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La répartition du pergélisol dans la partie méridionale de la zone discontinue du Québec-Labrador
Dauerfrostverteilung im sudlichen Teil der unterbrochenen Zone in Québec und Labrador

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See table of contents

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Article abstract

The distribution of permafrost in the southern part of the discontinuous zone in Québec and Labrador is described. At the southern limit of this subzone islands of permafrost vary in extent from a few tens of square metres to several hectares and in thickness from a few centimetres to a metre or so. Northward to the middle of the discontinuous zone permafrost becomes increasingly widespread reaching a thickness exceeding 100 metres. Permafrost occurs mainly in peatlands, on some north facing slopes and above treeline on mountain summits. The relationships of permafrost distribution to climatic and terrain factors, including air temperature, vegetation, drainage and snow cover are discussed, the last being particularly important. The paper concludes with an analysis of some prominent air photo patterns.

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PERMAFROST DISTRIBUTION IN THE SOUTHERN PART OF THE DISCONTINUOUS ZONE IN QUÉBEC AND LABRADOR*

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ABSTRACT The distribution of permafrost in the southern part of the discontinuous zone in Québec and Labrador is described. At the southern limit of this subzone islands of permafrost vary in extent from a few tens of square metres to several hectares and in thickness from a few centimetres to a metre or so. Northward to the middle of the discontinuous zone permafrost becomes increasingly widespread reaching a thickness exceeding 100 metres. Permafrost occurs mainly in peatlands, on some north facing slopes and above treeline on mountain summits. The relationships of permafrost distribution to climatic and terrain factors, including air temperature, vegetation, drainage and snow cover are discussed, the last being particularly important. The paper concludes with an analysis of some prominent air photo patterns.

RÉSUMÉ *La répartition du pergélisol dans la partie méridionale de la zone discontinue du Québec-Labrador.* Au sud de la zone de pergélisol discontinu, la superficie des îlots de pergélisol varie entre quelques dizaines de mètres carrés et plusieurs hectares et l'épaisseur du pergélisol se situe entre quelques centimètres et environ un mètre. En se dirigeant vers le nord, jusqu'au centre de la zone discontinue, le pergélisol devient plus dense et son épaisseur dépasse la centaine de mètres. Le pergélisol se manifeste surtout dans les tourbières, sur les versants exposés au nord et sur les sommets au-dessus de la limite arboréenne. Il est ensuite question des relations entre la répartition du pergélisol et les caractéristiques du climat et du terrain telles la température de l'air, la végétation, les conditions de drainage et l'épaisseur de la neige, ce dernier aspect étant particulièrement important. L'étude se termine par une analyse des traits saillants de quelques photos aériennes.

ZUSAMMENFASSUNG *Dauerfrostverteilung im sudlichen Teil der unterbrochenen Zone in Québec und Labrador.* Die Verteilung des Dauerfrostes im sudlichen Teil der Unterbrochenen Zone in Québec und Labrador ist beschrieben. An der Südlichen Grenze dieser Subzone finded man Inseln von Dauerfrost die im Durchmesser von wenigen Quadratmetern bis zu mehreren Hektaren varieren und wo er von wenigen Zentimetern bis zu ungefähr einem Meter dick ist. Weiter nördlich in der Mitte der unterbrochenen Zone wird der Dauerfrost immer häufiger und erreicht mehr als 100m Dicke. Dauerfrost kommt hauptsächlich in Mooren vor, an einigen Nordhangen und über der Baumlinie auf Berggipfeln. Die Beziehungen zwischen Dauerfrostverteilung und klimatischen und landschaftlichen factoren, einschliesslich Lufttemperaturen, Vegetation, Entwässerung und Schneedecke werden behandelt, die letztere ist von besonderer Wichtigkeit. Die Studienarbeit schliesst mit der Analyse einiger wichtiger Luftbildstrukturen.

* This paper is a contribution from the Division of Building Research, National Research Council of Canada, and is published with the approval of the Director of the Division.

INTRODUCTION

According to available information, the southern limit of the discontinuous permafrost zone in Québec and Labrador appears to extend approximately along the 51st parallel of latitude from the southern end of James Bay to the Strait of Belle-Isle, 1500 km to the east (Fig. 1). The northern limit of this southern part, or subzone, of the discontinuous zone begins at the western extremity on Hudson Bay in the vicinity of Poste-de-la-Baleine, 55°N latitude. Eastward on approximately the same parallel, Schefferville in the centre of the Québec-Labrador peninsula, and Hopedale on the Atlantic coast of Labrador, are both situated at the northern margin of the permafrost area under consideration.

PERMAFROST DISTRIBUTION AND FEATURES

In the southern half of the discontinuous zone, permafrost occurs in the form of scattered islands which increase in size and number from south to north. Generally the total area of permafrost terrain is less than 50 per cent of the entire land surface, very low at the southern limit and approaching this figure at the northern limit. North of the area under consideration in the northern part of the discontinuous zone, where permafrost is widespread, it comprises generally more than 50 per cent of the entire land surface. Here, islands of unfrozen ground are found scattered through the permafrost terrain, decreasing in size and number northward toward the continuous zone.

