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by

R.J.E. Brown

Since 1950 the Division of Building Research, National Research Council, 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 of 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 the temperature to 32°F. The existence of permafrost in this area is greatly influenced by the complex interrelationships among microclimate and local terrain conditions, which produce 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. In the northern sections of the western provinces of Canada and in adjacent portions of the Yukon Territory and Mackenzie District, new roads are being constructed.*

Because of the increasing development and the unusually difficult engineering problems encountered in the southern fringe of permafrost, the Division of Building Research initiated in 1962 a long-term program of field surveys along the roads in the affected regions of the Province of Alberta and the Mackenzie District (1). In 1963, these field surveys were extended to the provinces of Manitoba and Saskatchewan (2). In 1964, a field survey was carried out in northern British Columbia and southern Yukon Territory. This will be followed in future years by similar studies in the northern sections of the Provinces of Ontario, Quebec and Newfoundland into which the southern fringe of permafrost penetrates.

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* Because the information presented in this report was obtained in 1964, the description of the highway network pertains to that year. Since 1964, the highway system in the Yukon Territory has been considerably extended.

The area of British Columbia north of 56°N and of Yukon Territory south of 65°N was chosen as the site of the 1964 investigations, which completed the survey of western Canada begun in the Prairie Provinces two years earlier (Figure 1). Studying the permafrost boundary in this physiographic region is difficult for several reasons:

(1) The only access by land north of the latitude of Dawson Creek, B.C. (Mile 0, Alaska Highway - 56°N) is the Alaska Highway, which extends northwest into Yukon Territory (Figure 1). West of the Alaska Highway, in British Columbia, there is a recently constructed road extending southward from Watson Lake, Y.T. towards Stewart, B.C. (Stewart-Cassiar Highway). There is, however, a gap of approximately one hundred miles in the southern portion of this road which has not yet been constructed. In the northwest corner of British Columbia there is a branch road 60 miles long extending south to Atlin, B.C. and to the Haines Highway which extends from the Alaska Highway to Haines, Alaska. Between the Alaska Highway and the aforementioned roads, there is a large tract of virtually uninhabited country without land communications. The southwest and west central portions of Yukon Territory are served by the Alaska Highway and several branch roads. The eastern and northern portions of the Territory, like north-central British Columbia, are without land communications. The southern limit of permafrost on the Alaska Highway occurs about 90 miles north of Dawson Creek (56°N). Thus, the study area lies almost entirely within the permafrost region.

(2) The study area is located almost entirely in the Western Cordillera, which is mountainous and contains plateaus, intermontane valleys and trenches. This rugged and variable relief (elevations range from sea level to more than 10, 000 ft) restricts extensive field work away from the roads. The distribution of permafrost is complicated by the extreme variations in elevation producing a vertical zonation from discontinuous at lower elevations to continuous at higher levels. In many areas permafrost occurs on mountain slopes and summits but not at the valley bottoms. Variations in horizontal extent and thickness of permafrost occur between adjacent north- and south-facing slopes in addition to the normal increase in these parameters northward towards the continuous zone.

Economic development of the area has been increasing considerably during the past few years along the Alaska Highway and branch roads. There is virtually no development in the extensive areas not served by land communications. Mining developments have provided the main impetus to road construction. The Stewart-Cassiar Highway in northwestern British Columbia is being completed to open that area to mining development. A new base metal mine near Whitehorse began production in 1967. The road to Ross River in southeast Yukon Territory was opened a few years ago to provide access to the recently opened tungsten mine at Flat River (in the District of Mackenzie). A new sixty-mile long development road has been completed to an asbestos ore body north of Dawson Y. T. The Dempster Highway extends at present about eighty miles northeast of Dawson to the Peel Plateau. Eventually it will link Fort McPherson, N. W. T. to the Alaska Highway. This road is the site of considerable oil exploration. Since the Second World War, the tourist possibilities of the Alaska Highway and branch roads have been expanded with the development of many motels and campsites.

Contacts were established in Yukon Territory with the Northwest Highways System, Department of Public Works, and the Yukon Territorial Government, Department of Indian Affairs and Northern Development, Whitehorse, Y. T. Considerable information was obtained from these agencies on permafrost conditions encountered during construction and maintenance of the roads. This included that portion of the Alaska Highway in British Columbia south to the end of pavement at Mile 83 north of Dawson Creek, B. C. Information on permafrost was supplied also by the British Columbia Department of Highways.

These field investigations were carried out in September 1964 when the depth of thaw had reached its maximum, and seasonal frost of the forthcoming winter had not begun to form. Investigations were carried out along the Alaska Highway from Dawson Creek, B. C. (Mile 0) to the Yukon Territory - Alaska boundary (Mile 1230). Branch roads extending south of the Alaska Highway were investigated, including the Stewart-Cassiar Highway, Atlin Highway, Carcross Highway, and Haines Highway. North of the Alaska Highway, branch roads investigated included the Whitehorse-Mayo Highway, Dawson Highway and Dempster Highway (Figures 1 and 2).

METHODS AND SCOPE OF INVESTIGATIONS

Prior to the actual field investigations, information on the climate and terrain was obtained from the technical literature and agencies located in the study area. 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.

In the field, detailed investigations were carried out 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 the type of vegetation, the thickness of the living surface vegetation cover, the thickness of peat, the type of underlying mineral soil and the character of the ground ice.

The main objective was to delineate 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 consisted of portable, manually operated equipment. A 6-ft aluminium Hoffer probe and 1 1/2-inch diameter screw-type soil auger, both with 3-ft extensions, were 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 chop holes and obtain samples to a depth of 15 to 20 ft using the Hoffer probe equipped with a case-hardened serrated steel bit. Holes were also advanced to depths of 15 to 20 ft by chopping with an ice chisel attached to 3/4-in. pipe and cleaning out the frozen chips of soil with a 2-in. diameter posthole auger. Frozen clay soils could usually be penetrated with the screw-type auger because of their plastic nature and considerable unfrozen water content at even several degrees below 32°F. Frozen silty and sandy soils could be penetrated for a few feet without difficulty, but frozen stony and gravelly soils resisted the manual equipment.

The observations are listed in Table I beginning with the Alaska Highway and followed by the various branch roads mentioned previously. The location of each observation point is designated in Table I by the number of miles from the beginning of the road. Prevalent types of terrain on the southern section between Dawson Creek and Whitehorse are illustrated in Figures 3 to 14 inclusive.

The following example illustrates the use of the symbols in Table I to describe the terrain and permafrost conditions (Figure 6). Location No. 36 (Column 1) is located 254.5 miles north of the southern terminus of the Alaska Highway in British Columbia. It is a low area located in a peat bog (Column 3 - L) in which there are depressions and peat plateaux. The background and right side in Figure 6 is a peat plateau supporting dense spruce up to 30 ft high and tamarack (Column 4 - S(30) T). The depression on the left side is treeless (Column 4 - No). The ground vegetation on the peat plateau (Column 5 - (p)) consists of non-Sphagnum mosses, Sphagnum, lichen and Labrador tea (Column 5 - MSph Ln Lt). The depression is covered with sedge and ground birch, and the water table is at the ground surface (Column 5 - Se B (w)). In the peat plateau, the peat is 7 ft 6 in. thick (Column 6: 7 ft 6 in.); its thickness was not measured in the depression. The mineral soil is clay (Column 8 - Yes) but not in the depression (Column 8 - No). The depth to the permafrost table in the peat plateau is 3 ft 9 in. (Column 9: 3 ft 9 in.) and the permafrost is 14 ft 3 in. thick (Column 10: 14 ft 9 in.)

CLIMATE

The study area, comprising northern British Columbia and southern Yukon Territory between 55°N and 65°N, is situated in a mountainous region on the west side of North America. The following account is taken mainly from The Climate of British Columbia and the Yukon Territory (3) and The Climate of Canada (4).

Despite the proximity of the Pacific Ocean, the Coast Mountains in the Alaska panhandle and the St. Elias Mountains in the southwest portion of Yukon Territory are so continuous and lofty that they form an effective barrier against Pacific maritime influences. Several deep river valleys cut through these mountain barriers but they are too narrow and tortuous to allow much penetration by air masses or disturbances from the Pacific Ocean. On the east, the Rocky Mountains in northern British Columbia and the Mackenzie Mountains in western Mackenzie District provide less defence against winter cold waves from the Northwest Territories and Prairie Provinces. Between these two mountain systems lies a complex of mountain ranges and plateaux.

The climate is essentially continental, with long cold winters and short, generally mild to cool, summers. An outbreak of polar air may occur at any time during the summer and produce freezing temperatures. Yukon Territory, and to a lesser extent northern British Columbia, are subject to wide variations in temperature during the winter depending on whether the dominant influence is modified air from the Pacific or intensely cold air from the north or east. Although oceanic influences are modified by the mountain barrier, winters are milder in southwest Yukon Territory and northwestern British Columbia than in the interior. Within this broad framework, local variations in climate from one station to another are determined by elevation and exposure to prevailing winds. The climate also becomes increasingly severe towards the north.

Air temperature records are available for 15 stations in northern British Columbia and 13 stations in Yukon Territory (5 - 8). Their locations are shown in Figure 1 and monthly and annual averages of daily mean temperatures are given in Table II. Mean annual isotherms are also shown on Figure 15 (9, 10).

In the south, mean annual air temperatures vary from about 40°F at New Hazelton, Alice Arm and Stewart near the coast to about 35°F in the interior at Dawson Creek and Fort St. John. Farther north in British Columbia, the mean annual air temperature varies near the coast from 30°F depending on elevation to 35°F around Fort Nelson. In Yukon Territory, mean annual air temperatures vary from 29°F to 30°F in the south to about 25°F at the northern boundary of the study area around Dawson and Mayo. Here, as in the south, local variations depend on elevation and exposure. The coldest station is Snag in western Yukon Territory with a mean annual air temperature of 22°F.

January mean temperatures are only slightly above zero in northwestern British Columbia. Summer temperatures are among the lowest recorded in the province with July mean temperatures of 54°F at Atlin and 55°F at Dease Lake and Babine Lake. In the Peace River valley, January temperatures average about 5°F with mean July temperatures of 60°F. Northward in the Fort Nelson River valley winter temperatures are 10 degrees colder, while in July mean temperatures are quite similar in both valleys.

In Yukon Territory, which lies entirely north of latitude 60°N, winter days even in the south are short with no effective sunshine. In summer, long hours of daylight promote rapid growth where soil is available. January mean temperatures are -1°F at Whitehorse and -3°F at Teslin in the southwest. The colder winters in the interior are typified by January mean temperatures of -12°F at Watson Lake and -18°F at Dawson. The relief contributes to extremely low minimum temperatures during arctic cold waves. Snag holds the record for North America of -81°F on February 3, 1947. Other minimum records are -62°F at Whitehorse, -63°F at Teslin, -73°F at Mayo and -74°F at Watson Lake, Fortunately, periods of intense cold are usually of short duration. The transition period from winter to summer and vice versa is very short, the rapid change in daily temperatures reflecting the changing altitude of the sun. At Dawson, the mean temperature rises from 28°F to 57°F between mid April and mid June. Summers are short but warm with all stations reporting mean temperatures above 50°F during June, July and August. Graphs of mean monthly air temperatures at three stations representing the southern, central and northern portions of the study area are shown in Figure 16.

Freezing and thawing indices provide an indication of the amount of heat withdrawn from and added to the ground. On Figure 15 it can be seen that freezing indices vary from about 4000 degree days in the south to about 6500 in the vicinity of Dawson and Snag (11, 12). The range of thawing indices is smaller varying from about 3500 degree days in the south to 3000 in the vicinity of Dawson and Mayo.

Precipitation observations are available for the 28 stations (13, 14) and are presented in Tables III - V. Orographic effects are noticeable in the distribution of precipitation in this rugged country. East of the Coast Range in northwestern British Columbia, precipitation is light, averaging 11 in. at Atlin and 15 in. at Dease Lake, and increasing slightly eastward. Throughout the northeastern section of the province, east of the continental divide, the annual precipitation varies from 15 to 18 in., most of which occurs in the summer. Mean annual precipitation is fairly uniform over most of Yukon Territory, ranging from 9 to 17 in. at the valley stations for which records are available. There is no pronounced wet or dry season, although at most stations July and August are the rainiest months and spring has the least precipitation.

The heaviest snowfall occurs at stations on the windward slopes of the coastal mountains in northern British Columbia where more than 200 in. are recorded annually at Alice Armand Stewart. East of these mountains annual snowfalls range between 40 and 80 in. British Columbia stations experience greater snowfalls, ranging from 60 to 80 in., than Yukon Territory, where annual totals range mostly from 40 to 60 in. Heavier falls up to 80 in. occur in the Liard Valley (Watson Lake - 83 in., Frances Lake - 72 in.), in the St. Elias Mountains and on the westward slopes of the Mackenzie Mountains. July is the only snow-free month at all stations except Beatton River, which experiences an average fall of 0.1 in. Orographic effects are important in the distribution of snowfall as well as total precipitation. Data on the average depth of snow on the ground each month are available for 4 stations in northern British Columbia and 7 stations in Yukon Territory (Table VI). Monthly depths are generally higher in British Columbia. It must be noted that the recording stations are sparse and all located in the valley bottoms. The mountains receive more snow, especially on the west slopes. Graphs of mean monthly precipitation totals at 3 stations representing the southern, central and northern portions of the study area are shown in Figure 16.

In summary, the climate of the study area is essentially continental, with large differences between summer and winter air temperatures and most of the precipitation occurring during the summer. The main differences in air temperature result from latitudinal variations but the generally mountainous relief causes local variations. Precipitation totals are also influenced by latitudinal variations but orographic effects are more important. Hythergraphs based on the averages of the mean monthly temperatures and precipitations for the 3 stations in Figure 16 are shown in Figure 17.

GEOLOGY

The study area lies almost entirely within the Cordilleran Region except for the northeastern corner of British Columbia in the vicinity of Dawson Creek and Fort Nelson, which lies in the Interior Plains physiographic province. The Cordillera consists of three large systems differing broadly in their geological structure and topographical character (Figure 18). The following account is taken mainly from Bostock (5).

The Eastern system consists of two parts, namely, the Rocky Mountain and Mackenzie Mountain areas. In the south, the Rocky Mountain area extends to Liard River where it is followed north by the Mackenzie Mountain area. The latter curves in a great arc from Liard River to the west side of the Peel River, north of the study area, near 66°N.

The Rocky Mountain area includes the Rocky Mountain Foothills, the Rocky Mountains and Rocky Mountain Trench. The Rocky Mountain Foothills separate the mountains from the Interior Plains. Although mainly composed of rounded hills, they contain outlying mountain ridges nearly as high and rough as those of the main mountain area to the west. They are entirely of sedimentary origin, composed mostly of Mesozoic strata, but include Palaeozoic and Tertiary formations in many parts and some Precambrian rocks in the south. The Rocky Mountains form a continuous wall of mountains traversed by only one stream - Peace River. Many peaks rise above 9000 ft. For the greater part, they consist of ridges with a northwesterly alignment nearly parallel with that of the entire Rocky Mountain area. The ridges are separated by deep valleys cut along zones weakened by folds, fractures, and relatively soft strata. They are mainly formed of Palaeozoic sediments, but include some of late Precambrian age. The Rocky Mountain Trench is the great valley lying directly west of the Rocky Mountains forming their western boundary. The floor of the trench varies in width from 2 to more than 10 miles and lies between 2000 and 3000 ft above sea level.

The Mackenzie Mountain area, of more varied character than the Rocky Mountain area, consists of mountains, plateaux and plains. Only the Liard Plateau and the northwest corner of the Mackenzie Mountains lie within the study area. The Liard Plateau is an area of broad, even-topped ranges of hills rising more than 4500 ft above sea level separated by wide valleys 1500 to 2500 ft above sea level. The plateau is underlain by the same Palaeozoic and Mesozoic sedimentary formations, as in the Rocky and Mackenzie Mountains. The mountains in the northwest corner of the Mackenzie Mountains are rugged, with peaks rising above 7000 ft above sea level. The sediments are of Palaeozoic and Mesozoic origin but are thinner than in the Rocky Mountains and some areas of Precambrian strata may be exposed.

The Interior System forms the great intermediate unit of the three systems of the Canadian Cordillera and comprises most of the study area. It is composed of several major and minor mountain and plateau areas arranged in segment pairs. Each pair consists of a mountain area on the east and a less mountainous plateau area on the west. The area on the east is underlain largely by old rocks including thick sections of Precambrian sediments and later intrusive rocks. The area on the west is formed to a greater extent, except in the north, of younger rocks and less intrusive material.

In the southern part of the study area the Central Plateau and Mountain Area is composed of Omineca and Cassiar Mountains on the east and Skeena Mountains and Stikine Plateau on the west. The highest peaks in these mountains exceed 8000 ft above sea level and the plateau levels are above 4000 ft. In the north, the Northern Plateau and Mountain area is more difficult to divide because of its complex topography and geology. In its southern part it is composed of Selwyn Mountains on the northeast, Ogilvie Mountains on the northwest, and Yukon Plateau on the southwest. The rugged Selwyn Mountains contain some peaks that exceed 9000 ft elevation and the Ogilvie Mountains some that rise to elevations of 7000 ft. The Yukon Plateau has a varied topography consisting of several plateaux, mountain ranges and large persistent valleys. The plateaux are about 4000 to 5000 ft above sea level. The highest mountains rise above 6000 ft. The trench-like Tintina Valley and Shakwak Valley are about 5 to 10 miles wide, and their floor elevations are between 1500 and 2500 ft. Liard Plain is a large basin at an elevation of about 2500 ft. Hyland Plateau is formed of broad valleys and rolling hills rising to an elevation of 4000 ft.

The Western System of the Cordillera in Canada includes all land areas southwest of the Interior System. It is comprised of three parts: the Coast Mountain area, the Outer Mountain area, and the Coastal Trough. The Coast Mountain area, which borders the Interior System in the study area in British Columbia forms a continuous barrier of extremely rugged mountains, some rising to elevations exceeding 10, 000 ft. They are formed largely of granitic intrusive rocks of the Coast Range batholith. The St. Elias Mountains of the Outer Mountain area in northwestern British Columbia and southwestern Yukon Territory are the highest mountains of Canada, the highest being Mt. Logan rising to 19, 850 ft above sea level. The Coastal Trough is a depression lying between the two mountain areas outside the study area.

Glaciation was widespread in the Cordillera during the Pleistocene, and glaciers persist today in many places, chiefly in the St. Elias and Coast Mountains (Figure 19). A large area in the northwest corner of the study area in Yukon Territory escaped glaciation because the high St. Elias Mountains barred the moisture-laden winds from the Pacific to such an extent that ice did not form in much of the interior, despite the increased coldness of the period.

During the Pleistocene the Rocky Mountains appear to have been an area of relatively light precipitation and the effects of glaciation are light. Most of the Liard Plateau appears to have been covered by ice and the lower parts were well scoured. In the northwestern end of the Mackenzie Mountains cirque and valley glaciers were active. In the Interior System, glaciation in the Omineca and Cassiar Mountains was variable. Some ridges and valleys were heavily scoured while others were relatively lightly glaciated. Wide areas of Skeena Mountains were covered with ice and their lower levels and main valleys were much scoured. At present, small ice fields and glaciers are scattered through nearly all the ranges. Most of Stikine Plateau was covered by Pleistocene ice to about 6500 ft, only a few isolated mountains in the plateau areas being high enough to project above it. The Liard Plain and Hyland Plateau were mantled by thick deposits of glacial drift. In the Selwyn Mountains, ice extended in most areas to elevations of 3000 to 5000 ft. There were many nunataks, and glacial deposits and scour are widespread. A few small glaciers and icefields are present today in these mountains. It is believed that the effects of Pleistocene glaciation dwindled northward and westward in the Ogilvie Mountains although to the northeast some valley glaciers pushed to near the borders of the mountains. The eastern half of Yukon Plateau was covered with Pleistocene ice but the west half comprising the Klondike Plateau shows no signs of glaciation.

Glaciation was very active in the Western System. Ice probably covered all but the highest parts of the Coast Mountains. Active glaciation on a diminished but still considerable scale has continued in these ranges with periods of oscillation up to the present extensive stage of alpine glaciation. During the Pleistocene the ice fields of St. Elias Mountains were higher and pushed their glaciers out on all sides. On the interior side they extended far out on Kluane Plateau. The upper limit of ice during the later Pleistocene was probably about 6000 ft with considerable local variations due to topography.

The portion of the study area in northeastern British Columbia lying outside the Cordillera is underlain by Mesozoic rocks mainly of Upper Cretaceous age. The rocks are mainly sedimentary consisting primarily of shales and sandstones. Similar rocks of lower Cretaceous age form a band on the west side of the area bordering the Rocky Mountain Foothills. Glaciation covered the area with drift. The relief throughout most of the area is that of a plain dissected by wide incised river valleys bordered by broad terraces which give way to rolling uplands with low hills. In the south the relief is rolling with some plateau areas among low to high rounded hills.

TERRAIN

Relief

The relief of the area under study is varied, consisting of mountain ranges, intermontane valleys and trenches, and plateaux (Figure 20). In northern British Columbia, the region west of the continental divide is one of varied relief including several distinct mountain ranges and associated valleys. The extreme northeastern portion of the province lying east of the Rocky Mountains has mainly level to rolling relief. A drainage divide rising to 4000 ft separates the Peace River basin in the south from the Fort Nelson and Liard River basins in the north. Yukon Territory is a rugged land of mountain ranges and plateaux. Between the Rocky Mountains and the Coast Mountains lies the Interior Plateau, a rough irregularly rolling upland with an average elevation of 4000 ft but with large areas exceeding 5000 ft and isolated mountains reaching 6000 ft. Cutting through mountains and plateaux are numerous river valleys, some with flat bottoms and sloping sides and others deep narrow gorges with precipitous sides.

Elevations on the Alaska Highway and branch roads in the study area are variable. Between Dawson Creek, B. C. and Whitehorse the Alaska Highway varies from about 1000 ft above sea level to 4200 ft at Summit Lake about 100 miles west of Fort Nelson. West of Whitehorse the Alaska Highway does not rise above 4000 ft. Elevations of the branch roads are also all below 4000 ft.

Local relief consists of alternating elevated areas and depressions (hereafter referred to as "high areas" and "low areas" respectively);

differences in elevation vary from only a few feet to about 20 ft and more. These high and low areas vary in extent from a few hundred yards to several miles. Occasional low areas of a few hundred yards occur within high areas and vice versa.

The ground surface of the elevated areas is smooth and virtually devoid of the microrelief features that are common in the depressions; these consist of hummocks and peat plateaux rising to 3 or 4 ft above the surrounding surface.

Drainage

Regional drainage is provided by rivers flowing between mountain ranges in valleys and trenches. The study area is approximately cut in half by the continental divide. East of the divide in British Columbia and southeastern Yukon Territory, the Peace, Liard, and Fort Nelson Rivers flow eastward into the Mackenzie River system. West of the continental divide most of British Columbia and southwestern Yukon is drained through the Alaska panhandle to the Pacific Ocean by the Skeena, Nass, Stikine, Taku and Alsek Rivers and their tributaries. Northwestern British Columbia in the vicinity of Teslin and Atlin Lakes and western Yukon Territory are drained by the Yukon River and its tributaries westward into Alaska.

Local drainage varies considerably from good to excessive on mountain slopes and high areas to poor in valley bottoms and depressions. Bog conditions occur in low-lying areas; slightly elevated areas such as peat plateaux are well drained. The greatest area of bogs occurs south of Fort Nelson, B.C., where they extend for about 40 miles.

Vegetation

Most of the study area lies within the taiga or boreal forest region, which extends east-west across Canada in a band several hundred miles wide. The generally mountainous terrain causes subalpine forests at high elevations and tundra above the treeline. These vegetation regions are described by J.S. Rowe (16) and their distribution is shown in Figure 21.

The Boreal Forest Region in Canada is divided by Rowe into 45 sections of which 12 are found in the area under study. In the southeast corner of the study area there is an outlier of the Aspen Grove Section occurring in Peace River valley between Dawson Creek and Fort St. John. Aspen (Populus tremuloides) is the only species abundant in natural stands. Balsam poplar (Populus balsamifera) is frequently present on moist lowlands, and occasionally it is also prominent on uplands after fires. White birch (Betula papyrifera) is scattered but is usually found only on rough, broken land.

Surrounding this aspen outlier in the southeast corner of the area under study is the Mixed Wood Section. The characteristic forest association on well-drained uplands is a mixture of aspen, balsam poplar, white birch, white spruce (Picea glauca) and balsam fir (Abies balsamea). The cover type of greatest areal extent is the aspen. Jack pine (Pinus banksiana) grows on sandy areas and drier till soils, and mixes with black spruce (Picea mariana) on the plateau-like tops of higher hills. Black spruce and tamarack (Larix laricina) grow on poorly drained and boggy areas.

North of the Mixed Section lies the Lower Foothills Section. The Lodgepole pine (Pinus contorta var. latifolia), along with aspen and balsam poplar, has become dominant after fires. White spruce and black spruce are frequently present with scattered white birch on well-drained sites and tamarack on poorly-drained sites.

The Northern Foothills Section lies west of the previous section and the dominant species are white spruce, black spruce and lodgepole pine. Broadleaved trees are not abundant, although some birch is scattered through upland stands, aspen appears on south-facing slopes, and balsam polar is present on lowland alluvium. In general, the forest stands are patchy and open.

The northeast corner of British Columbia is in the Hay River Section, which represents the northern extension of the Mixed Wood Section somewhat modified by a colder drier climate. The quality of the forest growth is not as good, and black spruce predominates on the plateau-like uplands as well as in its usual lowland habitats. The mixed white spruce-poplar stands are fewer in number.

An arm of the Upper Mackenzie Section extends up Fort Nelson River to Fort Nelson, B.C. and westward along Liard River. White spruce and balsam poplar form the main cover types on alluvial flats bordering the rivers. On the benches above the floodplains, large areas of sandy soils are occupied by pine, aspen, and in moist to wet positions, by black spruce and tamarack.

On the east and west sides of the previous section lies the Upper Liard Section. Good forest growth is found here, particularly on soils of the alluvial flats. The dominant tree species are white spruce and balsam poplar, usually in pure stands. Above the river floodplains, the spruce grows with lodgepole pine, aspen and white birch on the best sites, with alpine fir on the higher lands. Black spruce and tamarack occur in low positions and the former species is also prominent on upland fine-textured soils where it associates with white spruce and lodgepole pine.

