

## Permafrost

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### Abstract

Permafrost occurs when the ground remains at or below a temperature of 0°C for a minimum period of two years. Permafrost occurs not only at high latitudes but also at high altitudes. Almost all of the soil moisture in permafrost occurs in the form of ground ice, which in turn occurs in several different forms. The quantity of ice in the ground varies widely. Permafrost and ground ice have had significant effects on the economic development of the North. It affects the energy and mining industries, as well as the construction of modern settlements and infrastructure elements such as roads, railways, airfields, and utilities.

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Permafrost is defined as a state when the ground, whether soil or rock, remains at or below a temperature of 0°C for a minimum period of two years. However, most permafrost has existed for much longer. The thickness of the permafrost is controlled by the balance between the heat emanating from the earth's interior and cold atmospheric conditions at the ground surface. Permafrost thickness ranges from a few decimetres at the southern limit of the permafrost to over 700 metres in the Arctic Islands. The mean annual temperature of permafrost in the upper 10 metres of the ground ranges approximately from 0°C to –20°C. The upper part of the ground that thaws each summer and refreezes each winter constitutes the active layer.

### Distribution of Permafrost

Permafrost underlies about half of Canada's landmass, as well as areas of the seabed in the western Arctic and is also believed to exist beneath the channels of the Arctic Islands. It develops wherever the heat lost from the ground surface in winter exceeds that gained in summer and where the resulting ground temperature remains below 0°C for the minimum time period of two consecutive winters and the intervening summer. This situation prevails not only at high latitudes but also at high altitudes, mainly in the mountains of western Canada.

The distribution of permafrost varies not only with latitude and altitude, but also with difference in climate, surface capability to absorb heat, vegetation type, snowpack conditions, topography (both elevation and slope aspect) and drainage. The successive Quaternary glaciations also had significant effects on the current nature and distribution of permafrost and ground ice.

## Ground Ice in Permafrost

Almost all the soil moisture in permafrost occurs in the form of ground ice. Ground ice usually exists at temperatures close to its melting point and so is liable to melt if the ground warms. Ground ice occurs in several forms: as coating on soil particles and crystals within the pores of sedimentary rocks and unconsolidated deposits; as thin, lamellar lenses and veins of ice, and as larger bodies of more-or-less pure ice, in the form of ice wedges, extensive sheets of massive ice, and pingo ice. (Pingos are small hills with an ice core growing by water injection; they are covered with soil and vegetation.) The quantity of ice in the ground varies widely. At one extreme, it can exceed 90% of the volume of the ground. In other areas, permafrost contains essentially no ground ice and is termed "dry". The distribution of ground ice is influenced by soil texture; in general, fine-grained soils (rich in clay and silt) and organic soils contain more ground ice than coarse-grained soils (sand and gravels).



**Figure 1:** Twenty-two metre high pingo

**Source:** Geological Survey of Canada (photo number A89S52)

## The Importance of Ground Ice Content in Permafrost

Ice-rich permafrost tends to be found within the upper layers of the ground – the very area of greatest significance for engineering and construction. Surface disturbances, whether caused by natural phenomena such as erosion, flooding or wildfire, or by the activities of society, can have strong influences on permafrost and ground ice conditions. Also, in subarctic latitudes, where mean annual ground temperature is only a few degrees below 0°C, permafrost is most vulnerable.

For nearly all forms of economic or development activity in northern regions, the temperature of the ground, as such, is less significant than the occurrence of ground ice within the permafrost. This is because of the ground stability problems associated with any disturbance and subsequent thawing of ice-rich permafrost. If ice thaws, the water from the melted ice occupies less space than the ice itself and creates an empty space. The covering materials will then cave in. Thus accurate information on the character, distribution and form of frozen ground and ground ice, as well as on the geographical and geological setting of its existence, is important for the rational planning of the development of northern Canada.

Permafrost and ground ice have had significant effects on the economic development of the North, not only for the energy and mining industries, but also for the construction of modern settlements and infrastructure elements such as roads, railways, airfields and utilities.

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## Map Sources

### Permafrost

This map was produced from Canada-Permafrost, Fifth Edition of the National Atlas of Canada [map], printed in 1993. The data was derived from the Geological Survey of Canada, Terrain Sciences Division. It portrays the extent of the zones covered by permafrost and ground ice in Canada.

## References

Harris, S.A. et al. 1988. Glossary of permafrost and related ground-ice terms. Permafrost Subcommittee, Associate Committee on Geotechnical Research, National Research Council of Canada. Ottawa: National Research Council Canada.

## Related Web sites (1999 – 2009)

### Federal Government

Natural Resources Canada. Earth Sciences Information Centre Catalogue

<http://geoinfo.gsc.nrcan.gc.ca/screens/opacmenu.html>

The Earth Sciences Information Centre (ESIC) holds Canada's largest collection of books, journals, maps and photos in the earth sciences, in print and electronic formats.

Natural Resources Canada. Geological Survey of Canada. Canadian Landscapes

[http://gsc.nrcan.gc.ca/landscapes/index\\_e.php](http://gsc.nrcan.gc.ca/landscapes/index_e.php)

This collection of photos of Canadian landscapes and landforms is presented as a public service to illustrate the great diversity of Canadian scenery.

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[http://gsc.nrcan.gc.ca/permafrost/index\\_e.php](http://gsc.nrcan.gc.ca/permafrost/index_e.php)

Permafrost research at the Geological Survey of Canada