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INTERACTION BETWEEN SURFACE COVER AND PERMAFROST

Although the extent and distribution of permafrost is fairly well known in most of Canada, there are still some areas where our knowledge in this respect is comparatively limited. One of these areas is certainly that to the east of Hudson Bay — the Labrador Peninsula. In this area, two factors may be responsible for a more complicated picture of the permafrost distribution than in the rest of Canada.

Firstly, the topography of the Labrador Peninsula must affect the distribution of the permafrost, as the most elevated areas are in its southern and eastern parts. Secondly, in contrast to most other areas in northern Canada, there is a heavy precipitation, of which about half falls as snow.

FIELD PROGRAM

In the Schefferville area, Quebec, soil temperature measurements were carried out in an attempt to evaluate the influence of certain surface covers and the effect of the exposure upon the thermal regime of the soil in a permafrost area. Fourteen thermocouple cables were installed to depths varying between 15—60 m, from which readings were taken on a bi-monthly basis throughout the period of 15 X 1961—1 X 1962. The accuracy of the readings was better than $\pm 0.2\,°C$, and annual mean temperatures of the soil could be obtained within an accuracy of $\pm 0.1\,°C$. In addition, six thermistor cables were installed down to 0.9 m. From three of these, temperature gradients in the snow could also be obtained.

Two weather stations were maintained in the area, and records were kept on snow conditions, soil moisture variations, ice lenses and ground ice. Finally, a vegetation map was drawn from air photos and checking in field.

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THE THERMAL REGIME IN THE INVESTIGATED AREA

The depth of penetration of the annual temperature wave showed great variations for the different sites, and a 0.5 °C temperature range was recorded at depths varying between 3.3—13.5 m. To some extent these variations were due to variations in the surface temperature range, but variations in the thermal properties of the soil must be the reason for at least the greater part.

The differences in the soil thermal properties were obtained by setting off the temperature range versus depth in a semi-logarithmic diagram. The inclination of these curves depend on the diffusivity of the soil. The apparent diffusivities in the active layer could in this way be determined to average about 0.002 cm^2/sec., and in frozen ground to about 0.010 cm^2/sec. Variations in these values due to different soil and bedrock conditions could also be found.

The present state of the permafrost can be clearly visualized by the variations in the annual mean temperature with increasing depth. As the annual temperature cycle was ascertained for 11—17 different levels at each site, the temperature variations with depth could be determined with a high degree of accuracy.

The curves showing the annual mean temperatures at various depths have a pronounced tendency towards decreasing temperatures with increasing depth (fig. 1). The annual mean temperature at the 5-m level is between —0.2 and —0.9 °C; only extremely exposed sites have temperatures between —1.2 and —1.6 °C. The coldest temperatures, however, are present at the 25-m level, where the temperature is found to be almost exactly 1.0 °C below the mean temperature at the 5-m level. The only installation which penetrates this coldest zone indicates from then on a steady increase in temperature, and the permafrost base could be ascertained at a depth of 65 m.

The shape of the mean temperature curves indicates that the permafrost is in a state of degrading, either due to an increase in the annual mean air temperature, or changed surface cover conditions.

The investigated area was generally very exposed, situated on a ridge elongated in a northwest-southeast direction. The spacing of the installations permitted drawing of the isotherms within the ridge in two sections.

The coldest parts were always found beneath the most exposed areas, but even a small depression in the ground surface seems to greatly affect the soil temperature, in some cases enough to create *taliks*. The heat flow in the ridge must be very complicated, and a predominantly vertical heat flow is only present beneath the most exposed areas (fig. 2).