In northwestern British Columbia, the Stikine Plateau Section is comprised of an open mixture of aspen, white spruce and lodgepole pine, interspersed with grassy areas. White brich is scattered and black cottonwood (<u>Populus trichocarpa</u>) appears on river banks. Some alpine fir grows near the treeline.

Four sections of the Boreal Forest Region are found in that portion of the study area located in Yukon Territory. In the Eastern Yukon Section, mixed stands of white spruce, aspen and birch grow on south and west facing slopes but north and east facing slopes are frequently non-forested. Alpine fir (<u>Abies lasiocarpa</u>) grows on the higher slopes either associated with spruce and birch, or alone forming a scrub growth at timber line (usually below 5000 ft elevation). On lower slopes and valley terraces the forest cover is dominated by white spruce, lodgepole pine and aspen in the southern parts, and by white spruce and birch northward and in the mountains. Black spruce grow in bogs and on slopes underlain by permafrost accompanied by tamarack on the former sites and by birch on the latter. Floodplains are generally narrow and support local patches of balsam poplar and white spruce on alluvium.

The Central Yukon Section occupies the south central part of the territory. The best forests grow in protected lowlands with growth grading off as elevation increases. White spruce grows up to 3000 ft. At these elevations it associates with alpine fir, which ascends to 4000 or 5000 ft. Grasslands are interspersed with islands of white spruce, willow and aspen on the mountain slopes. Erosional barrens occur in areas of soil instability. Lodgepole pine and white spruce dominate in the valleys on water-modified tills and coarse terrace materials. Spruce, pine and aspen in association are also common. Pine is particularly prevalent on dry sandy soils in the southeast; to the west and north it diminishes. Tamarack is mostly limited to the eastern side. Black spruce grows on level organic soils where the water table is high.

The southwest corner of Yukon Territory is occupied by the Kluane Section comprising a narrow strip in the rainshadow of the St. Elias Mountains. In the cold dry climate of the Yukon Plateau, the vegetation has a park-like appearance. The best forests are comprised of white spruce and poplar in the river valleys. White spruce, aspen and birch grow on the benchlands. Open forests of white spruce giving way to grassy treeless areas at about 4500 ft elevation grow on the upland slopes.

The Dawson Section comprises the northwest portion of the study area. Valley slopes are the main forest habitat, supporting stands of white spruce, either pure or mixed with birch or aspen. The aspen favours dry hilltops and steep south facing slopes. The most favourable spruce site is on lower slopes. In valley bottoms, bogs and exposed uplands, stunted stands of white and black spruce are usual except on levees adjacent to the rivers where white spruce predominates. Some alpine fir associated with white spruce grows up to the treeline at about 2500 ft.

The southern portion of the study area in the Cordillera lies not in the boreal forest but in the Subalpine Forest Region. This region is represented by the Interior Subalpine Section, which extends from southern British Columbia. This forest is greatly fragmented occupying the mountainous uplands up to the treeline surrounding the Nechako Plateau. Engelmann spruce (*Picea engelmanni*) is widespread in association with alpine fir which increases in abundance at higher elevations and dominates at treeline. Lodgepole pine grows extensively in burned over areas. The lower boundary of this forest lies generally between 3000 and 3500 ft. Below these elevations, spruce-pine forests are continuous from mountain slope to mountain slope across the intervening valleys.

Throughout the area under study, variations occur in the vegetation due to changes in local relief. The "low areas" are characterized by bog vegetation - open bogs with scattered stunted black spruce growing on deep accumulations of Sphagnum and sedge bogs. The best black spruce growth occurs where the organic accumulation is relatively thin and drainage is improved; this is a characteristic of both sedge and Sphagnum bogs. The tallest black spruce grow to about 30 ft. Tamarack is common, either mixed with black spruce, or less frequently, in pure stands. Scattered jack pine growing to 20 ft are encountered in drier bogs. The ground cover consists predominantly of Sphagnum, with patches of feather and club mosses, lichen and Labrador tea. There are also extensive wet sedge meadows.

The "high areas" with moderate to good drainage support a mixed cover of white spruce, black spruce, alpine fir, lodgepole pine, aspen and balsam poplar with undergrowth of willow and alder. The tallest trees grow to 80 and 100 ft in dense stands averaging about 5 ft between trees. Areas with more level relief, poorer drainage and finer textured soils have white spruce as the major cover, with occasional aspen. Improved drainage, coarser grained soils and more irregular relief results in an increase in aspen and a decrease in white spruce, ultimately giving rise to relatively pure aspen stands with occasional white birch on the crests of high areas in soils of sand-clay-loam textures. Mixed aspen-jack pine forest growth is common in regions of well-sorted sands. The ground vegetation consists of various berry plants, grasses, Labrador tea, discontinuous cover of feather and club mosses, and some lichen.

Scattered burned over areas occur in the study area. Following a fire it appears that aspen is the main species to regenerate on medium to fine-grained soils, and jack pine the main post-fire species on sandy areas.

Soils

Throughout the study area the soils vary from coarse-grained sands to gravel to fine-grained silts and clays. Their character is strongly influenced by their nature of origin, the coarse-grained soils being associated with till and moraine deposits, the fine-grained soils with alluvial and lacustrine deposits. Following deposition of these materials, profile development has occurred producing pedological variations.

Rowe (16) has described the pedological characteristics of the soils in each of his forest sections. In the Aspen Grove Section surface materials are deep tills and glacio-lacustrine deposits, mainly of loam to clay loam texture and moderately calcareous. Black earth profiles are predominant although some podzolic degradation can be recognized under aspen stands. In the Mixed Section rolling morainic deposits occur on the uplands and smoother glacio-lacustrine deposits on the lowlands. The characteristic soil development is grey wooded.

Brown wooded soils occur on level calcareous alluvial flats and terraces in the Northern Foothills Section. Grey wooded soils have developed on the upland tills. Regosols are common on colluvial materials and peats in poorly drained positions. To the west in the Upper Foothills Section, the glacial deposits and colluvial material, and the mature soils show podzol or grey wooded development. In northeastern British Columbia, glacial advance over Devonian limestones incorporated a high proportion of calcareous material in the surface drift of the Hay River Section. Soil profiles are frequently high in lime and hence shallowly leached.

In the Upper Mackenzie Section, bedrock is mostly buried deeply under till or more recently deposited lacustrine and alluvial materials. Grey wooded and brown wooded soils are developed on well-drained sites in the southern parts, although immature profiles are more usual in alluvium. Northward, the presence of permafrost prevents soil profile development. There are large areas of swamp and peat. The soil materials in the Upper Liard Section are derived from glacial, alluvial, and colluvial deposits developed on wide river valleys, broad terraces, and rolling uplands with low hills. In the Stikine Plateau, an uneven cover of till lies on the uplands, and alluvial and colluvial deposits occur in the valleys.

Heavy glaciation occurred in the Eastern Yukon, Central Yukon, and Kluane Sections resulting in till being the main material. In the Eastern Yukon Section, the till is mainly calcareous. Soil profile development in this material and in the valley alluvial deposits is limited. Peaty soils are extensively developed due to the widespread interruption of internal drainage by permafrost. In the Central Yukon Section, soil development is generally weak because of the youthfulness of the surface materials and the dry climate. Brown wooded soils are usual but grey wooded and degraded dark brown profiles also occur. Rooting depth of plants is affected in some areas by layers of volcanic ash and northward by permafrost. Soil profile development in the tills of the Kluane Section is limited.

Surface deposits in the unglaciated Dawson Section are mainly residual, due to breakdown in situ of the underlying Precambrian and Tertiary rock. There has been a significant accumulation of volcanic ash in some places and this apparently has some adverse effect on rooting of trees. Generally, the effects of parent material variations are overshadowed by the prevailing youthfulness of profile development. Some shallow, reddish-brown forest soils have been noted.

In the Interior Subalpine Section of the Subalpine Forest Region, the residual and glacial surface materials are variable in texture and composition. Soil development has also been variable in response to the wide range of local climatic conditions occurring in this mountainous region. Lithosols and shallow podzols are most frequent; brown wooded and brown podzolic profiles are less common.

PERMAFROST

The area under study comprising northern British Columbia, north of 56°N, and southern Yukon Territory, south of 65°N, is located in the discontinuous permafrost zone. In the Cordillera, however, the distribution of permafrost varies with elevation as well as latitude. The southern limit of permafrost shown on the map (Figure 22) marks approximately the boundary of permafrost occurrence at valley bottom levels. In the west, this boundary is located in the southwest corner of Yukon Territory. From here it tends in a southeasterly direction corresponding to the pattern of mean annual air isotherms to about 58°N in northeastern British Columbia.

In the southern fringe of the discontinuous zone lying north of this line, permafrost occurs in scattered patches varying in extent from less than 100 ft wide to several acres. The thickness of these patches varies from 1 to 2 ft at the southernmost extremity of the permafrost region to about 100 ft (approximate thickness at Aishihik, Y.T. estimated to be 50-100 ft). The northern portion of the area under study lies in the zone of widespread discontinuous permafrost. Permafrost varies in thickness from more than 100 ft (approximate thickness at Dawson, Y.T. estimated to be 200 ft) in the south to more than 500 ft at the north end of the Dempster Highway.

South of the boundary of permafrost occurrence at valley bottom levels, permafrost exists only at higher elevation. Throughout northern British Columbia, field observations indicate that the lower limit of permafrost is uniformly at about 4000 ft above sea level. Below this elevation, scattered permafrost islands occur only in specific types of terrain. Between 4000 ft and 6000 ft it appears that permafrost occurs in scattered patches, equivalent to the southern fringe of the discontinuous zone; between 6000 ft and 8000 ft permafrost is probably discontinuous but widespread; above 8000 ft it is probably continuous.

The mountainous relief causes local variations within the above described pattern. Permafrost is more widespread and thicker on north facing slopes than south facing slopes. In some valleys, permafrost occurs on north facing slopes but is absent on south facing slopes. The active layer is thinner on north facing slopes. Terrain factors such as vegetation and snow cover vary with slope and exposure; complicating further the distribution of permafrost.

The Alaska Highway and branch roads within the area under study are located almost entirely below an elevation of 4000 ft above sea level. The highest point is at Summit Lake, about Mile 390, where the Alaska Highway rises to an elevation of 4350 ft. Almost all field observations on this survey were made on the highways and thus reflect the permafrost conditions existing below the 4000 ft elevation. A few observations were made at mines at higher elevations.

Three stretches of highway extend south of the southern limit of permafrost shown in Figure 22: the Alaska Highway from Dawson Creek (Mile 0) north for about 150 miles, the Stewart-Cassiar Highway south of Cassiar for about 150 miles, and the Haines Highway. Along the Alaska Highway a few scattered patches of permafrost were encountered in peat bogs. The most southerly permafrost on the Alaska Highway was encountered at Mile 94.4 north of Dawson Creek (Location No. 5, Table I, Figure 3) where the permafrost is about 5 ft thick. Northward the next occurrence of permafrost, also in a peat bog, was found at Mile 153.0

north of Dawson Creek (Location No. 11, Table I) just about at the southern limit on the map. Permafrost was found at only one location on the Stewart-Cassiar Highway 154 miles south of the Alaska Highway (Location No. 122, Table I). No permafrost was encountered on the Haines Highway (Figure 23).

In the southern fringe of the discontinuous zone, permafrost in flat ground was restricted mostly to peat bogs. None was found in the relatively elevated stretches (high areas), which support tree growth consisting primarily of dense poplar and jack pine with tall spruce and some birch.

In the peat bogs occupying the depressions (low areas), the vegetation consists primarily of two associations:

1. Little or no tree growth; marsh sedge 1 to 2 ft high and thin moss, predominantly of the feather and other non-Sphagnum types; scattered patches of Sphagnum. These areas are almost always very wet.

2. Scattered, stunted black spruce and tamarack; thick, often very hummocky Sphagnum, scattered occasional patches of lichen; Labrador tea. Some of these areas are wet and some are fairly dry.

In the mountainous areas, most of the peat bogs are only a few hundred yards in extent, being confined by slopes. Peat bogs in river valleys and plateau areas are more extensive, covering several acres or square miles. South of Fort Nelson, the Alaska Highway traverses extensive peat bogs from about Mile 245 to Mile 285 (Location Nos. 35-46, Table I).

Permafrost is found frequently on north facing slopes supporting spruce and extensive moss cover but not on opposite south facing slopes where the tree growth is mainly deciduous and moss cover is patchy. For a distance of about 150 miles, the Alaska Highway is located on the north side of Liard River valley from Mile 483 in northern British Columbia to west of Watson Lake. No permafrost was reported along this section located on a south facing slope except at Leguil River, Mile 557-558, where it switches back onto a north facing slope. The vegetation on other north facing slopes along this section of the Alaska Highway is similar to Leguil River area and permafrost probably exists on these slopes. West of Whitehorse on the Alaska Highway, and on the Whitehorse-Mayo Highway north of Whitehorse, permafrost on north facing slopes is more widespread and thicker. Possibly it occurs on some south facing slopes where local vegetation or snow cover conditions favour its development.

High Areas

The terrain conditions encountered in high areas along the highways in the southern fringe of the discontinuous zone are similar to those of high areas near the southern limit of the permafrost region in the Prairie Provinces (1, 2). Elevations above the low areas ranged between a maximum of about 20 ft, with a considerable slope to the adjacent low areas, and less than 1 ft, with an almost imperceptible slope.

The tree species include jack pine, spruce, balsam, poplar and scattered birch varying in height from 40 to 80 ft. The stands are usually dense, trees averaging 2 to 5 ft apart. Undergrowth of willow and alder grows to a maximum height of about 10 ft. In rare cases, one or two tamarack were observed. Generally, the ground cover consists of forest litter with patches of feather moss, Sphagnum and lichen. Soils range from gravel to clay with stones and organic matter. The soils are frequently wet, the water table rising to within a few feet of the ground surface.

Numerous high areas, including those mentioned here, served as gravel and borrow pits during construction of the roads in the study area. No permafrost was encountered in subsurface investigations or in pits used for highway construction. The high area at Mile 500 on the Alaska Highway is typical (Figure 12).

Low Areas

Along the Alaska Highway in the southern fringe of the discontinuous zone between Dawson Creek (Mile 0) and Whitehorse (Mile 918), 84 low areas covering the range of terrain conditions were investigated for permafrost. They vary in extent from a few hundred feet to several miles. Several distinct associations of vegetation with related drainage occur in them.

Generally, the tree growth consists of stunted, scattered spruce varying in height from 2 to 20 ft, with occasional tamarack, willow, alder and ground birch. The ground surface vegetation is a mosaic of Sphagnum, feather and other mosses, Labrador tea and marsh sedge in various combinations. The micro-relief varies from flat to very hummocky. Individual hummocks vary to a maximum height of 3 ft and diameter of 4 ft. Variations in elevation from one association to another range through several feet. Peat plateaux rising 2 to 3 ft above the surrounding, poorly drained areas are prevalent. Surface and subsurface drainage is variable. Standing water is usually associated with marsh sedge areas and many of the lowest lying Sphagnum areas. The peat plateaux and individual hummocks are drier. Depth to the mineral soil (through the moss/lichen and peat) in 84 sites varied within wide limits from 2 in. to more than 7 ft, with an over-all average of 2 ft 4 in. This is considerably less than the average of 3 ft 9 in. encountered in Saskatchewan and Manitoba (2). The thickness of the peat exceeded 5 ft at only 8 sites.

As in the high areas, the mineral soil includes coarse and fine-grained materials. Silts and clays predominate and sand was not encountered south of Mile 274.8 (Location No. 42, Table I). Stony soils were found frequently, occurring at 30 of the 110 locations south of Whitehorse. Only 4 of the stony soil sites occurred south of Mile 274.8.

Permafrost was encountered in 46 of the 84 low sites examined. Sphagnum is a component of the ground cover at 37 of the permafrost sites and was absent from the other 9 permafrost sites. At the 38 sites with no permafrost, Sphagnum forms part of the ground cover at only 14 sites. Lichens (Cladonia sp. and Cetraria sp.) grow at 66 of the 84 low sites and were absent at the other 18 sites. In the 66 low sites where lichen was growing, permafrost was encountered in 41 sites and not in the remaining 25. In the 18 low sites where no lichen was growing, 5 had permafrost and 13 did not. These observations are presented in the following Table.

	Permafrost	No Permafrost
Sphagnum	37	14
No Sphagnum	9	24
Lichen	41	25
No Lichen	5	13

The depth of the permafrost table was determined at 51 locations. It occurred above the mineral soil in the peat in 40 of these locations. The average depth to permafrost of 51 determinations was 1 ft 11 in., and the minimum depth to the permafrost table encountered throughout the investigations was 1 ft 3 in. The maximum depths encountered were 3 ft 6 in. and 3 ft 9 in. The depth of the permafrost table at most of the sites was encountered between the 1 ft 6 in. depth and 2 ft 6 in. depth.

Permafrost thickness was determined at 22 sites. The thinnest permafrost encountered was 3 in. at Mile 882, about 50 miles southeast of Whitehorse (Location No. 108, Table I). The thickest permafrost that was penetrated occurred in a palsa* at Mile 254.5 about 55 miles south of Fort Nelson (Location No. 36, Table I, Figure 6). The permafrost is probably thicker than 14 ft at some other sites where subsurface observations were made. The position of the permafrost layer relative to the vertical position of the peat was examined at the 51 permafrost sites. At 6 of them, permafrost was confined to the peat layer; at another 6 the bottom of the permafrost layer coincided with the peat-mineral soil interface. Permafrost extended from peat into the mineral soil at 27 sites, and at 11 sites the permafrost layer occurred below the peat entirely in the mineral soil.

Ice was encountered in many of the holes advanced into permafrost. Much of it occurred in layers, the thickest about 1/4 in. It was found also in the form of small pellets and other random inclusions.

The relationship of permafrost occurrence to tree species was also noted. Jack pine was encountered in 12 of the low sites. Permafrost

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* A low hill or knoll of perennially frozen peat and mineral soil about 10 ft or less in height occurring in peatlands or peat bogs.

occurred in 2 of these but not in the remaining 10. Tamarack was encountered in 20 of the low sites with permafrost in 9 and not in the remaining 11.

Microrelief in the form of hummocks, peat plateaux, ridges and mounds rising to heights of 1 to 4 ft above the surrounding ground surface, was encountered at 63 of the low sites. Permafrost was encountered at 39 of these sites. The horizontal dimensions of the palsa at Mile 254.5 were not determined but it covered an area at least 100 ft square. The flat top of the palsa was about 4 ft above the surrounding bog surface, and was covered with a few tamarack, and dense spruce up to 30 ft high and 2 to 5 ft apart. The ground cover consisted of Sphagnum and other mosses, lichens and Labrador tea growing on hummocks 1 ft high. The peat was 7 ft 6 in. thick overlying blue-grey mottled clay. Depth to permafrost was 3 ft 9 in. and it was 14 ft thick. Ice occurred in 1/4-in. layers and nodules. The surrounding peat bog was wet, supporting a sparse growth of spruce, tamarack and ground birch with ground cover of sedge. Permafrost was absent here.

Permafrost conditions on the Alaska Highway south of Whitehorse are typified by the following observations:

<u>Location No. 28</u> (Alaska Highway - Mile 208.5) (Figure 5)

Soil Profile: 0 to 3 ft 4 in. - peat
below 3 ft 4 in. - silty clay
1 ft 4 in. to below 3 ft 4 in. - permafrost

<u>Location No. 48</u> (Alaska Highway - Mile 295) (Figure 8)

Soil Profile: 0 to 4 ft 8 in. - peat
4 ft 8 in. to 7 ft 9 in. - silty fine to medium sand with stones to 1/2-in. diameter.
2 ft 0 in. to below 7 ft 9 in. - permafrost

<u>Location No. 93</u> (Alaska Highway - Mile 788.5) (Figure 14)

Soil Profile: 0 to about 10 ft - peat
below 10 ft - clayey silt
1 ft 6 in. to below 4 ft 6 in. - permafrost

Extensive poorly drained low areas with no permafrost occur at several locations along the Alaska Highway. The tree growth is scattered but individual spruce trees are tall reaching as high as 60 ft. The ground cover consists of dense ground birch (Betula nana) because of the wet conditions, hummocky feather mosses, Labrador tea and scattered lichens. Sphagnum is absent. The peat layer is generally less than 1 ft and the underlying mineral soils range from fine grained to stony (Figures 4, 10, 13).

Air Photo Patterns

Vertical air photo coverage is available for the entire extent of the Alaska Highway and branch roads at a scale of 3333 ft: 1 in. (taken from an altitude of 20,000 ft). Examination of the air photographs reveals a great variety of patterns throughout the area under study because of the variations in relief, vegetation, soils and drainage. The patterns characteristic of the high and low areas were found to be similar to those encountered in the investigations carried out in the southern fringe of the discontinuous zone located in the Prairie Provinces (1, 2). Thus, the areas most probably containing permafrost - i.e. the low sites - can be delineated on the air photos and field investigations to verify its existence or absence can be concentrated in these locations.

The great variations in relief also contribute to variations in air photo patterns and permafrost distribution. Permafrost occurs most frequently on north facing slopes where the vegetation consists of spruce and moss cover. This association imparts a dark tone to these areas in contrast to south facing slopes which support mixed stands of spruce, jackpine and poplar producing a lighter tone and coarser texture on the photographs.

The most extensive section of low areas on the Alaska Highway occurs south of Fort Nelson between Mile 245 and Mile 285. Peat bogs are widespread with accompanying microrelief features such as plateaux, ridges, and mounds. Permafrost is found widely distributed in these features but is generally absent in the intervening depressions. A typical portion of this section is shown in Figure 24. Two main patterns are evident:

1. Dark grey to almost black tone with smooth to slightly grainy texture. This pattern occurs in scattered and coalescing circular

patches. These are peat plateaux covered with spruce and ground cover of hummocky Sphagnum, feather mosses, lichens and Labrador tea.

2. Medium to light grey tone with smooth to slightly grainy texture with scattered white blotches. This pattern occurs in irregularly shaped areas between the dark patches of Pattern 1. These patches are depressions between the peat plateaux covered with sedge and supporting scattered tamarack and ground birch.

Location No. 38, Table I at Mile 256.0 is typical of the terrain conditions described above on the selected air photo (Figure 7). The peat plateau supports spruce up to 25 ft high and scattered tamarack. The ground vegetation is hummocky Sphagnum, feather mosses, lichens and Labrador tea. The peat layer exceeds 7 ft in thickness overlying clayey soils. The permafrost table lies at a depth of 2 ft 0 in. and the permafrost layer is 3 ft thick. No permafrost exists in the depressions between the peat plateaux.

Sloping Areas

Along the Alaska Highway between Dawson Creek and Whitehorse, permafrost observations were carried out at 21 locations. Permafrost was encountered more frequently on north facing slopes than those facing other directions. Along this stretch of the highway extending through the southern fringe of the discontinuous zone, permafrost was absent in many north facing slopes. As a general rule, the peat layer was thicker on north facing slopes, varying from 0 ft 6 in. to 4 ft 6 in., than on slopes of other orientations where the maximum thickness encountered was 2 ft.

A typical situation where permafrost exists in a north facing slope but not in the opposite south facing slope is found in the Rocky Mountain section of the Alaska Highway at Mile 383.5 in the valley of the Tetsa River (Location No. 58, Table I, Figure 9). The north facing slope supports a dense tree growth of spruce up to 60 ft high with a few tamarack and poplar. The ground cover consists of Sphagnum and feather mosses, lichens, Labrador tea, grass, sedge and ground birch growing on hummocks 2 ft high. The peat layer is 4 ft 6 in. thick overlying stony soil. The permafrost table occurs at a depth of 1 ft 6 in. to 2 ft 0 in. and extends below the 4 ft 6 in. depth. The tree growth on the south facing slope is a mixture of spruce, poplar and jackpine. The peat layer is only about 1 ft thick overlying gravelly soil and no permafrost was encountered.

Another north facing slope was investigated at Mile 398.4 (Location No. 60, Table 1, Figure 11) where relocation of the road was necessary because of permafrost damage. The tree growth is dense spruce up to 35 ft high with a ground cover of Sphagnum, feather mosses, lichens and Labrador tea. The peat layer was 2 ft 2 in. overlying sandy to clayey silt with small stones. Permafrost was encountered at a depth of 2 ft 1 in. and extends below the 7 ft 6 in. depth containing layers of ice up to 1/16 in. thick.

The Atlin Highway and Carcross Highway branch southward from the Alaska Highway. No permafrost was encountered during the survey along these highways. The Department of Public Works, and the Territorial Government of Yukon Territory reported occurrences of permafrost encountered during construction. Permafrost was encountered between Mile 5.5 and 6.5 on the Atlin Highway on the slope below the road (Location No. 125, Table I). No permafrost was encountered above the road. On the Carcross Highway, permafrost was encountered during reconstruction of the road through a small stream valley at Mile 14 (Location No. 125, Table I).

Permafrost at High Elevation

The variations of permafrost distribution in response to changes in elevation have been noted previously. One illustration of this general pattern was observed at Cassiar, B.C. near 60°N where no permafrost occurs at the townsite, which is 3500 ft above sea level (Figure 25); just below 4500 ft, permafrost is patchy and above 4500 ft, it becomes widespread. It is encountered widely at the asbestos mine at the 6000 ft elevation.

Widespread Section of Discontinuous Permafrost Zone

North and west of Whitehorse on the Alaska Highway and its branch roads, permafrost becomes widespread and is encountered in other types of terrain besides those described in the southern fringe. Along the Alaska Highway no permafrost was encountered west of Whitehorse to about Mile 1113. Beyond here to the Alaska boundary, permafrost occurs widely in gravel flats, gravel banks and gravel pits.

The Department of Public Works conducted a gravel search between Mile 1150 and 1180 and encountered permafrost at all of the 19 locations investigated. A typical location is Mile 1170.7 shown in Figure 26. On the other hand, no permafrost was encountered between Mile 1202 and 1208 where the Alaska Highway extends for 6 miles along the top of a gravel ridge (Figure 27). Permafrost is found also in poorly drained depressions and low-lying areas such as at Mile 1127.5 (Location No. 113, Table I - Figure 28).

North of Whitehorse along the Whitehorse-Mayo Highway permafrost is found in various types of terrain. At Mile 35.7 north of Whitehorse (Location No. 127, Table I) permafrost was encountered in a southwest facing slope of fine grained soil overlooking Fox Lake. This slope supports tree growth of poplar, and dense spruce up to 50 ft high. Moss covers the ground surface overlying a layer of peat 1 ft thick. A road cut in the slope caused the permafrost to thaw. The melting of the large quantities of ice in the soil caused slumping and sliding (Figure 29).

