Permafrost terminology

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PERMAFROST TERMINOLOGY

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Preface

The steadily expanding economic developments in northern Canada, accompanied by increasing permafrost investigations for science and engineering, have intensified the need for standardized terminology. This list of terms related to permafrost was compiled under the sponsorship of the Permafrost Subcommittee, Associate Committee on Geotechnical Research, National Research Council of Canada, in an attempt to meet this requirement in Canada.

The first step in preparing this booklet was to compile a list of all terms considered to have any connection with permafrost. This primary list of more than 300 terms was circulated to a number of persons involved with permafrost investigations. On the basis of comments received, the list was reduced to 184 terms, of which 146 were to be defined and 38 cross-referenced to the defined terms. Added to these, for a total of 237 items, were 53 items which are inverse word order listings to achieve alphabetical groupings of related terms. Examples are the "ice" terms, such as *aggradational ice** and *buried ice*, which are listed as *ice, aggradational* and *ice, buried*; and the "permafrost" terms such as *contemporary permafrost* and *continuous permafrost*, which are listed as *permafrost, contemporary* and *permafrost, continuous*.

After the final selection of terms, definitions were developed by the authors. These were then circulated for comment and revisions were made on the basis of comments received. In this booklet supplementary comments are included with many definitions to provide additional information and clarification. References have been provided for some definitions to enable the reader to trace original sources or to obtain information beyond the scope of the short definition. A few photographs and diagrams have been included.

Some comments are in order to explain the selection of terms, the accepted or proposed definitions, and the supplementary information.

*Italic type has been used throughout to denote that a definition for the word or term can be found in this glossary. The only exceptions to this are "ice" and "permafrost" because they appear very frequently.

The authors' goal was to prepare a list of terms that enjoy common usage in current literature with special reference to Canada and Canadian conditions. Foreign language terms are included only if they are solidly established in English usage. The main concern is with current usage rather than original definitions and past usage. Persons interested in the historical development of present meanings can work back to original sources through the references provided. The aim is to promote current usage where it is acceptable and encourage development of better usage where improvements are required.

The authors realize that the list does not include all terms related to permafrost. For example, only the most commonly used periglacial terms are on the list and the reader can refer to Hamelin and Cook (1967) and Washburn (1973) for a more complete listing. Many other terms related to permafrost are being treated in several glossaries on northern terrain currently being prepared (e.g., Stanek, in preparation).

Some of the terms may be used elsewhere in a context unrelated to permafrost but they are defined here only within that framework. Examples of this dual usage include *active layer* and *drunken forest*, terms common to permafrost and landslide features.

Many useful comments on the first draft of the definitions were received by the authors. Conflicting opinions on the meanings of some terms indicated the considerable range of ideas that exists on current usage. The authors attempted to resolve these differences to the best of their ability. The definitions in this booklet thus reflect the ideas of the authors, comments from other persons involved with permafrost, and the technical literature on the subject.

A major semantic problem in permafrost terminology is the use of the word "frozen." Two conflicting schools of thought emerged in the comments received. One group contended that "frozen" should be used to refer to earth materials below 0°C whether or not water (in the solid and possibly liquid state) is present. The other group believed that earth materials should not be considered as "frozen" unless they contain ice.

The difficulty lies in the fact that the term "freezing" originally implied a change in the physical state of water from liquid to solid. Later it was applied to similar changes in other substances. The term "frozen" was thus used for the solid state regardless of whether the change of state took place at 0°C under 1 atmosphere of pressure, as it does with water, or under other conditions. There are no specific terms to designate

"above or below 0°C" and "contains or does not contain ice." The authors concur with those who stated the need for these specific terms and they therefore urge users of this terminology to contribute to the solution of this semantic problem. The awkwardness of terms such as "perennially frozen bedrock" is recognized by the authors as well as the varying views on the exact meaning of the most fundamental word in this terminology, "permafrost." In the absence of better terminology, however, the authors agree with the position of those who use the term "frozen" for all earth materials below 0°C regardless of the water/ice content and phase condition.

