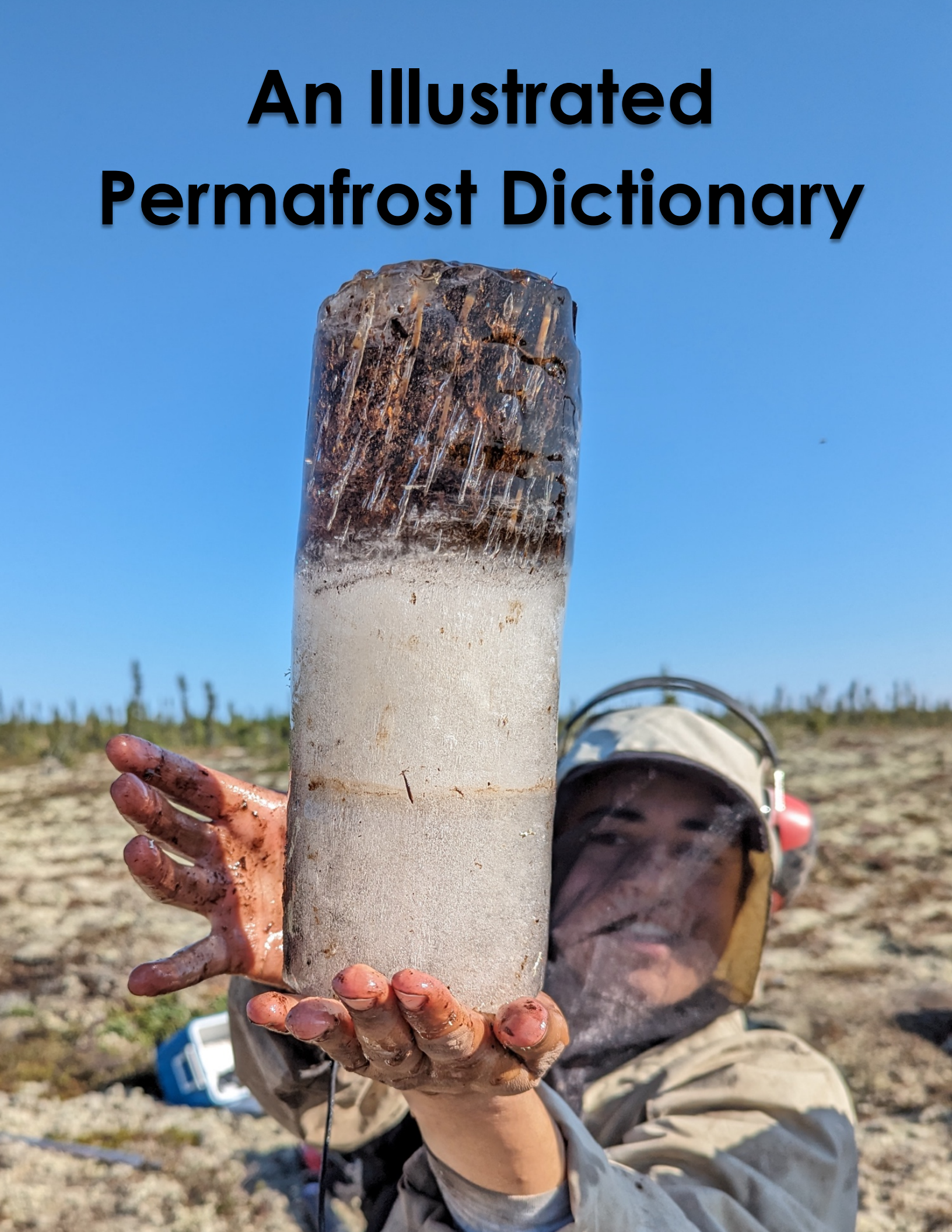
An Illustrated Permafrost Dictionary



Cover photo: A permafrost core showing peat frozen in pool ice over wedge ice, Hudson Bay Lowlands, Manitoba. (Photo: P. Roy-Léveillée)



CANADIAN PERMAFROST ASSOCIATION
ASSOCIATION CANADIENNE DU PERGÉLISOL

An Illustrated Permafrost Dictionary

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Preface

The *Illustrated Permafrost Dictionary* includes definitions for 100 terms relating to permafrost environments. It is intended to meet the needs of non-specialists interested in permafrost, including northerners (Indigenous and non-Indigenous), students, policy-makers, the media, and the general public in Canada and elsewhere. The terms are the most commonly used of those defined in the *Glossary of Permafrost and Related Ground-Ice Terms*, first published by the National Research Council of Canada in 1988. However, more than 20 terms have been added and the language of the *Dictionary* is designed to be more accessible. Each definition is supplemented by additional points and explanations that appear under the phrase, "Did you know…?" and by illustrations showing examples from across northern Canada and in some cases, from other countries. These allow the reader to compare permafrost-related phenomena across the Earth's cold regions.

The dictionary was produced by the Canadian Permafrost Association's (CPA's) Permafrost Terminology Action Group (PTAG), a volunteer committee made up of permafrost scientists and engineers at all career stages. PTAG was formed in 2021 with the dual goals of revising and updating the *Glossary*, and of producing the first plain-language and illustrated version of the most important terms relating to permafrost environments. The catalyst for both projects was the evolving nature of the field as climate change increasingly impacts permafrost regions. This has led to a growing appreciation of the importance of permafrost to northern residents and northern governments, and a broadening of scientific, media and public interest in the field, especially since the start of the millennium.

We regard the *Dictionary* as a dynamic document that will need revision and updating in the future. This version (1.0) is available for download from the CPA website as a printable document with entries typically having two or three illustrations. Most of these came from members of PTAG, but a few were kindly contributed by other colleagues. An on-line version with many more photographs is currently in development. We anticipate that the entries will be translated into French and into languages used by Indigenous peoples who live in permafrost regions within Canada. Above all, our hope is that the *Illustrated Permafrost Dictionary* will make the complexities and challenges of permafrost environments easier to understand for those interested in the unique aspects of perennially frozen ground.

Antoni Lewkowicz
Chair, Permafrost Terminology Action Group
Canadian Permafrost Association

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active layer

The top layer of the ground over permafrost that thaws in summer and freezes in winter.

Did you know…?
The active layer is thinner in the Arctic where the permafrost is continuous and thicker in the Subarctic where permafrost is discontinuous.



The active layer thaws in summer to a depth of about 75 cm on this slope on Ellesmere Island, Nunavut. It refreezes in the winter. The top of the permafrost (the permafrost table) is exposed in the base of the trench. The permafrost beneath extends to a depth of several hundred meters. (Photo: A. Lewkowicz)

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active-layer detachment failure

A landslide in which the thawed surface layer of the ground detaches and slides downslope over frozen soil.

Did you know…?
Active-layer detachment failures typically happen during particularly warm summers or after heavy rainfall or forest fire.



A large active-layer detachment failure that extended into the Thomsen River, Aulavik National Park, Banks Island, NWT. (Photo: A. Lewkowicz)



Active-layer detachment failures that developed after a forest fire and crossed an old trail in Steele Creek, near Dawson, Yukon. (Photo: A. Lewkowicz)

active-layer thickness

The thickness of the layer of ground over permafrost that thaws in summer and freezes in winter.

Did you know…?
The active-layer thickness is usually the same as the maximum depth of thaw at the end of summer (see page 88). Permafrost scientists measure active-layer thickness every year at many sites in the Arctic, Antarctic and high mountains as an indicator of climate change (see https://arcticdata.io/catalog/portals/CALM).



The active layer is about 1.3 m thick on this permafrost mound at treeline in Wolf Creek, near Whitehorse, Yukon. The permafrost, which starts at the base of the tape measure, is about 7 m thick and at a temperature of -0.1°C. (Photo: A. Lewkowicz)



The surface peat layer on this small mound is a very good insulator when it dries out in the summer. That's why the active-layer thickness at this site in the Sawtooth Mountains, Ellesmere Island, Nunavut, is only about 25 cm. (Photo: A. Lewkowicz)

adfreeze pile

A long post (called a pile) made of steel, wood or concrete that is solidly frozen into the permafrost in order to support a building or other structure.

Did you know…?
Buildings on adfreeze piles are usually raised off the ground to reduce heat entering the permafrost.



The school building at Inuvik, NWT, is supported by steel adfreeze piles that extend through the gravel pad into the permafrost. (Photo: A. Lewkowicz)



A building in Longyearbyen, Svalbard (Norway) is supported by adfreeze piles made of concrete. The gap between the floor of the building and the ground allows the ground to cool in the winter and helps to maintain the permafrost. (Photo: H.B. O'Neill)

air-cooled embankment

A coarse rock or gravel pad that contains air voids or pipes that allow air to circulate in winter, with warm air rising and flowing out while cold air is pulled in.

Did you know…?
The air movement in winter cools the interior of the embankment and helps preserve the permafrost beneath it.



A test section of the Alaska Highway near Beaver Creek, Yukon. The large rocks on both sides of the road make up the air-cooled embankment portion. Several other techniques are being tested to preserve the ice-rich permafrost beneath the highway, including the panels in the background which shade the ground and promote heat loss by keeping snow off the surface in winter. (Photo: A. Lewkowicz)



An air-cooled embankment on the side of a road near the University of Alaska campus, Fairbanks, Alaska (USA). (Photo: A. Lewkowicz)

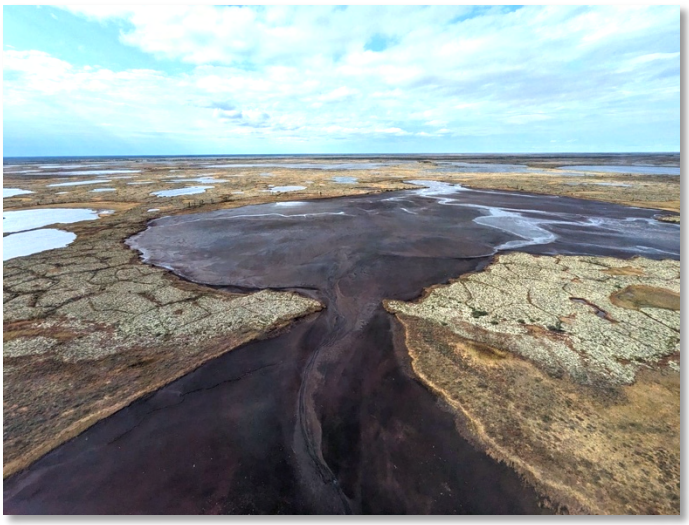
albedo

The fraction of sunlight that is reflected by a surface.

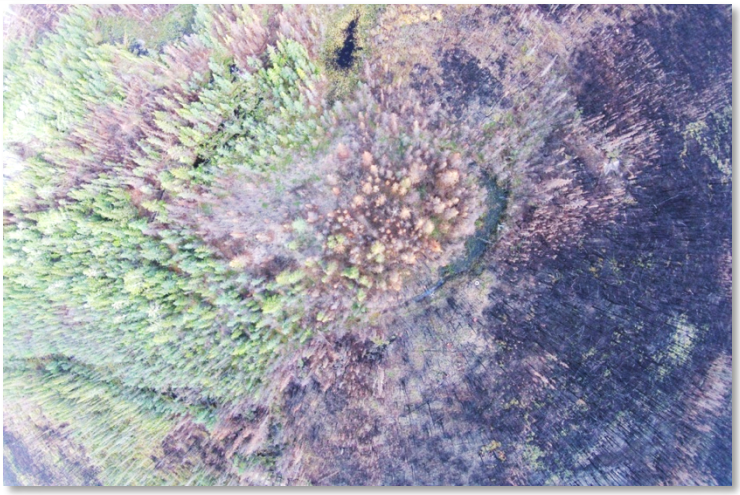
Did you know…?
Engineers have experimented with light-coloured road and runway surfaces that have a higher albedo, reflect more sunlight, reduce heat entering the ground and help maintain the permafrost.



The runway at Longyearbyen, Svalbard (Norway) was once surfaced with a higher albedo material to reduce heat flow into the permafrost. (Photo: A. Lewkowicz)



Permafrost landscapes, such as this one near Churchill, Manitoba, exhibit a considerable variation in albedo. The lichen-covered peat plateaus have the highest albedo while water bodies and exposed organic matter (as in these drained basins) have the lowest. There is even more variation in albedo through time, with most of the solar energy reflected by the snow cover in winter while the majority is absorbed by the ground in summer. (Photo: P. Roy-Léveillée)

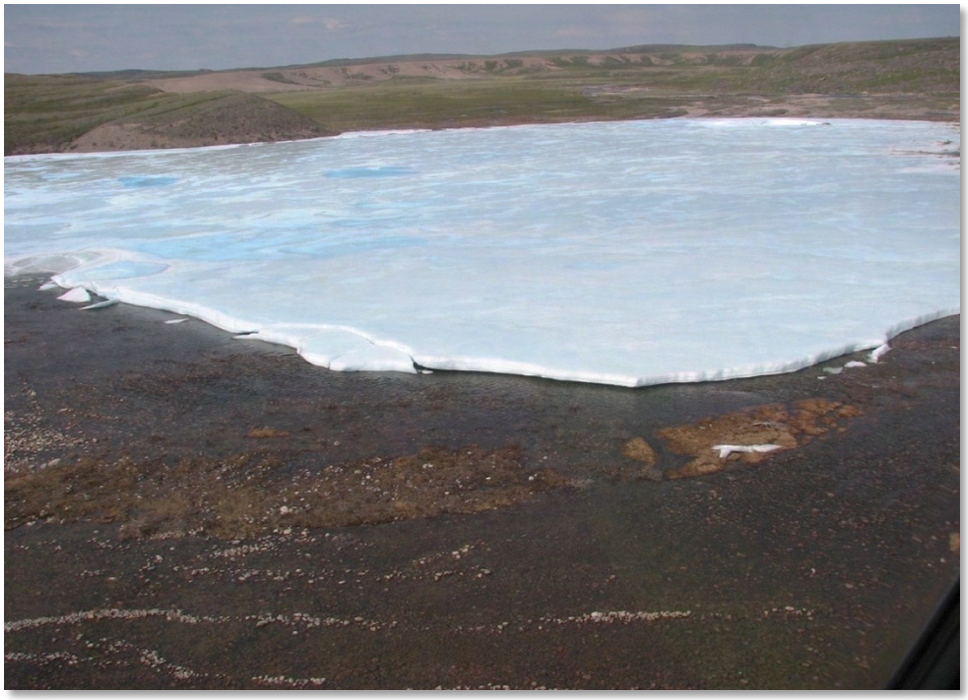


The albedo of the blackened ground surface after fire near Fort Providence, NWT, is lower than that of the undisturbed forest. This results in more solar energy being absorbed by the ground which can contribute to permafrost thaw. (Photo: J. Holloway)

aufeis

A thick sheet of ice (also called an icing) that builds up in layers on the ground in winter as water emerges under pressure.

Did you know…?
Aufeis that covers a road can be hazardous to vehicles because it is so smooth and slippery.



Aerial view of an extensive aufeis developed in a wide river valley floor in western Nunavut. The ice was melting when the photo was taken in mid-July. (Photo: V. Roujanski)



Aufeis on Steele Creek, near Dawson, Yukon. The aufeis builds up in layers as water continues to flow after freezing starts in the autumn. Most aufeis deposits melt away the following summer. (Photo: A. Lewkowicz)

beaded stream

A narrow stream that connects deeper pools, creating a bead-like appearance.

Did you know…?
The pools occur at the intersections of ice wedges.



A beaded stream in the Mackenzie Delta, NWT. The pools form over ice wedges and indicate that the permafrost is ice-rich. (Photo: A. Lewkowicz)

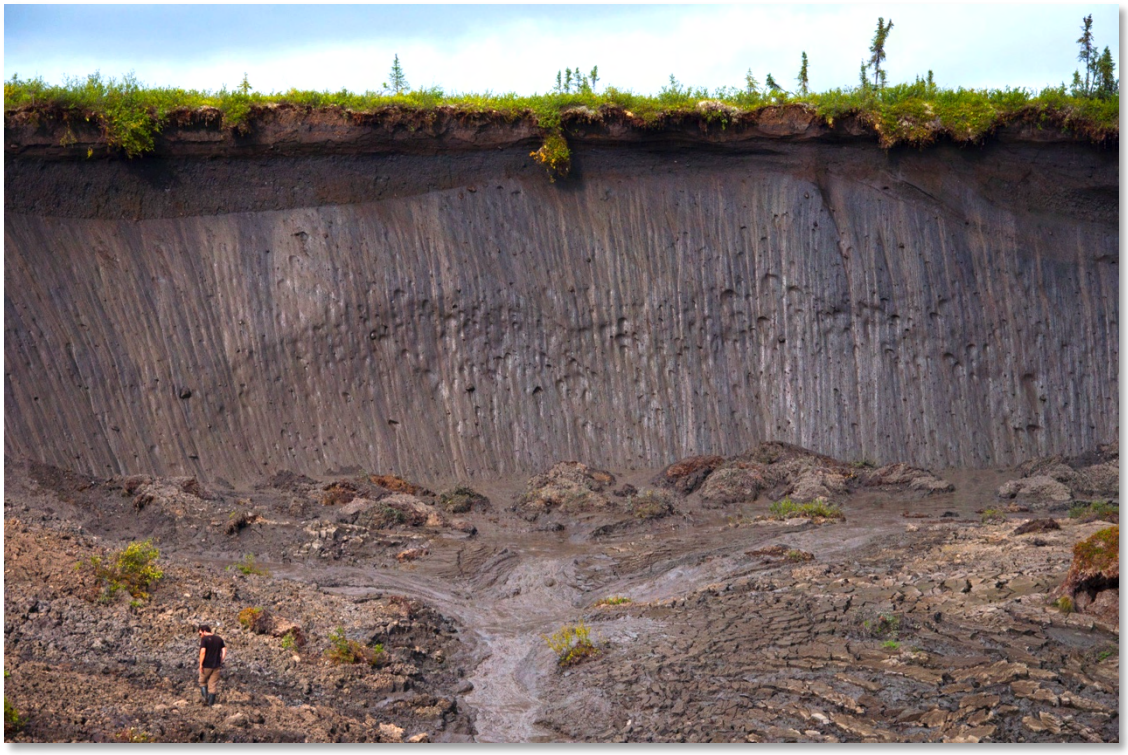


A pool in a beaded stream in the Blackstone Uplands, Yukon. (Photo: P. Roy-Léveillée)

buried ice

Ice that was covered by sediments and preserved in the permafrost.

Did you know…?
The ice may have been formed as part of a glacier, a snowbank, or lake ice. Some buried ice was formed in the last Ice Age and has been preserved as part of the permafrost for thousands of years.



Buried glacier ice exposed in the headwall of a retrogressive thaw slump on the Peel Plateau, NWT. Although the headwall may look like it contains a lot of sediment, it's almost pure ice that is more than 10 000 years old. (Photo: H.B. O'Neill)



A chain-saw being used to sample buried glacier ice in the Sand Hills moraine, Banks Island, NWT. The block of ice was kept frozen for later study in the laboratory. (Photo: A. Lewkowicz)

continuous permafrost

Permafrost that is present almost everywhere in a region.

Did you know…?
A mean annual air temperature below -6°C is usually needed for permafrost to be continuous.



Continuous permafrost is present at Salluit, Nunavik, Québec. (Photo: P. Roy-Léveillée



Permafrost is continuous at Paulatuk, NWT. Ice-wedge polygons are visible in the foreground. Some of them are degrading. (Photo: A. Lewkowicz)

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continuous permafrost zone

A geographic area where permafrost is estimated to be present beneath 90% or more of the land surface.

Did you know…?
In North America, the continuous permafrost zone generally starts close to treeline and extends throughout the tundra. (A map of all the permafrost zones is shown on page 74).



Part of the continuous permafrost zone at Pond Inlet, Nunavut. Permafrost is expected to be present almost everywhere, except beneath some glaciers, and lakes and rivers that do not freeze to the bottom in winter. (Photo: A. Lewkowicz)



The area around the community of Old Crow, Yukon, is part of the continuous permafrost zone, even though it is covered by boreal forest. That's due to its continental climate with warm summers, very cold winters and moderate snowfalls. (Photo: A. Lewkowicz)

creep of frozen ground

The slow deformation of frozen ground.

Did you know…?
Frozen ground creep is mostly due to ice in the ground slowly changing shape while under pressure, especially on slopes. It can affect the stability of buildings constructed on permafrost.



The creep of frozen ground affects many ice-rich slopes in permafrost, but it is rarely obvious. This rock glacier in Kluane National Park, Yukon, is moving slowly downslope by a combination of creep and other types of movement that produce its distinctive rippled surface. (Photo: A. Lewkowicz)

cryosphere

The portion of the Earth that contains ice or experiences freezing temperatures for at least part of the year.

Did you know…?
The cryosphere contains more than 90% of the world's freshwater and includes permafrost, glaciers, the Greenland and Antarctic ice sheets, and the seasonal snowpack.



Many of the components of the cryosphere are visible in the landscape near Pangnirtung, Baffin Island, Nunavut: seasonal snow, sea ice and glacier ice. Permafrost in the soil and rocks is also part of the cryosphere but in most places, it's not visible at the surface. (Photo: N. Brown).