Farther north at Mile 47 (Location No. 128) the road curves around the side of a spruce covered hill (Figure 30). The ground surface is covered with a continuous carpet of feather moss overlying a layer of peat 1 ft thick. The mineral soil is stony brown silt. No permafrost was encountered above the road but below the road the permafrost occurs at a depth of 1 ft, and extends below the 2 ft 6 in. depth. Layers of ice 1 to 2 in. thick occur in the perennially frozen soil.

At Mile 92 (Location No. 130), permafrost with ice layers were encountered in gravel in a stream valley on both sides of the creek. Permafrost occurs at a depth of 2 ft in a slope of silty sand overlying stony soil on which a high road fill has been placed (Figure 31). Spruce grow up to 30 ft high on a ground cover of feather mosses, lichens and Labrador tea. In 1962 a diagonal lens of ice 6 ft thick was encountered in a north facing slope in Tachun Creek valley at Mile 116 (Location No. 133). Between Mile 166 and 167, evidence of thawing of permafrost and slumping was observed in an area forested with dense spruce. Similar degradation of permafrost was noted in a west facing slope of gravelly stony soil supporting spruce, poplar and jackpine.

North of Stewart Crossing the highway crosses the Stewart River and extends northeastward along the north bank of the river to Mayo. Along this section of the highway located predominantly on south facing slopes, permafrost is rarely encountered (Figure 32). About 5 miles east of Stewart Crossing, observations on this south facing slope encountered no permafrost in silty gravel soil overlain by 6 in. of peat and feather moss on which spruce and poplar up to 60 ft high were growing (Location No. 137, Table I, Figure 33).

Near Mayo and along the road to Elsa, permafrost was encountered in wet depressions between peat plateaux. At Mile 232.7 (Location No. 138, Table I) near Mayo, the depressions support a vegetation of feather mosses, grass and sedge growing on medium stony sand. The depth to the permafrost table is 5 ft 6 in. (Figure 34).

At Elsa, elevation 3000 ft above sea level, permafrost is widespread. This mining community is situated on the valley slope of South McQuesten River, a tributary of McQuesten River flowing into the Stewart River. In the valley bottom at an elevation of 2300 ft above sea level, layers of permafrost interspersed with layers of unfrozen ground extend to a depth exceeding 140 ft (Figure 35).

Along the Dawson Highway between Stewart Crossing and the Alaska boundary, permafrost is widespread and occurs in most types of terrain as described in Appendix A. Mile 9 (Location No. 141, Table I) and Mile 52.8 (Location No. 143, Table I) are typical of situations where permafrost occurs in wet depressions and swampy areas. Generally the depth to the permafrost table is slightly greater in the swampy areas than in neighbouring peat plateaux. At Mile 9 the depth to the permafrost table in a peat plateau is 1 ft 9 in., in wet sedge areas 2 ft 7 in., and beneath a shallow pool of water, 3 ft 6 in. (Figure 36). At Mile 52.8 the depth of the permafrost table in the swampy valley of Collins Creek is 1 ft 6 in. (Figure 37).

At the town of Dawson, permafrost extends to a depth of about 200 ft. Thawing of the top layer of permafrost has caused severe settlement of some buildings (Figure 38). Permafrost occurs widely in the tributary valleys of Klondike River where placer gold mining in perennially frozen gravels has been taking place for several decades (Figure 39).

The thickest permafrost in the area under study is found along the Dempster Highway. In 1964 this road extended about 78 miles northeast of Dawson and will be constructed in the future to Fort McPherson, N. W. T., an additional distance of 200 miles. The road traverses dense spruce forest with peat bogs over the first 3 miles. Continuing up the valley of North Klondike River it rises into sparsely forested country and at Mile 44 it climbs over a pass into the headwaters of the Peel River system where it extends in a broad flat valley 4000 ft above sea level between mountains rising to 8000 ft. Northward the vegetation is arctic. Permafrost is virtually continuous, as described in Appendix A, and extends to depths of 500 or 1000 ft (Figure 40). At Mile 55 a few scattered polygonal trenches were observed. The depth to the permafrost table in the trenches was 1 ft 6 in. and in the ground near the trenches, 1 ft. Throughout this area, each valley has a terminal moraine consisting of well-drained coarse-grained soils with little vegetation cover. The active layer in these landforms is much greater than in the sedge and grass tundra on the plateau as shown in Figure 40.

DISCUSSION

The chief problem arising from permafrost investigations along the Alaska Highway and branch roads 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).

Southern Fringe of Discontinuous Permafrost Zone

The patchy distribution and thinness of permafrost in the study area south of Whitehorse is characteristic of the extreme southern fringe area of the discontinuous zone, where permafrost exists in a delicate thermal state close to 32°F. 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 much disagreement on this matter. In Canada the southern limit of permafrost, as known at present, coincides roughly with the 30°F 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 regime at the ground surface, which is influenced by these factors, and the snow cover cause the mean annual ground temperature measured at the level of zero annual amplitude to be several degrees warmer than the mean annual air temperature (17, 18).

The mean annual air temperature of stations in the southern portion of the area under study range from 32°F to 43°F. These stations are all situated below 2500 ft above sea level and permafrost does not occur at any of them. The location of the 30°F mean annual air isotherm is shown on Figure 15 and corresponds roughly with the southern limit of permafrost below the 4000 ft elevation. The stations in northern British Columbia - Beatton River, Fort Nelson and Dease Lake - have a mean annual air temperature of 30°F and are located approximately at the southern limit of permafrost. At these lower elevations in the Cordillera and the portion of the Interior Plains lying within the study area, permafrost conditions are similar to those encountered in the Prairie Provinces where mean annual air temperatures are comparable.

Between the 30°F and 25°F mean annual air isotherms fringe of the discontinuous zone permafrost occurs mostly in widely scattered patches in peat bogs, in heavily shaded areas, and in some north facing slopes. North of the 25°F isotherm, permafrost is widespread and found in most types of terrain.

In the southern fringe of the permafrost zone, permafrost can exist only in certain types of terrain described previously, provided the climate is sufficiently cool - i.e. mean annual air temperature 30°F 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. In the vicinity of the 25°F mean annual isotherm, the average difference of 6°F between the mean annual air and ground temperature produces a mean annual ground temperature of a fraction of a degree below 32°F in most types of terrain. From the 25°F 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 more important than terrain. Regardless of terrain conditions, permafrost will occur here, although variations in the terrain will cause variations in the depth to permafrost, its areal extent and thickness (19, 20).

The only available ground temperature observations are at Aishihik where the mean annual air temperature is 24.5°F. The mean annual ground temperature at the 20 ft depth is 28.3°F, only 4 F deg warmer. Below the 20 ft depth, at the level of zero annual amplitude, the mean annual ground temperature in the 50 to 100 ft thick permafrost is probably about 30°F or 31°F.

In previous investigations carried out in the Prairie Provinces, questions regarding the origin and persistence of permafrost and the factors governing development of various types of terrain were raised (1, 2). 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. The permafrost in north facing slopes apparently results from the reduction of solar radiation at the ground surface producing lower ground temperatures than in adjacent flat areas and south facing slopes. In forested stream banks, increased shading from summer thawing and possible reduction of snow cover enhance permafrost development. In peat bogs the thermal properties of the peat appear to determine the presence of permafrost.

The mechanism of permafrost formation in peat bogs appears to be related to changes in the thermal properties of the peat through the year. In the warm season, the surface layer of dry moss and peat with low thermal conductivity prevents warming of the underlying wet peat. During the cold season the peat becomes saturated at the surface and then freezes, greatly increasing its conductivity. The net ground heat gain tends to be reduced and the ground temperature decreased until the annual heat losses and heat gains are equal under steady state conditions. 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 throughout the year, permafrost results and is maintained as long as the thermal conditions leading to this lower temperature persist (21).

Other factors such as relief, drainage, and snow cover influence the ground thermal conditions and may be 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.

Consideration was given to the use of the various components of the environment as indicators of the presence of permafrost. Tree species by themselves cannot be employed as reliable indicators of permafrost. Most permafrost sites have Sphagnum and lichen but these species are unreliable indicators because they grow extensively in areas where permafrost does not exist. The type of soil does not appear to have any bearing on the existence of permafrost. Soil types range from gravel to clay in both the high and low areas, and it is rarely possible to determine them even from surface vegetation. The same type of permafrost and associated conditions prevail on all types of soil in relation to the vegetation, relief and drainage conditions.

No permafrost exists in the high areas; here the surface cover consists of forest litter with patches of feather moss, lichen and grass. These areas have good surface drainage, but frequently have high water tables. The ground vegetation does not appear to provide sufficient insulation to preserve permafrost, although there is not sufficient water in the soil to inhibit its formation.

Widespread Discontinuous Permafrost

North of the 25°F mean annual isotherm where permafrost becomes widespread, its occurrence is unpredictable because it is not restricted to a few types of terrain; however, it does not exist everywhere beneath the ground surface. Areas probably without permafrost are south facing slopes, areas of deep snow accumulation and low wet areas where bodies of water have been filled in recently. The type of soil is not a reliable indicator. Well-drained coarse-grained soils may be in a perennially frozen condition but the absence of ice belies the existence of temperatures below 32°F. Permafrost can only be detected in this situation by temperature measurements. Knowledge of the climatic history is important to ascertain whether existing bodies of permafrost are remnants of more widespread permafrost under cooler conditions. On the other hand, the climate may be cooling causing permafrost areas to enlarge. The changes, with time, in terrain factors are important because the complex interrelation of vegetation successions, changes in snowfall and drainage patterns all contribute to variations in the occurrence and extent of permafrost. It is impossible to be specific because the interrelation of factors changes from one area to another. Only direct field observations, keeping in mind the general possibilities, can reveal the permafrost situation in the northern part of the discontinuous zone.

Elevation and Slope

In the study area located in the Cordillera, a factor not encountered in the Prairie Provinces is elevation. Changes in permafrost distribution with elevation have been referred to previously. A paper published by the Soil Conservation Service, U.S. Department of Agriculture (22) makes some relevant comments. Differences in ground temperature related to elevation are relatively complex. With increased elevation, intensity of radiation increases, air temperature decreases, and rainfall and snow may vary erratically.

The mean annual air temperature tends to decrease about 2.7 F deg per 1000 ft increase in elevation of the earth's surface. (An average value of 3.3 F deg is commonly stated in texts on weather and climate). The temperature reduction with elevation is greatest in summer when it averages about 3.6 F deg per 1000 ft; in winter it averages only 2.2 F deg per 1000 ft.

The difference between air and ground temperature increases with elevation because of increased radiation and increased snow cover. Ground temperature may not decrease as much as air temperature.

Changes of ground temperature with elevation are complicated by slope orientation and steepness. There are few observations on the relation of slope gradient and direction to mean annual ground temperature. Investigations have been made in the United States of mean annual ground and air temperatures of north and south facing slopes. Over the year in a deciduous forest in New Jersey, the ground at a depth of 4 m on a 20° south facing slope was 4.8 F deg warmer than that on the 20° north facing slope. The air 5 cm above the soil was 6 F deg warmer on the south than on the north facing slope; 1 metre above the soil it was 1.7 F deg warmer, but at a height of 2 metres there was virtually no difference. At another site in California the mean annual soil temperature just below the surface under grass was 6.4 F deg warmer on a 20-30 per cent south facing slope than on a similar north facing slope. Only fragmentary data are available from high latitudes to indicate the importance of slope aspect and steepness on mean annual ground temperatures. Observations in the Matanuska Valley, Alaska, indicate that the situation is similar to temperate latitudes.

These few observations make it possible to estimate permafrost distribution in the Cordillera. Using the mean annual air temperature of available meteorological stations and an assumed decrease in this temperature of about 3 F deg per 1000 ft, the vertical distribution of permafrost in neighbouring mountains based on air temperatures can be surmised.

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. South of the 30°F isotherm permafrost occurrences are rare. Between the 30°F and 25°F isotherms, permafrost is patchy and restricted to certain types of terrain. North of the 25°F isotherm permafrost is widespread. In mountainous regions the same changes occur with increase in elevation. This general situation is complicated to some extent by variations in slope orientation and steepness.

The distribution of permafrost along the Alaska Highway between Dawson Creek, B.C. and Whitehorse, Y.T. is patchy and erratic, All observations were made on the highways and thus reflect the permafrost conditions below the 4000 ft elevation. A few observations were made at mines at higher elevations. Along the highway, permafrost occurs in some north facing slopes and in low areas but it is not found in the high areas. It does not exist where marsh sedge is growing and water lies at or near the ground surface; it is restricted to Sphagnum areas that are not wet. Drainage, therefore, appears to be one of the main terrain factors influencing the existence of permafrost, but drainage conditions are so closely interrelated with vegetation that it is difficult or virtually impossible to assess the contribution of each separately. Only a few scattered patches of permafrost were found on the branch roads extending south of the Alaska Highway.

North and west of Whitehorse, permafrost becomes more widespread and occurs in various types of terrain. It is found not only in peat bogs and north facing slopes, but also in high areas consisting of mineral soil, and in south facing slopes. The thickness of permafrost varies from 100 ft or more between Whitehorse and Dawson to probably more than 1000 ft at the north end of the Dempster Highway. The prediction of permafrost conditions is particularly difficult in this widespread part of the discontinuous zone because permafrost is not restricted to particular types of terrain nor is it found everywhere. The variations imposed by elevation in this mountainous region further complicate the situation.

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TITLES OF COLUMNS AND EXPLANATION OF SYMBOLS IN TABLE I

Column 1 - Reference number of observation point

Listed in numerical order beginning with southern end of Alaska Highway and progressing northwest to Yukon-Alaska boundary, followed by branch roads.

Column 2 - Location of observation point

Number of miles from beginning of road.

Column 3 - Relief

H - relatively elevated area.
L - relatively low area or depression
S - sloping
- subscripts:
  - n - north facing slope
  - e - east facing slope
  - s - south facing slope
  - w - west facing slope.

V - river or stream valley.

Column 4 - Tree species

P -	poplar	A -	alder
J -	jack pine	* -	number of brackets is height in feet of tallest trees.
S -	spruce		
T -	tamarack	(b) -	burned over.
W -	willow	No -	treeless.

Column 5 - Surface terrain features

Sph - Sphagnum
M - moss other than Sphagnum
Ln - lichen
Lt - Labrador tea
Se - sedge
G - grass
B - ground birch
H - hummocky
(p) - peat plateau

<u>Column 6</u> - <u>Thickness of living ground vegetation and peat</u>

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

<u>Column 7</u> - <u>Soil type</u>

G - gravel
Sa - sand
Si - silt
C - clay
x - scattered stones
O - organic
(w) - standing water or wet

<u>Column 8</u> - <u>Existence of permafrost</u>

<u>Column 9</u> - <u>Depth to permafrost</u>

<u>Column 10</u> - <u>Thickness of permafrost</u>

<u>Column 11</u> - <u>Figure number of photograph in report</u>

TABLE I

PERMAFROST SURVEY

1	2	3	4	5	6	7	8	9	10	11
ALASKA HIGHWAY										
British Columbia										
1	28.8	L	No S(20)	Se HMSphLnLt	3 ft 6 in.	CSi	No			
2	87.9	S_s	SP(20)	MG	0 ft 3 in.	SiC(w)	No			
3	90.1	L	S(30)J	MLnGLt	0 ft 2 in.		No			
4	92.5	L	S(40)	MG		- (w)	No			
5	94.4	L	S(15)AW	HMSphLnLt	3 ft 3 in.	SiCx	Yes	1 ft 9 in.	5 ft 9 in.	Fig. 3
6	128.1	L	S(15)	BHMGLt	0 ft 6 in.		No			
7	134.3	L	S(30)J	HMLnLt	3 ft 0 in.	SiC	No			
8	143.9	L	S(20)	HMLnLt	0 ft 6 in.	SiC	No			
9	148.5	L	S(30)	BHMLnLt	0 ft 6 in.		No			Fig. 4
10	151.4	L	S(15)	HMSphLnLt	2 ft 6 in.	SiC(w)	No			
11	153	L	S(15)	HMSphLnLt	2 ft 0 in.	SiC	Yes	2 ft 6 in.	>1 ft 0 in.	
				BHMGSe	1 ft 6 in.		No			
12	153.8	L	S(15)	BHMGSe	1 ft 3 in.		No			
13	154.7	L	S(30)	HMLnLtG	1 ft 9 in.	SiC	Yes	2 ft 0 in.	>4 ft 3 in.	
14	169.2	L	S(20)JP	HMSph LnLtGSe	1 ft 3 in.	SiC(w)	No			
15	170.4	S_n	SJ(40)	HMLnLt	0 ft 6 in.	SiCx(w)	No			
16	173	L	S(20)	HMSphLnLt	2 ft 3 in.	SiCx	Yes	2 ft 0 in.	4 ft 6 in.	
17	176.1	S	S(20)	MLtGSe	0 ft 6 in.	OSi(w)	No			
18	178	L	S(25)	BMLnLtGSe	1 ft 0 in.	SiC(w)	No			
			S(30)	HMLnLt	1 ft 6 in.	SiC	Yes	2 ft 0 in.	>4 ft 6 in.	
19	182.9	L	S(30)	HMSphLnLt	1 ft 3 in.	SiCx(w)	No			
20	187.2	L	S(20)	HMSphLnLt	4 ft 0 in.	CSi	Yes	1 ft 6 in.	2 ft 6 in.	
					0 ft 6 in.		No			
					1 ft 6 in.	OSi	Yes	3 ft 6 in.	>1 ft 6 in.	
21	194.5	L	SJ(20)	HMLnLt	0 ft 3 in.	CSix	No			
22	197.9	L	S(25)	HMSphLnLtGSe	5 ft 4 in.	SiC	Yes	1 ft 4 in.	1 ft 11 in.	
23	199.9	S_n	S(20)	HMSphLnLt	1 ft 0 in.	SiC	Yes	1 ft 6 in.	7 ft 6 in.	
24	202.5	L	S(20)	HMSphLnLtGSe	1 ft 0 in.	SiC(w)	No			

TABLE I (Cont'd)

1	2	3	4	5	6	7	8	9	10	11
25	204.6	L	S(20)	HMSphLnLtGSe	3 ft 7 in.	SiC	Yes	2 ft 0 in.	>4 ft 0 in.	
26	206.4	L	S(25)JP	HMSphLnLtGSe	2 ft 4 in.	SiC	Yes	1 ft 3 in.	>1 ft 1 in.	
27	207.5	L	S(20)T	HMSphLtGSe	1 ft 0 in.	SiC(w)	No			
28	208.5	L	S(10)(b)	HMSphLnLt	3 ft 4 in.	SiC	Yes	1 ft 4 in.	>2 ft 2 in.	Fig. 5
29	214.1	L	S(20)P	HSphMLnLt	3 ft 6 in.	CSi	Yes	2 ft 0 in.	1 ft 6 in.	
					5 ft 0 in.			1 ft 9 in.	3 ft 3 in.	
30	219.6	L	S(30)JP(b)	HMSphLt	3 ft 6 in.	SiC	Yes	1 ft 9 in.	1 ft 9 in.	
31	230	L	S(2)	BHSphMLtGSe	3 ft 6 in.	SiC(w)	No			
			S(30)	HSphMLt		SiC	Yes	1 ft 9 in.	1 ft 7 in.	
32	241.3	L	S(15)	HSphMLnLt	2 ft 9 in.	SiC	Yes	2 ft 3 in.	3 ft 3 in.	
33	242.8	L	ST(30)	SphMLnLt	4 ft 3 in.	SiC	Yes	2 ft 3 in.	4 ft 9 in.	
34	246.9	L	S	M			No			
35	249.6	L	S	Sph	>2 ft 6 in.	Si	Yes	1 ft 10 in.	>0 ft 6 in.	
36	254.5	L	S(30)T	MSphLnLt(p)	7 ft 6 in.	C	Yes	3 ft 9 in.	14 ft 3 in.	Fig. 6
			No	BSe(w)			No			
37	254.9	L	S(40)JPT	M	0 ft 2 in.	SiC	No			
38	256	L	S(25)T	HSphMLnLt(p)	>7 ft 0 in.	C	Yes	2 ft 0 in.	3 ft 0 in.	Fig. 7
39	260.4	L	S(25)	HSphMLnLt	3 ft 9 in.	C	Yes	1 ft 6 in.	2 ft 3 in.	
40	262.5	L	S	Sph			Yes			
41	266	L	S(20)	HSphMLnLt	2 ft 9 in.	C	Yes	1 ft 10 in.	0 ft 11 in.	
					3 ft 3 in.			2 ft 0 in.	3 ft 0 in.	
42	274.8	L	S(20)	HMSphLnLt	2 ft 6 in.	SaSix	Yes	1 ft 5 in.	>4 ft 9 in.	
43	275.7	L	S	Sph			Yes			
44	277.9	L	S(15)	HSphMLnLt	4 ft 6 in.	SaSix	Yes	1 ft 9 in.	>3 ft 9 in.	
45	280.1	L	ST(30)	HMLnLt	0 ft 3 in.	CSix	No			
46	286	L	S(25)	HSphMLnLt(p)	7 ft 0 in.	C	Yes	1 ft 9 in.	5 ft 1 in.	
				HSphMLnLt	4 ft 0 in.		No			
47	289.2	L	ST(40)	HSphMLnLt	1 ft 0 in.	CSi	No			
			No	GSe						
48	295	L	S(25)T	MSphLnLt	4 ft 8 in.	SiSax	Yes	2 ft 0 in.	>5 ft 9 in.	Fig. 8
			PWA							
49	323.3	L	TS				No			
50	330.2	L	S(30)T	HSphMLnLt	4 ft 0 in.	SiC	Yes	2 ft 3 in.	2 ft 3 in.	
51	331.2	L	S(30)A	BHSphMLnLt	1 ft 6 in.	SiC(w)	No			
52	332.5	L	S(40)	BHSphMLnLt	4 ft 0 in.	SiC	Yes	1 ft 11 in.	1 ft 10 in.	
53	339.9	L	ST(35)A	BHSphMLnLt	2 ft 0 in.	SiC(w)	No			
54	341.3	L	ST(15)	HSphMLnLt	2 ft 9 in.	C	Yes	1 ft 6 in.	>8 ft 9 in.	
55	359.9	S	S(40)P	MLnLt	0 ft 6 in.	SiCx(w)	No			

TABLE I (Cont'd)

1	2	3	4	5	6	7	8	9	10	11
56	364.5	L	S(35)T	BHSphMLnLt	3 ft 0 in.	SiSaC	Yes	2 ft 0 in.	>3 ft 6 in.	
57	368	L	S(40)T	BSphMLnLt	1 ft 6 in.	SiC(w)	No			
58	383.5	S_n	S(60)TP	BHSphMLnLtGSe	4 ft 6 in.	x	Yes	1 ft 9 in.	>3 ft 0 in.	
		S_s	SPJ			G	No			Fig. 9
59	394.5	S	S(60)	BHMLnLtG	0 ft 6 in.	x	No			Fig. 10
60	398.4	S	S(35)	HSphMLnLt	2 ft 2 in.	SaSiCx	Yes	2 ft 1 in.	>5 ft 5 in.	Fig. 11
61	400.5	L	S(20)	HMSphLnLtGSe (p)	4 ft 0 in.	SaSix	Yes	2 ft 0 in.	>3 ft 3 in.	
62	403.8	L	S(40)	HMSphLnLt	2 ft 6 in.	OSaSi	Yes	2 ft 0 in.	>2 ft 0 in.	
63	408.1	L	S(25)	HMSphLt	1 ft 0 in.	SaSi	No			
64	434.8	S_n	S(30)	HMLnLt	0 ft 8 in.	Sax	No			
65	474.1	S_n	SJ(25)	HMLnLt	0 ft 8 in.	CSi	No			
66	478.1	S_n	S(40)	HMLt	1 ft 6 in.	SiCx	No			
67	479	S_e	S(25)	HMLtLn	0 ft 6 in.	SaSix	No			
68	486.3						No			
69	488.5	L	ST(40)	HM			No			
70	546.5	L	S(50)T	HMLnLt	0 ft 9 in.	OSix	No			
71	557.8	S_n	S(35)	HMSph	3 ft 6 in.	x	Yes	1 ft 9 in.	>1 ft 9in.	
72	561.8	S_w	S(40)T	HMLnLt	1 ft 0 in.	SiSa	No			
73	562	L	S(40)	HMSphLnLt(p)	0 ft 10 in.	SaSi	Yes	1 ft 9 in.	>0 ft 9 in.	
			No	Se			No			
74	573	L	S(40)TJ	MLn	0 ft 6 in.	SiSa	No			
75	579.1	L	S(30)	HSphMLnLt(p)	1 ft 4 in.	SaSix	Yes	1 ft 6 in.	>4 ft 0 in.	
76	586.3	L	S(40)	HMLnLt	0 ft 2 in.	Sa	No			
77	587.6	L	S(40)A	HMLnLt	2 ft 3 in.	OSi	No			
78	597.5	L	S(45)T	HSphMLnLt(p)	4 ft 6 in.	x	Yes	1 ft 9 in.	>2 ft 9 in.	
79	603.3						No			
80	617	L	S(40)T	HMSphLnLt	0 ft 3 in.	SaSix	No			
				Yukon Territory						
81	627	L	S(40)	HMLnLt	3 ft 0 in.	Sa	No			
82	657.8	S					Yes			
83	681.1	L	S(50)T	HMSphLnLt	2 ft 2 in.	SiSax	Yes	1 ft 9 in.	0 ft 9 in.	
				HMGSe			No			
84	682.4						No			
85	731	L	S(40)	B			No			Fig. 13

TABLE I (Cont'd)

1	2	3	4	5	6	7	8	9	10	11
86	758.1		S			(w)	No			
87	762.4	L	S(b)	HMLtG	0 ft 9 in.	(w)	No			
88	771.6	L	S(50)J	HMLnLt	0 ft 9 in.	SiSax	No			
89	774	L	S(40)J	HMLnLt	0 ft 6 in.		No			
90	775.2	L	S	HSphMLnLt	1 ft 0 in.		No			
91	776.5	S	S	HSphMLnLt	1 ft 0 in.	GSa	No			
92	785.1						No			
93	788.5	L	S(40)	HMSphLnLt(p)	>4 ft 6 in.	CSi	Yes	1 ft 6 in.	>3 ft 0 in.	
				SeGMSph	6 ft 9 in.	CSi(w)	No			Fig. 14
94	794.8	L	S(50)	MLnLt	2 ft 0 in.	CSix	Yes	1 ft 6 in.	>2 ft 8 in.	
95	802.5	L	S(60)	MLnLtG	5 ft 0 in.	SiSax	Yes	2 ft 3 in.	>3 ft 3 in.	
96	803.3	L	S(40)	MLnLtG	3 ft 0 in.	x	Yes	2 ft 3 in.	>0 ft 9 in.	
97	807.3	L	S(50)	HMLnLt	1 ft 0 in.	SiSa	Yes	2 ft 4 in.	1 ft 0 in.	
				MLnLtGSe			No			
98	814	S	S	HMLnLt	2 ft 0 in.	CSix	No			
99	819.1	L	S(60)	MLnLt	1 ft 10 in.	SaSix	Yes	2 ft 0 in.	>1 ft 7 in.	
100	825.2	L	S(50)AW	HMLnLt	1 ft 6 in.	SiSax	Yes	1 ft 7 in.	>1 ft 7 in.	
101	828.8	S	S(40)AW	HMLnLt	1 ft 0 in.	SaSi	Yes	1 ft 10 in.	>5 ft 8 in.	
102	834	L	SJ(40)	MLnLt	0 ft 2 in.	Si	No			
103	844.1	L	S(50)AW	MLnLt	2 ft 0 in.	Sax	Yes	1 ft 7 in.	>0 ft 8 in.	
104	849	L	SJ(50)P	HMLt	0 ft 2 in.	CSi	No			
105	849.8	S	SPJ				No			
106	854	L	S			Si	No			
107	863.6	S_s	S	HMLn			Yes			
108	882	S	S(30)	HMLt	2 ft 0 in.	SaSi	Yes	1 ft 10 in.	0 ft 3 in.	
109	886.5	L	S(50)	HMLt	0 ft 3 in.	CSi	No			
110	891.5	L	S(40)	MGSe	0 ft 5 in.	- (w)	No			
111	1034	L	S(50)	BGSe		x	No			
112	1113					G	Yes			
113	1127.5	L	S	(p)			Yes			Fig. 28
				GSe						
114	1196	L	S							
115	1202 - 1208	H	SP(50)			G	No			Fig. 27
116	1210					SiSax	Yes	2 ft 0 in.	20 ft 0 in.	
117	1217	S	S(50)PW	MLtG			Yes	2 ft 6 in.		

