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by R. J. E. Brown

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R.J.E. Brown

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ABSTRACT

The distribution of permafrost in the southern part of the discontinuous zone in Quebec and Labrador is described. The relationship of this distribution to climatic and terrain factors is discussed. The paper also contains an analysis of some air photo patterns.

ÉTUDES DU PERGÉLISOL AU QUÉBEC ET À TERRE-NEUVE (LABRADOR)

par R.J.E. Brown

RÉSUMÉ

L'auteur décrit la distribution du pergélisol dans la partie sud de la zone discontinue du Québec et du Labrador, puis il examine le rapport entre cette distribution et les facteurs climatiques et topographiques. L'auteur analyse également quelques détails de photographies aériennes.

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PERMAFROST INVESTIGATIONS IN QUEBEC AND

AND NEWFOUNDLAND (LABRADOR)

by

R.J.E. Brown

Since 1950 the Division of Building Research, National Research Council of Canada, has been studying the numerous construction problems caused by permafrost in northern Canada. A basic requirement in solving these problems is knowledge of the distribution of permafrost and the location of its southern limit; information is being obtained continually from field investigations, scientific and technical literature, and reports from individuals and agencies working in permafrost areas.

Information regarding distribution and character of permafrost is particularly vital in the southern fringe where construction is complicated by patchy distribution of perennially frozen ground and the proximity of its temperature to 32°F (0°C). The existence of permafrost in this area is greatly influenced by microclimate and local terrain conditions, which form complex relationships producing variable and unpredictable ground thermal conditions.

At present, the southern fringe of the permafrost region is experiencing increasing economic development with the establishment of new towns, communication lines, mines and oil exploration. New roads are being constructed through this region in the northern sections of the western provinces of Canada and adjacent portions of the Yukon Territory and Mackenzie District. East of Hudson Bay, land communications are not as well developed; the only existing links are a road under construction to the James Bay hydro development and two railway lines extending from the Gulf of St. Lawrence northward to the extensive iron ore deposits in the interior of Quebec and Labrador.

This survey of the southern fringe of permafrost in Quebec and Newfoundland (Labrador) by the Division of Building Research was carried out in 1967 and 1968. Prior to this, similar investigations were carried out in northern Alberta and Mackenzie District in 1962 (Brown, 1964), Saskatchewan and western Manitoba in 1963 (Brown, 1965), northern British Columbia and southern Yukon Territory in 1964 (Brown, 1967a), and northern Ontario and northeastern Manitoba in 1965 (Brown, 1968). The present study completes this programme of investigations of the southern portion of the permafrost region across Canada.

The study area comprises that portion of Quebec and Newfoundland (Labrador) lying between latitudes 50°N and 56°N. It lies entirely within one physiographic region, the Precambrian Shield, except for a small area at the southern end of James Bay in the Hudson Bay Lowland, and the northern end of the island of Newfoundland which is in the Appalachian Region. The normal latitudinal increase in the extent of permafrost is complicated by the hilly to mountainous terrain causing variations with elevation. The southern limit of permafrost in the study area extends roughly along the 51st parallel of latitude from the southern end of James Bay eastward to the Strait of Belle Isle. The boundary in the middle of the discontinuous zone, separating the southern fringe from the subzone of widespread permafrost, is near the northern edge of the study area.

Little information on permafrost was available from the technical literature because of the paucity of economic development in this area prior to the survey. The field investigations were carried out by helicopter over two years: in 1967, in western Quebec from Hudson Bay to Schefferville, and in 1968, in eastern Quebec and Newfoundland (Labrador). Both took place during September when the depth of thaw had reached its maximum and seasonal frost of the forthcoming winter had not begun to form. The survey in 1967 began at Mattagami, P.Q. and extended eastward to Schefferville, P.Q. in a series of north-south traverses across the permafrost zone. In 1968 it began at Corner Brook, Nfld. and extended westward to Schefferville in a similar series of north-south traverses. This second series is shown in reverse order on the map so that the stops could be numbered in a continuous numerical sequence from Mattagami to Newfoundland (Figure 1).

METHODS AND SCOPE OF INVESTIGATIONS

Prior to the actual field investigations, information on the climate and terrain was obtained from the available technical literature (Appendix A). Aerial photographs and large-scale topographic maps of selected areas were examined in the office to identify the various types of terrain and the character of the relief, vegetation and surface drainage. From this preliminary examination, potential permafrost locations were noted for subsequent field investigations.

Field investigations were carried out at each stop (Figure 1) to obtain information on the areal extent of bodies of permafrost, the depth to the permafrost table, and, where possible, the thickness of the permafrost. Supplementary information included type of vegetation, thickness of the living surface vegetation cover, thickness of peat, type of underlying mineral soil and character of the ground ice.

The main objective was to delineate, approximately, the areas of permafrost and relate their distribution to the various environmental features such as relief, drainage, vegetation and soil type. With this information it is possible to predict in a qualitative manner where permafrost might be expected in other areas.

Field equipment was limited by weight restrictions imposed by the use of the helicopter and consisted of a 3-ft aluminum Hoffer probe 5/8 in. in diameter equipped with a case-hardened serrated steel bit and 3-ft extensions. It was used to determine the depth to permafrost and soil profiles in areas where permafrost did not exist. In frozen ground consisting either of peat or fine-grained mineral soils, it was usually possible to ram and rotate the probe to a depth of 15 or 20 ft and obtain undisturbed cores of the soil in 6-in. increments. Frozen fine to medium sand could be penetrated for a few feet but frozen stony and gravelly soils resisted the probe.

The observations are listed in Table I beginning with Stop No. 1, just north of Mattagami, P.Q. and ending with Stop No. 92 south of St. Anthony, Nfld. (Figure 1). Various types of terrain are illustrated in Figures 2 - 38 inclusive.

The following example illustrates the use of the symbols in Table I to describe the terrain and permafrost conditions (Figure 13 - ground view; Figure 14 - aerial view). Location No. 13 (Column 1) is situated about 50 miles south of Poste-de-la-Baleine (Great Whale River), P.Q. (Figure 1) at an elevation of about 550 ft above sea level (Column 2). It is a low area located in a peat bog (Column 3 - L) in which there are palsas and incipient peat plateaux. The flat ground around these features supports a few stunted scattered spruce up to 2 ft high (Column 4 - S(2)s) whereas the palsas and peat plateaux are treeless (Column 4 - No). The ground vegetation around the palsas and peat plateaux consists of hummocky Sphagnum, lichen, Labrador tea, sedge, other mosses, and grass (Column 5 - HSph Ln Lt Se M G). On the palsas and peat plateaux, the ground vegetation consists of hummocky Sphagnum and lichen (Column 5 - HSph Ln (p) P). The peat on the flat ground around the palsa in Figure 13 is 5 ft 9 in. thick (Column 6: 5 ft 9 in.); and on the palsa itself it is 3 ft 0 in. thick (Column 6: 3 ft 0 in.). The underlying mineral soil is grey silty fine sand with clay (Column 7 - Si Sa C). No permafrost was encountered in the low flat areas around the palsas and peat plateaux (Column 8 - No) but it occurs in these features (Column 8 - Yes). The depth to the permafrost table is 1 ft 9 in. (Column 9: 1 ft 9 in.). The thickness of the permafrost was not determined (Column 10 ———).

CLIMATE

The study area is located between Hudson Bay and James Bay to the west, and the Atlantic Ocean and Gulf of St. Lawrence to the east, a distance of 800 to 1,000 miles. The climate varies generally with latitude in response to general continental controls but the presence of the sea on both sides of the study area and the generally hilly to mountainous relief up to 4,000 feet above sea level are modifying factors. The presence of Hudson Bay and James Bay is manifested by the southward trend of mean annual air isotherms from west to east. The Atlantic Ocean and Gulf of St. Lawrence on the east have a strong ameliorating effect and the mean annual air isotherms curve sharply northward on the eastern margin of the study area (Canada, 1960b; Haurwitz and Austin, 1944; Putnam et al, 1952; Thompson, 1968).

The maritime influence of Hudson Bay and James Bay is modified by the ice cover which forms over these bodies of water for several months during the winter. The climate of the study area, except for the extreme southeast, is essentially continental in character with long cold winters and short, generally mild to warm summers. In winter, severe cold waves of polar continental air move westward across Hudson Bay or southward from the Arctic across Hudson Bay with little or no modification except in some of the more rugged areas. The weather patterns during the summer are characterized by frequent cool periods in the rear of eastward moving cyclones. Weather patterns along the Atlantic coast are characterized by milder stormy winters and cool summers.

Air temperature observations are available for fifteen stations within the area under consideration, nine in Quebec and six in Labrador (Table II) (Canada, 1970a; Canada, 1970b). Their locations are shown in Figure 39 and monthly and annual averages of daily mean temperatures are given in Table IIIa. Mean annual isotherms for 4.5°F (2.5°C) intervals from 23°F (-5°C) to 36.5°F (2.5°C) are also shown in Figure 39. The mean annual air temperatures vary with latitude but the mean annual isotherms also bend southward inland from Hudson Bay toward the centre of the Labrador-Ungava peninsula, curving sharply northward toward the Atlantic Ocean. The increasingly continental character of the climate inland from the sea and the effect of elevation (1,500 to nearly 2,000 ft above sea level) is reflected in the mean annual air temperatures of coastal stations on Hudson Bay and James Bay being 1°F (0.5°C) to 3°F (1.7°C) higher and stations on the Atlantic Ocean being 5°F (2.8°C) to 7°F (3.9°C) higher than interior stations at the same latitude. South of the study area the mean annual air temperature of Fort Rupert (Rupert House) on James Bay is estimated to be about 30.4°F (-0.9°C), similar to the nearest station (Moosonee, Ontario); at Battle Harbour, Nfld. on the Atlantic Ocean, it is 33.4°F (0.8°C) in contrast to the interior stations at Gagnon, P.Q. and Lake Eon, P.Q. where it is 27.7°F (-2.4°C) and 27.4°F (-2.6°C) respectively. In the middle of the study area, the mean annual air temperature of Fort George, P.Q. on James Bay is 26.4°F (-3.1°C); at Cartwright, Nfld. on the Atlantic Ocean, it is 32.4°F (0.2°C) in contrast to the interior stations at Nitchequon, P.Q. and Wabush, Nfld. where it is 25.3°F (-3.8°C) and 25.1°F (-3.7°C) respectively. In the north of the study area the mean annual air temperature of Poste-de-la-Baleine (Great Whale River), P.Q. on Hudson Bay is 24.6°F (-4.1°C); at Hopedale, Nfld. on the Atlantic Ocean, it is 28.9°F (-1.7°C) in contrast to the interior stations at Schefferville, P.Q. and Border, P.Q. where it is 23.8°F (-4.6°C) and 22.8°F (-5.1°C) respectively. Graphs of the averages of the mean monthly air temperatures for three stations, Cartwright, Nfld., Lake Eon, P.Q. and Schefferville, P.Q., representative of the warmest, intermediate and coldest parts of the study area, are shown in Figure 40.

Freezing and thawing indices indicate the amount of heat withdrawn from and added to the ground during the year (Thompson, 1966). It can be seen from Figure 39 that freezing indices vary from 2,500 degree days (°F) in the southeast to 5,000 in the north and northwest. Thawing indices vary from nearly 4,000 degree days in the southeast to 2,500 in the north. Both indices reflect the higher mean annual air temperatures on the Atlantic coast.

Precipitation observations are available for the fifteen stations (Table IIIb) (Canada, 1970a; Canada, 1970b). Maximum precipitation occurs in the summer months, being mostly frontal but partly convectional in origin. At stations on the Gulf of St. Lawrence and in southeastern Labrador the precipitation is more spread out through the year with high points in winter, also reflecting a more maritime regime. Annual totals are highest in these two regions (Harrington Harbour, P.Q.: 47.69 in.; Sept Iles, P.Q.: 42.92 in.) decreasing northward and toward Hudson Bay and James Bay. Graphs of the averages of the mean monthly total precipitation for the three stations, Cartwright Nfld., Lake Eon P.Q. and Schefferville P.Q. are shown in Figure 40.

The same pattern applies to the mean annual rainfall (Table IIIc). The stations on the Gulf of St. Lawrence and southeastern Labrador have the highest average annual rainfall (Harrington Harbour, P.Q.: 28.25 in.; Sept Iles, P.Q.: 26.66 in.; Battle Harbour, Nfld.: 22.35 in.; Cartwright, Nfld.: 20.10 in.). Amounts decrease to the north at Schefferville, P.Q. (15.62 in.) and the west coast (Poste-de-la-Baleine (Great Whale River), P.Q.: 15.16 in.; Fort George, P.Q.: 15.15 in.). Rain has been recorded at all stations in all months of the year except in December at Churchill Falls, Nfld.; in January at five stations (Fort George, Gagnon and Poste-de-la-Baleine (Great Whale River) in Quebec, and Churchill Falls and Wabush in Labrador); in February at Gagnon and Churchill Falls.

The mean annual snow fall follows the same pattern as the rainfall, the stations in the southeast of the study area having the highest totals (Harrington Harbour P.Q.: 192.2 in.) (Table IIId). Snowfall in the study area is the heaviest in Canada east of the Western Cordillera (Thomas, 1953). The highest monthly totals of snowfall at the stations on the west coast occur in November before Hudson Bay freezes over. Eastward, the highest monthly totals are in the middle of winter. No month is snow-free at all stations, three having snow in July (Border and Poste-de-la-Baleine (Great Whale River) in Quebec; Hopedale in Labrador), two having snow in August

(Nitchequon and Schefferville in Quebec). Data on the average depth of the snow cover each month are available for seven stations in Quebec and four in Labrador (Table IIIe) (Potter, 1965). Snow accumulation is greater in the southeast part of the study area. The maximum accumulation occurs in February and March. The ground is usually covered with snow until mid May after which it disappears rapidly.

In summary, it is evident that air temperatures and precipitation values for the fifteen stations are influenced by latitude relative to their proximity to the sea. The Atlantic Ocean and Gulf of St. Lawrence have greater ameliorating effects on air temperature and produce higher precipitation than Hudson Bay and James Bay. Hythergraphs based on the averages of mean monthly temperatures and mean monthly total precipitations for Cartwright, Nfld., Lake Eon, P.Q. and Schefferville, P.Q. are shown in Figure 41. The progressively lower monthly temperature and precipitation values from Cartwright on the Atlantic coast of southeastern Labrador to Schefferville in the northern interior position of the study area, are evident. The increasingly continental character of the climate inland is borne out by the progressively greater difference between summer and winter air temperatures (nearly 20°F (11°C) greater at Schefferville than at Cartwright) and the precipitation regime which is spread more uniformly through the year at Cartwright in contrast to the summer maxima at Lake Eon and Schefferville.

GEOLOGY

The study area lies entirely within the Precambrian Shield except for the southern tip of James Bay and the northern part of the Long Range Peninsula of Newfoundland. Much of this portion of the Shield in Quebec and Labrador is characterized by the typical terrain of rock knobs and ridges, peat-filled depressions, vast flat lying peat covered expanses, and innumerable lakes (Figure 2). The southern tip of James Bay lies in the Hudson Bay Lowland consisting of flat peatland with virtually no relief, overlying rocks of Palaeozoic and Mesozoic age (Figure 42). The northern end of Newfoundland is composed of Palaeozoic rocks (Canada, 1957; Canada, 1961; Canada, 1962).

Most of the Precambrian area contains intrusive Archaean and Proterozoic rocks, mainly acidic, consisting of granodiorite, granite, quartz diorite, and granite gneisses, including much granitized sedimentary and volcanic rocks. Within this large geological province there are about nine small subdivisions of Archaean and Proterozoic rocks (Figure 42): (1) Archaean and/or Proterozoic basic and ultra-basic rocks, mainly anorthosite and gabbro scattered through south-eastern Quebec and Labrador; (2) Proterozoic basic rocks: diabase sills and dykes, in a narrow belt on Hudson Bay at Richmond Gulf; (3) Prote-rozoic acid rocks: granite, granodiorite and diorite, in eastern

Labrador south of Hopedale; (4) Archaean undivided sedimentary, volcanic and metamorphic rocks in western Quebec inland from Fort George and Eastmain; (5) Archaean rocks, mainly volcanic and derived metamorphic rocks including andesite, dacite, basalt, rhyolite, trachyte, minor volcanic breccia and tuff, greenstone schist and hornblende gneiss in one small area southeast of Rupert House; (6) Archaean rocks, mainly sedimentary and derived metamorphic rocks including argillite, slate, arkose, quartzite, greywacke, conglomerate, sedimentary gneiss and schist, and iron formations located southeast of Fort Rupert (Rupert House), and at Sept Iles on the Gulf of St. Lawrence.

The largest of the nine subdivisions is the Labrador Trough (7), a long narrow belt of early Proterozoic sedimentary and volcanic rocks extending in a north-northwest to south-southeast direction for several hundred miles from Ungava Bay, north of the study area to western Labrador. It contains the large iron ore deposits at Schefferville, Wabush and Labrador City that are now being mined. Late Proterozoic sedimentary and volcanic rocks (8) consisting of sandstone, quartzite, conglomerate, shale, iron formations and basalt are found at several scattered locations at Richmond Gulf, south of Nitchequon and on the north side of Lake Melville in Labrador. One area of early Proterozoic sedimentary and volcanic rocks (9) consisting of shale, limestone, sandstone and other sedimentaries, and tuff, breccia and other volcanics occurs on the Gulf of St. Lawrence.

Palaeozoic rocks include Cambrian and Ordovician sedimentaries, shales, limestones and sandstones, in northern Newfoundland, and Devonian sedimentaries at the south end of James Bay. A small basin of Mesozoic sedimentary and volcanic rocks occurs near Gagnon in the south-central part of the study area.

During the Wisconsin glaciation in the late Pleistocene, the study area was glaciated by the Laurentide ice sheet. The sequence of events is somewhat controversial with different authors disagreeing on whether the ice sheet grew from a centre in the highlands of eastern Labrador (Flint, 1971) or on the Laurentian Plateau in the centre of the Labrador-Ungava Peninsula (Andrews, 1974; Ives and Andrews, 1963). The latter view appears more tenable in the light of the glacial landforms existing in the area at present. From the centre of growth and dispersal somewhere in the vicinity of the Schefferville area it appears that the ice moved and spread toward the coastal regions of the Labrador-Ungava Peninsula. Much of the study area is covered with a mantle of glacial drift of varying thickness (Figure 3) giving way to upland areas where the Precambrian rocks outcrop (Figure 27). The direction of ice movement exhibiting a circular pattern away from the centre of ice dispersal is manifested by drumlins, drumlinoid ridges, crag and tail hills, roches moutonnées, glacial flutings and striae (Figure 43) (Prest et al, 1967). Extensive areas of ribbed moraine transverse to the general direction of ice flow occur in western Quebec and to a lesser degree through central

Labrador. Small areas of hummocky dead ice and disintegration moraine are also found in western Quebec.

As the ice sheet retreated, an intensive network of glaciofluvial features including eskers, kames and kame-complexes were deposited (Figure 4). Their lineation exhibits the same circular orientation through the study area as the landforms associated with advance of the ice. The last remnants of ice appear to have existed at the centre of the study area in the vicinity of Schefferville.

During the retreat of the ice, lacustrine inundation took place in the southwest corner of the study area in glacial Lake Ojibway. The northeast corner of the study area west of the Quebec-Labrador boundary was also covered by glacial lakes. The resulting lacustrine deposits are of minor significance in terms of their extent in the study area.

Postglacial marine submergence affected the coastal areas of Hudson Bay and James Bay; marine deposits extend inland as much as 150 miles. Along the coast the marine deposists are terraced and inland they partially fill the river valleys. Small stretches of marine deposits also occur on the narrow coastal plain along the Gulf of St. Lawrence, around the north end of the Long Range Peninsula in Newfoundland, and around Lake Melville inLabrador.

TERRAIN

Relief

The relief of the area under study varies markedly from flat in the Hudson Bay Lowland at the southern end of James Bay and on the Laurentian Plateau, to mountainous in the Mealy Mountains of Eastern Labrador and Otish Mountains in Quebec. Elevations vary from sea level to about 3,700 ft in the Mealy Mountains (Figure 44) (Canada, 1957). The increase in elevation inland is characterized by fairly narrow gently sloping coastal areas below 500 ft changing to steep slopes and river valleys rising to a plateau surface 1000 - 2000 ft above sea level. The edge of this plateau surface is particularly well defined along the Laurentian Scarp facing the Gulf of St. Lawrence and the Atlantic coast. In the interior of the study area extensive areas rise to 3000 ft with the previously mentioned mountains forming the highest elevations. The most rugged relief is in the mountainous areas and along the river valleys cut into the edges of the plateau surface.

Local relief consists of alternating elevated areas and depressions (hereafter referred to as "high areas" and "low areas" respectively, Table I). Most of the permafrost observations were made in low areas, depressions surrounded by higher ground, occurring at all elevations from sea level to the highest mountains. The high areas in Table I refer to locations on higher ground above the depressions and also to mountain summits. Some of the low areas include a variety of permafrost microrelief features such as peat plateaux and palsas rising 3 - 10 ft above the surrounding surface.

Drainage

Regional drainage is provided in the study area by a total of nearly twenty major rivers which have their headwaters in the interior plateau and flow downward through deep valleys to the sea in Hudson Bay, the Gulf of St. Lawrence or the Atlantic Ocean. These rivers and their tributaries are interrupted at many points by rapids and falls the highest being Churchill Falls which exceeds 400 ft in height. It is now dry due to hydro electric construction. The interior Laurentian Plateau is a patchwork of lakes and bogs in a generally poorly drained condition.

Local drainage in exposed rock areas and overburden varies considerably from good to excessive on high areas. In the depressions (low areas), local drainage is generally poor except on peat plateaux and palsas.

Vegetation

The study area lies entirely within the boreal forest region or taiga, which extends east-west across Canada in a band several hundred miles wide. This vegetation zone has been described by several authors, but generally all of them attribute similar characteristics to it. Rowe (1959; 1972) describes the forest regions comprising the area under study; their distribution is shown in Figure 45.

The southern third of the study area lies in the Chibougamau-Natashquon Section which extends east-west in a band about 110 miles wide from the Strait of Belle Isle to within 100 miles of James Bay. This forest belt in which black spruce (*Picea mariana*) is the most abundant tree, lies along the south-facing slopes of the Laurentian Plateau between the productive fir-spruce forests south of the study area and the subarctic lichen-woodland to the north. The prominence of this species both on peaty lowland sites and on well-drained upland drift and rock, plus the relative scarcity of white spruce (*Picea glauca*) and balsam fir (*Abies balsamea*), makes for a limited variety of cover types. Groves of white birch (*Betula papyrifera*) are scattered throughout the Section but the other boreal hardwoods, aspen (*Populus tremuloides*) and balsam poplar (*Populus balsamifera*), are less conspicuous except in the immediate vicinity of rivers and lakeshores. Jack pine (*Pinus banksiana*) is confined to the western side of the Section. Evidence of a severe fire history is seen both in the upland heath barrens and open woodlands of the north and in the barren rock hills along the St. Lawrence River to the south.

The southwest corner of the study area lies in the Northern Clay Section. Extensive stands of black spruce cover the gently rising uplands as well as the lowland flats, alternating in the latter position with extensive sedge and heath bogs. Tamarack (Larix laricina) grows infrequently with the spruce except in young stands. Extensive areas of spruce-cedar swamp occur also. Improvement in drainage, due to slight changes in relief or to position beside rivers and lakes, is reflected in hardwood or mixed stands of aspen, balsam poplar, balsam fir, white spruce and the black spruce. Jack pine has a dominant position on many of the drier sites such as outwash deposits, old beaches and eskers .

The eastern extremity of the Hudson Bay Lowlands Section extends into the southwest corner of the study area immediately north of the Northern Clay Section. Here the vegetation has generally a subarctic appearance because of the predominance of an open cover of black spruce and tamarack in the swamps and peatlands. On the river banks, however, where drainage is better, forests of white spruce, balsam fir, aspen, balsam poplar and white birch occur, similar to those in the Northern Clay Section. Jack pine occurs only sparingly in the south.

The East James Bay Section forms a narrow band along the coast of James Bay, north of the Hudson Bay Lowlands Section. Conditions for forest growth are more favourable than those found over most of the Labrador-Ungava peninsula to the east or than those of the poorly drained coastal plains of James Bay and Hudson Bay to the west. The richest forests occur below the highest marine limit on the modified deposits of glaciofluvial materials. In the sheltered valleys, white and black spruce, balsam poplar, aspen, white birch, and balsam fir reach merchantable sizes; poor-growing black spruce, jack pine and tamarack are found on the thin tills of the intervening rock uplands. The limits of the Section to the east are indicated by a marked reduction in the abundance and quality of white spruce, balsam fir and balsam poplar, species apparently favoured by the maritime influences. Back from the coast there are limited areas of low-lying swamps, and on dry highlands the subarctic type of open lichen-woodland appears.