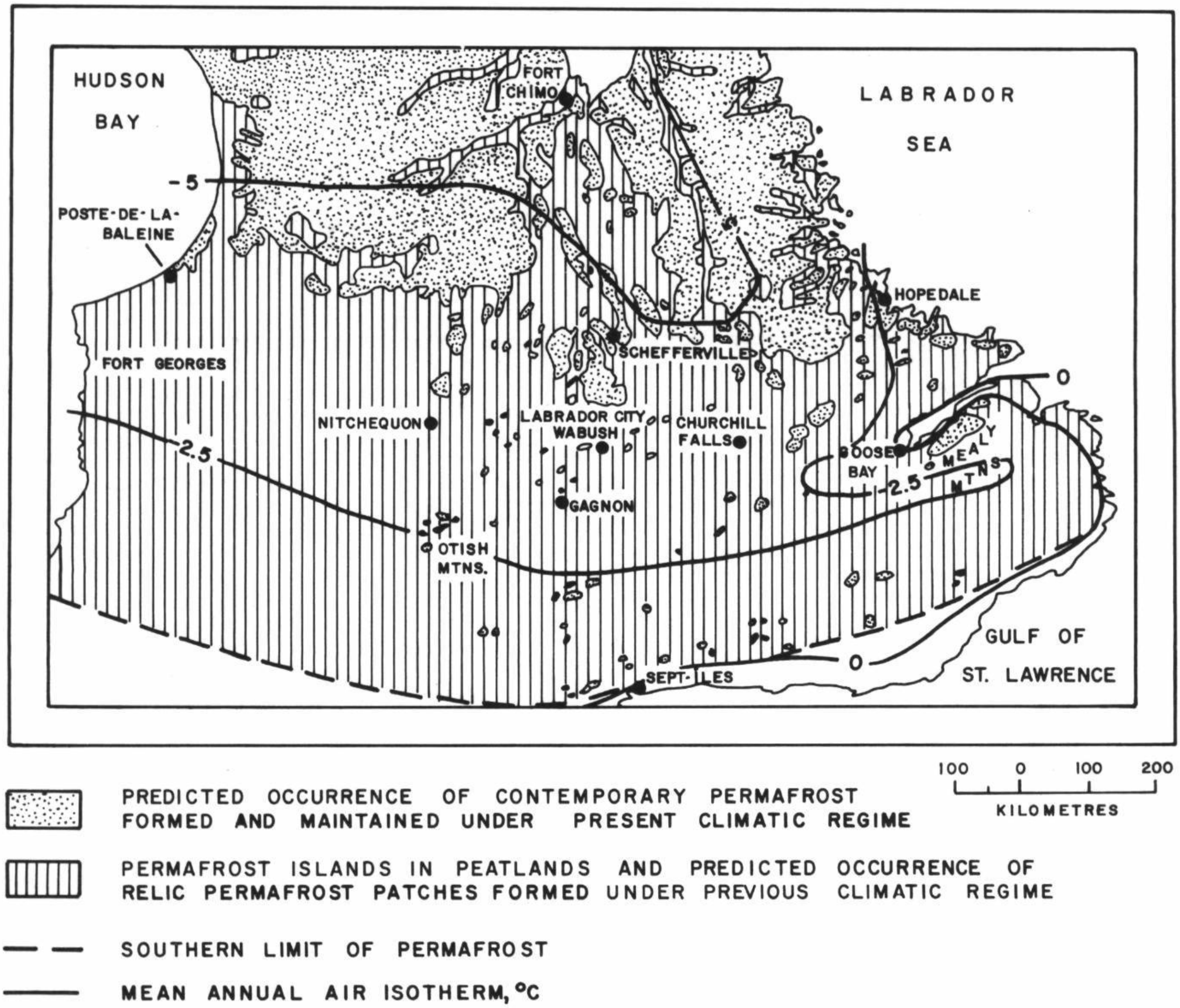

FIGURE 1. Permafrost distribution in Nouveau-Québec and Labrador (after BROWN, 1967, 1978; IVES, 1962).

La répartition du pergélisol au Nouveau-Québec et au Labrador (d'après BROWN, 1967, 1978; IVES, 1962).

The islands of permafrost vary in extent from less than a few tens of square metres to several hectares. The thickness of these patches varies from a few centimetres to a metre or so at the southern limit of the discontinuous zone to 100 m or more at the northern limit of the subzone under consideration. At Schefferville, for example, permafrost thickness of 120 m has been observed (Fig. 2) in the iron mining region (NICHOLSON, 1978). Many of the permafrost islands occur in peatlands associated with peat plateaux and palsas (Figs. 3, 4, 5). Some are found on valley slopes, usually north facing and in other special terrain situations such as where dense tree growth provides heavy shading or the snow cover is thin. Permafrost is also prevalent at high elevations on and near mountain summits which protrude above treeline (Figs. 6, 7). Even as far south as the Chic-Chocs Mountains in the Gaspé Peninsula, per mafrost occurs on treeless summits (GRAY and BROWN, 1979). It has been encountered at high elevations in the iron mines near Wabush and Labrador City to depths exceeding 60 m.