TABLE I (Cont'd)

1	2	3	4	5	6	7	8	9	10	11
118	1223	L	S(5)W	GSe		(w)	Yes	2 ft 0 in.		
119	1250	L	S(10)(b)	HSphMLtSe	>2 ft 0 in.	(w)	Yes	2 ft 0 in.		
				STEWART-CASSIAR HIGHWAY						
120	0-55		JSP	M		G	No			
121	135	S_s	SJ(80)		0 ft 9 in.	CSix	No			
		S_n	S(50)AP	MLnLt						
122	154	L	S(25)A	BHSphMLnLt	2 ft 0 in.	x	Yes	1 ft 9 in.	0 ft 2 in.	
123	156-189		S	BMSe		G(w)	No			
124	189	S_n	S	MSph	1 ft 6 in.	SiCx(w)	No			
				ATLIN HIGHWAY						
125	0-60		JSP(b)			SaG	No			
			SWA	B	1 ft 0 in.	SaG(w)				
				CARCROSS HIGHWAY						
126						SaG	No			
				WHITEHORSE-MAYO HIGHWAY						
127	35.7	S	S(50)P	M	1 ft 0 in.	CSi	Yes			Fig. 29
128	47	S	S(50)	M	1 ft 0 in.	Six	Yes	1 ft 0 in.		Fig. 30
129	50-90		S(b)	G		G	No			
130	92	V		M		G	Yes			Fig. 31
131	109	S	S(30)	MLnLt	0 ft 9 in.	SiSax	Yes	2 ft 0 in.		
132	114	S	S(20)			GC	Yes			
133	116	S_n	S	M			Yes			
134	158	L	S(50)	MLnLt	1 ft 6 in.	SaSi	Yes	1 ft 6 in.		
135	166-167		S				Yes			
136	197	S_w	SPJ			Gx	Yes			
137	213-243	S_s	SP(60)	M	0 ft 6 in.	SiG	No			Fig. 33
138	232.7	L	S(25)	HSphMLnLt(p)	5 ft 0 in.	Sax (w)	Yes	1 ft 6 in.		
			No	MGSe				5 ft 6 in.		Fig. 34

TABLE I (Cont'd)

1	2	3	4	5	6	7	8	9	10	11
139	251	S_n	S(40)	M	0 ft 9 in.	Sax	No			
140	257	L	S(30)	HSphMLnLt(p)	5 ft 0 in.	x	Yes	1 ft 6 in.		
			No	GSe			No			
				DAWSON HIGHWAY						
141	9	L	S(30)	HSphMLt(p)	>3 ft 6 in.	- (w)	Yes	1 ft 9 in.		
				MSe				2 ft 7 in.		Fig.36
142	20.5	L	P(15)WA	GM	0 ft 3 in.	SiSax	No			
			(b)							Fig.37
143	52.8	V	S(30)W	GSe	1 ft 6 in.	OSi	Yes	3 ft 6 in.		
144	54	H	P(25)S			Sax	No			
				DEMPSTER HIGHWAY						
145	0-78						Yes			Fig.40
				HAINES HIGHWAY						
146	0-159						No			Fig.23
147	103.2	S					No			
148	117.5	S					No			
149	132	S	S(30)W	BHMSphLt	1 ft 9 in.	Six	No			

LATITUDES, LONGITUDES AND ELEVATIONS (FT) IN TABLES II-VI

Station	Latitude	Longitude	Elevation (ft)
British Columbia			
1. Alice Arm	55° 41'N	129° 30'W	1031
2. Atlin	59° 35'N	133° 39'W	2200
3. Babine	55° 19'N	126° 37'W	2360
4. Baldonnel	56° 14'N	120° 50'W	2500
5. Beatton River	57° 23'N	121° 23'W	2755
6. Dawson Creek	55° 45'N	120° 13'W	2200
7. Dease Lake	58° 25'N	130° 00'W	2678
8. Fort Nelson	58° 50'N	122° 35'W	1230
9. Fort St. John	56° 15'N	120° 50'W	2210
10. Germansen Landing	55° 47'N	124° 42'W	2450
11. Hudson Hope	56° 05'N	121° 55'W	1606
12. New Hazelton	55° 14'N	127° 36'W	1030
13. Smith River	59° 54'N	126° 26'W	2208
14. Stewart	55° 56'N	130° 00'W	10
15. Telegraph Creek	57° 54'N	131° 10'W	600
Yukon Territory			
1. Aishihik	61° 39'N	137° 29'W	3170
2. Carcross	60° 11'N	134° 40'W	2200
3. Carmacks	62° 06'N	136° 18'W	1710
4. Dawson	64° 04'N	139° 26'W	1062
5. Elsa	63° 55'N	135° 29'W	3000
6. Fort Selkirk	62° 49'N	137° 22'W	1490
7. Frances Lake	61° 17'N	129° 24'W	2425
8. Haines Junction	60° 46'N	137° 35'W	1960
9. Mayo	63° 36'N	135° 53'W	1625
10. Snag	62° 22'N	140° 24'W	1925
11. Teslin	60° 10'N	132° 45'W	2300
12. Watson Lake	60° 07'N	128° 49'W	2248
13. Whitehorse	60° 43'N	135° 04'W	2289

TABLE II

MONTHLY AVERAGE OF DAILY MEAN AIR TEMPERATURES (°F)

British Columbia	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1. Alice Arm	23.8	26.1	31.7	39.4	46.0	53.4	57.0	56.4	50.4	41.3	31.6	26.6	40.1
2. Atlin	8.6	10.7	20.5	34.2	43.8	51.2	53.5	53.2	46.6	37.3	22.9	11.7	32.8
3. Babine	9.8	14.8	24.6	34.5	44.8	51.2	54.9	53.9	47.2	37.4	25.0	14.5	34.0
4. Baldonnel	3.6	10.4	21.5	37.7	50.1	55.9	60.1	57.9	49.9	38.7	21.1	8.7	34.6
5. Beatton River	-3.2	4.4	16.7	30.4	46.0	52.9	57.3	54.3	46.3	33.6	15.9	2.8	29.8
6. Dawson Creek	4.5	10.5	19.0	35.2	48.4	54.6	59.2	56.8	48.6	38.9	23.7	10.0	34.1
7. Dease Lake	-2.3	6.9	19.2	31.6	44.4	51.8	55.1	52.9	45.9	34.2	18.6	5.1	30.3
8. Fort Nelson	-8.4	0.4	16.3	34.7	50.0	57.8	62.2	58.5	48.8	34.1	10.2	-4.8	30.0
9. Fort St. John	4.2	10.6	22.1	38.0	50.6	56.5	61.1	58.8	50.8	39.7	21.6	9.0	35.3
10. Germansen Landing	0.7	12.9	22.3	34.6	45.4	52.2	57.1	54.5	47.0	34.6	20.1	9.3	32.6
11. Hudson Hope	7.6	12.0	22.5	38.3	49.6	56.0	60.0	58.6	49.1	39.7	21.8	7.0	35.2
12. New Hazelton	15.7	22.4	32.2	41.1	49.7	55.6	58.5	57.7	50.4	41.1	30.2	20.8	39.6
13. Smith River	-11.4	-0.5	14.6	29.8	45.2	53.6	57.3	53.7	44.8	30.5	9.7	-5.9	26.8
14. Stewart	24.1	27.2	33.6	40.5	49.5	55.3	57.3	56.2	50.6	41.8	33.0	26.4	41.3
15. Telegraph Creek	4.2	13.3	27.0	38.3	49.7	57.0	60.4	58.6	51.6	39.9	22.4	11.4	36.2
Yukon Territory													
1. Aishihik	-6.2	0.4	10.4	24.1	40.5	50.2	53.5	49.8	40.9	26.3	8.4	-4.1	24.5
2. Carcross	-2.0	4.0	16.0	30.0	42.0	51.0	55.0	52.0	45.0	34.0	18.0	6.0	29.0
3. Carmacks	-12.0	-5.0	14.0	30.0	47.0	55.0	59.0	54.0	43.0	29.0	2.0	-9.0	26.0
4. Dawson	-17.6	-11.1	5.7	29.4	46.6	56.9	59.8	54.5	43.5	26.4	2.5	-12.9	23.6
5. Elsa	-10.6	-3.4	8.4	25.5	43.1	54.9	56.9	49.7	39.9	21.5	6.6	-3.3	24.2
6. Fort Selkirk	-20.3	-8.2	7.6	31.0	45.5	55.3	58.7	54.2	43.1	24.4	5.9	-16.2	23.4
7. Frances Lake	-3.0	0.0	15.0	28.0	45.0	54.0	57.0	53.0	44.0	33.0	11.0	-4.0	28.0
8. Haines Junction	-5.6	2.0	15.9	29.4	42.1	50.8	53.8	50.6	42.4	28.2	10.9	-2.6	26.4
9. Mayo	-13.3	-5.5	11.3	31.0	46.3	55.7	58.4	53.4	43.4	28.4	5.2	-10.0	25.4
10. Snag	-18.5	-8.7	7.7	26.6	44.6	54.0	57.0	52.2	41.1	22.0	-1.0	-16.3	21.7
11. Teslin	-3.0	4.8	17.9	30.3	43.6	53.0	56.2	52.8	45.1	32.9	17.6	4.2	29.6
12. Watson Lake	-11.5	-1.5	14.0	31.3	45.9	55.7	59.1	55.3	46.3	32.3	9.2	-7.4	27.4
13. Whitehorse	-0.6	6.7	18.3	31.7	45.5	54.6	57.5	54.3	46.3	33.3	17.2	4.9	30.8

TABLE III

AVERAGE MONTHLY PRECIPITATION (IN.)

British Columbia	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1. Alice Arm	7.29	6.78	6.57	4.76	2.91	2.86	2.77	4.92	6.86	12.84	9.43	12.06	80.05
2. Atlin	1.27	0.63	0.46	0.24	0.34	0.88	1.17	0.95	1.06	1.85	1.28	0.82	10.95
3. Babine	2.47	1.73	1.36	1.14	1.53	2.11	1.95	1.49	1.81	2.52	2.64	2.41	23.16
4. Baldonnel	1.02	0.96	0.95	0.80	1.41	2.56	2.62	1.96	1.36	1.21	1.30	1.09	17.24
5. Beatton River	0.89	1.12	0.94	1.03	1.68	2.45	2.83	1.72	1.05	0.97	0.95	0.98	16.61
6. Dawson Creek	1.27	1.27	1.20	0.64	1.73	2.84	2.46	1.85	1.28	1.43	1.11	1.17	18.25
7. Dease Lake	1.15	0.94	0.91	0.42	0.71	1.48	2.13	2.11	1.53	1.33	1.23	1.31	15.25
8. Fort Nelson	0.95	1.04	1.02	0.74	1.54	2.60	2.56	1.99	1.34	1.01	1.23	1.11	17.13
9. Fort St. John	1.22	1.16	1.04	0.90	1.21	2.36	2.52	2.20	1.12	1.21	1.19	1.29	17.42
10. Germansen Landing	2.46	1.35	1.29	1.38	0.87	2.25	1.87	2.28	1.18	1.75	2.15	2.25	21.08
11. Hudson Hope	0.85	0.69	0.95	0.95	1.47	2.83	2.54	1.87	2.26	1.18	1.32	0.90	17.81
12. New Hazelton	1.47	1.07	0.72	0.75	1.17	2.06	2.02	1.69	2.24	2.24	2.01	1.73	19.17
13. Smith River	1.35	1.15	0.94	0.73	1.12	2.38	2.70	1.87	1.46	1.54	1.50	1.54	18.28
14. Stewart	7.70	5.19	4.77	3.85	2.69	2.55	3.43	4.37	6.86	12.22	9.15	8.14	70.92
15. Telegraph Creek	1.38	0.93	0.64	0.37	0.35	0.71	1.18	1.26	1.45	1.96	1.12	1.24	12.59
Yukon Territory													
1. Aishihik	0.51	0.41	0.50	0.35	0.83	1.50	1.75	1.63	0.77	0.55	0.61	0.47	9.88
2. Carcross	0.61	0.91	0.47	0.22	0.43	0.83	1.04	0.85	1.07	0.94	0.92	0.67	8.96
3. Carmacks	0.60	0.63	0.29	0.11	0.66	1.66	2.02	0.60	1.09	0.88	0.67	0.61	9.82
4. Dawson	0.81	0.55	0.52	0.31	0.97	1.28	1.98	1.94	1.22	1.09	1.05	0.95	12.67
5. Elsa	0.69	0.70	0.54	0.55	0.89	1.30	2.48	2.53	1.61	1.19	1.52	1.27	15.27
6. Fort Selkirk	0.79	0.55	0.44	0.21	0.68	1.20	1.95	1.72	0.72	0.60	1.08	0.93	10.87
7. Frances Lake	1.98	1.11	0.70	0.56	0.72	1.90	1.95	1.35	1.60	1.39	1.50	1.57	15.83
8. Haines Junction	0.73	0.45	0.37	0.26	0.46	1.07	1.36	1.07	1.08	1.25	1.43	1.41	10.94
9. Mayo	0.74	0.48	0.40	0.25	0.81	1.25	1.66	1.77	1.10	1.00	0.91	0.79	11.16
10. Snag	0.89	0.67	0.55	0.59	1.11	2.07	2.76	2.00	1.09	0.71	0.86	0.77	14.07
11. Teslin	1.08	0.71	0.77	0.50	0.67	1.12	1.43	1.44	1.37	1.20	1.22	1.23	12.74
12. Watson Lake	1.41	1.07	0.94	0.68	0.98	1.92	2.04	1.68	1.52	1.41	1.63	1.70	16.98
13. Whitehorse	0.70	0.56	0.59	0.43	0.50	1.06	1.36	1.44	0.98	0.73	0.91	0.79	10.05

TABLE IV

AVERAGE MONTHLY RAINFALL (IN.)

British Columbia	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1. Alice Arm	1.37	2.32	2.54	3.59	2.89	2.86	2.77	4.92	6.84	12.04	5.54	3.28	50.96
2. Atlin	0.19	0.08	0.01	0.09	0.33	0.88	1.17	0.95	1.06	1.38	0.36	0.11	6.61
3. Babine	0.11	0.06	0.14	0.57	1.51	2.11	1.95	1.49	1.78	1.86	0.77	0.10	12.45
4. Baldonnel	0.01	T	0.02	0.26	1.34	2.56	2.62	1.93	1.23	0.60	0.14	0.01	10.72
5. Beatton River	T	T	0.01	0.18	1.28	2.41	2.82	1.65	0.75	0.20	0.04	T	9.34
6. Dawson Creek	0	0	0.03	0.29	1.59	2.84	2.46	1.85	1.21	0.43	0.15	0.02	10.87
7. Dease Lake	0.01	0.01	0.03	0.08	0.61	1.46	2.13	2.11	1.51	0.58	0.12	0.02	8.67
8. Fort Nelson	T	0.01	0.02	0.23	1.39	2.60	2.56	1.99	1.17	0.37	0.02	T	10.36
9. Fort St. John	0.01	0.01	0.04	0.27	0.98	2.33	2.52	2.11	0.96	0.45	0.13	0.01	9.82
10. Germansen Landing	T	0.04	0.13	0.48	0.85	2.25	1.87	2.28	1.10	0.87	0.48	0.28	10.63
11. Hudson Hope	0.02	0	0.09	0.49	1.44	2.83	2.54	1.87	1.86	0.63	0.09	0.02	11.88
12. New Hazelton	0.34	0.27	0.30	0.69	1.17	2.06	2.02	1.69	2.24	2.15	1.38	0.39	14.70
13. Smith River	0.01	0.01	0.04	0.21	0.91	2.35	2.70	1.87	1.32	0.72	0.14	0.01	10.29
14. Stewart	2.05	1.61	2.64	3.47	2.67	2.55	3.43	4.37	6.86	11.80	6.89	2.52	50.86
15. Telegraph Creek	0.07	0.05	0.19	0.31	0.34	0.71	1.18	1.26	1.45	1.87	0.50	0.16	8.09
Yukon Territory													
1. Aishihik	T	T	T	0.03	0.58	1.50	1.75	1.63	0.51	0.05	T	T	6.05
2. Carcross	T	0.02	0.01	0.03	0.40	0.83	1.04	0.84	0.99	0.50	0.11	0.01	4.78
3. Carmacks	0	0	0	0.02	0.43	1.66	2.02	0.60	0.64	0.50	0	0	5.87
4. Dawson	0	0	0.01	0.09	0.95	1.28	1.98	1.94	1.11	0.30	T	0.02	7.68
5. Elsa	0	0	0	0.02	0.81	1.30	2.48	2.53	1.45	0.28	0.08	0.02	8.97
6. Fort Selkirk	0	0	0	0.06	0.68	1.20	1.95	1.72	0.63	0.18	0.02	0.03	6.47
7. Frances Lake	0	0	0	0.20	0.71	1.90	1.95	1.35	1.59	0.92	0.04	0	8.66
8. Haines Junction	0.01	T	0.02	0.08	0.39	1.06	1.36	1.07	0.99	0.52	0.37	0.33	6.20
9. Mayo	T	T	0.02	0.07	0.79	1.25	1.66	1.77	1.04	0.32	0.05	0.01	6.98
10. Snag	T	T	T	0.11	0.93	2.04	2.76	1.99	0.85	0.05	0.02	T	8.75
11. Teslin	T	0.02	0.02	0.07	0.60	1.12	1.43	1.44	1.26	0.59	0.10	T	6.65
12. Watson Lake	T	T	0.03	0.15	0.88	1.92	2.04	1.67	1.39	0.52	0.12	0.01	8.73
13. Whitehorse	T	T	T	0.03	0.42	1.06	1.36	1.44	0.85	0.26	0.06	0.01	5.49

TABLE V

AVERAGE MONTHLY SNOWFALL (IN.)

British Columbia	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
1. Alice Arm	59.2	44.6	40.3	11.7	0.2	0	0	0	0.2	8.0	38.9	87.8	290.9
2. Atlin	10.8	5.5	4.5	1.5	0.1	0	0	0	T	4.7	9.2	7.1	43.4
3. Babine	23.6	16.7	12.2	5.7	0.2	0	0	0	0.3	6.6	18.7	23.1	107.1
4. Baldonnel	10.1	9.6	9.3	5.4	0.7	T	0	0.3	1.3	6.1	11.6	10.8	65.2
5. Beatton River	8.9	11.2	9.3	8.5	4.0	0.4	0.1	0.7	3.0	7.7	9.1	9.8	72.7
6. Dawson Creek	12.7	12.7	11.7	3.5	1.4	0	0	0	0.7	10.0	9.6	11.5	73.8
7. Dease Lake	11.4	9.3	8.8	3.4	1.0	0.2	0	T	0.2	7.5	11.1	12.9	65.8
8. Fort Nelson	9.5	10.3	10.0	5.1	1.5	T	0	T	1.7	6.4	12.1	11.1	67.7
9. Fort St. John	12.1	11.5	10.0	6.3	2.3	0.3	0	0.9	1.6	7.6	10.6	12.8	76.0
10. Germansen Landing	24.6	13.1	11.6	9.0	0.2	0	0	0	0.8	8.8	16.7	19.7	104.5
11. Hudson Hope	8.3	6.9	8.6	4.6	0.3	0	0	0	4.0	5.5	12.3	8.8	59.3
12. New Hazelton	11.3	8.0	4.2	0.6	T	0	0	0	0	0.9	6.3	13.4	44.7
13. Smith River	13.4	11.4	9.0	5.2	2.1	0.3	0	T	1.4	8.2	13.6	15.3	79.9
14. Stewart	56.5	35.8	21.3	3.8	0.2	0	0	0	0	4.2	22.6	56.2	200.6
15. Telegraph Creek	13.1	8.8	4.5	0.6	0.1	T	0	0	0	0.9	6.2	10.8	45.0
Yukon Territory													
1. Aishihik	5.1	4.1	5.0	3.2	2.5	T	0	T	2.6	5.0	6.1	4.7	38.3
2. Carcross	6.1	8.9	4.6	1.9	0.3	0	0	0.1	0.8	4.4	8.1	6.6	41.8
3. Carmacks	6.0	6.3	2.9	0.9	2.3	0	0	0	4.5	3.8	6.7	6.1	39.5
4. Dawson	8.1	5.5	5.1	2.2	0.2	T	0	0	1.1	7.9	10.5	9.3	49.9
5. Elsa	6.9	7.0	5.4	5.3	0.8	0	0	T	1.6	9.1	14.4	12.5	63.0
6. Fort Selkirk	7.9	5.5	4.4	1.5	T	0	0	0	0.9	4.2	10.6	9.0	44.0
7. Frances Lake	14.8	11.1	7.0	3.6	0.1	T	0	0	0.1	4.7	14.6	15.7	71.7
8. Haines Junction	7.2	4.5	3.5	1.8	0.7	0.1	0	0	0.9	7.3	10.6	10.8	47.4
9. Mayo	7.4	4.8	3.8	1.8	0.2	0	0	0	0.6	6.8	8.6	7.8	41.8
10. Snag	8.9	6.7	5.5	4.8	1.8	0.3	0	0.1	2.4	6.6	8.4	7.7	53.2
11. Teslin	10.8	6.9	7.5	4.3	0.7	T	0	T	1.1	6.1	11.2	12.3	60.9
12. Watson Lake	14.1	10.7	9.1	5.3	1.0	T	0	0.1	1.3	8.9	15.1	16.9	82.5
13. Whitehorse	7.0	5.6	5.9	4.0	0.8	0	0	T	1.3	4.7	8.5	7.8	45.6

TABLE VI

NORMAL MONTHLY DEPTH OF SNOW ON GROUND (IN.)

