Permafrost in soils[1]

Henry D. Foth[2]

ABSTRACT

A set of 20 slides demonstrates the major features of permafrost soils, including permafrost table, active layer, patterned ground, solifluction lobes, thermokarst, pingos, and building of engineering structures on permafrost soils. Soils are classified in both Canadian System of Soil Classification and Soil Taxonomy.

Additional index words: **Pergelic, Permafrost, Cryosol, Cryaquept, Cryoturbation, Polygon, Solifluction, Pingo, Thermokarst.**

SOILS with permafrost or frost action are of increasing interest because of efforts to find new sources of oil and minerals and to improve the livelihood of people living in the Arctic. A slide set was designed to provide teachers with materials concerning properties and classification of permafrost soils and means to construct roads, buildings, and other structures on soils with permafrost. The locale of the slides is Tuktoyaktuk and Inuvik in Northwest Territories and Dawson City in Yukon Territory. The slides were obtained by the author on tour 18, "Soil, Permafrost and Vegetation Relationships in Northwestern Canada," during the International Society of Soil Science meetings in 1978. Tuktoyaktuk and Inuvik are located in the low Arctic continuous permafrost zone, and Dawson City is located in the Subarctic discontinuous permafrost zone. Detailed information in the tour guidebook can be used to supplement the information in this paper (2).

FEATURES AND CLASSIFICATION OF FROST-AFFECTED SOILS

Soils with permafrost are in pergelic subgroups in Soil Taxonomy (4), and Pergelic Cryaquepts are the most extensive soils in Alaska (3). Soils with permafrost in the Canadian System of Soil Classification are in the Cryosolic order (Cryosols) and cover about 40% of the land in Canada. The great groups are Turbic Cryosol, Static Cryosol, and Organic Cryosol. Turbic Cryosols are mineral soils that show evidence of strong cryoturbation and typically hummocky microrelief. Static Cryosols are mineral soils that have little or no evidence of cryoturbation and are minor soils in Canada found on coarse-textured deposits. Organic Cryosols are organic soils with permafrost.

Frost action features shown, in addition to hummocks, are ice wedge polygons, stone nets or stone polygons, solifluction lobes, and pingos. Methods for construction of buildings, roads, and other structures are based on insulation of permafrost or building on piling to inhibit permafrost melting or thermokarst.

GENERAL DESCRIPTION AND CONTENT OF SLIDES

(**Ed. Note**—Narrative for all slides is given below, although only six slides were selected to illustrate this article. Reviewers have evaluated the entire slide set for quality and technical accuracy.)

1. Low altitude view of treeless tundra on Arctic coastal plain with numerous lakes. "Large" ice wedge polygons are pictured in the foreground and surrounded by land covered with "small" light-colored, lichen-covered hummocks.
2. (*Fig. 1*) Irregular permafrost table exposed in Organic Cryosol near Tuktoyaktuk on treeless tundra. Vegetation is dwarf shrubs. The trought on the right marks the location of an ice wedge. A Pergelic Cryohemist in Soil Taxonomy.
3. (*Fig. 2*) Drawing of mineral soil profile with permafrost.
4. (*Fig. 3*) Soil profile showing organic matter moving downward in troughs between hummocks. This horizon is labelled Omy: organic (O), mesic or intermediate state of decomposition (m), and cryoturbation (y). Horizons on hummock are Bm1, Bm2 and BCy. Water from permafrost melting in summer keeps soil wet immediately above the permafrost, although the top of the hummock surface may be a dry site in summer for establishment of plants and the hummock surface may remain bare as in this case (Brunisolic Turbic Cryosol as

Fig. 1. Irregular permafrost table (permafrost) exposed in bottom of pit of Organic Cryosol or Pergelic Cryohemist. (*Slide 2*)

[1] Contribution from Crop and Soil Sciences Dep. at Michigan State Univ., East Lansing, MI 48824.

[2] Professor of soil science.

