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PERMAFROST, REAL ESTATE, AND CLIMATE CHANGE: THE CASE OF THOMPSON, NORTHERN MANITOBA, CANADA

Abstract

Unambiguous evidence that permafrost is degrading in response to current global warming is difficult to obtain. Some of the clearest signals are probably provided by changes in permafrost distribution in the subarctic regions, at the extreme southern fringes of the discontinuous permafrost zone. This hypothesis is discussed with reference to Thompson (lat: 55 degrees north; long: 98 degrees west), northern Manitoba. During initial construction of the town site in the early 1960's, marginal permafrost bodies were encountered. Some of these have now degraded. Recent air temperature records indicate that the annual mean air temperature in the area has probably increased over the period 1910–1993 by approximately 0.5–1.0°C. A permafrost monitoring program, conducted at 4 forested sites adjacent to the town site between 1969–1976 found that one permafrost sites degraded during the period 1968–1971 and two other, non-permafrost sites, showed slight warming. In the 1960's, building had not been permitted on certain subdivision lots where drilling had indicated the presence of shallow permafrost bodies. In the 1990's, the potential high real estate value of these lots promted further additional drilling by city authorities. These investigations indicate the absence of permafrost from certain lots, and, as a consequence, new residential housing has been allowed.

It is unclear whether the thaw of permafrost bodies at Thompson is the result of 1) recent climate warming, 2) increased thaw consequent upon destruction of the boreal forest, or 3) natrural variability.

INTRODUCTION

Although preliminary cold-climate terrain studies had been carried out in Siberia, Alaska and northern Canada in the latter part of the nineteenth and early part of the twenthieth centuries, the early growth of periglacial geomorphology owes much to the stimulus provided by the International Geological Congress excursion to Svalbard in 1910–1911. Curiously, and in spite of these early beginnings, the subsequent development of periglacial geomorphology in the middle part of the twentieth century became dominated by Pleistocene studies and mid-latitude palaeogeographic reconstruction. To a large degree, this was the result of the influence of Polish geomorphologists and, in particular, of Professor JAN DYLIK and his colleagues at the University of Łódź. Then, beginning in the 1960's and expanding in the 1970's and 1980's, as the economic

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importance of resource extraction in the high latitudes became obvious, attention shifted once again to the study of present day cold-climate processes. The Soviet and North American arctic regions became the focus of interest. Now, as the twenty-first century approaches, periglacial geomorphology is moving to a new phase, in that the cold regions of the world are being viewed as but one component of the entire global system. At the same time, periglacial geomorphology is no longer a simple academic discipline but has strong applied applications. The problem of man-induced thermokarst, the sensitivity of tundra terrain to trafficability, the management of boreal forest fire, and the slope and instability hazards of permafrost terrain are examples.

This short paper reflects the distance that periglacial geomorphology had come in the last 25 years. It is recognition of the academic basis of periglacial geomorphology that Professor DYLIK nurtured and developed.

PERMAFROST CONTROLS

A map recently compiled and published under the auspices of The International Permafrost Association (BROWN *et al.*, 1998), indicates that permafrost occupies approximately 20–25% of the earth land surface in the northern hemisphere. In the case of the North American continent, field observations in both Canada (e.g. BROWN, 1967; National Atlas of Canada, 1995) and Alaska (e.g. FERRIANS, 1994) indicate that the southern limit of continuous permafrost coincides with the general position of the –6 to –8°C mean annual air temperature (MAAT) isotherm. This relates to a ground temperature of about –5°C measured just beneath the depth at which seasonal fluctuations are minimal. The discontinuous permafrost zone lies to the south of the continuous zone. Its southern limit approximate the –1°C MAAT isotherm and ground temperatures vary from just below 0°C to –3° to –4°C. The most extreme, or southern, occurrences of permafrost are usually found beneath peaty materials, the result of the distinct insulating properties of such material (BROWN and WILLIAMS, 1972). For example, in northern Manitoba and northern Saskatchewan, the southern limit of permafrost beneath peaty sediments can lie more than 100 km south of the southern limit of discontinuous permafrost (e.g. ZOLTAI, 1971, 1972; ZOLTAI and TARNOCAI, 1971).

PERMAFROST AND CLIMATE CHANGE

Possible indicators of climate warming in the permafrost regions of northern latitudes are summarized by MAXWELL (1997). They include: (a) increases in thickness of the active layer, (b) increases in the frequency of occurrence of active layer failures and slope instability, and (c) increased thermokarst activity, especially related to an icreased frequency of forest fires in the boreal forest or taiga.