British Columbia	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
Beatton River	22	26	20	7	-	-	-	-	-	3	7	17
Dease Lake	22	23	18	9						2	8	15
Fort Nelson	17	20	13	2						3	8	15
Smith River	22	26	21	6						1	9	17
Yukon Territory												
Aishihik	10	11	9	1						1	5	6
Dawson	24	24	23	3						2	10	18
Mayo Landing	17	16	13	1						2	6	12
Snag	17	19	15	4						3	7	12
Teslin	16	17	14	3						2	7	11
Watson Lake	23	27	18	4						2	12	17
Whitehorse	11	10	5	1						1	6	7

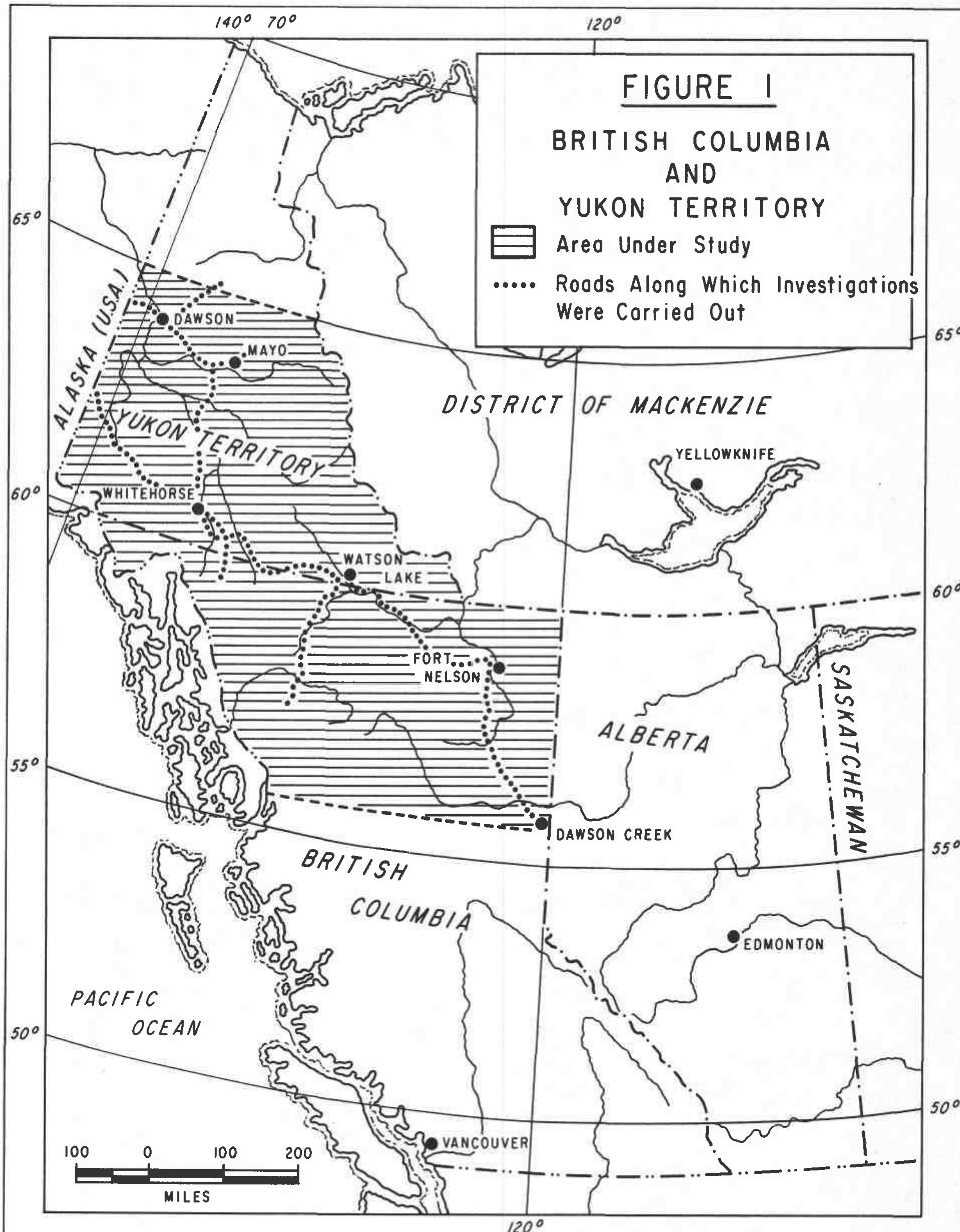
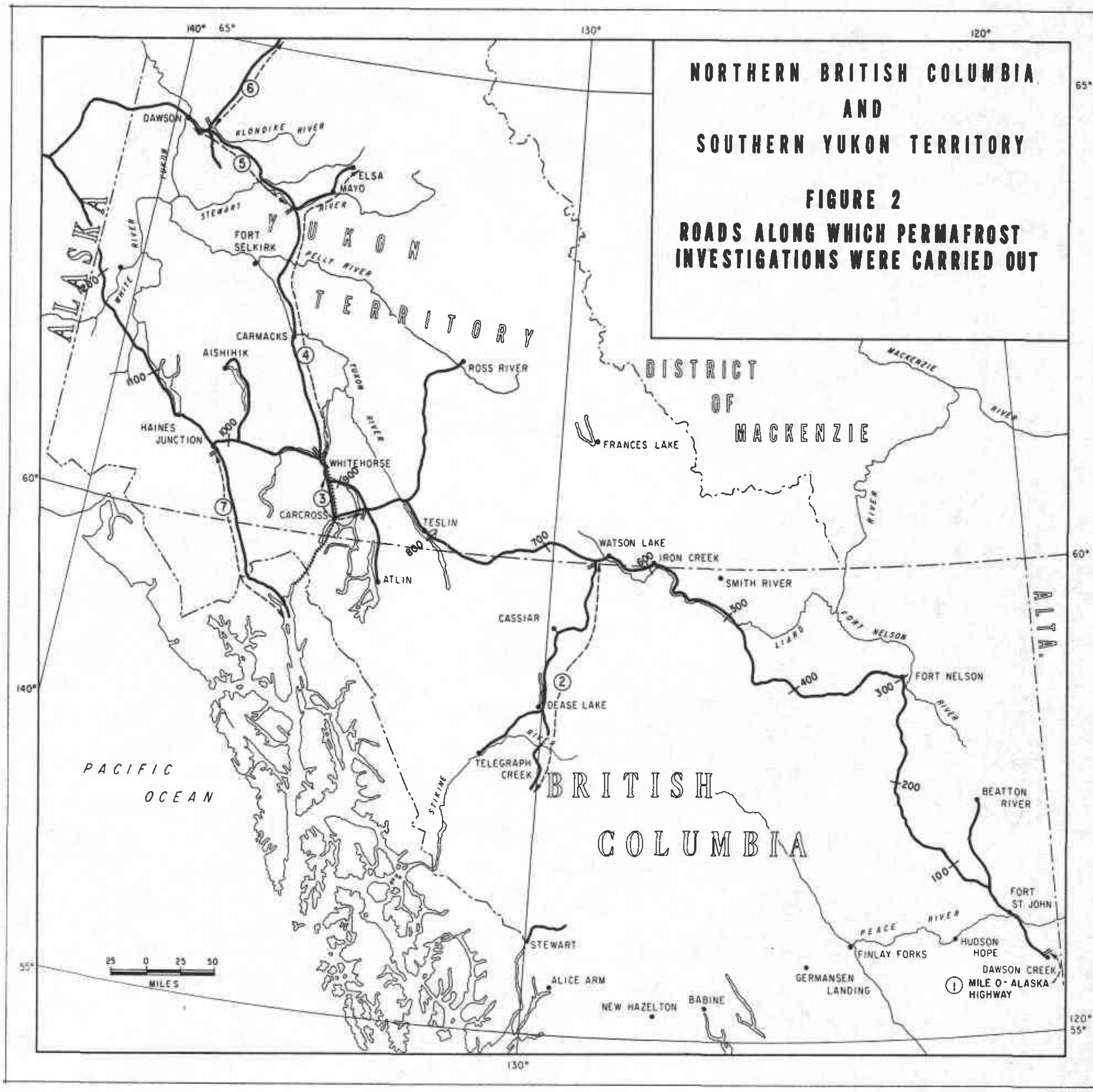


FIGURE I
BRITISH COLUMBIA
AND
YUKON TERRITORY
Area Under Study
Roads Along Which Investigations Were Carried Out
140° 70°
120°
65°
60°
55°
50°
ALASKA (U.S.A.)
DAWSON
MAYO
YUKON TERRITORY
WHITEHORSE
WATSON LAKE
FORT NELSON
DAWSON CREEK
DISTRICT OF MACKENZIE
YELLOWKNIFE
ALBERTA
SASKATCHEWAN
BRITISH COLUMBIA
EDMONTON
PACIFIC OCEAN
VANCOUVER
100 0 100 200
MILES

BR 4045 - 1



NORTHERN BRITISH COLUMBIA AND SOUTHERN YUKON TERRITORY

FIGURE 2

ROADS ALONG WHICH PERMAFROST INVESTIGATIONS WERE CARRIED OUT

LEGEND

ROAD-SHORT DOUBLE LINE INDICATES POSITION OF MILE 0

1. ALASKA HIGHWAY	5. DAWSON HIGHWAY
2. STEWART-CASSIAR HIGHWAY	6. DEMPSTER HIGHWAY
3. CARCROSS HIGHWAY	7. HAINES HIGHWAY
4. WHITEHORSE-MAYO HIGHWAY	—100—HIGHWAY MILEAGE

Figure 3 Location No. 5 - Mile 94.4 - Alaska Highway, B.C. This low area has tree growth of dense spruce up to 15 ft high with alder and willow. The ground vegetation is hummocky Sphagnum, feather moss, lichen and Labrador tea below which is peat to a depth of 3 ft 3 in. overlying silty clay. The permafrost table is at the 1 ft 9 in. depth (in the peat) and the permafrost is 5 ft 9 in. thick. September 9, 1964.

Figure 4 Location No. 9 - Mile 148.5 - Alaska Highway, B.C. This low area has tree growth of scattered spruce up to 30 ft high with ground vegetation of dense ground birch, hummocky feather moss, Labrador tea and scattered lichen below which is peat 0 ft 6 in. thick. No permafrost was encountered at this location. September 11, 1964.

Figure 5 Location No. 28 - Mile 208.5 - Alaska Highway, B.C. This low area has tree growth of spruce up to 10 ft high with ground vegetation of hummocky Sphagnum, feather moss, lichen, and Labrador tea, below which is peat to a depth of 3 ft 4 in. overlying silty clay. The permafrost table is at the 1 ft 4 in. depth (in the peat) and extends into the mineral soil. September 12, 1964.

Figure 6 Location No. 36 - Mile 254.5 - Alaska Highway, B.C. This low area consists of peat plateaux interspersed with wet depressions. The tree growth on the peat plateau is dense spruce up to 30 ft high and tamarack with ground vegetation of feather moss, Sphagnum, lichen and Labrador tea below which is peat to a depth of 7 ft 6 in. overlying clay soil. The permafrost table is at the 3 ft 9 in. depth (in the peat) and the permafrost is 14 ft 3 in. thick. In the depressions the vegetation consists of ground birch and sedge, and the water table is at the ground surface. No permafrost was encountered in the depressions. September 13, 1964.

Figure 7 Location No. 38 - Mile 256.0 - Alaska Highway, B.C. This low area consists of peat plateaux interspersed with wet depressions. The tree growth on the peat plateau consists of spruce up to 25 ft and tamarack with ground vegetation of hummocky Sphagnum, feather moss, lichen and Labrador tea below which is peat exceeding 7 ft in thickness overlying clay soil. The depth to the permafrost table is 2 ft 0 in. and the permafrost is 3 ft 0 in. thick. In the depressions the vegetation consists of feather moss, Sphagnum, grass and sedge below which is peat 4 ft 0 in. thick overlying clay soil. No permafrost was encountered in this depression. September 13, 1964.

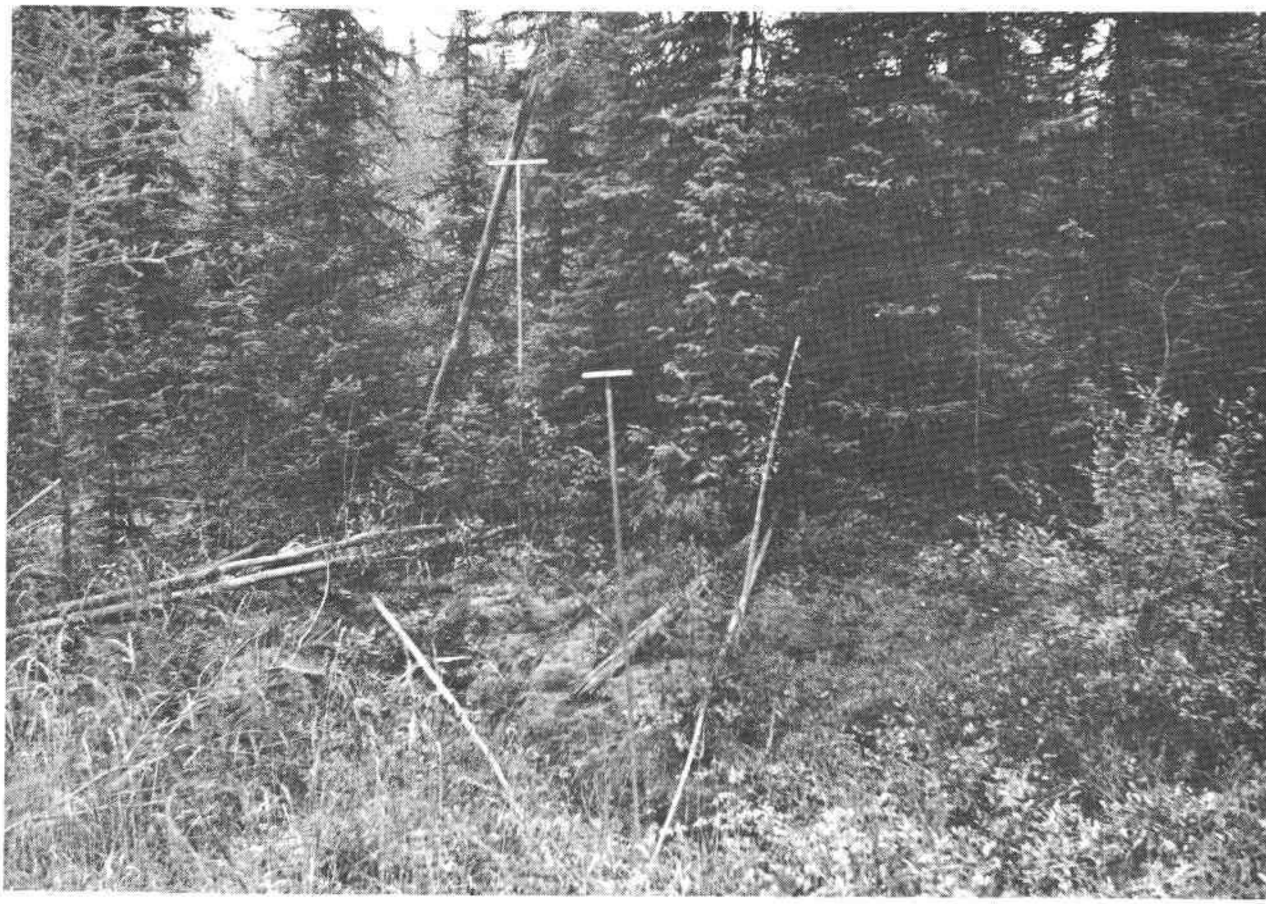


Figure 8 Location No. 48 - Mile 295 - Alaska Highway, B.C. This low area consists of peat plateaux interspersed with wet depressions. The tree growth on the peat plateaux consists of dense spruce 25 ft high and tamarack, poplar, willow and alder with ground vegetation of feather moss, Sphagnum, lichen and Labrador tea below which is peat to a depth of 4 ft 8 in. overlying silty fine to medium sandy soil with stones. The permafrost table is at the 2 ft 0 in. depth and the thickness of the permafrost exceeds 5 ft 9 in. Note the two Hoffer probes indicating that the peat plateau is about 3 ft high. September 13, 1964.

Figure 9 Location No. 58 - Mile 383.5 - Alaska Highway, B.C. The slope on the left is north facing with tree growth of spruce up to 60 ft high and a few tamarack and stunted poplar with ground cover of ground birch, hummocky Sphagnum, feather moss, lichen, Labrador tea, grass and sedge below which is peat to a depth of 4 ft 6 in. overlying stony soil. The permafrost table is at the 1 ft 9 in. depth and the permafrost exceeds 3 ft 0 in. in thickness. The slope on the right is south facing with tree growth of poplar and scattered spruce and jackpine below which is a thin layer of forest litter overlying gravelly soil. No permafrost was encountered on this slope. September 14, 1964.

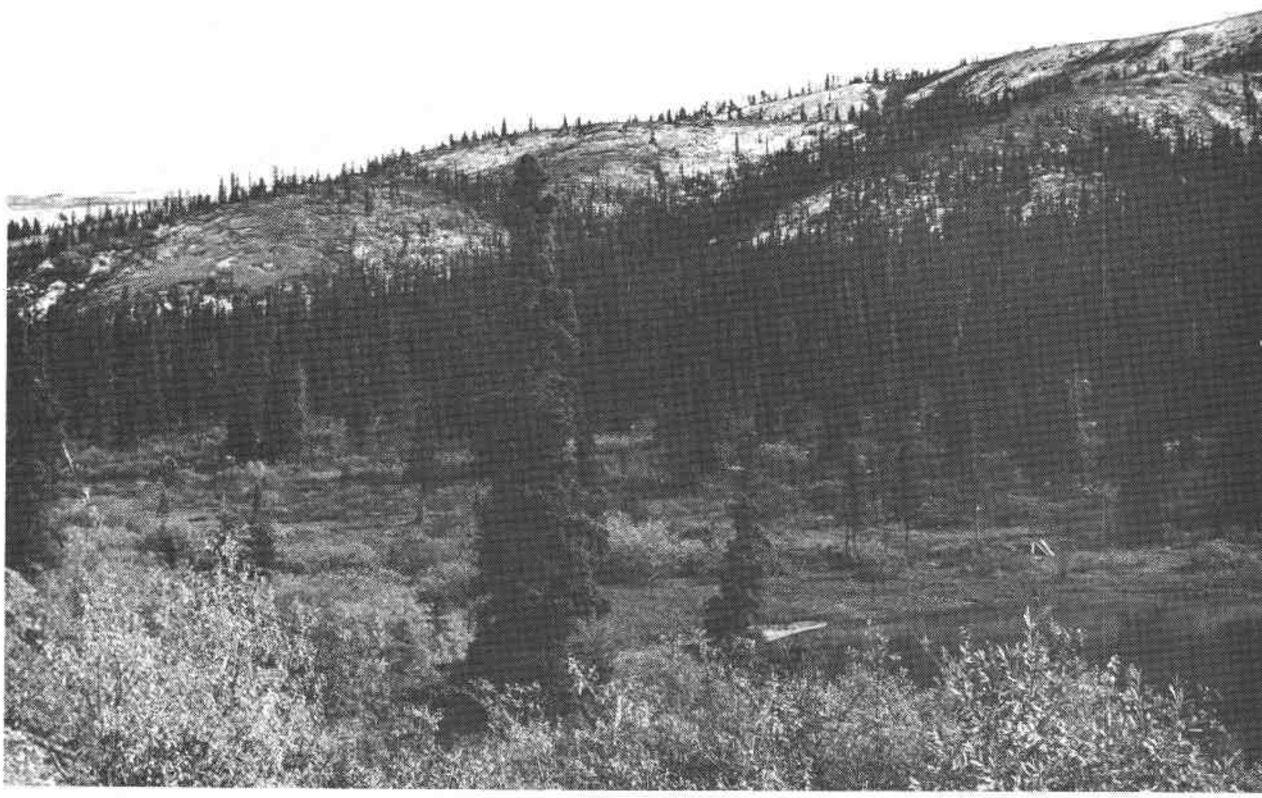


Figure 10 Location 59 - Mile 394.5 - Alaska Highway, B.C. This gently sloping area in the foreground has tree growth of scattered spruce up to 60 ft high with ground vegetation of ground birch, hummocky feather moss, lichen, Labrador tea and grass below which is peat 0 ft 6 in. thick overlying stony soil. No permafrost was encountered at this location. September 7, 1964.

Figure 11 Location 60 - Mile 398.4 - Alaska Highway, B.C. This sloping area has tree growth of spruce up to 35 ft high with ground vegetation of hummocky Sphagnum, feather moss, lichen and Labrador tea below which is peat 2 ft 2 in. thick overlying sandy to clayey silt soil with small stones. The permafrost table is at the 2 ft 1 in. depth and the permafrost exceeds 5 ft 5 in. in thickness. Note area in foreground stripped of vegetation for road relocation. September 14, 1964.

Figure 12 This high area located about Mile 500 on the Alaska Highway is typical of the high areas south of Whitehorse. The tree growth consists of tall spruce, jackpine and poplar. No permafrost was encountered in these locations. September 15, 1964.

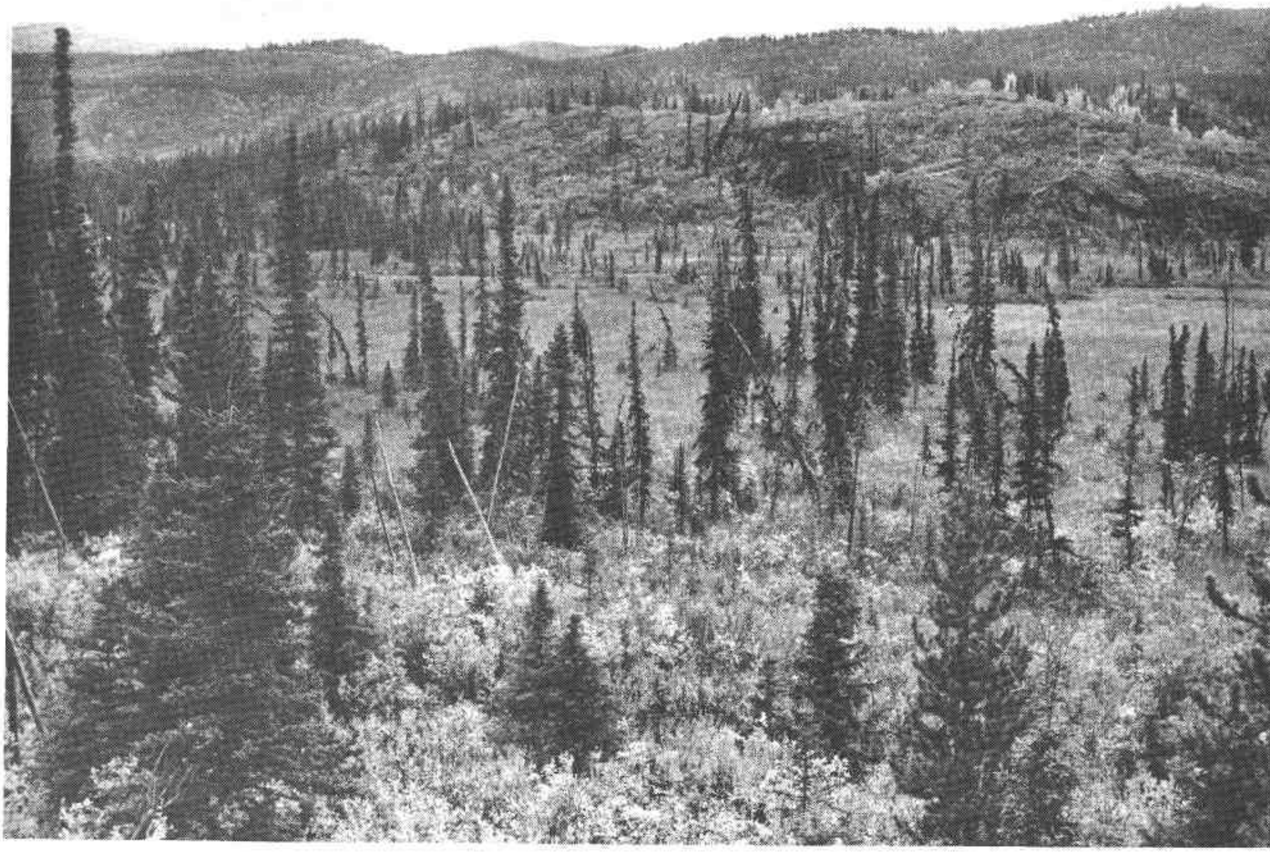
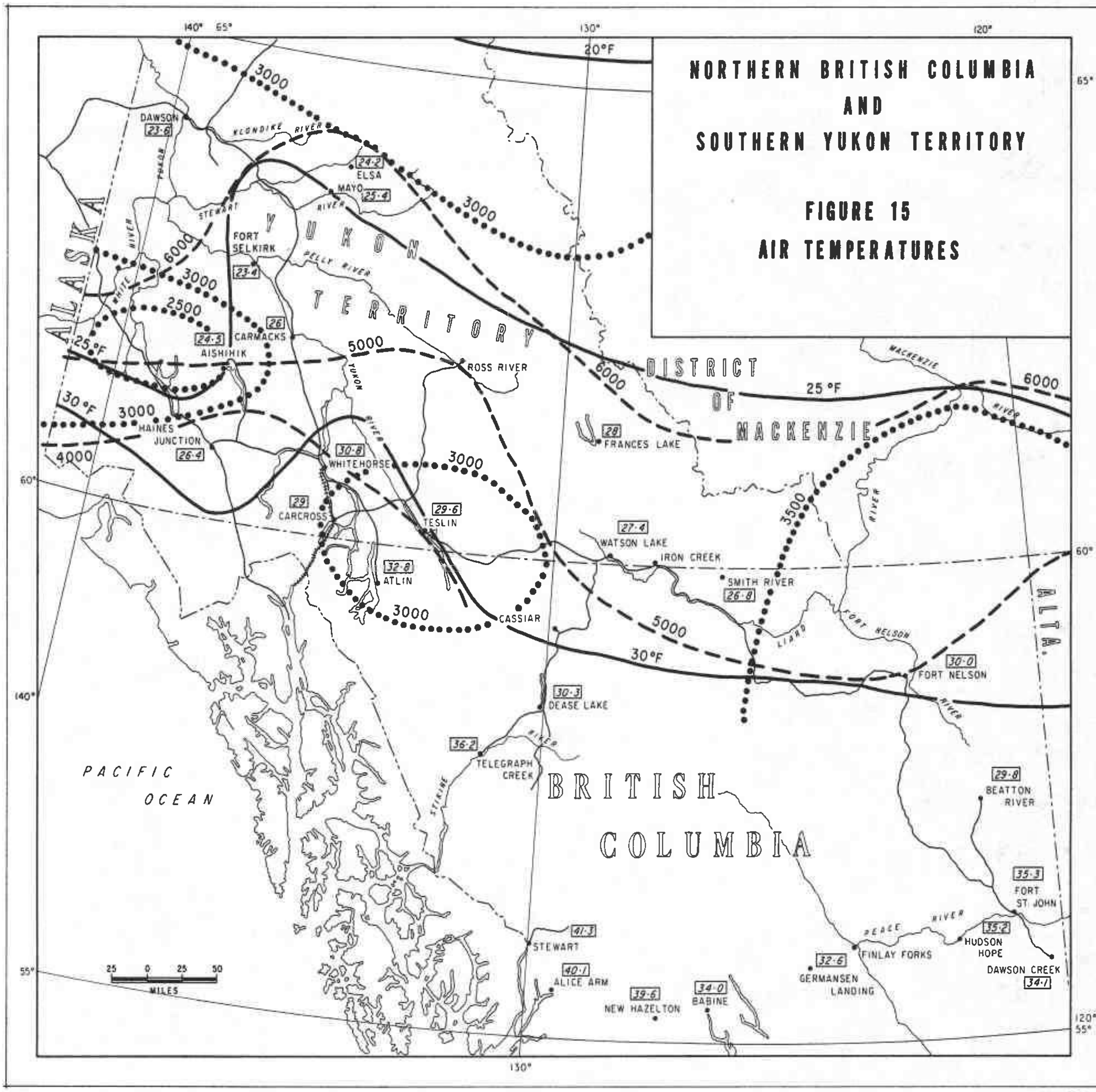


Figure 13 Location No. 85 - Mile 731 - Alaska Highway, Y.T. This low area has tree growth of scattered spruce up to 40 ft high with ground cover of ground birch. No permafrost was encountered at this location. September 19, 1964.

Figure 14 Location No. 93 - Mile 788.5 - Alaska Highway, B.C. This low area consists of peat plateaux interspersed with wet depressions. The tree growth on the peat plateaux consists of dense spruce up to 40 ft high with ground vegetation of very hummocky feather moss, Sphagnum, lichen and Labrador tea below which is peat exceeding 4 ft 6 in. in thickness overlying clayey silty soil. The permafrost table is at the 1 ft 6 in. depth and permafrost exceeds 3 ft 0 in. in thickness. In the depressions, the vegetation consists of sedge, grass, feather moss and Sphagnum and the water table is at the ground surface. The peat is 6 ft 9 in. thick overlying clayey silty soil. No permafrost was encountered in the depressions. September 19, 1964.