The Churchill and Eagle Valleys Section comprises several of the river valleys along the eastern border of the Laurentian Plateau where the richer composition of the forest and better quality of growth stands distinctly apart from the subarctic vegetation of the adjacent uplands. The largest part of this outlier of the southern boreal forest is in the valley of the Churchill River, 500 - 800 ft below the level of the surrounding country. Other segments of the Section occur on the Kaipokok, Eagle, Hawke and Alexis rivers, just inside the coastal Forest-Tundra Section. Conifers form the matrix of the forest cover; the most prevalent species over the range of sites is black spruce which is the pioneer invader after fire. It occupies the poorly drained flats and the shallow soils of the upland slopes in pure stands, or mixed with balsam fir and white birch. On the deeper lowland soils where conditions for forest growth are most favourable, prominent associates of the black spruce are balsam fir, white spruce, which grows to a large size here, white birch, balsam poplar and, occupying the northern part of its range, the aspen. On elevated sandy terraces and on the upper slopes of the hills where transition is made to the subarctic forest, open lichen-woodland dominated by black spruce appears on the dry sites and closed coniferous forest of spruce-fir on the moist sites. Occasional small stands of pure birch and aspen mark areas of past disturbance by landslide or fire. Jack pine does not extend into this Section, and tamarack though present, is not abundant.

The Northeastern Transition Section is the largest in the study area, extending across the peninsula in a band about 300 miles wide. It is a broad band of subarctic forest which extends across central Labrador and Quebec, bounded on the north by the Forest-Tundra Section and on the east and west by narrow coastal strips of the same Section. The southern boundary is marked by an abrupt decrease in the prevalence of open lichen-woodland and a corresponding increase in closed-canopy coniferous forest on mesic sites. The land is a patchwork of lakes and rivers, bogs, swamps and peatland, with areas of upland barrens and forest, the characteristic form of the latter being the open, park-like woodland of black spruce with an associated ground cover of lichens. Closed forest stands are less common, although they do appear, dominated by the ubiquitous black spruce, where sites are of the moist, seepage type, as on mid-slopes and in shallow peaty draws. Species associating to some extent with black spruce in upland types are balsam fir and white spruce, the latter usually conspicuous in its sporadic occurence due to a taller growth form than the other conifers. On the lowlands, where open peatland and string bog stretch for miles, an open wet woodland type of black spruce is developed regardless of underlying soil materials. Strips of tamarack frame the lakes and water courses, but this species rarely migrates in any quantity from the wet, peaty lowland soils. Jack pine is confined to the southwestern half of the Section, aspen is uncommon except along the southern boundary, balsam poplar occurs infrequently along streams, and the white birch has a limited abundance on the upper slopes of hills, particularly in the south.

The Fort George Section occupies an area roughly 200 miles square on the lower reaches of La Grande Rivière (Fort George River). This till-covered lowland with a gradual upward slope to the east has generally a better forest cover than the adjacent Northeastern Transition Section, and extensive areas on both upland and lowland are clothed with open or closed stands of conifers. North of La Grande Rivière (Fort George River) the jack pine is abundant on low, stony morainic ridges, while black spruce with an undergrowth of dwarf shrubs occupies the shallow organic soils of the intervening clay-filled depressions. Southward the uplands are more hilly, bearing open lichen-floored stands of black spruce with some white spruce and balsam fir. There are large areas of peatland and open bog.

The Newfoundland-Labrador Barrens Section occupies south-eastern Labrador, the northern tip of Newfoundland and the upper levels of the Long Range Mountains, which are on the island. The vegetation is a stunted, open and patchy or sometimes continuous cover of black spruce and balsam fir, alternating with moss and heath barrens, rock outcrop and lakes, on a generally featureless, windswept terrain. There is a lesser percentage of non-forested barren land in the Labrador sector than elsewhere in the Section, for open lichen-woodlands dominated by black spruce are usual on the uplands. On the other hand, many upland areas and slopes on the island of Newfoundland are blanketed with moss bogs, a possible reflection of the high moisture surplus. The primary forest types of black spruce and balsam fir are often dense though usually dwarfed, indicating that conditions are suitable for establishment if not for later growth of the conifers. The presence of occasional good stands of trees on sheltered, well-drained morainic hillocks suggests that the generally poor forest growth is a result of wet, cold soils, and exposure to wind. Secondary species associating with the black spruce and fir are white spruce and white birch with tamarack on the wetter sites.

The Forest Tundra Section occupies the northern reaches of the study area, forming the transitional zone between the subarctic forest and the tundra. The vegetative pattern is one of tundra barrens and patches of stunted forest, the former on upland interfluves and the latter usually along the shores of lakes and rivers. The primary species is white spruce, which predominates over black spruce under the maritime influence of Hudson Bay and along the Atlantic coast of Labrador. Tamarack, alder and willow are also found here. Inland, black spruce and tamarack form most of the forest patches. Balsam fir, white birch, aspen and balsam poplar are infrequent. The general environment for tree growth is precarious because of the harsh climate, especially due to strong winds and low air temperatures, and the presence of widespread permafrost. There is evidence that the treeline has fluctuated widely in the past.

Throughout the area under study, variations occur in the vegetation corresponding to changes in local relief. The "low areas" are characterized by bog vegetation: open bogs with scattered stunted black spruce growing on Sphagnum and sedge peat overlying a variety of mineral soils. The best black spruce growth occurs where the organic accumulation is relatively thin and drainage is improved; this is a characteristic of both Sphagnum and sedge bogs. The tallest spruce grow to about 40 ft but the majority of trees are about 30 ft or less in height. Tamarack is the second coniferous species but much less common than on similar sites west of Hudson Bay. It mixes with the spruce and rarely grows in pure stands. Jack pine was found at only one location. The ground cover consists predominantly of Sphagnum with patches of feather and club mosses, lichen and Labrador tea. In many areas, lichen covers 25 percent or more of the ground surface (Figures 7, 8). Sedge predominates in the wet treeless areas. String bogs are abundant in all stages of development especially on the Laurentian Plateau (Figure 6). The palsas observed in Quebec and Labrador are devoid of trees in contrast to those in the Hudson Bay Lowland and further west, which support dense tree growth (Figures 13 - 18).

The "high areas" with moderate to good drainage include valley slopes, undulating ground moraine surfaces, rocky areas in the Precambrian Shield, and mountain summits in the Mealy Mountains (Eastern Labrador), Otish Mountains (Quebec), Long Range Mountains (Newfoundland), the Labrador Trough and Laurentian Scarp. The tree growth on valley slopes frequently consists of dense willow up to 3 ft in height with scattered spruce 25 - 30 ft high. The undulating ground moraine supports dense growth, mainly spruce with scattered aspen, balsam poplar, willow and alder, and a ground vegetation of hummocky Sphagnum, lichen, Labrador tea and grass. Extensive tracts of this type of terrain showed evidence of recent forest fires (Figure 3). Rocky areas in the Precambrian Shield are generally devoid of vegetation excepth for small patches of ground plants in shallow depressions (Figure 2). The mountain summits are devoid of all but a few scattered spruce trees and where vegetated, support a ground cover of scattered moss, lichen, Labrador tea, grass and sedge (Figures 26 - 33). Mountain sides and gentler slopes are generally covered with dense spruce growth (Figure 27). Jack pine grows in the southern part of the study area but is rare north of the Otish Mountains or in Labrador possibly due to the cool maritime climate, late retreat of the Wisconsin continental ice sheet or other unknown factors (Hustich, personal communication).

Soils

Throughout the study area the mineral soils vary from coarse-grained sands and gravels to fine-grained silts and clays. Their character is strongly influenced by the nature of their origin, coarse-grained soils being associated with moraine, glaciofluvial and shoreline deposits, fine-grained soils with lacustrine and marine deposits (Figure 43). Following deposition of these materials, profile development has produced pedological variations.

Rowe (1959; 1972) has described the pedological characteristics of the soils in each of his forest sections. In the Chibougamau-Natashguan Section, podzol soil profiles are typically developed in the surface materials, particularly in association with dwarf shrubs and spruce cover. Peaty gleysolic soils occupy the narrow swamps (low areas) between hills, while relatively fertile humus podzols are locally developed on richer tills in association with balsam fir.

In the Northern Clay Section grey wooded soils have developed on the calcareous upland clays and modified tills, with podzolic and peaty gleysols on the flats. A podzol profile is usual on sand ridges.

Organic soils predominate in the Hudson Bay Lowland, some associated with perennially frozen ground. Weak brown wooded soil profiles have developed in well-drained locations on alluvium and on ridges.

In the East James Bay Section, podzolic soil development occurs in drift which partially covers the Precambrian rock uplands. Peaty gleysols are found in the lowlands.

The Churchill and Eagle Valleys Section has fine-textured surface deposits, derived partly from underlying metamorphosed Precambrian rocks or younger basic intrusives, which fill the broad valley bottoms and stand as terrace materials beside the rivers and lakes. The poorer upland soils seem to have resulted from the weathering of a thin sandy till and to some extent from a breakdown in situ of the gneissic bedrock. Podzols are usual in the well-drained areas; there is extensive development of sedge and moss peat on wetter sites.

Sandy to silty clay glacial drift blankets much of the Northeastern Transition Section, being drumlinized or forming a thin layer over bedrock on the uplands. It is deeper in terrace or outwash deposits in the valleys. "Subarctic brown" profiles, podzols, gleysols, regosols and peats are present, and permafrost occurs at many locations.

In the Fort George Section, the Precambrian bedrock is overlain by glacial drift. Rock outcrops are prominent at higher elevations. Although the soils have not been investigated, podzolic or "subarctic brown" profiles are to be expected on the well-drained uplands.

The Newfoundland-Labrador Barrens Section has underlying bedrock of Precambrian and Palaeozoic granites and sedimentary rocks. Peaty soils are prominent on the surface drift, and podzols develop on well-drained sites.

PERMAFROST

The parts of Quebec and Labrador in the study area lie almost entirely within the discontinuous permafrost zone. The southern edge, south of the latitude of James Bay, and the narrow coastal plain below the Laurentian Scarp along the Gulf of St. Lawrence are located south of the permafrost region. Most of the study area is in the southern half of the discontinuous zone where permafrost occurs in scattered islands. The northern part beyond the latitude of Poste-de-la-Baleine (Great Whale River), Schefferville and Hopedale lies within the subzone of widespread permafrost in the discontinuous permafrost zone (Figure 46) (Brown, 1967b; 1970; in press). A notable feature of the permafrost zonation in Quebec and Labrador is that the discontinuous zone extends much further north in this region east of Hudson Bay than on the west side where the continuous zone extends southward to the northern end of James Bay. The distribution of permafrost in Quebec and Labrador is more complicated than in the provinces immediately west of Hudson Bay because of the extensive areas of hilly to mountainous relief.

Within most of the study area covered by the helicopter traverses, north to the latitude of Schefferville, excepting areas at high elevations, permafrost occurs in scattered islands varying in extent from less than a few tens of square feet to several acres. The thickness of these patches varies from a few inches to 2 ft at the southern limit of the permafrost region to tens of feet towards the northern limits of the study area. Peat plateaux and palsas are associated with some of these permafrost areas. Virtually no information is available on the thickness of permafrost in this subzone extending from the southern limit of permafrost northward to Poste-de-la-Baleine (Great Whale River) and Schefferville but it is presumably not more than 50 ft thick in the peatlands. At higher elevations such as in the Otish and Mealy Mountains it is probably several hundred feet thick. Permafrost has been encountered at high elevations in the iron mines near Wabush and Labrador City to depths exceeding 200 ft (Garg, Iron Ore Co. of Canada Ltd., personal communication); near Schefferville it reaches a thickness of 400 ft (Nicholson and Thom, 1973).

The location of the southern limit of permafrost in Quebec and Labrador is more difficult to determine than west of Hudson Bay because of the greater relief coupled with the scarcity of detailed observations. The southern limit shown in Figure 46 was drawn on the basis of the approximate location of the 30°F (-1°C) mean annual air isotherm which has proven to coincide generally with the southern limit of permafrost west of Hudson Bay and James Bay. The helicopter traverses were arranged to cross the southern limit in approximately parallel lines at intervals of 100 to 200 miles from west to east (Figure 1). Unfortunately, adverse flying conditions and difficulties with fuel caches prevented the extension of the traverse legs southward to the southern limit of permafrost in Quebec between the coast of James Bay and Sept Iles on the Gulf of St. Lawrence. Five legs of the traverse did cross the southern limit of permafrost, however, and the two legs in western Quebec extended within 100 miles or less of the boundary.

The main feature of the distribution of permafrost observed on the traverses was that its existence in peatlands was much less common than expected and the most southerly occurrences were found further north than anticipated in comparison with the situation prevailing west of Hudson Bay and James Bay. Permafrost was found at only 19 of the 92 stops and some of these occurrences were on mountain summits and high elevations. Along the first leg of the traverse, the first occurrence of permafrost north of the southern limit was encountered only 30 miles south of Poste-de-la-Baleine (Great Whale River) in a group of palsas (Stop No. 13 - Figures 13, 14). On the next leg southward almost to Eastmain River and northward again, no permafrost was found in peatlands south of La Grande Rivière de la Baleine (Great Whale River). Permafrost was encountered at only two locations, Stop No. 18, 28, on the north end of this leg. The third leg of the traverse encountered permafrost at only two locations, both on mountain summits (Stop No. 35, 38 - Figures 32, 30 respectively).

On the next leg from Sept Iles to Schefferville, permafrost was encountered in peatlands between Labrador City and Schefferville at Stop No. 43 and at Schefferville (Stop No. 44). The fifth leg through western Labrador via Churchill Falls and south to Havre St. Pierre on the Gulf of St. Lawrence encountered permafrost in peatland at only one location, Stop No. 46, between Schefferville and Churchill Falls. East of Havre St. Pierre the traverse extended in a loop up the Romaine River and southeast to Harrington Harbour along which permafrost was found at one location, Stop No. 55. The sixth leg of the traverse extended from Harrington Harbour through Goose Bay and northward to the 55th parallel in north central Labrador where permafrost was encountered at only two locations, Stop No. 67, 69, both at the northern end. The seventh and last leg of the traverse extended from Hopedale on the Atlantic Ocean southward near the Labrador coast and around Lake Melville to Cartwright, to Red Bay at the Strait of Belle Isle and southward over the Long Range Mountains in Newfoundland to Corner Brook. Large groups of palsas were observed at several locations, Stop No. 78, 85, 90 (Figures 19, 20), the most surprising being the last at an elevation of only 400 ft above sea level near Red Bay on the Strait of Belle Isle. Permafrost was also encountered at Stop No. 84 (Figures 28, 29) on the Mealy Mountains but none was found at Stop No. 91, (Figure 37) and 92 on the Long Range Mountains in Newfoundland.

As previously mentioned, all occurrences of permafrost encountered on the survey were in peatlands (Figure 47) or at high elevations on and near mountain summits. Other occurrences were seen from the air or reported by others on some river valley slopes and other scattered locations. No permafrost was reported to occur in the exposed Precambrian rock.

<u>Low Areas</u>

During the survey, 86 low areas covering the range of peatland conditions in the study area were investigated for permafrost.

They vary in extent from a few hundred feet in confined rock basins to many miles as on the Laurentian Plateau (Figure 6) and on the Gulf of St Lawrence (Figures 11, 12). As mentioned previously, several distinct associations of vegetation with related drainage occur.

Generally the tree growth consists of scattered to dense spruce varying in height from 2 - 40 ft, the majority of trees being 25 - 30 ft in height. Only 12 sites have no trees and all the others have spruce growth. Other species are present in much smaller numbers than on similar sites west of Hudson Bay. Tamarack is the second coniferous species, growing at only 13 sites. Jack pine was found at only one site. Alder and willow were virtually absent. Burned trees were not encountered at any sites. The ground vegetation is a mosaic of Sphagnum, feather and other mosses, lichen, Labrador tea, grass and marsh sedge in various combinations. Sphagnum is the predominant moss occurring at all but 7 sites. Lichen is also common being found at all but 7 sites (Figures 7, 8). The microrelief ranges from flat to very hummocky. All but 13 sites have hummocky microrelief. Individual hummocks vary in size to a maximum of about 3 ft high and 4 ft wide. Within the confines of one site, where two associations of vegetation occur, variations in elevation from one site to another range through several feet. Peat plateaux rising 3 - 4 ft above the surrounding poorly drained areas are prevalent in sites with or without permafrost. They were observed at 13 of the sites, 3 with permafrost and 10 having no permafrost. Palsas up to 12 ft and more in height were observed at 7 sites and from the air at many other locations. Surface and subsurface drainage is variable. Standing water is usually associated with marsh sedge areas and many of the lowest lying Sphagnum areas. The individual hummocks, peat plateaux and palsas are drier. Depth to the mineral soil (thickness of moss/lichen and peat) at the 86 low sites varies from a minimum of 3 in. to a maximum of 12 ft or more. At most of the sites the depth ranged from 2 - 7 ft with an average of 3 - 4 ft.

Sand is the predominant mineral soil occurring at 55 of the sites, mostly in combination with other soils. Gravel, random stones and boulders are common due to widespread distribution of glacial materials in the form of till, and glaciofluvial deposits. Fine-grained soils, silts and clays are less common constituents occurring at only about 20 per cent of the sites. Permafrost was encountered at only 16 of the 86 low areas examined in the survey. The cover comprises Sphagnum at 13 of the permafrost sites and at 63 sites where no permafrost was encountered. Lichens (Cladonia sp. and Cetraria sp.) grow at 79 sites and are absent at 7 sites. Of the 79 sites where lichen was found, permafrost was encountered in only 16 (Figures 7, 8). Of the 7 sites where no lichen was growing, none had permafrost. These observations are presented in the following Table.

	Permafrost	No Permafrost
Sphagnum	13	63
No Sphagnum	3	4
Lichen	16	63
No Lichen	0	7

The depth of the permafrost table was determined at all 16 low sites. It occurs above the mineral soil in the peat at all locations. The average depth to permafrost was 1 ft 7 in. The minimum depth to the permafrost table encountered during the investigations was 1 ft 2 in. and the maximum depth was 2 ft 9 in. The depth of the permafrost table at most of the sites was encountered at 1 ft 6 in.

Permafrost thickness could only be determined at 4 sites. It was 1 ft or less at these locations and confined to the surface peat layer. At the other sites, the permafrost extended downward into the mineral soils, which are vitually all coarse-grained, making penetration difficult.

The relationship of permafrost occurrence to tree species was also noted. Spruce grows at all the treed sites and tamarack was encountered at only 1 site. No trees were observed on the palsas or the peat plateaux in which permafrost occurs.

Subsurface investigations in permafrost (excluding palsas which are described separately) were carried out at several locations including the following:

<u>Stop No. 16</u> (between Poste-de-la-Baleine (Great Whale River), P.Q. and Richmond Gulf) (Figures 22, 23)

Soil Profile: 0 - 2 ft 0 in. - peat
below 2 ft 0 in. - sand and boulders
below 1 ft 6 in. - permafrost which extends into the mineral soil.

<u>Stop No. 64</u> (about 40 miles south of Goose Bay, Nfld.) (Figure 5).

Soil Profile: 0 - 5 ft 9 in. - peat
below 5 ft 9 in. - grey clayey silt
No permafrost was encountered at this site although the peat and mineral soil were cold.

<u>Stop No. 89</u> (about 25 miles north of Strait of Belle Isle, Nfld.) (Figure 9)

Soil Profile: 0 - 6 ft 0 in. - peat
below 6 ft 0 in. - stony sand
No permafrost encountered.

As previously mentioned, microrelief in the form of hummocks was encountered at virtually all of the low sites whether permafrost existed or not. Peat plateaux also did not necessarily indicate the existence of permafrost which was more often absent.

Palsas always indicated the presence of permafrost. Many peat plateaux which do not contain permafrost present the appearance of having had a perennially frozen condition. This is the situation at Stop No. 89 (Figure 9) where peat plateaux are interspersed with depressions which appear to be collapse scars.

Palsas And Other Peatland Features

Palsas are prevalent in the study area although they are not as numerous as in the Hudson Bay Lowland (Brown, 1968). They occurred at 7 low sites, which were examined on the survey. Palsas were also observed at many locations from the air (Figure 21). Palsas encountered at Stop No. 90 (Figures 19, 20) about 5 miles north of the Strait of Belle Isle at an elevation of 400 ft, constitute the most southerly occurrence of permafrost on the helicopter traverses. These palsas and peat plateaux are 4 ft high and several hundreds of square feet in extent situated in a shallow rock basin in hilly terrain. No other palsas were seen in the vicinity. There are no trees and the surface vegetation consists of Sphagnum, lichen and Labrador tea. Subsurface exploration revealed a layer of peat 6 ft thick overlying stony sand. The permafrost table is 1 ft 7 in. below the ground surface and permafrost extends into the mineral soil. Small patches of permafrost several feet in extent occur in the depressions between the palsas.

The next occurrence of palsas on the same leg of the helicopter traverse was encountered at Cartwright on the Atlantic coast (Stop No. 85 - Figures 17, 18; Figure 48, air photo). Large palsas and peat plateaux exist in a circular depression about 1 mile in diameter beside the settlement about 50 ft above sea level. They are about 5 ft in height, several tens of feet wide and up to several hundred feet long. There are no trees and the surface vegetation consists of hummocky Sphagnum and grey lichen. Scattered areas of exposed peat occur on the surface and scattered cracks extend to a depth of 2 ft. The peat varies in thickness from 2 - 4 ft overlying sandy soil. The depth to the permafrost table is 1 ft 6 in. and permafrost extends into the mineral soil. A few areas which were probed in the palsas showed no trace of permafrost. In the low areas between the palsas, no permafrost was encountered. This palsa bog was visited and described by Hustich and Wenner in 1939 who observed the same conditions (Hustich, 1939; Wenner, 1947). A large area of palsas and peat plateaux was observed on Huntingdon Island a few miles offshore from Cartwright.

Another very large group of palsas and peat plateaux was observed on Neveisik Island in Lake Melville at Stop No. 78 (Figures 15, 16; Figure 49, air photo) (Blake, 1953). They are situated about 100 ft above sea level in a broad shallow rock basin several miles in extent. There is about 6 ft of microrelief, individual palsas and peat plateaux being several hundred feet in extent. There are no trees and the surface vegetation consists of hummocky Sphagnum, lichen and Labrador tea below which is peat 2 - 4 ft thick overlying silty clay. The permafrost table is about 2 ft below the surface and the permafrost extends into the mineral soil. Cracks extending to a depth of 2 ft are scattered over the surface of the palsas. No permafrost occurs in the depressions between palsas.

At the other extremity of the study area the most southerly palsas were observed 25 miles south of Great Whale River (Stop No. 13 - Figures 13, 14). Palsas have been reported by others in this vicinity (Canada, 1960a; Hamelin and Cailleux, 1969) and further south in the vicinity of Fort George (Skinner, Geological Survey of Canada, personal communication) and Fort Rupert (Rupert House) (Lee, Lockwood Survey Corp. Ltd., personal communication). This group near Poste-de-la-Baleine (Great Whale River) is much smaller than the ones described previously on the Labrador coast. There are about 5 palsas each 50 - 100 ft long, up to 30 ft wide, and about 8 ft high. There are no trees and the ground cover consists of hummocky Sphagnum and lichen, below which is peat 3 ft thick overlying silty fine sand. The permafrost table is 1 ft 9 in. below the ground surface and the permafrost extends into the mineral soil to a depth of possibly 20 ft. Cracks extending to a depth of 2 ft are scattered over the surface of the palsas. No permafrost was encountered between palsas except for a few scattered patches beneath some lichen patches where the active layer was about 1 ft 9 in. and the thickness of the permafrost 3 in. to 2 ft.

The palsas described above are some of the more prominent ones in the study area. They are not nearly as prevalent as in the Hudson Bay Lowland where they were observed to extend over vast flat areas. In Quebec and Labrador they occur in rock basins and other depressions, the largest being found on the Labrador coast. Palsas were seen at various scattered locations inland from the Atlantic coast and Hudson Bay but they do not generally attain the size of those described previously. They are prevalent in the vicinity of Poste-de-la-Baleine (Great Whale River) north of Stop No. 13. They exist in various stages of development and degradation. At Stop No. 15, for example, there is a palsa about 100 ft by 50 ft in size from which the surface peat layer has been mostly removed by wind action exposing the underlying sandy soil. Patches of the redeposited peat lie several hundred feet from the palsa in which the permafrost has disappeared. Large groups of palsas occur in Precambrian rock basins between Poste-de-la-Baleine (Great Whale River) and Richmond Gulf such as those shown in Figure 21.

Few palsas were observed east of the Hudson Bay coastal zone until the traverse from Schefferville to Sept Iles. They occur in the Schefferville area and at various locations to the south, such as on the summit of Mount Wright 2,500 ft above sea level. Closer to Sept Iles on the Laurentian Scarp there are small areas of palsas on summits about 2,600 ft above sea level. Further east north of Havre St. Pierre (Stop No. 55 - Figure 34), and near Harrington Harbour, scattered areas of palsas were observed at similar elevations on the Laurentian Scarp. North of Goose Bay, occurrences of palsas become more frequent such as those at Stop No. 70 (Figures 24, 25) located 50 miles west of Hopedale. The palsas, about 3 ft high, extend into a small lake. There are no trees and the ground vegetation consists of lichen patches, although bare peat predominates. The peat is 4 ft thick overlying grey medium sand. The permafrost table is 1 ft 6 in. below the ground surface and the permafrost extends into the mineral soil. Scattered areas of palsas occur at elevations up to about 1,200 ft above sea level around Lake Melville (Stop No. 80 - Figures 35,36).

One of the notable features of palsas, especially mature ones, observed in Quebec and Labrador, is the virtual absence of tree growth. This contrasts markedly with palsas in the Hudson Bay Lowland and further west on which some of the densest and tallest trees of the region are growing. Generally there was no sign even of seedlings.