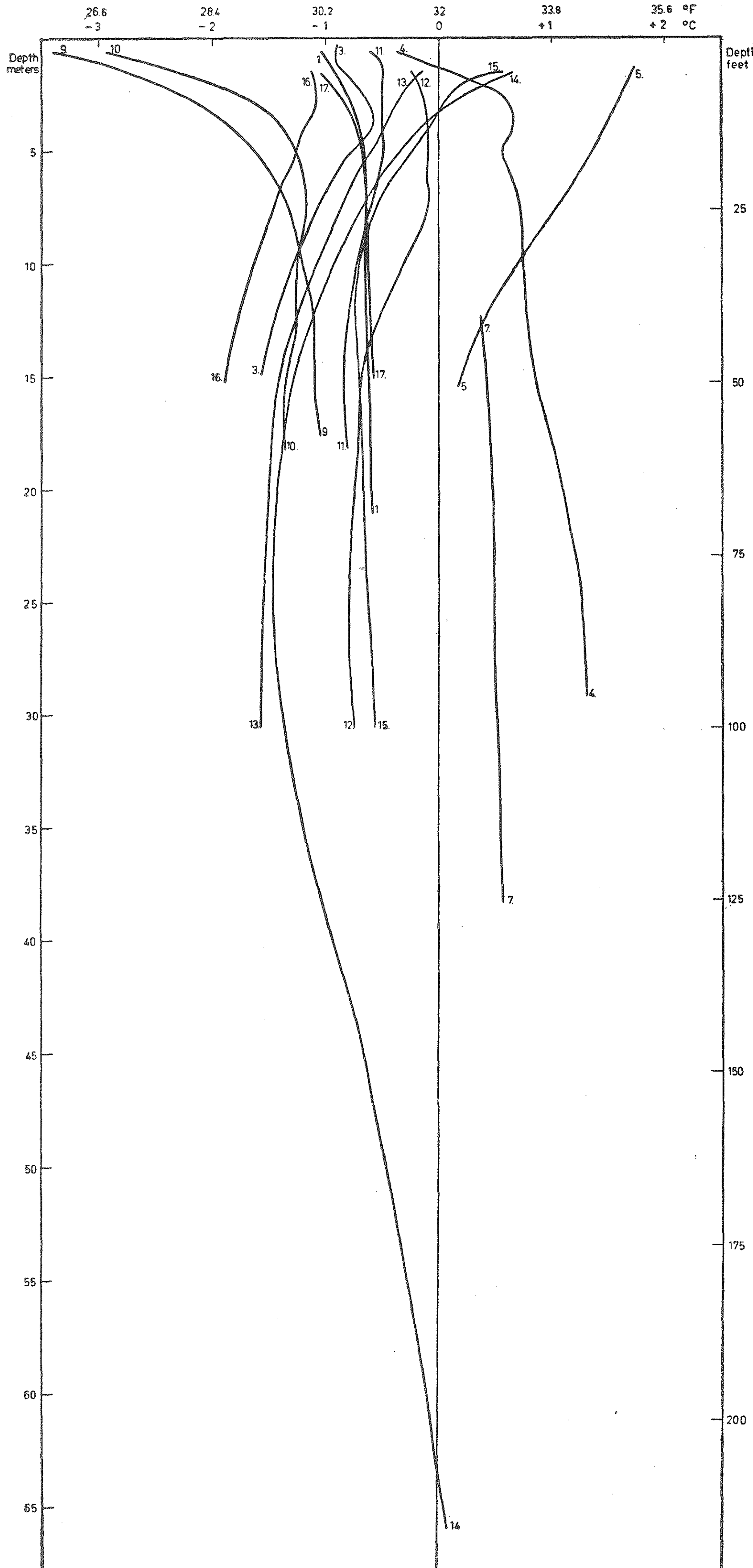

Fig. 1. Annual mean soil temperatures versus depth, 1. 10. 1961—1. 10. 1962

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THE TEMPERATURE EFFECT OF CERTAIN SURFACE COVERS AND EXPOSURE

VEGETATION COVER

Temperature readings in areas with different vegetation covers showed very small variations in temperature. The maximum temperature difference between summer temperatures at a depth of 0.9 m was found to be 2.0 °C between a brush wood area (warmest) and an area completely lacking vegetation.

Certain inconcistencies in the soil temperatures were present, however, and the only definite conclusion to be drawn from the temperature measurements is that at least brush wood areas show significant higher annual mean soil temperatures than those found beneath a more scanty vegetation. But regarding the small variations in summer temperatures, it seems more reasonable to assume the higher annual mean temperature not to be caused by the vegetation, but rather due to other factors which maintain a more favourable heat balance of the soil, sufficient for plant growth.

SNOW COVER

Permafrost can only be maintained where the annual mean surface temperature of the ground is below 0 °C. From this point of view, it would be very much desired to establish the insulating effect of the snow cover, and estimate the snow depth necessary to increase the annual mean surface temperature above zero.

Snow temperature measurements indicated that the annual temperature minimum in a snow cover diminished approximately with the function $e^{-0.01x\sqrt{2}}$ (x = depth below snow surface), indicating a very rapid change in the minimum temperature at small snow depths. At snow depths over 100 cm, there seemed to be very small variations in the soil surface temperature due to any change in snow cover.

The same trend could also be found in the soil temperatures at the 1.5-m level.

The snow temperature measurements, as well as the 1.5-m soil temperatures when correlated to snow depth, indicated that permafrost conditions are present only when the snow depth is less than 40 cm.

The snow cover in the Schefferville area is generally far in excess of this figure. Areas of sufficient extension having snow depths less than 40 cm are in fact restricted to the most exposed areas.