The cryosphere includes snow, lake ice, glacial ice and permafrost in the Southern Hemisphere, such as in this part of East Antarctica. The coldest permafrost on Earth (estimated to be around -35°C) is found at high elevations in the Trans-Antarctic Mountains. (Photo: A. Lewkowicz)

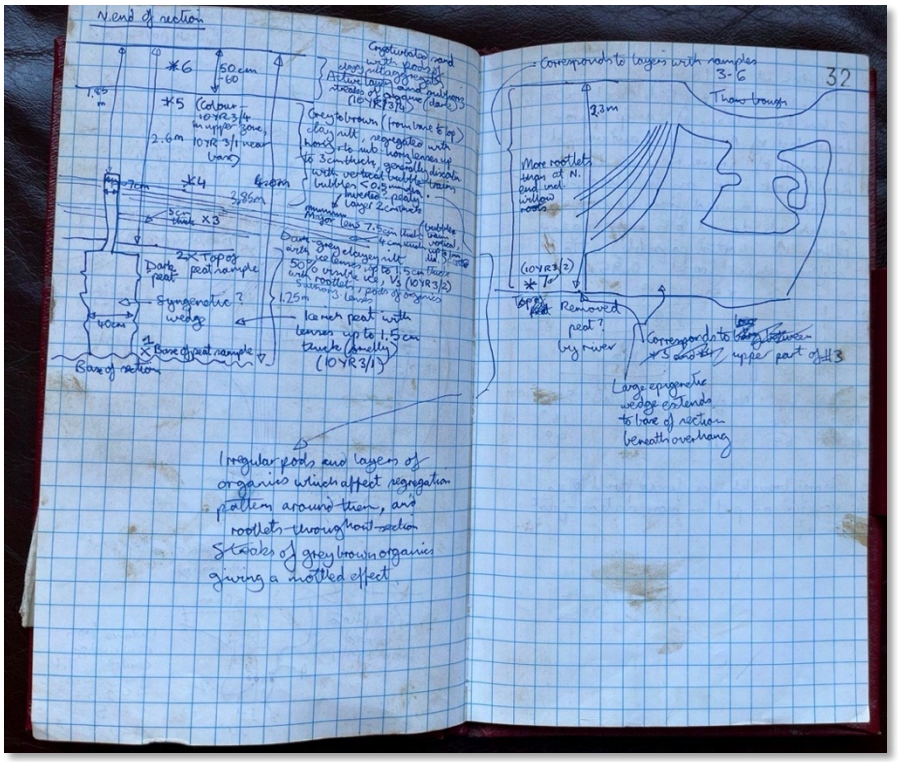
cryostratigraphy

The study of frozen layers in the Earth's crust to understand how they formed.

Did you know…?
Layers of sediment and rock develop unique patterns and shapes due to freezing and thawing.



A group of permafrost researchers examining the structures present in the frozen headwall of a retrogressive thaw slump in the Ibex Valley, near Whitehorse, Yukon. (Photo: A. Lewkowicz)



Pages from a field notebook showing cryostratigraphic observations of an exposure of permafrost on Ellesmere Island, Nunavut. The sediments, the bodies of ice and their relationships are described with the goal of understanding the history of the permafrost at this site. (Photo: A. Lewkowicz)

cryostructure

The relative amounts and arrangement of soil and ice in permafrost.

Did you know…?
There are many types of cryostructure. One common kind looks like alternating layers of ice and sediment while another looks like vertical wedges of ice.



Two cryostructures are visible in the headwall of this retrogressive thaw slump on Ellesmere Island, Nunavut. The upper part is made up of long blocks of frozen soil, separated by sheets and layers of ice; this is called a reticulate cryostructure. The bottom part is nearly pure ice, with folded dirtier bands; this is called a solid cryostructure. (Photo: A. Lewkowicz)



A permafrost core sample from Inukjuak, Nunavik, Québec, that has a layered cryostructure. (Photo: P. Roy-Léveillée)

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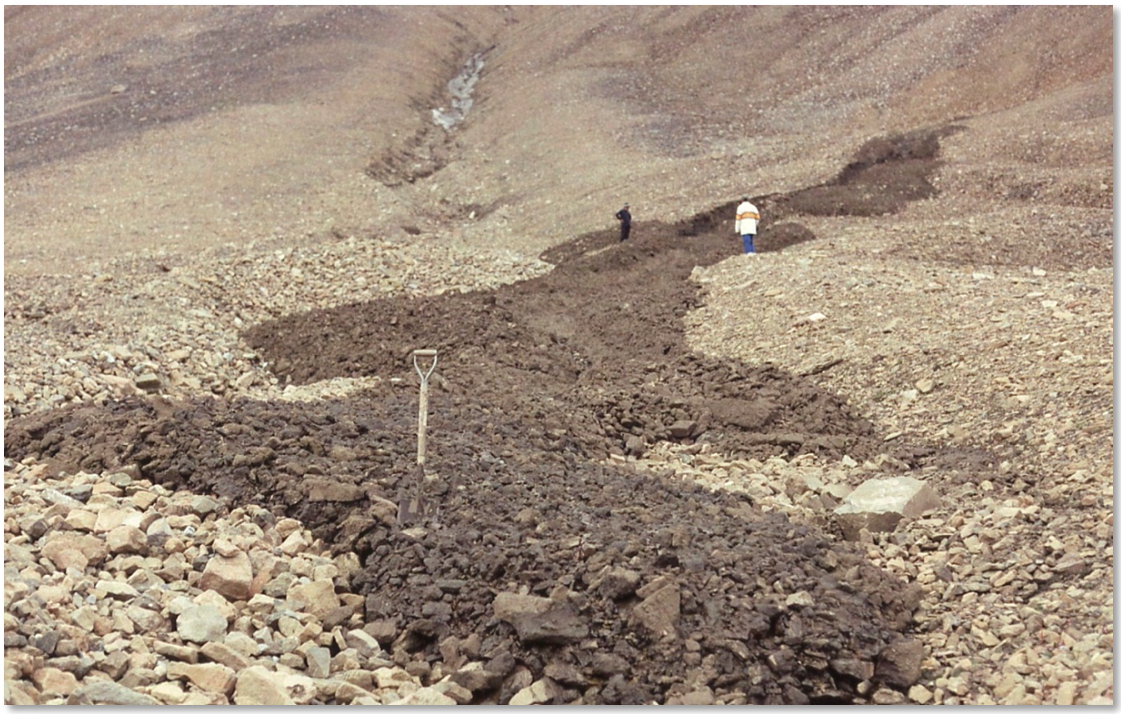
debris flow

A landslide composed of mud, rocks and water that flows rapidly down a slope.

Did you know…?
Debris flows usually develop on steep slopes and are most often triggered by rapid snowmelt or heavy rain. They move fast enough to be dangerous and destructive. They can occur in areas with or without permafrost.



(Left): This bowl-shaped hollow was the source of a debris flow near Carmacks, Yukon. Note the people in the floor of the bowl for scale. (Right): The flow travelled several kilometers down an existing stream channel, destroying the forest on its floor and eventually crossed the Alaska Highway. Long-term changes in permafrost conditions at the site are thought to have caused the slope to become unstable. (Photos: A. Lewkowicz)



A fresh debris flow in the Sawtooth Mountains, Ellesmere Island, Nunavut. The flow happened after a rainstorm and movement was confined to the active layer. (Photo: A. Lewkowicz)

discontinuous permafrost

Permafrost present under some, but not all, of the land in a region.

Did you know…?
Where permafrost is discontinuous, it is absent from the warmest parts of the landscape, such as well-drained, sunny slopes.



Permafrost is discontinuous in the area around Dawson, Yukon. About half of the town is built on warm, ice-rich, permafrost while the other half is constructed on ground that freezes seasonally. (Photo: A. Lewkowicz)



Permafrost is discontinuous at Nain, Nunatsiavut, Newfoundland and Labrador. In many parts of the community, the ground freezes seasonally and permafrost is absent. However, permafrost was discovered at the planned site of the Illusuak cultural centre. As a result, long piles were needed to support the building. (Photo: A. Lewkowicz)

discontinuous permafrost zone

A geographical area where permafrost is estimated to be present beneath more than half, but less than 90%, of the land surface.

Did you know…?
In North America, the discontinuous permafrost zone (also called the extensive discontinuous permafrost zone in Canada) generally starts within the boreal forest and extends northwards to the treeline. (A map of all the permafrost zones is shown on page 74).



Part of the discontinuous permafrost zone at Beaver Creek, Yukon. Permafrost is expected to underlie more than half of the terrain but less than 90% of the surface. In the landscape shown in the photo, it is present beneath most forested surfaces and absent in boggy areas. (Photo: A. Lewkowicz)

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drunken forest

Trees leaning in differing directions as if unable to stand upright.

Did you know…?
Drunken forest can be caused by ice forming or melting in the ground beneath the trees. It's often a good indication that permafrost is present.



Drunken forest near Inuvik, NWT. The trees are nearly all black spruce. (Photo: H.B. O'Neill)



Drunken forest alongside the Klondike Highway, Yukon. The trees are a mixture of black spruce and white spruce. (Photo: A. Lewkowicz)

electrical resistivity tomography (ERT)

A scientific technique that can be used to examine the characteristics of permafrost at a site.

Did you know…?
ERT uses a small amount of electricity from a battery to distinguish between unfrozen ground containing water (a good conductor) and permafrost containing ice (a poor conductor).



An ERT survey on a palsa in a bog in Macmillan Pass, Yukon. The orange cables are attached to metal rods which transmit the electricity into the ground. ERT can reveal where permafrost is present and where it is absent, as well as its thickness (see page 64). (Photo: A. Lewkowicz)

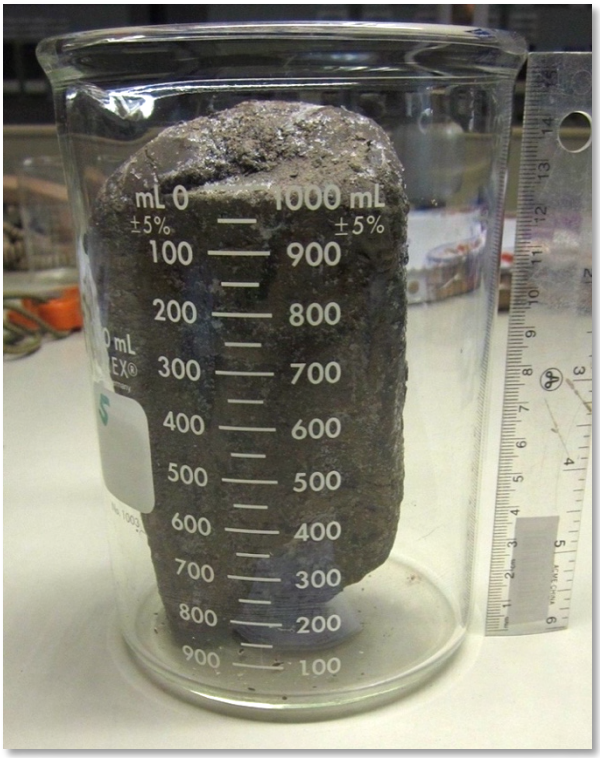


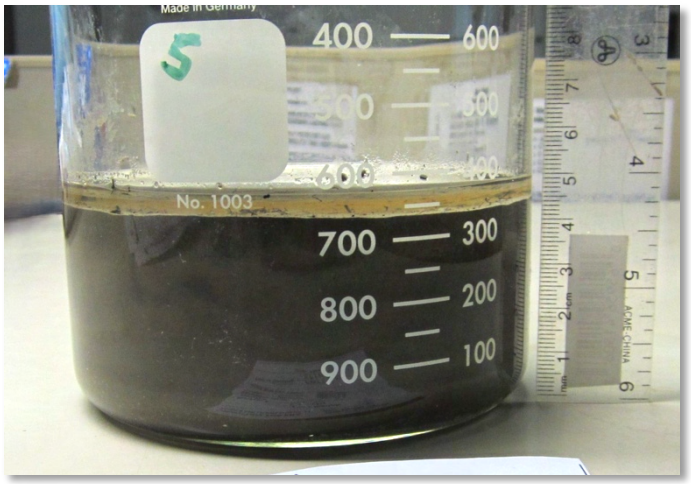
An ERT survey line laid out to examine permafrost conditions beneath the John Tyzia Centre in Old Crow, Yukon. Because ERT does not create any disturbance, it can be used almost anywhere. (Photo: A. Lewkowicz)

excess ice

Ice, which when melted, exceeds the space available for water to be stored in the ground.

Did you know…?
Excess ice is often visible when it is present in a sample of frozen soil. If excess ice melts, water is lost and the ground settles.





A permafrost sample with excess ice collected as a core (left) and the same sample after thawing (above). The frozen soil has thawed and transformed into saturated mud with a layer of clear water (called supernatant water) on top, because there was too much water for it to be contained in the soil pore spaces. If this permafrost were to thaw in the field, the water would pond on the surface or flow away and the ground would settle. (Photos: E. Palczewski)



A core sample from the top of the permafrost in Adventdalen, Svalbard (Norway) with visible and excess ice contents of about 50%. (Photo: A. Lewkowicz)

food cellar

A chamber excavated in the permafrost that is used to refrigerate or freeze country foods.

Did you know…?
Some food cellars (also known as ice cellars, ice houses and meat cellars) have become unusable in recent years as flooding has occurred or the permafrost has become too warm to safely store meat or fish.



The entrance to a food cellar on Herschel Island, Yukon. (Photo: C. Burn)

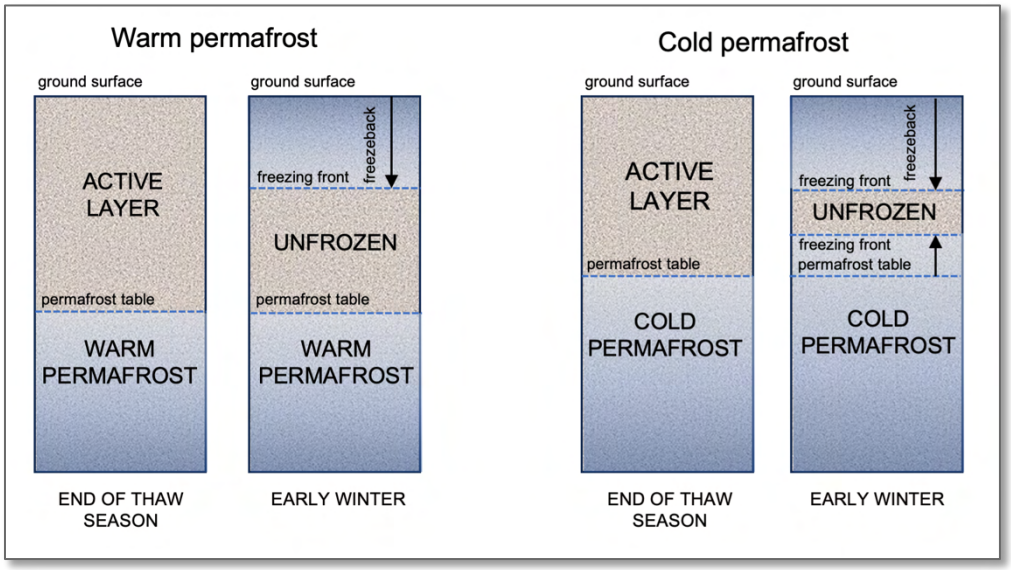


The interior of a food cellar at Tuktoyaktuk, NWT. Large ice crystals have grown from water vapour condensing on the ceiling while the lower parts of the walls show cryostructures in the permafrost. (Photo: K. Yoshikawa)

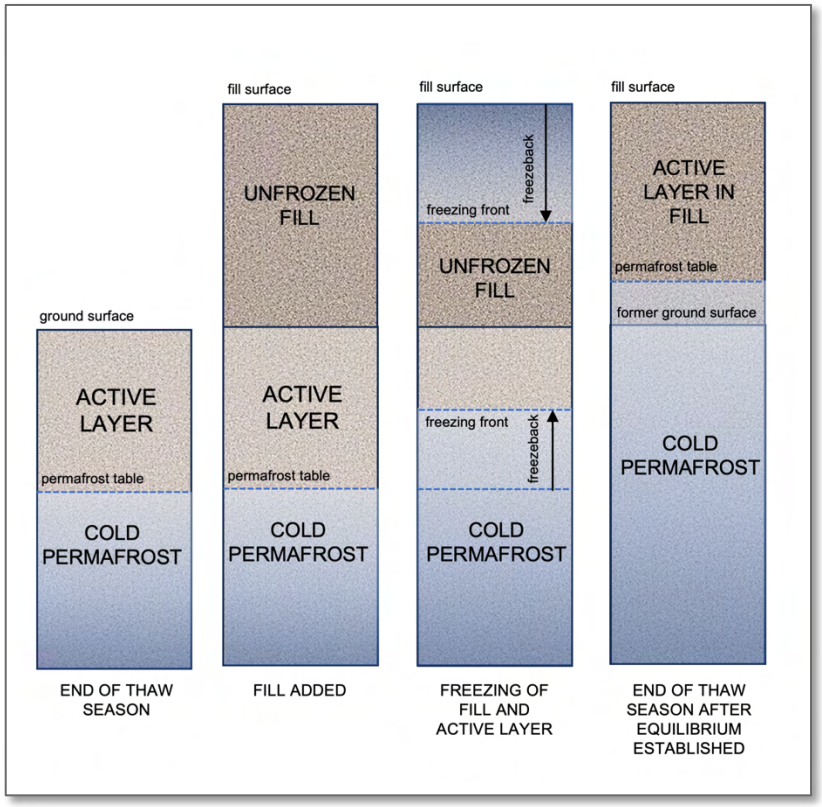
freezeback

Refreezing of soil that thawed during the summer, or freezing of unfrozen materials that were placed during construction on permafrost.

Did you know…?
Freezeback of the entire active layer may take a few weeks to a few months in the tundra (see page 50), and all winter at sites in the boreal forest.



Freezeback of the active layer where the permafrost is warm (average temperature between -2°C and 0°C) and cold (below -2°C). In warm permafrost, the freezing front advances from the ground surface downwards. In cold permafrost, two freezing fronts develop, with the second one moving upwards from the permafrost table (see page 50). (Figure: N. Brown and A. Lewkowicz)



Freezeback of a layer of fill placed on top of the ground for construction purposes. In the winter, a freezing front moves downwards from the new surface and a second front advances upwards through the active layer from the cold permafrost. It may take several years before the fill is frozen through and a new equilibrium thaw depth is established. (Figure: N. Brown and A. Lewkowicz)

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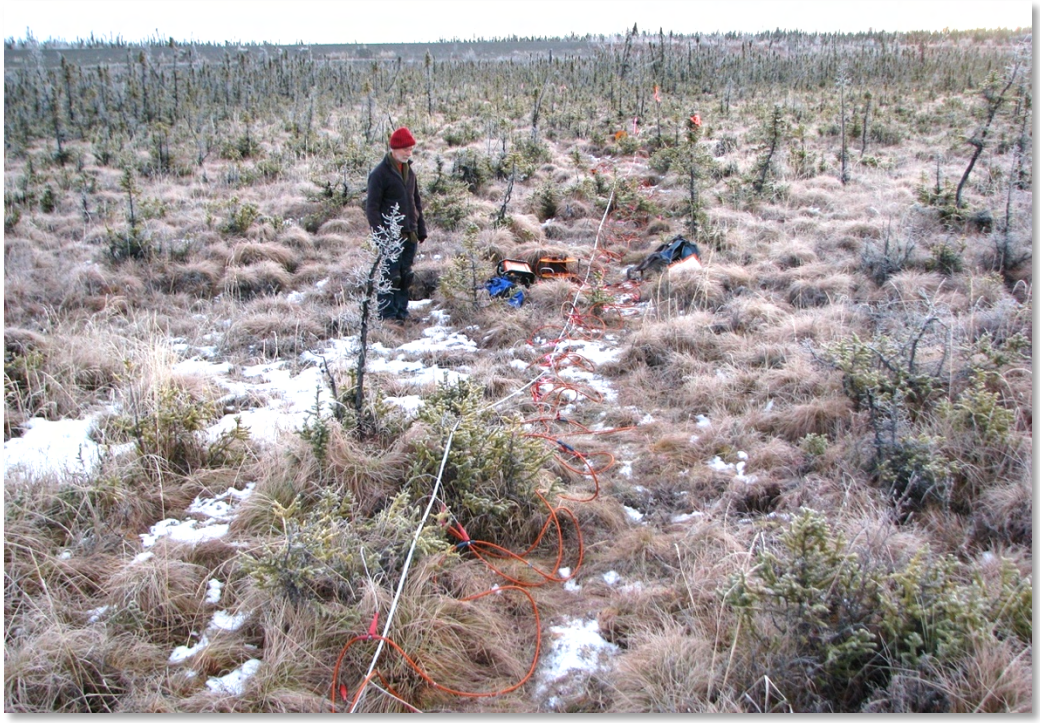
freezing of ground

The process of turning some, or all of the water in the ground into ice.