The depth of the permafrost table in the peatlands averages 50 cm with observed variations from a minimum of about 35 cm to a maximum of about 85 cm. The permafrost table usually lies in the peat above the mineral soil, the thickness of the peat layer ranging from about 0.6 to 2.0 m with an average of about 1 to 1.3 m. Peat in excess of 3 m thickness has been observed at some locations.

Very few ground temperature measurements are available for this region. The permafrost islands near the southern limit have temperatures ranging from −0.1°C to only a few tenths of a degree cooler. Northward the ground temperatures decrease steadily to the latitude of Schefferville. At this location they are observed to be as low as −2.8°C at the 15 m depth (approximate depth of zero annual amplitude) (NICHOLSON and THOM, 1973).

PALSAS AND OTHER PEATLAND FEATURES

Peat plateaux and palsas occur at numerous sites in Québec and Labrador within the area under consideration although they do not appear to be as numerous as in the Hudson Bay Lowland of northern Ontario and Manitoba (BROWN, 1967, 1973). The greatest concentrations have been observed in the west, between the marine limit of the Tyrrell Sea and Hudson Bay (DIONNE, 1978) and to a lesser extent in the east near the Atlantic coast (BROWN, 1975).

In the west, DIONNE (1978) has mapped the distribution of palsas from the coast of James Bay eastward for 200 km to the approximate boundary of the Tyrrell Sea deposits lying roughly along longitude 76°W. Within this broad coastal zone, palsas and peat plateaux are very prevalent. To the east their numbers are greatly reduced. Particularly heavy concentrations of these features are shown by Dionne in the vicinity of Fort George and in the eastern portion of the Tyrrell Sea region between Eastmain River and the Grande Rivière. Two areas of palsas and peat plateaux occur about 50 km and 150 km south of the permafrost region in Figure 1 : Lac Evans at latitude 51°N and near Matagami at latitude 50°N respectively (DIONNE, 1978).

Various studies have been carried out on palsas and peat plateaux in northwestern Québec. HAMELIN and CAILLEUX (1969) described the palsas in the basin of Great Whale River. LAGAREC (1978), LAVERDIÈRE and GUIMONT (1976), PAYETTE *et al.* (1976) and SEGUIN and CRÉPAULT (1978) made extensive investigations on the evolution of permafrost in palsas and other landforms from the northern portion of the James Bay region to Poste-de-la-Baleine and further north. Southward, observations have been reported from the vicinity of Fort George (VINCENT, 1977) and Fort Rupert (DIONNE, 1978). These investigators observed that forested palsas occur further south than unforested palsas. Many are relic especially in the extreme south.

The palsa shown in Figure 3 is typical of those encountered in this western region. There are 5 in a group each 15 to 30 m long, about 10 m wide and 2 to 3 m high. They have no trees although many palsas are forested (PAYETTE *et al.*, 1976). The ground cover consists of hummocky Sphagnum and lichen (mainly *Cladonia alpestris)* below which is Sphagnum peat about 1 m thick overlying silty fine sand. The permafrost table is 50 to 60 cm below the ground surface and the permafrost is probably 5 to 10 m thick. Cracks extending to a depth of nearly 1 m are scattered over the surface of the palsas. No permafrost occurs between palsas except for a few scattered patches beneath some lichen patches where the active layer is about 50 cm and the thickness of the permafrost 10 to 50 cm.

East of the Tyrrell Sea region there are relatively few palsas until reaching the longitude of Schefferville (67°W). They occur in the Schefferville area and have been noted at various locations to the south, such as on the summit of Mount Wright (now demolished for mining operations) 750 m above sea level. Closer to Sept-Îles on the Laurentidian Scarp, there are small areas of palsas on summits about 800 m above sea level. Further east, north of Havre-Saint-Pierre and near Harrington Harbour, scattered areas of palsas occur at similar elevations on the Laurentidian Scarp. There are also palsas at elevations up to about 350 m above sea level around Lake Melville.

In the extreme southeast of the region under consideration palsas and peat plateaux exist 8 km north of the Strait of Belle-Isle at an elevation of 120 m above sea level. These features, situated in a shallow rock

FIGURE 2. Terrain at Timmins orebody, Iron Ore Company of Canada Limited, 32 km north of Schefferville, and 770 m above sea level. Non-sorted circles cover the ground surface. The depth to the permafrost table varies from 3 to 4 m and the permafrost extends to a depth of about 100 m.

Le gisement de Timmins 4 de la Iron Ore Company of Canada, à 32 km au nord de Shefferville et à 770 m au-dessus du niveau de la mer. Des cercles sans triage couvrent la surface. Le pergélisol se manifeste à partir de 3 ou 4 m de profondeur et son épaisseur atteint 100 m.

