DISTRIBUTION OF PERMAFROST IN CANADA

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(Summary)[2]

The theme of this Conference is concerned with permafrost problems related to the mining and oil and gas production industries. The purpose of this paper is to set the stage by describing some of the characteristics of the permafrost region of Canada. In 1967 a permafrost map of Canada was published in colour jointly by the Division of Building Research, National Research Council, and the Geological Survey of Canada, Department of Energy, Mines and Resources. Copies of the map can be obtained from either of these agencies.

This map shows the extent of the continuous and discontinuous zones and their relations to the climate and physiographic regions. The distribution of permafrost at high elevations in the Cordillera in British Columbia, south of the discontinuous zone is also shown on the map. A table listing ground temperatures and thickness of permafrost for 24 locations in northern Canada is included. Explanatory notes accompanying the map describe the nature of permafrost and its relation to climatic and terrain factors.

A diagrammatic profile of permafrost through the continuous zones in Canada is shown in Figure 1. (Note that thicknesses of the permafrost and active layer are shown in metres.) Permafrost is several hundreds to more than 1,000 feet thick in the continuous zone and the active layer is generally 1 to 3 feet thick. Southward in the discontinuous zone, the permafrost is interspersed with areas of unfrozen ground. In the northern part of this zone, permafrost is widespread varying in thickness from about 50 to 200 feet. In the southern part of the zone, termed the "southern fringe", permafrost occurs in scattered islands ranging in size from a few square feet to several acres, and varying in thickness from a few feet to a maximum of about 50 feet. The active layer is thicker than in the continuous zone and it does not extend everywhere to the permafrost table. Figure 2 shows typical profiles in the continuous and discontinuous permafrost zones.

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[1]See Appendix "A" for affiliation of authors of papers.

[2]Information in this paper is contained in various papers bv the authors which have been published by the Division of Building Research, National Research Council, Ottawa, Ontario, Canada. Copies can be obtained by sending requests to the Publications Section of this Division.

The ground thermal regime (Figure 3) is an important aspect particularly because the definition of permafrost is based on temperature referring to ground which remains below 32°F continuously for more than one year. This is the minimum length of time required for frozen ground to be considered as permafrost, or perennially frozen ground. At the other end of the time scale is permafrost which is thousands of years old and hundreds of feet thick. Fluctuations in air temperature during the year produce corresponding temperature fluctuations about the mean annual ground temperature to depths of about 20 to 50 feet. The amplitude of these fluctuations decreases with depth to less than 0.1°F. The depth at which fluctuations became imperceptible is called the "level of negligible annual amplitude" or "level of zero annual amplitude". Below this, ground temperatures change only in response to long-term climatic changes extending over centuries. The ground temperature in the permafrost and below increases steadily under the influence of the heat from the Earth's interior.

Tundra polygons (Figure 4) and pingos (Figure 5) are among the most distinctive permafrost surface features in the continuous zone. Polygons attain sizes of 50 to 100 feet in diameter and the marginal fissures are frequently underlain by vertical ice wedges extending to depths of tens of feet. Pingos are conical hills up to 100 feet or more in height containing a core or plug of massive ice. They may be either the closed system type usually associated with old lake beds in the continuous permafrost zone or open system type associated with groundwater movement through unfrozen ground in the discontinuous zone. Ice wedge polygons are also found in the discontinuous zone but they attain their greatest development in the continuous zone.

Surface permafrost features are not as distinctive in the discontinuous zone although some terrain patterns attest to the presence of permafrost. Figures 6, 7 and 8 are vertical, oblique and ground photographs in an area of widespread discontinuous permafrost. Unfortunately the distribution of permafrost is not usually delineated so readily from surface terrain features. In many parts of the discontinuous zone, the permafrost does not have any surface expression and its presence can only be inferred or ascertained by subsurface field investigations.

In the southern part of the discontinuous zone, where permafrost occurs in scattered islands, the most distinctive permafrost feature is the palsa (Figure 9). These peat mounds have a core of permafrost with a peat cover. They are found in some peatlands and peat bogs southward to the southern limit of the permafrost region.

Ground ice is an important component of permafrost occurring widely in many forms in overburden and bedrock (Figure 10). Ice forms include segregated ice, forming discrete layers or lenses, pore fillings which cement or bond individual soil particles, intrusive or injected ice formed by freezing of injected water, vein or wedge ice in thermal contraction cracks, and buried ice including snowbanks, glacier ice, and ice on water bodies. The existence of large masses of ground ice is immediately evident where such features as pingos and ice wedge polygons occur. Many areas where ground ice occurs, however, may not exhibit any surface manifestation and its presence can only be inferred from the type of earth materials.

As the mining and oil and gas production industries expand their activities in the permafrost region, knowledge of the distribution of permafrost and features associated with it is assuming increasing importance. The following papers describe various aspects of exploration and production affected by permafrost.