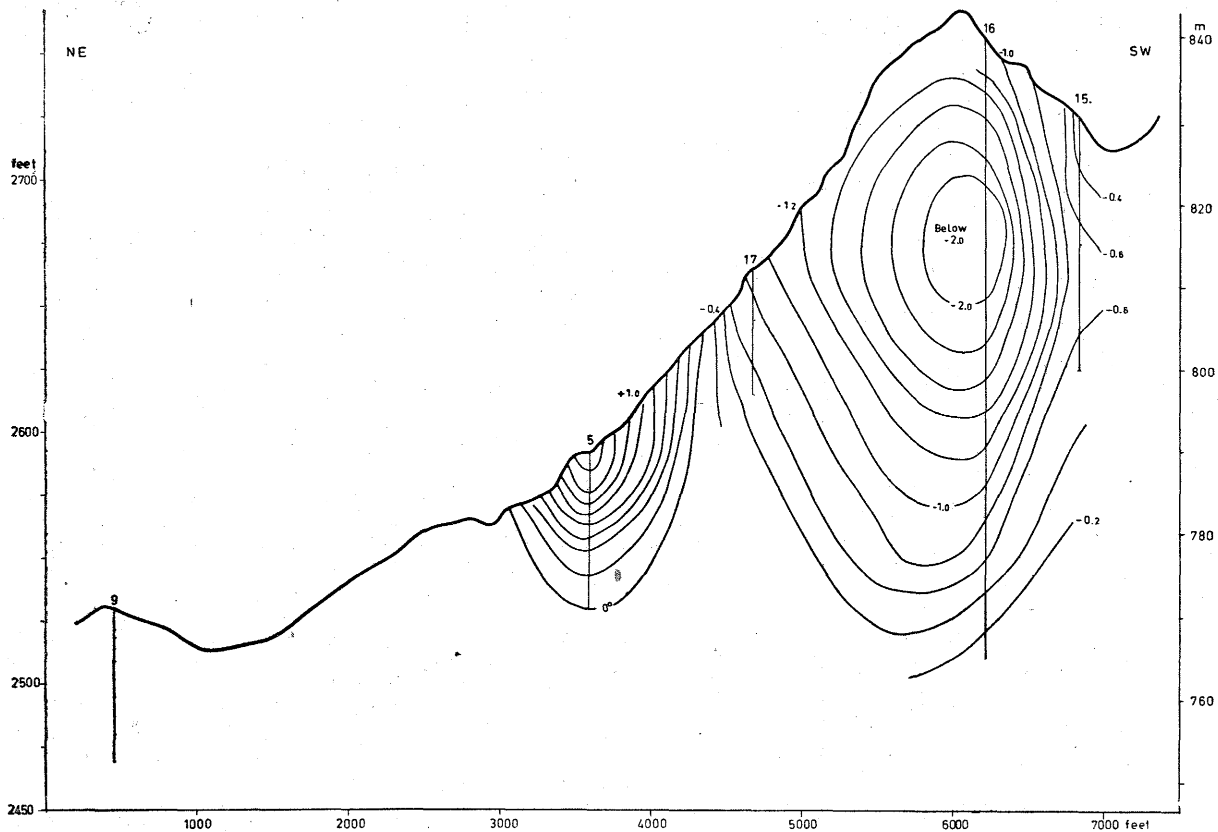

Fig. 2. Isotherms in a section across the Ferriman Ridge
isotherms interval 0.2° C

