that soils denoted by an asterisk (*) are affected by cryoturbation.

cryoturbation. As a result of cryoturbation the horizons are distorted and intrusions of organic materials, wood fragments and B materials may be found throughout the profile. The horizons affected by cryoturbation are designated by "y". These soils are associated with hummocks in Zones 1, 2 and 3. A representative profile of cryoturbed Cryic Gleyed Orthic Eutric Brunisol developed on lacustrine sediment is described as follows:

Profile ZT15 Cryic Gleyed Orthic Eutric Brunisol* (Appendix I: Table 18)

L-H- 5 to 0 cm, very dark brown (10YR 2/2, moist), litter of black spruce, Ledum, mosses and lichens; extremely acid; clear, wavy boundary.

Bmg- 0 to 10 cm, very dark grayish brown (10YR 3/2, moist), silt loam; medium granular; slightly sticky, slightly plastic; friable when moist, hard when dry; neutral; clear, wavy boundary.

Cgy- 10 to 50 cm, dark gray (10YR 4/1, moist), silt loam; amorphous; extremely cryoturbed; intrusions of organic material (L-H), organic smears and stains; slightly sticky and slightly plastic; friable when moist, hard when dry; mildly alkaline; abrupt, wavy boundary.

Cg- 50 to 63 cm, gray (10YR 5/1, moist), silt loam; amorphous; slightly sticky and slightly plastic; friable when moist, hard when dry; mildly alkaline; abrupt, smooth boundary.

Cz- 63+ cm, frozen silt loam.

Dystric Brunisols

These soils have the general characteristics of the Brunisols; they have organic surface horizons (L-H) over Bm horizons in which the base saturation is usually 65 to 100 percent and the pH usually 5.5 or lower. These soils may also have weakly expressed (Aej) or strongly

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* Influenced by cryoturbation.

expressed (Ae) eluvial horizons. These soils are found in the Inuvik area and are associated with patterned ground.

Cryic Orthic Dystric Brunisol

These soils have the general characteristics of Dystric Brunisols but have the permafrost table within the control section. They occur in the treeless tundra area and are associated with ice wedge polygons. A representative profile of a Cryic Orthic Dystric Brunisol developed on glacio-fluvial deposits in the Eskimo Lakes area is described below:

Profile ZT27 Cryic Orthic Dystric Brunisol (Appendix I: Table 19 & Plate 8A)

Bm- 0 to 9 cm, dark brown (7.5YR 4/2, moist), sandy loam; pumice-like+, single-grained; non-sticky, non-plastic; loose when moist, loose when dry; extremely acid; tundra pavement on the surface; clear, wavy boundary.

BC- 9 to 25 cm, brown (10YR 5/3, moist), sand; single-grained; non-sticky, non-plastic; loose when moist, loose when dry; extremely acid; clear, wavy boundary.

C- 25 to 60 cm, grayish brown (10YR 5/2, moist) sand; single-grained; non-sticky, non-plastic; loose when moist, loose when dry; strongly acid; abrupt, wavy boundary.

Cz- 60+ cm, grayish brown (10YR 5/2, moist), frozen sand.

Cryic Orthic Dystric Brunisol*

These are Cryic Orthic Dystric Brunisols affected by cryoturbation. As a result of cryoturbation the sequence of horizons is changed and distorted with blobs of organic materials, organic smears, wood fragments and intrusions of Ah or B horizons being found in the cryoturbed horizons, which are designated by "y". These soils are

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+ pumice-like structure: great amounts of air voids due to frost action.

* influenced by **cryoturbation.**

associated with a patterned ground of nonsorted circles, stone nets and hummocks. They have developed on fine-textured glacial till (profiles ZT16 and ZT29), lacustrine sediments and colluvial materials (profile ZT8).

Profile ZT8A Cryic Orthic Dystric Brunisol* (Figure 11, Appendix I: Table 20 & Plate 8B)

L-F- 6 to 0 cm, very dark grayish brown (10YR 3/2, moist), litter of leaves, twigs of dwarf shrubs and lichens; extremely acid; abrupt, wavy boundary.

Bmy- 0 to 13 cm, yellowish brown (10YR 5/4, moist), loam; slightly cryoturbed; smears and intrusions of parent material (C); slightly sticky, slightly plastic; friable when moist, hard when dry; extremely acid; clear, wavy boundary.

Cy- 13 to 50 cm, gray (10YR 5/1, moist), loam; cryoturbed; intrusions of B material; slightly sticky, slightly plastic; friable when moist, hard when dry; extremely acid.

Profile ZT29 Cryic Orthic Dystric Brunisol* (Figure 12, Appendix I: Table 21 & Plate 9B)

Bm- 0 to 25 cm, dark gray (10YR 4/1, moist), silty clay; fine granular to shotty; sticky and plastic; firm when moist, hard when dry; extremely acid; fine roots; clear, wavy boundary.

Cy- 25 to 103 cm, gray (10YR 5/1, moist), silty clay; amorphous; cryoturbed; organic smears; very sticky, very plastic; firm when moist, hard when dry; extremely acid; abrupt, smooth boundary.

Cz- 103+ cm, gray (10YR 5/1, moist), frozen silty clay; vein ice, ice content approximately 40 percent; very sticky, very plastic; firm when moist, hard when dry.

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* influenced by cryoturbation.

Profile ZT16 Cryic Orthic Dystric Brunisol* (Figure 12, Appendix I: Table 22 & Plate 9A)

L-H- 1 to 0 cm, very dark brown (10YR 2/2, moist), litter of leaves, twigs of dwarf shrubs and lichens; abrupt, wavy boundary.

Bm- 0 to 32 cm, grayish brown (10YR 5/2, moist), silty clay; medium granular to shotty; sticky and plastic; firm when moist, hard when dry; extremely acid; great amounts of fine roots; clear, wavy boundary.

BCy- 32 to 64 cm, dark gray (10YR 4/1, moist), silty clay; medium subangular blocky to amorphous; extremely cryoturbed; intrusion of organic materials (L-H), organic smears and stains, small intrusions of parent material (C); sticky and plastic; firm when moist, hard when dry; extremely acid; abrupt, smooth boundary.

Ayhz- 64 to 78 cm, very dark gray (10YR 3/1, moist), frozen silty clay loam; amorphous; extremely cryoturbed; veins of organic material and organics mixed with mineral material; vein ice and ice crystals, ice content approximately 40 percent; sticky and plastic; firm when moist, hard when dry; extremely acid; abrupt, smooth boundary.

Cz- 78 to 300 cm, dark gray (2.5Y 4/0, moist), frozen silty clay loam; amorphous; vein ice and buried ice wedges, ice content approximately 50-70 percent; sticky and plastic; firm when moist, hard when dry; extremely acid.

Profile ZT8B Cryic Orthic Dystric Brunisol* (Figure 11, Appendix I: Table 20 & Plate 8B)

Bm- 0 to 20 cm, brown (10YR 5/3, moist), silt loam; cryoturbed; intrusions of parent material; slightly sticky, slightly plastic; friable when moist, hard when dry; extremely acid; clear, wavy boundary.

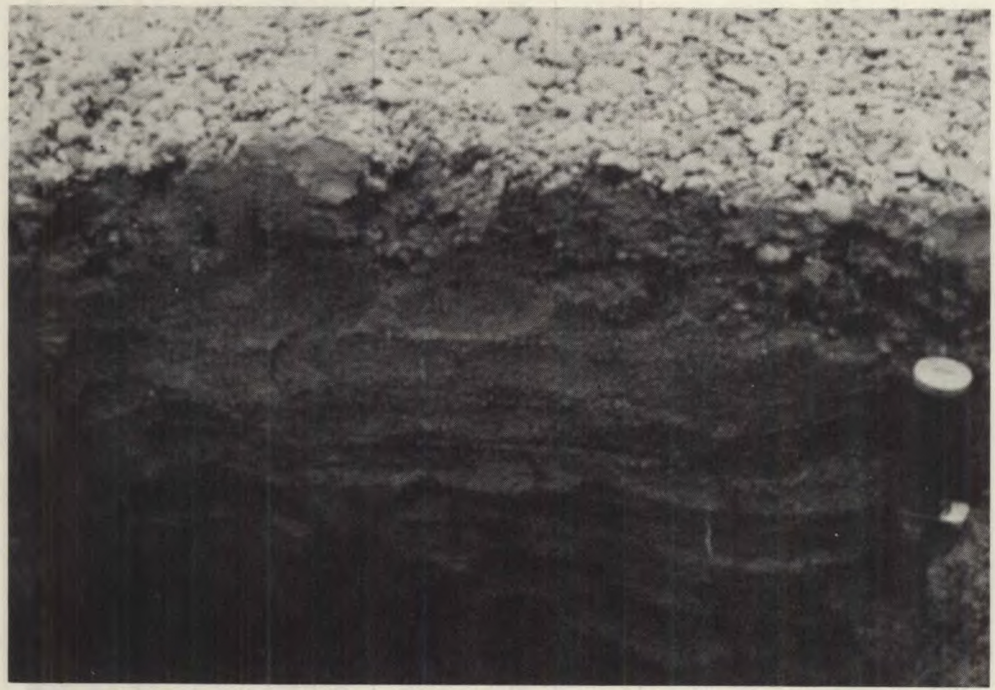
BCy- 20 to 39 cm, gray (10YR 5/1, moist), silt loam; extremely cryoturbed; mixed B and C materials, intrusions of parent material; slightly sticky, slightly plastic; friable when moist, hard when dry; clear, wavy boundary.

Bmy- 39 to 50 cm, yellowish brown (10YR 5/4, moist), loam; moderately cryoturbed; intrusions of parent material; slightly sticky, slightly plastic; friable when moist, hard when dry; very strongly acid; clear, wavy boundary.

C- 50 to 80 cm, gray (10YR 6/1, moist), loam; slightly sticky, slightly plastic; friable when moist, hard when dry; extremely acid.