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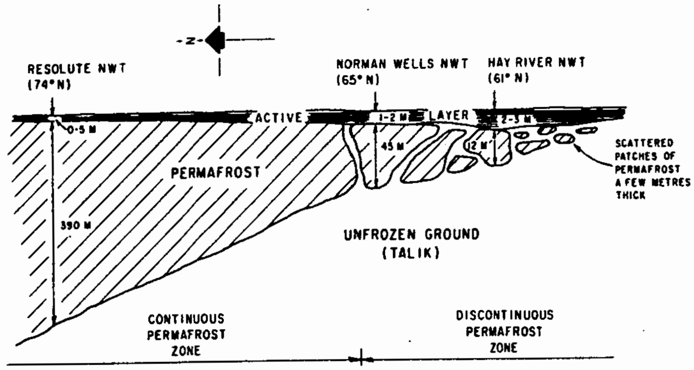
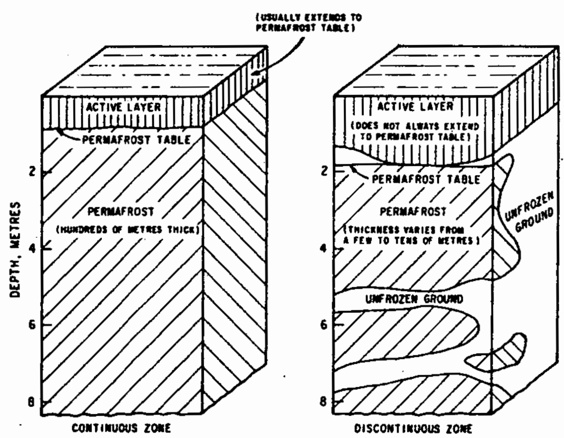
Discussion

Mr. B.L. Odom asked if there is a maximum depth below which one would not expect to find large masses of ice in the ground and if this is so, what determines this depth? Dr. Brown replied that his colleague, Mr. P.J. Williams, Division of Building Research, National Research Council, Ottawa, Ontario, published a paper on this subject entitled "Ice Distribution in Permafrost Profiles", Canadian Journal of Earth Sciences, Vol. 5, No. 12, Dec. 1968, pp. 1381-1386. In this paper Mr. Williams analyzed soil samples from the Mackenzie River delta comparing field observations of ice segregation in the samples with theoretical calculations of maximum depths at which ice segregation and lensing would occur. He found that the quantity of ice in the soil diminished with depth and below relatively shallow depths of perhaps 10 to 15 feet little ice was present. This is a situation where there is a slow but steady accumulation of sediments over many centuries. A different type of situation exists in northern Baffin Island where there are extensive deposits of glaciofluvial sands and gravels. Massive blocks several tens of feet thick to depths of 80 feet or deeper have been encountered in drilling for engineering site investigations as described in Mr. Samson's paper. This ice might be buried glacier remnants or formed by injection of water prior to freezing. The distribution of ice in the ground in permafrost regions appears to depend to some degree on the type of material and the mode of deposition.



TYPICAL VERTICAL DISTRIBUTION AND THICKNESS OF PERMAFROST

Fig. 1 Typical vertical distribution and thickness of permafrost.



TYPICAL PROFILES IN PERMAFROST REGION

Fig. 2 Typical profiles in permafrost region.

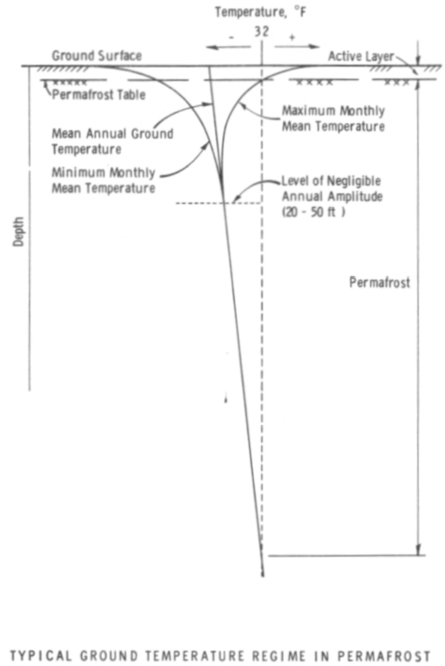


Fig. 3 Typical ground temperature regime in permafrost.