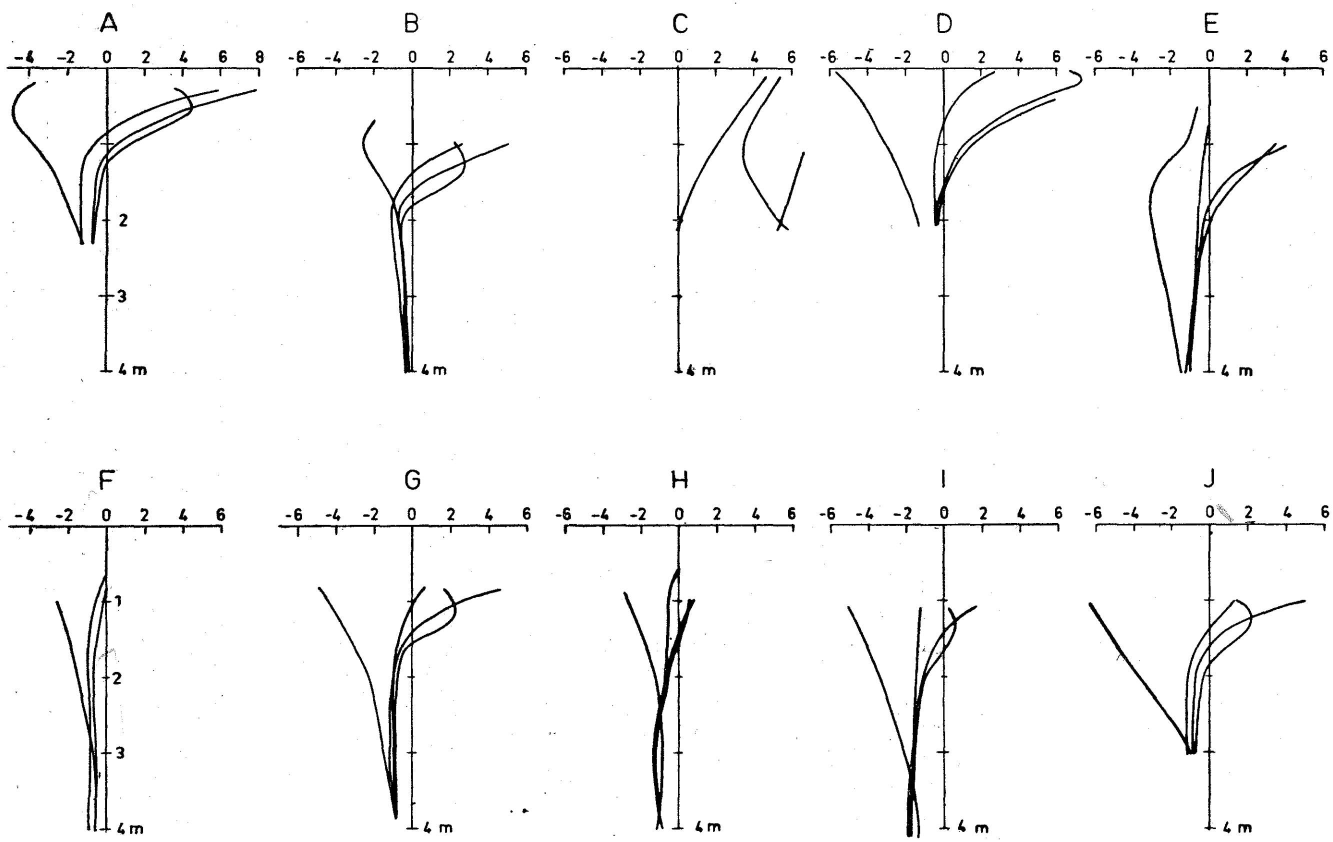

Fig. 3. Temperature (°C) versus depth of the ground. Padjelanta, Lapland, June 1963—April 1964

Tautochrones for 15.7, 13.8, 22.9, and 7.4

EXPOSURE

The effect of the exposure, both in respect of direction and relief, could also be estimated to some degree. North-east facing slopes had an active layer about half as thick as those found on slopes facing south-west, and a 0.5 °C colder annual mean soil temperature. The effect of the relief acts probably through the reduction in snow cover.

OTHER FACTORS

Within the area small patches of *taliks* or depressions in the permafrost table were present. The occurrence of these was treated analytically by the simplified method, suggested by Werenskiold (1953), and indicated that the permafrost must be very sensitive to even small temperature variations.

If the annual mean temperature of the ground surface locally is increased to 0 °C, patches of completely unfrozen ground may occur where this warmer area has a diameter of about 65 m. An increase in the surface mean temperature above 0 °C would probably reduce this diameter by half.

Summarizing the temperature measurements in the Schefferville area, it is evident that the most important single factor which controls the thermal regime of the ground is the snow cover. If the same mechanism for developing permafrost could be applied to most areas in northern Quebec, it is very likely that permafrost would be found even as far south as the elevated areas of the Laurentide massif. But on the other hand, this permafrost must be very sporadic, and even in the Schefferville area, less than one percent of the area is underlain by permafrost.

GROUND TEMPERATURE MEASUREMENTS IN THE SCANDINAVIAN MOUNTAINS

In an area with tundra polygons in Padjelanta (lat. 67°20′N, long. 17°E, alt. 760 m), permafrost was recently found below an active layer 1—2.5 m depth. At 10 sites, thermistors were installed at depths down to 4 m, spaced in 1 m intervals. Readings from these were taken in the period July 1—September 22, 1963, and will be continued.

The vegetation indicated a very thin snow cover, as could also be confirmed from air photos taken in winter 1963. The soil temperatures indicated an annual mean surface temperature around —1.0 °C (fig. 3). In comparison with the temperature readings from the Schefferville area, the Padjelanta readings were generally some tenths of a degree below those found at the coldest sites in the Schefferville area.

References

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Werenskiold, W. 1953 — The extent of frozen ground under the sea bottom and glacier beds. *Jour. Glaciology,* vol. 2, no 13.