Did you know…?
Water in the ground does not start to freeze at exactly 0°C because it always contains dissolved salts which lower the freezing point. In fine-grained soils (silts and clays), a fraction of the moisture can remain unfrozen at several degrees below 0°C because it is contained in very small pore spaces and tightly bonded to the soil particles.



Overnight freezing of the ground in September caused the formation of needle ice crystals that lifted the top layer of gravel on a slope at Kerlingarfjöll (Iceland). (Photo: A. Lewkowicz)



Freezing of the ground surface accompanying the first snowfall of autumn at Beaver Creek, Yukon. The vegetation was coated with ice crystals and the ground was frozen to a depth of 10 cm. (Photo: A. Lewkowicz)

frost action

The freezing and thawing of moisture in soil and rock, and the resulting effects on the ground, buildings and infrastructure.

Did you know…?
Frost action has many effects, including the breakdown of rocks and the heaving of roads.



Frost action has heaved this rock to the surface, and split it along lines of weakness in Aulavik National Park on Banks Island, NWT. (Photo: A. Lewkowicz)



Frost action has heaved and deformed this utilidor at Ny-Ålesund, Svalbard (Norway). (Photo: A. Lewkowicz)

frost blister

A frozen mound raised up in a single winter by pressurized water confined between the freezing active layer and the permafrost.

Did you know…?
Frost blisters have cores made up of long crystals of almost pure ice. They usually melt out during the summer after they form.



A frost blister in North Fork Pass, Yukon, that formed during the winter and is melting out in the summer. (Photo: A. Lewkowicz)



Ground ice exposed in a frost blister near the Dalton Highway, Alaska (USA). (Photo: A. Lewkowicz)

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frost boil

A patch of bare soil with a slightly mounded central area, formed by frost action.

Did you know…?
Frost boils are used by some geologists as collection points for soil samples during mineral exploration because they bring material from deeper in the ground to the surface.



Frost boils on a slope at treeline in Wolf Creek, near Whitehorse, Yukon. (Photo: A. Lewkowicz)

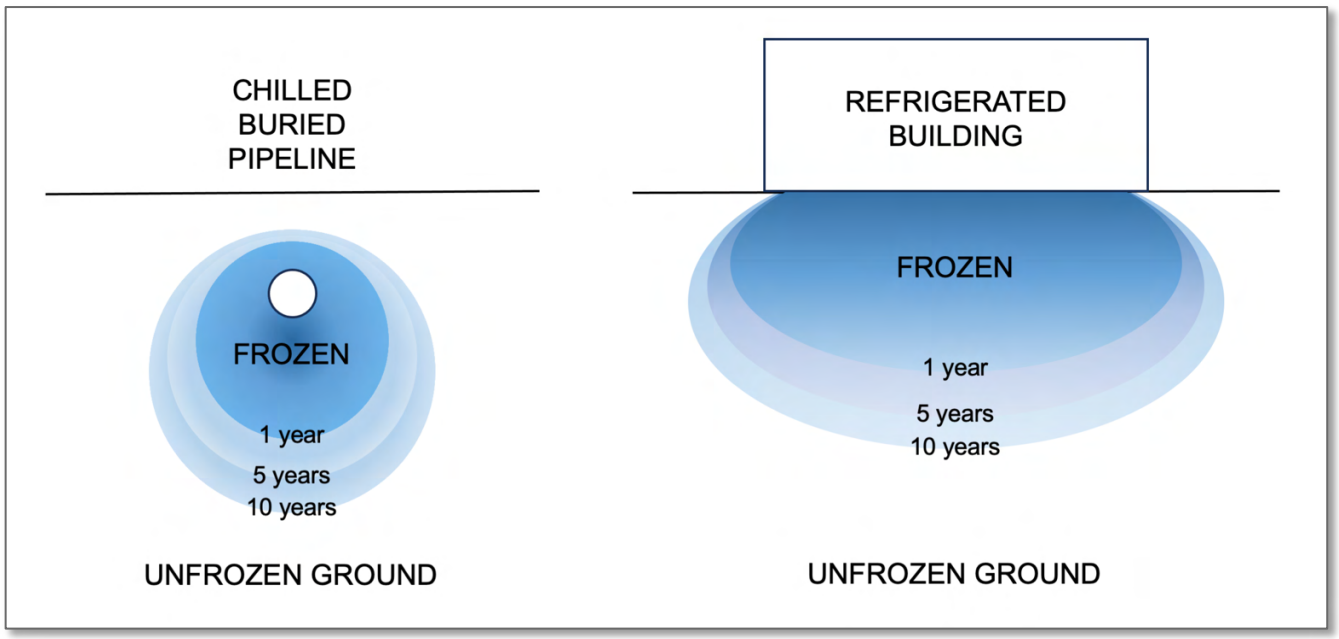


A group of frost boils viewed from the air, near Walmsley Lake in the North Slave Region, NWT. (Photo: N. Brown)

frost bulb

A zone of frozen ground that forms around an engineered structure chilled below the freezing point.

Did you know…?
Frost bulbs can form below refrigerated hockey rinks.



The development of a frost bulb (not to scale) in unfrozen ground due to the continuous operation of (left) a chilled buried pipeline and (right) a building at a temperature below 0°C (e.g., a hockey arena). If the soil is frost-susceptible, the growth of a frost bulb will be accompanied by ground ice formation and frost heave. (Figure: A. Lewkowicz, based on Figure 23 in Associate Committee on Geotechnical Research (1988). Glossary of Permafrost and Related Ground-Ice Terms. Ottawa: National Research Council of Canada).

frost heave

The upward movement of the ground due to ice formed while freezing.

Did you know…?
Frost heave generates enough force that it can lift even very heavy objects on the ground surface.



Frost heaving of jointed bedrock, NWT. Note the large erratic boulder on top. It was transported by a continental ice sheet during the last glaciation and lifted up as the big bedrock slabs frost heaved, long after the ice had melted. (Photo: V. Roujanski)





(Above right): The base of this sign in Yellowknife, NWT, has been frost heaved more at one end than at the other, causing it to tilt. (Photo: E. Hoeve)

(Left): A laboratory experiment in Caen (France) to measure frost heave associated with the operation of a chilled gas pipeline. During the experiment, one part of the trench was filled with a soil (silt) that heaved upwards during freezing while the other part was filled with a soil (sand) that heaved less. The differing amounts of heave bent the steel pipe (273 mm in diameter with a wall thickness of 5 mm), showing the enormous forces that can be produced by soil freezing. (Photo: A. Lewkowicz)

frost jacking

The lifting by frost heave of piles or other posts embedded in the ground.

Did you know…?
This can be a serious problem for buildings and bridges, especially because each pile is nearly always jacked by a different amount.





Frost jacking of a steel pipe in a permafrost monitoring borehole near Teslin, Yukon. The pipe, marked by flagging tape, extends 3 m into permafrost, but it was jacked by more than 50 cm over 9 years. This happened because the heaving force associated with yearly refreezing of the active layer was stronger than the bond between the pipe and the warm permafrost. (Photos: A. Lewkowicz)



Frost jacking of the supports of the airport fence at Tulita, NWT. (Photo: E. Hoeve)

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frost probe

A metal rod that is pushed into the ground to the point of resistance to measure the depth of the frost table (i.e., the thaw depth; see page 88).

Did you know...?
With experience, it may be possible to use the feel of the rebound and the sound that the probe makes to tell whether it has hit frozen ground or a rock embedded in the soil. Probing at the end of summer that encounters frozen ground shows that permafrost is present and the depth of the probe tip is roughly equal to the active layer thickness.



Pushing a frost probe into the soil until it hits the frost table, Muncho Lake, British Columbia. (Photo: A. Lewkowicz)



Obtaining the thaw depth by measuring the distance from the tip of the probe to the spot that was at the ground surface, Muncho Lake, British Columbia. (Photo: A. Lewkowicz)

frost shattering

Freezing that breaks up rock into smaller pieces.

Did you know…?
The movement of water through the rock and its expansion as it changes into ice creates the high pressures that cause rock to shatter.



Frost-shattered rock below a bedrock outcrop at Resolute, Nunavut. (Photo: A. Lewkowicz)

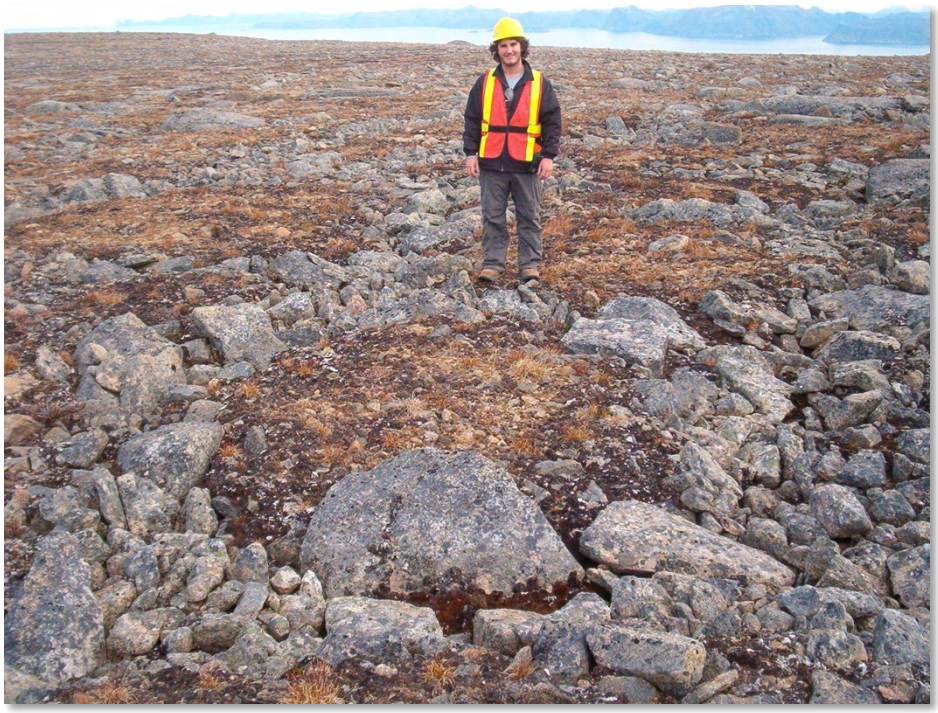


Frost-shattered rock covering the surface of Mont Jacques Cartier, Gaspé Peninsula, Québec. (Photo: A. Lewkowicz)

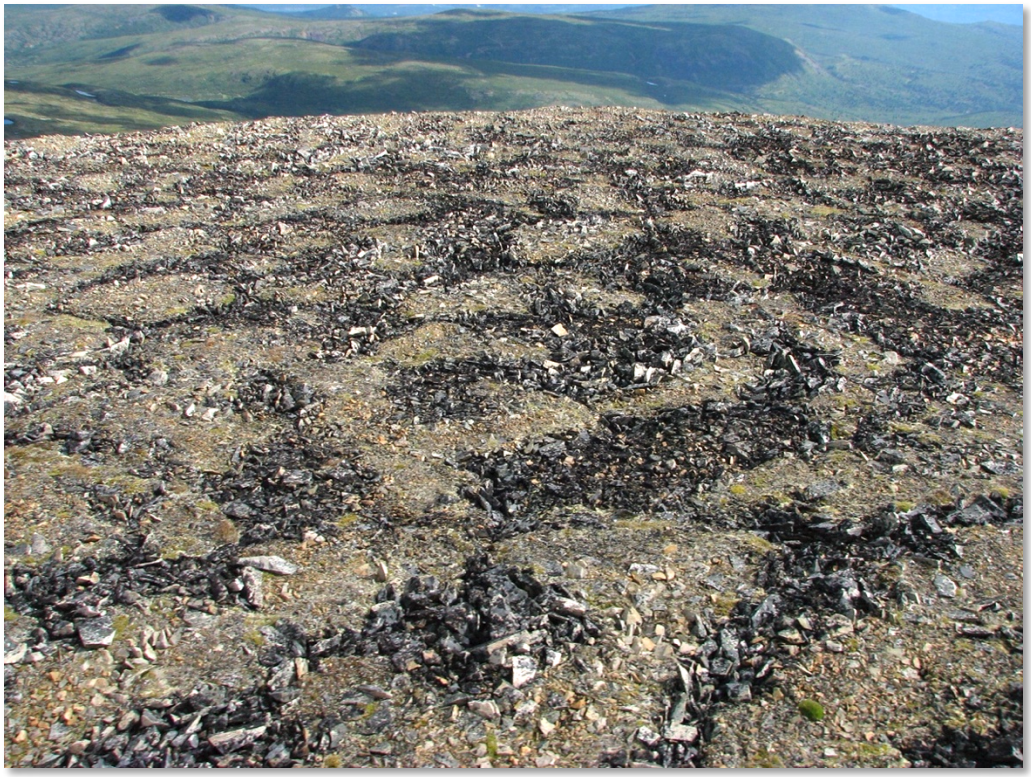
frost sorting

The re-arrangement of soil particles and stones by frost action into groups of differing sizes.

Did you know…?
Frost sorting is linked to the formation of unique patterned ground features, including sorted nets, circles, stripes, and polygons.



A sorted circle on Broughton Island, Nunavut. In this type of patterned ground, the dominant shape is circular and the larger rocks form the borders of the circle. (Photo: V. Roujanski)



The flat summit of Mt. Granger (2080 m above sea level) near Whitehorse, Yukon, shows a patterned ground net linked to frost sorting. (Photo: A. Lewkowicz)

frost-stable ground

Ground in which little or no ice forms during freezing.

Did you know…?
Frost-stable ground is usually composed of coarse-grained soils, such as sands or gravels, or unfractured bedrock. These are also called non-frost-susceptible materials. Buildings constructed on them are unaffected by ground freezing or thawing.



Frost-stable ground near Haines Junction, Yukon. This site is in the sporadic permafrost zone but there is no permafrost present in these non-frost-susceptible sandy gravels. (Photo: A. Lewkowicz)



Storage tanks on a pad of non-frost-susceptible materials at Inuvik, NWT. Most ground in the Inuvik townsite is not frost stable. Where structures, like these tanks, must rest directly on the ground, frost stable materials must be placed beneath them. (Photo: A. Lewkowicz)

frost-susceptible ground

Ground in which excess ice may form during freezing, causing frost heave.

Did you know…?
Frost-susceptible ground is usually composed of fine-grained soils, such as silts and clays. These are also called frost-susceptible materials. Buildings constructed on perennially frozen frost-susceptible materials are typically designed to maintain the permafrost because these



(Left): Tilted steel plates show that uninsulated pavement laid on frost-susceptible ground (on the left) has heaved relative to an insulated apron (on the right) that is rigidly attached to a building in Yellowknife, NWT. (Photo: E. Hoeve)



(Right): A frost-susceptible organic silt with numerous clear ice lenses (appearing black in this image), Macmillan Pass, NWT. The frozen ground was exposed in the side of a lithalsa which had been frost heaved during its formation. (Photo: A. Lewkowicz)



A core of frost-susceptible, silty soil extracted from near-surface permafrost, Fairbanks, Alaska (USA). Photo: A. Lewkowicz)

frozen ground

Soil or rock that contains ice.

Did you know…?
In fine-grained clay soils or saline soils, some water may remain liquid even when the ground temperature is well below 0°C.



Frozen ground (permafrost) exposed in the side of a lithalsa in Wolf Creek, near Whitehorse, Yukon. The ground could be easily scraped with a shovel because some of the water in the fine-grained soil was in liquid form despite temperatures below 0°C. (Photo: A. Lewkowicz)



Frozen ground exposed in a trench, Terra Nova Bay, East Antarctica. A jack-hammer was needed to break up the coarse-grained soil which was solidly frozen with little or no water in liquid form. (Photo: A. Lewkowicz)

geocryology

The study of permafrost and seasonally frozen ground.

Did you know…?
Geocryologists may be trained as scientists, engineers or both. They have formed organizations such as the Canadian Permafrost Association and the International Permafrost Association to share knowledge with other geocryologists and with those who live or work on permafrost.



A field excursion took participants in the 2022 North Yukon Permafrost Conference to the Top-of-the-World Highway near Dawson, Yukon. The permafrost distribution in this region is complex, influenced by elevation and aspect. (Photo: A. Lewkowicz)

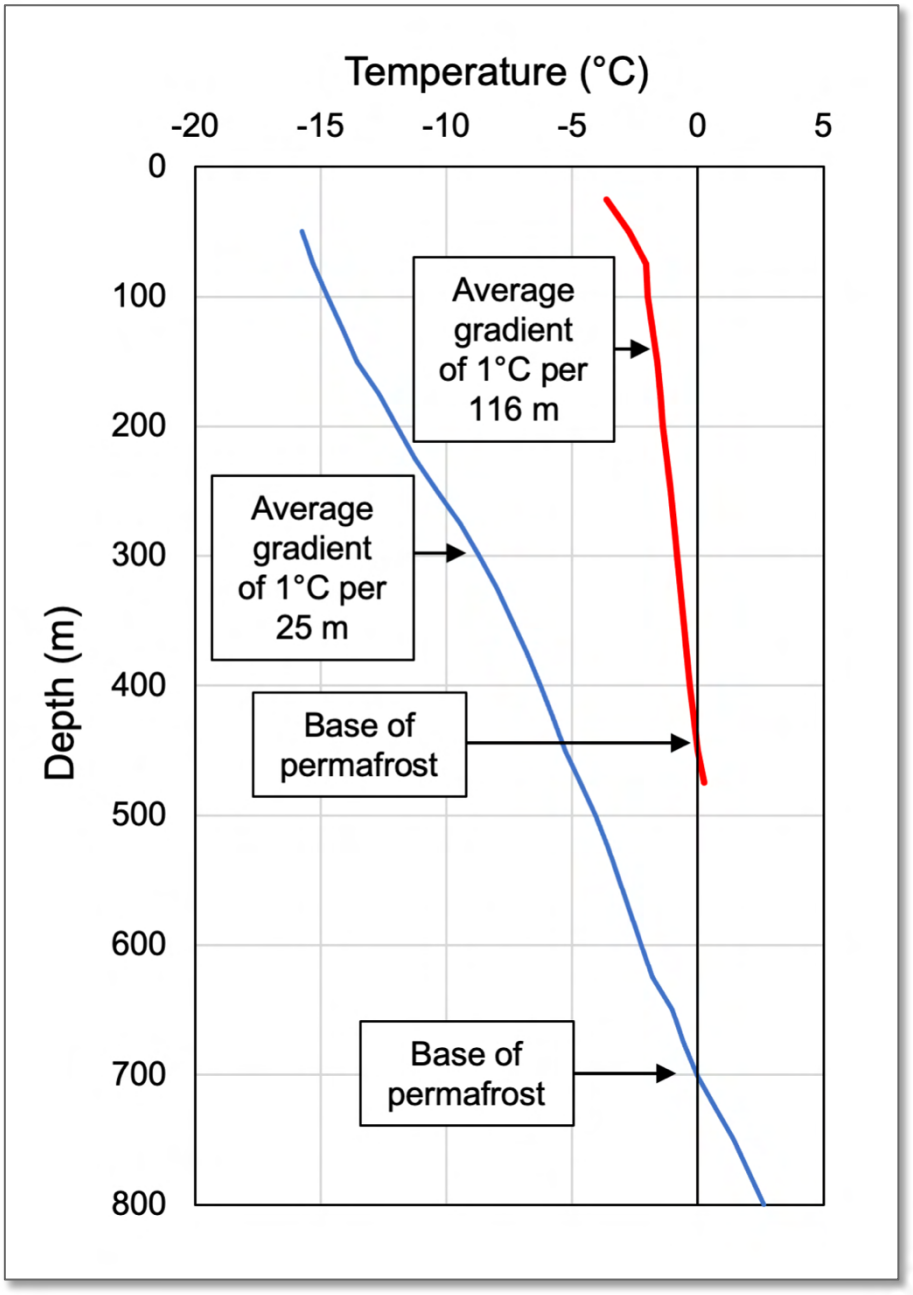


Geocryologists examine an exposure of permafrost containing large inactive ice wedges near Fairbanks, Alaska (USA) during the Fourth International Conference on Permafrost. (Photo: A. Lewkowicz)

geothermal gradient

The rate at which the temperature of the ground changes with depth.

Did you know…?
The ground typically gets warmer as you go deeper. Due to recent climate warming, however, the surface layers of permafrost may be as warm as, or warmer than, deeper layers.



This graph shows ground temperatures measured in the 1970s in two deep Canadian boreholes in continuous permafrost. The boreholes were drilled to explore for oil and gas. The blue line is for the Bent Horn wellsite on Cameron Island (76.36°N 103.97°W) and the red line is for the Kedji Lake hole (67.73°N, 126.83°W) near Colville Lake, NWT. Both lines show the ground getting warmer as depth increases. The geothermal gradient averages 1°C per 25 m at Bent Horn while the gradient is lower at Kedji Lake (1°C per 116 m). The permafrost base, which is where the lines cross 0°C, is 700 m deep at Bent Horn and 450 m deep at Kedji Lake. Data source: Judge, A.S., Taylor, A.E., Burgess, M., Allen, V.S. (1981). Canadian Geothermal Data Collection – Northern Wells 1978-80. Geothermal Series Number 12. Ottawa: Earth Physics Branch, Energy, Mines and Resources Canada. (Figure: A. Lewkowicz)

ground ice

Ice in the ground.

