U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY
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INTERNATIONAL PERMAFROST ASSOCIATION

CIRCUM-ARCTIC MAP OF PERMAFROST AND GROUND ICE CONDITIONS

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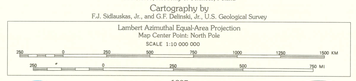
Lambert Azimuthal Equal-Area Projection
Map Center Point: North Pole
SCALE 1:10 000 000



1997

Map Production by the
UNITED STATES GEOLOGICAL SURVEY
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CIRCUM-PACIFIC MAP PROJECT
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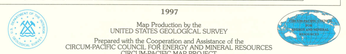
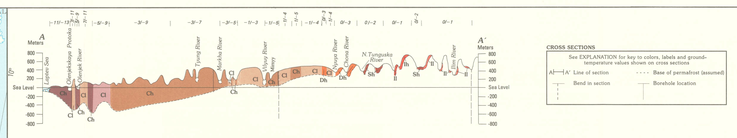


Base by U.S. Geological Survey, 1995



CROSS SECTIONS

See EXPLANATION for key to colors, labels and ground-temperature values shown on cross sections

A1——A' Line of section
Bend in section
Base of permafrost (assumed)
Borehole location

PERMAFROST AND GROUND ICE

Extent of Permafrost (percent of area)	Ground-Ice Content (visible ice in the upper 10–20m of the ground; percent volume)				
	Lowlands, highlands, and intra- and intermontane depressions characterized by thick overburden cover (>5–10 m)			Mountains, highlands, ridges, and plateaus characterized by thin overburden cover (<5–10 m) and exposed bedrock.	
	High (>20%)	Medium (10–20%)	Low (0–10%)	High to medium (>10%)	Low (0–10%)
Continuous (90–100%)	Ch	Cm	Cl	Ch	Cl
Discontinuous (50–90%)	Dh	Dm	Dl	Dh	Dl
Sporadic (10–50%)	Sh	Sm	Sl	Sh	Sl
Isolated patches (0–10%)	h	m	l	h	l

Variations in the extent of permafrost are shown by the different colors; variations in the amount of ground ice are shown by the different intensities of color and, for the large bodies of ground ice, by symbols. Letter codes assist in determining to which basic permafrost and ground-ice class any particular unit belongs. The symbols for the large bodies of ground ice contribute to the definition of the map units. For example, "Ch" = "extensive with underlain by continuous permafrost with high ice content, and characterized by sparse ice wedges and abundant massive ice.

OTHER FORMS OF PERMAFROST

Deep relict permafrost (where known)

χ Cryopegs within the upper 10–20 m of the ground, (shown only for Russia)

GROUND-ICE BODIES — General distribution of known occurrences of large bodies of ground ice

▽ ▼ Ice wedges (sparse, abundant)

Massive ice bodies (sparse, abundant)

Pingo ice and other perennial frost mound ice (sparse, abundant)

TEMPERATURE AND THICKNESS OF PERMAFROST

–10.7 Typical mean annual ground temperature at the base of the layer of annual temperature fluctuations (°C)

–3/–7 Range of typical mean annual ground temperature at the base of the layer of annual temperature fluctuations (°C). On the map, ranges are shown for both units and subunits; on cross sections, ranges are shown for selected areas and represent end-member values; values are shown at the tops of the profiles

≈16 Measured or interpolated thickness (m)

■ (787) Extrapolated or calculated thickness (m)

150/ 400 Depth to the top (numerator) and bottom (denominator) of relict permafrost (m)

SURFACE ICE

Ice caps and glaciers

Icings (shown only for Russia)

BOUNDARIES

Boundaries of permafrost and ground-ice units; long dashed where gradational or estimated

Southern limit of deep relict permafrost

Northern limit of the area within which subsea permafrost is known or presumed to occur

Lithological and mean annual ground temperature boundaries for morphogenetic and natural geosystems subunits

Northern limit of trees

MORPHOGENETIC AND NATURAL GEOSYSTEMS

Morphogenetic and natural geosystem types (see Tables A and B for explanation)

LITHOLOGICAL CLASSES — Dominant rock types within the upper 10-20 m of the ground (shown only for Russia)

Unbuffed:
c Clay and silt
d Coarse clastic deposits (debris)
l Loess and eolian-sand deposits
p Peat
s Sand

Littlified:
k Soluble rocks (limestone, dolomite, gypsum)
r Insoluble rocks

Note: Combinations of letters indicate mixed composition of unlithified rocks (pe), listed in order of predominance, or layered composition of unlithified over lithified rocks (c/k); Saline ground is indicated by a bar above the letter (l̄).

COMPILATION METHODS AND DEFINITIONS

This map summarizes current knowledge of the distribution and character of permafrost and ground ice in the Northern Hemisphere, using a physiographic approach for the delineation of the map units. The map portrays the relationships between the areal extent of permafrost and ground ice is presented in a reasonably consistent manner for the continental land masses, including areas of mountain and plateau permafrost. It should be emphasized, however, that the present map has been compiled from source maps that are based on widely varying amounts of field and laboratory data sources, with varying densities of data and different approaches to data integration. The present map reflects these differences in approach. Map units in the major regions of Alaska, Canada, China, and Russia are defined differently, and the permafrost and ground-ice characteristics of these regions are shown on separate, detailed maps. Where necessary, map units have been adjusted adjacent to international land boundaries.

The mapping strategy followed was to use existing physiographic or landscape maps in each of the three major national areas (Alaska, Canada, and Russia) as a basis for defining and delineating the permafrost map units. In preparing this map no attempt was made to conduct new field studies, and every attempt was made to use all readily available published and unpublished information.