Palsas and associated peat plateaux are the most noticeable permafrost features in the low areas but other indications of existing and past occurrences of permafrost are also evident. Many peatlands and peat bogs have peat plateaux but no 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 in the study area especially on the Laurentian Plateau in Labrador (Figures 5, 6, 10) (Hamelin, 1957; 1958; Potzger and Courtemanche, 1955; Thom, 1972). They are not necessarily directly related to the presence of permafrost, where in fact conditions are usually too wet for perennially frozen ground to form. They occur south of the permafrost region but attain their best development near the southern limit of permafrost.

High Areas And Other Permafrost Occurrences

In addition to peatlands where present and past permafrost conditions were encountered, periglacial features associated with severe climatic conditions and frequently, existence of permafrost, were observed in other types of terrain. Most of these occur at high elevations on and near mountain summits. The locations examined on the ground are designated as high areas in Table I. Sorted circles (stony earth circles), stone nets, and polygonal markings were observed on the Mealy Mountains 3,600 ft above sea level near the Labrador coast (Stop No. 84 - Figures 28, 29), on the Otish Mountains 3,300 ft above sea level north of Nitchequon (Stop No. 38 - Figure 30) and on mountain summits 1,800 ft above sea level south of Nitchequon at Stop No. 34 (Figure 31) and Stop No. 35 (Figure 32) 2,300 ft above sea level. These features were also present on summits reaching 3,000 ft above sea level in the Laurentian Scarp north of Sept Iles.

In the northern reaches of the study area where the discontinuous permafrost becomes more widespread and thicker, these surface features are more prevalent. Between Stop No. 30, 31, at the northern end of one of the helicopter traverses, polygonal cracks are widespread in sandy gravel ice contact glaciofluvial features. Stone nets and sorted circles commonly occur in the Schefferville area where permafrost is widespread and several hundred feet thick (Figure 33). They exist south of Schefferville on mountain summits at elevations of 2,700 ft above sea level. Sorted circles and stone nets were observed southeast of Schefferville en route to Churchill Falls on mountain summits 2,200 ft above sea level. Similar features are widespread further east in north central Labrador between Stop No. 68, 69. Sorted circles and stripes occur on the coast at Postville, on the summit of Post Hill 1,400 ft above sea level.

Periglacial features in the form of stone nets and solifluction lobes were also observed in the southern reaches of the study area in northern Newfoundland at high elevations on the Long Range Mountains. They were encountered at 1,990 ft above sea level at Stop No. 91 (Figure 37). The nets are about 20 ft in diameter. The vegetation consists of moss, grass and sedge overlying 8 in. of organic material below which are rock fragments. No permafrost was encountered at this site and it probably does not occur here.

Stone nets were also observed in another type of situation in the vicinity of Churchill Falls. Here they occur on the low flat shorelines of the large shallow lakes on the Laurentian Plateau above the falls. They were also seen on the lake bottoms near the shore in shallow water which presumably freezes to the bottom in winter. The nets at Stop No. 47 (Figure 38), on the shore of a lake, were about 10 ft in diameter, individual stones being as large as 1 ft in size. The centres of the nets are distinctly convex consisting of gravelly soil. No permafrost was encountered in the nets.

Several other occurrences of features associated with permafrost and periglacial conditions were observed and reported. On the coast of Labrador between Rigolet and Hopedale, thaw slumps were seen on the south facing slopes of several river valleys in clayey soils. Thaw slumps were encountered on the spruce covered north facing slope of the Unknown River, a tributary of the Churchill River near Churchill Falls where the occurrence of permafrost was described earlier by Andrews (1961) and Caplan (1961). No slumping was observed on the deciduous covered south facing slopes. Permafrost was encountered to a depth of 17 ft in till on an island in Lobstick Lake at the hydro-electric construction at Churchill Falls, and at another location, also in till, on an island in Ossokmanuan Lake. No permafrost was encountered at the Churchill Falls townsite or airport during construction (Acres Canadian Bechtel Ltd., personal communication).

Air Photo Patterns

Vertical air photo coverage is available for the study area at a scale of 5,000 ft: 1 in. or 3,333 ft: 1 in. (taken at altitudes of 30,000 and 20,000 ft respectively). Examination of the air photographs reveals a variety of patterns throughout the area under study because of the variations in relief, vegetation, soils and drainage. The patterns characteristic of the low areas were found to be similar to those encountered in the investigations carried out in the southern fringe of the discontinuous zone west of Hudson Bay (Brown, 1964; 1967; 1968). Thus the areas at low elevations most probably containing permafrost, i.e., the low sites in 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. The high areas in Table I are all located at high elevations on or close to mountain summits. Surface features associated with permafrost included non-sorted circles and stripes, and polygons, all of which are identifiable on air photographs. In the northern part of the study area 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.

Two areas have been selected from the study area to illustrate some of the patterns including permafrost features (Figures 48, 49). Both stereoscopic pairs of photographs are from eastern Labrador where palsas were encountered: Cartwright, Stop No. 78 (Figures 15, 16) and Neveisik Island in Lake Melville, Stop No. 85 (Figures 17, 18).

I. The village of Cartwright on the Atlantic coast can be observed in the top left hand corner in the first stereoscopic pair of aerial photographs. Two distinctive areas of peat plateaux and palsas occur in the centre of the photographs.

The first area in the centre on the left side has a pattern of smooth textured, light grey, rounded and elongated shapes on an almost circular smooth textured area of medium grey tone. This is a depression near sea level about three-quarters of a mile in diameter. The light grey rounded and elongated areas are treeless palsas which contain permafrost; the medium grey areas are the low flat areas between the palsas in which no permafrost exists. Ground and low level oblique photographs of this palsa bog are shown in Figures 17, 18 respectively.

The second area in the centre on the right side has a fine network of closely spaced dark grey to black flecks in a medium to light grey mesh-like matrix. This pattern is located in a subrounded depression, 1/2 mile by 1 mile in extent, with a smooth textured medium to light grey tone. The light grey, low narrow sinuous ridges in the network-mesh pattern are peat plateaux and palsas with permafrost. No permafrost was encountered in the dark grey to black flecks, which are pools of water, or in the surrounding medium to light grey areas in the depression.

II. In the second stereoscopic pair of aerial photographs, the area with the permafrost features comprises virtually the entire extent except the rock outcrops on the left side. The most predominant pattern is similar to the second one in the first stereo pair. It 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. Ground and low level oblique photographs of this extensive palsa area are shown in Figures 16 and 17.

DISCUSSION

The chief problem arising from permafrost investigations in Quebec and Labrador is the prediction of permafrost conditions from existing climatic and terrain features. An accompanying problem is the assessment of the relative influence of climate and terrain on the formation and maintenance of a permafrost condition (perennially below 32°F (0°C)).

Relation of Permafrost Distribution to Air Temperatures

The patchy distribution and thinness of the permafrost in the southern part of the study area is characteristic of the southern fringe of the discontinuous zone, where permafrost exists in a delicate thermal state close to 32°F (0°C). Observations in Canada and other countries indicate the existence of a broad relation between mean annual air and ground temperatures in permafrost. Many investigators have estimated the mean annual air temperature required to produce and maintain a perennially frozen condition in the ground, but there is some disagreement on this matter. In Canada, the southern limit of permafrost, as known at present, coincides roughly with the 30°F (-1.1°C) mean annual air isotherm. The difference between mean annual air and mean annual ground temperatures, and variations in this difference from one location to another, are caused by climatic factors other than air temperature, in combination with surface and subsurface terrain factors. The complex energy exchange at the ground surface, which is influenced by these factors, and the snow cover which reduces the cooling influence of winter air temperatures, cause the mean annual ground temperature measured at the depth of zero annual amplitude to be up to several degrees warmer than the mean annual air temperature (Brown, 1966c).

The mean annual air temperature in the study area ranges from 36.5°F (2.5°C) in northern Newfoundland to about 23°F (-5°C) at Schefferville and Border (Figure 39). The 30°F (-1.1°C) isotherm is not shown on this map, but its location can be roughly interpolated at the southern end of James Bay extending eastward about halfway between the 27.5°F (-2.5°C) and 32°F (0°C) isotherms. (East of Sept Iles this corresponds roughly with the freezing index isopleth for 3,000 degree days). This corresponds approximately with the southern limit of permafrost shown on Figure 46. Permafrost occurs between the 30°F (-1°C) and 25°F (-3.9°C) mean annual air isotherms in the southern fringe of the discontinuous zone, mostly in scattered patches and islands in peatlands and peat bogs, possibly in heavily shaded areas, and in some north-facing slopes. The 25°F (-3.9°C) isotherm is not shown on this map, but its location can be interpolated roughly halfway between the 23°F (-5°C) and 27.5°F (-2.5°C) isotherms. (It also lies roughly between the freezing index isopleths for 4,500 and 5,000 degree days). Thus it extends in an arc from the vicinity of Poste-de-la-Baleine (Great Whale River) in the west, southeastward to Nitchequon and Wabush, thence northeast and northward through Labrador. North of the 25°F (-3.9°C) isotherm, permafrost is widespread and found in most types of terrain. As mentioned previously, the two subzones of the discontinuous zone, southern fringe and widespread, are much wider in Quebec and Labrador than in Ontario west of Hudson Bay and James Bay.

In the southern fringe of the permafrost region, permafrost can exist only in certain types of terrain described previously, provided the climate is sufficiently cool, i.e., the mean annual air temperature is 30°F (-1.1°C) or less. Southward, permafrost occurrences are rare and small in size and generally are not found in the same types of terrain because the climate is too warm. Such occurrences have been noted in the Prairie Provinces (Zoltai, 1971), but none was encountered in Ontario (Brown, 1968). No permafrost was found in the study area, for example, in the peat covered coastal plain along the Gulf of St. Lawrence where the mean annual air temperature is 34-35°F (1.1-1.7°C) (Harrington Harbour, 34.7°F (1.5°C); Sept Iles, 34.1°F (1.2°C)). The conditions at Stop No. 53, which was 5 miles north of Havre St. Pierre, located between Harrington Harbour and Sept Iles, typify this situation where a ground cover of moss and lichen (no trees) grows on peat 7 ft thick overlying sand (Figures 11, 12). No permafrost was encountered in this type of terrain. The existence of palsas, however, a few miles from Red Bay on the Strait of Belle Isle (Stop No. 90 - Figures 19, 20) where the mean annual air temperature is about 32°F (0°C) (Figure 39), is an exception to this general situation. The elevation of these palsas is 400 ft above sea level which may make the mean annual air temperature at the site a degree or so less.

In the vicinity of the 25°F (-3.9°C) mean annual isotherm, the average difference of 6°F (3.3°C) between the mean annual air and ground temperature produces a mean annual ground temperature of a fraction of a degree below 32°F (0°C), in most types of terrain. From the 25°F (-3.9°C) mean annual air isotherm northward, permafrost becomes increasingly widespread and thick, and the mean annual ground temperature decreases. The influence of climate on the existence of permafrost becomes increasingly important and variations in the terrain cause variations in the depth to permafrost, its area extent and thickness (Brown, 1965; 1970). The southern limit of the continuous permafrost zone, where permafrost occurs everywhere beneath the land surface, lies north of the 17°F (-8.4°C) mean annual air isotherms, which is outside of the study area.

Ground Temperatures

The only available ground temperature observations are at Schefferville at the northern edge of the study area (Nicholson and Thom, 1973). Many thermocouple and thermistor cables have been installed in the iron ore deposits to monitor permafrost conditions. Permafrost has not been encountered in the townsite at an elevation of 1,680 ft above sea level where the mean annual air temperature is 23.8°F (-4.6°C). Several miles northward where permafrost was encountered in several iron mining areas, the elevation is 2,300 ft above sea level, the mean annual air temperature 22°F (-5.6°C), the permafrost varies in thickness from a few tens of feet to a maximum of about 400 ft and the ground temperature at the 50 ft depth (depth of zero annual amplitude) ranges from about 28°F (-2.2°C) to a fraction of a degree below 32°F (0°C).

Role of Peat in Permafrost Occurrences

In previous investigations carried out west of Hudson Bay, questions regarding the origin and persistence of permafrost and the factors governing development of various types of terrain were raised (Brown, 1964; 1965; 1967a; 1968). The same questions apply to the area under discussion referring to the reasons for permafrost occurring only in certain types of terrain in the southern fringe of the discontinuous zone. All of the permafrost observed in the study area was found in peatlands and peat bogs (excluding the mountainous areas); it appears that the thermal properties of the peat are an important factor in determining the presence of permafrost.

The mechanism of permafrost formation in peat terrain appears to be related to changes in the thermal properties of the peat through the year (Brown, 1966b; Tyrtikov, 1959). 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 32°F (0°C) throughout the year, permafrost results and is maintained as long as the thermal conditions leading to this lower temperature persist.

Other factors such as microrelief, drainage and snow cover, influence the ground thermal conditions and are also involved in the production of permafrost islands. Such a close relationship exists between these and other environmental factors that it is difficult to single out the significant effect of each of these factors on the permafrost.

Permafrost Indicators

Consideration was given to the use of the various components of the environment as indicators of the presence of permafrost. Tree types by themselves cannot be employed as reliable permafrost indicators. Spruce is the predominant tree on peatlands and peat bogs in the study area; it grows both on permafrost sites and sites with no permafrost. Tamarack grows at only 13 of the sites examined for permafrost and permafrost was found at only one of these sites. Thus tamarack could be considered as an indicator of the general absence of permafrost within the context of other factors.

Most of the permafrost sites have Sphagnum and all of them have lichen, but these plants are unreliable indicators because they grow extensively in areas where permafrost does not exist. Various attempts have been made to correlate the distribution of permafrost in peat terrain with the occurrence of lichen. This supposition was examined in detail in a previous paper and proved invalid (Brown, 1966a). Nevertheless, macro-lichens are so prolific in the study area that special note was taken on the survey of their occurrence in relation to permafrost distribution (Hare, 1959). Lichen covering 25 per cent or more of the peatland terrain, and thus qualifying as Redforth's muskeg H factor, was noted in 12 of the sites examined, of which permafrost exists in only one. As shown in the table on page 17, lichen grows at 79 sites of which only 16 have permafrost (see Table I). In the case of young palsas and peat plateaux, lichen does not begin to grow on them until many years after the perennially frozen core has developed. The absence of lichens on these newly formed features, therefore, does not indicate the absence of permafrost.

The type of mineral soil does not appear to have any bearing on the existence of permafrost. Coarse-grained soils, mainly sandy, predominate at the sites where permafrost was present and where it was absent. Fine-grained soils such as silts and clays were found at sites with permafrost as well as at sites without it.

It is rarely possible to determine the mineral soil type in the peatlands from the surface vegetation. The same type of permafrost and associated conditions prevail on all types of soil in relation to the vegetation, microrelief and drainage conditions.

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 Laurentian 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, 1 - 2 ft, such as at Stop No. 48, 49, south of Churchill Falls, 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 some of these areas but not all of them so this terrain situation does not guarantee the existence of permafrost.

Microrelief features such as palsas and peat plateaux, which rise above the wet areas and have good local drainage, contain permafrost and are reliable indicators of the existence of this perennially frozen condition. The critical factors controlling their distribution in Quebec and Labrador are not definitely known but local climatic, water supply and snowfall conditions seem to be important. This is based on observations in Scandinavia and the Hudson Bay Lowland. A puzzling aspect is the presence of large mature palsas, mentioned previously, on the Labrador coast at Red Bay, at Cartwright and on Neveisik Island in Lake Melville, where the mean annual air temperature is 32°F (0°C) and high snowfalls occur. Cool air temperatures and prevailing overcast sky conditions in summer due to influence of the ocean may contribute to the development of these permafrost features.

Another puzzling aspect in the survey of permafrost indicators was the absence of permafrost in the peat that existed at many locations in the study area although this peat was sufficiently thick and dry to support its formation and existence. This type of terrain condition in the Hudson Bay Lowland and westward in the Prairie Provinces and British Columbia north of the 30°F (-1.1°C) mean annual air isotherm usually indicated the presence of permafrost but none was encountered at many such sites east of James Bay and Hudson Bay. At Stop No. 23 - 26 inclusive, for example, where dry peat 3 ft thick was encountered in peat bogs, no permafrost was observed. The peat was cold to the touch, but not frozen, and the mean annual air temperature was about 26°F (-3.3°C). This situation was found at many points along the other traverses both to the west along the coasts of James Bay and Hudson Bay, and eastward into Labrador especially near the east coast.

This general scarcity of permafrost in the peatlands of Quebec and Labrador located in the southern fringe of the discontinuous zone appears to be related to regional snowfall conditions and perhaps air temperature. The mean annual snowfall east of Hudson Bay ranges from about 100 in. in western Quebec to more than 200 in. in eastern Labrador. In contrast to this, the mean annual snowfall west of Hudson varies from 80 - 90 in. in the Hudson Bay Lowland to 40 in. or less in the northern Prairie Provinces (Thomas, 1953). Furthermore, 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. 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 effect of minor variations in air temperature on permafrost occurrence is less obvious than that of snowfall conditions but it may be significant. The fact that many of the surprisingly small number of permafrost islands encountered in the peatlands throughout the study area were thin and marginally frozen, leads to the possibility that they persist for a few years and then dissipate during warmer than average summers. Summer air temperatures for the weather stations in the study area, from June to September inclusive, 1967 and 1968, the two years of the survey, were compared with the thirty year means (1941 - 1970, Table IIIa). Throughout the portion of the study area in Quebec covered by the survey in 1967 between Hudson Bay and James Bay on the west, then eastward to Schefferville and Wabush, the mean air temperature for the summer period (June to September inclusive) was 2 - 3°F (1 - 1.5°C) above the thirty year mean. In the summer of 1968, the same situation did not prevail in the Labrador portion of the study area which experienced a much cooler summer, 1.5 - 2.5°F (0.8 - 1.4°C) below the thirty year average. September 1968 air temperatures in Labrador, however, were several degrees above normal as were the 1967 temperatures for the June to September period. Several years of observations on permafrost occurrences in the peatlands and year to year air temperature trends are necessary to establish any definite relationships. Probably the influence of snow cover as described above overrides these small variations in air temperature.

The variable relief and existence of high elevations throughout the study area have a significant effect on the distribution of permafrost. In Ontario and the Prairie Provinces this factor is of virtually no significance. It is suggested that permafrost exists at all locations above treeline in the discontinuous zone of Quebec and Labrador (Ives, 1962; 1974). The Mealy Mountains in eastern Labrador and the Otish Mountains in Quebec have permafrost on their summits which are above treeline (Stop No. 84 - Figures 28, 29; Stop No. 38 - Figure 30; Figure 46). Other areas with summits above treeline are shown as dark islands on the map of permafrost distribution (Figure 46) and are typified by the photographs of typical mountainous terrain in Figures 26, 27. The mountain summits near Nitchequon shown in Figures 31, 32, are also above treeline and have permafrost. No permafrost was encountered in the townsites of Wabush and Labrador City at an elevation of about 1800 ft above sea level. As mentioned previously, permafrost occurs above 2500 ft in the nearby iron mines and has been found to depths exceeding 200 ft (Garg, Iron Ore Company of Canada Ltd., personal communication). Palsas can be seen in most peat bogs on mountain summits above treeline, confirming the presence of permafrost.

The extensive work at Schefferville on permafrost distribution, which has been carried out during the past 15 years by McGill University and the Iron Ore Company of Canada, has shown the close relationship between environmental conditions and permafrost. Although Schefferville is located at the northern extremity of the study area, it is reasonable to assume that the same relationships prevail further south where the distribution of permafrost is affected by relief and elevation. Scattered permafrost islands exist in peat bogs near the town at an elevation of 1681 ft above sea level. Thick, widespread permafrost exists above treeline at about 2300 ft elevation where mining operations are underway. Here it is found that snow is the most important factor controlling permafrost distribution and that there is a linear relationship between ground temperatures and snow depth. Groundwater is an important subsidiary factor, but has not yet been quantified. Permafrost exists generally where the snow cover is less than 28 in. Permafrost occurs in ridges where snow cover is thin but not in valley bottoms where the snow is deep (Nicholson and Granberg, 1973; Nicholson and Thom, 1973).

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 was not found in the study area south of the 30°F (-1.1°C) isotherm except in southeast Labrador under unusual local conditions. Between the 30°F (-1.1°C) and 25°F (-3.9°C) isotherms, permafrost is patchy and restricted to certain types of terrain, mainly peatlands. Permafrost is widespread north of the 25°F (-3.9°C) isotherm.

Permafrost is much less common in peatlands in the study area 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 Quebec 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 climate map (Figure 39).

The use of helicopter transport for the survey made it possible to cover large distances and survey the terrain types and related potential permafrost conditions from the air. It was not possible to stop at every potential permafrost site because of time restrictions and the frequent lack of a sufficiently large open area. Thus, some permafrost occurrences may have been missed. Nevertheless the broad patterns of permafrost distribution were established.

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TITLES OF COLUMNS AND EXPLANATION OF SYMBOLS IN TABLE I

Column 1 - Reference number of observation point

Beginning with helicopter Stop No. 1 north of Mattagami, P.Q. and ending with Stop No. 92 in Newfoundland north of Corner Brook

Column 2 - Elevation

Height in feet above sea level

Column 3 - Relief

H - relatively elevated area
L - relatively low area or depression
V - river or stream valley
- subscripts: n - north facing slope
  s - south facing slope

Column 4 - Tree species

S - spruce
J - jackpine
T - tamarack
W - willow

(40) - number in brackets is height in feet of tallest tree
d - dense growth
s - sparse growth
No - no trees present

Column 5 - Surface terrain features

H - hummocky
Sph - Sphagnum
M - moss other than Sphagnum
Ln - lichen
(25) - percentage of ground surface covered by lichen
Lt - Labrador tea
G - grass
Se - sedge
B - ground birch
(w) - standing water or wet
(p) - peat plateau
P - palsa
No - bare peat or mineral soil

Column 6 - Thickness of peat

i.e., depth from ground surface to top of mineral soil

Column 7 - Soil type

G - gravel
Sa - sand
Si - silt
C - clay
X - stones or rock fragments
O - organic
B - bedrock
(w) - wet

Column 8 - Existence of permafrost

Yes - encountered
No - not encountered but may be present in the area

Column 9 - Depth to permafrost table

Column 10 - Thickness of permafrost

Column 11 - Figure number in report

TABLE I

QUEBEC AND LABRADOR PERMAFROST SURVEY

1	2	3	4	5	6	7	8	9	10	11
					QUEBEC					
1	900	L	S(10)s	HSphSe(w)	> 9 ft 0 in.		No			
			S(25)d	HSph						
2	800	L	S(15)s	HSphLnLtSeM	10 ft 0 in.	C(w)	No			
			S(25)s	HSphLnLt(w)						
3	400	L	S(15)JT(10)s	HSphLn(25)Se	>12 ft 0 in.	Sa	No			
			S(25)d	HSphLn(10)Lt	9 ft 0 in.					
4	100	L	S	SphLn(p)			No			
5	250	L	S	SphLn(p)	> 9 ft 0 in.		No			
6	100	L	ST(20)s	SeM	1 ft 0 in.	SaG	No			
			S(30)d	HSphLnLt						
7	Below 500	L	S(40)d	HSphLnLtB	2 ft 0 in.	Sa	No			
8	150	L	S(2)T(15)s	HSphLnSeM	6 ft 0 in.		No			
			S(40)d	HSphLn(25)Lt	3 ft 6 in.		No			
9	150	L	S(2)	HSphLnLtSeM	5 ft 0 in.	SiSa	No			
			S(35)d	HSphLn(25)Lt						
10	Below 500	L	S(35)d	HSphLn(25-40)Lt	3 ft 0 in.	SiCSaG	No			
11	Below	Vs	S(25)W(3)d	HSphLn(10)LtG	2 ft 6 in.	SiCSaG	No			
	500	Vn	W(3)d			C(w)	No			
12	Below 500	L	S(20)s	HSphLn(33)Lt	4 ft 0 in. to 7 ft 0 in.	SaG	No			Fig. 7
13	550	L	S(2)s	HSphLnLtSeMG	5 ft 9 in.	SiSaC	No			Figs.
			No	HSphLn(p)P	3 ft 0 in.		Yes	1 ft 9 in.		13, 14
14	400	L	No	Se	3 ft 9 in.	Sa	No	1 ft 9 in. to		
				LnP			Yes	2 ft 9 in.		
15	400	L	S(10)s	No		SaX	No			
			No		0 ft 3 in.					
16	500	L	S(2)s	SeM	2 ft 0 in.	SaX	Yes	1 ft 6 in.		Figs.
				HSphLnLt						22,23
17	600	L	S(30)s	HSphLnLtSeMB(w)	2 ft 0 in.	SiC	No			
		Vs	SW(2)d	MLnG(w)	0 ft 9 in.	C				
18	1000	L	S(30)d	HSphLn(67)Lt	1 ft 9 in.	SaX	Yes	1 ft 6 in.	>1 ft 0 in.	
19	1000	L	S(30)d	HSphLn(10)Lt(w)	5 ft 6 in.	SaGX	No			
20	1200	L	S(30)d	HSphLn(10)Lt	3 ft 6 in.	GX	No			
21	800	L	S(40)d	HSphLn(10)Lt	5 ft 0 in. to	SaX	No			
			No	SeM	6 ft 9 in.					
22	900	L	S(25)s	HSphLn(25)Lt(p)	6 ft 9 in.	Sa	No			
23	750	L	S(40)d	HSphLn(10-25)Lt(p)	6 ft 9 in.	SiSaC	No			
			No	SeM	3 ft 3 in.					
24	900	L	S(40)d	HSphLn(10)Lt	2 ft 9 in. to 3 ft 3 in.	SaGB	No			
25	1000	L	S(25)d	HSphLnLt	3 ft 0 in.	Sa	No			
26	1100	L	S(40)d	HSphLt	2 ft 9 in.	Sa(w)	No			