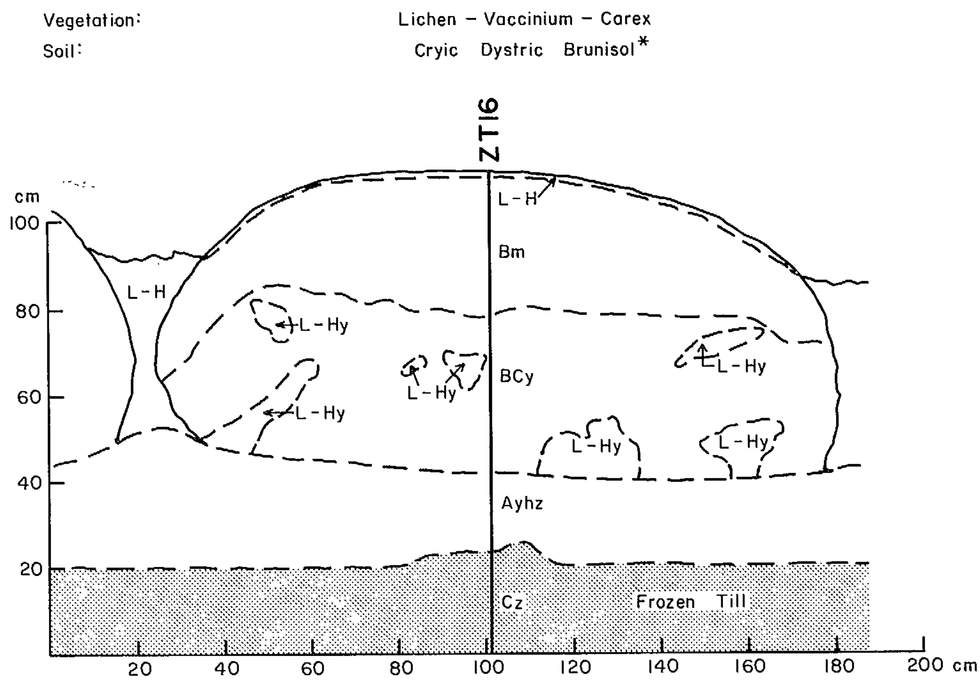
* Influenced by cryoturbation.

Plate 7



A. Cryic Orthic Dystric Brunisol developed on glacio-fluvial sand. Note the stone layer or "tundra pavement" on the surface. Profile ZT27, Eskimo Lake area.

B. Unvegetated hummocks in the area of site ZT29 north of Inuvik.



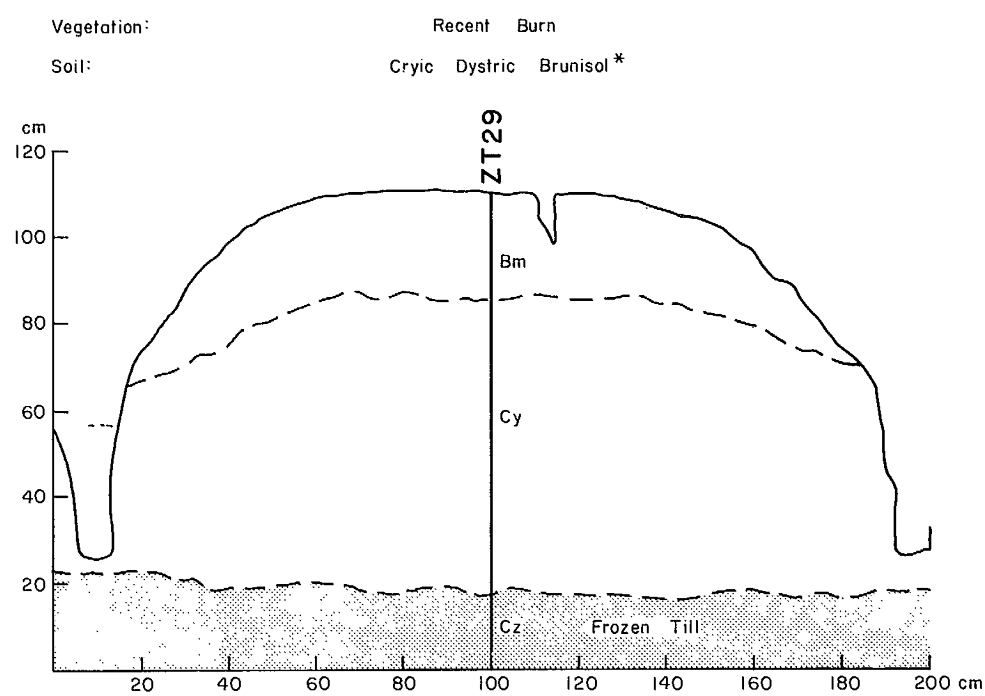


Figure 12. Cross-section of hummocks (sites ZT16 and ZT29). Soils associated with this patterned ground are affected by cryoturbation and are indicated by an asterisk (*).

A. Brunisolic Gray Luvisol developed on moderately to strongly calcareous glacial till. Sibbeston Lake map area.

B. Orthic Eutric Brunisol developed on a glacio-fluvial sand and gravel deposit. Profile C28, Wrigley map area.

A. Cryoturbed Cryic Dystric Brunisol developed on a hummock. Note the shotty structure in the B horizon and intrusions of organic materials and organic smears, and the build-up of organic matter in the Ayhz horizon, which occurs on top of the permafrost table. Profile ZT16 north of Inuvik.

B. Unvegetated hummock north of Inuvik, profile ZT29. Cryoturbed Cryic Dystric Brunisol developed on glacial till. Note the granular or shotty B horizon and the massive cryoturbed C horizon.

A. Extremely cryoturbed Cryic Orthic Dystric Brunisol developed on unglaciated terrain in the Mackenzie Mountains. Note the displaced B and C horizons. Profiles ZT8A and B, located on a nonsorted circle.

B. Cryic Rego Gleysol developed on fine-textured till. Site R170, Dahadinni River map-area.

Topography:

Brunisols developed on moraine plains have a flat to gently sloping topography; on drumlins and flutings a gently to moderately sloping topography; on ridge moraines a strongly to steeply sloping topography; on hummocky, subdued hummocky and rolling moraines a strongly to steeply sloping topography; on alluvial terraces a level to slightly sloping topography, occasionally interrupted with shallow channels; on colluvial landforms gently to steeply sloping topography; on aeolian deposits a gently to moderately sloping topography; on glacio-lacustrine beaches a moderately sloping topography and; on glacio-lacustrine and glacio-fluvial deposits a flat to gently sloping topography.

Vegetation:

On well-drained glacial till, alluvium and lacustrine deposits in Zones 4, 5, 6S and 6N mixed broad-leaf and coniferous forests are typical. Due to repeated fires, pure stands of aspen, birch, and lodgepole or jack pine are common. Balsam poplar commonly occurs along drainage channels and creeks. The broad-leaf species, especially aspen, birch and balsam poplar, dominate the early successional stages with white spruce taking over and representing a later stage of succession. The shrub layer is dominated by *Alnus crispa*, *Salix* spp. and *Shepherdia canadensis*. The herb and moss layer is composed dominantly of *Cornus canadensis*, *Vaccinium vitis-idaea*, *Pyrola* sp., feather mosses and lichens. On imperfectly drained sites composed of the above-mentioned materials the occurrence of conifers, especially black spruce, is more frequent. *Ledum groenlandicum* and *Potentilla fruticosa* are common in the shrub layer. A continuous carpet of feather mosses is associated with small groups of evergreen herbs and Equisetum sp.

Vegetation on sandy dunes, gravelly-sandy beaches and terraces is dominated by pure or mixed pine, birch, aspen and white spruce forests. Here again, succession is toward the white spruce type. Repeated fires, however, maintain large areas of pine and birch. The shrub layer is dominated by Shepherdia canadensis, Rose sp. and Juniperus communis. The herb and moss layer is dominated by Cornus canadensis, Pyrola spp., Lecopodium spp., Arctostaphylos uva-ursi, feather mosses and lichens.

In Zones 2 and 3, on well and imperfectly drained mineral soils, black spruce becomes dominant, especially on the imperfectly drained sites. On perennially frozen soils black spruce with a thick carpet of feather mosses forms the dominant forest cover.

The timberline occurs at 3,800 feet in the Nahanni Butte area. The timberline further north, on Cap Mountain, is found at an elevation of 3,300 to 3,400 feet. It is interesting to note that alpine fir forms the timberline in the Nahanni Butte area, while in the Cap Mountain area alpine fir is absent and white spruce forms the timberline. Above the timberline, on mineral soils, typical alpine tundra vegetation is found.

On patterned ground, nonsorted circles, and hummocks in Zones 1, 2, and 3, the tree layer is composed dominantly of black spruce with some larch and white birch also being present. The shrub layer is composed of Ledum groenlandicum, L. decumbens, Betula glandulosa, Alnus crispa, Vaccinium spp. and Rubus chamaemorus. The herb and moss layer contains lichens (Cladonia alpestris, C. Mitis,

C. rangiferina), feather mosses and some Carex spp. and Equisetum sp. In Zone 0, under similar terrain conditions, the vegetation is composed of lichens, ericaceous shrubs and some Carex spp. and willows. Some of the hummocks in this zone are completely devoid of vegetation (see Plate 9B and Plate 10A).

Physical and Chemical Characteristics:

The till material contains very few stones with the exception of sample T6 obtained at Nahanni Hot Springs which contains a large amount of stones (54%). This site is located, however, on a mountain slope and the till is probably mixed with various amounts of colluvial material. This shows in samples collected from the Camsell Range (site T30) which is also a colluviated till and contains 34 percent stones. Soils developed on glacio-fluvial materials contain various amounts of stones.

Soils developed on lacustrine and aeolian materials are stone free. The texture of soils developed on glacial till varies from silt loam to silty clay. Some of the soils sampled in the Dahadinni River area are of clay texture. The texture of soils on colluviated till is generally loamy and on lacustrine and aeolian deposits it is silty loam and loamy sand, respectively.

The depth of unfrozen soils developed on glacial till is approximately 40 to 55 cm. Perennially frozen soils developed on this material are, however, much shallower and extend only approximately half as deep as do the unfrozen soils. This is probably due to the soil climate and the effect of permafrost on soil development. The depth of cryic soils which have been affected by cryoturbation varies greatly but, generally, they range as do the cryic soils

(20 to 30 cm). Depth does, however, depend on the extent of mixing and injection of organic matter and parent material into the solum as this can greatly increase the depth (see profile ZT16). Soils developed on sandy aeolian deposits are generally deep (1 m or more) and have the deepest B horizons of Brunisolic soils found in the area. It is interesting to note that site T6, located at Nahanni Hot Springs, has a well developed, deep B horizon. This is probably a local situation occurring around the Hot Springs where the soil temperature increases by depth, being 14°C at the surface (2.5 cm depth) and 17.5°C at a depth of 1 m, resulting in a slightly more favorable soil climate for soil development.