Did you know…?
Ground ice comes in numerous shapes and sizes and has many different origins. Its presence is what makes permafrost thaw so significant.



Massive ground ice exposed in the headwall of a large retrogressive thaw slump, Aulavik National Park, Banks Island, NWT. The melt of ground ice results in the formation and growth of this landform. Note the person in the distance for scale. (Photo: A. Lewkowicz)



Ground ice in a cave within the base of a rock glacier, Longyearbyen, Svalbard (Norway). The white ice crystals are formed from water vapour condensing on the ceiling. The blocks on the left are separated by masses of almost clear ice. (Photo: A. Lewkowicz)

hummock

A small mound or hump on the ground surface, typically made up of fine-grained soil or vegetation.

Did you know…?
Hummocks often occur in groups which give the ground a bumpy, patterned appearance. This unevenness can make walking quite difficult.



Hummocks formed on a slope on Ellesmere Island, Nunavut. (Photo: A. Lewkowicz)



Hummocks in the North Slave region, NWT. (Photo: N. Brown)

hydraulic thawing

The thawing of frozen soil using jets of water or steam.

Did you know…?
This technique is used to thaw permafrost in the Yukon and elsewhere, to allow gold to be extracted from frozen gravels.



Placer mining using hydraulic thawing in Quartz Creek, near Dawson, Yukon. The jets of water thaw and erode the ice-rich permafrost which lies above the gold-bearing gravels. Once the frozen soil has been removed, the gravel can be dug out and run through a sluice to extract the gold. (Photos: D. Froese)



ice lens

Ground ice in the shape of a lens.

Did you know…?
The thickness of an ice lens in permafrost can range from the diameter of a human hair to 10 m or more.



Ice lenses 10-20 mm thick in a permafrost core from a lithalsa, Wolf Creek, near Whitehorse, Yukon. (Photo: A. Lewkowicz)



Ice lenses varying in thickness from less than 1 mm to 5 mm from a core collected near the Dalton Highway, Alaska (USA). (Photo: A. Lewkowicz)

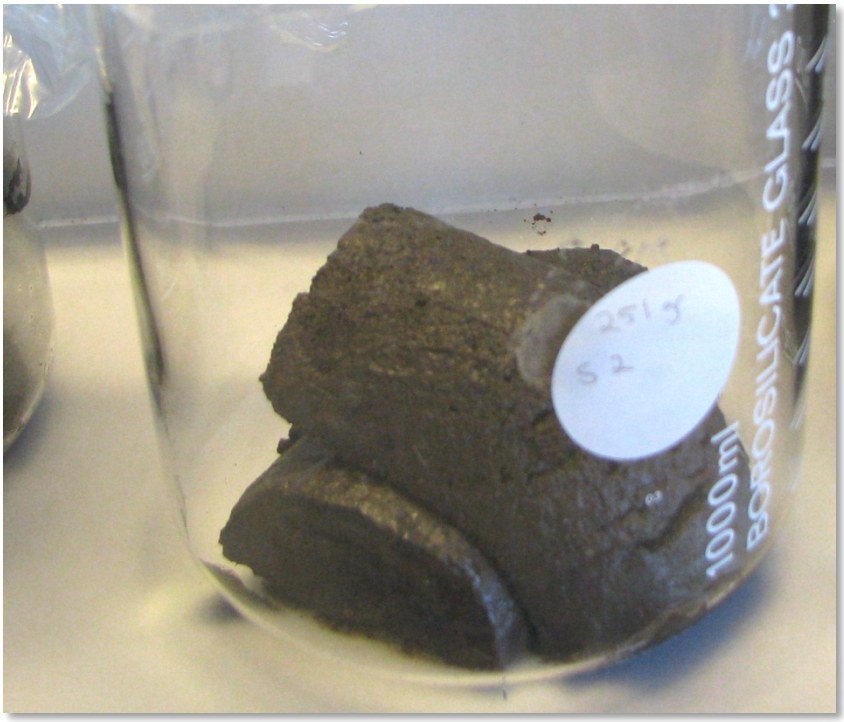
ice-poor permafrost

Permafrost with a low ground ice content.

Did you know…?
Ice-poor permafrost is most common in coarse-grained soils (sands and gravels) and in unfractured bedrock. A building constructed on ice-poor permafrost will be almost unaffected if the permafrost thaws.



Ice-poor mountain permafrost in the 60-Mile area, Yukon. Permafrost is present almost everywhere above treeline, but construction of a dirt road and other mining activities do not lead to thaw settlement or other forms of thermokarst. That's because most of the permafrost is ice-poor soil or bedrock. (Photo: A. Lewkowicz)



A permafrost core sample from Svalbard (Norway) after thawing in a glass beaker. All the water produced during thawing could be held in the pore spaces showing that there was no excess ice and that the permafrost was ice-poor. (Photo: A. Lewkowicz)

ice-rich permafrost

Permafrost with a high ground ice content.

Did you know…?
Ice-rich permafrost is particularly common in areas of fine-grained soils (silts and clays). Buildings constructed on ice-rich permafrost must be designed to prevent it from thawing.



Ice-rich permafrost exposed on the slide plane of an active-layer detachment failure, Mackenzie Valley, NWT. The slope failure surface shows lenses of ground ice(black) in fine-grained sediments (grey). (Photo: A. Lewkowicz)



Permafrost at Inuvik, NWT, is almost all ice-rich. Buildings, such as these houses, must be constructed to avoid permafrost thaw. Here, they are elevated above the ground surface using piles which reduce heat flow into the ground. (Photo: A. Lewkowicz)

ice vein

Ice occurring within a crack or fissure in the ground.

Did you know…?
Ice wedges are made up of many ice veins.



An ice vein exposed beneath peat at the top of permafrost in the North Fork Pass, Yukon. The crack opened in the winter and meltwater entered and froze in the spring. The vein shown may have formed in a single winter or over several years. (Photo: A. Lewkowicz)



A vein of white ice within a thermal contraction crack on Ellesmere Island, Nunavut. The ice was formed when water entered the open crack while the active layer was still frozen. (Photo: A. Lewkowicz)

ice wedge

A wedge-shaped body of ice, tapering downward into the ground.

Did you know…?
An ice wedge forms by a yearly cycle of contraction and cracking of the frozen ground in winter, followed by meltwater entering and freezing within the crack in the spring.



A tall ice wedge in the outer Mackenzie Delta, NWT. This wedge is epigenetic, meaning it formed after the deposition of the sediment in which it is found. The wedge sticks out from the frozen face, revealing its true shape, because it melts more slowly than the surrounding soil thaws (Photo: A. Lewkowicz)



The top of an ice wedge on the Yamal Peninsula, Western Siberia (Russia). This wedge is syngenetic, meaning it formed at the same time as the deposition of the sediment in which it is found. Syngenetic wedges can be particularly tall. (Photo: A. Lewkowicz)

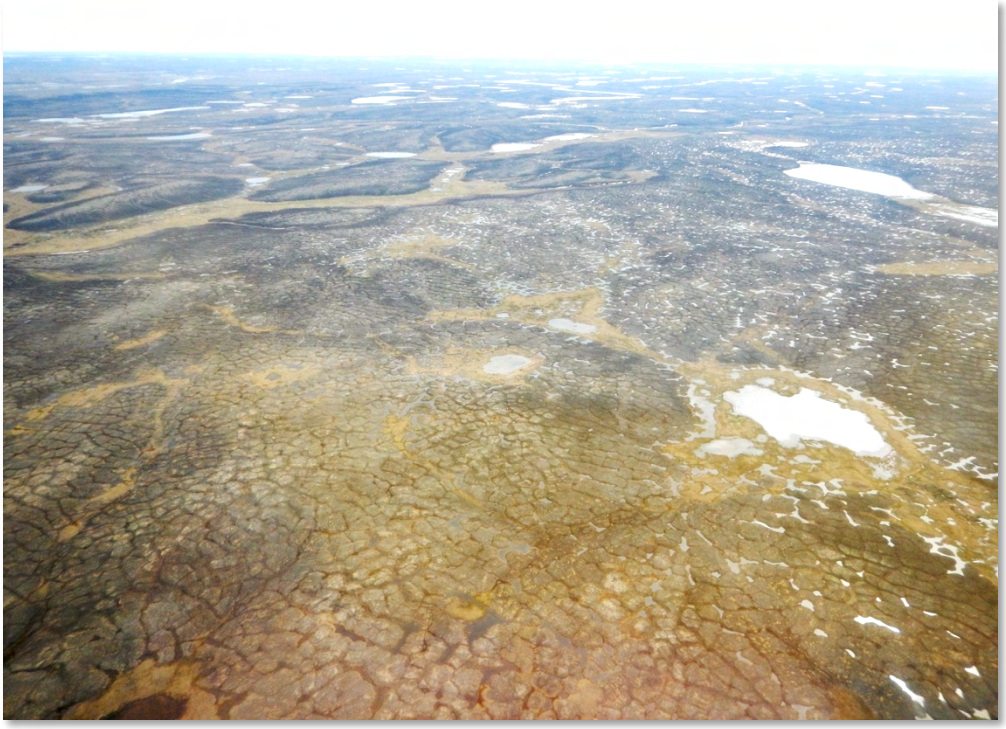
ice-wedge melt pond

A narrow pond developed over a partially melted ice wedge.

Did you know…?
These ponds have become common in some regions because warmer summers have caused the tops of ice wedges to melt, forming a depression that fills with water.



Ice-wedge melt ponds in Aulavik National Park, Banks Island, NWT. Cracks running parallel to the edges of the ponds show that settling of the surface is continuing. (Photo: A. Lewkowicz)

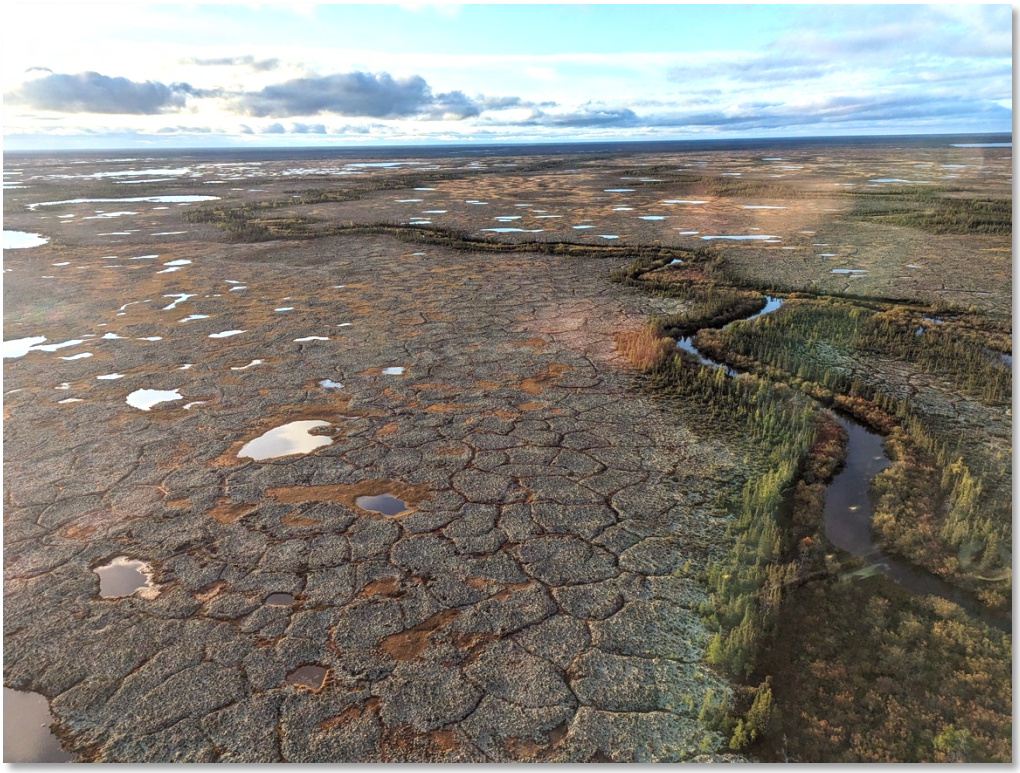


Thousands of ice-wedge melt ponds have developed on parts of Banks Island, NWT as a result of greater thaw depths than in the past. In a particularly warm summer, the top of a shallow ice wedge can melt, the surface settles and a closed depression forms that can fill with water. (Photo: A. Lewkowicz)

ice-wedge polygon

A polygon on the ground surface with ice wedges present beneath its borders.

Did you know…?
Ice-wedge polygons can be high-centred or low-centred and usually form a network.



A network of ice-wedge polygons in the Hudson Bay Lowlands, south of Churchill, Manitoba. (Photo: P. Roy-Léveillée)



High-centred polygons, with troughs forming their borders are present on the upper part of this slope on Ellesmere Island, Nunavut. Low-centred polygons, bordered by prominent ridges, are distributed nearer the valley bottom. Ice wedges form a network beneath the borders of both types of polygons. (Photo: A. Lewkowicz)

isolated patches of permafrost zone

A geographical area where patches of permafrost are estimated to be present beneath less than 10% of the land surface.

Did you know…?
In North America, permafrost in the isolated patches zone is mostly found in peatlands where it is only a few meters thick. (A map of all the permafrost zones is shown on page 74).



Part of the isolated patches of permafrost zone near Buckinghorse, northeast British Columbia. The forested area in the centre of the photo is a peat plateau where the permafrost is about 10 m thick. It is the only permafrost found in the immediate vicinity. (Photo: A. Lewkowicz)



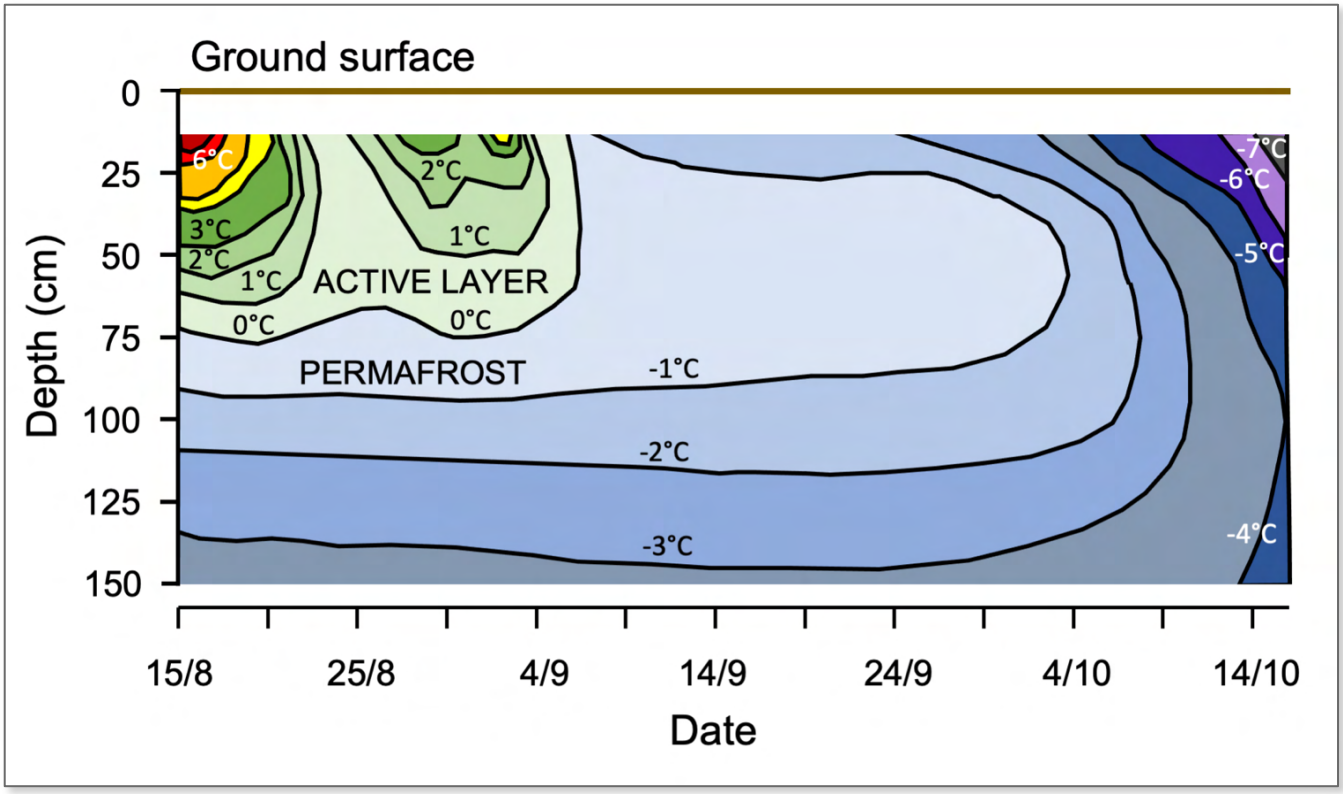
Permafrost is degrading in the isolated patches of permafrost zone near Blanc Sablon, Québec. The palsa in the background is still perennially frozen while the two red-brown patches of peat in the foreground are the locations of fully degraded palsas. (Photo: A. Lewkowicz)

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isotherm

A line on a map or scientific diagram that links points of equal temperature.

Did you know…?
The pattern of isotherms on a map shows how temperature varies through space while isotherms on a graph can be used to show how temperature varies through time.



Isotherms showing the freezeback of the active layer through time at Hot Weather Creek, Ellesmere Island, Nunavut. The lines show the average daily temperatures measured at nine depths in the ground over two months from August 15 to October 15. The 0°C isotherm reached a maximum depth of 75 cm, approximating the base of the active layer. The active layer cooled slowly over the first 20 days of the record until temperatures rapidly dropped below 0°C on September 6. It then took almost a month for most of the active layer to cool below -1°C. This indicates that most of the water in this fine-grained soil did not freeze at exactly 0°C, but over a range of sub-zero temperatures. (Data source: unpublished field data. Figure: A. Lewkowicz)

lithalsa

A permafrost mound up to a few meters high composed almost entirely of mineral soil and layers of ice.

Did you know…?
Lithalsas typically occur in wetlands where permafrost is discontinuous. The layers of ground ice within a lithalsa are the main reason it rises above the surrounding wetland.



A lithalsa near Kangiqsualujjuaq, Nunavik, Québec. The mound has an organic mat that covers sediment containing numerous ice lenses. This lithalsa is degrading and collapsing into the adjacent pond. (Photo: P. Roy-Léveillée).

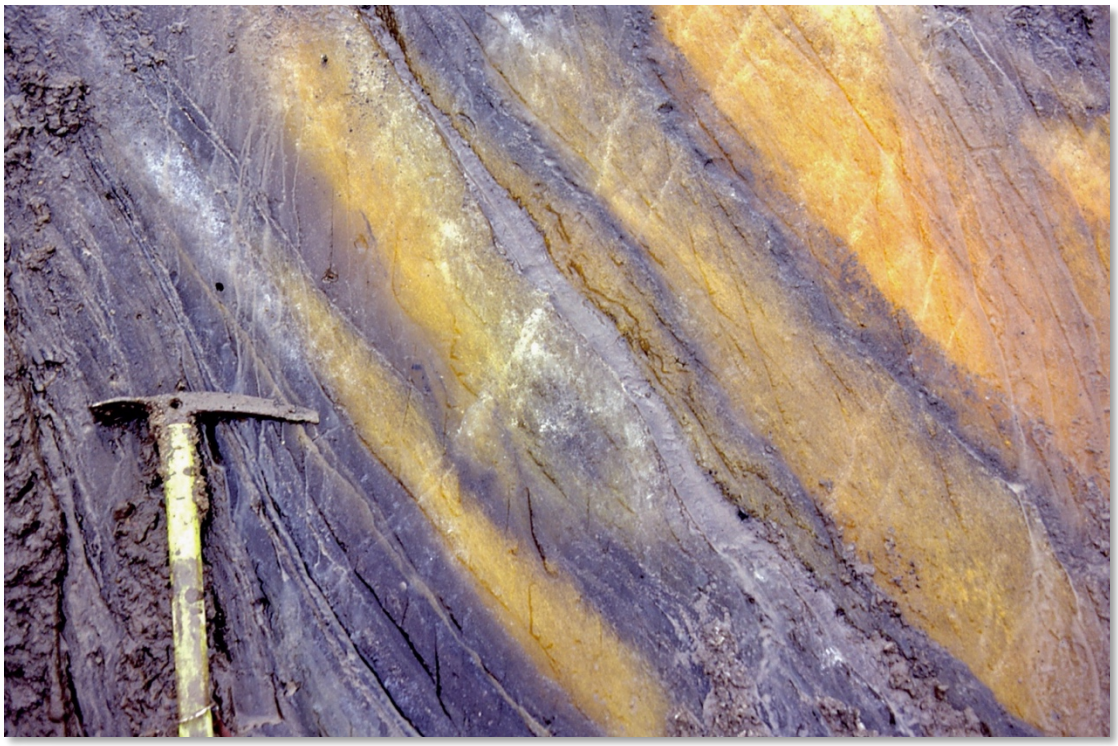


A lithalsa at treeline in Wolf Creek, near Whitehorse, Yukon. Aerial photographs show that the mound formed more than 75 years ago and it has remained relatively stable over the past two decades. (Photo: A. Lewkowicz)

massive ice

Masses of nearly pure ice in the ground.