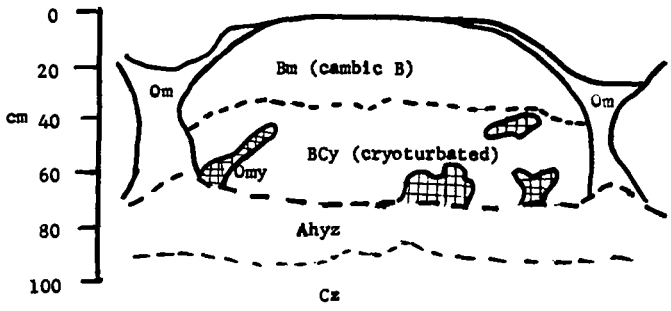

Fig. 2. Diagrammatic horizon pattern of Brunlsolic Turbic Cryosol with Om horizon (m for mesic or intermediate decomposed organic matter) in the troughs and on shoulders of hummocks. (Orthic Turbic Cryosols have hummocks completely covered with a fibric organic layer, Of.) The Ahyz layer is mainly mineral with well-decomposed organic matter (h), is cryoturbated (y) and has permafrost (z). Adapted from the Canada Survey Committee (1). (*Slide 3*)

showing involuted organic matter, Omy, in trough between hummocks. (*Slide 4*)

shown in *Fig. 2*). Plants get started easier part of the way down hummock sides or in troughs where moisture is more adequate. Flowers are of cotton grass (*Eriophorum russeolum*). This pit site was burned in 1968, and in the unburned area in rear are small and widely spaced black spruce (*Picea marriana*) of the typical black spruce–lichen Subarctic forest. Parent material is fine-textured colluvium on undulating morainal plain near Inuvik. A Pergelic Ruptic Cryaquept in Soil Taxonomy.

5. Alpine tundra site on rolling end moraine in a "U" shaped valley west of Dawson City showing light-colored lichen covered tops of hummocks. Loamy skeletal till and vegetation dominated by low birch shrubs (*Betula glandulosa*) in troughs and lichens and small ericaceous shrubs on hummock tops. The patterned ground is unsorted nets.
6. Close-up soil of *slide 5*. Note again wetness in pit bottom from permafrost melting and hummocks with shrubs growing in troughs where there is good water supply and protection from winds. The soil is an Orthic Turbic Cryosol or a Pergelic Ruptic Cryaquept.
7. Black spruce–lichen forest on hummocky ground.

Fig. 4. Discontinuous permafrost on lower part of north facing slope where vegetation is mainly lichens with scattered black spruce. Site Y3 in left foreground is identified by light-colored sheet of plywood. (*Slide 8*)

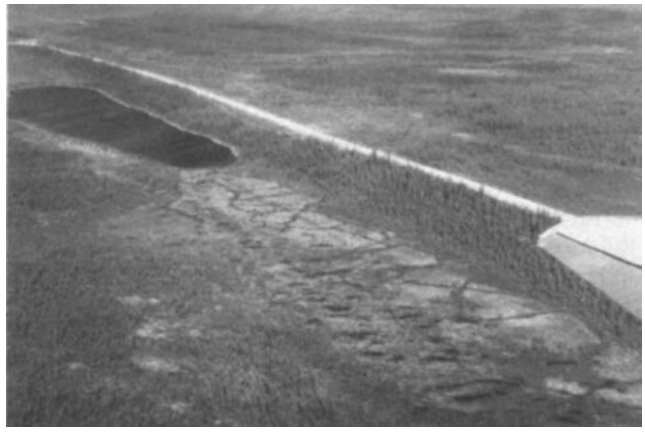

Fig. 5. Ice wedge polygons in foreground of an organic soil area. (*Slide 15*)

The trees grow on sides of hummocks and lean depending on frost action that moves the soil. Note lichen-covered hummocks. Parent material and topography similar to site shown in *slide 4*. Orthic Turbic Cryosol or Pergelic Ruptic Cryaquept near Inuvik in the low or subarctic where the black spruce grow to this size and then die. The forest does not produce marketable trees. Dense wood is produced in direction of lean and the cross section of a 119-year-old tree showed eight distinct leaning periods (6).