The pH of Eutric Brunisols is 5.5 or higher with the exception of profile T6. Perennially frozen soils also have a very strongly acid solum in spite of the fact that the reaction of the parent material is neutral or mildly alkaline. The pH of Dystric Brunisols is 5.5 or lower. These soils have developed on strongly to very strongly acid parent materials (pH 4.5 - 5.5) resulting in an extremely acid (pH less than 4.5) solum.

Soils affected by cryoturbation and denoted by an asterisk have very typical physical and chemical characteristics. As a result of cryoturbation, the horizons are distorted, mixed with other horizons or, in some cases, the whole horizon is displaced or injected into another horizon. The structure of the surface horizon is typically granular to shotty, and in some cases, a platy structure was also noted.

A typical pumice-like macro-structure (great amounts of air voids due to frost action) is also associated with these soils.' The moisture content of these soils is also typical and is somewhat similar to that of cryic organic soils. The elevated portions of the hummock have a lower moisture content than do the trenches or the materials above the permafrost table. On flat or depressional terrain the water table is close to the surface and its depth is affected greatly by the depth of the permafrost table. Very little information is available concerning the development and removal (melting) of the seasonal frost in the active layer but it is likely that, in the late spring and summer, certain parts of the soil above the seasonal frost table are always water saturated. Determination of the drainage in the field is based on the moisture regime of the active layer and especially of the rooting zone (10-20 cm below the surface) which essentially controls the type of vegetation developed on a site.

Probably one of the most striking features of the cryoturbed Brunisols is the presence of organic matter throughout the profile. The organic material was found in the form of intrusions (displaced blobs of material), organic smears and stains. Above the permafrost table a definite build-up of organic material was noted in all of these soils. This is especially outstanding in the case of profile T16 where the organic carbon content reaches a value of 11.7 percent.

8.2.1.3 Regosols

The Regosols consist of well to imperfectly drained soils having a horizon development too weak to meet the requirements of soils in any other order.

Lithic Orthic Regosol

These soils have an organic-rich mineral horizon (Ah). The lithic contact occurs at a depth greater than 10 cm but less than 50 cm below the mineral surface. These soils have developed on colluvial materials of the Mackenzie and Franklin Mountains. A representative profile of Lithic Orthic Regosol, sampled on Ram Plateau, is described below:

Profile B70A   Lithic Orthic Regosol (Appendix I: Table 23)

L-H-   7 to 0 cm, black (10YR 2/1, moist), litter of ericaceous shrubs, lichens, mosses and grasses; slightly acid; clear, wavy boundary.

Ah-   0 to 15 cm, very dark gray (10YR 3/1, moist), silt loam; fine granular; non-sticky, non-plastic; very friable when moist, soft when dry; slightly acid; abrupt, smooth boundary.

R-   15+ cm, limestone bedrock.

Lithic Orthic Regosol*

These Lithic Orthic Regosols affected by cryoturbation are found on non-sorted circles and stone stripes. The surface of the soil is covered with various amounts of unsorted stones and intrusions of organic materials are common throughout the profile. A representative profile of a cryoturbed Lithic Orthic Regosol, sampled on a nonsorted circle, is described below:

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* Influenced by cryoturbation.

Profile B70B Lithic Orthic Regosol* (Appendix I: Table 24 & Plate 10B)

L-H- 3 to 0 cm, dark brown (10YR 3/3, moist), litter of lichens, mosses and ericaceous shrubs; medium acid; clear, wavy boundary.

Cy- 0 to 22 cm, brown (10YR 5/3, moist), sandy loam; cryoturbed; fine granular; non-sticky, non-plastic; very friable when moist, soft when dry; slightly acid; intrusions of organic material up to 2 cm thick, very dark gray (10YR 3/1, moist); abrupt, smooth boundary.

R- 22+ cm, limestone bedrock.

Gleyed Lithic Orthic Regosol

These are Orthic Regosols having mottling and dull colors within 50 cm of the surface. These soils also have a thicker L-H horizon than do the well-drained Orthic Regosols.

Cumulic Regosol

These soils have a surface Ah horizon and several buried Ah horizons below the surface. These soils have developed on alluvial floodplains and alluvial fan deposits.

Gleyed Cumulic Regosol

These are Cumulic Regosols having mottling and dull colors within 50 cm of the surface.

Topography:

Regosols developed on alluvial terraces have a level to slightly

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* Influenced by cryoturbation

sloping topography; on alluvial fans a gently to moderately sloping topography; and on colluvial deposits a gently to steeply sloping, irregular topography.

Vegetation:

The vegetation on alluvial floodplains as described by Jeffrey (1964) is composed dominantly of the *Salix*, *Salix-Alnus*, *Populus-Alnus*, Balsam poplar - white spruce - *Equisetum* and white spruce-birch-poplar types of vegetation. The vegetation on alluvial fan deposits is dominantly *Salix*, *Salix-Alnus*, and white spruce mixed with broadleaf tree species. The vegetation on colluvial deposits is of the alpine tundra type above the timberline while the timberline forest is composed dominantly of alpine fir and white spruce.

Physical and Chemical Characteristics:

Most of the Regosolic soils are very shallow because they are composed of either shallow material over bedrock or young soil on recently deposited materials. These soils are slightly acid to neutral in reaction and their texture varies from coarse to moderately fine.

8.2.1.4 Gleysols

The Gleysols consist of soils which are saturated with water and are under reducing conditions either continuously or during some period of the year.

Rego Gleysol

These soils have either no Ah horizon or an Ah horizon up to 8 cm thick and they also lack a B horizon. The L-H horizon is well-developed sphagnum or forest peat. Rego Gleysols are very common throughout the study area.

Cryic Rego Gleysol

The permafrost table occurs in the control section of these Rego Gleysols and is very often found just below the surface peat layer. These soils cover large areas and are commonly found under a stunted open black spruce type of vegetation. A representative profile of Cryic Rego Gleysol developed on fine-textured till material is described below:

Profile R170, Cryic Rego Gleysol (Appendix I: Table 25 & Plate 11)

L-F- 18 to 0 cm, dark reddish brown (5YR 2/2, moist), woody forest peat; extremely acid; clear, wavy boundary.

Cg- 0 to 22 cm, very dark gray (5Y 3/1, moist), silty clay loam; weak medium subangular blocky to amorphous; sticky, slightly plastic; firm when moist, hard when dry; medium acid; clear, smooth boundary.

Cgz- 22 to 52 cm, very dark gray (5Y 3/1, moist), frozen silty clay; vein ice, ice crystals; ice content approximately 55 percent; very slightly cryoturbed.

Cryic Rego Gleysol*

These Cryic Rego Gleysols affected by cryoturbation are found on patterned ground. A representative profile of a cryoturbed Cryic Rego Gleysol, sampled on a hummock in the Norman Wells area, is described below:

* Influenced by cryoturbation.

Profile ZT6, Cryic Rego Gleysol* (Appendix I: Table 26)

L-H- 23 to 0 m, dark brown (10YR 3/3, moist), undecomposed sphagnum peat with a thin layer of dark brown to black cladonia forest peat; extremely acid; clear, wavy boundary.

Cyg- 0 to 29 cm, very dark gray (5Y 3/1, moist), loam; cryoturbed; intrusions of organic material, organic stains and smears; slight build-up of organic matter in the lower portion of this horizon; weak medium subangular blocky; slightly sticky, slightly plastic; friable when moist, slightly hard when dry; medium acid; abrupt, wavy boundary.

Cygz- 29+ cm, frozen cryoturbed loam; slight build-up of organic matter in the top of this horizon; vein ice, ice crystals; ice content approximately 50 percent.

Topography:

Gleysolic soils have developed on all of the poorly drained materials mapped in the study area. The topography is flat to gently sloping on lacustrine deposits and moderately to strongly sloping on hillsides and high mountain plateaus.

Vegetation:

Black spruce dominates these soils along with birch and larch. The shrub and herb layers indicate a transition to peatland. *Potentilla fruticosa* and *Betula glandulosa* are the most common tall shrubs present with the dwarf shrubs being *Ledum groenlandicum*, *Vaccinium* spp. and *Empetrum nigrum*. The herb layer is dominated by feather mosses and *Sphagnum fuscum*.

Physical and Chemical Characteristics:

Most of the Gleysolic soils are shallow with various amounts of surface peat. These soils are slightly to medium acid and medium to moderately fine in texture.

* Influenced by cryoturbation.

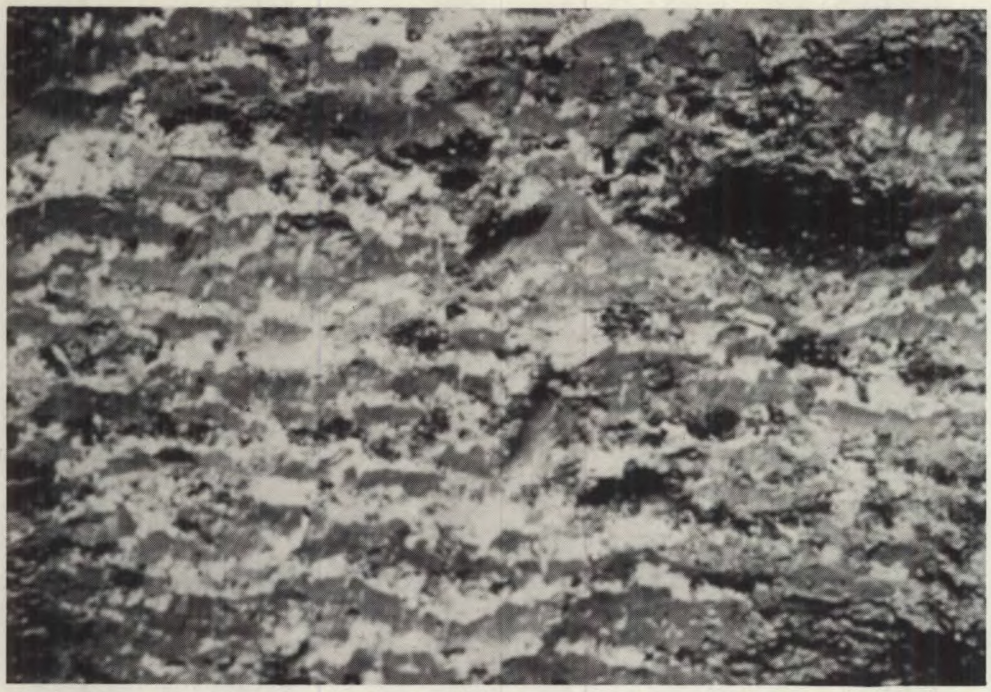
8.2.2. Ice Content of Mineral Soils

The ice content of mineral soils was determined on a weight basis[+] due to the difficulty of obtaining core samples in these coarse textured or stony materials. It was also difficult to penetrate the frozen mineral materials and thus the samples were taken from exposed faces, e.g. from flow slides along the river banks and mountain slopes, from disturbed areas where, due to human activities, thermal erosion was taking place and from excavations.