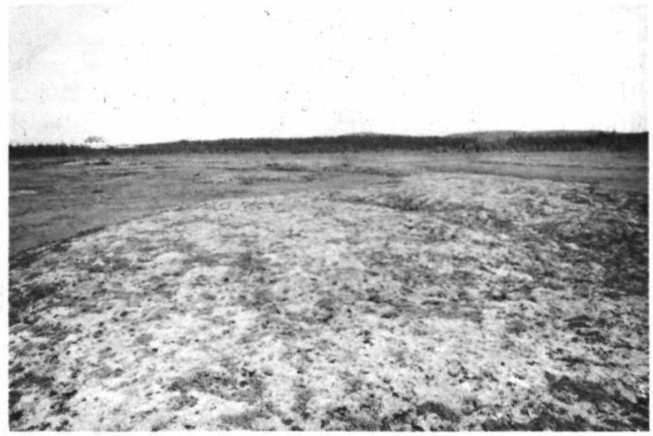

FIGURE 3. Typical palsa located 40 km south of Poste-de-la-Baleine. It is 15 m long by 9 m wide and 2,5 m high with vegetative cover of hummocky Sphagnum and lichen below which is peat 0,9 m thick overlying silty fine sand. The permafrost table is 53 cm below the ground surface and the permafrost is probably about 5 to 10 m thick. Permafrost a few centimetres to 1 m thick occurs in small hummocky Sphagnum lichen areas (incipient peat plateaux) near the palsa. There is no permafrost in the surrounding sedge covered areas.

Palse typique située à 40 km au sud de Poste-de-la-Baleine; elle mesure 15 m de longueur, 9 m de largeur et 2,5 m de hauteur. Son couvert végétal se compose de buttes de sphaigne et de lichen sous lesquelles 0,9 m de tourbe couvre un sable fin silteux. Le pergélisol se trouve à une profondeur de 53 cm et son épaisseur atteint probablement 5 à 10 m. Autour de la palse, une bande de pergélisol, épaisse de quelques centimètres à 1 m, apparaît dans les zones composées de petites buttes de sphaigne (débuts de plateaux tourbeux). Il n'y a pas de pergélisol dans les terrains couverts de carex à proximité.

FIGURE 4. Palsas and peat plateaux 1.5 m high at Cartwright, Labrador, with vegetative cover of hummocky Sphagnum and lichen below which is peat 1.2 m thick overlying sandy soil. The permafrost table is 45 cm below the ground surface and the permafrost extends into the mineral soil. No permafrost occurs in the surrounding low areas.

Palses et plateaux tourbeux de 1,5 m de hauteur à Cartwright, Labrador, dont le couvert végétal est composé de buttes de sphaigne et de lichen sous lesquelles une épaisseur de 1,2 m de tourbe recouvre un sol sablonneux. Le pergélisol se manifeste à partir de 45 cm de la surface et s'étend jusqu'au sol minéral. Il n'y a pas de pergélisol dans les dépressions avoisinantes.

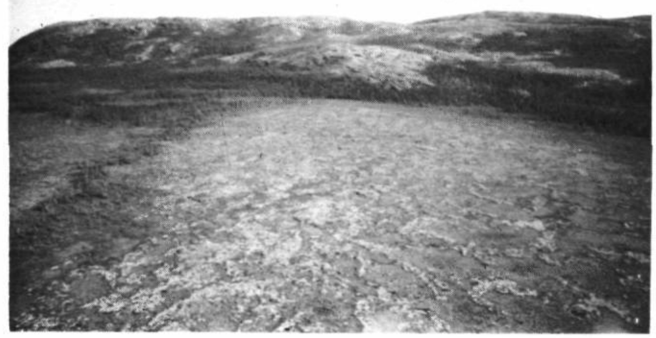

FIGURE 5. Aerial view from altitude of 150 m of palsas and peat plateaux on Neveisik Island in Lake Melville.

Vue aérienne, prise à une altitude de 150 m, des palses et des plateaux tourbeux de l'île Neveisik du lac Melville.