TABLE I (Cont'd)

1	2	3	4	5	6	7	8	9	10	11
27	1400	L	S(35)d	HSphLnLt	3 ft 0 in.	Sa	No			
28	1300	L	S(35)d	HSphLn(5)Lt	3 ft 0 in. to 5 ft 0 in.	B	Yes	1 ft 6 in.	0 ft 7 in.	
29	1200	L	S(25)d	HSphLnLt	2 ft 0 in. to 3 ft 0 in.	SaB	No			
30	1200	L	S	HSphLn(10)Lt(w)	3 ft 0 in. to 4 ft 0 in.	SaB	No			
31	1200	L	S	HSphLnLt SeM(w)	2 ft 0 in. to 3 ft 0 in.	SaB	No			
32	1200	L	S(30)d	HSphLnLt GSe	3 ft 0 in. to 3 ft 9 in.	SaB(w)	No			
33	1200	L	S(30)d	HSphLnLt GSe	3 ft 0 in. to 4 ft 0 in.	Sa(w) Sa(w)	No			
34	1800	H	S(10)s	LnB	0 ft 2 in.	SaG(w)	No			Fig. 31
35	2333	H	No	MLnGSe	2 ft 0 in.	GSa	Yes	1 ft 6 in.		Fig. 32
36	1650	L	S(35)dT	HSphLnLt	6 ft 0 in.	Sa	No			
37	1800	L	S(40)dT	HSphLnLt	3 ft 0 in. to 4 ft 0 in.	Sa	No			
38	3330	H	No	HMLn	3 ft 0 in.	B	Yes	1 ft 6 in.		Fig. 30
39	1800	L	S(30)d	HSphLnLt	3 ft 3 in.	Sa	No			
40	1100	L	S(30)dT	HSphLnLt	3 ft 3 in.	Sa	No			
41	2000	L	S	HSphLn(25)Lt GSeM	2 ft 3 in. to 2 ft 6 in.	G	No			
					LABRADOR					
42	1850	L	S(35)d T(10)s	HSphLnLt SeM(w)	1 ft 8 in. to 2 ft 6 in.	SaG	No			
43	1900	L	S(30)d	HSphLnLt	2 ft 6 in. to 4 ft 0 in.	Sa	Yes	1 ft 6 in.	0 ft 7 in.	
					QUEBEC					
44	1700	L	No S	HSphSeM(w) HSphLnLt	4 ft 0 in. 3 ft 0 in.	SaGB	Yes	1 ft 6 in.	0 ft 6 in. 1 ft 0 in.	
					LABRADOR					
45	1600	L	S(15)d	HSph	4 ft 6 in.	SaG	No			
46	1750	L	ST(10)s	HLnLt	4 ft 3 in.	CSi	Yes	1 ft 6 in.		
47	1800	L	No	G	None	SiCG	No			Fig. 38
48	1700	L	S(25)d No	HSphLnLtSeG SphSe(w)	2 ft 0 in. to 3 ft 6 in.	B	No			
49	1700	L	S(25)d No	HSphLnLtSeG SphSe(w)	1 ft 0 in. to 2 ft 0 in.	G	No			
50	2000	L	S(25)d	HSphLn(40)LtSeG	2 ft 2 in.	OSa	No			

TABLE I (Cont'd)

1	2	3	4	5	6	7	8	9	10	11
					QUEBEC					
51	2700	L	S(1)	HSphLnLtSeG(p)	3 ft 6 in.	SaGB	No			
52	1700	L	S(20)s	HSphLnLtSeG	3 ft 0 in. to 4 ft 6 in.	SaG	No			
53	10	L	S(10)s	HLn	7 ft 0 in.	Sa	No			Figs. 11, 12
54	1200	L	S(20)T(5)s	HSphLtSeG	4 ft 6 in. to 5 ft 0 in.	SaG(w)	No			
55	2600	L	S(2)s No	Sph LnLtP	>1 ft 6 in.		No Yes	1 ft 6 in.		Fig. 34
56	1600	L	S(10)s	HSphLn(10)LtSeG	>6 ft 9 in.		No			
57	1450	L	S(2)s	HSphLn(25)LtSeG	5 ft 3 in.	Si	No			
58	600	L	S(20)d No	HSphLn(15)LtSeG(p) HSphLn(5)SeG	>6 ft 9 in. 5 ft 0 in.	CSi(w)	No			
59	200	L	No	HSphLnLt(w) MSeG	>6 ft 9 in.		No			
60	700	L	S(30)d	HSphLtSeG	3 ft 6 in.	SiSa	No			
61	1200	L	S(25)d	HSphLnLtSeG	>6 ft 9 in.		No			
					LABRADOR					
62	1150	L	S(25)d	HSphLnLtSeG	3 ft 6 in.	SaSi	No			
63	1250	L	S(25)d	HSphLnLtSeG	5 ft 6 in.	Sa	No			Fig. 6
64	1200	L	No	SphLnLt(p)	5 ft 9 in.	SaCSi	No			Fig. 5
65	650	L	S(40)d	HSphLnLtG(p)	4 ft 0 in.	SaG	No			
66	750	L	S(40)d No	HSphLnLt SeG	1 ft 3 in.	X	No			
67	750	L	No	HSphLnLtG	>1 ft 6 in.		Yes	1 ft 6 in.		
68	750	L	No	HSphLnLtSeG(p)(w)	6 ft 0 in.	SaG(w)	No			
69	1900	L	No	HSphLnLt(p) MSe	>1 ft 4 in.		Yes	1 ft 4 in.		
70	800	L	No	Ln(p)P	4 ft 0 in.	Sa	Yes	1 ft 6 in.		Figs. 24, 25
71	300	L	S(25)s	HSphLn(33)LtG	2 ft 0 in.	Sa	No			
72	300	L	S(20)d	HSphLnLtSeG	4 ft 9 in.	C	No			
73	300	L	S(30)s S(40)d	HSphLn(15)LtMSeG HSphLnLtM	>6 ft 9 in. 4 ft 6 in.	C	No			
74	100	L	S(20)s No	HSphLn(10)LtSeG SeGM	4 ft 6 in.	G	No			
75	1000	L	ST(2)d No	HSphLtLnSeG SeGM(w)	2 ft 6 in.	Sa	No			
76	150	L	S(6)s	HSphLn(67)Lt	4 ft 6 in.	Sa	No			
77	1000	L	S(5)s	HSphLnLtSeG SeGM(w)	2 ft 0 in.	Sa	No			

TABLE I (Cont'd)

1	2	3	4	5	6	7	8	9	10	11
78	100	L	S(10)s	HSphLnLt(p)P	2 ft 1 in.	SiC	Yes	2 ft 0 in.		Figs.
			S(2)s	SeM(w)	4 ft 0 in.		No			15, 16
79	300	L	S(2)s	HSphLn(75)Lt	4 ft 6 in.	Sa	No			
80	1200	L	No	SphLnM(p)	5 ft 0 in.		Yes	1 ft 2 in.		Figs.
				HMSeG(w)			No			35,36
81	300	L	ST(10)s	HSphLnLtSeG	3 ft 0 in. to	Sa	No			
					4 ft 6 in.					
82	50	L	ST(5)s	HSphLtSeG	2 ft 0 in. to	Sa(w)	No			
				SeG(w)	3 ft 0 in.					
83	150	L	S(5)s	HSphLnLtSeG	>6 ft 9 in.		No			
84	3600	H	No	LnMSeG	0 ft 3 in.	SiSaG	Yes			Figs.
										28, 29
85	50	L	No	HSphLnP	2 ft 0 in. to	Sa(w)	Yes	1 ft 6 in.		Figs.
				SphMSeGB	4 ft 0 in.		No			17, 18
86	400	L	ST(5)s	HSphLnLtSeG	3 ft 0 in.	Sa	No			
87	450	L	No	HSphLnLtSeG	6 ft 0 in.	Sa	No			
			S(25)s		3 ft 6 in.					
88	800	L	ST(2)s	SphLnMLt	>6 ft 9 in.		No			
			No	SeG						
89	900	L	S(5)s	HSphLnLtSeGM(p)	6 ft 0 in.	SaX	No			Fig. 9
90	400	L	No	SphLnLtMP	6 ft 0 in.	SaG	Yes	1 ft 7 in.		Figs.
										19, 20
91	1990	H	No	MSeGLn	0 ft 8 in.	X	No			Fig. 37
92	1200	L	No	HSphLn(10)SeGM	3 ft 5 in.	B	No			

TABLE II

LATITUDES, LONGITUDES AND ELEVATIONS OF METEOROLOGICAL STATIONS IN TABLE III

Station	Latitude	Longitude	Elevation (ft)
Quebec			
1. Border	55° 20'N	63° 13'W	1594
2. Fort George	53° 50'N	79° 00'W	22
3. Gagnon	51° 58'N	68° 10'W	1800
4. Harrington Harbour	50° 32'N	59° 30'W	25
5. Lake Eon	51° 51'N	63° 17'W	1840
6. Nitchequon	53° 12'N	70° 54'W	1690
7. Poste-de-la-Baleine (Great Whale River)	55° 17'N	77° 46'W	86
8. Schefferville	54° 48'N	66° 49'W	1681
9. Sept Iles	50° 13'N	66° 16'W	190
Newfoundland (Labrador)			
1. Battle Harbour	52° 15'N	55° 36'W	31
2. Cartwright	53° 43'N	57° 01'W	47
3. Churchill Falls	53° 33'N	64° 06'W	1426
4. Goose Bay	53° 19'N	60° 25'W	144
5. Hopedale	55° 27'N	60° 14'W	35
6. Wabush	52° 56'N	66° 52'W	1807

TABLE IIIa

MONTHLY AVERAGES OF DAILY MEAN AIR TEMPERATURES (°F)

Quebec	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1. Border	-7.4	-4.4	5.0	16.1	31.3	43.4	52.0	50.0	40.6	29.2	15.9	2.4	22.8 (-5.1°C)
2. Fort George	-8.7	-6.2	5.1	22.2	36.5	47.8	54.3	52.2	46.6	37.3	24.3	5.8	26.4 (-3.1°C)
3. Gagnon	-2.1	0.1	12.1	24.0	37.1	50.1	56.5	54.6	44.9	33.4	19.1	2.2	27.7 (-2.4°C)
4. Harrington Harbour	12.8	14.0	21.8	30.5	39.0	47.7	54.5	55.7	49.8	40.9	31.4	18.3	34.7 (1.5°C)
5. Lake Eon	-1.3	0.3	11.2	23.4	35.5	48.2	56.0	53.5	44.6	33.2	20.3	3.4	27.4 (-2.6°C)
6. Nitchequon	-9.3	-5.6	6.0	21.5	35.0	49.2	56.5	53.6	44.5	32.9	17.8	-1.0	25.1 (-3.8°C)
7. Poste-de-la-Baleine (Great Whale River)	-8.1	-8.0	2.3	19.7	33.6	43.4	51.0	50.6	45.5	36.2	23.5	5.3	24.6 (-4.1°C)
8. Schefferville	-8.9	-6.1	5.4	19.5	33.7	47.3	54.6	51.4	42.1	30.3	16.3	-0.5	23.8 (-4.6°C)
9. Sept Iles	7.0	9.2	19.9	31.4	42.2	52.8	59.2	57.5	49.3	39.2	28.1	13.3	34.1 (1.2°C)
Newfoundland (Labrador)													
1. Battle Harbour	15.1	12.1	20.4	29.5	35.7	43.3	50.9	51.5	47.5	39.9	31.3	22.0	33.3 (0.8°C)
2. Cartwright	8.4	10.3	17.6	27.3	37.5	47.0	55.2	54.0	47.8	38.2	28.8	16.5	32.4 (0.2°C)
3. Churchill Falls	-4.4	-2.6	8.9	21.3	35.6	47.1	56.4	55.2	45.0	32.6	19.1	0.5	26.2 (-3.2°C)
4. Goose Bay	2.6	6.1	16.8	28.8	40.8	51.9	60.5	58.1	49.6	37.8	25.5	9.8	32.4 (0.2°C)
5. Hopedale	3.4	4.6	12.9	23.0	34.6	43.7	51.4	51.9	45.9	36.3	26.0	12.6	28.9 (-1.7°C)
6. Wabush	-7.4	-5.2	7.6	21.7	35.3	48.2	55.1	52.5	43.8	31.8	18.9	0.8	25.3 (-3.7°C)

TABLE IIIb

AVERAGE MONTHLY PRECIPITATION (IN.)

Quebec	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1. Border	1.75	1.62	1.30	1.39	1.20	3.38	3.59	3.34	2.41	2.45	2.20	1.19	25.82
2. Fort George	0.90	0.83	1.02	0.84	1.38	1.95	3.26	2.66	2.73	2.69	2.61	2.01	22.88
3. Gagnon	2.06	2.22	2.24	2.23	2.57	3.80	6.60	5.02	4.58	3.96	3.78	2.80	41.86
4. Harrington Harbour	5.32	4.83	4.34	3.49	3.31	2.92	3.46	3.63	3.24	3.69	5.12	4.34	47.69
5. Lake Eon	2.69	2.11	2.98	2.15	2.92	3.08	3.79	4.02	3.19	3.71	2.36	2.36	35.36
6. Nitchequon	1.41	1.27	1.29	1.31	2.28	3.38	3.98	4.29	3.53	3.19	2.39	1.77	30.09
7. Poste-de-la-Baleine (Great Whale River)	1.10	1.00	1.02	1.28	1.73	1.93	3.24	3.61	3.29	2.69	2.42	1.72	25.03
8. Schefferville	1.62	1.44	1.45	1.37	1.76	3.11	3.49	3.86	3.26	2.76	2.51	1.81	28.44
9. Sept Iles	3.93	3.62	2.87	2.29	3.22	3.37	4.09	3.89	3.97	3.44	4.31	3.92	42.92
Newfoundland (Labrador)													
1. Battle Harbour	3.10	3.56	4.33	3.19	2.73	3.39	2.84	3.31	2.97	2.90	3.12	2.42	37.86
2. Cartwright	3.49	2.95	3.76	2.86	2.35	2.97	3.33	3.33	3.36	2.98	2.92	2.96	37.26
3. Churchill Falls	3.61	3.31	2.06	1.95	2.37	3.92	3.65	3.15	3.21	2.80	2.65	2.94	35.12
4. Goose Bay	2.72	2.37	2.73	2.13	2.43	3.21	4.02	3.65	2.99	2.83	2.75	2.69	34.52
5. Hopedale	2.44	1.97	2.18	1.83	2.15	2.84	3.40	3.41	2.89	2.46	2.25	2.23	30.05
6. Wabush	2.63	1.88	1.92	1.36	2.35	3.27	4.16	3.89	3.61	3.38	3.27	3.00	34.72

TABLE IIIc

AVERAGE MONTHLY RAINFALL (IN.)

Quebec	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1. Border	0.07	0.04	0.01	0.20	0.45	2.94	3.45	3.34	1.93	0.74	0.25	0.07	13.49
2. Fort George	0	0.03	0.14	0.38	1.13	1.94	3.26	2.66	2.73	2.22	0.53	0.13	15.15
3. Gagnon	0	0	0.08	0.50	1.82	3.74	6.60	5.02	4.41	2.64	1.36	0.04	26.21
4. Harrington Harbour	0.93	0.75	0.63	1.41	2.86	2.92	3.46	3.63	3.24	3.55	3.67	1.20	28.25
5. Lake Eon	0.09	0.15	0.30	0.41	1.47	2.92	3.79	4.02	2.80	2.07	0.66	0.20	18.88
6. Nitchequon	0.01	0.01	0.10	0.27	1.50	3.31	3.98	4.24	3.28	1.84	0.52	0.12	19.18
7. Poste-de-la-Baleine (Great Whale River)	0	0.02	0.07	0.18	0.87	1.73	3.23	3.61	3.24	1.83	0.31	0.07	15.16
8. Schefferville	0.07	0.02	0.07	0.18	0.79	2.86	3.49	3.79	2.44	1.38	0.45	0.08	15.62
9. Sept Iles	0.26	0.36	0.28	1.21	3.08	3.37	4.09	3.89	3.97	3.06	2.30	0.79	26.66
Newfoundland (Labrador)													
1. Battle Harbour	0.41	0.22	0.22	1.44	2.13	3.33	2.84	3.27	2.97	2.77	2.11	0.64	22.35
2. Cartwright	0.35	0.24	0.25	0.66	1.56	2.85	3.33	3.33	3.35	2.54	1.31	0.33	20.10
3. Churchill Falls	0	0	0.06	0.24	1.35	3.28	3.65	3.15	2.46	1.22	0.81	0	16.22
4. Goose Bay	0.08	0.16	0.15	0.44	1.72	3.13	4.02	3.65	2.90	1.82	0.73	0.18	18.98
5. Hopedale	0.14	0.20	0.16	0.30	1.23	2.62	3.39	3.41	2.78	1.62	0.60	0.17	16.62
6. Wabush	0	0.02	0.05	0.11	1.30	3.20	4.16	3.89	3.32	1.17	1.03	0.10	18.35

TABLE IIId

AVERAGE MONTHLY SNOWFALL (IN.)

Quebec	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1. Border	17.3	17.4	14.1	13.0	8.2	4.1	1.0	0	5.2	17.0	19.5	12.9	129.7
2. Fort George	8.9	7.9	8.8	4.6	2.3	0.1	0	0	0	4.6	20.8	18.7	76.7
3. Gagnon	23.7	24.1	24.0	18.5	7.8	0.6	0	0	1.7	13.1	25.1	29.5	168.1
4. Harrington Harbour	43.0	40.6	36.7	20.6	4.4	0	0	0	0	1.4	14.4	31.1	192.2
5. Lake Eon	26.0	19.6	26.8	17.4	14.5	1.6	0	0	3.9	16.4	17.0	21.6	164.8
6. Nitchequon	14.4	13.5	12.4	10.7	7.9	0.7	0	0.4	2.7	13.5	19.0	16.9	112.1
7. Poste-de-la-Baleine (Great Whale River)	11.0	9.8	9.5	11.0	8.6	2.0	0.1	0	0.5	8.6	21.1	16.5	98.7
8. Schefferville	15.9	14.8	14.3	12.4	9.7	2.5	0	0.7	8.2	14.3	21.4	17.9	132.1
9. Sept Iles	38.4	34.0	26.0	11.0	1.4	0	0	0	0	3.7	20.4	31.7	166.6
Newfoundland (Labrador)													
1. Battle Harbour	26.9	33.4	41.1	17.5	6.0	0.5	0	0	0	1.2	10.1	17.9	154.6
2. Cartwright	32.0	27.6	35.0	21.7	6.8	1.0	0	0	0.2	4.2	15.8	26.5	170.8
3. Churchill Falls	36.1	33.1	20.0	17.1	10.2	1.4	0	0	7.5	15.8	18.4	29.4	189.0
4. Goose Bay	28.0	22.8	27.8	17.1	6.9	0.7	0	0	1.0	9.8	20.7	26.3	161.1
5. Hopedale	23.0	17.5	20.0	15.2	8.8	2.1	0.2	0	1.1	8.3	16.2	20.5	132.9
6. Wabush	28.3	19.4	19.9	13.0	11.2	0.7	0	0	2.9	21.3	23.8	30.0	170.5

TABLE IIIe

MEDIAN (MIDDLE VALUE) DEPTH OF SNOW COVER (IN. AT END OF MONTH) (POTTER, 1965)

Quebec	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Border	23	30	37	27	7	T	0	0	1	2	6	12
Gagnon	23	29	32	17	0	0	0	0	0	2	9	18
Harrington Harbour	24	38	45	2	0	0	0	0	0	0	4	14
Nitchequon	32	36	40	21	1	0	0	0	0	1	13	18
Poste-de-la-Baleine (Great Whale River)	22	25	16	3	0	0	0	0	0	0	6	22
Schefferville	22	29	30	13	0	0	0	0	0	1	9	15
Sept Iles	41	56	37	2	0	0	0	0	0	0	7	18
Newfoundland (Labrador)												
Cartwright	27	39	47	28	0	0	0	0	0	0	4	12
Churchill Falls	48	56	55	29	2	0	0	0	T	3	14	27
Goose Bay	28	34	32	9	0	0	0	0	0	0	6	21
Hopedale	24	31	32	25	1	0	0	0	0	0	11	14

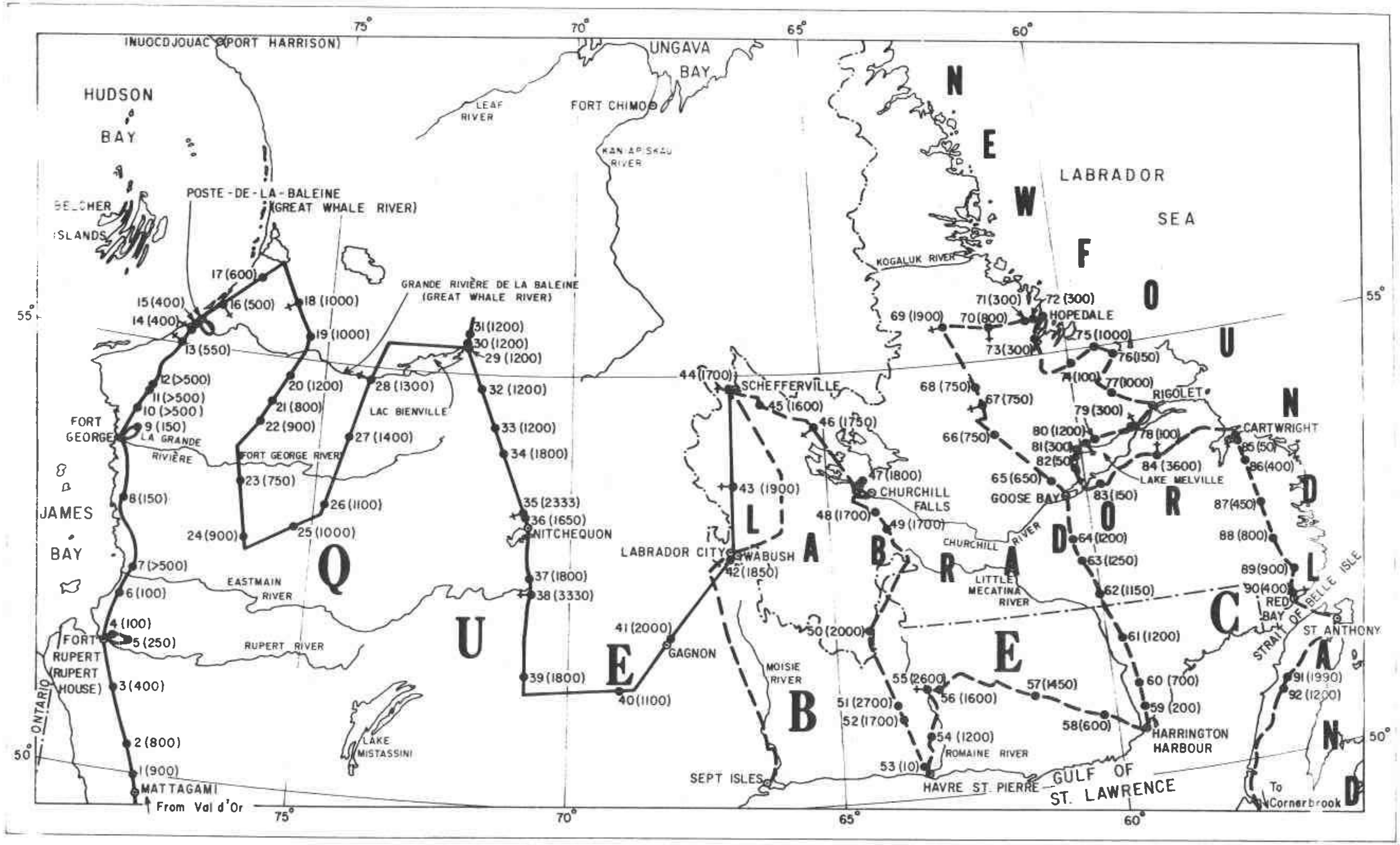


FIGURE 1 QUEBEC AND NEWFOUNDLAND (LABRADOR) SURVEY ROUTE

——— HELICOPTER SURVEY ROUTE FROM VAL D'OR, P.Q. TO SCHEFFERVILLE, P.Q. IN 1967.
— — — HELICOPTER SURVEY ROUTE FROM SEPT ISLES, P.Q. TO CORNERBROOK, NEWFOUNDLAND IN 1968.