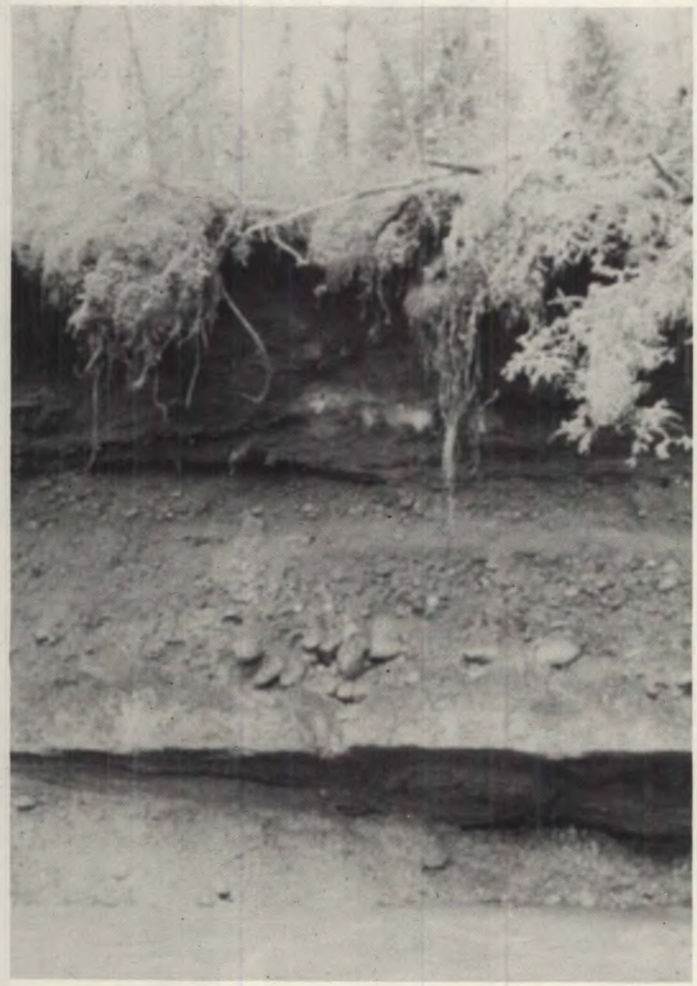
A sample collected from an excavation in the townsite of Fort Simpson had an ice content of 27 percent when measured on a weight basis. Here, the thaw layer was 5 feet on July 31, 1972 and the sample was collected at a depth of 15 feet on this date. The material was sandy loam textured alluvium. The ice occurred in the form of very fine ice crystals; no ice lenses were observed in this excavation.

Samples were collected from an abandoned oil drill site on the southwest side of the Wrigley sheet. Considerable erosion had taken place exposing an approximately 2 m deep gully. Here, samples were taken at depths of 10 cm, 55 cm and 92 cm. The ice content was found to be highest at the surface, almost pure ice, having a value of 2,787 percent on a weight basis. At a depth of 55 cm the ice content was found to be 58 percent, and at a depth of 92 cm 36 percent when calculated on a weight basis. The ice was in the form of massive clear ice with mineral veins at the surface and vein ice at lower depths (see Plate 12A).

[+] ice content percent on a weight basis = $\dfrac{\text{weight of ice (water)}}{\text{weight of solids (dry weight)}} \times 100$



A. Vein ice in fine textured till at a depth of 55 cm. The ice content of this depth was found to be 58 percent on a weight basis. Southwest side of the Wrigley Sheet.



B. Perennially frozen fine textured till and gravel deposits. Fast mountain rivers undercut these frozen materials, thus contributing considerably to river bank erosion. Dahadinni River area.

Another site was sampled on an active flow slide in the Wrigley area along the Wrigley River. Here, the ice content was found to be 61 percent on a weight basis.

Great amounts of ground ice in the form of ice wedges and massive ground ice were encountered in the area north of Inuvik and are shown on Plates 13A and 13B.

9. DISCUSSION

9.1. Organic Soils

Organic soils are one of the major soil types occurring in the Mackenzie River area. Their depth varies but most of them are moderately deep (greater than 160 cm). They are composed basically of three types of peat materials: sphagnum, forest and fen peat. The rate of accumulation of these peats was determined using the White River volcanic ash as a datum line. Based on this, it was found that sphagnum peat provided the greatest accumulation, being 2.94 cm per 100 years (*Sph. fuscum*) and 6.93 cm per 100 years (*Sph. riparium*, in open water), followed by forest peat at 2.54 cm per 100 years and fen peat at 1.47 cm per 100 years.

The soils developed from the above peat materials are classified into two groups: Mesisols and Fibrisols. The Mesisols developed mainly from fen and forest peat materials, and the Fibrisols developed mainly from sphagnum peat materials. The Mesisols are better supplied with nutrients and have a higher pH than do the Fibrisols which are extremely acid and very low in nutrients.

The temperature of these soils is generally lower than that of the mineral soils, thus, on the southern portion of the study area permafrost occurs mainly in these soils. The ice content of the frozen peat materials ranges between 75 and 90 percent on a volume basis, approximately. The ice is found mainly in the form of crystals and veins. Large amounts of ground ice were also found in these soils, e.g. wooded palsa with pure ice layer (site T29B) and ice wedges associated with peat polygons.

The chemical composition of the frozen peat differs greatly from that of the unfrozen peat in the same profile. This difference is shown in profiles T28A, T35A and T27C, where the pH was found to be approximately 2, the exchangeable calcium 4 to 8 m.e./100 gms and the exchangeable hydrogen 70 to 85 m.e./100 gms in the unfrozen active layer. By contrast, the pH of the frozen peat layer was between pH 3.0 and 4.7, the exchangeable calcium approximately 30 to 69 m.e./100 gms and the exchangeable hydrogen 43 to 85 m.e./100 gms. The large amount of calcium in the frozen layer results from water migration along the thermal gradient as well as other factors, as has been explained by Tarnocai (1972). It is also interesting to note that the calcium concentration of ice from the ice wedge (water sample 114) is lower than that from the water sample (111) taken from a water-filled unfrozen polygonal trench. This indicates that nutrients like calcium are freed from the ice during the process of ice formation and occupy the exchangeable sites on the organic soils, thus resulting in a higher nutrient concentration and pH in the frozen soil.

The pH of the sample (114) obtained from an ice wedge, however, is higher than that of the open water (sample 111) in spite of the fact that a large amount of calcium has been removed from the system, indicating that other chemical changes are also taking place due to ice formation.

9.2. Mineral Soils

The unfrozen mineral soils developed under forest vegetation generally have the properties of forest soils found elsewhere in the

Boreal Forest Region. These soils are all characterized by L-H horizons of various depths, composed of forest litter. Nutrient concentration is higher in these horizons than in any of the underlying mineral horizons due to the cycling process of nutrients by forest vegetation. The Luvisols have extremely acid B horizons even though these soils have developed on strongly to very strongly calcareous parent materials. The exchangeable hydrogen is high, especially in profile T1, indicating that these soils are fairly well leached. By contrast, the Eutric Brunisols, developed on calcareous materials, have a higher pH in the solum than do the Luvisols. The Luvisols occur mainly in the southern portion of the study area with Brunisols occurring mainly on coarse-textured materials. Proceeding northward, however, Luvisols give way to Brunisols on all mineral deposits and, in Zones 2 and 3, Brunisols are the dominant soils with weakly developed Luvisols being found in only a few locations.

Soil development, however, is greatly affected by cryogenic processes which begin to appear in the well-drained mineral soils in the southern portions of Zones 2 and 3 and northern portions of Zones 4 and 5. This begins first with the occurrence of a permafrost table in the profiles, patterned surface features (hummocks, stripes, circles) and very weak, if any, cryoturbation. In the middle portion of the Mackenzie Valley the soils show much greater effects of cryoturbation. Finally, mineral soils examined in the tundra area north of Inuvik all show extremely active cryoturbation with the exception of soils developed on coarse-textured, sandy and gravelly materials. It is well established in literature that these soils which have developed in the subarctic and arctic regions have different morphological, physical and chemical characteristics than those which have developed in the southern regions. Most of the features which are related to these cryoturbed arctic soils are shown in profile ZT16, located north of Inuvik.

The surface organic horizons of these soils are not always observable or are discontinuous because, due to frost action, they are incorporated into the mineral horizons. Even in this situation, however, some build-up of organic material was found in the inter-hummock depressions. The surface mineral horizons usually have a granular to shotty structure although a platy structure sometimes may also occur. This structure is probably due to soil freezing, which is known to enhance aggregation (Karavaeva, 1963). Soil freezing also produces mechanical sorting of materials associated with certain forms of patterned ground. Intrusion or displacement of horizons due to cryoturbation is also one of the main characteristics of these soils.