LEGEND (AFTER THOMPSON 1963)

— MEAN ANNUAL ISOTHERM

– – FREEZING INDEX (DEGREE DAYS)

• • • THAWING INDEX (DEGREE DAYS)

[30.3] MEAN ANNUAL AIR TEMPERATURE OF STATION

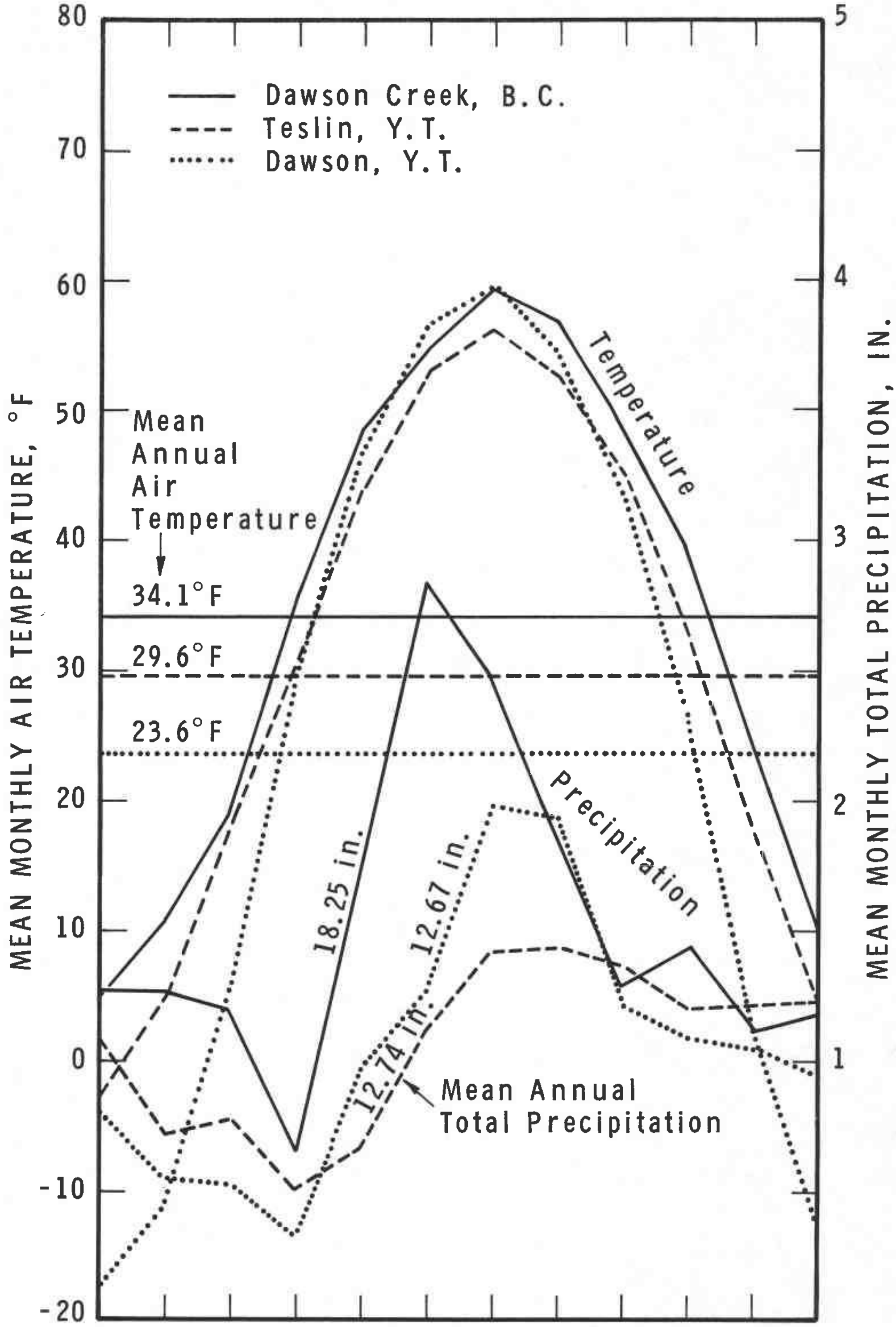


FIGURE 16

MEAN MONTHLY AIR TEMPERATURE AND MEAN MONTHLY PRECIPITATION FOR DAWSON CREEK B.C., TESLIN Y.T., AND DAWSON Y.T.

BR4045-5

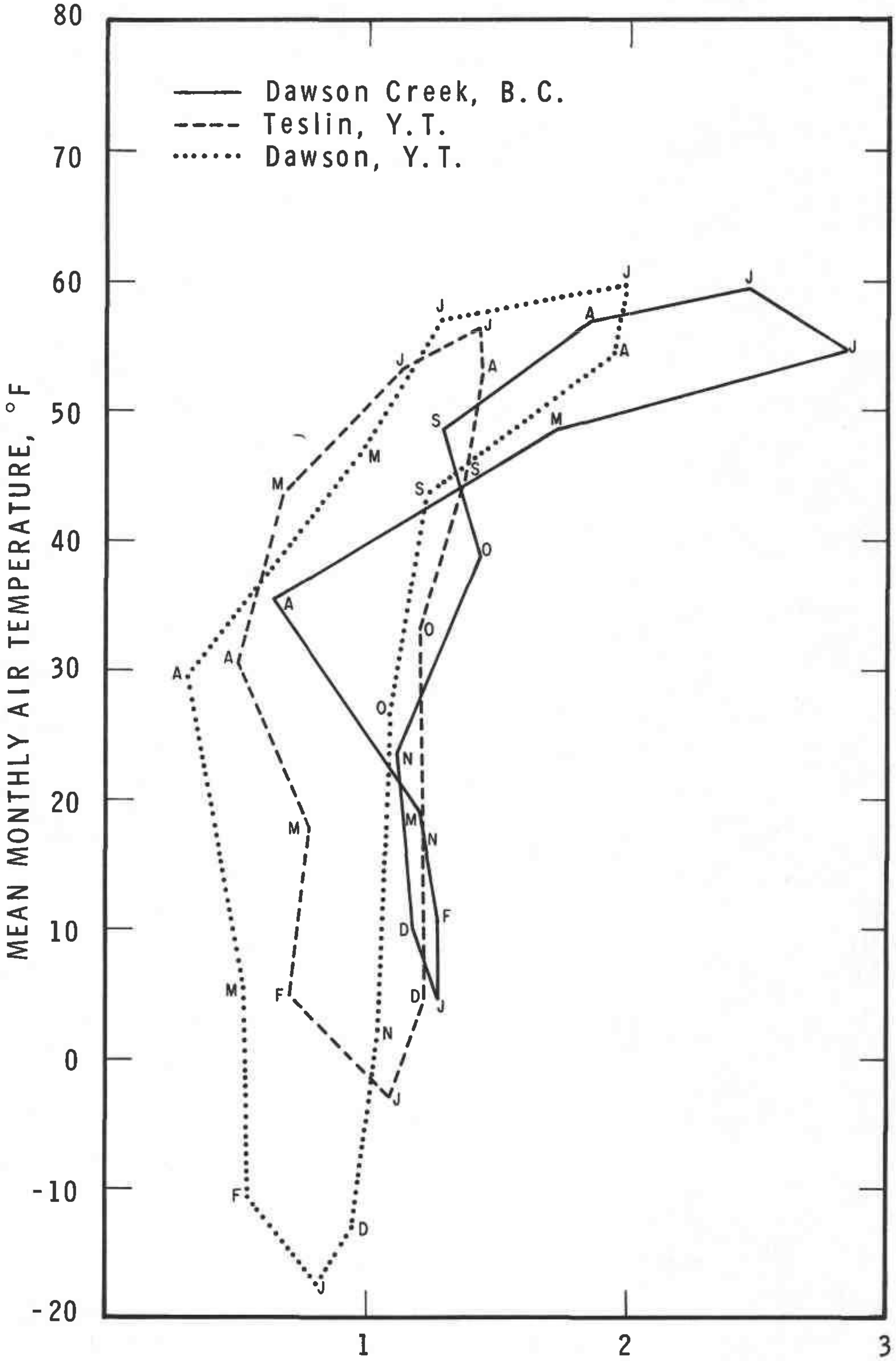
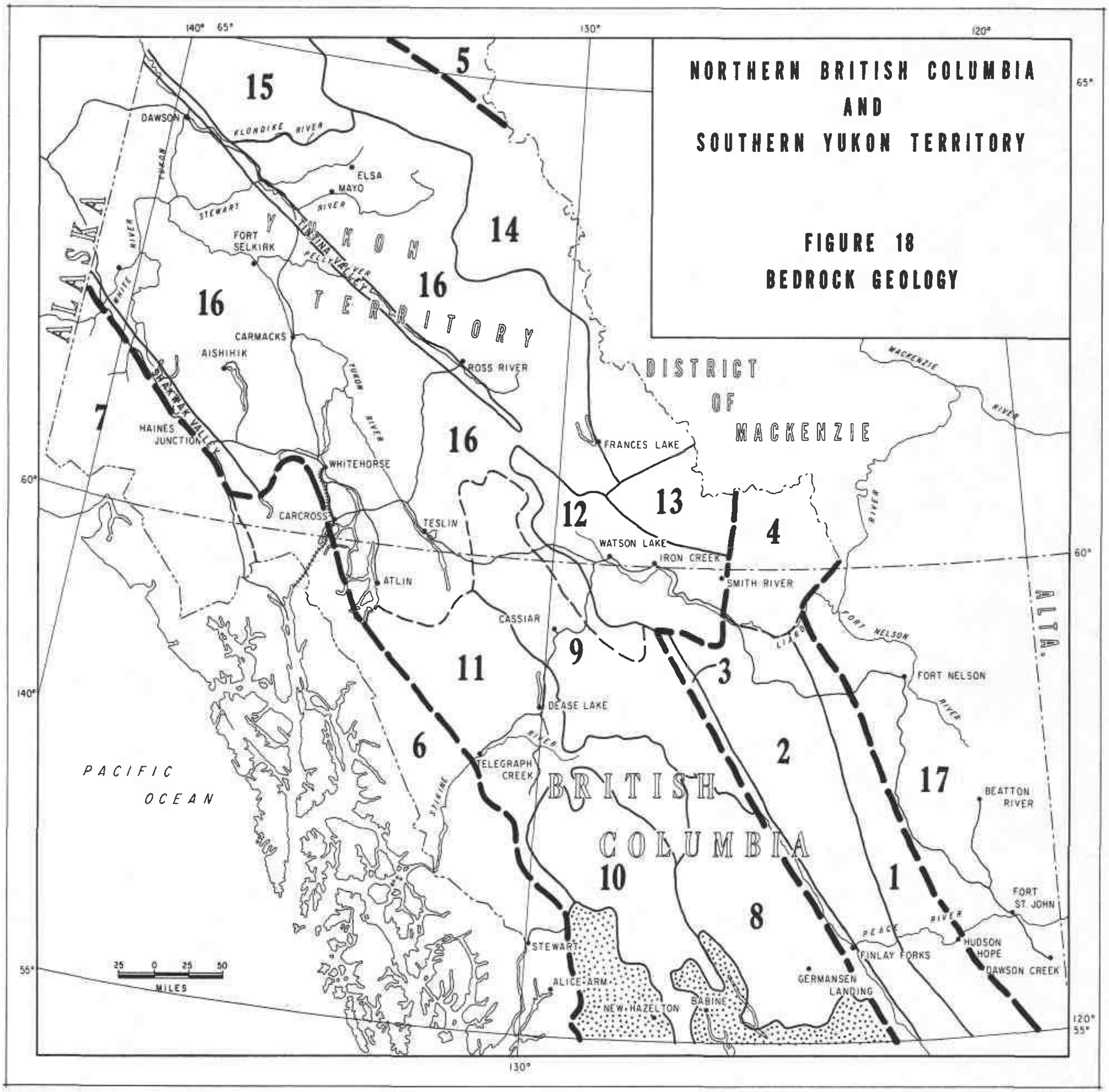


FIGURE 17
HYTHERGRAPHS FOR DAWSON CREEK B.C., TESLIN Y.T., AND DAWSON Y.T.

BR4645-6



LEGEND: (AFTER H.S. BOSTOCK 1965)

EASTERN SYSTEM

ROCKY MOUNTAIN AREA
1. ROCKY MOUNTAIN FOOTHILLS
2. ROCKY MOUNTAINS
3. ROCKY MOUNTAIN TRENCH
MACKENZIE MOUNTAIN AREA
4. LIARD PLATEAU
5. MACKENZIE MOUNTAINS

WESTERN SYSTEM

COAST MOUNTAIN AREA
6. COAST MOUNTAINS
OUTER MOUNTAIN AREA
7. ST. ELIAS MOUNTAINS

INTERIOR SYSTEM

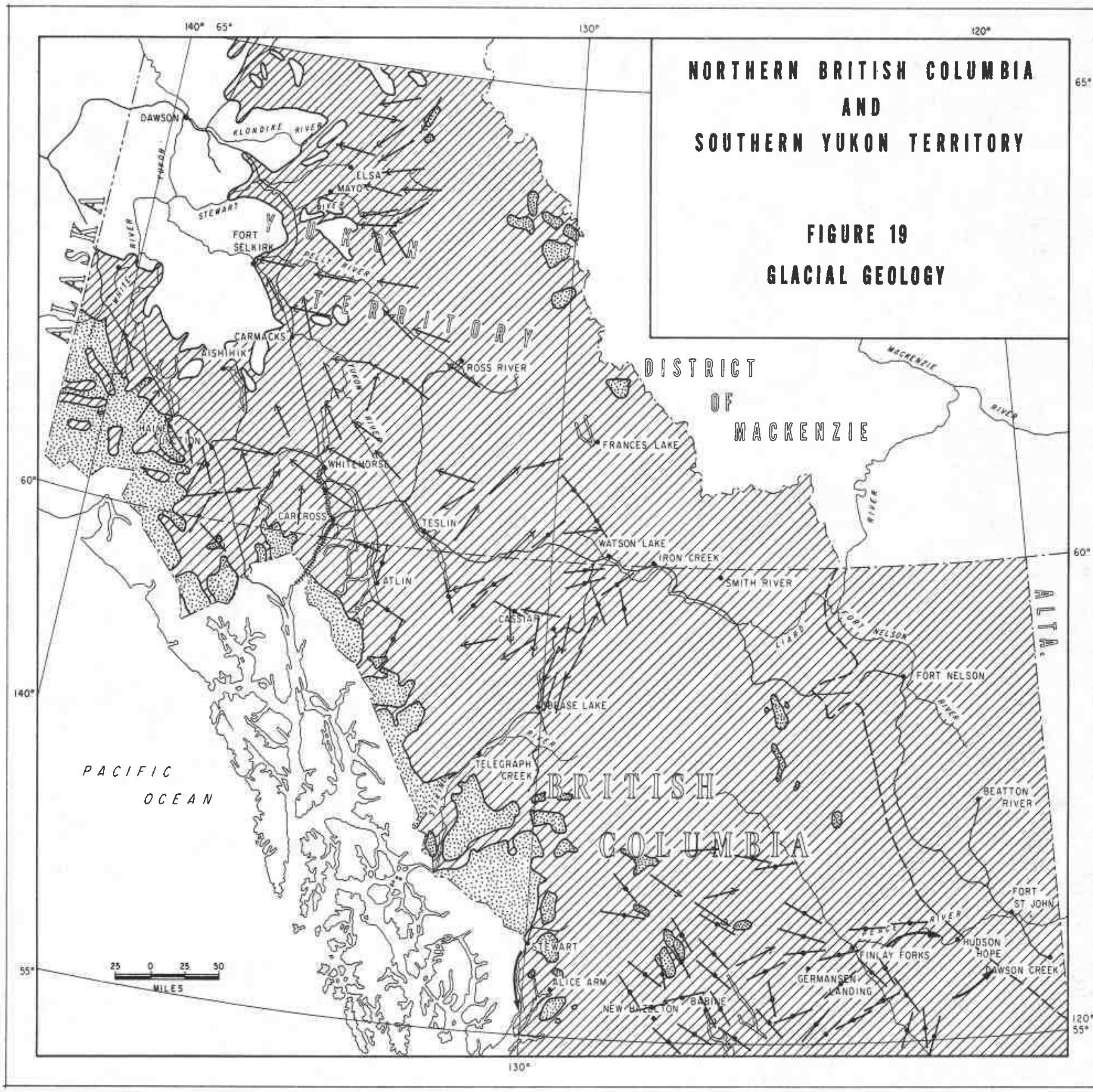
CENTRAL PLATEAU AND MOUNTAIN AREA
8. OMENICA MOUNTAINS
9. CASSIAR MOUNTAINS
10. SKEENA MOUNTAINS
11. STIKINE PLATEAU
NORTHERN PLATEAU AND MOUNTAIN AREA
12. LIARD PLAIN
13. HYLAND PLATEAU
14. SELWYN MOUNTAINS
15. OGILVIE MOUNTAINS
16. YUKON PLATEAU - SHAKWAK VALLEY
- TINTINA VALLEY

17. INTERIOR PLAINS

SYSTEM BOUNDARY

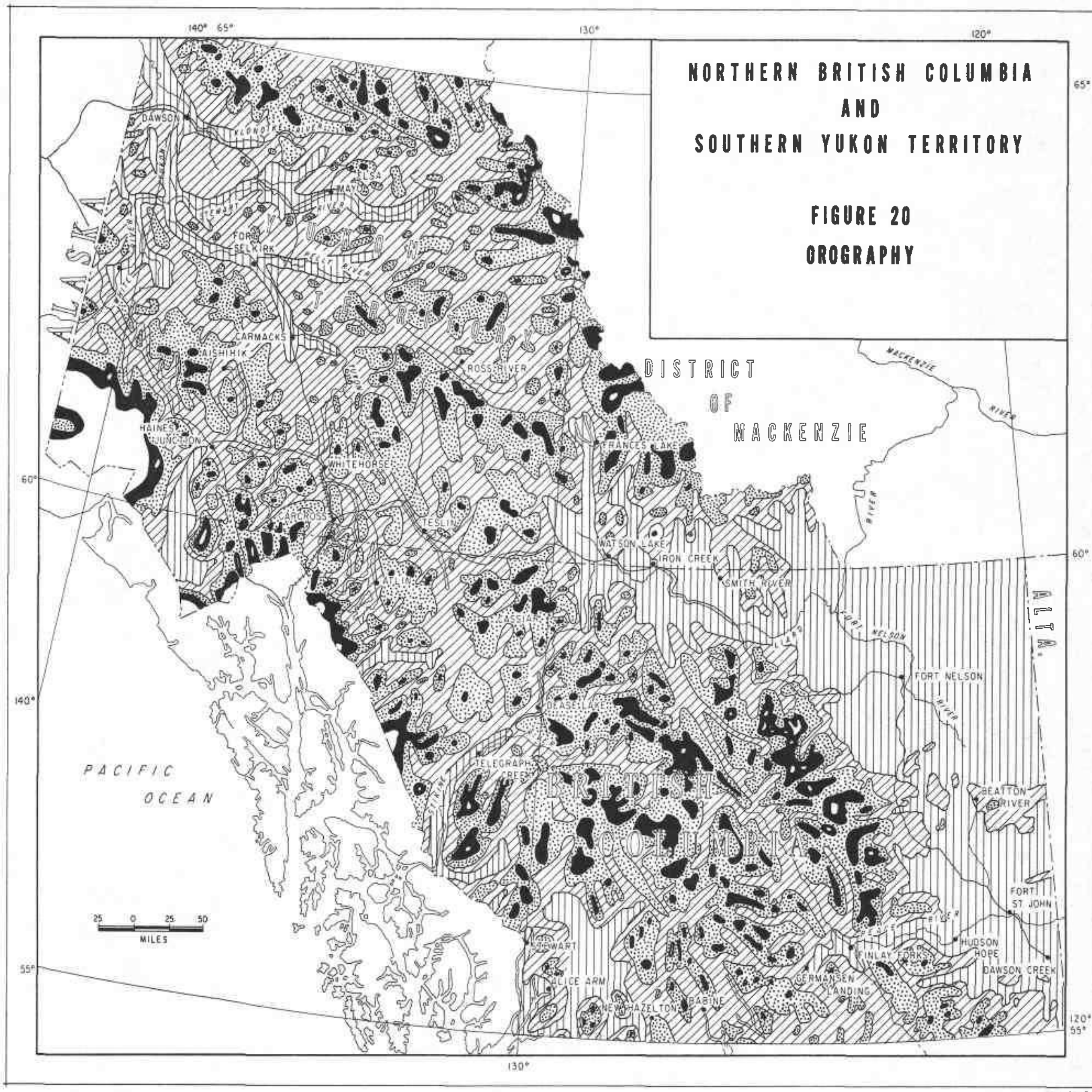
UNIT BOUNDARY

OTHER PHYSIOGRAPHIC UNITS NOT CONSIDERED IN STUDY AREA



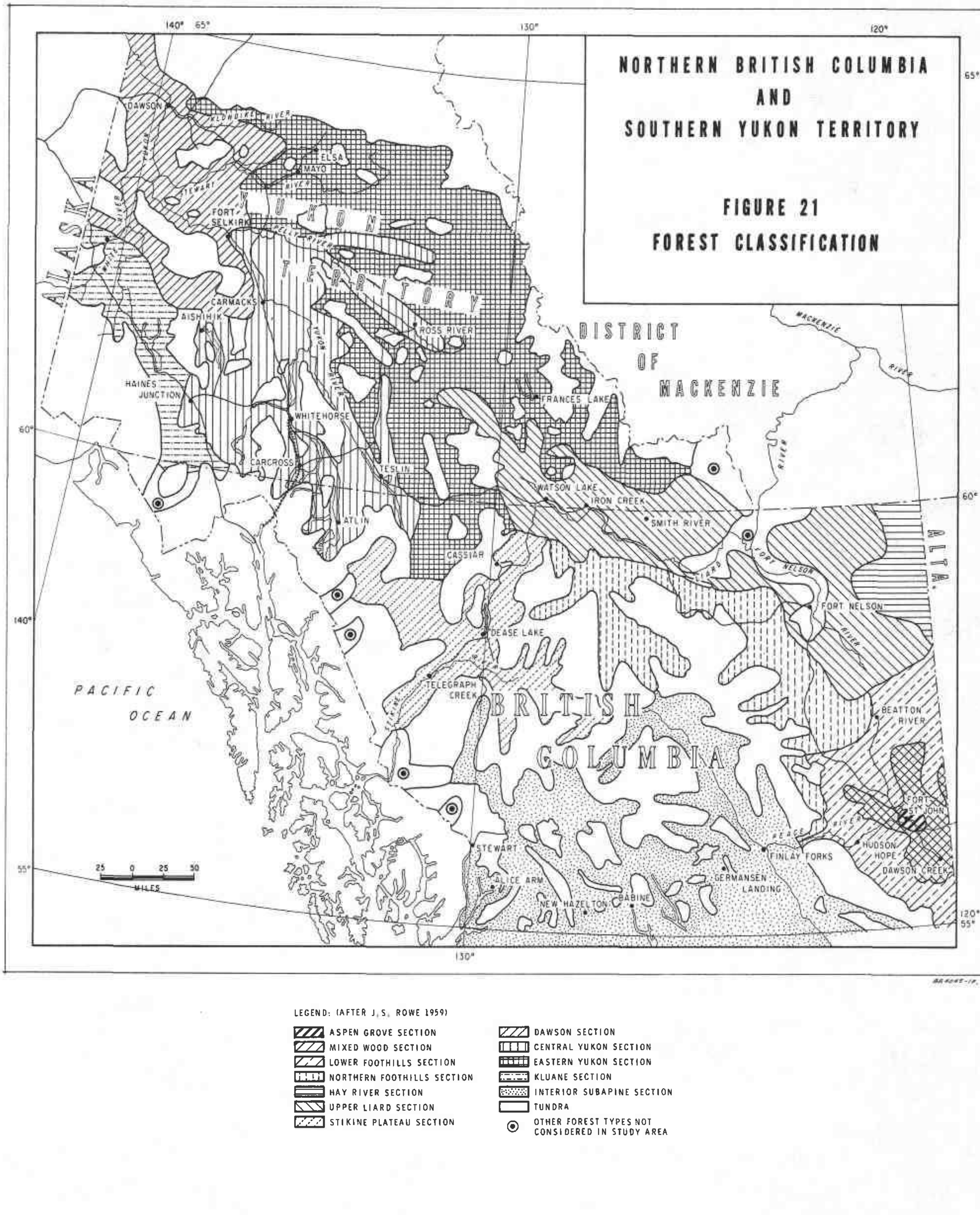
LEGEND: (AFTER ATLAS OF CANADA, 1957)

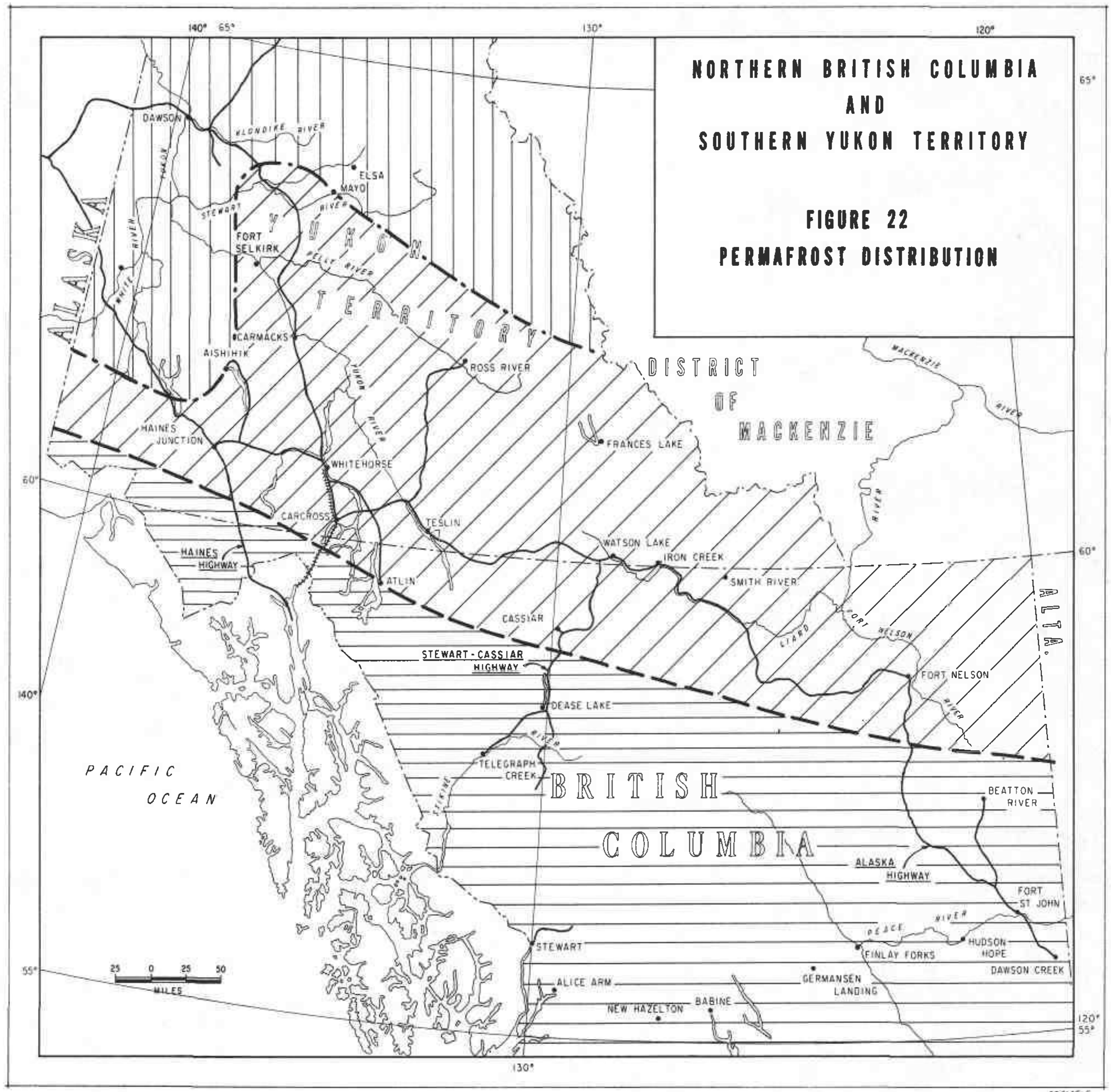
- EXISTING GLACIERS AND ICE CAPS
- UNGLACIATED AREA
- UNDIFFERENTIATED GLACIAL DRIFT-TILL, GRAVEL, SAND, SILT AND CLAY
- WESTERN LIMIT OF CANADIAN SHIELD DRIFT
- TREND OF DRUMLINS, DRUMLINOID RIDGES, FLUTINGS
- TREND OF GLACIAL STRIAE, GROOVES, ROCHEMOUTONEE, DIRECTION OF ICE MOVEMENT
- DIRECTION OF VALLEY GLACIER MOVEMENTS