In addition to theses parameters, however, probably one of the clearest signals will be provided by changes in permafrost distribution in the subarctic regions, at the extreme southern fringes of the discontinuous permafrost zone. In such areas, the permafrost is typically less than –1°C to –2°C in temperature. There, in addition to the thermal influence of peat bodies, the boreal forest acts to maintain permafrost in marginal situations since, by restricting the depth of snow on the ground in winter, it enhances winter frost penetration. Subtle variations in surface characteristics can also produce significant permafrost changes, as illustrated by the permafrost degradation that follows upon forest fires (e.g. MACKAY, 1995; BURN, 1998). Therefore, if climate warming is occurring, the marginal permafrost present at the extreme southern fringes of the discontinuous zone appears to be especially sensitive.

PERMAFROST CONDITIONS AT THOMPSON, NORTHERN MANITOBA (55° 36'N; 98° 42'W)

In northern Manitoba, there is a broad zone, often several hundred km in extent north-south, in which bodies of perennially frozen and unfrozen ground coexist (Brown, 1968; 1978). In this southern zone, permafrost bodies are often associated with peaty materials (Brown and Williams, 1972; ZOLTAI, 1971). At the local scale, surface morphology, vegetation and various site factors (e.g. snow cover) also influence their distribution. However, in the vicinity of the mining settlement of Thompson (population 15.000; Fig. 1), there is no obvious control over the distribution of perennially frozen bodies. Peat is largely absent and the town site is underlain by glacio-lacustrine clays (JOHNSTON *et al.*, 1963). The site is to the north of the extreme southern limit of discontinuous permafrost as mapped by ZOLTAI (1971).

During the initial planning and construction of the town site between 1958–1961 (JOHNSTON *et al.*, 1963), apparently random bodies of frozen ground were encountered at depths of 1.0–1.5 m. Many were 3.0–4.0 m thick. In all cases the permafrost was marginal, with mean annual groumd temperatures ranging between –0.5°C and –1.5°C.

In an attempt to understand more fully the controls over permafrost distribution in this area, the National Research Council of Canada undertook field measurements for eight years (1968–1976) at four closely spaced and apparently similar sites in the boreal forest adjacent to the town site (Pl. 1). Previous drilling had revealed that two of the sites possessed

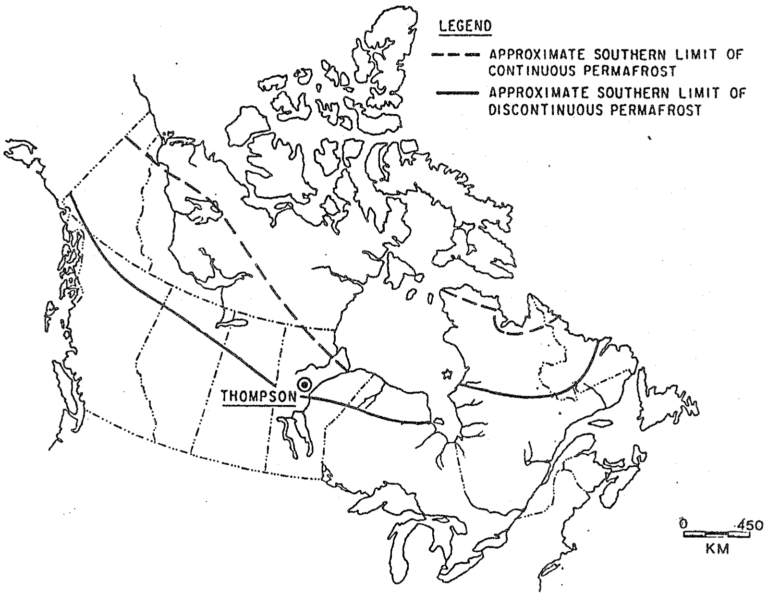


Fig. 1. Location of Thompson, northern Manitoba, and the southern limits of discontinuous permafrost and peaty permafrost landforms in Manitoba and Saskatchewan. (from ZOLTAI, 1971)

Photo by the author

Pl. 1. Typical undistrubed boreal forest in vicinity of Thompson permafrost. During the early period of observation, permafrost degraded and disappeared from one of the sites, and ground temperatures warmed slightly at the two non-permafrost sites (Brown, 1973, 1978; Brown and Williams, 1972; see French, 1996, Fig. 8.1). No obvious climatic, soil, or microclimatic differences between sites could be detected.