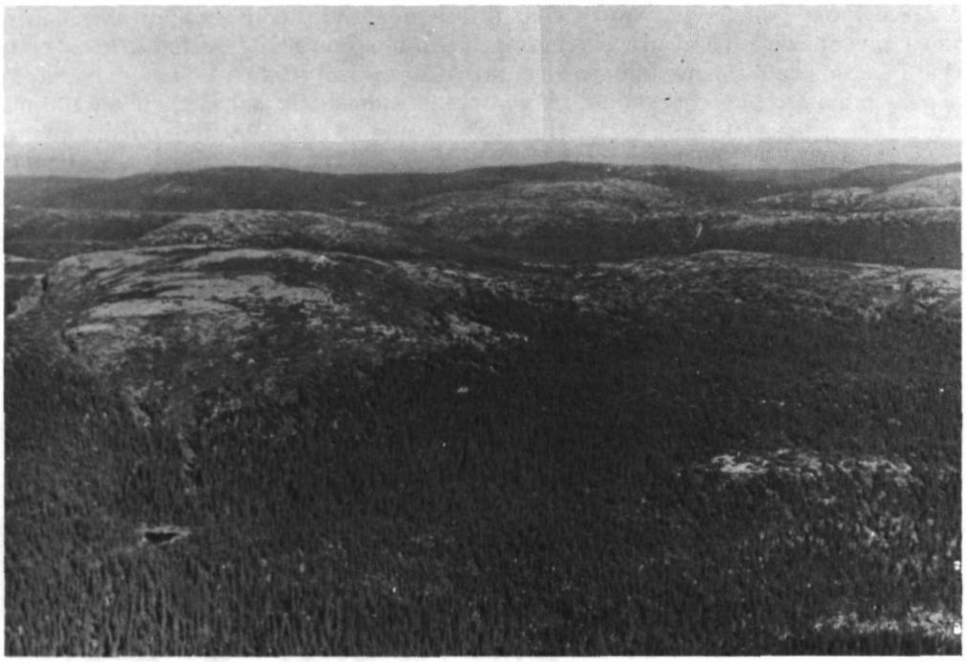

FIGURE 6. Mountainous terrain 150 km southwest of Gagnon. The summits are about 750 m above sea level. Permafrost probably exists above treeline.

Terrain montagneux à 150 km au sud-ouest de Gagnon. Les sommets atteignent 750 m au-dessus du niveau de la mer. Le pergélisol se rencontre probablement au-dessus de la limite de la végétation arboréenne.

FIGURE 7. The Otish Mountains 1000 m above sea level 80 km north of Nitchequon. Non-sorted circles are widespread. Permafrost occurs at a depth of 45 cm in a peat bog beside the lake and probably exist in these summits which are above treeline.

Les monts Otish (1000 m au-dessus du niveau de la mer) à 80 km au nord de Nitchequon. Les cercles sans triage y sont courants. Le pergélisol se retrouve à une profondeur de 45 cm dans une tourbière à côté du lac et probablement sur les sommets au-dessus de la limite de la végétation arboréenne.

basin in hilly terrain, are 1.3 m high, and each several hundreds of square metres in area. There are no trees; the surface vegetation is Sphagnum and lichen on a peat layer 1.8 m thick overlying stony sandy soil. The permafrost table is 50 cm below the ground surface and permafrost extends into the mineral soil.

Concentrations of palsas 2 to 3 m high are found at Cartwright on the Atlantic coast, on Huntingdon Island a few kilometres offshore, and on Neveisik Island in Lake Melville. There are no trees and the surface vegetation consists of Sphagnum and grey lichen. Scattered cracks extend to a depth of 60 cm. The peat layer is 60 cm to 1.2 m thick overlying silty sandy soil. The permafrost table is 60 cm below the ground surface. The palsas were described initially by HUSTICH (1939) and WENNER (1947).

Palsas and peat plateaux are the most prominent permafrost features but other indications of existing and past occurrences of permafrost are also evident. Many peatlands and peat bogs have peat plateaux but not existing permafrost. Collapse scars and thermokarst lakes are common, also with no permafrost present (CAILLEUX, 1959, 1971; LAGAREC, 1973; THIBODEAU and CAILLEUX, 1973). String bogs are very common especially on the Laurentidian Plateau in Labrador (ALLINGTON, 1961; HAMELIN, 1957, 1958; POTZGER and COURTEMANCHE, 1955; THOM, 1972). They are not necessarily directly related to the presence of permafrost; conditions in these features are usually too wet for perennially frozen ground to form. They also occur south of the permafrost region (DIONNE, 1968) but attain their best development in periglacial conditions where permafrost exists.

PERMAFROST AT HIGH ELEVATIONS AND OTHER PERMAFROST FEATURES

Outside of the peatlands, permafrost and related features are found in other types of terrain particularly at high elevations above treeline on and near mountain summits. Sorted circles, stone nets, and polygonal cracks have been observed on the Mealy Mountains 1080 m above sea level near the Labrador coast, on the Otish Mountains 1000 m above sea level 120 km south of Nitchequon and on summits 540 m and 700 m above sea level north of this location. These features are also present on summits reaching 900 m above sea level on the Laurentidian Scarp north of Sept-Îles. In the northern reaches of the area under consideration these surface features are more prevalent. Sorted circles and stone nets are widespread in the Schefferville area where permafrost is widespread and more than 100 m thick. They exist south of Schefferville on mountain summits at elevations of 800 m above sea level and near Churchill Falls on summits 650 m above sea level.

Stone nets 3 to 4 m in diameter also occur in another type of location on the Laurentidian Plateau. Near Churchill Falls they were observed on low flat shorelines of the large shallow lakes (Fig. 8). They can also be seen on lake bottoms near the shores in shallow water (DIONNE, 1974). There is a good possibility of permafrost existing at these sites because the lakes, at least their margins, freeze to the bottom in winter.