● 27 PERMAFROST OBSERVATION STOP (TABLE I)
(1200) ELEVATION (FEET ABOVE SEA LEVEL)
← PERMAFROST ENCOUNTERED (TABLE I)

BR 5418-1

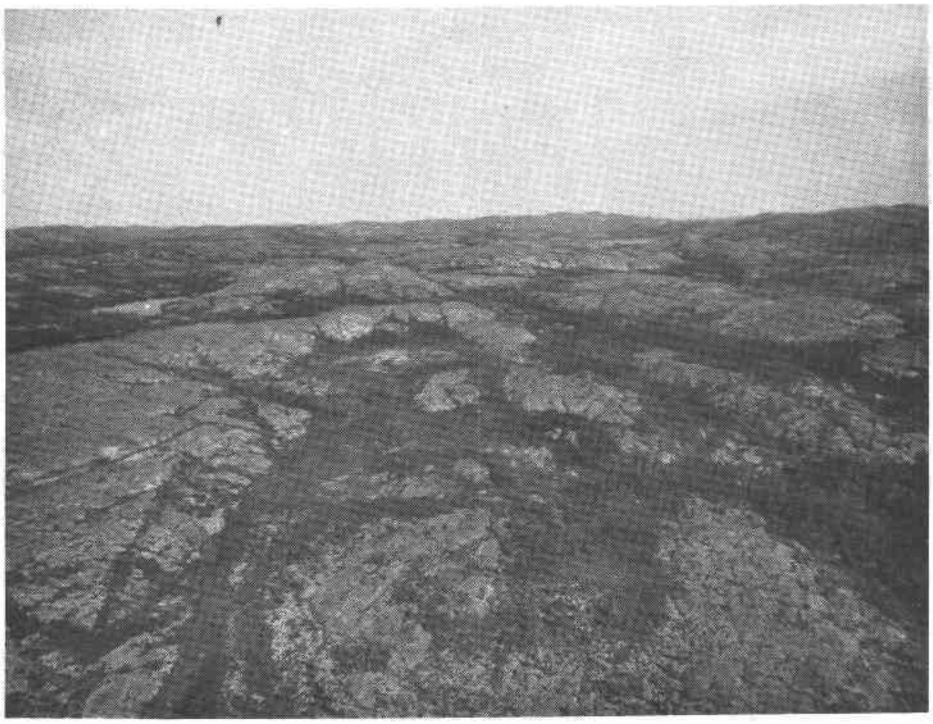


Figure 2

Aerial view from altitude of 500 ft of hilly Precambrian Shield terrain, 15 miles south of Hopedale (Labrador) between Stop No. 72, 73. Islands of permafrost occur in the peat covered depressions but probably not in the exposed bedrock. 5 September 1968.

Figure 3

Aerial view from altitude of 500 ft of recently burned undulating bouldery ground moraine about 50 miles south of Poste-de-la-Baleine (Great Whale River) between Stop No. 27, 28. 16 September 1967.

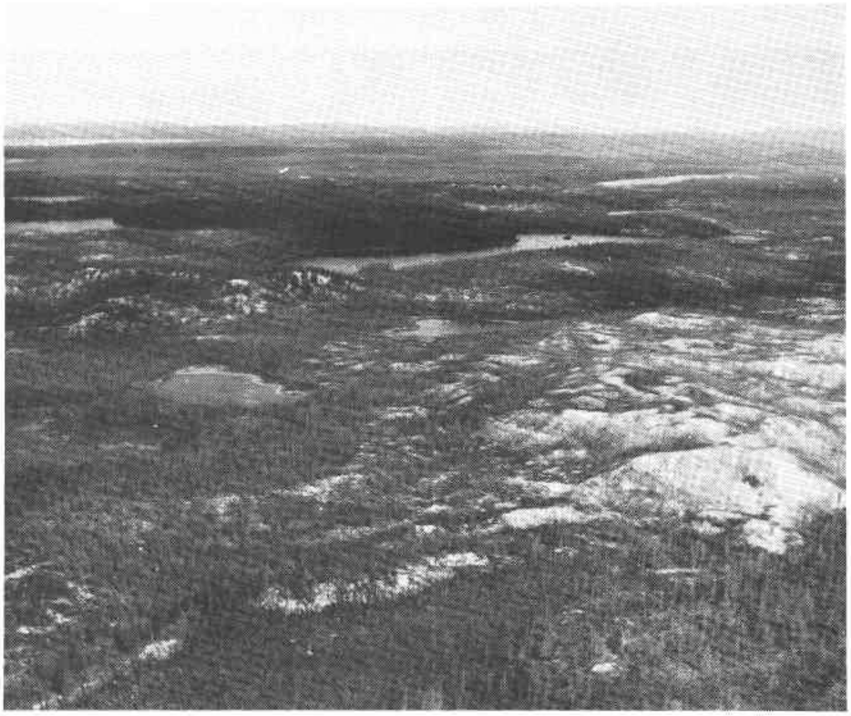


Figure 4

Aerial view from altitude of 600 ft of glaciofluvial ice contact features (kames, eskers, deltas) near La Grande Rivière (Fort George River) between Stop No. 26, 27. 16 September 1967.

Figure 5

Stop No. 64 - String bog 40 miles south of Goose Bay (Labrador). Ridge in foreground is 30 ft long, 4 ft wide and 2 ft high with ground cover of Sphagnum, lichen and Labrador tea below which is moist peat 5 ft 9 in. thick overlying grey clayey silt. Low wet area in background has ground cover of sedge overlying a peat and mineral soil profile similar to the ridge. No permafrost was encountered although the peat and mineral soil beneath the ridge were cold. 7 September 1968.

Figure 6

Stop No. 63 - Aerial view from altitude of 500 ft of string bog 60 miles south of Goose Bay (Labrador). Forested areas consist of spruce up to 25 ft high, 5 - 10 ft apart, on low peat plateaux with ground cover of hummocky Sphagnum, scattered lichen and Labrador tea below which is dry peat 5 - 6 ft thick overlying sand. No permafrost was encountered at this location. 7 September 1968.

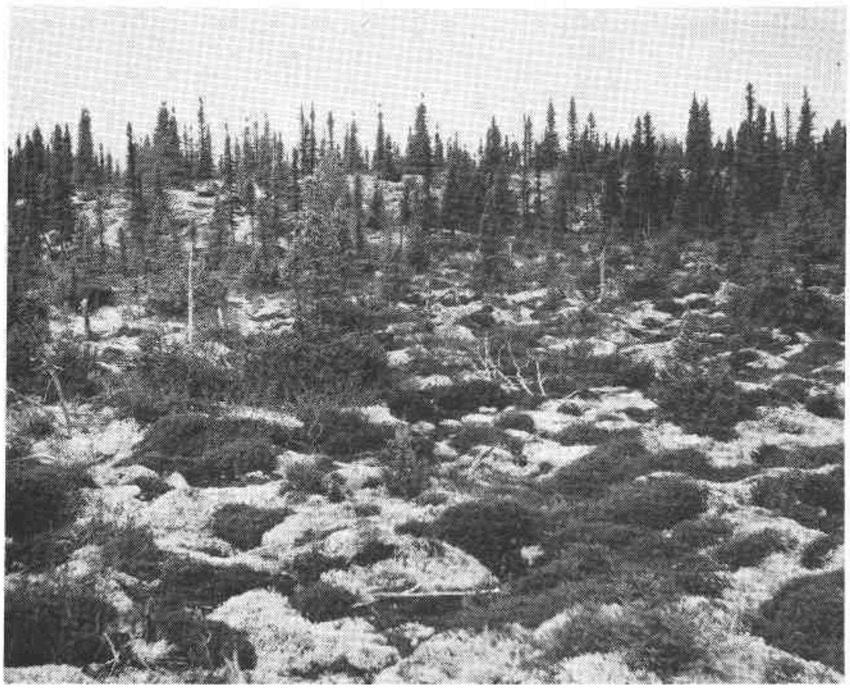


Figure 7

Stop No. 12 - Scattered spruce up to 20 ft high with ground cover of hummocky Sphagnum, lichen (one-half coverage) and Labrador tea below which is peat 4 - 7 ft thick overlying sandy gravel located 50 miles north of Fort George, P.Q. No permafrost was encountered at this location. 5 September 1967.

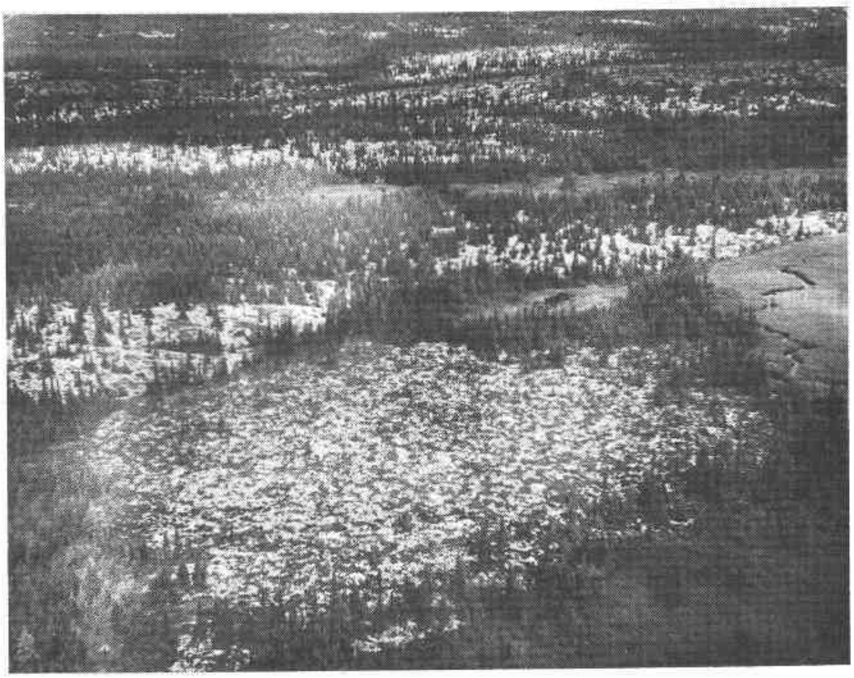


Figure 8

Aerial view from altitude of 500 ft of terrain at Stop No. 12 - enclosed spruce-lichen bog about 300 ft in diameter in lower half of photograph.

Figure 9

Stop No. 89 - Peat bog 25 miles north of Strait of Belle Isle in Labrador. Tree growth is very sparse consisting of scattered spruce up to 5 ft high with ground cover of hummocky Sphagnum, mosses, lichen and Labrador tea below which is peat 6 ft thick overlying stony sandy soil. No permafrost was encountered in the raised peat bog or the depression in the centre which appears to be a collapse scar. 3 September 1968.

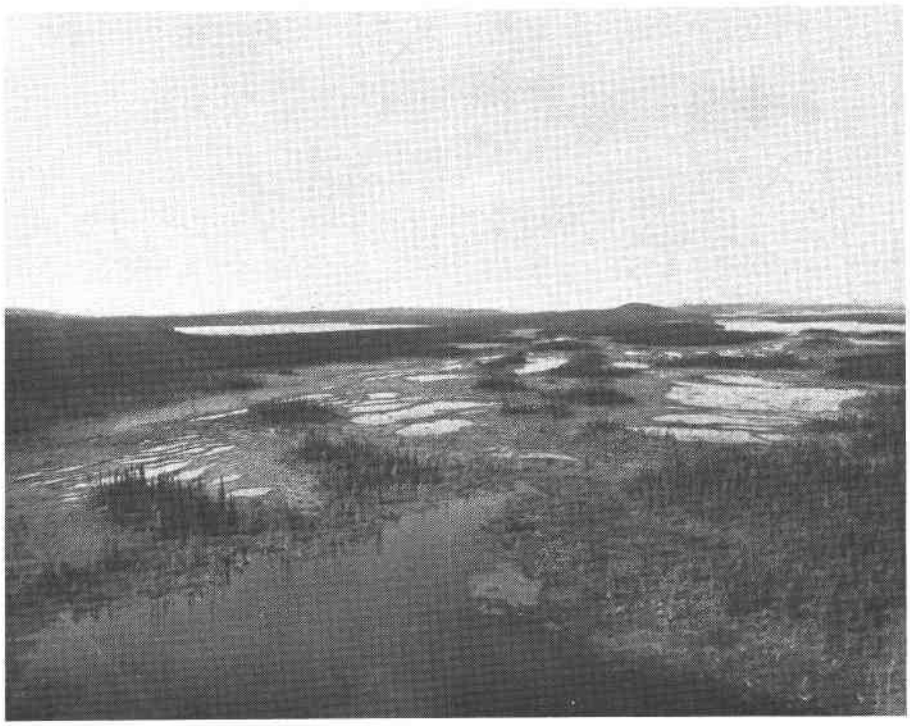


Figure 10

Aerial view from altitude of 500 ft of string bogs near Wabush (Labrador). There is probably no permafrost in the bog ridges but it may occur in the spruce islands. 15 September 1968.

Figure 11

Stop No. 53 - Flat treeless peat bog with ground cover of moss and lichen below which is peat 7 ft thick overlying fairly dry sand located about 5 miles north of Gulf of St. Lawrence at Havre St. Pierre, P.Q. No permafrost was encountered at this location. 10 September 1968.

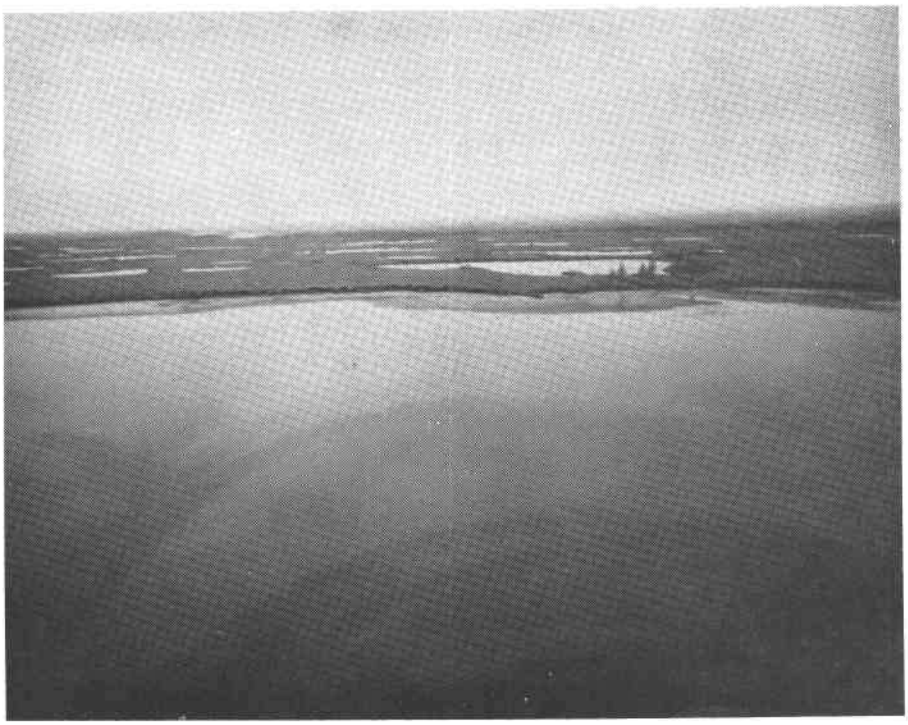


Figure 12

Aerial view from altitude of 500 ft of terrain at Stop No. 53 on peat covered coastal plain.

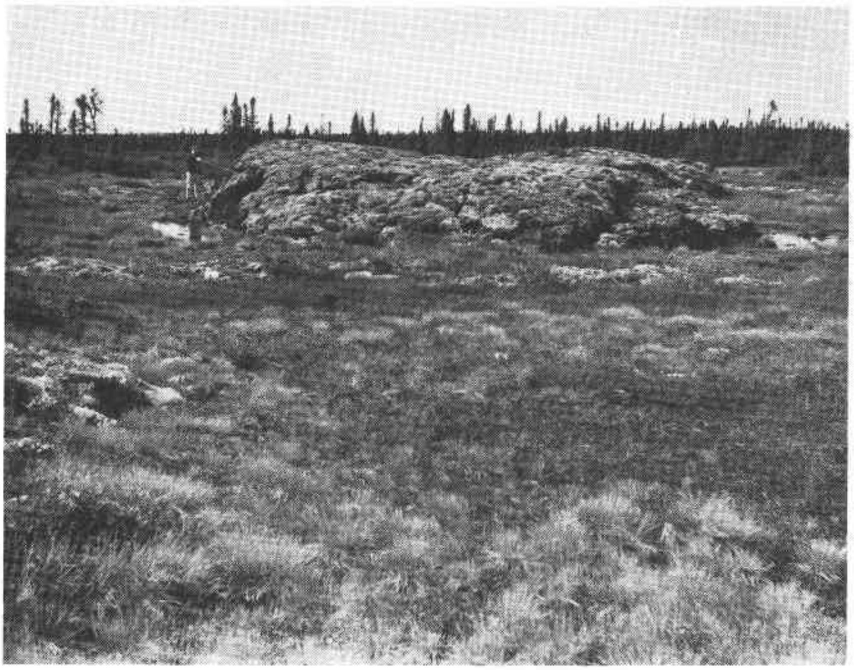


Figure 13

Stop No. 13 - Palsa located 25 miles south of Poste-de-la-Baleine (Great Whale River), P.Q. It is 50 ft long by 30 ft wide by 8 ft high with ground cover of hummocky Sphagnum and lichen below which is peat 3 ft thick overlying silty fine sand. The permafrost table is 1 ft 9 in. below the ground surface and the permafrost is probably about 20 ft thick. Permafrost a few inches to 2 ft thick was also encountered in small hummocky Sphagnum lichen areas (incipient peat plateaux) near palsa. No permafrost occurs in the sedge covered depression around the palsa. 12 September 1967.

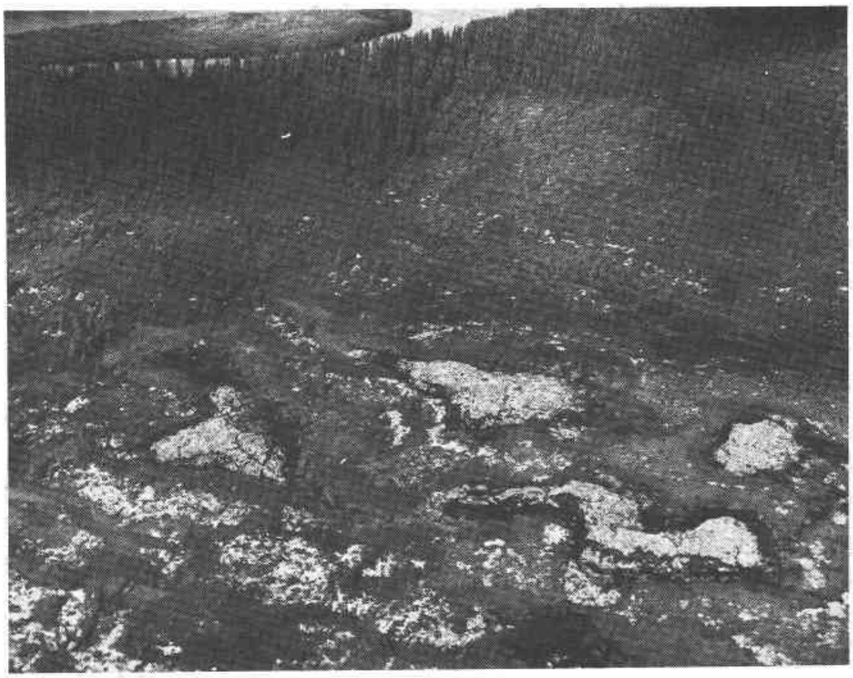


Figure 14

Aerial view from altitude of 500 ft of lichen covered palsas at Stop No. 13 in lower half of photograph.

Figure 15

Stop No. 78 - Palsas and peat plateaux 6 ft high on Neveisik Island in Lake Melville (Labrador) with ground cover of hummocky Sphagnum, lichen and Labrador tea below which is peat 2 - 4 ft thick overlying silty clay. The permafrost table is about 2 ft below the ground surface and the permafrost extends into the mineral soil. The permafrost wedges out at the edges of the palsas. No permafrost occurs in the depressions between palsas. 4 September 1968.

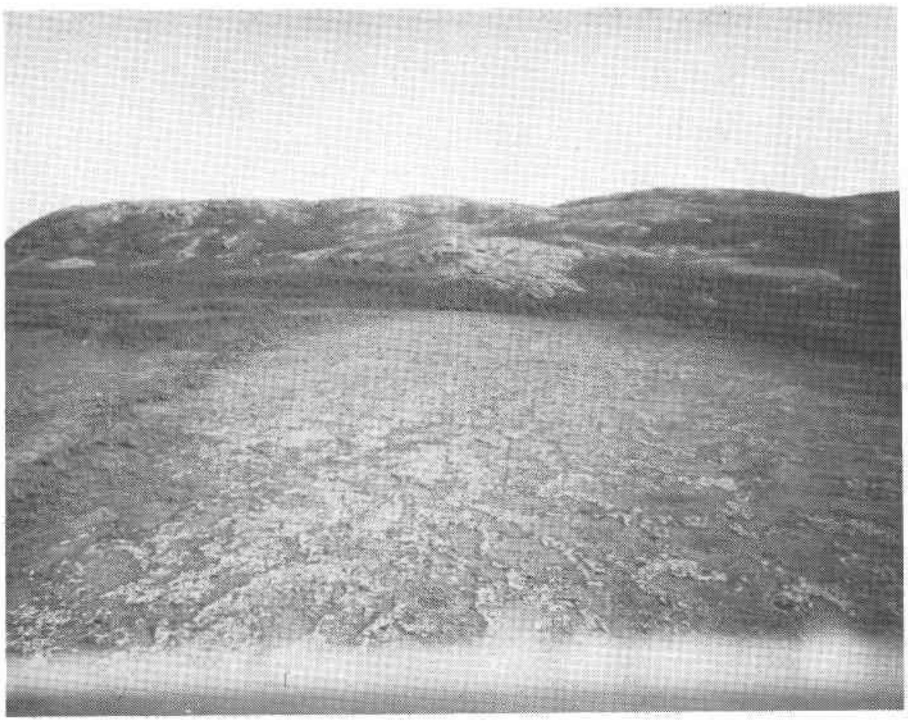


Figure 16

Aerial view from altitude of 500 ft of palsas and peat plateaux at Stop No. 78. See air photo stereo pair in Figure 49.

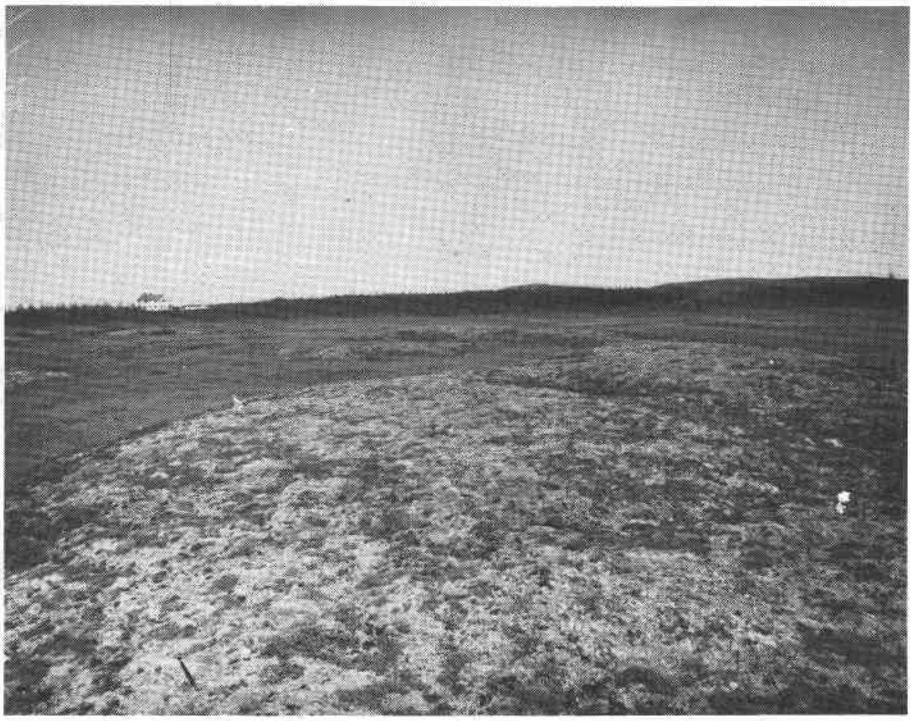


Figure 17

Stop No. 85 - Palsas and peat plateaux 5 ft high at Cartwright (Labrador) with ground cover of hummocky Sphagnum and lichen below which is peat 4 ft thick overlying sandy soil. The permafrost table is 1 ft 6 in. below the ground surface and the permafrost extends into the mineral soil. No permafrost occurs in the depressions between palsas. 3 September 1968.