One possible explanation may now be found in the longer-term, historic, record. For example, a standarized 400 year proxy climate record of surface air temperatures in the northern latitudes (Overpeck *et al.*, 1997) indicates temperartures greater than one standard deviation warmer than average for the twentieth century for central Canada. This is supported by the analysis of the actual air temperature records for a number of weather stations in central and northern Manitoba, in some instances extending back to 1910 (Fig. 2). Interpolation between these data sets enables one to predict that the mean annual air temperature at the Thompson locality has increased over the period 1910–1993 by approximately 0.5–1.0°C (French and Egorov, 1998). It is tempting therefore, to interpret the degradation of permafrost at one of the 4 monitored sites between 1968 and 1976 as being a simple reflection of this change. However, the absence of significant change at the other permafrost site is problematic. For example, the possibility of modifications to the snow cover and active layer hydrology, as the result of the daily visit of the technician, cannot be ruled out.

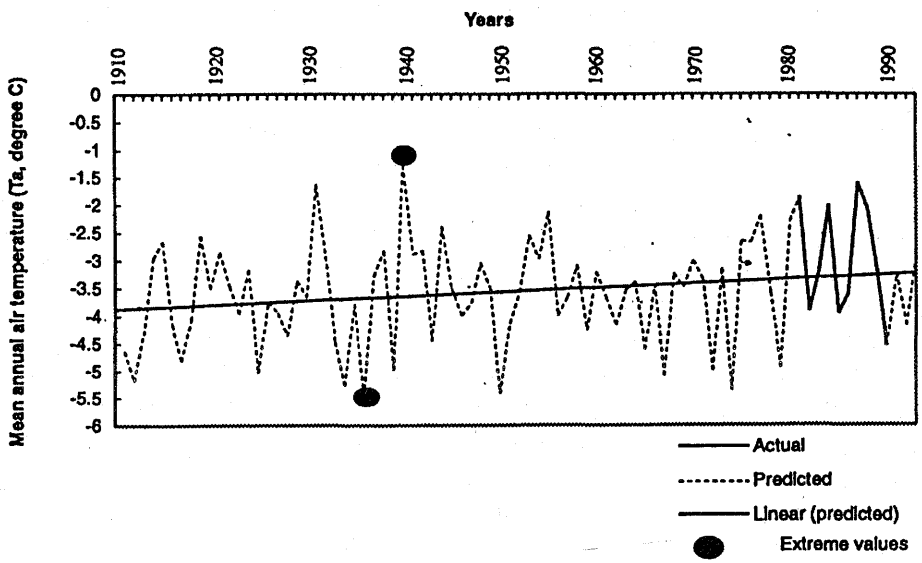


Fig. 2. Predicted changes in air temperatures at Thompson, 1910–1993 (from French and Egorov, 1998)