Other occurrences of features associated with permafrost and periglacial conditions have been observed and reported. On the coast of Labrador north of Rigolet, thaw slumps occur on the south-facing slopes of several river valleys in fine-grained soils (BROWN, 1975). Thaw slumps were encountered on the tree-covered north-facing slope of the Unknown River, a tributary of the Churchill River near Churchill Falls where the existence of permafrost was described by ANDREWS (1961) and CAPLAN (1961). No slumping was observed on the deciduous-covered south-facing slopes. Permafrost was encountered to a depth of 5 m in fill on an island in Lobstick Lake at the hydroelectric construction at Churchill Falls, and at another location, also in till, on an island in Ossokmanuan Lake (Acres Canadian Bechtel Ltd., personal communication).

FIGURE 8. Stone nets about 3 m in diameter at edge of a small shallow lake near Churchill Falls. The soil is a mixture of silt, clay and gravel. Permafrost possibly exists at this site because the lake, although nearby, freezes to the bottom in winter.

Réseaux polygonaux de pierres, de 3 m de diamètre environ, en bordure d'un petit lac peu profond près de Churchill Falls. Le sol est composé de silt, d'argile et de gravier. Le pergélisol existe probablement à cet endroit puisque le lac, bien que voisin, gèle jusqu'au fond en hiver.

The distribution of permafrost in Québec and Labrador has fluctuated with time in response to changes in climate and terrain conditions. Such questions as: what permafrost is contemporary and what is relic; is the present permafrost in equilibrium with environmental conditions; what was the distribution of permafrost in the past; and what are the future trends — all require answers to complete the understanding of permafrost conditions in Québec and Labrador. The paper in this volume by IVES (1979) presents the most recent information and discussion on these important considerations.

ENVIRONMENTAL FACTORS

Climate is the most important factor influencing the formation and existence of permafrost in the region under consideration. Within this framework the most prominent terrain factors are vegetation, relief, drainage and snow cover.

CLIMATIC INFLUENCES ON PERMAFROST

Air temperature is the only climatic parameter for which sufficient data are available to permit comparisons with the distribution of permafrost. In Canada, west of Hudson Bay, the southern limit of permafrost coincides roughly with a mean annual air temperature of −1°C (BROWN, 1978). This relationship also appears to hold generally in Québec from James Bay eastward toward the Strait of Belle-Isle (Fig. 1). In southeastern Labrador, however, the 0°C mean annual air isotherm curves northward placing the Atlantic Coast, between the Strait of Belle-Isle and Cartwright, and the Lake Melville region in an area with higher air temperatures. Palsas exist at Cartwright, where the mean annual air temperature is 0.2°C. They may have formed under cooler conditions of an earlier period. Low solar radiation values during the summer in this maritime climatic region may also be a factor.

In the southern fringe of the permafrost region, permafrost exists only in certain types of terrain mentioned at the beginning of this paper, provided the climate is sufficiently cool, *i.e.,* the mean annual air temperature is −1°C or less. Southward, permafrost occurrences are rare and generally are not found in the same types of terrain because the climate is too warm. A few palsas were noted by DIONNE (1978) near Matagami where the mean annual air temperature is about 0°C. These palsas, which are forested, are disintegrating today. A few widely scattered patches of permafrost, probably relic, and polygonal cracks have been reported in the peat-covered coastal plain along the Gulf of St. Lawrence such as at Mingan Island, 35 km west of Havre-Saint-Pierre (LANDRY and DUBOIS, 1977).

At the northern boundary of the region under consideration, *i.e.,* extending from Poste-de-la-Baleine through Schefferville to Hopedale, permafrost becomes widespread and is found in many types of terrain. West of Hudson Bay the southern limit of this widespread subzone of the discontinuous zone generally coincides with a mean annual air temperature of about −3.5°C to −4°C. In Northern Québec and Labrador, however, the same broad relationship does not hold. The mean annual air temperature at Poste-de-la-Baleine (55°N latitude) is −4.1°C but the −4°C mean annual air isotherm veers southeastward almost to Nitchequon (53°N latitude), then northeastward between Churchill Falls (54°N latitude) and Schefferville (55°N latitude), those two stations having mean annual air temperatures of −3.2°C and −4.6°C respectively. From here it extends almost due north about 250 km inland from Hopedale, which has a mean annual air temperature of only −1.7°C but permafrost conditions similar to those at Poste-de-la-Baleine.

TERRAIN FACTORS

Vegetation is one of the most important components of the terrain, mainly in the role which peat plays in the distribution of permafrost. Most of the occurrences of permafrost in the region under consideration are in peatlands and peat bogs.

The mechanism of permafrost formation in peat terrain is known to be related to changes in the thermal properties of the peat through the year. During the summer the surface layers of peat become dry through evaporation. The thermal conductivity of the peat is low and warming of the underlying soil is impeded. The lower peat layers gradually thaw downward and become wet as the ice layers in the seasonally frozen layer melt. In the autumn there tends to be more moisture in the surface layers of the peat because of a decreased evaporation rate. When it freezes the thermal conductivity of the peat is increased considerably. Thus the peat offers less resistance to the cooling of the underlying soil in winter than to the warming of it in summer. The mean ground temperature under peat will therefore be lower than under adjacent areas without peat. When conditions under the peat are such that the ground temperature remains below 0°C throughout the year, permafrost results and is maintained as long as the thermal conditions leading to this lower temperature persist.