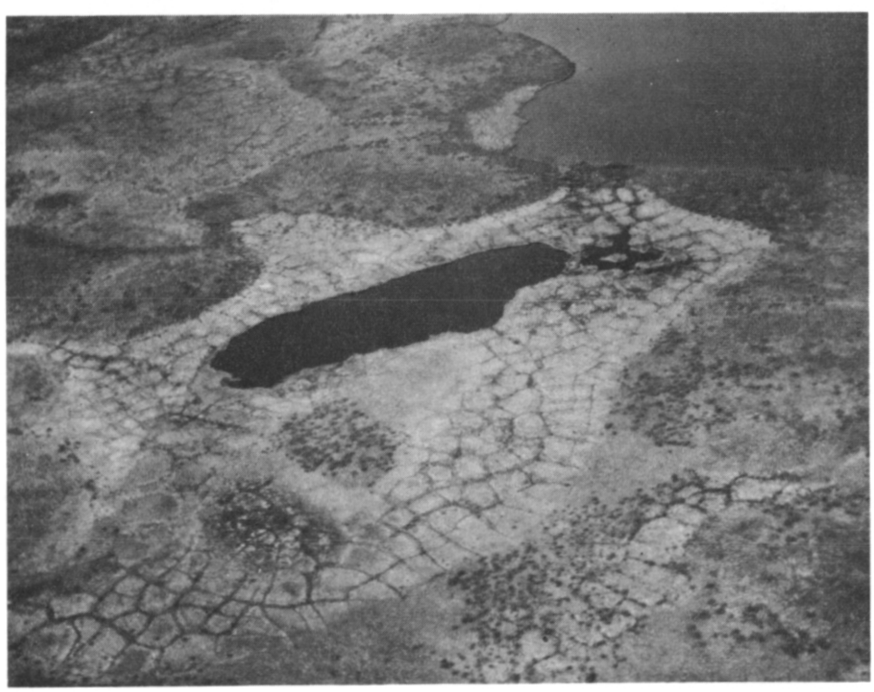


Fig. 4 Aerial view from about 1,000 feet of tundra ice wedge polygons, 50 to 100 feet in diameter, in continuous permafrost zone near Tuktoyaktuk, N. W. T. The cracks or fissures are underlain by wedge-shaped masses of ice up to 3 feet wide extending to depths of 10 to 20 feet.

Fig. 5 Aerial view from about 800 feet of a pingo near Tuktoyaktuk, N. W. T., near the arctic coast, east of the Mackenzie River delta, in the continuous permafrost zone. This pingo is about 130 feet high and has a crater on the summit. It is located in a lake bed and has a core of massive ice.

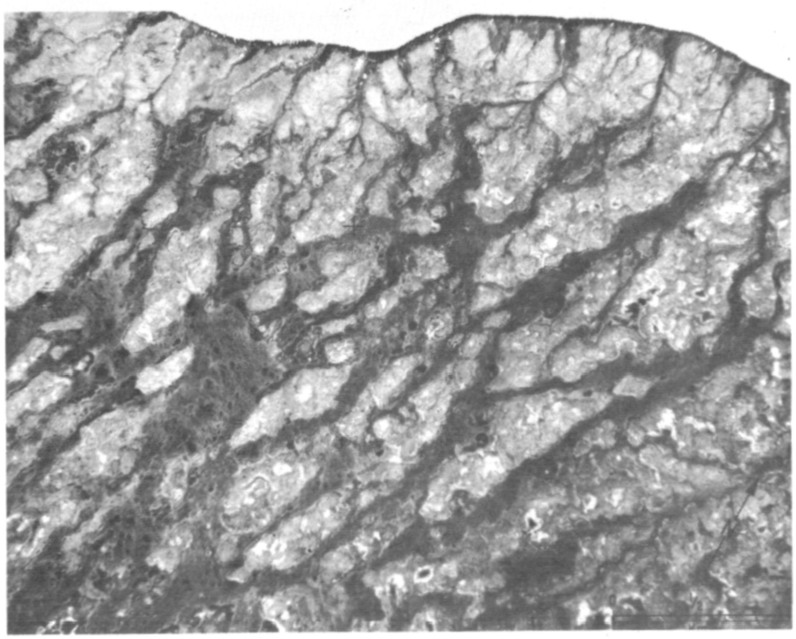


Fig. 6 Aerial photograph (scale - 1.6 inches: 1 mile) of terrain near Gillam, Manitoba, on Nelson River in northern part of discontinuous zone where permafrost is widespread. Light-toned areas are forested peat plateaux with permafrost about 80 feet thick. Dark areas are wet, sedge-covered depressions with no permafrost.

Fig. 7 Aerial view from about 400 feet of terrain shown in Fig. 6. Forested peat plateau with permafrost at top of photograph. Wet, sedge-covered depression with no permafrost in middle of photograph.

Fig. 8 Ground view of terrain shown in Fig. 6. Man is standing on peat plateau underlain by permafrost. Wet sedge-covered depression with no permafrost is in foreground.

Fig. 9 Mature palsa (peat mound) in southern fringe of discontinuous permafrost zone near Great Whale River, P.Q. The peat is 3 feet thick overlying silty clay soil. The depth to permafrost in the palsa is about 1 1/2 feet. The permafrost in the palsa is probably between 10 and 20 feet thick. No permafrost occurs in the surrounding terrain.

Fig. 10 Massive horizontal layers of ground ice in perennially frozen soil face exposed by landslide. The ice is protected from melting by overhanging vegetation. This exposure is located in a soil slump at the base of the Richardson Mountains which flank the west side of the Mackenzie River delta about 15 miles southwest of Aklavik, N.W.T.