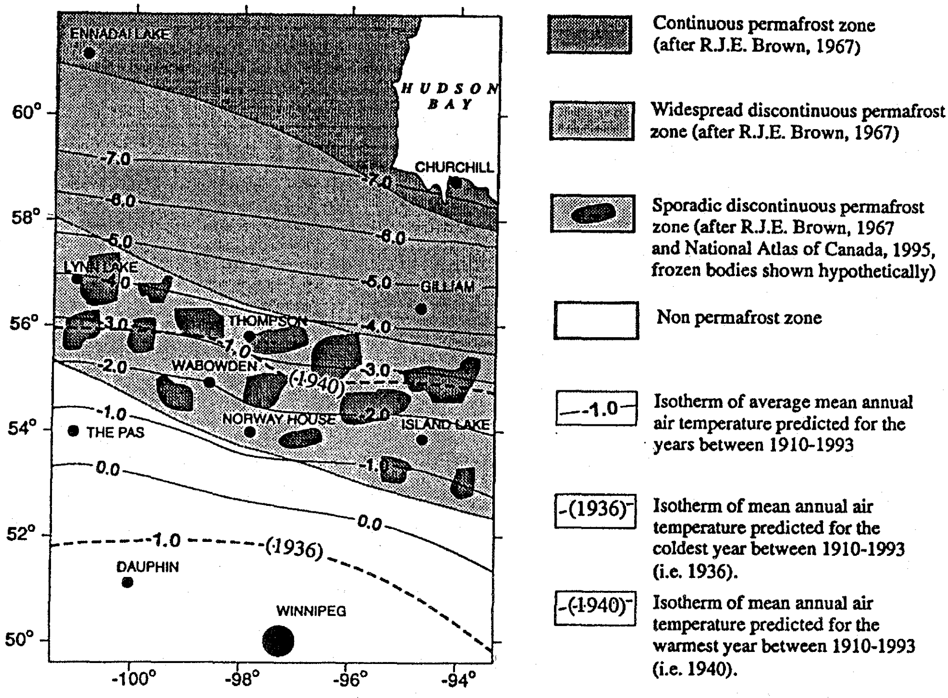


Fig. 3. Map showing the predicted location of the –1.0°C mean annual air temperature isotherm for the coldest year on record (1936) and the warmest year on record (1940) (from French and Egorov, 1998)

Of equal, if not greater, relevance is the possibility of short-term, or decade-duration, natural variability, as stressed by Overpeck *et al.* (1997). For example, figure 3 shows the probable position of the predicted –1.0°C mean annual temperature isotherm for the coldest year on record (1936) together with the warmest year on record (1940). If these are correct, a number of temporary frozen bodies might have developed to the south of the generally accepted southern limit of discontinuous permafrost during the coldest years in the 1930's. Likewise, in the warmest years, probably in the 1940's, the –1°C mean annual air temperature isotherm would have been to the north of its present limit. Any short-term permafrost, formed during the preceding decade at the extreme southern limits for permafrost growth, would have thawed. This type of short term climatic variability may explain the disappearance of frozen ground from one of the four monitored sites at Thompson during the 1969–1976 period.

URBAN RESPONSE

Equally complex is the urban response to the permafrost conditions at Thompson. During the initial construction of the settlement, in the 4 years

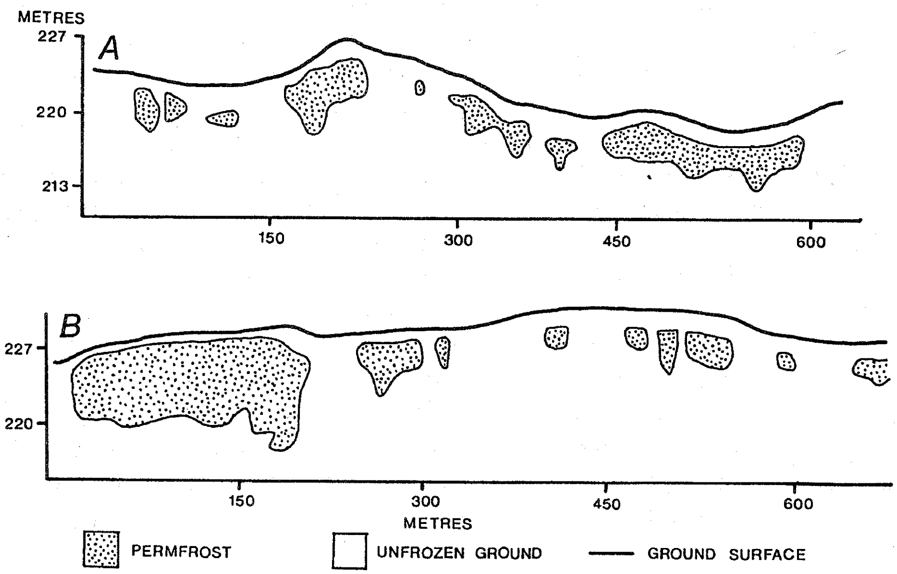
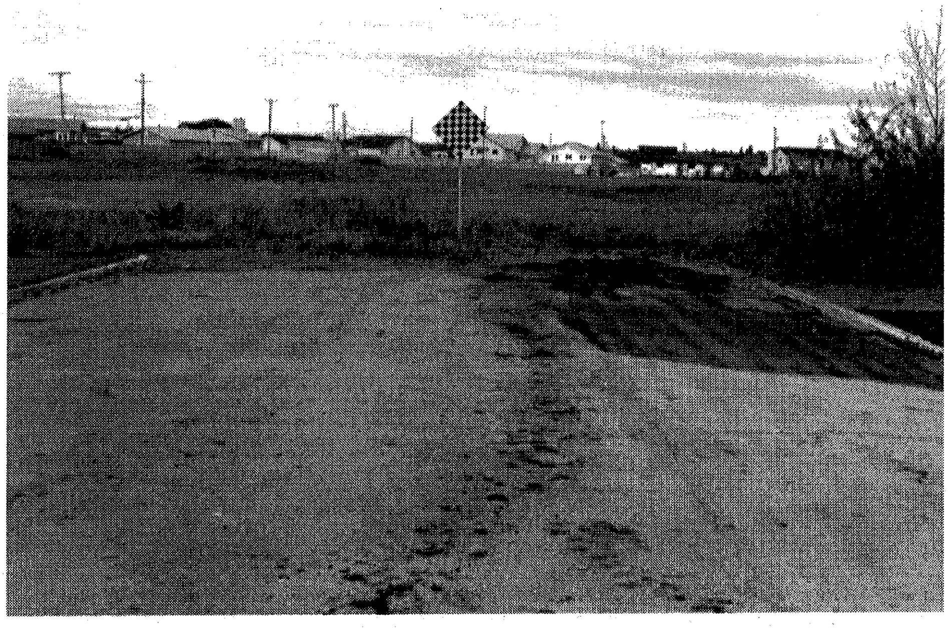