Did you know…?
Massive ice beds can be more than 40 m thick and extend over distances of 2 km.



Massive ice containing coloured sediment, Ellesmere Island, Nunavut. (Photo: A. Lewkowicz)



An exposure of almost pure massive ice on the Yamal Peninsula, Western Siberia (Russia). (Photo: A. Lewkowicz)

mean annual air temperature

The temperature of the air, averaged from daily means, for at least one complete year.

Did you know…?
Mean annual air temperatures in the Arctic and Subarctic are rising rapidly and causing permafrost to warm and thaw.



A federal government climate station in Aulavik National Park, Banks Island, NWT, that records air temperature, relative humidity, wind speed, rainfall and snowfall. The sensors for air temperature are inside the white box which prevents them from being heated by sunlight. The mean annual air temperature at this tundra site is -13°C which is about 1°C colder than the temperature of the permafrost. (Photo: A. Lewkowicz)



A basic climate station used for permafrost research in the boreal forest near Teslin, Yukon. Air temperature is measured by a datalogger with a sensor inside the white screen. The mean annual air temperature over 8 years at this site was -1°C. The average permafrost temperature measured in a borehole at the site is -0.1°C. (Photo: A. Lewkowicz)

mountain permafrost

Permafrost within the mountains of the world.

Did you know…?
Permafrost can exist in mountains when it is absent in nearby valleys because the climate is colder at high elevations. Permafrost is also more common beneath shaded mountain slopes, which face north in the Northern Hemisphere (e.g., in the Rocky Mountains and the European Alps) and south in the Southern Hemisphere (e.g., in the Andes).



Mountain permafrost at Pink Mountain, northern British Columbia. Lowlands in this region exhibit isolated patches of permafrost, whereas more extensive permafrost occurs at higher elevations where the climate is colder. (Photo: N. Brown)



The summit of Mont Jacques Cartier on the Gaspé Peninsula, Québec, is one of the most southerly occurrences of permafrost in Canada. This mountain permafrost can exist because air temperatures are low at its elevation of about 1250 m above sea level, and because much of the snow is blown off the summit by strong winds in winter. This loss of insulating snow helps the ground to lose heat into the air. (Photo: A. Lewkowicz)



Mountain permafrost viewed from Annapurna base camp at an elevation of about 4000 m above sea level in Nepal. Permafrost can occur at low latitudes in the Himalayas because the climate is so cold at very high elevations (Photo: N. Brown)

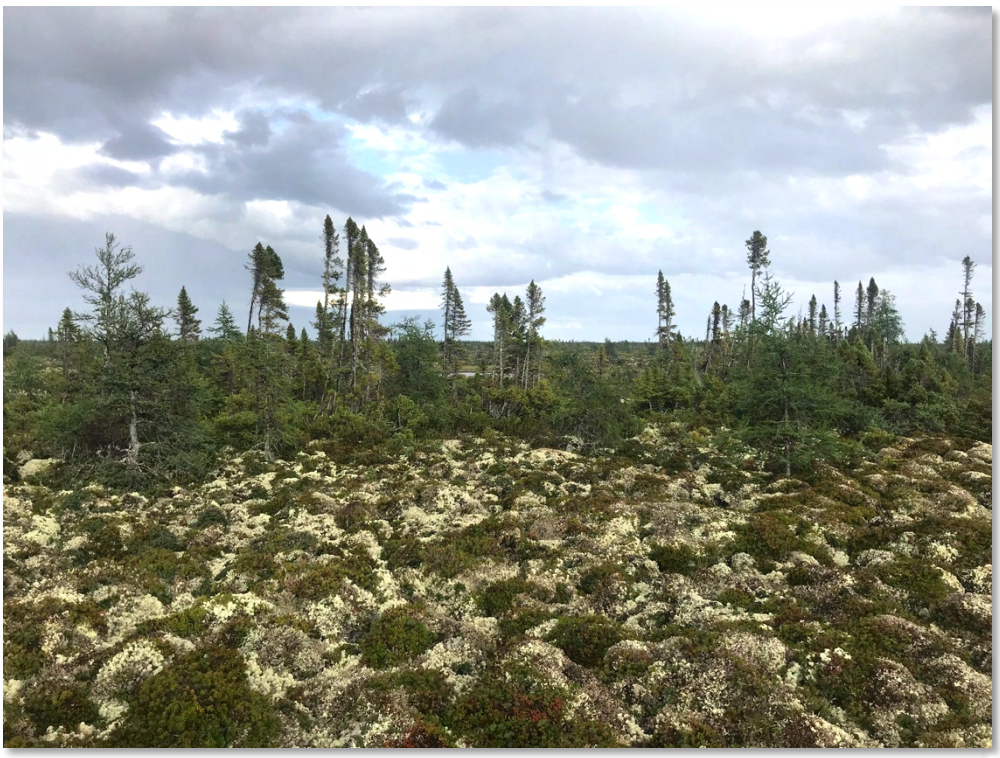
muskeg

Peat-covered wetlands that may include permafrost mounds.

Did you know…?
Muskeg is a word that has its roots in Algonquian languages. The southernmost permafrost in North America that is not in mountains is found in muskeg.



Muskeg in the Hudson Bay Lowlands, Manitoba. (Photo: P. Roy-Léveillée)



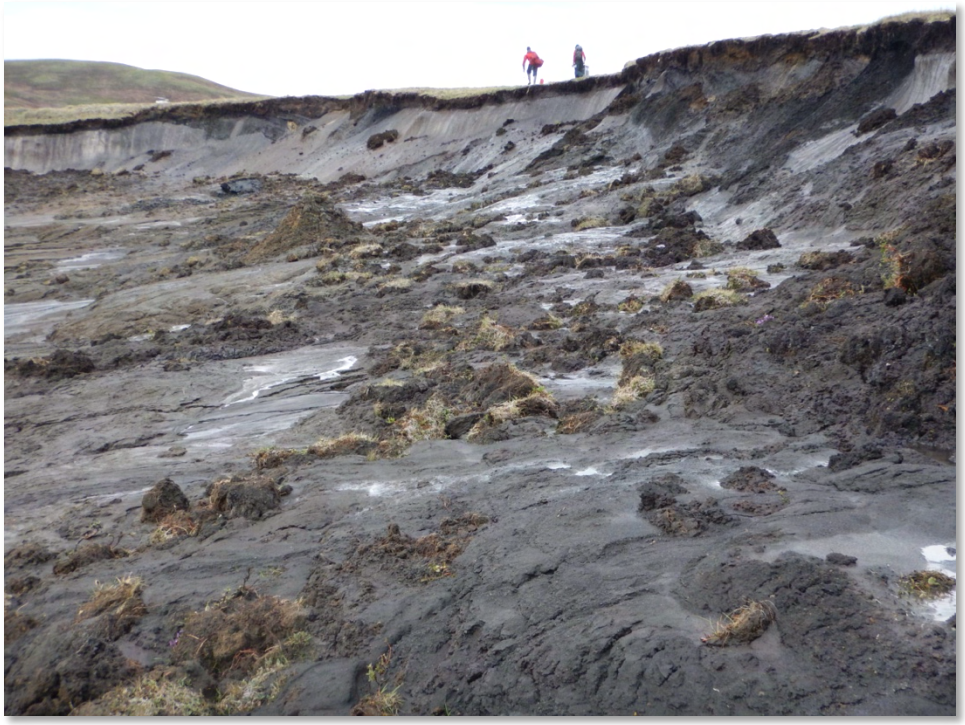
Muskeg near Peawanuck in the Hudson Bay Lowlands, Ontario. (Photo: A. Kirkwood)

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near-surface permafrost

Permafrost within 3-4 m of the ground surface.

Did you know…?
Computer models can be used to predict the impact of climate warming on near-surface permafrost which will be the first part to thaw, and which often contains more ice than deeper layers.



Near-surface permafrost exposed in a retrogressive thaw slump in Aulavik National Park, Banks Island, NWT. The upper layers of near-surface permafrost are often particularly ice-rich due to presence of ice wedges and the typical distribution of other types of ice in the ground. (Photo: A. Lewkowicz)



Near-surface permafrost thawing next to the Alaska Highway in the Ibex Valley near Whitehorse, Yukon. (Photo: A. Lewkowicz)

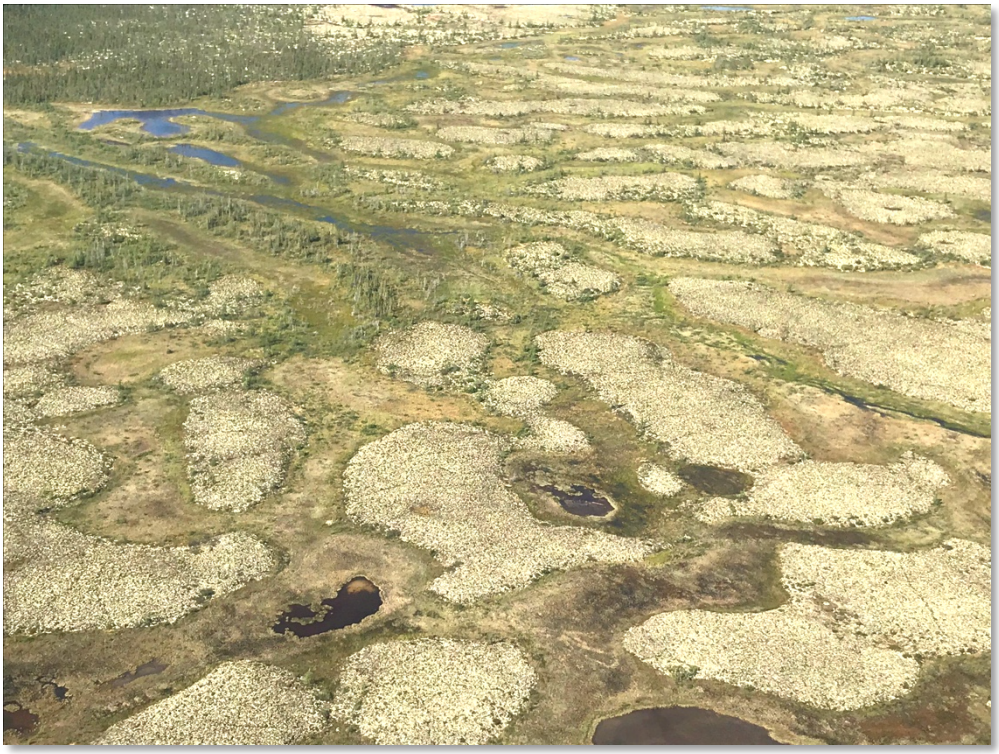
palsa

A permafrost mound up to a few meters high composed mainly of frozen peat and layers of ice.

Did you know…?
Palsas typically occur in wetlands where permafrost is discontinuous. The layers of ground ice within a palsa are the main reason it rises above the surrounding wetland.



A palsa in a bog in Macmillan Pass, NWT. A group of ten palsas were observed at this site in 1944. Only two are left and both are degrading as a result of climate change. (Photo: A. Lewkowicz)



A large group of palsas near Peawanuck in the Hudson Bay Lowlands, Ontario. Their cream colour is due to a cover of lichens. Permafrost is present in the palsas and absent in the boggy areas between them. (Photo: A. Kirkwood)

patterned ground

A repeating pattern of polygons, circles, nets, stripes or steps visible on the ground surface.

Did you know…?
Patterned ground can be outlined by differences in vegetation or by the size of soil particles. It is linked to ground freezing and thawing and may be an indication that permafrost is present.



Nonsorted stripes downslope of a snowbank site in the valley of the Sachs River, Banks Island, NWT. This type of stripe is outlined by differences in vegetation and in the rate of solifluction. (Photo: A. Lewkowicz)



Sorted circles at Kvadehuksletta, Svalbard (Norway). These circles are quite rare globally as they require specific soil, moisture and climate conditions to form. These examples are probably the best in the world. (Photo: A. Lewkowicz)

peat

Decaying plant matter, usually found at the ground surface, forming a layer over other soils.

Did you know…?
Peat is an excellent natural insulator, better than many manufactured ones. This can allow permafrost to be present at peat-covered sites where the climate is otherwise too warm for it to exist.



A layer of peat covering a layer of massive ice in a frost blister, North Fork Pass, Yukon. (Photo: A. Lewkowicz)





A surface exposure of a peat deposit (left) and a section through the peat (right) in the North Slave region, NWT. (Photos: N. Brown)

DOI: 10.52381/CPA.permafrostdictionary.1

peatland

Peat-covered ground, commonly referred to as muskeg in North America.

Did you know…?
The southernmost permafrost in North America that is not in mountains is found in peatlands.



The Old Crow Flats, Yukon, are extensive peatlands in the continuous permafrost zone. (Photo: P. Roy-Léveillée)

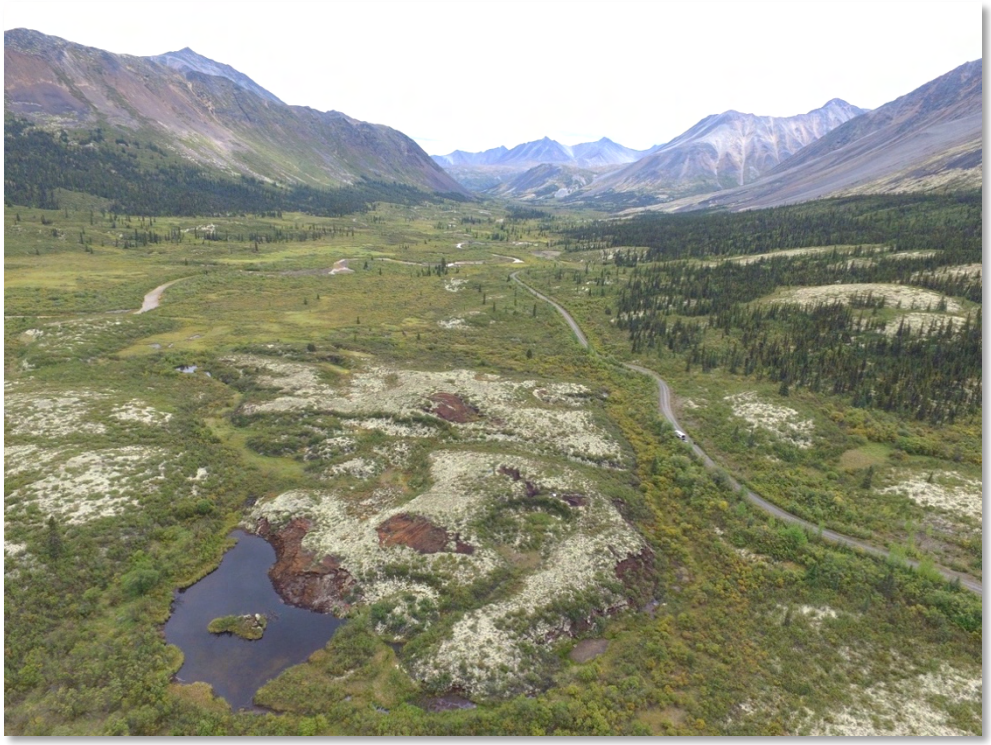


A lichen-covered peatland in the isolated patches of permafrost zone, Prisoner's Island, Newfoundland and Labrador. (Photo: A. Lewkowicz)

peat plateau

An isolated, flat-topped, elevated area of peat containing permafrost, usually within a wetland.

Did you know…?
Reindeer lichen often grows on peat plateaus, making them good habitat for caribou.



A peat plateau covered in lichen in Macmillan Pass, Yukon. Part of the plateau is collapsing into the pond in the foreground as the permafrost degrades. (Photo: A. Lewkowicz)



A degrading peat plateau near Parson's Lake, north of Inuvik, NWT. The large troughs and ponds have developed above a network of ice wedges. (Photo: V. Roujanski)

permafrost

Ground that remains at or below a temperature of 0°C for at least two years in a row.

Did you know…?
Permafrost is defined by temperature but it usually contains some ice. However, there are exceptions. For example, a soil with a high concentration of salts does not freeze at 0°C so it can be permafrost and contain only liquid water, while both liquid water and ice can be absent in dry permafrost at sites in Antarctica.



Ice-rich permafrost exposed in Aulavik National Park, Banks Island, NWT. Many people imagine permafrost to always look like this. In fact, extensive areas of permafrost contain only small concentrations of ice. (Photo: A. Lewkowicz)

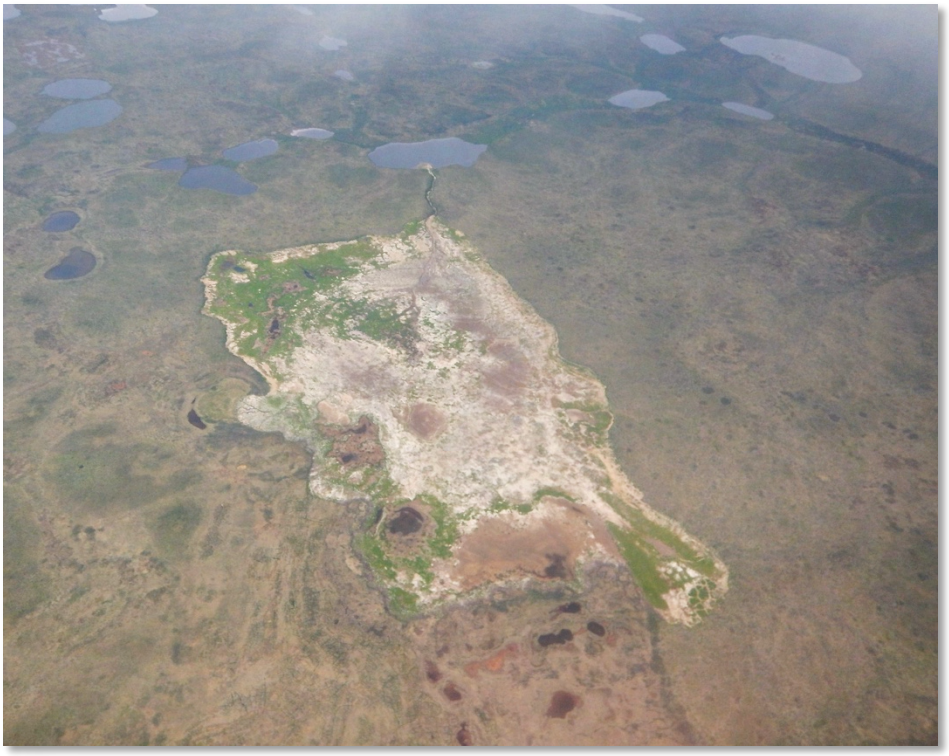


Permafrost at Mt. Keinath in East Antarctica. The strangely weathered and eroded bedrock at this site probably contains little or no ice but it is still permafrost because its temperature remains below 0°C year-round. (Photo: A. Lewkowicz)

permafrost aggradation

The formation or growth of permafrost upwards, downwards, or sideways.

Did you know…?
Global climate warming means that permafrost aggradation is now quite rare. It can still occur, however, if unfrozen sediments are newly exposed to a cold climate, such as when a lake drains on the tundra and permafrost aggrades in the former lake bottom.



A recently drained lake basin in the continuous permafrost zone near Anderson River, NWT. The sediments that were previously beneath the lake were unfrozen when first exposed. The site's cold climate means that permafrost will start to aggrade in the basin. (Photo: A. Lewkowicz)

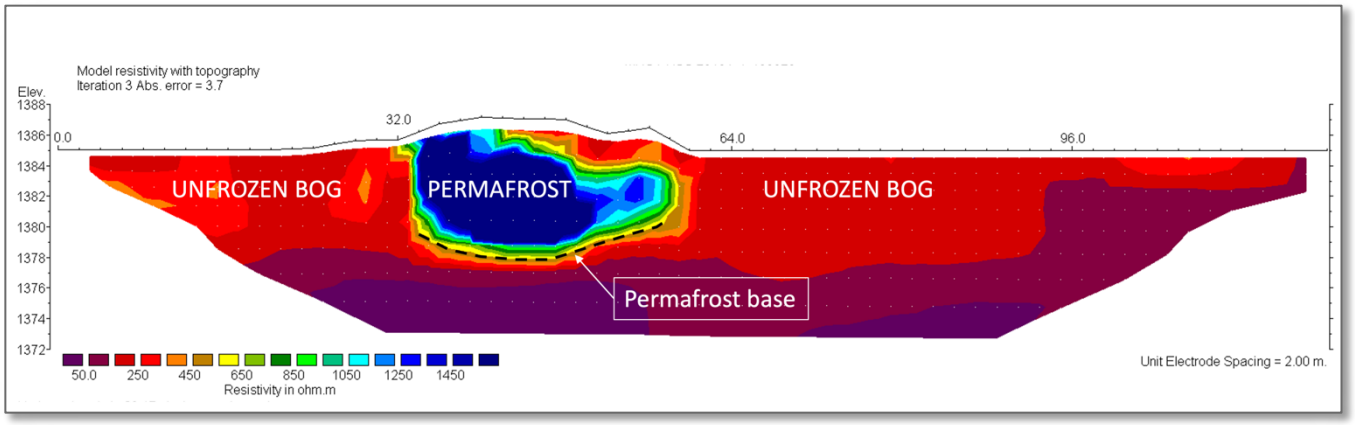


Permafrost is aggrading at this site (Illisarvik) in the Mackenzie Delta, NWT, where a lake was drained in 1978 by the late Professor J. Ross Mackay. This was the biggest permafrost experiment ever carried out in Canada. Geocryological and ecological processes occurring at Illisarvik as the permafrost aggrades have now been monitored for nearly half a century. During that time, almost 15 m of permafrost has developed in the bottom of the former lake. (Photo: A. Lewkowicz)

permafrost base

The lower boundary of permafrost.