One of the most striking features of these cryoturbed soils is the high organic matter content of the mineral horizons. The organic matter occurs in the form of organic smears, stains, intrusions and organic-rich subsurface Ah horizons developed in situ. Mackay (1958), in his study of the origin of the subsurface organic layers in the Mackenzie Delta soils, theorizes that they are the result of the organic material that has accumulated in the inter-hummock depressions being progressively rolled under and smeared along the base of the active layer and on top of the permafrost table. These organic layers are very old; layers in tundra soils of Alaska range from 5,300 to 10,900 years in age (Tedrow and Douglas, 1958). Similarly, undecomposed surface wood fragments, Ledum leaves, artifacts, bones and charcoal are also rolled under, indicating that this is an on-going process including both old and recent materials. Karavaeva and Targul'yan (1963) suggest that there is a certain amount of migration of mobile humus substances into the deeper part of the soil, toward the frozen layer, in the spring. This is the season when the soil thaws and the level of surface water subsides. In the summer, however, migration of solutions toward the permafrost table occurs along the thermal gradient. Appendix I: Table 22 shows the increase not only of the organic matter but also of the calcium in an Ayhz horizon which has developed on top of the permafrost table. Karavaeva (1963) suggests also that the high organic matter content of the surface mineral horizon is due to the fact that the ratio of the surface to underground biomass weights of tundra vegetation is 1:6. The bulk of the underground biomass is found in the 0 to 18 cm surface layer.

Most of the soils examined in the arctic region show very weak profile development. This is probably the result of: (1) a cold, harsh climate which provides very little opportunity for either chemical weathering, removal and addition of materials (Fedorova et al., 1972) and (2) the action of cryoturbation which tends to dislocate and intermix materials which are produced by the other pedological processes. Thus, these soil forming processes give rise to new soil types which are typical of the subarctic and arctic regions.

10. IMPLICATIONS AND RECOMMENDATIONS

10.1. Relating to General Scientific Information

a. It is evident from this and other studies that the Canadian System of Soil Classification cannot adequately describe those soils which are affected by cryoturbation. It is the feeling of this author that it is necessary to modify the Canadian soil classification system to more adequately accommodate these soils.

Therefore, the following classification changes (those which are underlined) in the present Canadian System of Soil Classification are recommended.

5.2 Eutric Brunisol Great Group

5.21	Orthic Eutric Brunisol
5.22	Degraded Eutric Brunisol
5.23	Alpine Eutric Brunisol
5.2-/7	Cryic Eutric Brunisol
5.2-/8	Gleyed Eutric Brunisol
5.2-/9	Lithic Eutric Brunisol
<u>5.2-/10</u>	<u>Turbic Eutric Brunisol</u>

5.4 Dystric Brunisol Great Group

5.41	Orthic Dystric Brunisol
5.42	Degraded Dystric Brunisol
5.43	Alpine Dystric Brunisol
5.4-/7	Cryic Dystric Brunisol
5.4-/8	Gleyed Dystric Brunisol
5.4-/9	Lithic Dystric Brunisol
<u>5.4-/10</u>	<u>Turbic Dystric Brunisol</u>

6.1 Regosol Great Group

6.11	Orthic Regosol
6.12	Cumulic Regosol
6.1-/5	Saline Regosol
6.1-/7	Cryic Regosol
6.1-/8	Gleyed Regosol
6.1-/9	Lithic Regosol
<u>6.1-/10</u>	<u>Turbic Regosol</u>

7.2 Gleysol Great Group

7.21	Orthic Gleysol
7.22	Rego Gleysol
7.23	Fera Gleysol
7.2-/5	Saline Gleysol
7.2-/6	Carbonated Gleysol
7.2-/7	Cryic Gleysol
7.2-/9	Lithic Gleysol
7.2-/10	Turbic Gleysol

Thus, soils showing such effects of cryoturbation (indicated by cryoturbed horizon "y") as disrupted horizons, displacement, and incorporation of organic and other materials in the active layer through frost action, and typical patterned ground associations (denoted by an asterisk (*) in the report) would be termed Turbic according to the great group to which they belong. For example: profile ZT16 would, according to the recommended system, be called Turbic Cryic Dystric Brunisol; profile B70B, Turbic Lithic Orthic Regosol and; profile ZT6, Turbic Cryic Rego Gleysol.

b. Soil temperatures obtained in the Upper Mackenzie River area indicate that most of the frozen soils have a temperature of 0°C or slightly lower. This indicates that various amounts of unfrozen water are present in the frozen system. This unfrozen water greatly influences the thermal properties, load bearing capacity and, not the least, the sensitivity of soil to disturbance. It is recommended that studies be carried out to determine the relationship between the amount of unfrozen water in frozen soils and such factors as temperature, texture, and soil type.

c. Very little information is available concerning the soil forming processes in the Canadian subarctic and arctic regions. This is especially true of cryoturbation which is probably one of the most important factors. Cryoturbation affects not only the development of the soil but also distribution of vegetation and the stability of terrain. It is recommended that soil scientists study this process jointly with ecologists to determine the effect of cryoturbation on the ecosystem.

d. In ecological studies, such as the study of plant succession and re-establishment of vegetative cover on disturbed areas, soil scientists should be involved together with ecologists and botanists. Soil scientists would provide information relevant to plant growth. This would include the physical (texture, structure) and chemical (nutrient content, pH) properties of the soils as well as its moisture content, depth of active layer, soil temperature, ice content and the degree of cryoturbation.

e. Panchromatic, small-scale black and white photographs which were taken in the mid-1950's were used to conduct soil studies. If reconnaissance surveys and other environmental studies are to be undertaken in the future some funds and preplanning must be directed towards obtaining higher quality, recent, multispectral aerial photography and other remote sensing data. Studies carried out in other areas using recent remote sensing data were more accurate and provided greater amounts of terrain information than was obtained using old panchromatic, small-scale, black and white photographs.

10.2. Relating to Pipeline Construction

a. During pipeline and highway construction, extra care should be taken in the area north of Wrigley on the east side of Roche-qui-Trempe-a-l'Eau and Gaudet Mountains. This area is dominated by peatland whose soils have a very high ice content interspersed with layers of pure ice as, for example, site T29.

b. It was found that soil temperatures of collapse scars and small unfrozen bodies surrounded by frozen peatland are much lower than those of large unfrozen peatlands. A cool (below 0°C) gas pipeline will affect these bodies because of their small size and low soil temperature. Probably freezing of these bodies would occur first with subsequent vaulting due to ice lens formation. Attention should be given to overcoming this serious problem, which could lead to pipeline rupture.

c. The Mackenzie River area, like other parts of the boreal region, is dominated by organic soils. Studies should be initiated to determine the effect of oil spills on different types of peatlands. Included in this study should be the effect of oil spills on the thermal regime, on physical and chemical properties of organic soils and water associated with peatlands and on vegetation or other biological systems.

d. Most of the test sites relating to pipeline construction are located on either mineral terrain or mineral terrain with thin peat cover. Some of these tests should be carried out on the various types of peatland since they constitute a high percentage of the land types along the corridor.

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12. A P P E N D I C E S

Appendix I: Table 1. Analysis of Profiles T15B, T36B and T44.

Hor.	Depth cm	Mechanical Analysis Text. Class	% Sand	% Silt	% Clay	% Un-rubbed Fiber	% Pyro-phos. Sol.	% Ash	% Org. C	% Total N	C/N Ratio	pH in KCl	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca	Mg	K	Na	H
						Typic Mesisol (T15B)												
Om	0-130					60	0.68	14.09	59.3	2.28	26	5.7	109	74.74	9.85	0.15	0.93	22.95
11 Cg	130+	C.L.	-	-	-				-	-	-	-	-	-	-	-	-	-
						Typic Mesisol (T36B)												
Of	0-40					92	0.14	5.08	59.3	2.23	27	7.5	85	68.17	12.12	2.81	1.35	6.30
Om	40-220					50	0.21	7.76	63.2	2.53	25	5.8	102	78.72	6.81	0.20	1.24	15.30
11 Cg	220-250	S	-	-	-				-	-	-	-	-	-	-	-	-	-
						Terric Humic Mesisol (T44)												
Om	0-22					34	0.57	9.19	59.1	3.58	16	7.1	125	104.5	11.86	0.47	0.80	7.50
Oh	22-42					28	0.72	20.03	55.4	3.08	18	6.2	125	102.1	10.60	0.15	0.72	11.70
11 Cg	42+	C.L.	-	-	-				-	-	-	-	-	-	-	-	-	-

Appendix I: Table 2. Analysis of Profiles T36C and T5A.

Hor.	Depth cm	Mechanical Analysis Text. Class	% Sand	% Silt	% Clay	% Unrubbed Fiber	% Pyrophos. Sol.	% Ash	% Org. C	% Total N	C/N Ratio	pH in KCl	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca	Mg	K	Na	H
						Cryic Mesisol (T36C)												
Of	0-56					92	0.07	1.28	63.2	0.70	90	2.7	103	14.14	5.05	0.92	0.72	81.90
Omz	56-255					34	0.50	8.03	56.0	2.42	23	5.3	115	84.33	7.07	0.14	0.76	22.85
11Cgz	255-280	S	-	-	-				-	-	-	-	-	-	-	-	-	-
						Cryic Mesisol (T5A)												
Om	0-22					56	0.27	4.62	62.0	1.93	32	2.7	106	9.59	5.80	0.77	0.65	90.00
Of	22-45					92	0.05	3.87	61.3	0.70	87	3.1	95	25.25	9.84	0.33	0.72	58.95
Omz_1	45-256					56	0.12	6.31	62.4	1.45	43	3.5	106	23.23	13.38	0.19	0.76	67.00
Omz_2	256-265					54	0.35	17.35	57.7	1.90	30	4.8	97	39.39	11.86	0.21	0.72	45.00
11Cgz	265-300	Si.L.	8.01	65.43	26.56				-	-	-	4.7	46	26.93	4.38	0.49	2.85	14.55

Appendix I: Table 3. Analysis of Profiles T35B and T36D.

Hor.	Depth cm	Mechanical Analysis Text. Class	% Sand	% Silt	% Clay	% Un-rubbed Fiber	% Pyro-phos. Sol.	% Ash	% Org. C	% Total N	C/N Ratio	pH in KCl	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca	Mg	K	Na	H
				Cryic Mesisol (T35B)														
Of	0-18					88	0.14	2.30	58.1	1.30	45	2.8	99	13.13	3.53	0.66	0.70	81.00
Omz	18-57					48	0.24	3.52	61.5	1.20	51	3.0	92	12.62	4.04	0.40	0.72	73.80
Ice	57-164																	
11Cgz	164-170	Si.C.	-	-	-				-	-	-	-	-	-	-	-	-	-
				Typic Mesisol (T36D)														
Of	0-60					72	0.02	1.53	59.8	0.94	64	3.6	81	21.71	8.58	0.74	1.35	48.15
Om	60-185					48	0.80	9.36	59.7	2.23	27	5.3	131	85.34	9.60	0.15	0.76	35.10
11Cg	185-	S	-	-	-				-	-	-	-	-	-	-	-	-	-

Appendix I: Table 4. Analysis of Profiles T28A and T35A.