The legend in Alaska are based on the 1965 map "Physiographic Divisions of Alaska" (Wahrhaftig, 1965) and contains additional information that has become available since publication of the 1:2,500,000-scale map of Alaska (Ferrians, 1965). The Canadian compilation utilizes the 1973 map "Physiographic Regions of Canada" (1:5,000,000), and the permafrost characteristics of the information presented on the new permafrost and ground-ice map prepared for the National Atlas of Canada, 5th edition (Heginbottom and Radburn, 1992). The compilation of permafrost in China was derived from the zonations or landscape approach described by Melnikov (1988); in which natural geosystems are delineated according to common relief, vegetation, soil and sediments materials, and climate (Table A). Units for Russia and Mongolia are based on the compilation by Ershov and Shi and Mi (1988) and from Sodnom and Nyandag (1990), respectively. Existing information for Nordic countries (Åkerman, 1993), Greenland, and other mountainous regions of Europe (King and Åkerman, 1993) and Asia (Qiu, 1993) was modified and compiled from numerous published and unpublished sources, with the assistance of regional specialists.

Permafrost is defined as a state of the ground, whether soil or rock, that remains at or below a temperature of 0°C for long periods (Permafrost Subcommittee, 1988). The minimum period is two years, but permafrost commonly has existed for centuries or longer in areas. It diminishes in areal extent until, at the southern limit, it occurs as isolated patches under favorable terrain conditions. Areas of high and medium ground ice are known to occur in regions of discontinuous, sporadic, and isolated patches of permafrost as well as beneath some deep lakes and rivers.

Beneath land areas, most permafrost has existed for a long time, and has formed, degraded, and re-formed throughout the Pleistocene. In addition to occurring beneath land areas, it also occurs as extensive bodies of **subsea permafrost** beneath the continental shelves that border the Arctic Ocean (Osterkamp and Harrison, 1985). These are relics of the periods of lower sea level during the glacial maxima of the Quaternary Period, when large areas of continental shelf, beyond the edges of the continental glaciers, were exposed to the intense cold of a full glacial climate. During the interglacials and interstadials, the sea flooded across the shelves and the cold, saline ocean, and the **relict permafrost** of the continental shelves has been preserved. Extensive masses of deep relict permafrost occur at the seaward boundary of permafrost on the Siberian shelves. Permafrost formed during the glacial maxima of the Quaternary Period, but which has subsequently thawed, is known as **thawed permafrost**.

Ground ice occurs in three main forms: as coatings on soil particles and rock fragments and as cements in soils and sedimentary rocks and as unconsolidated deposits (**pure ice**), as thin, lenticular layers and veins of ice (**segregated ice, intrusive ice and reticulate ice**), and as larger bodies of more-or-less pure ice, in the form of **ice wedges**, extensive sheets of **massive ice**, and perennial frost mound cores (**pingo ice**). Much of the ground ice is of segregated origin. Some ground ice bodies are known to result from the burial and preservation of bodies of surface ice, such as snow banks, river icings, and glacier ice.

The permafrost **temperature** and **thickness** values shown on the cross sections are generalized from a variety of measurements or calculations. Not all the boreholes penetrated the full thickness of the permafrost; some thickness values are based on calculation or extrapolation from other geophysical profiles. The mean annual temperature of the permafrost is represented by the temperature of the permafrost at the level of negligible annual change, at approximately 15–20 m depth.

Table A. Complexes of Cryogenic Processes in Different Regions

Geocryological regions (Figure 1)	Permafrost zones*	Morphogenetic groups of natural geosystems (Table B)	Basic complex of cryogenic processes*
Arctic Islands	C	I, II, III	s, k, c
	D	II	s, k, c
European Russia and Ural	C	I	s, k, c
	D	I, II	s, k, c
	I	I, II	s, k, c in depressions only
	S	I, II, III, V	s, k, c in depressions
II Ural	C	I	s, k, c
	D	I, II	s, k, c
	I	I, II	s, k, c in depressions
	S	I, II	s, k, c in depressions
	P	I	s, k, c in tundra in north ridge
	I	II	s, k, c in north ridge
	S	II	s, k, c in north ridge
	P	II	s, k, c in north ridge depressions
	I	II	s, k, c in north ridge depressions
	I, P	III	s, k, c in north ridge
	I	I, II	s, k, c in valleys
	I, P	III	s, k, c in hills tops interfluves
	I	III	s, k, c in hills tops valleys
	I	III	s, k, c in north tops interfluves
	I	III	s, k, c in north tops valleys
III Western Siberia	C	I, II, III	s, k, c in interfluves in valleys
	D	I, II, III	s, k, c in interfluves in valleys
	I	I, II, III	s, k, c in interfluves in valleys
	S	I, II, III	s, k, c in interfluves in valleys
IV East Siberia	C	I, II, III, IV	s, k, c in interfluves in valleys
	D	I, II, III, IV	s, k, c in interfluves in valleys
	I	I, II, III, IV	s, k, c in interfluves in valleys
	S	I, II, III, IV	s, k, c in interfluves in valleys
	P	I, II, III, IV	s, k, c in interfluves in valleys
	I	I, II, III, IV	s, k, c in interfluves in valleys
	P	I, II, III, IV	s, k, c in interfluves in valleys
	I	I, II, III, IV	s, k, c in interfluves in valleys
	I	I, II, III, IV	s, k, c in interfluves in valleys
	I