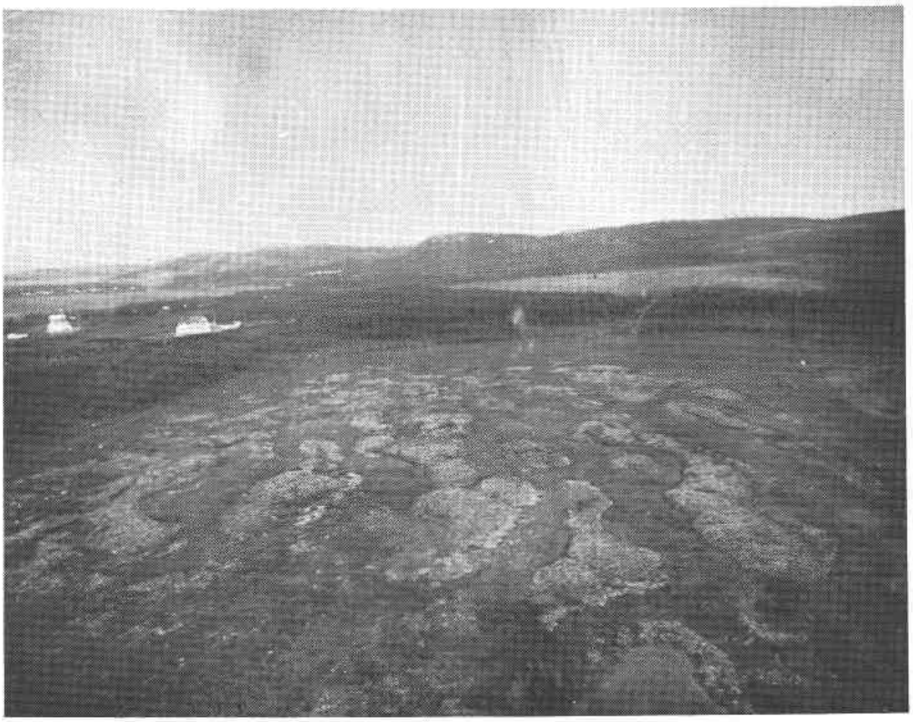


Figure 18

Aerial view from altitude of 500 ft of palsas and peat plateaux at Stop No. 85. See air photo stereo pair in Figure 48.

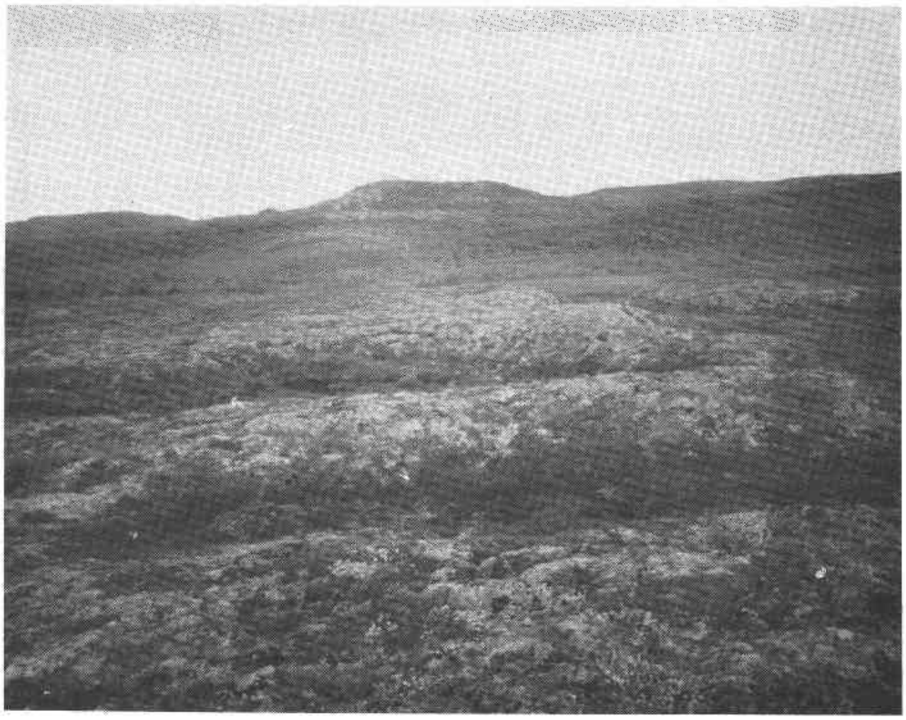


Figure 19

Stop No. 90 - Palsas and peat plateaux 4 ft high located 5 miles north of Red Bay (Labrador) with ground cover of Sphagnum, lichen and Labrador tea below which is peat 6 ft thick overlying stony sand. The permafrost table is 1 ft 7 in. below the ground surface and permafrost extends into the mineral soil. No permafrost occurs in the depressions between palsas. 3 September 1968.

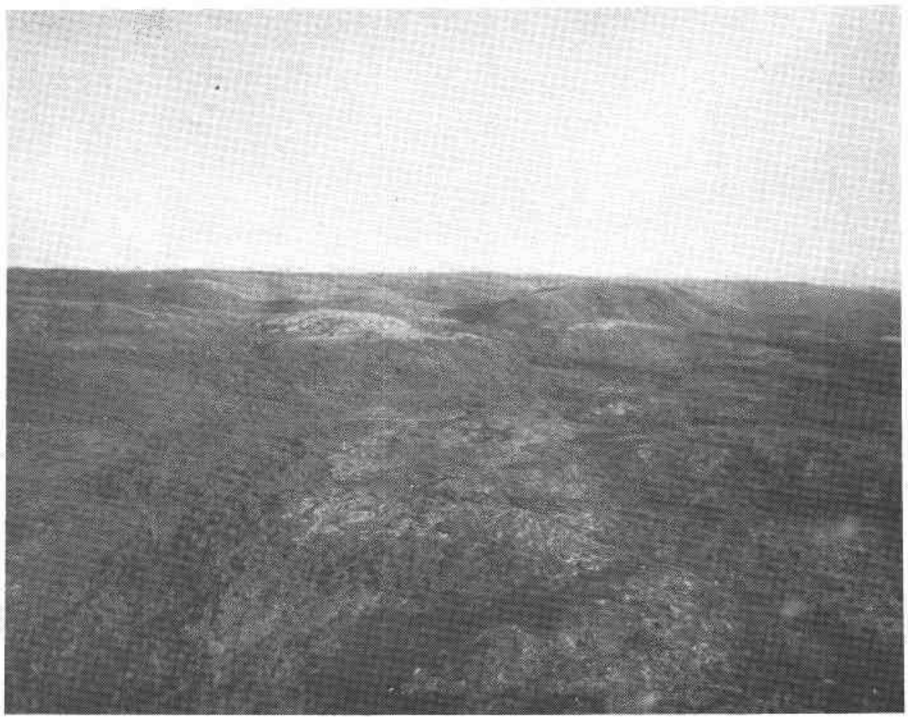


Figure 20

Aerial view from altitude of 300 ft of palsas at Stop No. 90.

Figure 21

Aerial view from altitude of 800 ft of palsas between Stop No. 16 and 17 (Poste-de-la-Baleine (Great Whale River), P.Q. and Richmond Gulf) in Precambrian rock basin.

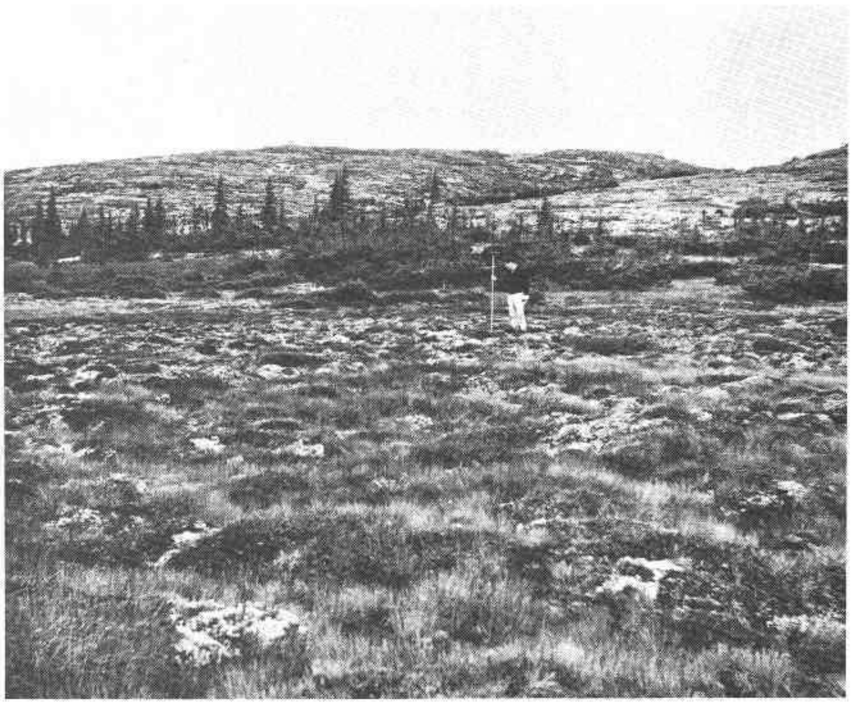


Figure 22

Stop No. 16 - Small peat plateaux and incipient palsas 1 - 2 ft high located between Poste-de-la-Baleine (Great Whale River), P.Q. and Richmond Gulf with ground cover of hummocky Sphagnum, lichen and Labrador tea below which is peat 2 ft thick overlying a mixture of sand and boulders. The permafrost table is 1 ft 6 in. below the ground surface and the permafrost extends into the mineral soil. Patches of permafrost occur also beneath the intervening moss and sedge covered areas, the permafrost table being at the 1 ft 6 in. depth. 13 September 1967.

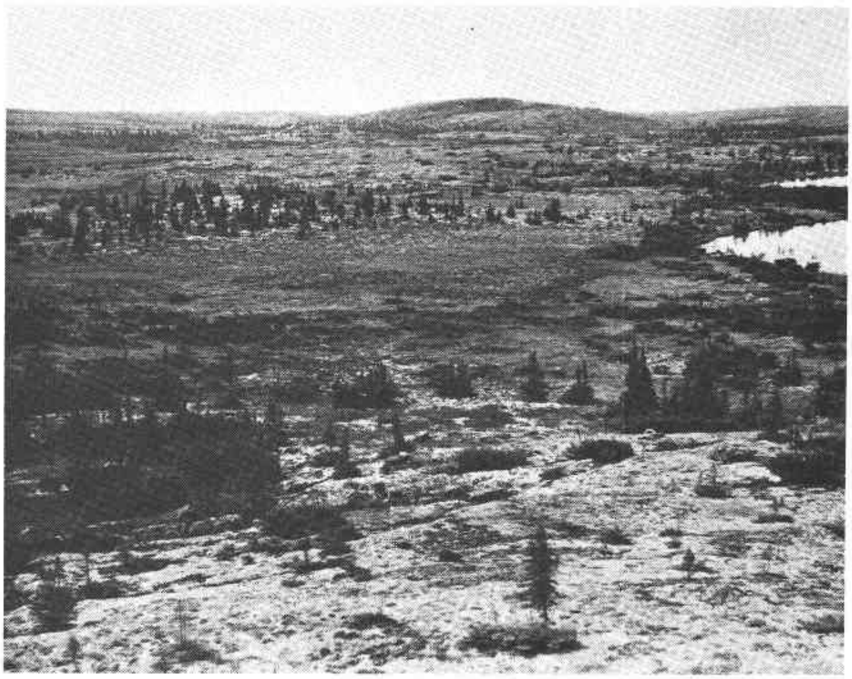


Figure 23

View from 500 ft high Precambrian rock hill of terrain at Stop No. 16.

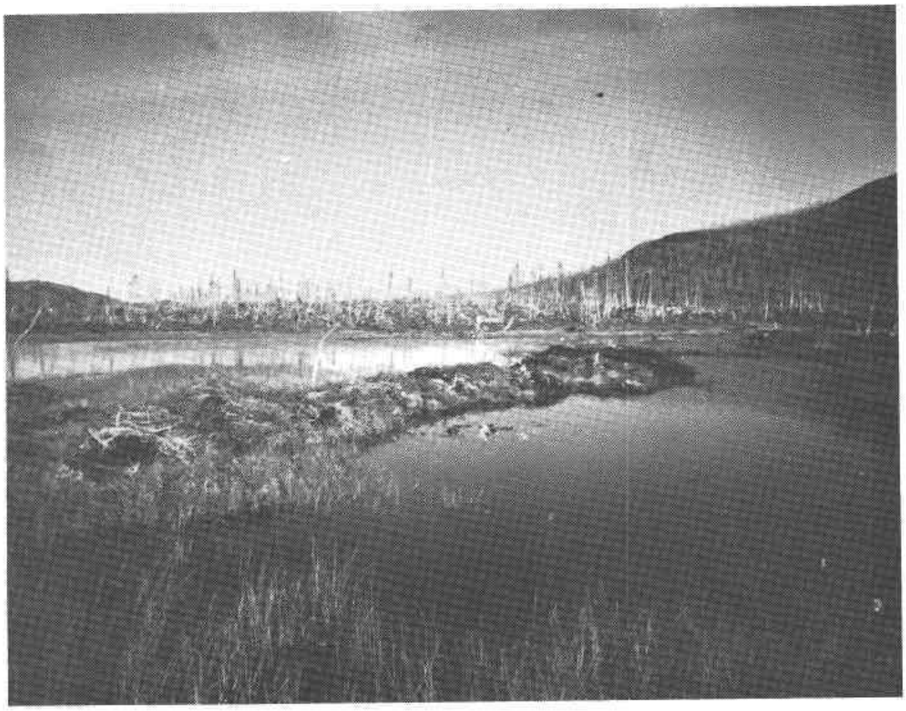


Figure 24

Stop No. 70 - Palsa 3 ft high in lake located 50 miles west of Hopedale (Labrador) with lichen patches and predominantly bare peat which is 4 ft thick overlying grey medium sand. The permafrost table is 1 ft 6 in. below the ground surface and the permafrost extends into the mineral soil. 5 September 1968.

Figure 25

Aerial view from altitude of 300 ft of palsa and adjacent peat plateaux at Stop No. 70 in small lake in centre of photograph.

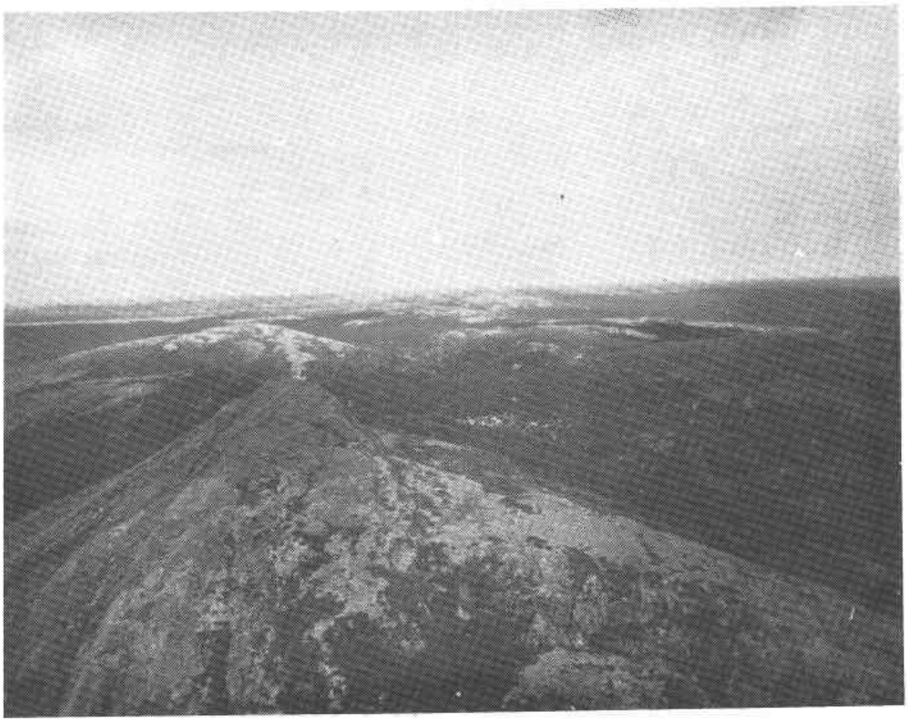


Figure 26

Aerial view of summit of Mount Wright (3,009 ft above sea level) located 25 miles southwest of Wabush (Labrador). A few small palsas occur in a small bog near the summit. 15 September 1968.

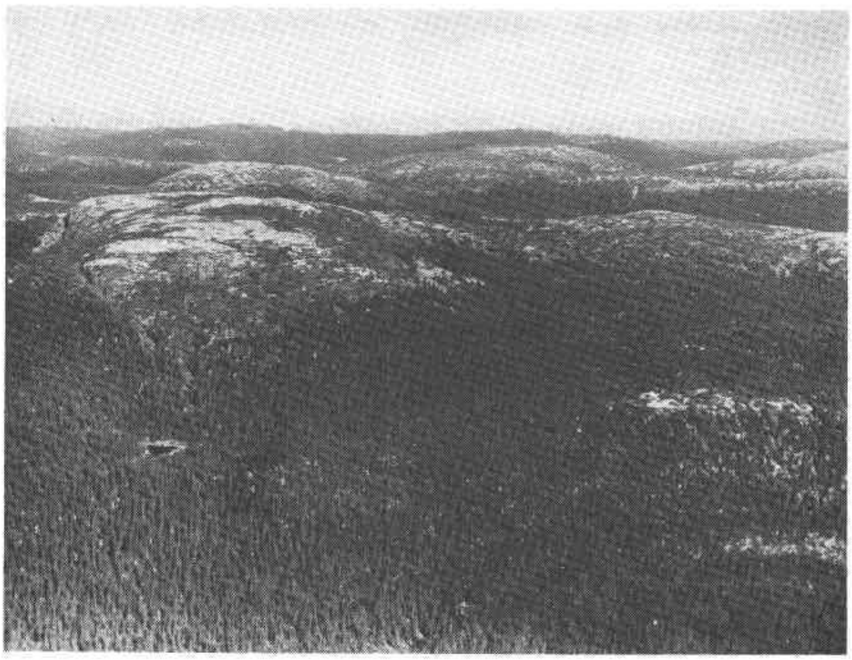


Figure 27

Aerial view of mountain summits between Stop No. 39 and 40, about 100 miles southwest of Gagnon, P.Q. The summits are about 2,500 ft above sea level. Permafrost probably exists in the areas above treeline. 19 September 1967.

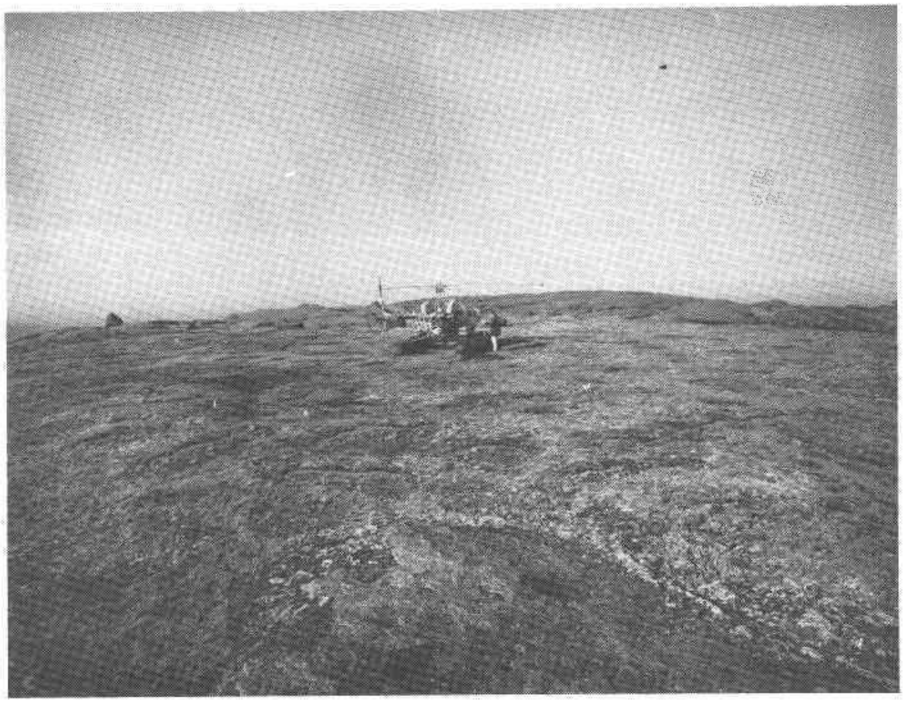


Figure 28

Stop No. 84 - Summit of Mealy Mountains at an elevation of 3,600 ft above sea level located between Cartwright and Goose Bay in eastern Labrador. The ground surface is covered with non-sorted circles (stony earth circles). The intervening areas are covered with moss, lichen, grass and sedge with 3 in. of organic matter. The soil in the non-sorted circles and beneath the vegetative cover is sandy gravel with silt and clay. Permafrost probably exists here although the depth to the permafrost table was not determined. 3 September 1968.

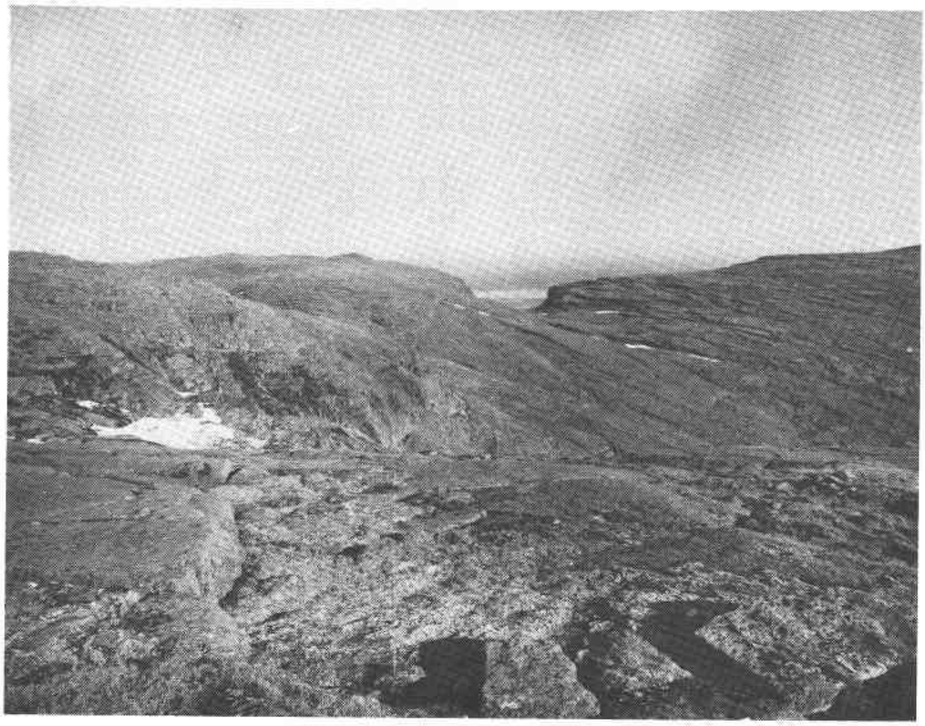


Figure 29

Aerial view of summit of Mealy Mountains in vicinity of Stop No. 84.

Figure 30

Stop No. 38 - Summit of Otish Mountains at an elevation of 3,300 ft above sea level located about 50 miles north of Nitchequon, P.Q. There are many non-sorted circles (stony earth circles) on the ground surface. A small bog adjacent to the small lake has a ground cover of hummocky moss and lichen below which is peat 3 ft thick overlying Precambrian bedrock. The depth to the permafrost table is 1 ft 6 in. and the permafrost extends downward to the rock surface and probably lower. 19 September 1967.

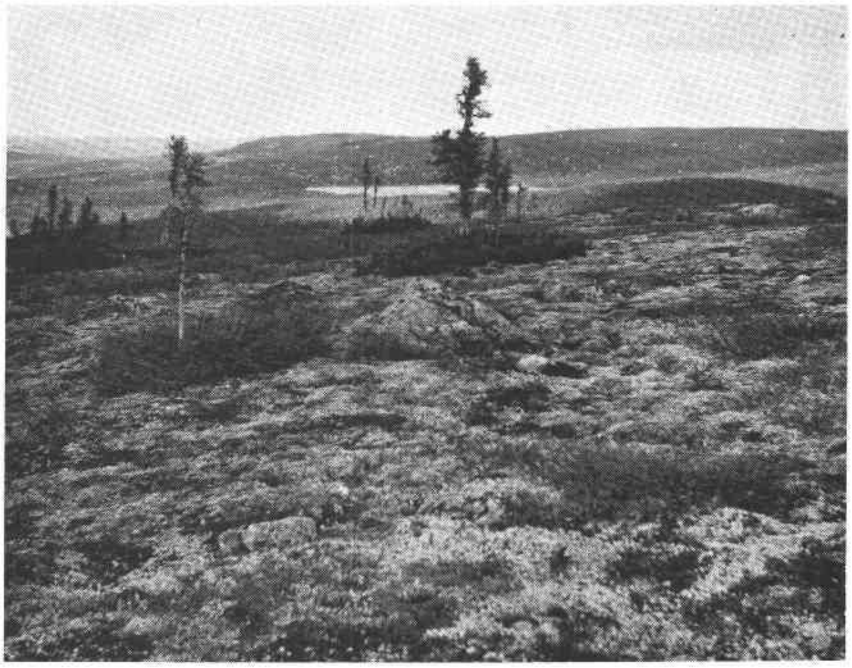


Figure 31

Stop No. 34 - Mountain summit at an elevation of 1,800 ft above sea level located 70 miles northwest of Nitchequon, P.Q. The vegetation consists of a few spruce and tamarack trees up to 10 ft high with ground cover of lichen 2 in. thick overlying wet sandy gravel. A few non-sorted circles (stony earth circles) and scattered boulders up to 5 ft in diameter occur on the ground surface. Permafrost probably exists here although the depth to the permafrost table was not determined. 18 September 1967.