Hor.	Depth cm	Mechanical Analysis Text. Class	% Sand	% Silt	% Clay	% Unrubbed Fiber	% Pyrophos. Sol.	% Ash	% Org. C	% Total N	C/N Ratio	pH in KCl	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca	Mg	K	Na	H
							Cryic Fibrisol (T28A)											
Of	0-31					98	0.07	0.93	61.8	0.69	90	2.5	95	4.04	5.05	1.73	0.61	83.92
Ofz_1	31-83					76	0.25	7.09	60.9	0.92	66	3.3	113	32.06	8.83	0.49	0.65	71.55
Ofz_2	83-112					64	1.00	14.83	53.6	1.39	39	4.4	128	69.94	9.85	0.18	0.70	47.25
IICgz	112-123	C	7.32	38.84	53.84				-	-	-	5.0	-	-	-	-	-	-
							Cryic Fibrisol (T35A)											
Of	0-23					76	0.67	5.42	62.0	1.43	43	2.7	83	5.05	4.04	0.18	0.61	73.35
Ofz_1	23-79					67	0.40	4.06	62.4	1.19	53	3.0	106	28.78	2.52	0.29	0.59	73.35
Ofz_2	79-140					65	0.28	4.64	63.6	1.11	57	4.2	97	40.40	7.07	0.28	0.83	48.60
Ofz_3	140-200					68	0.32	7.24	56.6	1.19	47	4.4	111	56.30	10.35	0.26	0.78	43.65
IICgz	200-257	C.L.	20.79	46.63	32.58			-	-	-	-	6.9	39	35.60	2.27	0.35	0.87	0.0

Appendix I: Table 5. Analysis of Profile T27C.

Hor.	Depth cm	Mechanical Analysis Text. Class	% Sand	% Silt	% Clay	% Un-rubbed Fiber	% Pyro-phos. Sol.	% Ash	% Org. C	% Total N	C/N Ratio	pH in KCl	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca	Mg	K	Na	H
						Cryic Fibrisol (T27C)												
Of	0-25					88	0.12	2.61	60.3	1.57	38	2.5	99	8.08	3.03	0.89	0.61	85.95
Ofz$_1$	25-119					80	0.18	2.90	61.6	0.91	68	3.1	109	20.70	2.52	0.16	0.63	85.00
Ofz$_2$	119-212					78	0.20	4.41	64.8	0.81	80	4.1	105	40.90	4.79	0.20	0.65	58.00
Ofz$_3$	212-260					72	0.64	12.28	58.5	1.11	53	4.7	131	73.73	11.86	0.20	0.80	44.50
11Cgz	260-290	C.L.	20.35	46.93	32.72				-	-	-	6.0	28	21.79	4.25	0.37	0.50	0.58

Appendix I: Table 6. Analysis of Profile T1 Orthic Gray Luvisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	4-0	5.2	0.57	-	-	-	52.0	1.30	40	78	38.63	7.98	2.49	0.85	25.22
Ae	0-3	3.8	0.21	-	-	-	1.7	0.06	29	10	2.07	0.54	0.16	0.57	7.04
Bt	3-19	4.3	0.08	-	-	-	0.9	0.06	14	19	8.87	0.95	0.27	0.72	7.04
C	19-54	7.7	0.21	31.5	24.1	6.8	-	-	-	10	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	%	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	4-0	-	-	-	-	-	-	-	-	-	-	-
Ae	0-3	-	-	-	0.85	1.34	3.00	11.40	16.59	76.21	7.20	SiL
Bt	3-19	-	-	0.61	1.58	3.51	6.75	12.32	24.77	45.66	29.57	CL
C	19-54	-	-	0.63	0.68	1.22	4.79	14.05	21.37	54.59	24.04	SiL

Appendix I: Table 7. Analysis of Profile T17 Orthic Gray Luvisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	3-0	5.6	0.68	-	-	-	56.6	1.42	40	97	69.22	11.07	3.58	0.33	14.55
Ae	0-10	4.6	0.11	-	-	-	0.6	0.05	13	10	5.06	2.74	0.15	0.14	2.72
Bt	10-23	4.6	0.11	-	-	-	0.6	0.06	11	19	9.91	5.99	0.27	0.21	3.80
BC	23-45	5.1	0.14	-	-	-	0.2	0.04	6	11	7.53	3.17	0.14	0.20	1.32
C	45-80	8.0	0.30	19.7	17.6	1.9	-	-	-	8	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	%	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	3-0	-	-	-	-	-	-	-	-	-	-	-
Ae	0-10	-	-	-	-	-	-	-	5.70	80.91	13.39	SiL
Bt	10-23	-	-	-	0.24	0.76	3.18	7.49	11.67	61.47	26.86	SiL
BC	23-45	-	-	-	-	1.52	18.23	24.03	43.78	38.92	17.30	L
C	45-80	-	-	-	0.18	0.99	8.79	22.07	32.04	48.52	19.44	L

Appendix I: Table 8. Analysis of Profile T3, Brunisolic Gray Luvisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	8-0	5.3	0.86	-	-	-	55.5	1.92	28.9	99	65.51	11.12	5.05	0.30	18.24
Aej	0-2	5.1	0.21	-	-	-	3.4	0.17	20.1	14	8.06	3.32	0.16	0.26	3.41
Bm	2-20	4.4	0.80	-	-	-	0.5	0.05	9.2	9	3.52	2.02	0.11	0.12	3.41
Bt	20-45	4.2	0.74	-	-	-	0.6	0.08	8.1	23	17.00	3.28	0.35	0.16	4.07
C	45-70	7.6	0.23	17.2	9.3	7.3	-	-	-	13	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	%	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	8-0	-	-	-	-	-	-	-	-	-	-	-
Aej	0-2	-	-	-	-	0.89	1.13	8.83	10.85	81.66	7.49	Si
Bm	2-20	-	-	-	-	-	-	-	7.40	81.78	10.82	Si
Bt	20-45	-	-	1.68	2.56	4.16	5.50	5.47	19.37	37.83	42.76	C
C	45-70	¼"-1/3"	6.7	4.60	4.61	5.81	6.75	7.95	29.72	40.27	30.01	CL

Appendix I: Table 9. Analysis of Profile B68, Brunisolic Gray Luvisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	3-0	6.7	0.51	-	-	-	13.9	0.31	45	31	28.38	1.96	0.83	0.13	0.63
Bm	0-5	6.8	0.25	-	-	-	5.1	0.22	23	22	19.78	2.37	0.49	0.07	1.25
Ae	5-20	6.4	0.21	-	-	-	0.6	0.06	11	8	5.91	0.85	0.15	0.05	0.94
Bt	20-45	4.9	0.08	-	-	-	0.8	0.06	11	20	13.45	2.66	0.26	0.07	3.51
C	45-70	7.4	0.19	8.3	3.2	4.7	-	-	-	14	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	%	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	3-0	-	-	-	-	-	-	-	-	-	-	-
Bm	0-5	-	-	1.54	5.05	8.73	10.02	10.73	36.06	39.61	24.33	L
Ae	5-20	1/8"-1/4"	6.2	1.34	4.30	6.59	7.68	7.99	27.91	62.20	9.89	SiL
Bt	20-45	1/8"-1/4"	6.6	2.34	6.05	8.57	8.81	8.95	34.72	30.75	34.53	CL
C	45-70	1/8"-1/3"	10.6	2.98	6.36	8.12	9.00	7.37	33.82	37.08	29.10	CL

Appendix I: Table 10. Analysis of Profile C28, Orthic Eutric Brunisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
Ah	0-8	7.3	0.68	-	-	-	13.7	0.45	30	35	29.97	3.85	0.64	0.38	0.0
Bm	8-40	7.4	0.22	-	-	-	0.5	0.04	13	8	7.84	1.53	0.15	0.16	0.0
C	40-100	7.9	0.29	7.8	4.4	3.1	-	-	-	4	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	%	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
Ah	0-8	-	-	0.35	2.70	27.89	21.30	11.29	63.54	21.40	15.06	SL
Bm	8-40	1/8"-½"	16.6	1.20	4.23	31.42	27.04	9.47	73.37	17.81	8.82	SL
C	40-100	½"-1"	41.4	4.13	2.87	40.58	38.08	7.59	89.25	6.51	4.24	S

Appendix I: Table 11. Analysis of Profile B172, Orthic Eutric Brunisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	8-0	6.3	0.43	-	-	-	52.3	1.05	50	88	71.89	7.62	0.64	0.21	9.22
Bm	0-14	6.9	0.32	-	-	-	1.9	0.09	22	24	20.71	2.61	0.44	0.03	0.78
BC	14-55	7.7	0.21	36.0	36.0	-	1.3	0.09	14	19	-	-	-	-	-
C	55-100	7.8	0.22	42.2	36.2	5.5	-	-	-	10	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	Stones %	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	8-0	-	-	-	-	-	-	-	-	-	-	-
Bm	0-14	1/8"	6.5	1.95	2.35	4.27	6.92	9.10	24.59	34.82	40.59	C
BC	14-55	1/8"	2.9	-	-	-	-	-	4.10	45.87	50.03	SiC
C	55-100	½"	3.8	-	-	-	-	-	6.20	65.45	28.35	SiCL

Appendix I: Table 12. Analysis of Profile T6, Orthic Eutric Brunisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	10-0	4.6	0.60	-	-	-	48.5	1.67	29	92	51.50	3.19	2.62	0.54	34.44
Bm	0-45	4.2	0.20	-	-	-	1.2	0.09	14	10	3.05	0.93	0.26	0.23	6.07
C	45-70	7.2	1.08	6.9	2.7	3.9	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	Stones %	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	10-0	-	-	-	-	-	-	-	-	-	-	-
Bm	0-45	-	-	7.61	2.61	2.53	15.28	16.51	44.54	51.55	3.91	SiL
C	45-70	1/8"-1"	54.0	-	1.73	4.96	9.31	18.25	34.26	50.33	15.41	SiL