There is a somewhat puzzling aspect of the abovementioned role of peat in the formation and existence of permafrost. In the region under consideration permafrost is absent in the peat at many locations although this peat is sufficiently thick and dry. This type of terrain condition west of Hudson Bay north of the −1°C mean annual air isotherm usually indicates the presence of permafrost but none occurs at many such sites east of James Bay and Hudson Bay, and eastward into Labrador. At numerous locations where dry peat 1 m and more in thickness is encountered in peat bogs, no permafrost exists. The peat is cold to the touch, but not frozen even where the mean annual air temperature is several degrees below 0°C.

The variable relief and existence of high elevations throughout the sutdy area have a significant effect on the distribution of permafrost. It is suggested that permafrost exists at all locations above treeline in the discontinuous zone of Québec and Labrador (IVES, 1962, 1974). The Mealy Mountains in eastern Labrador and the Otish Mountains (Fig. 7) in Québec have permafrost on their summits which are above treeline (BROWN, 1975). Other areas with summits above treeline are shown as dark islands on the map of permafrost distribution (Fig. 1) and are typified by the photograph of typical mountainous terrain in Figure 6. Mountain summits near Nitchequon are also above treeline and have permafrost. Palsas can be seen in many peat bogs on mountain summits above treeline, confirming the presence of permafrost. No permafrost was encountered in the townsites of Wabush and Labrador City 540 m above sea level. As mentioned previously, permafrost occurs above 750 m in the nearby iron mines and has been found to depths exceeding 60 m. At Schefferville scattered permafrost islands exist in peat bogs near the town at an elevation of about 500 m above sea level. Thick, widespread permafrost exists above treeline at about 700 m elevation where mining operations are underway.

Drainage appears to be an important factor related to the occurrence of permafrost in the discontinuous zone. The importance of water conditions is shown by the absence of permafrost in areas where the water table is at the ground surface, even if the ground cover consists of Sphagnum. The extensive string bogs on the Laurentidian Plateau in Labrador are too wet for permafrost even in the Sphagnum-covered ridges. In some of these areas, the surface peat layer is thin, only 30 to 50 cm, and mineral soil and boulders are visible in the bottoms of the shallow pools. At many locations in the study area, open wet treeless bogs with no permafrost are bordered or surrounded by slightly higher and drier peatland with scattered tree growth. Scattered permafrost islands can be found in only some of these areas so this terrain situation does not guarantee the existence of permafrost.

Regional snowfall conditions appear to be a major factor contributing to the general scarcity of permafrost in the peatlands of Québec and Labrador located in the southern fringe of the discontinuous zone. The mean annual snowfall east of Hudson Bay and James Bay ranges from about 200 to 250 cm at the west increasing eastward to nearly 500 cm in Labrador (Table I). In contrast to this, the mean annual snowfall west of Hudson Bay varies from a maximum of 200 cm in the Hudson Bay Lowland to lower amounts in central Manitoba. Furthermore, Table I indicates that snowfall is much greater in the fall months, October to December inclusive, east of Hudson Bay than to the west during the onset of freezing air temperatures. The snow cover on the ground during the fall, and over the entire winter, is also about 50 per cent greater east of Hudson Bay. Freezing ground temperatures and the formation of permafrost are therefore considerably inhibited in contrast to the southern fringe of the discontinuous zone west of Hudson Bay.

The importance of the snow cover has also been demonstrated by investigations at Schefferville. Here it was found that snow is the most important factor controlling permafrost distribution and that there is a linear relationship between ground temperatures and snow depth. Permafrost exists generally where the snow cover is less than about 70 cm. Permafrost occurs in ridges where snow cover in thin but not in valley bottoms where the snow is deep (NICHOLSON and GRANBERG, 1973; NICHOLSON and THOM, 1973).

AIRPHOTO PATTERNS

Aerial photographs reveal a variety of patterns throughout the region under consideration because of the variations in relief, vegetation, soils and drainage. The areas most probably containing permafrost, *i.e.*, the peatlands, can be delineated on the air photos; field investigations to verify its existence or absence can be concentrated in these locations. Within this broad framework, however, the recognition of such permafrost features as peat plateaux and palsas is hindered somewhat by their small size on the available photographs. Some peat plateaux do not contain permafrost, which is a complicating feature. North-facing slopes are also potential permafrost areas as are treeless mountain summits. Surface features associated with permafrost include nonsorted circles and stripes, and polygons, all of which are identifiable on aerial photographs. Northward where permafrost becomes widespread, such as in the vicinity of Schefferville, the identification of permafrost is complicated by its existence in various types of terrain without associated surface features.