8. (*Fig. 4*) Landscape in discontinuous permafrost zone of the Subarctic near Dawson City. Permafrost occurs where the land appears covered with lichens and moss and a few scattered black spruce. Permafrost is absent where the trees are the largest. The permafrost is favored on north slopes and where soils are fine-textured and wet.
9. Soil in permafrost area of previous landscape slide that is a Regosolic Turbic Cryosol. Horizons are

Fig. 6. Utilidor used for servicing houses in Inuvik, Northwest Territories. (*Slide 18*)

Om, Cz1, Ahbz and Cz2. The upper horizon is composed of decomposed mosses, the second and third are sandy loam and the bottom horizon is gravelly sandy loam. The third horizon is labelled Ahbz and is an A horizon with well decomposed organic matter (h) that is buried (b) and has permafrost (z).

10. Soil on opposite south facing slope near site of soil in *slide 9*. Soil is Orthic Dystric Brunisol or Lithic Cryochrept formed in colluvium over metamorphic bedrock. Vegetation is boreal forest of aspen (*Populus tremuloides*), white birch (*Betula papyrifera*) and white spruce (*Picea glauca*). Horizons are F-H, Aej (j for weak or juvenile), Bm1 and IIBm.
11. Thermokarst, subsidence due to permafrost melting, caused by vehicular traffic that disrupted the surface insulation organic layer.
12. Solifluction lobes on slope underlain with permafrost.
13. Cross section of Orthic Turbic Cryosol showing sorting of stones to trough areas in formation of stone nets (stone polygons) due to frost action.
14. Stone nets or stone polygons located on cryoplanation terrace west of Dawson City near Alaska border at site of soil in *slide 13*.
15. (*Fig. 5*) Ice wedge polygons in organic soil area in right foreground.
16. City of Inuvik, population about 4000, established between 1955–1961 to relocate and enlarge the school, hospital, airport and administrative facilities that were located at Aklavik, Located on edge of Mackenzie River delta with good source of gravel for road construction. Permafrost about 330 m thick. Inuvik is also a major petroleum exploration base for the western Canadian Arctic.
17. Center of Inuvik from dome of the Catholic church showing "utilidor" system that is the enclosed structure built on piling and contains hot and cold water and sewage service for servicing buildings. In the center is a garden that is capable of producing leafy vegetables.
18. (*Fig. 6*) Utilidor serving residential houses in Inuvik.
19. Apartment building built on piling to allow maximum freezing of soil in winter and minimum heating of soil by building heat. Also note the thickness of gravel for road construction. For roads about 1 m of gravel is spread over the land to insulate and maintain the permafrost.
20. Two pingos near Tuktoyaktuk in the Mackenzie Delta. One pingo is the vegetation covered mound on the island in the foreground. The other pingo is the mound just to the rear of the airplane wing near the wing tip. Pingos originate from the arching of an impervious sheet of frozen ground forced up by intrusion of water under pressure and subsequent freezing of the water. This is a closed-system pingo formed after quick draining of a shallow lake that did not have permafrost underneath but was enclosed by permafrost in soil surrounding the lake.

Additional information and references are given in the publications by Rieger et al. (3) and Tedrow (5). Both references have numerous black and white photographs, and the latter has a color plate section that includes soils with permafrost and a striking exposure of an ice wedge.

Information about purchase of slide set is available from: Henry D. Foth, Crop and Soil Sciences Dep., Michigan State Univ., East Lansing, MI 48824.

LITERATURE CITED

1. Canada Soil Survey Committee. 1978. The Canadian system of soil classification, Canada Dep. of Agric., Publ. 1646, Supply and Services, Ottawa.
2. Pettapiece, W. W., et al. 1978. Guidebook for tour of soil, permafrost and vegetation relationships in the Yukon and Northwest Territories of Northwestern Canada, Tour 18, 11th International Congress of Soil Science, Edmonton.
3. Rieger, S., D. B. Schoephorster, and C. E. Furbush. 1979. Exploratory soil survey of Alaska. USDA, Soil Conservation Service, Washington, D.C.
4. Soil Survey Staff. 1975. Soil taxonomy. USDA Agric. Handb. 436. Washington, D.C.
5. Tedrow, J. C. F. 1977. Soils of the polar landscapes. Rutgers Univ. Press, New Brunswick, N.J.
6. Zoltai, S. C. 1975. Tree ring record of soil movement in permafrost. Arctic Alpine Res. 7:331–340.