Appendix I: Table 13. Analysis of Profile R166, Cryic Orthic Eutric Brunisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-F	3-0	4.4	-	-	-	-	53.4	1.51	35	83	33.58	7.83	0.43	0.24	40.00
Bm	0-12	4.5	0.11	-	-	-	0.5	0.18	3	26	12.32	3.52	0.44	0.49	8.94
BC	12-28	5.7	0.10	-	-	-	1.4	0.12	11	25	18.27	3.64	0.46	0.62	2.60
C	28-85	7.4	0.21	2.7	2.7	-	-	-	-	20	-	-	-	-	-
Cz	85-110	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	Stones %	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-F	3-0	-	-	-	-	-	-	-	-	-	-	-
Bm	0-12	-	0	-	-	-	-	-	4.17	52.48	43.35	SiC
BC	12-28	-	0	-	-	-	-	-	4.10	47.43	48.47	SiC
C	28-85	-	0	-	-	-	-	-	3.47	38.67	57.86	C
Cz	85-110	-	-	-	-	-	-	-	-	-	-	C

Appendix I: Table 14. Analysis of Profile T30A, Orthic Eutric Brunisol*

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
Bmy	0-48	6.0	0.11	-	-	-	0.55	0.05	11	14	8.54	3.96	0.12	0.16	1.16
Bm	48-76	5.6	0.14	-	-	-	0.57	0.06	9	20	11.68	6.12	0.23	0.17	1.75
R	76+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	Stones %	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
Bmy	0-48	1/3"-½"	14.1	2.88	5.10	12.05	14.48	9.18	43.69	45.09	11.22	L
Bm	48-76	¼"-1/3"	33.9	3.42	5.10	9.13	10.16	9.46	37.26	36.05	26.69	L
R	76+	-	-	-	-	-	-	-	-	-	-	-

* influenced by cryoturbation

Appendix I: Table 15. Analysis of Profile T50, Degraded Eutric Brunisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms.				
											Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-F	2-0	6.6	-	-	-	-	47.0	1.58	30	86	73.54	10.51	0.25	0.20	2.91
Ae	0-12	4.0	0.06	-	-	-	0.3	0.02	17	3	0.88	0.23	0.05	0.02	2.29
Bm_1	12-61	5.1	0.04	-	-	-	0.1	0.02	7	3	1.50	0.54	0.10	0.01	0.83
Bm_2	61-107	5.9	0.05	-	-	-	0.1	0.03	3	5	2.78	1.28	0.13	0.03	0.72
C	107-150	7.8	0.15	13.5	7.2	5.8	-	-	-	2	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	Stones %	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-F	2-0	-	0	-	-	-	-	-	-	-	-	-
Ae	0-12	-	0	-	-	0.39	0.90	15.34	16.63	66.45	16.92	SiL
Bm_1	12-61	-	0	-	-	0.68	27.12	60.48	88.28	4.49	7.23	LS
Bm_2	61-107	-	0	-	-	1.60	45.11	44.86	91.58	4.67	3.75	S
C	107-150	-	0	-	-	0.51	36.14	61.33	97.98	0.00	2.02	S

Appendix I: Table 16. Analysis of Profile T30B, Alpine Eutric Brunisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	3-0	6.0	0.39	-	-	-	50.7	1.13	45	90	58.92	16.38	2.05	0.74	12.29
Ah	0-13	5.6	0.16	-	-	-	13.4	0.55	24	38	27.69	8.83	0.26	0.15	1.53
Bm_1	13-41	5.4	0.07	-	-	-	0.6	0.07	8	17	9.58	5.54	0.17	0.17	2.06
Bm_2	41-78	5.8	0.10	-	-	-	0.5	0.06	8	18	10.68	6.12	0.20	0.16	1.20
R	78+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	Stones %	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	3-0	-	-	-	-	-	-	-	-	-	-	-
Ah	0-13	-	-	4.83	9.29	13.31	11.13	5.96	44.52	40.86	14.62	L
Bm_1	13-41	1/3"-½"	6.9	2.23	5.05	8.75	11.62	8.39	36.04	38.04	25.88	L
Bm_2	41-78	½"	12.1	2.88	5.40	9.26	11.47	9.24	38.25	35.39	26.36	L
R	78+	-	-	-	-	-	-	-	-	-	-	-

Appendix I: Table 17. Analysis of Profile B89, Cryic Gleyed Orthic Eutric Brunisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	5-0	3.5	0.24	-	-	-	53.6	1.39	39	85	11.64	8.95	1.98	0.93	61.10
Bmg	0-15	4.5	0.09	-	-	-	2.0	0.17	12	27	13.43	4.25	0.54	0.17	8.52
Cg	15-84	7.5	0.19	2.0	1.3	0.6	-	-	-	13	-	-	-	-	-
Cz	84+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	%	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	5-0	-	-	-	-	-	-	-	-	-	-	-
Bmg	0-15	-	0		-	-	-	-	3.32	48.54	48.14	SiC
Cg	15-84	-	0	3.42	5.16	3.93	2.91	2.22	17.64	53.13	29.23	SiCL
Cz	84+	-	0	-	-	-	-	-	-	-	-	-

Appendix I: Table 18. Analysis of Profile ZT15, Cryic Gleyed Orthic Eutric Brunisol*

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	5-0	3.8	-	-	-	-	43.7	1.22	36	77	24.10	7.42	1.03	0.75	42.92
Bmg	0-10	7.2	-	3.6	1.1	2.3	3.9	0.19	20	26	-	-	-	-	-
Cgy	10-50	7.4	-	8.3	3.3	5.1	5.1	0.16	32	19	-	-	-	-	-
Cg	50-63	7.6	-	16.5	6.6	9.1	0.6	0.06	9	10	-	-	-	-	-
Cz	63+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	%	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	5-0	-	-	-	-	-	-	-	-	-	-	-
Bmg	0-10	-	0	-	-	-	-	-	4.50	69.72	25.78	SiL
Cgy	10-50	-	0	-	-	-	-	-	3.93	69.96	26.11	SiL
Cg	50-63	-	0	-	-	-	-	-	6.10	73.38	20.52	SiL
Cz	63+	-	0	-	-	-	-	-	-	-	-	-

* influenced by cryoturbation

Appendix I: Table 19. Analysis of Profile ZT27, Cryic Orthic Dystric Brunisol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
Bm	0-9	4.3	-	-	-	-	0.6	0.05	13	5	1.04	0.63	0.18	0.26	2.33
BC	9-25	4.5	-	-	-	-	0.01	0.01	1	1	0.49	0.23	0.02	0.22	0.19
C	25-60	5.1	-	-	-	-	-	-	-	1	0.37	0.16	0.02	0.22	0.00
Cz	60+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	Stones %	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
Bm	0-9	1/8"-½"	23.1	0.80	7.03	4.33	8.72	1.51	61.39	28.03	10.58	SL
BC	9-25	1/8"	2.1	-	4.89	58.79	29.66	1.28	94.63	2.33	3.04	S
C	25-60	1/8"	1.0	-	1.84	56.60	36.48	1.66	96.57	2.68	0.75	S
Cz	60+	-	-	-	-	-	-	-	-	-	-	-

Appendix I: Table 20. Analysis of Profiles ZTA and B, Crvic Orthic Dystric Brunisol*

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
				Profile ZT8A											
L-F	6-0	3.4	-	-	-	-	52.8	0.67	79	4	0.79	0.46	0.05	0.37	2.37
Bmy	0-13	4.2	-	-	-	-	0.5	0.04	13	3	0.38	0.37	0.05	0.37	2.27
Cy	13-50	4.4	-	-	-	-	-	-	-	-	-	-	-	-	-
				Profile ZT8B											
Bm	0-20	4.0					0.4	0.03	14	4	0.68	0.45	0.05	0.37	2.89
BCy	20-39	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bmy	39-50	4.85	-	-	-	-	0.5	0.03	16	6	1.98	1.10	0.05	0.56	2.35
C	50-80	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	%	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
				Profile ZT8A								
L-F	6-0	-	-	-	-	-	-	-	-	-	-	-
Bmy	0-13	-	0	0.60	1.77	7.46	28.83	8.25	46.91	45.18	7.91	L
Cy	13-50	$\frac{1}{4}$"	3.5	0.56	1.81	6.61	22.44	8.81	43.72	48.32	7.96	L
				Profile ZT8B								
Bm	0-20	-	0	1.78	1.72	6.00	22.16	7.64	39.30	51.70	9.00	SiL
BCy	20-39	-	-	-	-	-	-	-	-	-	-	-
Bmy	39-50	-	0	1.20	1.94	7.37	6.18	6.93	43.54	45.9	10.56	L
C	50-80	-	-	-	-	-	-	-	-	-	-	-

* influenced by cryoturbation

Appendix I: Table 21. Analysis of Profile ZT29, Cryic Orthic Dystric Brunisol*

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^{+}	Na^{+}	H^{+}
Bm	0-25	3.7	-	-	-	-	2.4	0.51	5	21	0.08	0.70	0.23	0.28	19.59
Cy	25-103	3.6	-	-	-	-	2.7	0.45	6	22	0.10	0.85	0.31	0.24	20.56
Cz	103+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	Stones %	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
Bm	0-25	-	0	-	-	-	-	-	5.88	49.22	44.90	SiC
Cy	25-103	-	0	-	-	-	-	-	4.38	48.29	47.33	SiC
Cz	103+	-	0	-	-	-	-	-	-	-	-	SiC

* influenced by cryoturbation

Appendix I: Table 22. Analysis of Profile ZT16, Cryic Orthic Dystric Brunisol*

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	1-0	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Bm	0-32	4.0	-	-	-	-	3.1	0.18	17	25	0.29	2.60	0.41	0.33	21.24
BCy	32-64	4.3	-	-	-	-	3.6	0.31	18	31	0.92	4.11	0.59	0.32	25.51
Ayhz	64-78	3.6	-	-	-	-	11.7	0.45	26	36	2.06	1.85	0.74	0.83	30.65
Cz	78-300	5.1	-	-	-	-	4.0	0.13	31	31	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	%	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	1-0	-	-	-	-	-	-	-	-	-	-	-
Bm	0-32	-	0	-	-	-	-	-	4.75	44.40	50.86	SiC
BCy	32-64	-	0	-	-	-	-	-	4.97	50.65	44.38	SiC
Ayhz	64-78	-	0	-	-	-	-	-	9.27	50.78	39.95	SiCL
Cz	78-300	-	0	-	-	-	-	-	9.00	59.54	31.46	SiCL