Figure 32

Stop No. 35 - Aerial view of mountain summit at an elevation of 2,333 ft above sea level located about 20 miles north of Nitchequon, P.Q. Boulders up to 5 ft in diameter and blowouts exposing gravelly sand are scattered over the surface. The patchy ground vegetation consists of moss, lichen, grass and sedge a few inches thick overlying gravelly sand. In a few of the shallow blowouts there is peat 2 ft thick. The depth to the permafrost table is 1 ft 6 in. and the permafrost extends into the underlying mineral soil. 18 September 1967.

Figure 33

Aerial view of Timmins 4 orebody at an elevation of about 2,300 ft above sea level located 20 miles north of Schefferville, P.Q. Non-sorted circles (stony earth circles) cover the ground surface. The depth to the permafrost table varies from 10 - 13 ft and the permafrost extends to maximum depths of 300 - 400 ft. 21 September 1967.

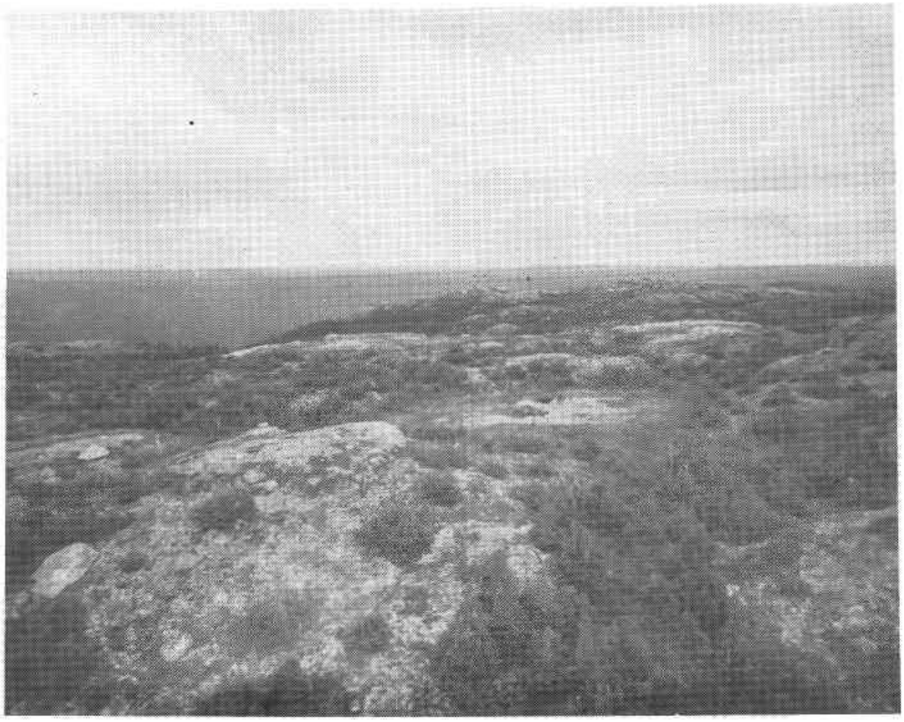


Figure 34

Stop No. 55 - Aerial view of small bog with 2 ft high palsa in centre of photograph in small rock basin on mountain summit at an elevation of 2,600 ft above sea level located 70 miles north of Havre St. Pierre, P.Q. The vegetation on the palsa is lichen and Labrador tea below which is peat exceeding 1 ft 6 in. thickness. The depth to the permafrost table is 1 ft 6 in. 7 September 1968.

Figure 35

Stop No. 80 - Peat bog near mountain summit at an elevation of 1,200 ft above sea level located 40 miles northeast of Goose Bay (Labrador). The vegetation consists of scattered 1 ft high peat plateaux (incipient palsas) with vegetation cover of Sphagnum and other mosses, lichen interspersed with wet areas of grass, sedge and mosses below which is peat 5 ft thick overlying bedrock. The depth to the permafrost table in the peat plateaux is 1 ft 2 in. and the permafrost extends downward to the bedrock and probably lower. 4 September 1968.

Figure 36

Aerial view from altitude of 400 ft of peat bog at Stop No. 80.

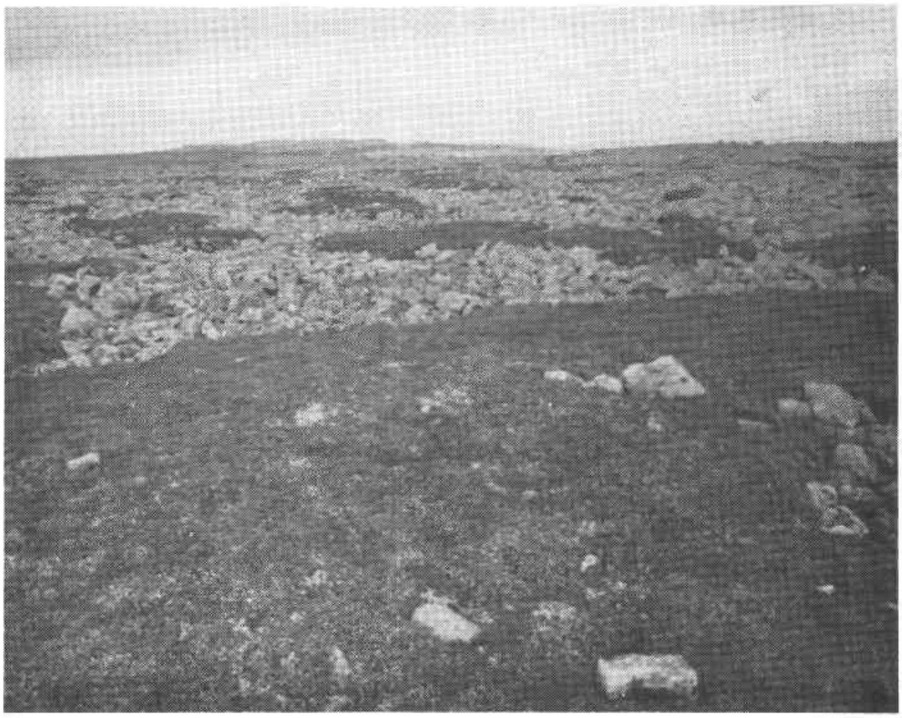


Figure 37

Stop No. 91 - Stone nets about 20 ft in diameter at an elevation of 1,990 ft in the Long Range Mountains located 75 miles southwest of St. Anthony, Nfld. The vegetation consists of moss, grass and sedge overlying 8 in. of organic material below which are rock fragments. Permafrost probably does not exist at this site. 1 September 1968.

Figure 38

Stop No. 47 - Stone nets about 10 ft in diameter at edge of small lake near Churchill Falls (Labrador). The soil is a mixture of silt, clay and gravel. Permafrost probably does not exist at this site because of its close proximity to the lake. 14 September 1968.

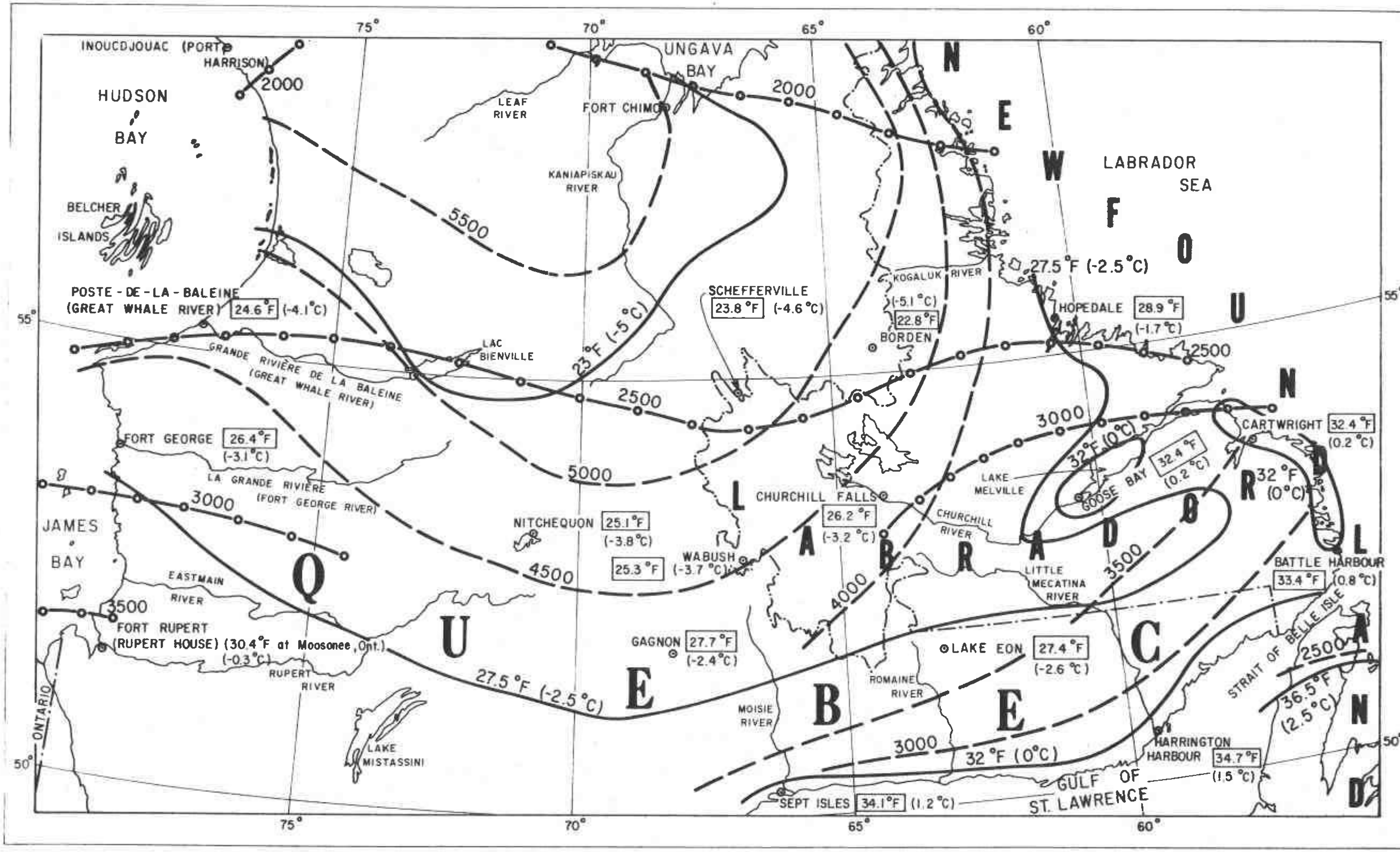


FIGURE 39

QUEBEC AND NEWFOUNDLAND (LABRADOR) CLIMATE

— — FREEZING INDEX (DEGREE DAYS, °F)
o—o THAWING INDEX (DEGREE DAYS, °F)

—— MEAN ANNUAL ISOTHERM
28.9°F (-1.7°C) MEAN ANNUAL AIR TEMPERATURE OF STATION

Meteorological Information From H. A. Thompson, 1963 And Canadian Meteorological Records 1941-1970

BP 54 9-2

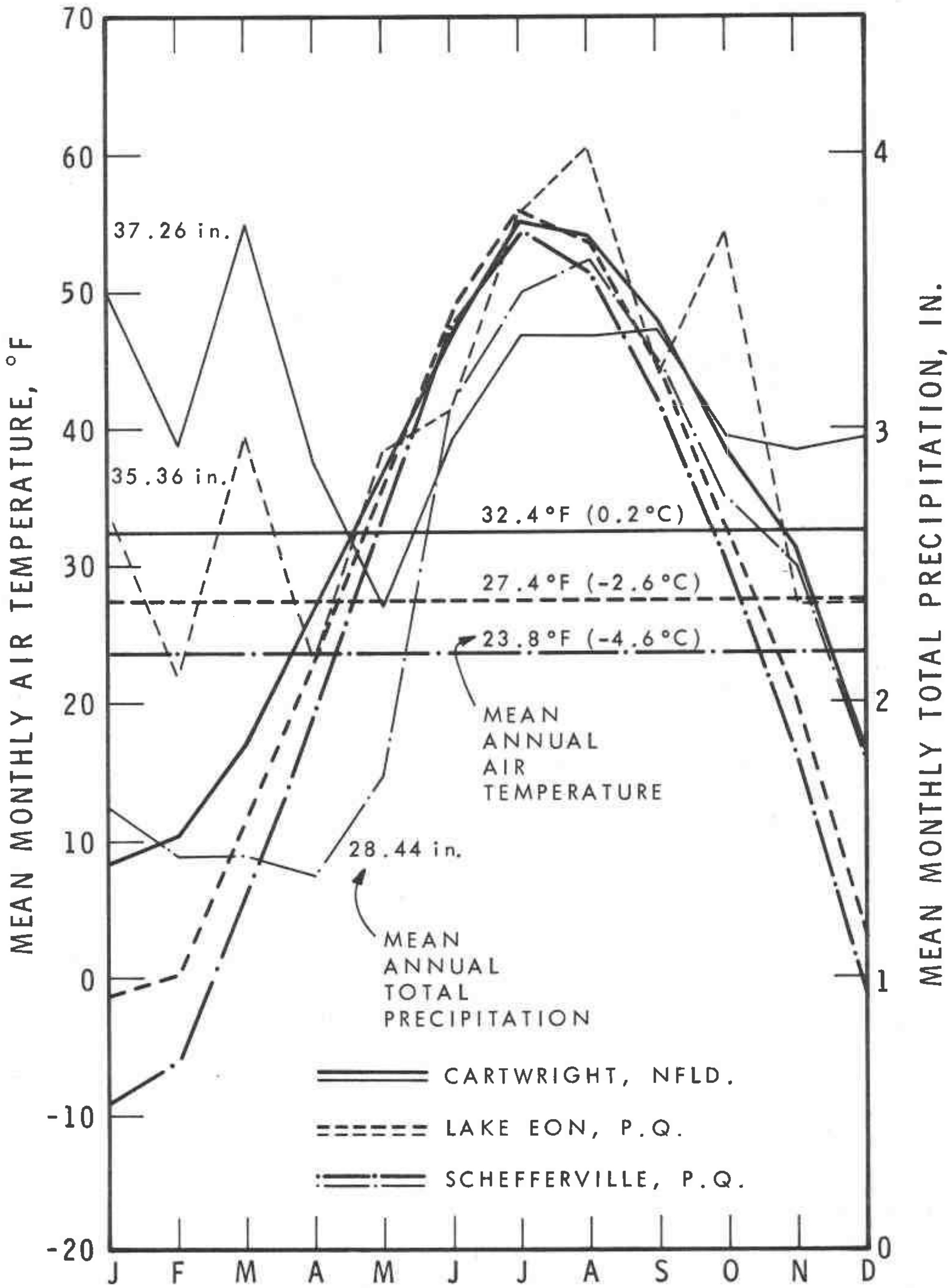


FIGURE 40

MEAN MONTHLY AIR TEMPERATURE AND MEAN MONTHLY PRECIPITATION FOR CARTWRIGHT, NFLD., LAKE EON, P.Q. AND SCHEFFERVILLE, P.Q.

BR 5418-3

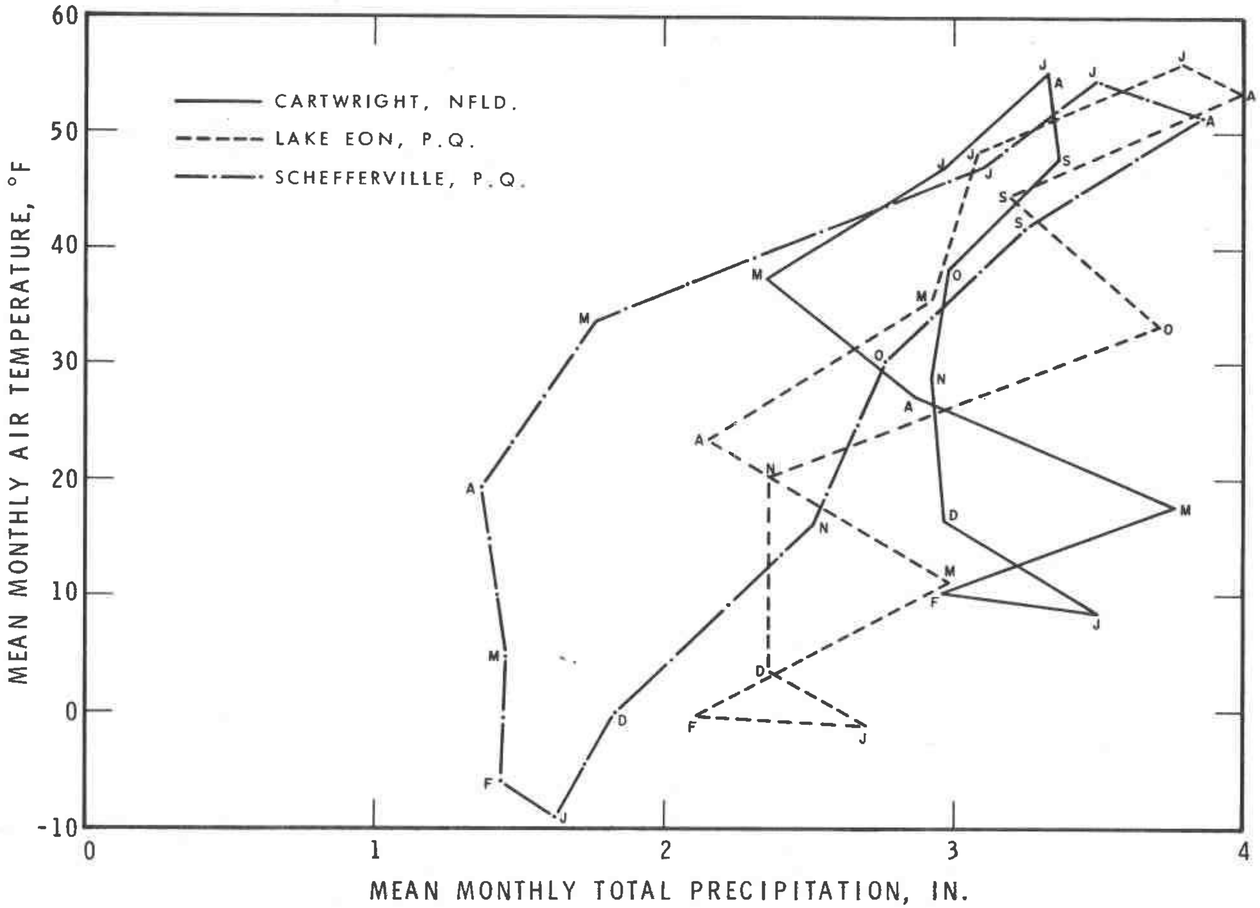
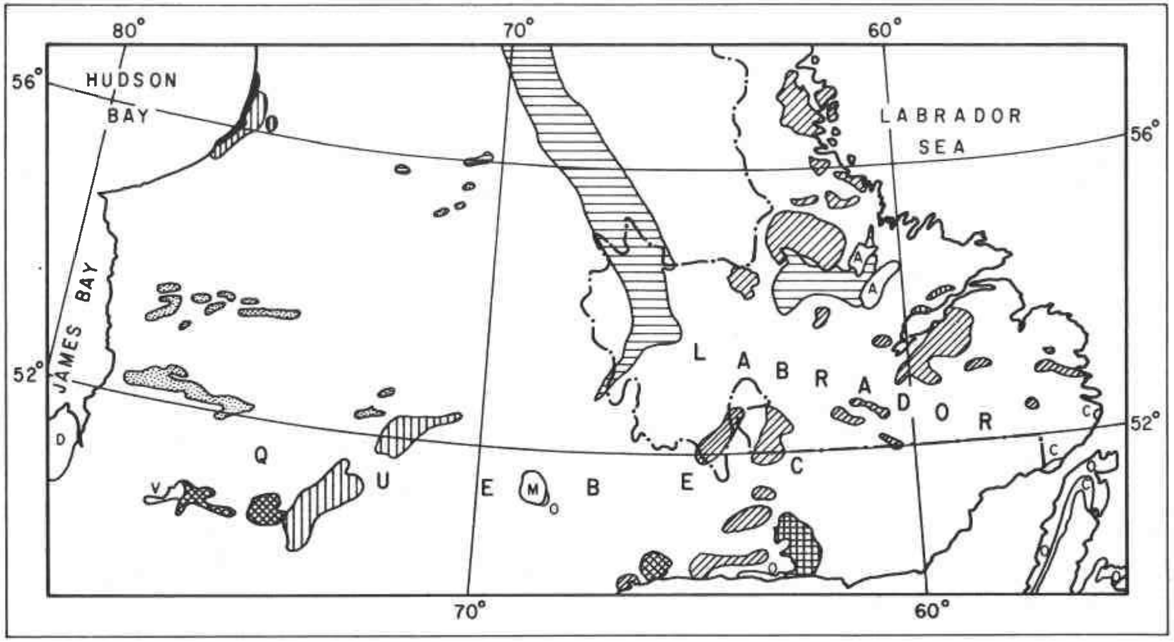


FIGURE 41
HYTHERGRAPHS FOR CARTWRIGHT, NFLD., LAKE EON, P.Q. AND SCHEFFERVILLE, P.Q.

BR 5418-4



100 0 100
MILES

FIGURE 42 QUEBEC AND NEWFOUNDLAND (LABRADOR)
BEDROCK GEOLOGY

(After Geological Map of Canada, 1962)

PRECAMBRIAN INTRUSIVE ROCKS

- PRECAMBRIAN (UNDIVIDED)
- ARCHAEAN AND/OR PROTEROZOIC (BASIC)
- PROTEROZOIC (BASIC)
- A PROTEROZOIC (ACID)

SEDIMENTARY AND VOLCANIC ROCKS

- ARCHAEAN (UNDIVIDED)
- V ARCHAEAN (VOLC.)
- ARCHAEAN (SED.)
- PROTEROZOIC (SED. & VOLC.)
- LATE PROTEROZOIC (SED. & VOLC.)
- EARLY PROTEROZOIC (SED. & VOLC.)
- C CAMBRIAN (SED.)
- O ORDOVICIAN (SED.)
- D DEVONIAN (SED. & VOLC.)
- M MESOZOIC (SED. & VOLC.)