LEGEND: (AFTER ATLAS OF CANADA 1957)

BELOW 3000 FEET ABOVE SEA LEVEL
3000 - 4000 FEET ABOVE SEA LEVEL
4000 - 6000 FEET ABOVE SEA LEVEL
6000 - 8000 FEET ABOVE SEA LEVEL
EXCEEDING 8000 FEET ABOVE SEA LEVEL


NORTHERN BRITISH COLUMBIA
AND
SOUTHERN YUKON TERRITORY
FIGURE 21
FOREST CLASSIFICATION
YUKON TERRITORY
DISTRICT OF MACKENZIE
BRITISH COLUMBIA
ALASKA
ALTA.
PACIFIC OCEAN
DAWSON
ELSA
MAYO
FORT SELKIRK
CARMACKS
AISHIHIK
ROSS RIVER
HAINES JUNCTION
WHITEHORSE
CARCROSS
TESLIN
ATLIN
FRANCES LAKE
WATSON LAKE
IRON CREEK
SMITH RIVER
CASSIAR
FORT NELSON
DEASE LAKE
TELEGRAPH CREEK
BEATTON RIVER
FORT ST. JOHN
HUDSON HOPE
DAWSON CREEK
FINLAY FORKS
GERMANSEN LANDING
STEWART
ALICE ARM
NEW HAZELTON
BABINE
KLONDIKE RIVER
STEWART RIVER
PELLY RIVER
YUKON RIVER
LIARD
FORT NELSON RIVER
PEACE RIVER
MACKENZIE RIVER
25 0 25 50
MILES
LEGEND: (AFTER J. S. ROWE 1959)
ASPEN GROVE SECTION
MIXED WOOD SECTION
LOWER FOOTHILLS SECTION
NORTHERN FOOTHILLS SECTION
HAY RIVER SECTION
UPPER LIARD SECTION
STIKINE PLATEAU SECTION
DAWSON SECTION
CENTRAL YUKON SECTION
EASTERN YUKON SECTION
KLUANE SECTION
INTERIOR SUBAPINE SECTION
TUNDRA
OTHER FOREST TYPES NOT CONSIDERED IN STUDY AREA



LEGEND

- WIDESPREAD DISCONTINUOUS PERMAFROST
- BOUNDARY BETWEEN WIDESPREAD AND PATCHY PERMAFROST
- SOUTHERN FRINGE OF PERMAFROST REGION
- SOUTHERN LIMIT OF PERMAFROST
- PERMAFROST AT HIGH ALTITUDE - GENERALLY ABOVE 4000 FEET

DISCONTINUOUS ZONE (first three entries)

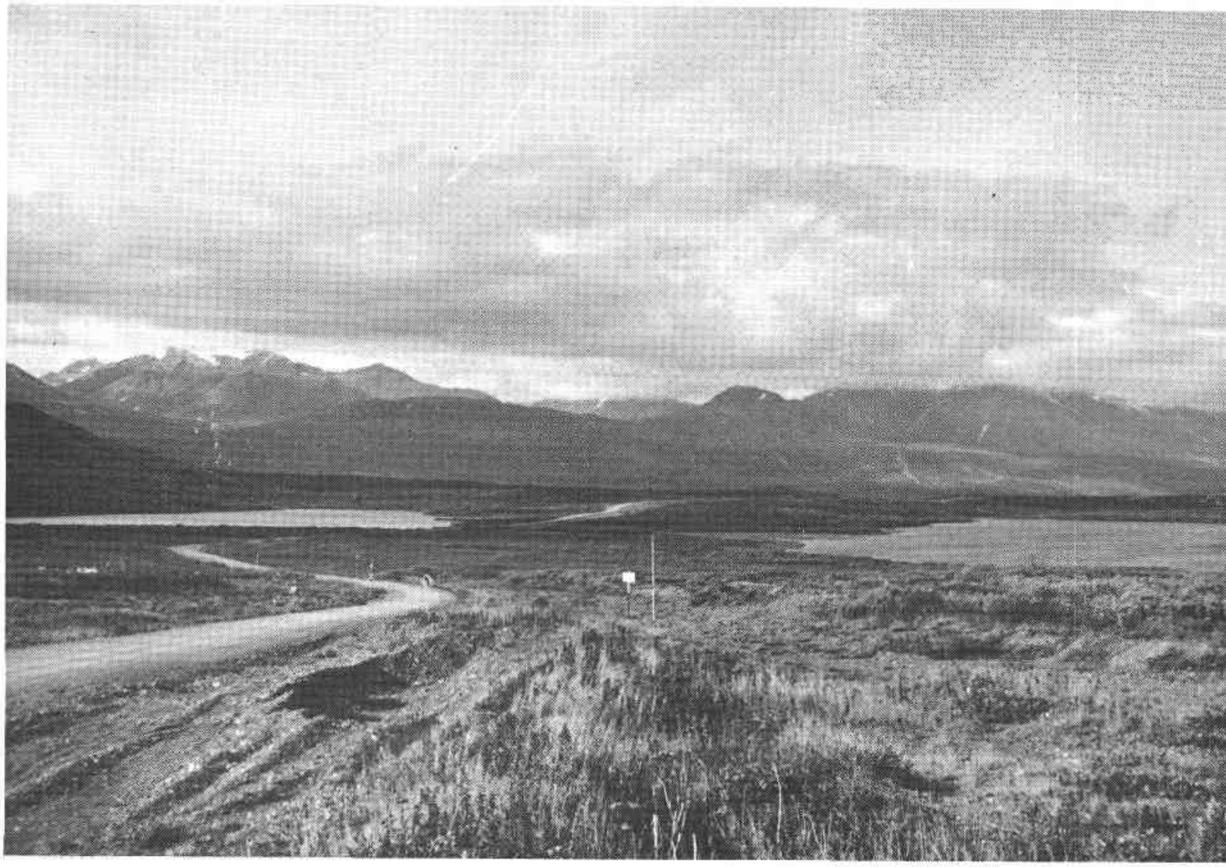


Figure 23 Mile 86 - Haines Highway, B.C. No permafrost was encountered in this alpine-tundra upland 3000 ft above sea level about half way between the Alaska Highway and Haines, Alaska at tidewater. September 28, 1964.

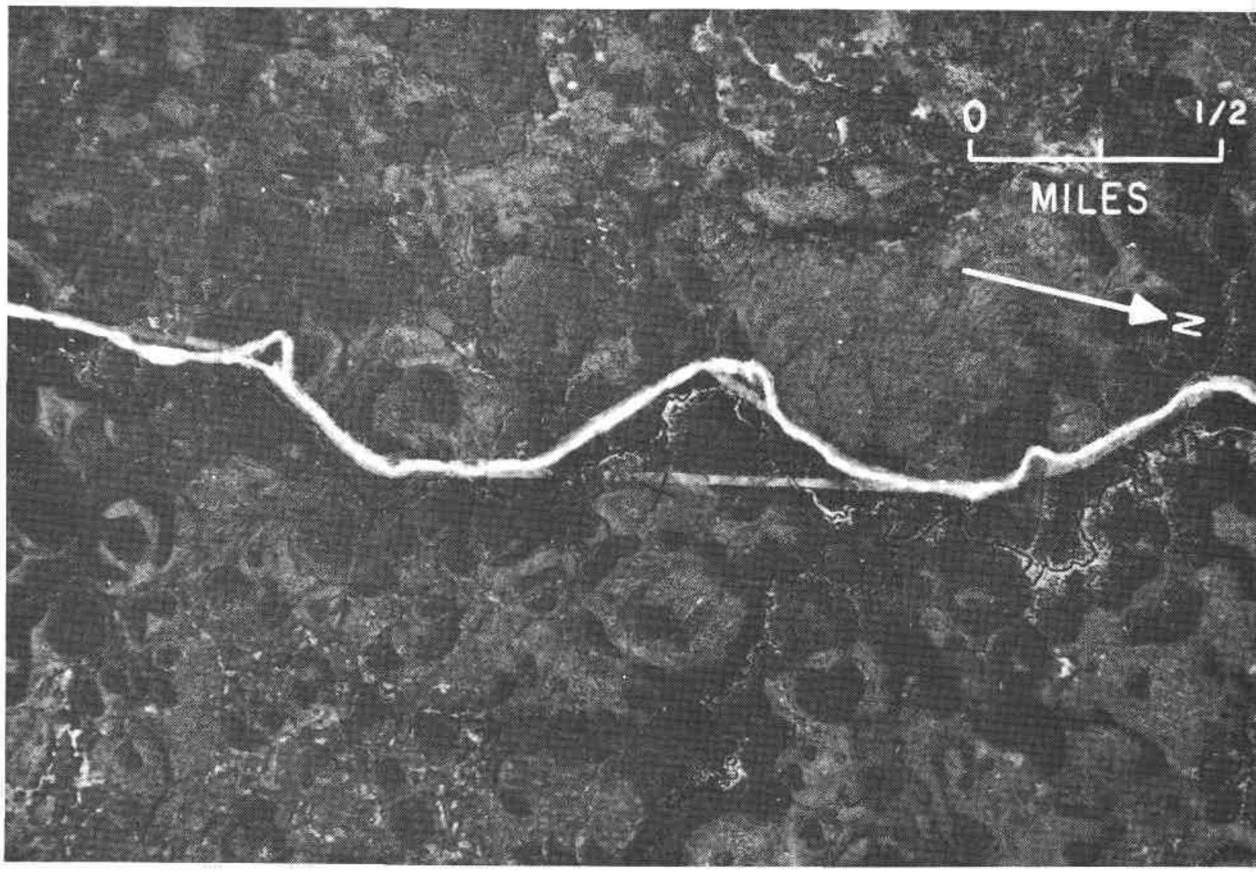


Figure 24 Section of RCAF air photo A11367-324 of Alaska Highway in Northern British Columbia from about Mile 255 to 259.

Figure 25 Tramline to asbestos mine at Cassiar, B.C. No permafrost occurs at townsite elevation of 3500 ft above sea level in foreground. Permafrost is widespread at top of tramline at asbestos mine at summit of mountain in centre background 6000 ft above sea level. September 17, 1964.

Figure 26 Permafrost is widespread in this gravel deposit at Mile 1170.7 - Alaska Highway, Y.T. September 27, 1964.

Figure 27	Location No. 115 - Mile 1202 - Alaska Highway, Y. T. No permafrost occurs in this gravel ridge supporting tree growth of spruce and poplar up to 50 ft high. September 27, 1964.

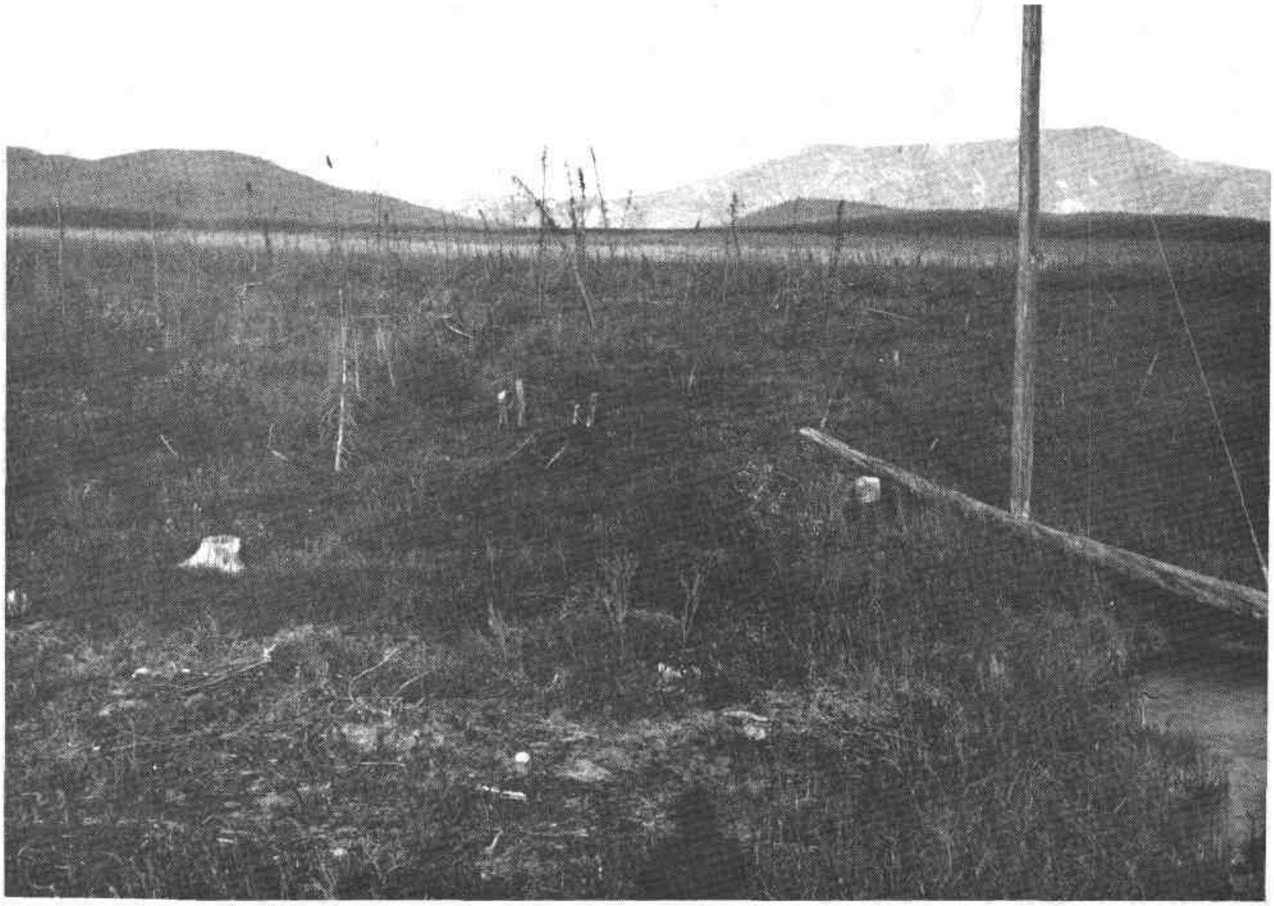


Figure 28 Location No. 113 - Mile 1127.5 - Alaska Highway, Y.T. Permafrost is widespread in both peat plateaux supporting scattered spruce, and wet grass - sedge covered depressions. September 27, 1964.

Figure 29 Location No. 127 - Mile 35.7 - Whitehorse-Mayo Highway, Y.T. This sloping area beside Fox Lake supports dense spruce up to 50 ft high and poplar with ground vegetation of moss below which is peat 1 ft 0 in. thick overlying fine-grained soil. Widening of the road in 1963 caused thawing of the widespread permafrost containing ice resulting in slumping and downslope movement of soil and vegetation. September 22, 1964.

Figure 30 Location No. 128 - Mile 47 - Whitehorse-Mayo Highway, Y.T. This sloping area supports dense spruce up to 50 ft high with ground vegetation of continuous moss carpet below which is peat 1 ft 0 in. thick overlying brown silt. No permafrost was encountered above the road. Downslope from the road the permafrost table is at the 1 ft 0 in. depth. September 22, 1964.

Figure 31 Location No. 131 - Mile 109 - Whitehorse-Mayo Highway, Y.T. This sloping area supports dense spruce up to 30 ft high with ground cover of feather moss, lichen and Labrador tea below which is peat 0 ft 9 in. thick overlying silty sand. The permafrost table is at the 2 ft 0 in. depth. September 22, 1964.

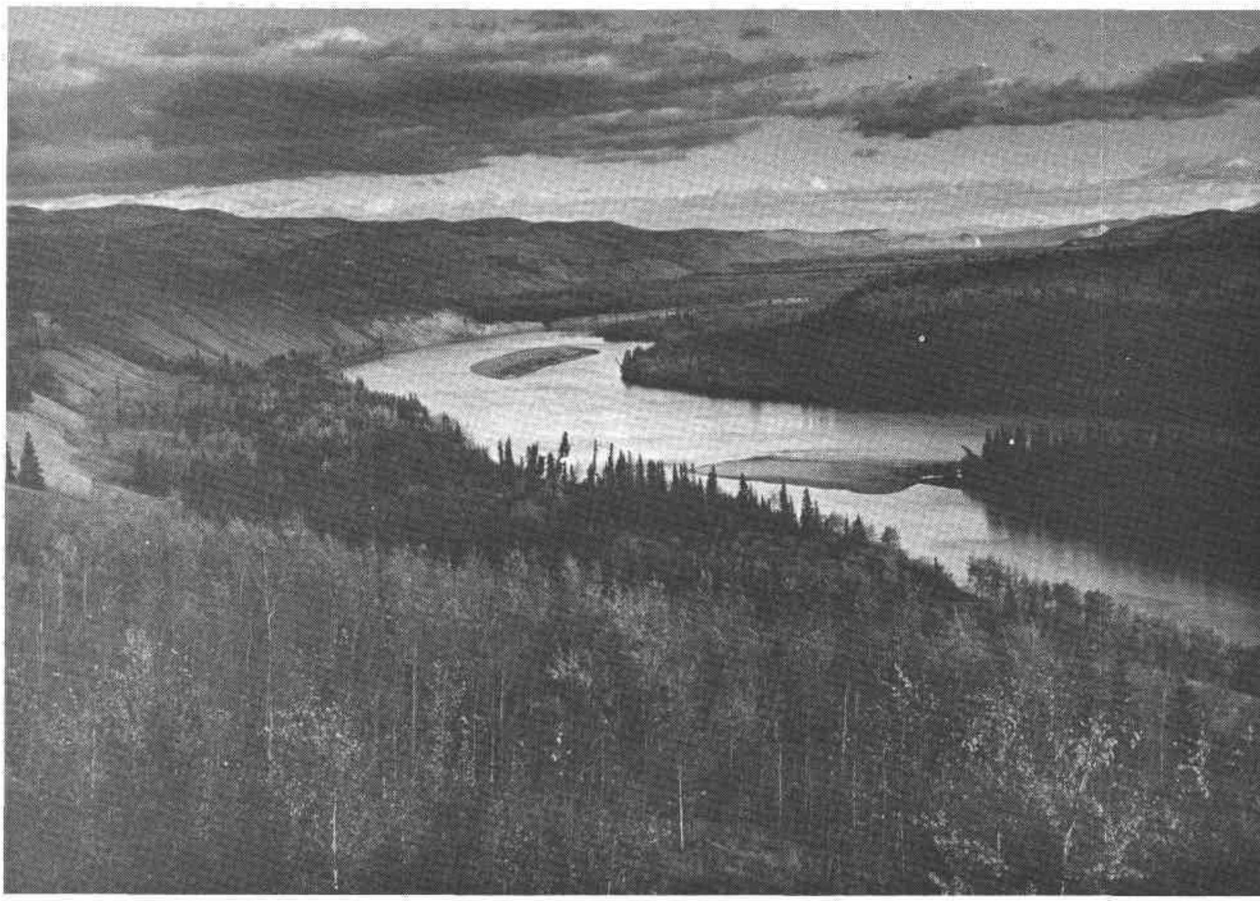


Figure 32 View northeast up Stewart River in central Yukon Territory from Stewart Crossing, Y. T. The south facing slope on the left supports spruce and poplar up to 60 ft high with ground vegetation of feather moss below which is peat about 6 in. thick overlying silty gravel. No permafrost was encountered on this slope. The opposite north facing slope on the right supports dense spruce growth and is suspected to have permafrost. September 23, 1964.

Figure 33 Location No. 137 - Mile 213 to 243 - Whitehorse-Mayo Highway, Y.T. This location is typical of the south facing slope of the Stewart River valley described in Figure 32. September 23, 1964.

Figure 34 Location No. 138 - Mile 232.7 - Whitehorse-Mayo Highway, Y.T. This low area consists of peat plateaux interspersed with wet depressions. The tree growth on the peat plateaux consists of spruce up to 25 ft high with ground vegetation of hummocky Sphagnum, feather moss, lichen and Labrador tea below which is peat 5 ft 0 in. thick overlying medium sand with sands. The permafrost table is at the 1 ft 6 in. depth. In the depressions, the vegetation consists of feather moss, grass and sedge and the water table is at the ground surface. No permafrost was encountered in the depressions except in slightly higher patches where the moss surface was dry. In these areas the permafrost table was at the 5 ft 6 in. depth. September 23, 1964.

Figure 35 View northward up the South McQueston River valley at Elsa, Y.T. Permafrost is widespread in the valley bottom and slopes. September 23, 1964.

Figure 36 Location No. 141 - Mile 9 - Dawson Highway, Y.T. This low area has scattered spruce up to 30 ft high growing mostly on low peat plateaux about 1 ft high, with ground vegetation of hummocky Sphagnum, feather moss and Labrador tea below which is peat exceeding 3 ft 6 in. in thickness. The permafrost table is at the 1 ft 9 in. depth. The low wet depressions support scattered spruce up to 30 ft high with ground vegetation of feather moss, grass and sedge, and the water table is at the ground surface. The permafrost table is at the 2 ft 7 in. depth in these wet areas and at the 3 ft 6 in. depth beneath the surface of a pool of water 1 ft 3 in. deep. September 23, 1964.

Figure 37 Location No. 143 - Mile 52.8 - Dawson Highway, Y.T. This wide shallow valley of Collins Creek supports scattered spruce up to 30 ft high and dense willow up to 5 ft high. Scattered depressions (foreground) support grass and sedge, and the water table is at the ground surface. The underlying soil is organic silt. Permafrost occurs throughout the area at a depth of 3 ft 6 in. September 23, 1964.

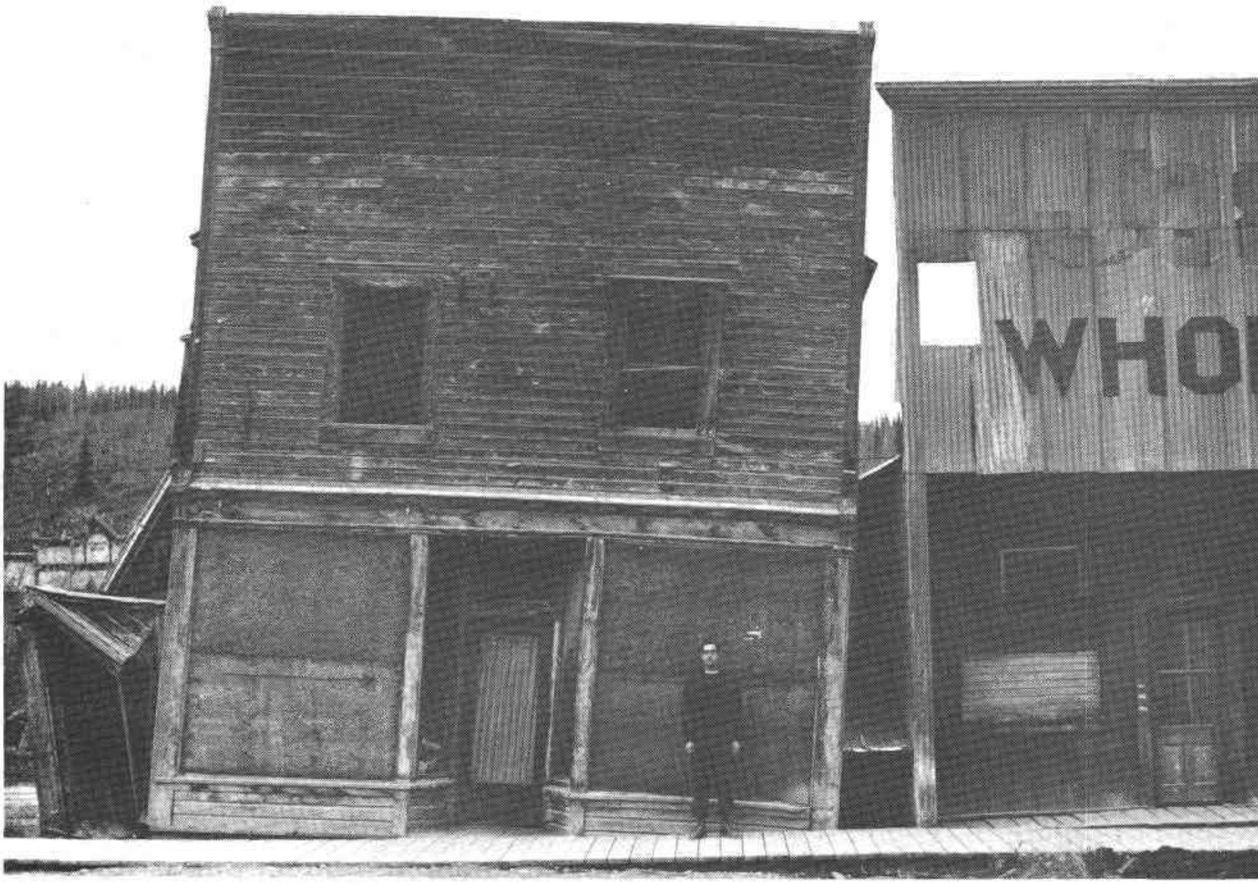


Figure 38 Abandoned store at Dawson, Y. T. which has settled differentially because of thawing of underlying perennially frozen fine-grained soil containing large quantities of ground ice. September 26, 1964.