The area shown in Figure 9 was selected from eastern Labrador to illustrate some patterns, including permafrost features. The area with the permafrost features comprises virtually the entire extent except for the rock outcrops on the left side. The most predominant pattern

TABLE I

Snowfall (cm) at selected stations east and west of Hudson Bay

Location	Oct.	Nov.	Dec.	3 month total	annual average
QUÉBEC					
Fort George	11	52	47	110	195
Poste-de-la-Baleine	22	53	41	116	251
Nitchequon	34	48	42	124	285
Gagnon	33	64	75	172	427
Schefferville	36	54	45	135	336
LABRADOR					
Churchill Falls	40	47	75	162	480
Goose Bay	25	53	67	145	409
Cartwright	11	40	67	118	434
ONTARIO					
Moosonee	18	49	50	117	280
Winisk	15	34	38	87	202
Trout Lake	20	44	26	90	196
MANITOBA					
Gods Lake Narrows	20	41	32	93	191
Norway House	7	29	20	56	123
Churchill	26	42	21	89	184

Snow cover (cm) on ground east and west of Hudson Bay

Location	Oct.	Nov.	Dec.	maximum annual average
East of Hudson Bay	20-25	50-75	50-75	115-125
West of Hudson Bay	12-15	25-50	25-50	75-85

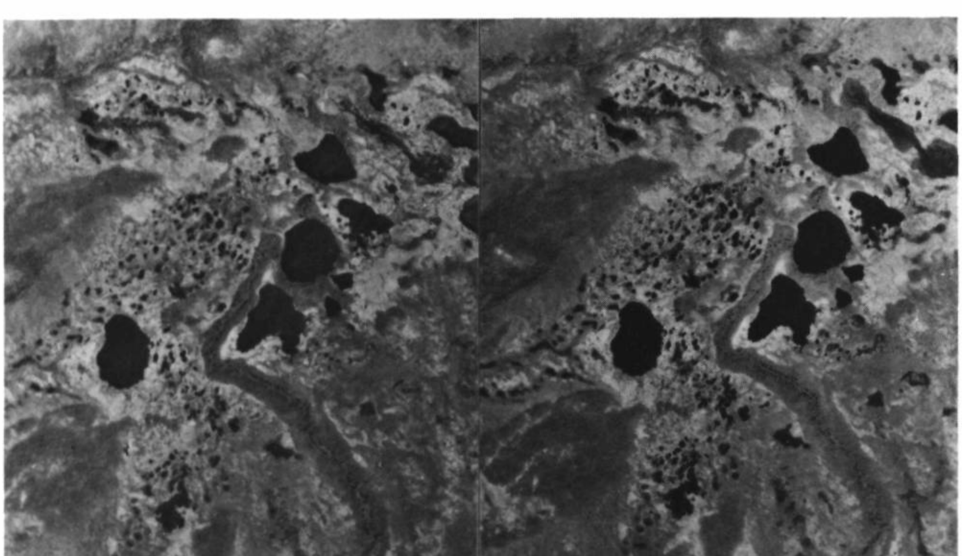

FIGURE 9. Stereoscopic pair sections of RCAF air photos A22524-35 and 36 showing bogs with peat plateaux and palsas on Neveisik Island in Lake Melville.

Couple stéréoscopique de photographies aériennes (nos A 22524-35 et 36) montrant des tourbières avec des plateaux tourbeux et des palses dans l'île Neveisik du lac Melville.

consists of a network of closely spaced black flecks in a medium to light grey mesh-like matrix. The light grey hummocks are palsas and peat plateaux and the black flecks are small ponds.

CONCLUSION

Climate is the most important factor influencing the formation and continued existence of permafrost. This is borne out by the location of the mean annual air isotherms relative to the distribution of permafrost, and indicates the existence of a broad relationship. Permafrost is generally not found south of the −1°C isotherm except in southeastern Labrador under unusual local conditions. Between the −1°C and −4°C isotherms, permafrost is patchy and restricted to certain types of terrain, mainly peatlands. Permafrost is widespread north of the −4°C isotherm.

Permafrost is much less common in peatlands in the region under consideration than in similar terrain conditions west of Hudson Bay. The greater snowfall east of Hudson Bay appears to be the predominant factor causing this situation. Even in the peat terrain, permafrost does not exist where water lies at or near the ground surface. It is restricted mainly to the positive microrelief peat features — peat plateaux and palsas. Drainage is therefore an important terrain factor influencing the existence of permafrost. The excessive wetness of vast peatland areas may be due in part to the heavy winter snowfall combined with relatively low summer evaporation. The role of vegetation in the distribution of permafrost in peatlands is complex. The tree growth, predominantly spruce with some tamarack, is not by itself an indicator of permafrost occurrence because these trees also grow on sites where permafrost is absent. The Sphagnum and lichen cannot be used as indicators of the existence of permafrost.

The distribution of permafrost in Québec and Labrador is complicated by relief and elevation. Its existence is more extensive than merely occurring in peatlands and it is found on mountain summits and high elevations above treeline where mean annual air temperatures are several degrees lower than shown on the permafrost map (Fig. 1).

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