Fig. 4. Distribution of frozen ground bodies in the proposed Westwood subdivision, Thompson, at time of initial construction in 1961 (from JOHNSTON *et al.*, 1963, figures 35 and 36); A – Westwood Drive South, observed in water main trench excavations exposed between 24.03.1962 and 10.04.1962; B – Sauger Crescent and Rainbow Crescent, observed in sanitary sewer excavations exposed between 27.03.1962 and 25.08.1962

between 1959 and 1963, numerous scattered bodies of permafrost were encountered in borehols, sewer trenches, man-holes and other excavations. These are documented in JOHNSTON *et al.* (1963, figures 33–50). In one area, which subsequently became the Westwood subdivision, field investigations in August and September 1961 found frozen ground in the transition zones between high and low ground and at the margins of several spruce "islands" (Fig. 4). As a direct consequence, the City authorities denied building permits for certain lots in the subdivision. Today, these plots remain as open, but cleared, land within the subdivision.. At the same time they now have a relatively high real estate value because of the growth of the town over the last 20 years. One road, Char Bay Road initially planned for residential housing (Pl. 2 i 3) had been left unfinished because of the presence of permafrost while elsewhere, a normal subdivision of detached houses quickly developed. In recent years, several of these vacant permafrost plots have attracted attention, primarily because of their location. On several plots, detached houses have been built following drilling programs which indicated no permafrost to be present (Pl. 3). However, on the other plots, including several in the vicinity of the Char Bay Road, drilling in 1995 by the City indicated frozen ground to be still present.

A second residential subdivision, Burntwood South, was also developed during the early 1990's in an area which had been cleared of trees approximately 20 years earlier. At the time of clearance, scattered bodies of frozen ground had been noted. However, construction in the 1990's did not encounter significant frozen ground.

A final consideration of relevance is that subsidence due to permafrost thaw has caused structural problems in a number of the early homes which had been built upon land where permafrost was present but which had not been detected prior to construction. The drill hole logs from 1962 (JOHNSTON *et al.*, 1963) indicate icy lacustrine clay to underlie certain areas of the town site. In nearly all cases, damage has occurred to buildings where the basements have been of wood construction rather than concrete. Since wood is generally a better insulator than concrete, this suggests that the warmth from the structure was not the critical factor leading to thaw and that the strength and ridigity of the more expensive concrete basements had saved the latter from damage.



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Pl. 2. Urban development in the Westwood subdivision, October 3–5, 1997. Permafrost persists on undeveloped plots of land at the end of the (unfinished) Char Bay Road

CONCLUSIONS

The recent history of urban development at Thompson does not allow one to draw firm conclusions about the relationship between permafrost degradation and current global climate warming. While the twenthieth

Photo by the author

Pl. 3. Urban development in the Westwood subdivision, October 3–5, 1997. A new house was constructed in 1992 on South Westwood Drive where drilling had revealed that permafrost, present in the 1960's, has disappeared by 1990

century increase in air temperature may be one contributing cause of the thaw of marginal permafrost bodies, it is also possible that the clearance of the forest prior to construction may have led to an increase in snow depth on the ground in winter, thereby also raising the mean annual ground temperature.

Natural variability, especially of a short-term, decade-duration nature, may be very important for the formation and decay of extreme marginal permafrost bodies. This may confuse any longer term climatic signal. If warming is indeed occurring today, and once the buffering thermal effect of the active layer has been overcome, marginal permafrost bodies located at the extreme southern fringes of the discontinuous permafrost zone will be the first to be affected.

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