Figure 39 Placer gold mining operations in perennially frozen gravels in Bear Creek valley, a tributary of Klondike River near Dawson, Y.T. The stacks of pipe comprise the dismantled network through which cold water is circulated to thaw the frozen gravel. September 25, 1964.

Figure 40 Dempster Highway about 60 miles north of Dawson Highway where permafrost is widespread or virtually continuous extending to a depth of 500 to 1000 ft. No trees grow in this alpine-arctic area in the Ogilvie Mountains. The ground vegetation consists of hummocky moss, grass and sedge. Polygonal cracks occur widely and the permafrost table is at the 1 ft 0 in. depth. September 23, 1964.

APPENDIX A

In addition to the permafrost investigations carried out along the roads in the study area, information on occurrences of permafrost in British Columbia and Yukon Territory have been obtained from the technical literature, questionnaires and personal interviews. The locations and sources of information are listed below in alphabetical order and are shown on Figure A-1. The information 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 one another. The absence of permafrost at a particular site does not necessarily preclude the existence of permafrost nearby in a different type of terrain.

BRITISH COLUMBIA

1. Alaska Highway

Permafrost reports from British Columbia section of highway listed in Yukon Territory section.

2. Cassiar (59°17'N, 129°48'W)

No permafrost encountered in gravel outwash at townsite at elevation of 3500 ft above sea level. Just below 4500 ft, permafrost ispatchy and above 4500 ft it becomes widespread (18.)

3. Cracker Creek (59°45'N, 133°14'W)

Permafrost in surface trenches in talus at elevation of 6000 ft above sea level at head of creek (5).

4. Dease Lake (approx. 58°37'N, 130°02'W)

No permafrost encountered in surface deposits around lake at elevation of 3000 ft above sea level (31).

5. Garibaldi Park (approx. 50°N, 123°W)

Permafrost encountered in cinder cone beside Helm Glacier at elevation of 6000 ft above sea level. Mean annual air temperature is approximately 32°F (33).

6. Granby Mining Co. Ltd. (near Grand Forks - 49°02'N, 118°27'W)

Patches of permafrost encountered in Phoenix Mine between 4550 and 4950 ft elevations (32).

7. Granduc Mines Ltd. (approx. 56°N, 130°W)

No permafrost encountered (25).

8. Grayling River (59°21'N, 125°02'W)

Extensive permafrost encountered in seismic exploration. Depth to permafrost varies from 2 to 4 ft beneath thick moss in poorly drained areas. No permafrost encountered in well drained areas or along river banks where moss is thin (12).

9. Ingenika Mines Ltd. (approx. 56°30'N, 125°30'W)

No permafrost reported (30).

10. Morris Summit Mines Ltd. (east of Stewart, B.C.)

No permafrost encountered (34).

11. Silver Standard Mines Ltd. (location unknown)

No permafrost reported (37).

12. Squaw Creek (60°00'N, 137°07'W)

Patches of permafrost encountered in northwest facing slope at 3 ft depth in moss-covered silt clay till at elevation of 2500 ft above sea level. No frozen ground encountered in gravel soils at same location (1).

13. Stewart-Cassiar Highway

Unconfirmed report of ground ice in road cut along Dease Lake (approx. 58°30'N, 130°00'W). Road settlement caused possibly by thawing permafrost occurred at locations between Telegraph Creek Junction and Burrage River (approx. 57°20'N, 130°00'W to 58°25'N, 130°00'W). Island of permafrost 170 ft long by 30 ft wide encountered during road construction one mile north of Gnat Pass summit (approx. 58°15'N, 130°00'W) in moss and peat-covered soil. Unconfirmed report of ground ice in north facing peat bank a few miles south of Tsahabe Creek (approx. 57°55'N, 130°00'W) (4).

14. Table Mountain Mines Ltd. (location unknown)

No permafrost reported (39).

15. Telegraph Creek (57°54'N, 131°09'W)

No permafrost reported (27).

16. Topley Mines Syndicate Ltd. (location unknown)

No permafrost reported (40).

YUKON TERRITORY

1. Aishihik (61°39'N, 137°28'W)

Permafrost encountered in silt, sand and gravel at 3 ft depth and extending to 89 ft depth. Permafrost encountered 5 ft below ground surface and extending to thickness of 45 ft (7, 10).

2. Alaska Highway

From Whitehorse southeast to the upper crossing of Liard River near Watson Lake, a distance of about 275 miles, the highway was built over permafrost for only about 19 miles - 6.5 per cent. Permafrost was noted also at a few isolated spots farther to the southeast. Between Whitehorse and Big Delta, Alaska, 28 per cent of the road is built over ground that was classed as permafrost (20) at the time of construction (23).

Only about 6 sites on the highway present permafrost problems - Mile 558, 828, 1048, 1121, 1156 and 1221 (41).

Icings encountered at Mile 246.9, 398.4, 410, 412, 486.3, 557.8, 828.6 - 829. Some of these icings are associated with permafrost but others are not (6).

(i) Mile 246.9 - Permafrost encountered at bridge crossing in road relocation (6).

(ii) Mile 368.0 - Permafrost encountered in peat bog during road construction (6).

(iii) Mile 398.4 - Permafrost at least 14 ft thick in organic silt and gravel overlain by 4 ft of peat encountered in side hill causing road failure and necessity for relocation (6).

(iv) Mile 486.3 - Permafrost caused difficulty during road construction (6).

(v) Mile 543 - Permafrost encountered on long hill west of Coal River crossing in fall of 1963 (6).

(vi) Mile 557.8 - 558.1 - Permafrost encountered during road construction in vicinity of Leguil Creek. This section of road is reported to be fairly stable now but ditches require cleaning periodically (6).

(vii) Mile 680 to 685 - Permafrost islands encountered along this section (6).

(viii) Mile 733 to 770 - No permafrost reported (6).

(ix) Mile 828.5 - 829 - Perennially frozen silt encountered during construction. Thaw settlement is still occurring (6).

(x) Mile 1005.6 - Thawing permafrost caused damage to concrete abutment of Marshall Creek bridge on wood piles (6).

(xi) Mile 1034 - Permafrost encountered at bridge crossing necessitating use of 40 foot piles (6).

(xii) Mile 1083 - During the drilling of a well to 99 ft depth, permafrost was encountered (3).

(xiii) Mile 1095 - During the drilling of a well at a motel to 158 ft depth, permafrost was encountered (3).

(xiv) Mile 1100 - 1127 - Several areas of permafrost occur in this section (8).

(xv) Mile 1124 - Several wells were drilled in Donjek River valley to depths of 150 to 235 feet. Permafrost was encountered in two of the wells during drilling operations (3).

(xvi) Mile 1128.7 - Permafrost encountered in large gravel pit (6).

(xvii) Mile 1150.1 - 1178.1 - Permafrost encountered at 19 locations in sandy and silty gravel during gravel search for road maintenance purposes (6).

(xviii) Mile 1156 - Permafrost encountered in borehole at Long's Creek from a depth of 6 ft to 34 ft in silt, sand and gravel (6).

(xix) Mile 1164 - During the drilling of a well at the crossing of Koidern River to depth exceeding 35 ft, permafrost was encountered (2). In a borehole, permafrost was encountered in silt at depths varying between 2 to 12 ft and 8 to 22 ft (6).

(xx) Mile 1196 - Permafrost encountered in borehole to 9 ft depth in silt (6).

(xxi) Mile 1202 - During the drilling of wells in sand and gravel to depths of 60 to 110 ft, no permafrost was encountered (3).

(xxii) Mile 1205-1221 - Permafrost conditions in this section are very difficult for road maintenance (6).

(xxiii) Mile 1208 - Permafrost encountered at Snag Creek bridge crossing (6).

(xxiv) Mile 1210 - Permafrost encountered in borehole from 2 to 22 ft depth in silt, sand, and fractured rock (6).

(xxv) Mile 1213 - Permafrost encountered in borehole from 1 to 7 ft depth in silt, sand and gravel (6).

(xxvi) Mile 1217.8 - Permafrost encountered from 1 to 11 ft depth in clay at Little Scottie Creek (6).

(xxvii) Mile 1221 - Permafrost encountered from 1 to 30 ft depth in silt during road relocation (6).

3. Alsek River

(i) Kathleen Canyon Dam Site (60°45'N, 137°25'W)

Frozen ground (probably permafrost) encountered on north facing side of river valley in till and glacio-lacustrine silt on lower river terrace and on slope beneath upper terrace. Depth to frozen ground varied from 10 to 18 in. beneath moss and peat on 9 September, 1961 (11).

(ii) Kathleen Lake Dam Site (60°35'N, 137°15'W)

Frozen ground (probably permafrost) encountered on north facing slope usually in clay silt. Depth to frozen ground varied from 12 to 14 in. No frozen ground encountered on south facing slope (11).

4. Atlin Highway

Mile 5.5-6.5 - Permafrost encountered during road construction on slope below the road. No permafrost was encountered on slope above road (16).

5. Blind Creek (62°15'N, 134°15'W)

No permafrost encountered in gravel, sand and clay soil with discontinuous 6-in. thick moss cover (42).

6. Boundary (62°38'N, 141°00'W)

Permafrost encountered in well drilling from surface to depth exceeding 150 ft (35).

7. Canada Tungsten Mining Corp. Ltd. (62°N, 128°15'W)

Discontinuous permafrost in peat bogs at 2 to 3 ft depth below ground surface varying in thickness from 6 to 12 ft (14).

8. Canol Metal Mines Ltd. (61°30'N, 132°46'W)

No permafrost reported (17).

9. Canol Road

Permafrost was encountered at Mile 38, and Mile 55-60 (Quiet Lake) (16).

10. Carcross Highway

Mile 14 - Permafrost encountered during road construction in a cut in a small stream valley necessitating straightening of the road (16).

11. Carmacks (62°36'N, 136°19'W)

Discontinuous permafrost on north facing slopes in moss covered gravel, silt and clay, and in peat bogs; depth to permafrost is about 5 ft (10, 13). Continuous permafrost encountered at depth of 2 ft in silty gravel 25 miles northwest of Carmacks (22).

12. Dawson (64°04'N, 139°29'W)

Permafrost encountered to maximum depth of 200 ft (31).

13. Dease Creek (location unknown)

Permafrost encountered throughout length of tunnel driven 150 ft horizontally into hillside; end of tunnel 40 ft below the ground surface (22).

14. Dempster Highway

Permafrost was encountered along the entire length except in a few steep south facing gravel slopes at the south end (16).

15. Discovery Mines Ltd. (Carmacks, Y. T.)

No permafrost encountered in 2500 ft long mine adits on south facing slope 3300 to 3475 ft above sea level. Permafrost encountered in bottoms of gullies, which are shaded, and on north facing slopes during road construction (24).

16. Donjek River (61°39'N, 139°47'W)

Permafrost encountered at Alaska Highway bridge crossing (26).

17. Eldorado Creek (63°50'N, 139°10'W)

Thickness of permafrost in creek valley exceeds 200 ft (31).

18. Frances River

(i) False Canyon Site (60°43'N, 129°05'W)

Frozen ground (probably permafrost) encountered in one test pit dug in sand to depth of 8 ft (11).

(ii) Lower Canyon Dam Site (60°26'N, 129°11'W)

Frozen ground (probably permafrost) encountered in fill (11).

19. Haines Junction (60°46'N, 137°32'W)

Permafrost encountered in moss covered fine-grained soils at depth of 1 ft; ice layers increase in thickness with depth (13).

Permafrost was encountered at a few scattered locations in the early 1950's at the Dominion Experimental Farm, Mile 1019, Alaska Highway, 3 miles west of Haines Junction. After cultivation, the permafrost thawed and did not re-form (9).

20. Hershel Island (69°34'N, 138°48'W)

Permafrost containing ice encountered in moss covered organic soil at depth of 1 ft (13).

21. Jensen Creek (63°45'N, 138°32'W)

Water in reservoir seeped through base of retaining earth dam and thawed underlying permafrost (35).

22. Keno City (63°54'N, 135°18'W)

Discontinuous permafrost encountered in moss covered clay containing boulders (13).

23. Klondike District

Permafrost encountered in glacial drift. It is thinner on ridge summits than in valleys and more widespread on north facing slopes. On a ridge south of Eldorado Creek the bottom of the permafrost was encountered at a depth of 60 ft (31).

24. Klondike River

Permafrost is 175 ft thick on plateau between Bonanza Creek and Klondike River (31).

25. Kluane District

Permafrost encountered in gravel benches along Burwash Creek (31).

26. Kluane Lake

Continuous permafrost encountered at depth of 18 in. in moss-covered silt, sand and gravel (19).

27. Kluane River

Kluane Canyon Site (61°30'N, 139°10'W)

Frozen ground (probably permafrost) is widespread (11).

28. Koidern River (61°54'N, 140°14'W)

Permafrost encountered at depth of 2 ft and extending to 42 ft depth on moss and peat covered hill composed of glacial clay and pebbles (21).

29. Lapie River (62°30'N, 133°00'W)

No permafrost encountered along river (10).

30. Liard River

(i) Lower Liard Canyon Site (60°01'N, 128°36'W)

Frozen ground (probably permafrost) encountered at one location (11).

(ii) Upper Liard Canyon Site (60°02'N, 128°38'W)

No frozen ground encountered at site (11).

31. MacMillan River (63°00'N, 131°00'W)

Depth to frozen ground (probably permafrost) is 1 to 2 ft and the thickness is unknown (10).

32. Mayo (63°35'N, 135°51'W)

Permafrost containing ice encountered at depth of 6 ft in peat-covered fine-grained soil in excavation on bank of Stewart River near Mayo (13).

Layers of permafrost encountered in well drilling in silt bank of Stewart River in southeast section of Mayo (11).

33. Old Crow (67°35'N, 139°50'W)

Continuous permafrost encountered in excavation at depth of 1 ft 6 in. in silt (13).

34. Pelly River

Frozen soil (probably permafrost) observed at several locations along the north facing bank of the river at depth of 1 ft 6 in. and extending to water level (22).

(i) Braden's Canyon Dam Site (approx. 62°51'N, 136°57'W)

No frozen ground encountered on either side of river to height of 250 ft above river (11).

(ii) Gerc Dam Site (approx. 62°50'N, 136°22'W)

No frozen ground encountered on either side of river to height of 220 ft above river (11).

(iii) Ross Canyon Dam Site (approx. 62°02'N, 132°22'W)

No frozen ground encountered at site (11).

35. Ross River (approx. 62°50'N, 131°00'W)

Permafrost encountered in vicinity of Sheldon Lake (15).

36. Ross River-Carmacks Road (approx. 62°N, 132°30'W to 62°N, 136°W)

Permafrost is discontinuous along this proposed road location. It occurs on most north facing slopes and in depressions with thick moss cover. Permafrost is not found in south facing slopes or mineral soils with little or no moss cover (28).

37. Snag (62°24'N, 140°22'W)

Discontinuous permafrost encountered at depth of 16 ft and extending to depth of 62 ft in gravel (5). Permafrost encountered at depth of 30 ft and extending to depth of 50 ft (10).

38. Stewart Crossing - Dawson - Alaska Boundary

(i) Mile 5.6 - Permafrost islands in both banks of creek to depths exceeding 10 ft (16).

(ii) Mile 7 - Permafrost encountered in muck at Dry Creek bridge crossing (16).

(iii) Mile 52 - Permafrost encountered in both banks of creek (16).

East of Dawson, permafrost is widespread in Klondike River valley flats in muck deposits. The most difficult section of road to maintain lies between Dawson and the Dempster Highway junction where melting of ground ice causes dips in the road. Permafrost occurs in all north facing slopes and is widespread in south facing slopes but not as extensive or thick. Permafrost is found in poplar-covered hilltops at a depth of 8 to 10 ft below the ground surface. Gravel pits are opened one year before they are required, to allow the gravel to thaw. Large ice lenses are frequently encountered. Permafrost was not encountered in the first 6 mile section west of Dawson but westward to the international boundary it is continuous (16).

39. Takhini River

Frozen ground (probably permafrost) encountered at depth of 25 ft in bridge pier construction (approx. 60°51'N, 135°30'W) (6). Some pitted areas, particularly south of Takhini River opposite mouth of Little River may be marked by thaw lakes and depressions (approx. 60°53'N, 135°43'W). Shallow pitted areas such as those near mouth of Takhini River may represent thaw depressions rather than kettles (approx. 60°50'N, 135°10'W) (44).

40. Teslin (60°10'N, 132°44'W)

Scattered patches of permafrost in vicinity of town (10).

41. Teslin River

(i) North West Power Industries Dam Site (approx. 60°55'N, 134°05'W)

No frozen ground encountered from river level to heights of 300 ft and 200 ft on east and west banks respectively (11).

(ii) Swift River Dam Site (approx. 60°45'N, 133°50'W)

No frozen ground encountered from river level to height of 300 ft on east and west banks (11).

42. United Keno Hill Mines Ltd. (63°51'N, 135°31'W)

Permafrost is patchy in distribution depending on elevation, exposure, vegetation, drainage and depth of overburden. Above an elevation of 4500 ft above sea level, the maximum thickness of permafrost in the mine is 450 ft. In the valley bottom at an elevation of 2300 ft above sea level, permafrost exceeds 140 ft in thickness. Across the valley, no permafrost was encountered in mine exploration investigations at an elevation of 2550 feet above sea level on a south facing slope (20, 36).

43. Watson Lake (60°07'N, 128°48'W)

No permafrost encountered in vicinity of town (13).

44. Watson Lake-Ross River Highway

Patches of permafrost encountered along 30-mile stretch of highway southwest of Ross River. Along the next 20-mile stretch of highway, permafrost is more widespread, occurring in moss-covered silt (43). Permafrost was encountered at Mile 34 (west approach of Frances River crossing), Mile 50-55, Mile 67, and Mile 106 (Money Creek) (16).

45. White River

Permafrost reported to be 90 ft thick (31).

(i) Lower Canyon Dam Site (approx. 61°55'N, 140°30'W)

Frozen ground (probably permafrost) reported to be widespread (11).

46. Whitehorse (60°43'N, 135°05'W)

Only reported occurrence of permafrost encountered at depth of 9 ft in sewer excavation in stony clay (13).

47. Whitehorse-Mayo Highway

(i) Mile 158 - Pelly River - No permafrost encountered (16).

(ii) Mile 205 - Permafrost encountered in both slopes of Crooked Creek (16).

(iii) Mayo to Elsa - Permafrost is widespread. It was encountered at Glacier Hill a few miles north of Mayo (16).

(iv) Elsa to Keno - Permafrost occurs on all north facing slopes (16).

48. Wolf Creek (61°20'N, 139°30'W)

Permafrost encountered at depth of 1 ft in moss-covered gravel at an elevation of 2500 ft above sea level (38).

49. Wolf River (mouth at 60°16'N, 132°33'W)

Frozen ground (probably permafrost) encountered in river banks (22).

50. Yukon River

(i) Big Salmon Dam Site (approx. 62°00'N, 135°20'W)

No frozen ground reported to height of 200 ft above river level (11).

(ii) Boundary Dam Site (approx. 64°41'N, 140°59'W)

Frozen ground (probably permafrost) encountered in test pits in moss-covered river terrace up to height of 300 ft above river level (11).

(iii) Britannia Dam Site (approx. 62°52'N, 138°46'W)

Frozen ground (probably permafrost) encountered on lower terrace on south side of river in moss-covered silty sand (11).

(iv) Five Fingers Rapids Dam Site (approx. 62°16'N, 136°23'W)

No frozen ground encountered on either side of river from water level to height of 300 to 400 ft (11).

(v) Five Fingers Rapids Draw Extension (approx. 62°18'N, 136°26'W)

No frozen ground encountered from water level to height of 250 ft (11).

(vi) Fort Selkirk Dam Site (approx. 62°48'N, 137°27'W)

No frozen ground encountered on either side of river from water level to height of 400 to 450 ft (11).

(vii) Fort Selkirk Saddle Dam Site (approx. 62°47'N, 137°30'W)

No frozen ground encountered on north facing slope of river valley (11).

(viii) Lower Dawson Dam Site (approx. 64°11'N, 139°33'W)

Frozen ground (probably permafrost) encountered in moss-covered silty sand from river level to height of 350 ft (11).

(ix) Lower Ogilvie Dam Site (approx. 63°34'N, 139°45'W)

Frozen ground (probably permafrost) encountered in river island and on west bank in silt from river level to height of about 200 ft (11).

(x) Selwyn Dam Site (approx. 62°47'N, 138°14'W)

Frozen ground (probably permafrost) encountered in moss-covered silty sand terrace immediately north of river (11).

(xi) Upper Dawson Dam Site (approx. 64°02'N, 139°32'W)

Frozen ground (probably permafrost) encountered everywhere under the ground surface to height of 300 ft above river level (11).

(xii) Upper Ogilvie Dam Site (approx. 63°38'N, 139°45'W)

No frozen ground encountered at this site (11).

(xiii) Wolverine Dam Site (approx. 62°43'N, 137°17'W)

No frozen ground encountered on east bank of river. Frozen ground (probably permafrost) encountered on west bank between river and rock bluff forming left abutment (11).

(xiv) Wolverine Draw Section (approx. 62°45'N, 137°13'W)

No frozen ground encountered at this site (11).

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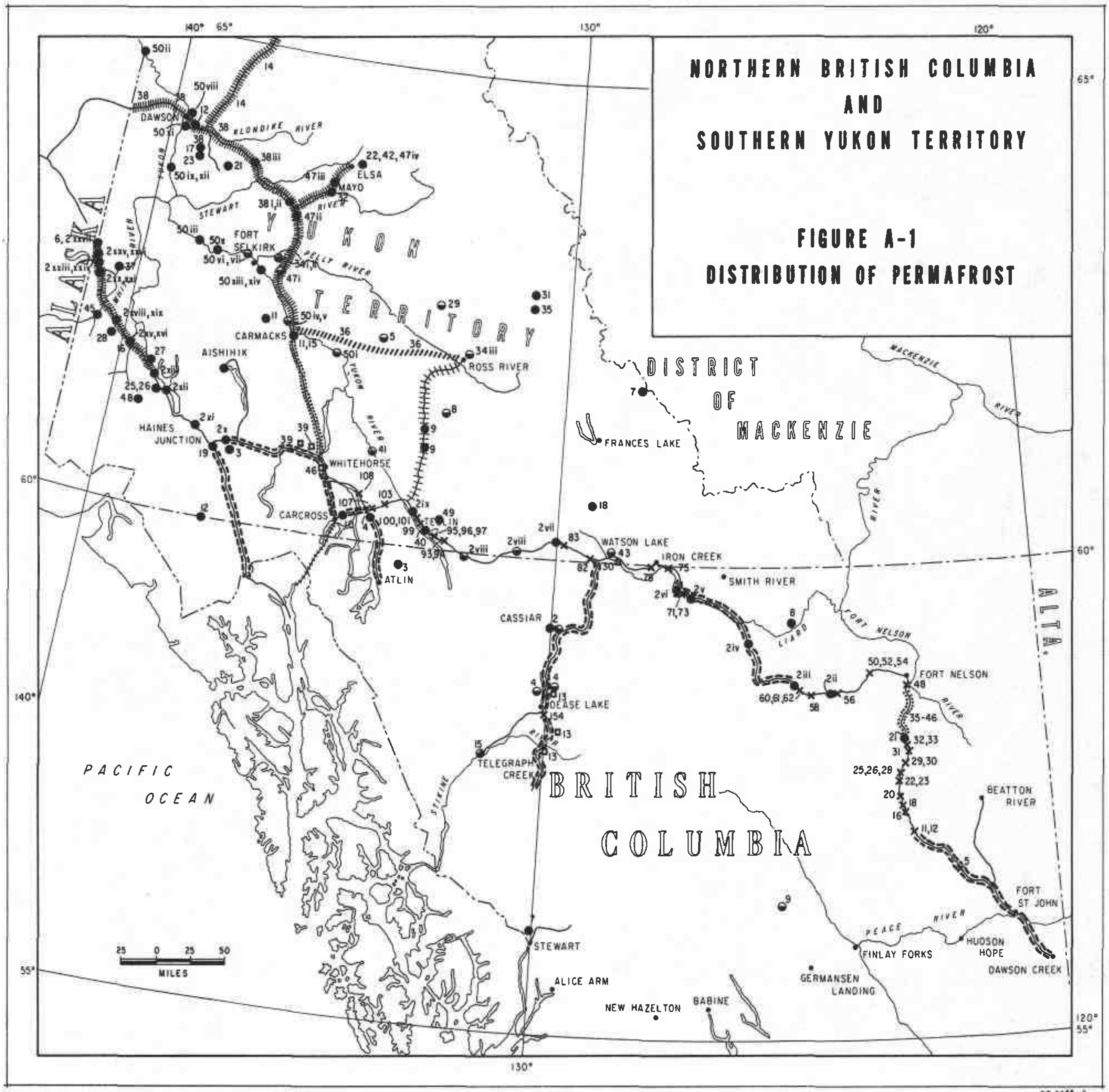

NORTHERN BRITISH COLUMBIA
AND
SOUTHERN YUKON TERRITORY

FIGURE A-1
DISTRIBUTION OF PERMAFROST

BR 4045-2

LEGEND:

FIELD INVESTIGATIONS

- × PERMAFROST LOCATION (NUMBERS REFER TO LOCATIONS IN TABLE 1)
- SCATTERED PERMAFROST ENCOUNTERED ALONG ROAD
- WIDESPREAD PERMAFROST ENCOUNTERED ALONG ROAD
- NO PERMAFROST ENCOUNTERED ALONG ROAD

SECONDARY SOURCES OF INFORMATION (NUMBERS REFER TO LOCATIONS IN APPENDIX A)

- ● PERMAFROST LOCATION
- NO PERMAFROST REPORTED (PERMAFROST MAY EXIST NEARBY IN DIFFERENT TYPE OF TERRAIN)
- EXISTENCE OF PERMAFROST UNCERTAIN
- SCATTERED PERMAFROST ALONG ROADS
- WIDESPREAD PERMAFROST ALONG ROADS