Did you know…?
The base of permafrost, where ground temperatures begin again to be higher than 0°C, may be only a few meters deep in the boreal forest but several hundred meters deep beneath the tundra.



The base of permafrost is generally not visible because it's far below the ground surface. However, it can be detected by measuring ground temperatures in a deep enough borehole (see page 38), or by imaging some of the other changes that occur across the boundary between frozen and unfrozen ground. This 120 m long profile through the ground runs across a palsa in Macmillan Pass, NWT and was carried out using a geophysical technique called electrical resistivity tomography (ERT) (see page 20). The blue area is the ice-rich permafrost within the palsa where the electrical resistivity was high because ground ice is a poor conductor. The red areas are the surrounding unfrozen bog where the electricity passes easily. The base of the permafrost is about 10 m beneath the centre of the palsa where the ground changes rapidly from being a poor conductor (frozen), to being a good conductor (unfrozen). (Data source: unpublished field data. Figure: A. Lewkowicz)

permafrost carbon

Organic carbon stored in permafrost.

Did you know…?
There is a massive amount of permafrost carbon stored in the Arctic and Subarctic. Most of it is made up of shoots and roots of plants that were incorporated into the soil and then became frozen as the permafrost formed.



(Right): A core sample from the Hudson Bay Lowlands in Manitoba, showing the edge of an ice wedge and frozen peat. The peat is a small part of the huge store of permafrost carbon in the Circumpolar North. (Photo: P. Roy-Léveillée)

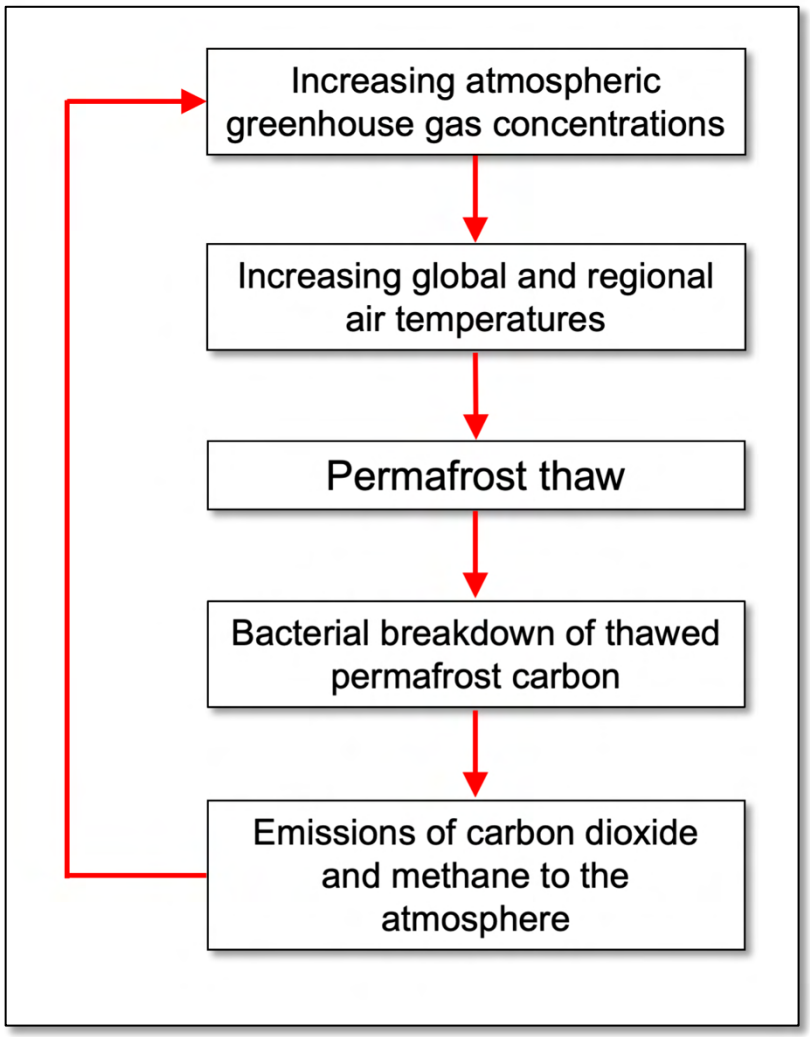


(Left): An ice wedge in Western Siberia (Russia), within permafrost that has a high organic content made up of the partially decomposed roots and shoots of plants. This wedge grew upwards at the same time as sediment was regularly deposited on the ground surface, partially covering the plants. As the surface continued to rise, the plant remnants eventually stopped being located within the active layer and became part of the permafrost. They now form a fraction of the massive global store of permafrost carbon. (Photo: A. Lewkowicz)

permafrost carbon-climate feedbacks

The processes by which a rise in global air temperature causes, and is affected by, permafrost change.

Did you know…?
Thawing permafrost can make stored organic carbon (mainly partially decomposed plant roots and shoots) available for breakdown by bacteria, and this decay can generate additional greenhouse gases, amplifying the global rise in air temperature. Though less well documented, climate change and thawing permafrost may also enable accelerated plant growth and carbon accumulation. These important feedbacks are still being studied but could affect the climate of the entire Earth.



The best-known permafrost carbon-climate feedback is between global warming and permafrost thaw. Increasing concentrations of greenhouse gases in the atmosphere due to human activities have caused the globe to warm. Warming in northern permafrost regions is happening at 2-3 times the global rate and is causing permafrost thaw. Stores of organic material (mainly partially decayed plant shoots and roots), previously frozen within the permafrost, are broken down by bacteria. The bacteria emit carbon dioxide or methane into the atmosphere, further increasing greenhouse gas concentrations and amplifying the initial increase in global air temperatures. These systems and feedbacks are complex and continue to be studied by permafrost scientists, ecologists, climatologists and modellers. (Figure: A. Lewkowicz, based on Schaefer et al. (2014). The impact of the permafrost carbon feedback on global climate. Environmental Research Letters 9 085003: doi:10.1088/1748-9326/9/8/085003)

permafrost core sample

A sample of permafrost, typically consisting of a cylinder of frozen soil or rock and ice, obtained using a specialized drill.

Did you know…?
Core samples can be used for many purposes, such as describing the distribution of ice in the permafrost and for measuring its strength in the laboratory as it thaws.



(Right): A permafrost core sample with a layered cryostructure from a lithalsa at Kangiqsualujjuaq, Nunavik, Québec. (Photo: P. Roy-Léveillée)



(Left): A permafrost core with a lensed cryostructure from Inuvik, NWT. (Photo: H.B. O'Neill)

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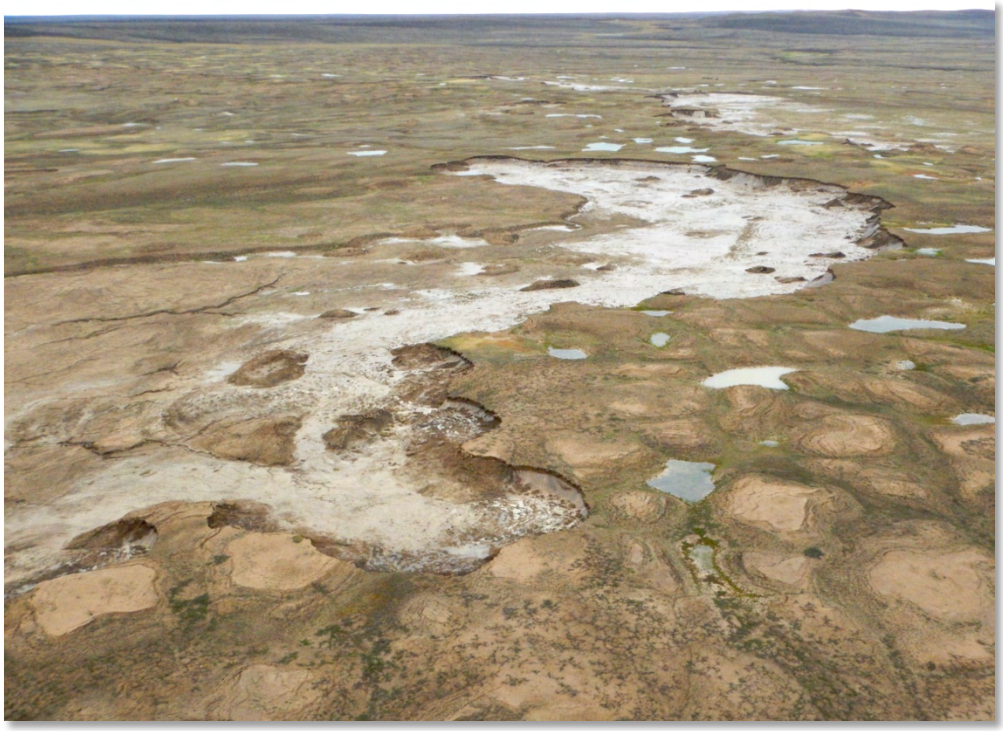
permafrost degradation

Changes in the physical characteristics of permafrost due to thaw or warming from the top down, bottom up, or sideways.

Did you know…?
Permafrost degradation has become widespread as the climate has warmed. It can have major ecological impacts and can also negatively affect buildings and other infrastructure.



Permafrost degrading on the edge of a pond near Yellowknife, NWT. The tilted trees are an indication that the surface has settled as the permafrost has thawed. (Photo: A. Lewkowicz)



Extensive degradation of near-surface ice-rich permafrost in Aulavik National Park, Banks Island, NWT. The ponds have developed where ice wedges have melted from above. The large retrogressive thaw slump represents sideways degradation of permafrost. (Photo: A. Lewkowicz)

permafrost melt

A commonly-used phrase to describe permafrost thaw.

Did you know…?
Permafrost scientists and engineers prefer to say that permafrost thaws, not melts. That's because the ice alone melts, while the soils and rocks that make up most of the permafrost do not.

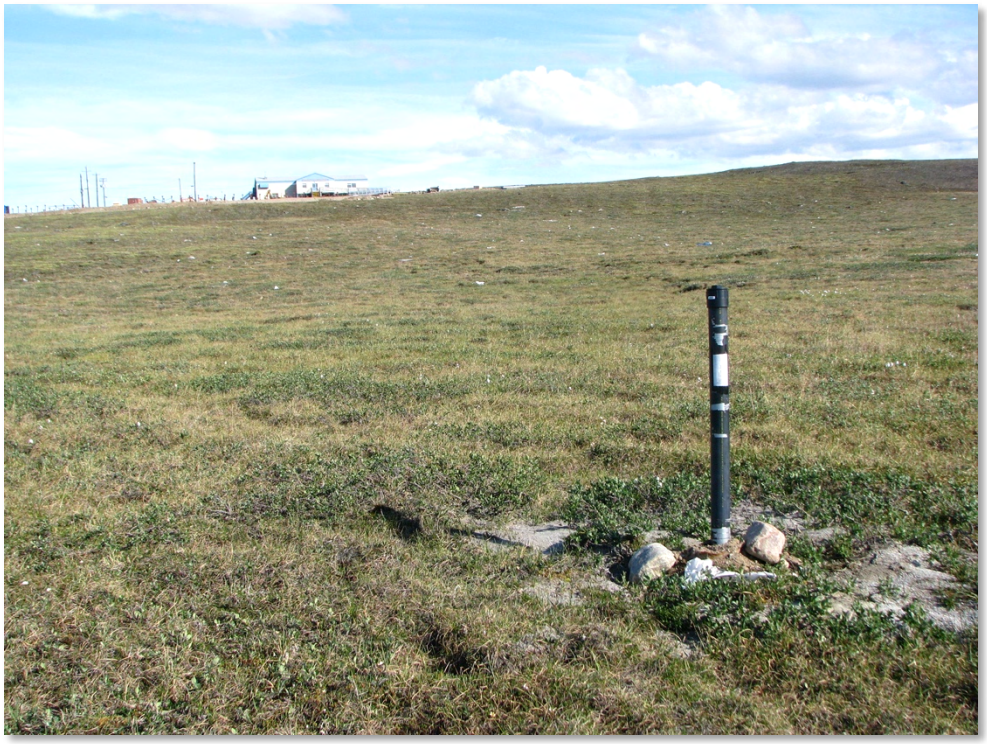


A retrogressive thaw slump in the Ibex Valley near Whitehorse, Yukon. The water produced by the melt of the ground ice may suggest that the permafrost is melting. But this is mud, not molten lava, and the soil particles do not melt. It's more accurate to say the permafrost is thawing. (Photo: A. Lewkowicz)

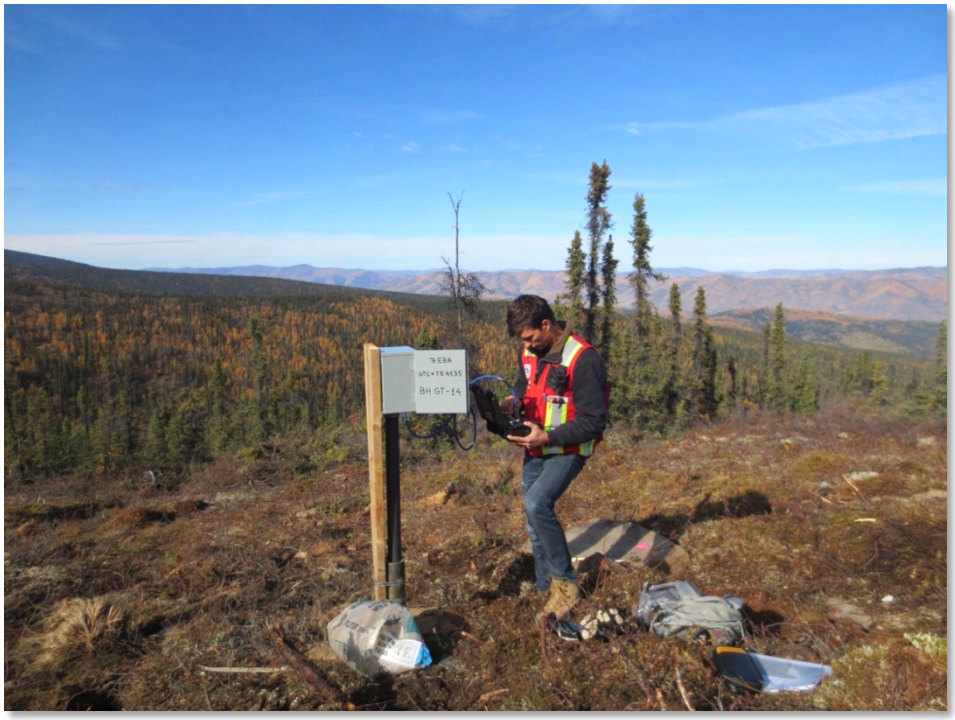
permafrost monitoring borehole

A borehole drilled in permafrost and equipped with sensors that measure ground temperature.

Did you know…?
Hundreds of monitoring boreholes in the Arctic, Antarctic and at high elevations contribute to the Global Terrestrial Network for Permafrost whose goal is to measure permafrost warming and thawing over the long term (see the map on page 74 and https://gtnp.arcticportal.org/).



A permafrost monitoring borehole at Pond Inlet, Nunavut. Temperatures recorded in the ground at this site are used by the Geological Survey of Canada to track the impact of climate change on permafrost. (Photo: A. Lewkowicz)



A permafrost monitoring borehole in the Dawson Range, west central Yukon. The measured ground temperatures are used to make engineering decisions about infrastructure at the site. (Photo: V. Roujanski)

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permafrost table

The top boundary of permafrost.

Did you know…?
The permafrost table can be less than 1 m deep beneath the tundra but can be several meters below the ground surface where permafrost degradation is occurring.



The permafrost table typically parallels the ground surface, as shown in this lithalsa on Little Fox Lake, Yukon. The permafrost table is quite shallow because the peat cover is such a good insulator. (Photo: A. Lewkowicz)



A trench across the trough of a high-centred polygon on Ellesmere Island, Nunavut. The top of the ice wedge is visible at the base of the trench and represents the permafrost table. (Photo: A. Lewkowicz)

permafrost thaw

Progressive loss of ground ice in permafrost.

Did you know…?
Permafrost thaw usually takes place quite slowly due to the amount of heat needed, but large amounts of ice in the ground can affect thaw processes, resulting in thermokarst development and what is sometimes called abrupt thaw.



The ground surface has collapsed due to the thaw of ice-rich permafrost at this site adjacent to the Dempster Highway, Yukon. (Photo: A. Lewkowicz)

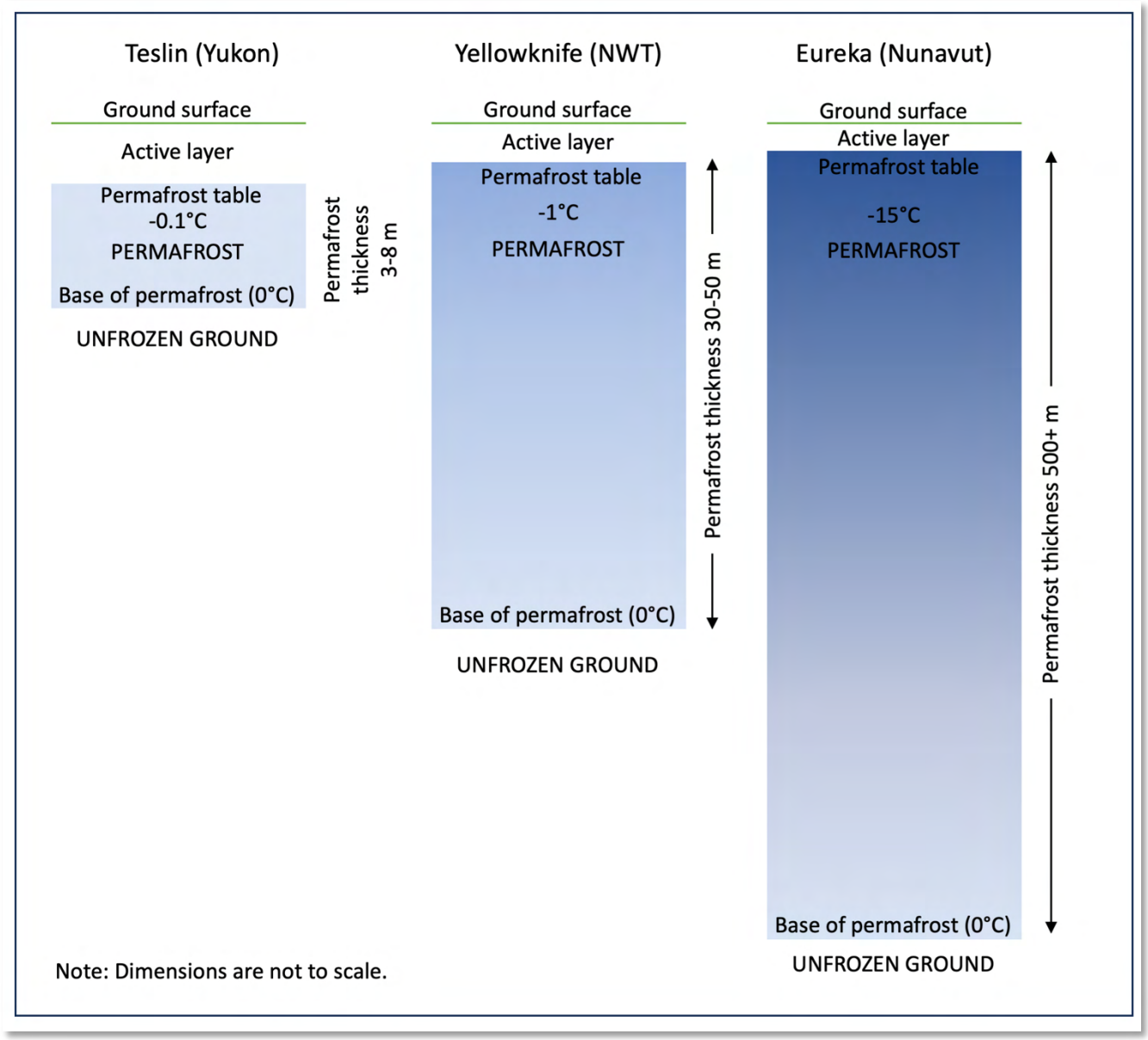


This building in Dawson, Yukon, has settled unevenly as some of the permafrost beneath it has thawed. (Photo: A. Lewkowicz)

permafrost thickness

The thickness of permafrost measured from the permafrost table to its base.