BR 5418-5

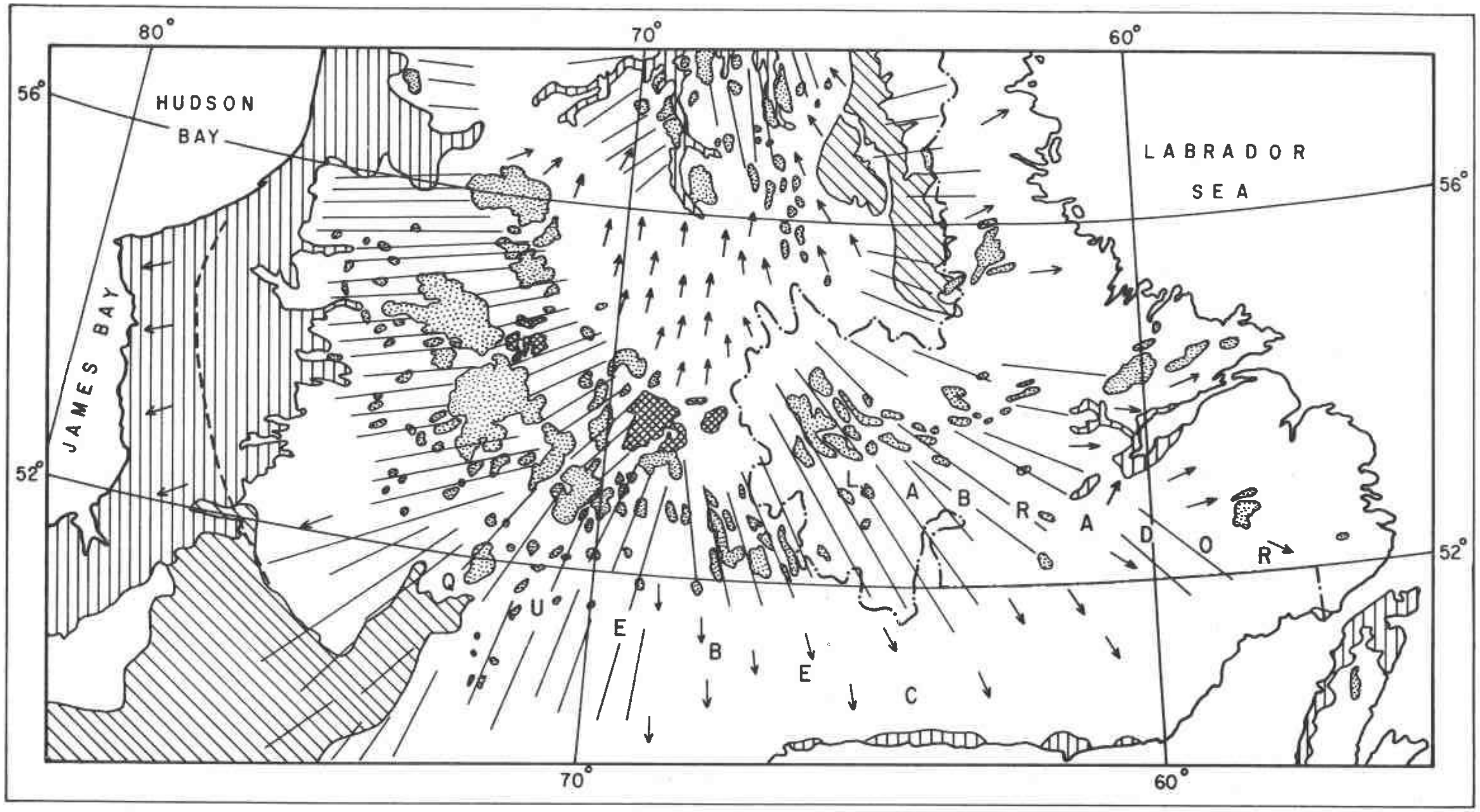


FIGURE 43

QUEBEC AND NEWFOUNDLAND (LABRADOR)

GLACIAL GEOLOGY

(After V.K. Prest et al, Glacial Map of Canada, 1967)

MAINLY GROUND MORAINE

TRACE OF END MORAINE

ICE FLOW DIRECTION

MAXIMUM MARINE OVERLAP

ESKER, KAME, KAME-COMPLEX

RIBBED MORAINE-MAINLY TRANSVERSE TO ICE FLOW DIRECTION

HUMMOCKY TERRAIN-DEAD ICE AND DISINTEGRATION MORAINE

MAXIMUM GLACIAL LAKE COVERAGE

N.B. FOR MORE DETAIL REFER TO GLACIAL MAP OF CANADA, 1967

BR 5418-6

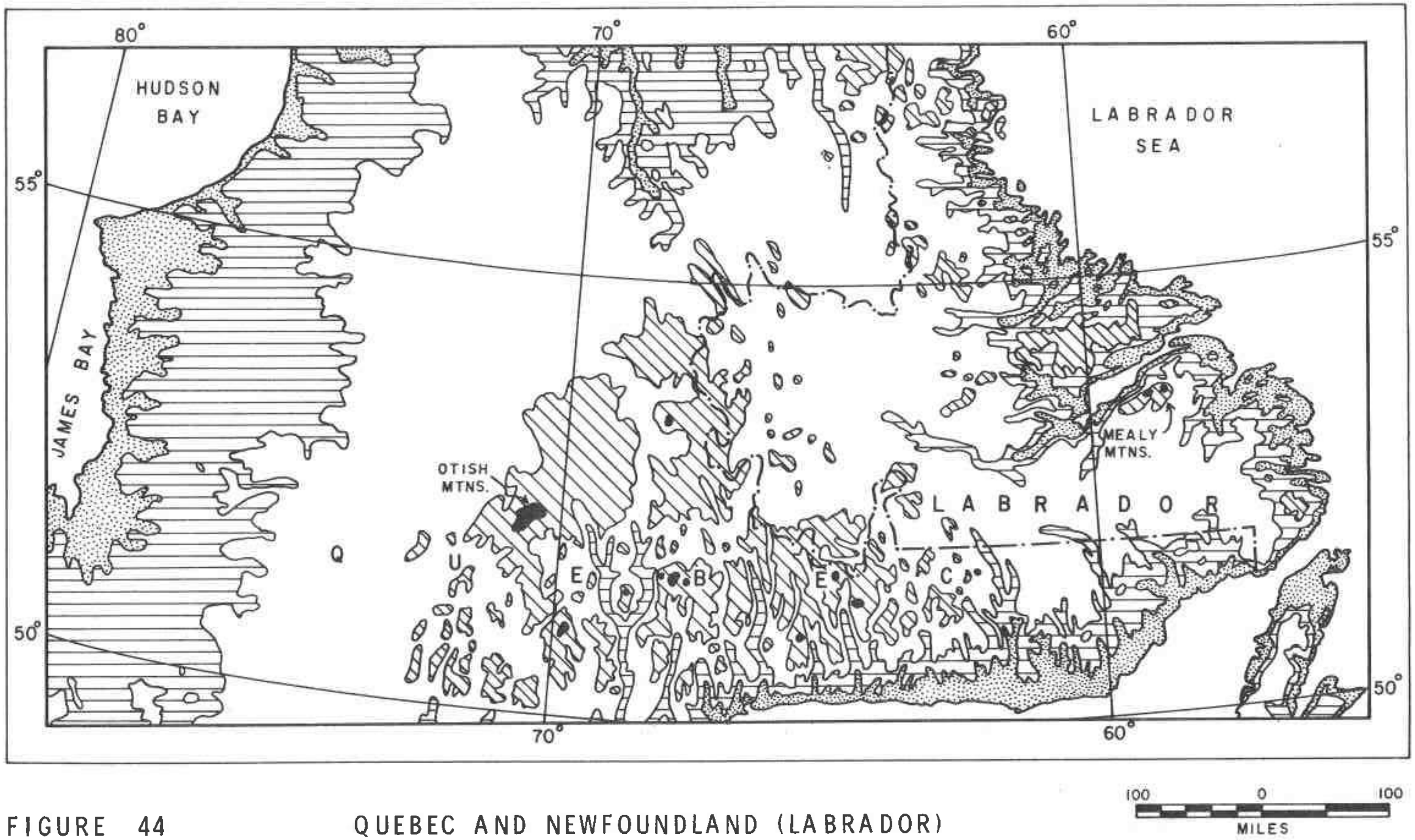
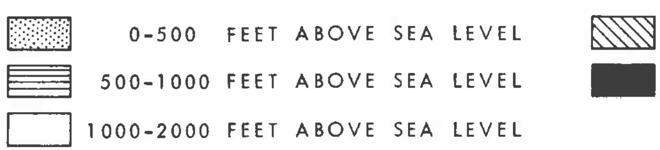


FIGURE 44 QUEBEC AND NEWFOUNDLAND (LABRADOR)

OROGRAPHY

(After Atlas of Canada, 1957)



0-500 FEET ABOVE SEA LEVEL

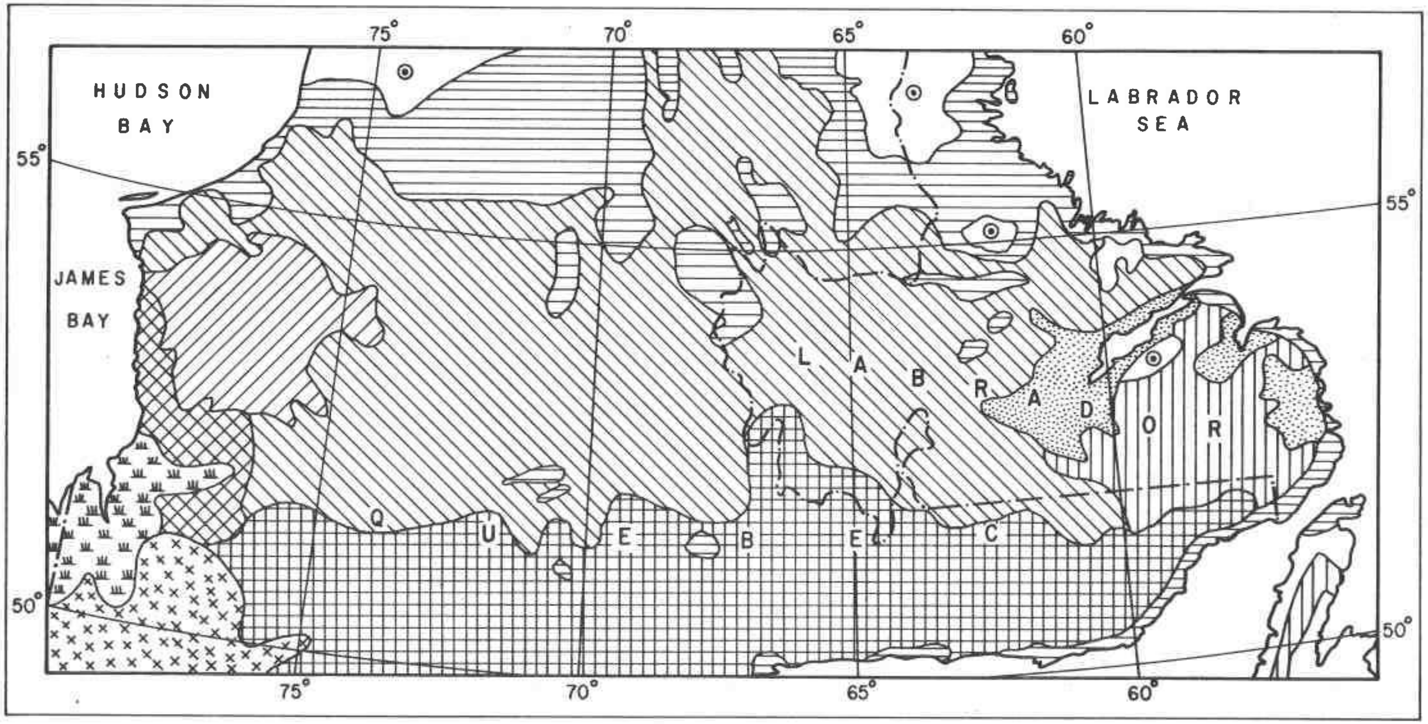
500-1000 FEET ABOVE SEA LEVEL

1000-2000 FEET ABOVE SEA LEVEL

2000-3000 FEET ABOVE SEA LEVEL

3000-4000 FEET ABOVE SEA LEVEL

BR 5418-7



100 0 100
MILES

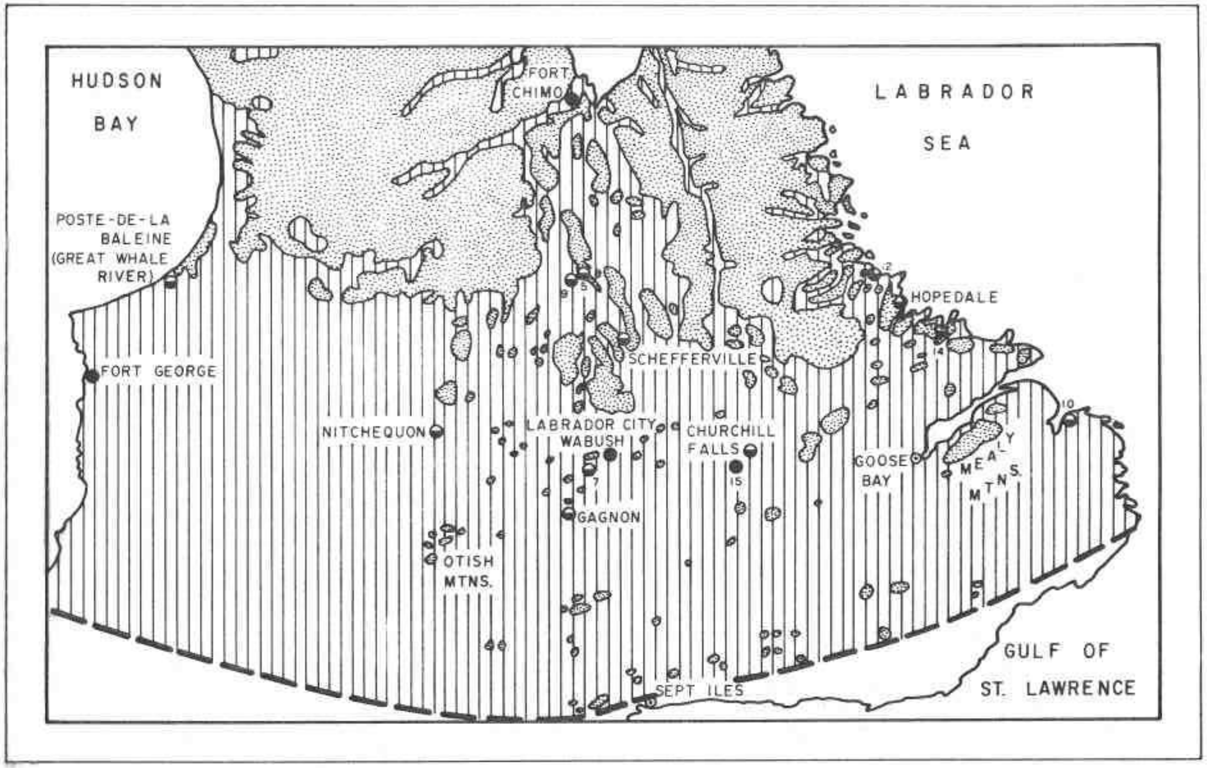
FIGURE 45

QUEBEC AND NEWFOUNDLAND (LABRADOR)
FOREST CLASSIFICATION

(After F.K. Rowe, 1959; J.S. Rowe, 1959; and J.S. Rowe, 1972)

- CHIBOUGAMAU-NATASHQUON SECTION
- NORTHERN CLAY SECTION
- HUDSON BAY LOWLANDS SECTION
- EAST JAMES BAY SECTION
- CHURCHILL AND EAGLE VALLEYS SECTION
- NORTHEASTERN TRANSITION SECTION
- FORT GEORGE SECTION
- NEWFOUNDLAND-LABRADOR BARRENS SECTION
- FOREST-TUNDRA SECTION
- TUNDRA

BR 5418-8



100 0 100
MILES

FIGURE 46 QUEBEC AND NEWFOUNDLAND (LABRADOR)
PERMAFROST DISTRIBUTION

(After Brown, 1967; Brown, in press; Ives, 1962)

PREDICTED OCCURRENCE OF CONTEMPORARY PERMAFROST FORMED AND MAINTAINED UNDER PRESENT CLIMATIC REGIME

PERMAFROST ISLANDS IN PEATLANDS; AND PREDICTED OCCURRENCE OF RELIC PERMAFROST PATCHES FORMED UNDER PREVIOUS CLIMATIC REGIME

SOUTHERN LIMIT OF PERMAFROST

PERMAFROST OBSERVATIONS

NUMBERS REFER TO LOCATIONS IN APPENDIX A

● PERMAFROST LOCATION

◒ NO PERMAFROST REPORTED
(MAY EXIST NEARBY IN DIFFERENT TERRAIN)

BR 5418-9

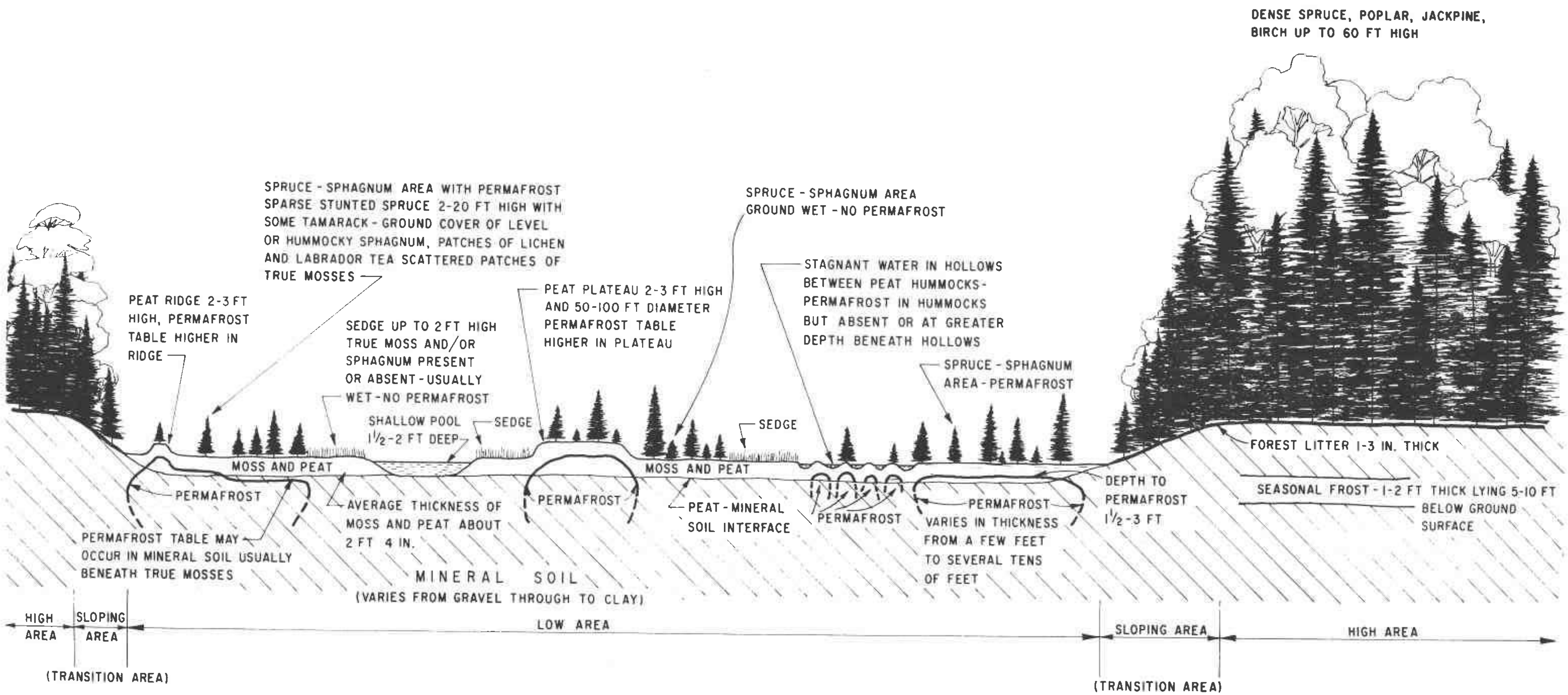


FIGURE 47

PROFILE THROUGH TYPICAL PEAT BOG IN SOUTHERN FRINGE OF DISCONTINUOUS ZONE SHOWING VEGETATION, DRAINAGE AND MICRO-RELIEF, AND ASSOCIATED PERMAFROST DISTRIBUTION.

BR 3119-11

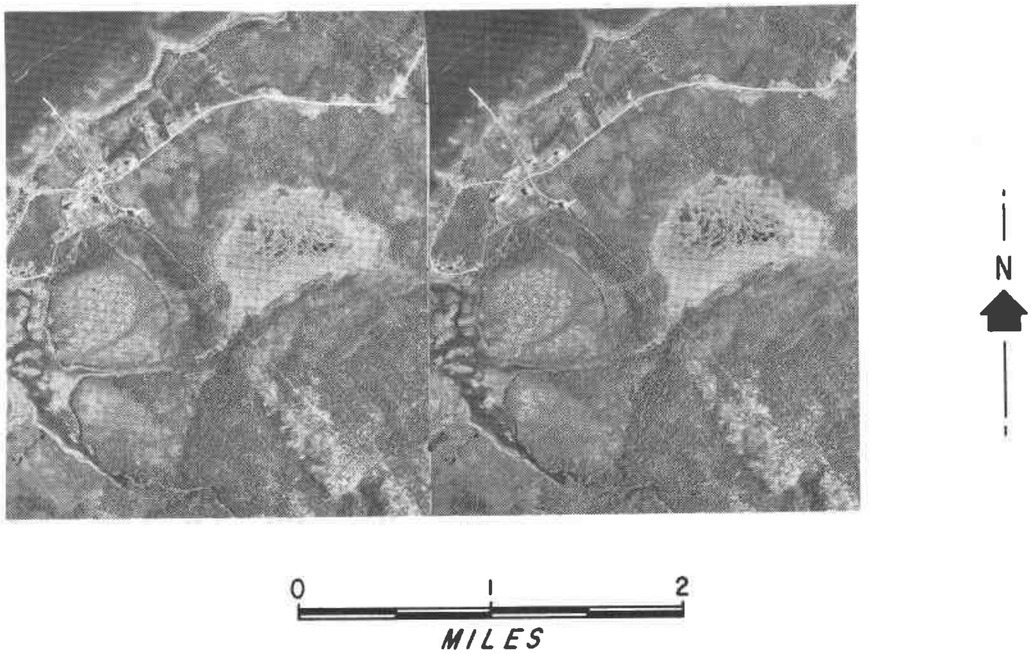


Figure 48

Stereoscopic pair of sections of RCAF air photos A22346 - 145 and 146 (Scale 1:63,360; altitude 30,000 ft) at Stop No. 85 showing palsa bog at Cartwright (Labrador).

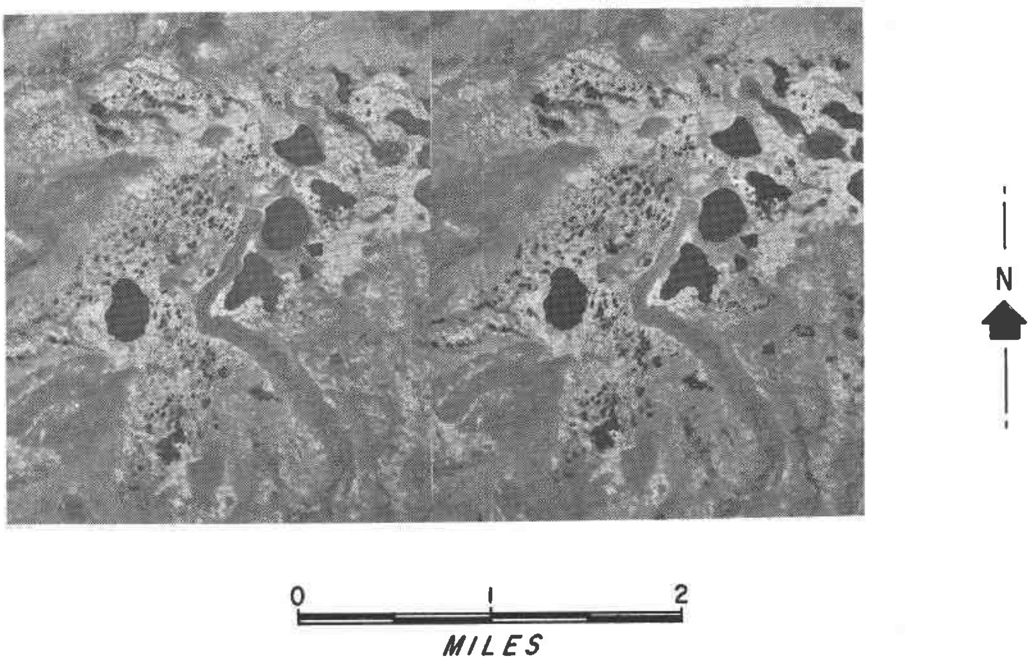


Figure 49

Stereoscopic pair of sections of RCAF air photos A22524 - 35 and 36 (Scale 1:63,360; altitude 30,000 ft) at Stop No. 78 showing palsa bogs on Neveisik Island (Labrador).

APPENDIX A

In addition to the permafrost investigations carried out by helicopter in the study area, information on occurrences of permafrost is available in the technical literature, and some has been obtained from questionnaires and personal interviews. The locations and sources of information from the last two sources are listed below in alphabetical order and shown on Figure 46. The literature containing permafrost information in Quebec and Labrador is included in the list of references or bibliography.

The information from the questionnaires and personal interviews is presented as it was obtained from the source and the reliability of the observations has not been verified. Observations at one site from several sources may conflict with each other. The absence of permafrost at a particular site does not necessarily preclude the existence of permafrost nearby in a different type of terrain.

QUEBEC

Fort Chimo

Continuous permafrost containing ice encountered in sand and clay deposits at depth of 4 - 5 ft below ground surface and extends to depths of 100 - 125 ft (8, 16)*.

Fort George

No permafrost reported (10). Palsas occur about 1,000 ft from coast (3).

Gagnon

No permafrost reported (15).

Poste-de-la-Baleine (Great Whale River)

No permafrost reported in beach ridges at townsite (5, 9, 12).

Kivivic Lake

Frozen ground of unknown thickness encountered at depth of 5 ft (4).

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* Numbers in parentheses refer to sources of information - see page A-3.

Mid Canada Line

No permafrost encountered at hilltop sites from Hopedale (Labrador) to Schefferville, P.Q. to Poste-de-la-Baleine (Great Whale River), P.Q. (4).

Mount Wright

No permafrost encountered in deep trenching for mineral exploration on slopes of mountain (13).

Nitchequon

No permafrost encountered in mineral soil or bogs (1).

Wakuach Lake

Permafrost of unknown thickness encountered at depth of 5 ft (6).

NEWFOUNDLAND (LABRADOR)

Cartwright

No permafrost encountered in water well drilling in townsite to depth of 12 ft in silt, sand and gravel mixture (14).

Churchill Falls

No permafrost reported in townsite or powerhouse construction (2).

Davis Inlet

No permafrost reported in sand and gravel soil in townsite (7).

Labrador City - Wabush

Permafrost encountered to depth of 300 ft and more in iron mines (11).

Postville

No permafrost reported in sandy soil in townsite (7).

Twin Falls

Large body of permafrost encountered during excavation of powerhouse in bottom of dry valley about one mile east of Scott Falls. One occurrence of permafrost found on construction of transmission of power line from Twin Falls to Wabush (2).

SOURCES OF INFORMATION

1. Baldwin, W.W. National Herbarium, National Museums of Canada.
2. British Newfoundland Corporation Ltd.
3. Canada, Department of Energy, Mines and Resources, Geological Survey of Canada.
4. Canada, Department of Mines and Resources, Geographical Bureau. Jenness, J.L. Permafrost questionnaire - 22 July 1946.
5. Canada, Department of Mines and Technical Surveys, Geographical Branch.
6. Canada, Department of National Defence.
7. Canada, Post Office Department.
8. Canada, Indian Health Service.
9. Canada, National Research Council, Division of Building Research.
10. Hudson's Bay Company.
11. Iron Ore Company of Canada Ltd.
12. Maybank, W. Great Whale Iron Mines Ltd.
13. Mount Wright Iron Mines Ltd.
14. Pardy, W.E. Cartwright, Newfoundland.
15. Quebec Cartier Mining Company Ltd.
16. Salamita Consolidated Mining Company Ltd.