The Earth's Dynamic Cryosphere and the Earth System

Permafrost and Periglacial Environments

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Permafrost or perennially frozen ground is defined as Earth material that remains at or below 0 degree Celsius (°C) for at least 2 consecutive years. In the Northern Hemisphere, permafrost regions occupy approximately 24 percent of the exposed land area, principally at high latitudes (areas beneath ice sheets and ice caps are not included in this estimate) (fig. 1). Permafrost occurs in lower-latitude mountainous regions and plateaus of both hemispheres and is commonly referred to as mountain (or alpine) permafrost and plateau permafrost, respectively. Permafrost underlies essentially all ice-free areas of the Antarctic continent. Large areas of subsea permafrost are found beneath the continental shelves bordering the Arctic Ocean, especially along the Siberian shelves. Periglacial conditions, processes, and landforms are associated with cold, nonglacial environments.

Because permafrost is not present everywhere in permafrost regions, the actual land area underlain by permafrost ranges from 12.2 to 16.9×10^6 square kilometers (km^2), or from 13 to 18 percent of the exposed land area. The regions underlain by permafrost comprise about 60 percent of present-day Russia, 50 percent of Canada, 23 percent of China, and 90 percent of Alaska. Permafrost ranges from very cold (temperatures of less than -10° C) and very thick (as much as 1,400 meters (m)) in the Arctic, to warm (within 1 or 2 degrees below 0°C) and thin (less than 0.1 m thick) in the subarctic and boreal regions. During glacial intervals, permafrost attained thicknesses greater than 1,500 m in unglaciated parts of Siberia and in northwestern North America. The colder and deeper permafrost is likely to have survived several interglacials. The permafrost temperature regime (at depths of 10 to 200 m) is a sensitive indicator of decade-to-century climatic variability and of long-term changes in the surface energy balance.

A key characteristic of permafrost is the presence of ground ice that occurs in various forms, including large masses of relatively pure ice or ground ice (fig. 2).

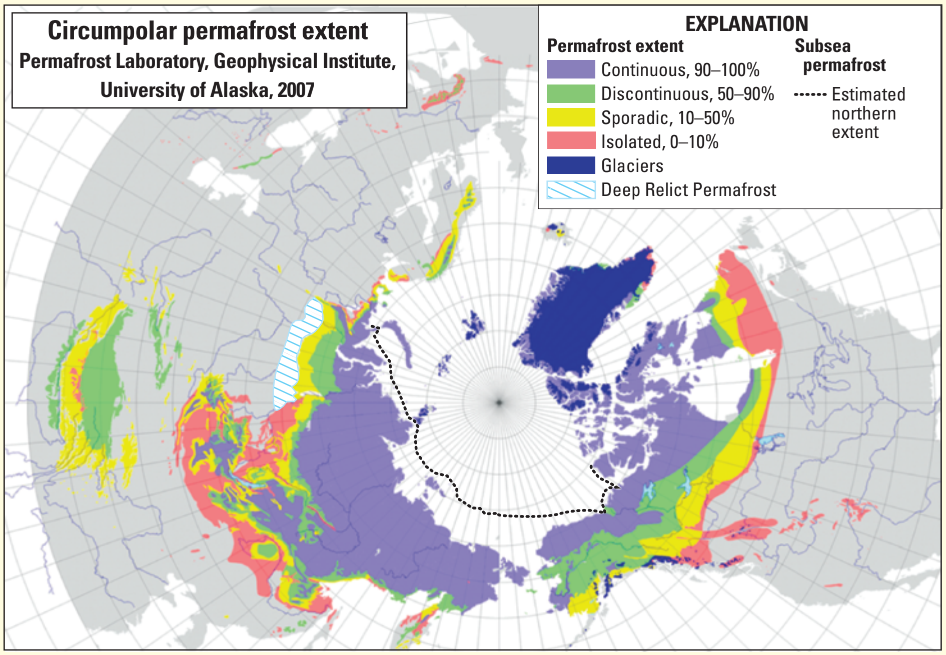

Figure 1. Map showing areal distribution of permafrost regions in the Northern Hemisphere. Prepared in 2007 by the Permafrost Laboratory, Geophysical Institute, University of Alaska Fairbanks. Map derived from the electronic version of the "Circum-Arctic Map of Permafrost and Ground-Ice Conditions" (Brown and others, 1997, http://nsidc.org/fgdc/)

Figure 2. Ground photograph of massive ice wedge and thawing of permafrost along the bank of the Kolyma River, Siberia, Russia. Photograph provided by Vladimir Romanovsky, Geophysical Institute, University of Alaska Fairbanks.

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Most ground ice is found in the upper tens of meters of the Earth's surface and occurs in three main forms: pore ice, ice lenses and ice veins, and larger bodies of more or less pure ice. Melting of ground ice gives rise to subsidence and development of periglacial features and intensifies slope failures. Thermokarst terrain forms wherever ice-rich permafrost thaws and the ground surface subsides. In lowland areas, large-scale thawing of permafrost results in lakes and wetlands. In mountains, rock glaciers are characteristic large-scale flow features consisting of ice-rich, frozen material. Other forms of periglacial features or patterned ground (fig. 3) are common throughout the permafrost regions. Inactive or relict features are indicative of former cold periods.

Northern peatlands and frozen, organic-rich sediments contain large amounts of carbon. Deep, perennially frozen sediments, both onshore and beneath the Arctic shelves, contain methane hydrates. These carbon-rich deposits are potential sources of greenhouse gases, especially methane (CH_4), if climate warming continues.

Special precautions and engineering designs are required for constructing buildings and pipelines (fig. 4) on permafrost, especially on ice-rich terrain. Measures to prevent thawing of the underlying frozen ground include elevating buildings and pipelines on piles, placing insulation on the ground surface, and using cooling systems. More aggressive measures require removing ice-rich soil and replacing it with material that is not susceptible to frost or allowing the excess ice to melt before construction begins. Long-term measurements of permafrost temperatures and active-layer thicknesses are required in order to identify the scale of spatial variation, establish trends, and validate models.

Figure 3. Oblique aerial photograph of ice-wedge polygonal ground on the Alaska Arctic coastal plain. Photograph by Robert I. Lewellen, Lewellen Arctic Research, Inc., Palmer, Alaska.

Figure 4. Ground photograph of the Trans-Alaska Pipeline and parallel access road constructed on ice-rich permafrost. The pipeline is constructed on elevated thermopiles to dissipate heat and prevent thawing of permafrost.

URL Addresses:

http://gtnp.org/

http://ipa.arcticportal.org/

http://www.udel.edu/Geography/calm/

http://nsidc.org/fgdc/

http://www.permafrostwatch.org

http://nsidc.org/data/g02190.html

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