Did you know…?
The thickness of permafrost varies from a few meters in the isolated patches zone to more than 1000 meters in the coldest parts of the continuous permafrost zone.

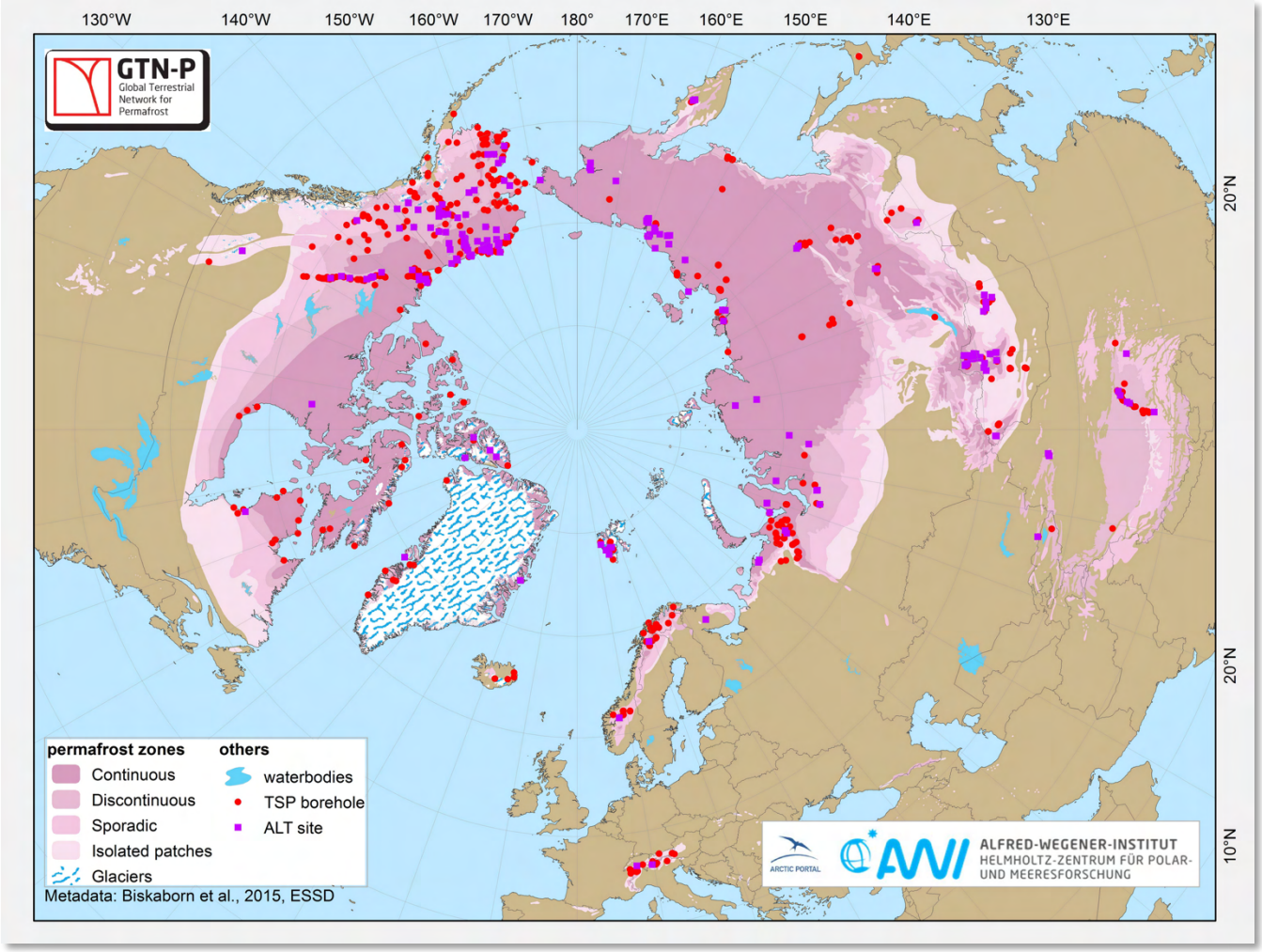


Permafrost thickness (not to scale) for three Canadian sites. Permafrost thickness depends mainly on the average temperature of the ground: the colder it is, the thicker the permafrost. However, a great deal of local variation exists. For example, Teslin is in the sporadic permafrost zone; most of the area around the community has ground temperatures above 0°C and no permafrost. Where it is present, permafrost is only a few meters thick. Yellowknife is in the discontinuous permafrost zone; more than half of the area has permafrost and its thickness is greater than at Teslin, but still varies considerably. Permafrost is continuous at Eureka and several hundred meters thick. There, local variation in ground temperature typically affects permafrost thickness, but not its presence. (Figure: A. Lewkowicz)

permafrost zone

A geographical area where permafrost is estimated to be present beneath a certain proportion of the ground surface.

Did you know…?
There are four main permafrost zones, defined by the estimated percentage of the land surface underlain by permafrost: continuous (90-100%), discontinuous (50-90%), sporadic (10-50%) and isolated patches (less than 10%).



Map of permafrost zones in the Northern Hemisphere and the locations of permafrost monitoring boreholes and active-layer thickness measurements contributing to the Global Terrestrial Network for Permafrost. Source: https://gtnp.arcticportal.org/images/Pictures/Maps/GTN-P_map_permafrostzones_Arctic.jpg (Figure: B. Biskaborn)

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pingo

A dome-shaped or conical hill formed by the growth of an ice core within permafrost.

Did you know…?
The term pingo, which has been adopted worldwide, is a regional Inuvialuktun word for these features in the Mackenzie Delta Region, Canada.



Ibyuk pingo near Tuktoyaktuk, NWT, is probably the most-photographed of these features in the world. It grew as the permafrost aggraded in a drained lake basin and is known as a closed-system pingo. (Photo: V. Roujanski)



A pingo in the Brooks Range, Alaska (USA). This is known as an open-system pingo because the pressures to raise it up came from groundwater in the surrounding mountains. (Photo: A. Lewkowicz)

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pore ice

Ice formed when water freezes in the pore spaces of soil or rock.

Did you know…?
Pore ice may be visible without a magnifying glass in frozen coarse-grained sands and gravels. It is invisible in fine-grained silts and clays because their pore spaces are so small.



Pore ice cementing a sandy gravel core from the Hudson Bay Lowlands, Manitoba. (Photo: P. Roy-Léveillée)



Pore ice in very coarse-grained permafrost in the Andes, Chile. (Photo: L. Arenson)

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radiator

The part of a thermosyphon that extends above the ground and transfers heat into the air.

Did you know…?
You can tell if a thermosyphon is working by pointing a thermal imaging camera at its radiator (also known as a condenser) in the winter. The radiator should appear bright in an image, showing that it's warmer than its surroundings.





Radiators on thermosyphons at the hospital in Inuvik, NWT (left), and at the Ekati diamond mine, NWT (right). The fins create a large surface area that helps transmit heat into the air in winter. (Photos: A. Lewkowicz)

(Below right): Thermal image of radiators on thermopiles beneath the RCMP building in Inuvik, NWT. The radiator temperature is -13.3°C while the surroundings are much colder. This shows that the system is working to extract heat from the permafrost and transfer it into the air. (Photo: J. Panagapko)





(Left): Radiators on thermosyphons within the vertical support members of the Trans-Alaska oil pipeline, Dalton Highway, Alaska (USA). The role of the thermosyphons is to prevent additional heat being conducted into the permafrost by the steel tubes. The pipeline, which was built in the 1970s, was the first project to use thermosyphons extensively to prevent permafrost thaw. (Photo: A. Lewkowicz)

relict permafrost

Permafrost that persists in areas where it cannot form today because the environment has warmed.

Did you know…?
Some relict permafrost formed only a few hundred years ago when the climate was cooler in the Northern Hemisphere.



Relict permafrost in a mid-elevation valley south of Coal Lake, near Whitehorse, Yukon. The ice-rich mounds in the valley floor mainly consist of frozen former lake-bottom deposits that were heaved during permafrost formation. Measurements in newly exposed lake floors, however, show that they do not freeze deeply enough under the current climate to form permafrost. This demonstrates that the permafrost in the mounds is relict and that once it thaws, it cannot re-develop. (Photo: A. Lewkowicz)

retrogressive thaw slump

A bowl-shaped landslide in ice-rich permafrost that enlarges each summer as exposed ground ice melts and the headwall collapses.

Did you know…?
These thermokarst landforms have become more common in recent years as the climate has warmed. The discharge of sediment and dissolved salts from the largest retrogressive thaw slumps (called mega-slumps) can affect entire valleys.



Two retrogressive thaw slumps in the Ibex Valley, near Whitehorse, Yukon. The ice-rich headwall of the larger slump retrogressed until a realignment of the Alaska Highway was needed to prevent it from being undermined. (Photo: A. Lewkowicz



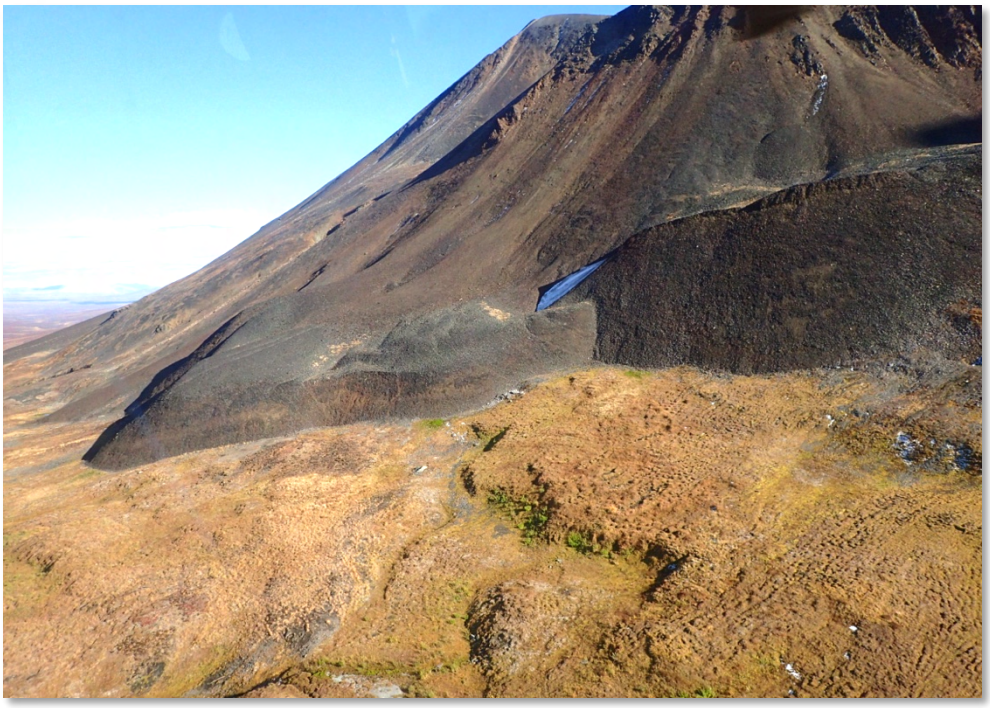
A mega-slump thawing relict glacier ice on Gwich'in Lands of the Richardson Plateau, NWT. This disturbance is one of the world's most rapidly growing thaw slumps, with a headwall about 45 m high and a fill volume exceeding 5 million m^3. It generates enormous volumes of water and mud that flow downstream and have major implications for water quality, ecosystems and traditional use. Note the helicopter for scale (bottom right). (Photo: J. van der Sluijs, NWT Geological Survey)

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rock glacier

A thick, tongue-shaped mass of rock and finer material that contains perennial ice within its core and moves slowly down a mountain slope.

Did you know…?
The distribution of moving rock glaciers has been used to help map and predict where permafrost is present in many mountain ranges, including the European Alps and the Andes.



A rock glacier in the Selwyn Mountains on the border between Yukon and NWT. (Photo: V. Roujanski)



The terminus of a rock glacier adjacent to the Dalton Highway near Atigun Pass, Alaska (USA). The unvegetated, steep front indicates that it is actively moving. (Photo: A. Lewkowicz)

saline permafrost

Permafrost with a high concentration of salts due to natural factors or pollution.

Did you know…?
Water in saline permafrost may not freeze until its temperature falls well below 0°C. As a result, saline permafrost near 0°C can behave like unfrozen soil in terms of its strength to support buildings or its ability to store contaminants.



Geotechnical investigations in saline permafrost, eastern coast of the Yamal Peninsula, Western Siberia (Russia). (Photo: V. Roujanski)



A bridge under construction in saline permafrost, eastern coast of the Yamal Peninsula, Western Siberia (Russia). The high salt content of saline permafrost can mean that it contains only water (not ice), even at temperatures below 0°C. This affects its physical properties, such as its strength to support a structure like a bridge. (Photo: V. Roujanski)

seasonally frozen ground

Ground that is frozen for more than 15 days per year but thaws annually.

Did you know…?
Global climate change over the past few decades has caused the average thickness of seasonally frozen ground to decrease in some non-permafrost areas.



These hummocks, known as thufur, are produced by seasonal freezing of the ground in the coastal parts of Iceland. If they are flattened, seasonal freezing can cause them to redevelop in only 20 years. They do not form where permafrost is present on the island. (Photo: A. Lewkowicz)

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solifluction

The slow, downslope movement of the surface layer of the ground resulting from freezing and thawing of the soil.

Did you know…?
Solifluction movements of a few millimeters to a few centimeters per year can occur on both permafrost and non-permafrost slopes. The process creates characteristic features, including lobes, sheets, steps and stripes.



A solifluction lobe at Outpost Mountain, Kluane, Yukon. Numerous lobes are present on the same slope which is underlain by permafrost. (Photo: A. Lewkowicz)



These wooden piles at Longyearbyen, Svalbard (Norway) have been affected by solifluction. They were upright when installed in the ground, but after many years (and demolition of the building), solifluction has tilted them and moved them downslope. (Photo: A. Lewkowicz)

space frame foundation

A network of metal tubes joined together to support a building constructed on permafrost.

Did you know…?
Space frame foundations are made up of many connected triangles which are particularly stable shapes. This type of foundation can be adjusted easily to keep a building level even if the ground heaves or settles.



A space frame foundation under a house in Old Crow, Yukon. (Photo: A. Lewkowicz)



A space frame foundation before construction of a building, Inuvik, NWT. If the ground surface settles or heaves, threaded supports beneath the junctions of the frame can be adjusted to keep the building level. (Photo: A. Lewkowicz)

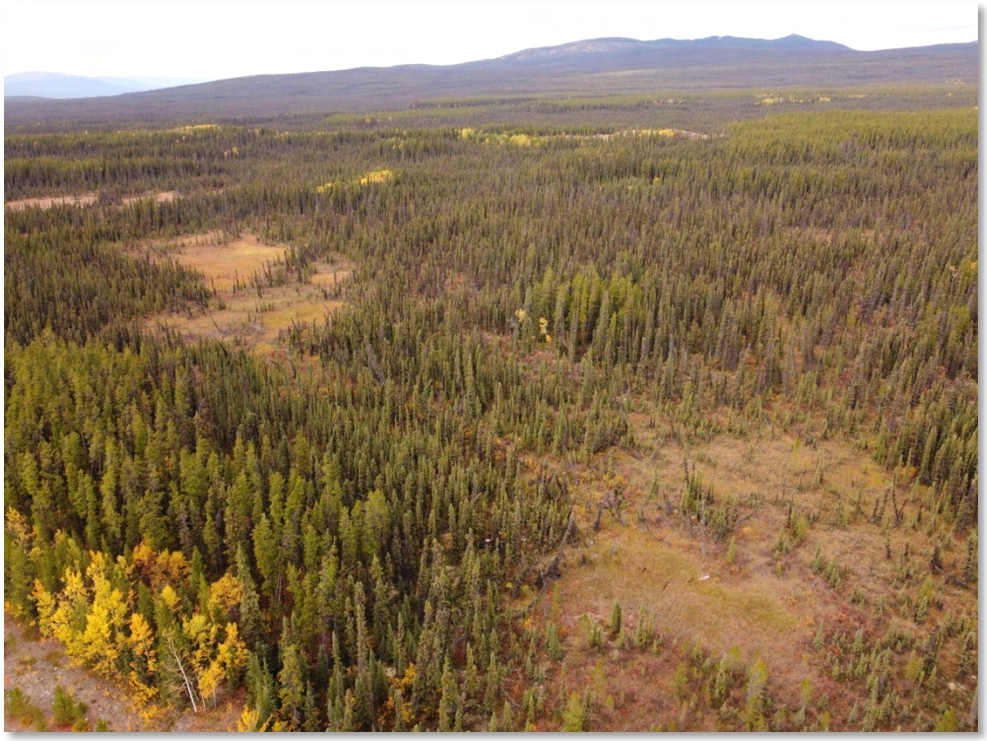
sporadic permafrost zone

A geographical area where disconnected bodies of permafrost are estimated to be present beneath more than 10% and less than half of the land surface.

Did you know…?
Most of the sporadic permafrost zone in North America is covered by boreal forest. (A map of all the permafrost zones is shown on page 74).



Part of the sporadic permafrost zone, Steen River, northern Alberta. The 1.2 m long frost probe was pushed into the ground until it encountered the frost table at a depth of about 60 cm. Since the probing was done at the end of summer, this indicates that permafrost is present at the site. (Photo: A. Lewkowicz)



Part of the sporadic permafrost zone near Teslin, Yukon. The bog in the foreground of the photo does not have permafrost, but it is 5-7 m thick in the treed area immediately adjacent to it. (Photo: A. Lewkowicz)

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suprapermafrost groundwater

Water that occurs in unfrozen parts of the ground above permafrost.

Did you know…?
Suprapermafrost water that emerges onto the ground in the autumn and winter can freeze to form thick layers of aufeis (also known as icings; see page 7), resulting in problems on some highways.



Suprapermafrost groundwater visible in a pit in the active layer, southern Banks Island, NWT. (Photo: A. Lewkowicz)



Suprapermafrost groundwater emerging and freezing in the headwall of a retrogressive thaw slump in the Ibex Valley near Whitehorse, Yukon. (Photo: A. Lewkowicz)

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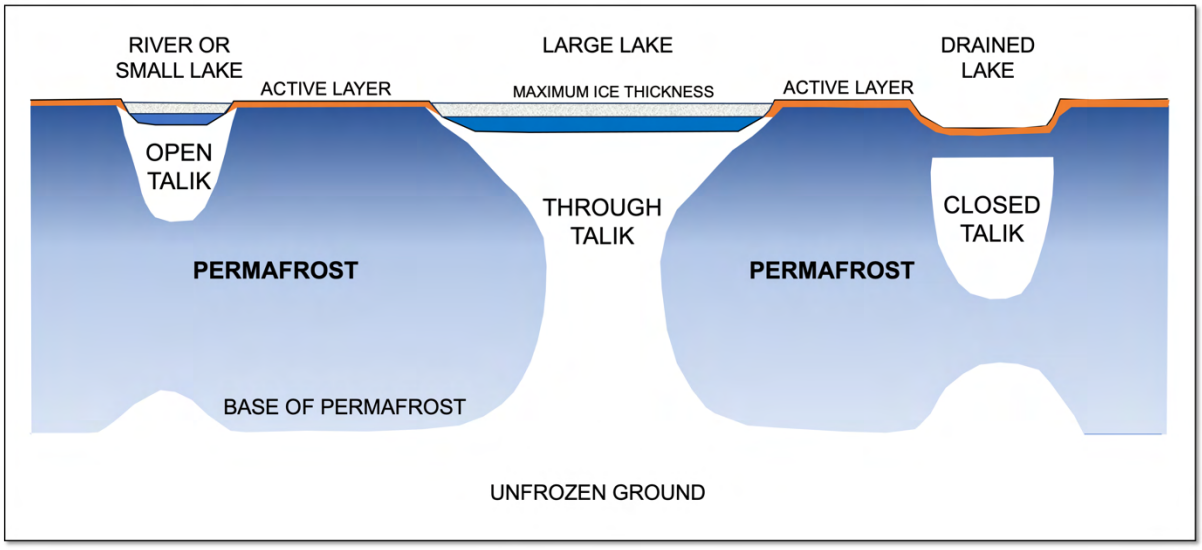
talik

A part of the ground at a site with permafrost that remains unfrozen throughout the year.

Did you know…?
Taliks are present beneath lakes and rivers, even in areas of continuous permafrost, providing the water is deep enough that it does not freeze to the bottom in winter. They can also develop between the base of the active layer and the permafrost table as permafrost degrades.



The Mackenzie Delta, NWT, is made up of numerous lakes and channels. Permafrost is present beneath almost all the exposed land. In contrast, taliks exist beneath all the lakes and river channels that are deeper than about 3-4 m and therefore do not freeze to the bottom in winter. (Photo: A. Lewkowicz)



Three kinds of taliks due to the effects of ground warming by rivers and lakes are shown on this diagram. Ice cover typically reaches a maximum thickness of 2-3 m on northern rivers and lakes. If water depths are greater than this, a layer of water will be present year-round above the lake-bed or river-bed. The sediment immediately beneath will also be unfrozen year-round, and this body of unfrozen ground is called a talik. An open talik (left) is connected to the surface but permafrost is present around and beneath it. A through talik (centre) penetrates all the way through the permafrost and is produced by a large water body. A closed talik (right) can develop if the original thermal disturbance is removed, such as when a lake drains. A closed-system pingo may grow in a drained lake basin as the talik slowly freezes (see page 75). (Figure: A. Lewkowicz)

thaw depth

The distance from the ground surface to the top of frozen ground.