* influenced by cryoturbation

Appendix I: Table 23. Analysis of Profile B70A, Lithic Orthic Regosol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	7-0	6.4	0.24	-	-	-	18.7	1.01	18	63	57.69	1.41	0.21	0.11	3.23
Ah	0-15	6.5	0.14	-	-	-	12.9	0.74	17	49	45.16	1.04	0.10	0.04	2.55
R	15+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	Stones %	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	7-0	-	-	-	-	-	-	-	-	-	-	-
Ah	0-15	1/8"	2.0	-	1.01	5.00	7.17	4.84	18.02	57.76	24.22	SiL
R	15+											

Appendix I: Table 24. Analysis of Profile B70B, Lithic Orthic Regosol*

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	3-0	5.1	0.43	-	-	-	50.7	1.07	47.4	68	37.60	7.31	1.98	0.15	21.93
Cy	0-22	6.1	0.11	-	-	-	2.6	0.15	13.3	16	13.18	2.06	0.07	0.04	1.79
R	22+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	%	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	3-0	-	-	-	-	-	-	-	-	-	-	-
Cy	0-22	-	0	16.23	12.24	9.68	10.38	14.73	63.26	27.06	9.68	SL
R	22+	-	-	-	-	-	-	-	-	-	-	-

* influenced by cryoturbation

Appendix I: Table 25. Analysis of Profile R170, Cryic Rego Gleysol

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-F	18-0	3.4	-				56.4	1.72	33	138	69.91	10.94	0.08	0.24	57.50
Cg	0-22	5.6	0.12				-	-	-	41	28.86	6.08	0.32	0.57	5.61
Cgz	22-52	-					-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	Stones %	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-F	18-0	-	-	-	-	-	-	-	-	-	-	-
Cg	0-22	-	0	-	0.28	1.14	2.97	7.67	12.07	53.05	34.88	SiCL
Cgz	22-52	-	-	-	-	-	-	-	-	-	-	-

Appendix I: Table 26. Analysis of Profile ZT6, Cryic Rego Gleysol*

Chemical Characteristics

Hor.	Depth cm	pH	Conductivity mmhos/cm	% $CaCO_3$ Equiv.	% Calcite	% Dolomite	% Org.C.	% Total N	C/N Ratio	C.E.C. m.e.	Exchangeable Cations m.e./100 gms. Ca^{2+}	Mg^{2+}	K^+	Na^+	H^+
L-H	23-0	2.8	-	-	-	-	55.9	0.87	64	100	10.30	6.39	0.27	0.23	82.21
Cyg	0-29	5.8	-	-	-	-	-	-	-	34	25.43	4.14	0.12	0.70	3.62
Cygz	29+	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Particle Size Characteristics

Hor.	Depth cm	Stones Dominant size	Stones %	Sand Fraction % V.C.S.	C.S.	M.S.	F.S.	V.F.S.	Total Sand %	Silt %	Clay %	Textural Class
L-H	23-0	-	-	-	-	-	-	-	-	-	-	-
Cyg	0-29	-	0	2.01	2.57	5.73	9.55	11.85	31.72	48.05	20.23	L
Cygz	29+	-	-	-	-	-	-	-	-	-	-	-

* influenced by cryoturbation

Appendix II. Analysis of Water Samples

Wetland	Sample No.	pH	Conductivity	ppm							
				Ca^{++}	Mg^{++}	Na^{+}	Total Cations	$SO_4^{=}$	Cl^{-}	HCO_3^{-}	Total Anions
Spring Fen	101	7.30	0.33	54.91	11.80	29.89	96.60	106.63	8.87	291.07	406.57
Patterned Fen	100	7.80	0.20	18.64	22.25	7.59	48.48	29.78	17.73	97.02	144.53
Water Track	115	7.82	0.55	83.77	28.82	4.14	116.73	50.43	10.64	242.86	303.93
Willow Swamp	116	6.70	0.25	46.69	13.74	0.69	61.12	29.78	1.06	164.14	194.98
Flat Fen	(118	6.84	0.24	30.46	2.80	5.98	39.24	13.93	2.13	137.30	153.36
	(119	6.92	0.28	37.07	3.28	5.98	46.33	1.92	3.55	164.14	169.61
Collapse Scar	(103	4.55	0.33	2.00	0.12	Tr	2.12	Tr	Tr	Tr	Tr
	(107	4.10	0.07	2.00	0.73	Tr	2.73	Tr	Tr	Tr	Tr
	(113	4.50	0.04	2.81	0.24	Tr	3.05	Tr	Tr	Tr	Tr
	(120	4.90	0.10	8.42	1.82	5.98	16.22	9.13	8.81	19.53	37.53
Bog Plateau	108	4.70	0.05	2.00	0.73	Tr	2.73	Tr	Tr	Tr	Tr
Peat Polygon	(102	3.90	0.05	1.40	0.12	Tr	1.52	Tr	Tr	Tr	Tr
	(111	4.05	0.05	2.81	0.12	Tr	2.93	Tr	Tr	Tr	Tr
Ice Wedge	114	5.90	0.02	1.00	Tr	Tr	1.00	Tr	Tr	Tr	Tr
Small Lake	109	7.05	0.07	8.22	1.58	Tr	9.80	Tr	Tr	Tr	Tr
Small Stream	110	5.30	0.01	2.00	0.12	Tr	2.12	Tr	Tr	Tr	Tr
Mineral Spring (hot, 32°C)	106	7.25	11.40	736.87	158.44	3287.57	4182.88	2327.53	4969.72	194.04	7491.29
Mineral Spring (cool)	117	7.50	1.43	256.71	82.69	10.81	350.21	737.26	20.57	196.48	954.31

Tr: Traces, less than .1 ppm

Appendix III. Location of Detailed Sample Sites

Site No.	Lat.	Long.	N.T.S. No.	Elevation a.s.l. (feet)
T1	61°01'	122°02'	95G	1090
T2	61°07'	122°44'	95G	750
T3	61°08'	122°29'	95G	1170
T4	61°12'	123°15'	95G	1400
T5	61°29'	123°02'	95G	1290
T6	61°15'	124°04'	95F	800
T7	61°50'	122°12'	95G	2040
T8	61°50'	122°13'	95G	2060
T9	61°51'	122°38'	95G	1350
T10	61°50'	122°55'	95G	1150
T11	61°48'	123°16'	95G	1750
T12	61°43'	122°40'	95G	1100
T13	61°46'	122°32'	95G	1190
T14	61°48'	122°13'	95G	2100
T15	62°32'	120°46'	95I	950
T16	62°43'	121°04'	95I	810
T17	61°47'	121°16'	95H	620
T18	61°36'	121°24'	95H	650
T19	61°32'	121°18'	95H	620
T20	61°22'	121°01'	95H	730
T21	61°22'	120°59'	95H	750
T22	61°22'	120°54'	95H	770
T23	61°21'	120°48'	95H	700
T24	61°14'	120°25'	95H	900
T25	61°27'	121°16'	95H	660
T26	61°25'	121°22'	95H	760
T27	61°57'	120°07'	95H	2750
T28	63°18'	123°36'	950	710
T29	63°19'	123°36'	950	710
T30	63°04'	123°45'	950	2800
T31	63°25'	123°15'	950	4450
T32	63°25'	123°14'	950	5000
T33	63°24'	123°13'	950	4272
T34	63°24'	123°13'	950	4200
T35	63°22'	123°00'	950	1950
T36	60°59'	119°49'	85D	1020
T37	61°08'	119°44'	85E	900
T38	61°09'	119°34'	85E	800
T39	61°08'	119°17'	85E	820
T40	61°05'	118°42'	85E	850
T41	61°13'	117°32'	85F	540
T42	61°09'	117°33'	85F	610
T43	61°04'	117°33'	85F	760
T44	61°07'	118°02'	85E	800
T45	61°04'	118°20'	85E	770
T46	61°09'	119°54'	85E	810
T47	61°12'	120°04'	95H	880
T48	61°17'	120°35'	95H	790
T49	61°21'	120°45'	95H	700
T50	61°26'	121°14'	95H	670
T51	61°04'	121°24'	95H	600
T52	61°38'	121°24'	95H	620

Appendix III. (con't.)

Site No.	Lat.	Long.	N.T.S. No.	Elevation a.s.l. (feet)
ZT1	65°16'	127°22'	96E	600
ZT2	65°24'	127°52'	96E	650
ZT3	65°10'	128°30'	106H	3600
ZT4	65°18'	128°19'	106H	1100
ZT5	65°15'	128°23'	106H	1150
ZT6	64°58'	126°34'	96D	650
ZT7	65°03'	127°54'	96E	4500
ZT8	65°09'	128°26'	106H	4150
ZT9	64°49'	125°54'	96C	480
ZT10	65°29'	129°36'	106H	900
ZT11	65°57'	129°54'	106H	480
ZT12	66°03'	129°12'	106I	420
ZT13	65°44'	128°41'	106H	410
ZT14	65°45'	128°01'	106H	500
ZT15	65°31'	128°32'	106H	480
ZT16	68°38'	133°48'	107B	460
ZT17	68°23'	133°45'	107B	80
ZT18	69°14'	134°44'	107C	90
ZT19	69°23'	134°37'	107C	50
ZT20	69°21'	134°04'	107C	100
ZT21	69°06'	133°50'	107C	180
ZT22	68°57'	133°45'	107B	100
ZT23	68°30'	133°41'	107B	350
ZT24	69°25'	132°43'	107C	100
ZT25	69°34'	132°35'	107C	80
ZT26	69°18'	132°30'	107C	60
ZT27	69°05'	132°23'	107C	100
ZT28	68°52'	132°44'	107B	80
B68	61°52'	123°13'	95G	990
B70	61°47'	123°56'	95G	3640
B71	61°56'	123°21'	95G	1200
B89	63°24'	123°57'	950	1550
B123	63°37'	123°00'	950	1550
B172	60°40'	119°04'	85D	1020
R155	63°24'	124°31'	95N	1200
R166	63°49'	124°51'	95N	650
R170	63°52'	125°28'	95N	3200

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