Did you know…?
The thaw depth at a permafrost site increases throughout the summer, typically reaching a maximum at the start of autumn when, unless a talik is present, it will be the same as the active-layer thickness.



A trench excavated through the front of an active layer detachment failure on Ellesmere Island, Nunavut. Thaw depths along the section varied from 50-75 cm in July. They would be expected to increase by a further 10-20 cm before freezeback begins in late August (see page 50). (Photo: A. Lewkowicz)



These blocks of soil slid across the floor of an active layer detachment failure on Ellesmere Island, Nunavut, the year before the photo was taken. The height of the blocks (60-70 cm) is roughly equal to the depth of thaw when the landslide occurred in August. (Photo: A. Lewkowicz)

thaw-sensitive permafrost

Permafrost containing enough ice that it would lose strength and settle significantly if it were to thaw.

Did you know…?
Buildings on thaw-sensitive permafrost are designed to maintain the frozen ground beneath them.



A building under construction on thaw-sensitive permafrost at Dawson, Yukon. The wooden blocks supporting the building are called cribbing. They prevent heat from the building from entering the ground and causing the permafrost to thaw. They can be adjusted by adding shims if this proves necessary to keep the building level. (Photo: A. Lewkowicz)



Buildings on Third Avenue in Dawson, Yukon, that were constructed in 1901, a few years after the end of the Klondike Gold Rush. Heat from the buildings when they were in use affected the thaw-sensitive permafrost and led to their settling. They are preserved (but not restored) by Parks Canada. (Photo: A. Lewkowicz)

thaw settlement

Settling of the ground surface, buildings or infrastructure caused by melt of ice within the soil.

Did you know…?
Significant thaw settlement can make buildings and infrastructure unusable, partly because the uneven distribution of ice in the ground means that settling is also uneven.



Thaw settlement of a building (now demolished) at Nain, Nunatsiavut, Newfoundland and Labrador. The building was used as a corner store for many years, despite the tilting caused by greater thaw settlement at one end than the other. (Photo: A. Lewkowicz)





(Left): Thaw settlement has caused the side of the Dempster Highway to crack and become unstable in the Richardson Mountains, NWT. (Photo: H.B. O'Neill).
(Above right): Thaw settlement beneath the Alaska Highway north of Burwash Landing, Yukon. The hollow in the highway has been resurfaced, but ongoing maintenance will be needed. (Photo: A. Lewkowicz).

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thaw slumping

A landsliding process involving the melting of ground ice and the collapse of thawed sediments.

Did you know…?
Thaw slumping is a thermokarst process that is linked to the expansion of retrogressive thaw slumps and thermokarst lakes, as well as coastal erosion.



Thaw slumping involving the melt of massive ice in the face of a retrogressive thaw slump, and the collapse of the overlying sediment at Peninsula Point, Mackenzie Delta, NWT. (Photo: A. Lewkowicz)



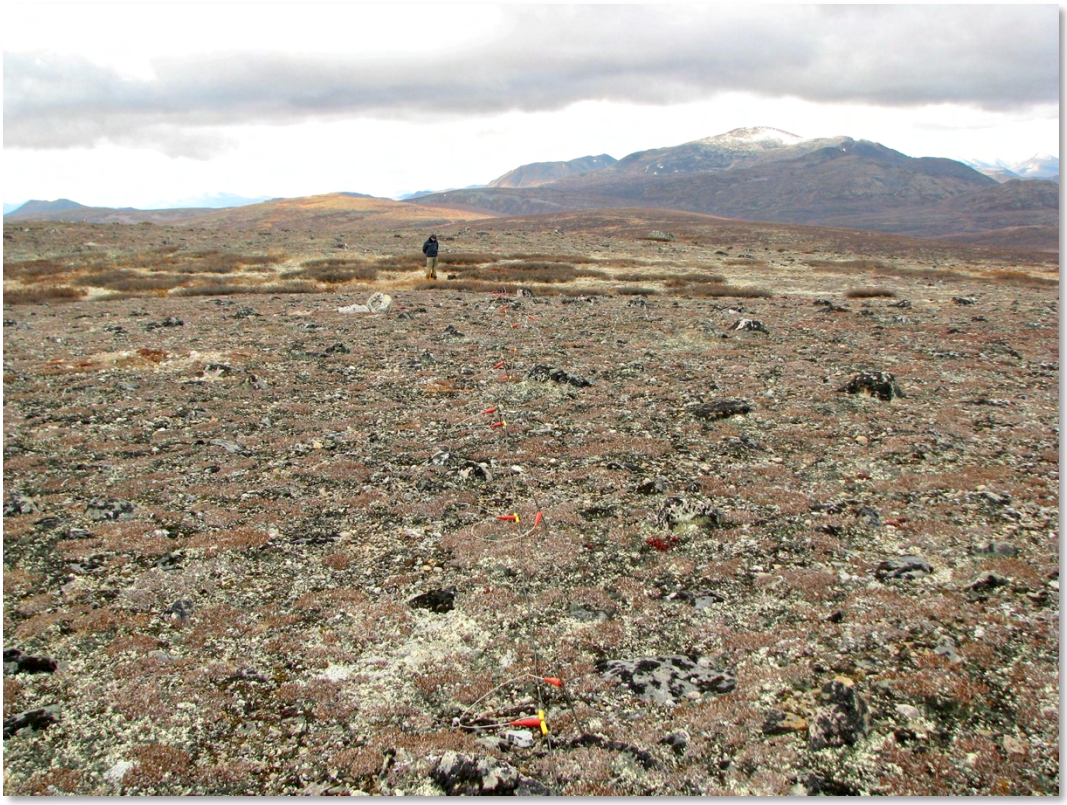


(Left): Thaw slumping on the edge of a lake in the Old Crow Flats, Yukon (Photo: P. Roy-Léveillée) and (above right) along a riverbank on Svalbard (Norway) (Photo: H.B. O'Neill). Thaw slumping in these environments involves thaw of permafrost and erosion by waves and currents.

thaw-stable ground

Ground that contains little or no ice when frozen and that remains strong if it thaws.

Did you know…?
Thaw-stable ground is typically composed of rock, sands or gravels.



Thaw-stable ground on the summit of Mount McIntyre, near Whitehorse, Yukon. Permafrost exists in the weathered bedrock to a depth of more than 30 m, but its thermal behaviour shows that there is little or no ice present. (Photo: A. Lewkowicz)



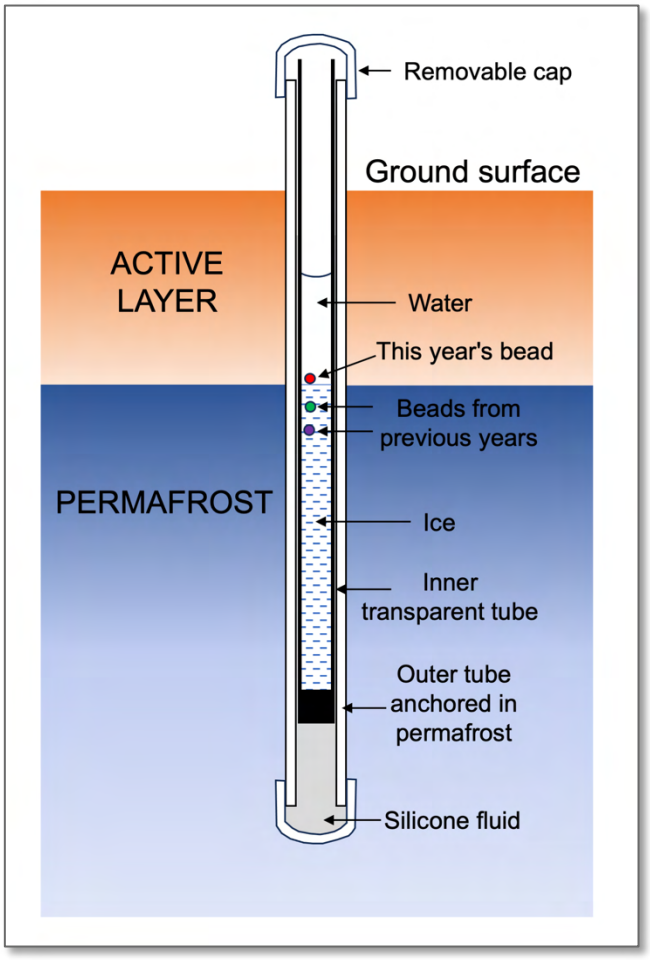


(Left): A deep pit excavated in thaw-stable sands and gravels in the North Slave Region, NWT (Photo: N. Brown). (Above): Buildings constructed directly on thaw-stable bedrock at the Italian research station, Terra Nova Bay, Antarctica (Photo: A. Lewkowicz).

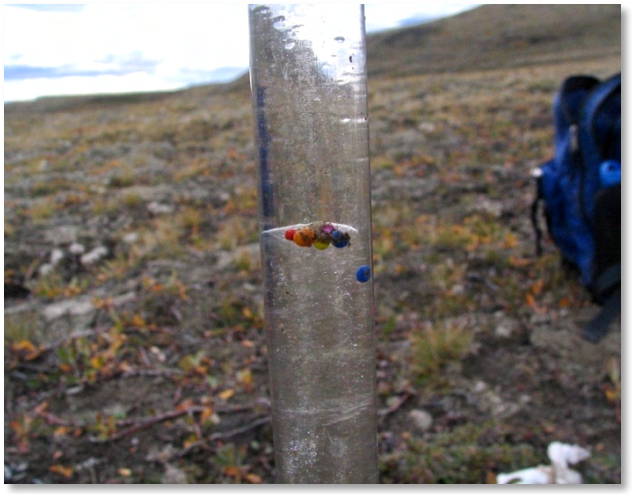
thaw tube

A device installed in the ground to monitor the annual thickness of the active layer.

Did you know…?
One type of thaw tube is filled with water and inserted vertically into a hole drilled into the permafrost. A coloured bead placed in the tube descends to the boundary between water and ice, and at the end of summer, it refreezes and marks the base of the active layer for that year.







(Above left): A diagram of a thaw tube showing the inner transparent tube within an outer tube anchored in the permafrost. The boundary between the water in the upper part of the tube and ice in the lower part, marks the frost table. A bead dropped in the water settles to this boundary and descends further if additional thaw occurs after the site visit. The final position of the bead is measured the following year. (Above right): A thaw tube at Hot Weather Creek, Ellesmere Island, Nunavut after it was removed from the outer tube for inspection. (Lower right): The same tube during a warm summer. Nearly all the beads were at the same level in early August and the following year when they were checked they had all descended a further 5 cm. This shows that this was the greatest thaw depth since the tube had been installed. (Figure and photos: A. Lewkowicz)

thermal erosion

The erosion of frozen soils by moving water.

Did you know…?
Thermal erosion both melts ground ice and removes the thawed sediment. It creates tunnels and deep channels on slopes, as well as cavities beneath frozen coastal cliffs, lakeshores and riverbanks, that may suddenly collapse.



A tunnel created by thermal erosion within an ice wedge, Dempster Highway, Yukon. (Photo: A. Lewkowicz)



A long gully created by thermal erosion on Melville Island, Nunavut. The gully was started in 1970 when a bulldozer travelled across the ground in summer, compressing the surface, deepening the active layer, concentrating water flow, and causing the erosion of ice-rich permafrost. (Photo: A. Lewkowicz)

thermokarst

Processes linked to the thaw of ice-rich permafrost, including thaw settlement, thaw slumping, and thermal erosion, and the impact of these processes on the landscape.

Did you know…?
Thermokarst can be started by widespread climate warming or by localized disturbances, such as poor construction practices or forest and tundra fires.

(Right): Thermokarst due to the thaw settlement and collapse of palsas and peat plateaus in the Hudson Bay lowlands near Peawanuck, Ontario. The bright green mosses identify the parts of the landforms where collapse has occurred recently. (Photo: A. Kirkwood)





(Left): Thermokarst due to thaw settlement and thaw pond development over ice wedges creating a pitted surface, Aulavik National Park, Banks Island, NWT. (Photo: A. Lewkowicz)

(Right): Two of the hundreds of active retrogressive thaw slumps in Aulavik National Park, Banks Island, NWT. They are examples of thermokarst in the form of thaw slumping. (Photo: A. Lewkowicz)





(Left): Thermal erosion taking place in a small stream near Toolik Lake, Alaska (USA). The running water creates tunnels and gullies by a combination of melting ice and eroding sediment. (Photo: A. Lewkowicz)

thermokarst lake

A lake formed or affected by the thaw of ice-rich permafrost.

Did you know…?
Thermokarst lakes can expand as their banks thaw and collapse by thaw slumping.



Thermokarst lakes in the Old Crow Flats, Yukon. (Photo: P. Roy-Léveillée)



Thermokarst lakes on a river terrace in southern Banks Island, NWT. The shapes of the shorelines indicate that some of these lakes have expanded and conjoined with a neighbouring water body. (Photo: A. Lewkowicz)

thermosyphon

A piping system, with one end buried in the permafrost and the other extending above ground (see page 77), that transfers heat from the ground to the air in winter without needing a power source.

Did you know…?
Thermosyphons are often used to prevent the ground from thawing beneath buildings, but the technology was originally developed to cool space capsules re-entering the atmosphere.



Thermosyphons installed alongside the Alaska Highway at Dry Creek, Yukon. Massive ice is present at this location. The thermosyphons are to ensure that the permafrost remains frozen. (Photo: A. Lewkowicz)

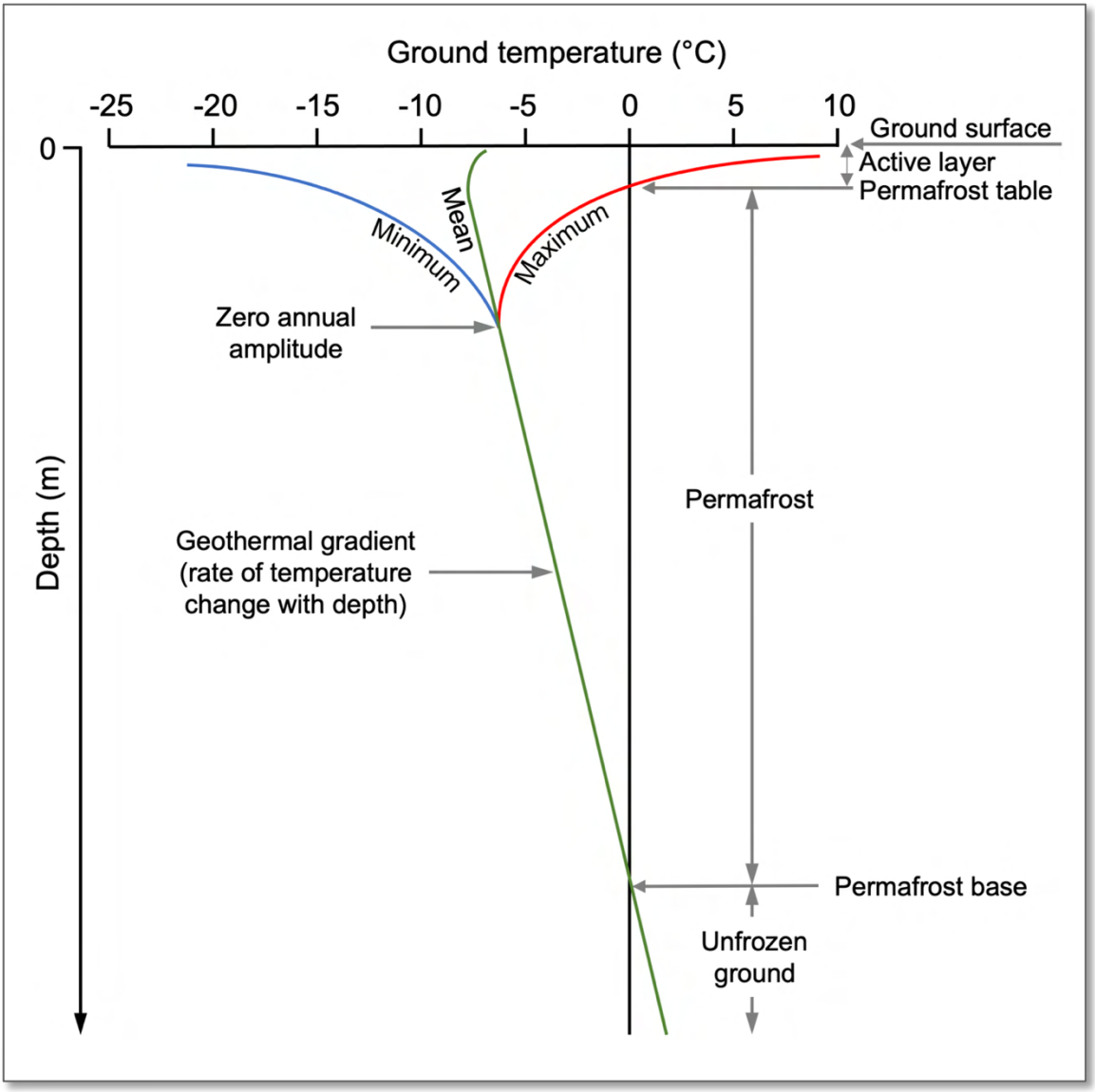


Thermosyphons being used to cool the foundation of a building in Salluit, Nunavik, Québec. The building includes a garage so it cannot be elevated on piles. The thermosyphons extract the additional heat conducted from the building into the ground and prevent permafrost thaw. (Photo: P. Roy-Léveillée)

trumpet curve

A line graph showing the year's maximum and minimum ground temperatures (and often the average ground temperature) against depth.

Did you know…?
A trumpet curve is a simple way to summarize ground temperatures at a permafrost site. The maximum and minimum lines meet at depths of 2-20 m, giving the appearance of the bell of a trumpet.



A trumpet curve diagram showing the ground thermal regime generalized for a cold permafrost site. Temperatures near the ground surface vary through the year, dropping well below 0°C in winter as the active layer freezes, and rising above 0°C in summer when it thaws. The depth where the maximum temperature line (red) crosses 0°C is the permafrost table. The active layer thickness is approximately equal to the distance between this depth and the ground surface. Seasonal temperature variations decrease deeper in the ground until they cease altogether at the depth of zero annual amplitude. Below this, the ground warms according to the geothermal gradient (see page 38) until the temperature exceeds 0°C, which represents the base of permafrost. Perennially unfrozen ground is present at still greater depths. (Figure: A. Lewkowicz)

utilidor

An insulated box or large conduit, supported above ground, that encloses a network of piping for water supply, sewage and other services in a community constructed on thaw-sensitive permafrost.

Did you know…?
Utilidors permit the supply of running water year-round without the pipes thawing the permafrost.



Utilidors connecting residences in Inuvik, NWT. Utilidors are supported on piles, like the buildings themselves, to prevent additional heat from entering the ground and thawing the permafrost. (Photo: A. Lewkowicz)



Utilidors at Longyearbyen, Svalbard (Norway). (Photo: A. Lewkowicz)

yedoma

Very ice-rich permafrost, containing large ice wedges, found in parts of Siberia, Alaska and Yukon that were too dry to be covered by glaciers during the last Ice Age.

Did you know…?
Yedoma, also known as "muck" in Yukon, has preserved many animal bones and even the bodies of extinct animals, such as the woolly mammoth, Yukon horse, and steppe bison.



A yedoma deposit in Quartz Creek, Klondike, near Dawson, Yukon. Yedoma is only found at sites that were not covered by ice sheets during the last glaciation. These are extensive in Siberia and Alaska but limited in Canada to parts of the Yukon. The oldest known permafrost in Canada is in these areas. It is more than 700 thousand years old. (Photo: D. Froese)





Yedoma deposits may contain the bones of Ice Age animals. (Left): A mammoth tusk found during gravel extraction on the Yamal Peninsula, Western Siberia (Russia). (Right): Numerous animal bones found during gold placer mining in the Klondike, near Dawson, Yukon. (Photos: A. Lewkowicz)

Acknowledgments

We thank the many Indigenous Peoples of northern Canada (First Nations, Inuit and Métis) and of other countries, for allowing us to access their lands and traditional territories to document permafrost features and take the photographs that illustrate this dictionary. We acknowledge the funding agencies and other organizations that supported fieldwork carried out by members of PTAG over many years, especially NSERC, the Polar Continental Shelf Project and the Geological Survey of Canada. We thank those colleagues who supplied photos or figures that enhance the range of examples or agreed to be featured in the photos selected. Finally, we appreciate the support of the board members of the Canadian Permafrost Association who encouraged us throughout the last three years.

Suggestions for future editions

Recommendations for changes to existing entries or suggestions for additional terms can be sent by email to Antoni Lewkowicz: alewkowi@uottawa.ca.

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Back cover photo: reticulate and solid cryostructures exposed in a retrogressive thaw slump near Eureka, Ellesmere Island, Nunavut. (Photo: A. Lewkowicz)