The following persons provided comments on the first draft of definitions: J. Brown, U.S. Army Cold Regions Research and Engineering Laboratory; B.M. Burns, Atmospheric Environment Service, Environment Canada; C.W. Drew, J.C. Sproule and Assocs. Ltd.; O. Garg, Iron Ore Company of Canada Ltd.; L. W. Gold, Division of Building Research, National Research Council of Canada; V.F. Haavisto, Canadian Forestry Service, Environment Canada; J. A. Heginbottom, Geological Survey of Canada, Department of Energy, Mines and Resources; R.A. Hemstock, Canadian Arctic Gas Study Limited; J.K. Jeglum, Canadian Forestry Service, Environment Canada; G.H. Johnston, Division of Building Research, National Research Council of Canada; A. Judge, Earth Physics Branch, Department of Energy, Mines and Resources; T. Lewis, Earth Physics Branch, Department of Energy, Mines and Resources; J.R. Mackay, Department of Geography, University of British Columbia; J.D. Mollard, J.D. Mollard and Assocs. Ltd.; N.R. Morgenstern, Department of Civil Engineering, University of Alberta; R. Noble, Canadian Arctic Gas Study Limited; J.B. Railton, Canadian Arctic Gas Study Limited; V.N. Rampton, Geological Survey of Canada, Department of Energy, Mines and Resources; G. Rempel, Imperial Oil Limited; L. Samson, Terratech Ltd.; P. Stacey, Golder, Brawner Associates Ltd.; W. Stanek, Canadian Forestry Service, Environment Canada; W.A. Slusarchuk, Northern Engineering Services Ltd.; S. Thomson, Department of Civil Engineering, University of Alberta; A.L. Washburn, Quaternary Research Center, University of Washington. The comments of these persons were invaluable in composing the definitions in this booklet and the authors gratefully acknowledge this assistance.

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Thanks are here recorded to those who gave their permission for the inclusion of the illustrations. Acknowledgement of the original source is noted in the figure captions.

This booklet of permafrost terminology is considered to be only a first attempt. The authors intend to revise it periodically. Comments and suggestions on selection of terms, definitions, and format, are invited and encouraged to achieve improved standardized terminology in permafrost.

A French translation of this booklet will be available as soon as possible.

Any comments should be sent to:

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A

active ice wedge [see *ice wedge, active*]

active layer [see also *depth of thaw, seasonal frost, seasonally frozen ground, seasonally thawed ground*]

The top layer of ground above the *permafrost table* that thaws each summer and refreezes each fall.

COMMENT: In temperature terms the active layer is the top layer of the ground in the permafrost region, the temperature of which fluctuates above and below 0° during the year. The thickness of the active layer varies. As a rule it is fairly thin in the Far North, as little as 15 cm, and becomes thicker to the south, as much as 1 m or more. In the *continuous permafrost zone* (Figure 1) it generally reaches the *permafrost table* except in the vicinity of water bodies. In the *discontinuous permafrost zone* it extends downward to the *permafrost table* in some locations but not in others. Its thickness, which depends on many factors, including the degree and orientation of slope, vegetation, drainage, snow cover, soil and rock type, and ground moisture content, may vary from year to year depending on local weather conditions. The active layer is referred to erroneously by some as the "active zone," the term "zone" being limited in its use to continuous and discontinuous zones of permafrost. Terms such as *depth of thaw*, *depth to permafrost*, and *annually thawed layer* are sometimes used as synonyms for active layer. This usage is acceptable in areas where the active layer extends downward to the *permafrost table*, but it is misleading where the active layer is separated from the permafrost by a layer of ground which remains in the unfrozen state throughout the year. REFERENCES: Brown, 1971; Hamelin and Cook, 1967; Muller, 1947; Williams, 1965.

aggradation of permafrost [see *permafrost aggradation*]

aggradational ice [see *ice, aggradational*]

alas or *alass* [see also *thermokarst depression*]

A circular to irregular lowland, of less than 1 km^2 to many times

that unit in area, from which the originally large ice content (up to 80% by volume) has essentially disappeared resulting in a lowering of the ground surface by 5 to 20 m.

COMMENT: This Yakut (Siberia) word is achieving some usage in the English literature. REFERENCES: Czudek and Demek, 1970; Péwé, 1973.

annually frozen layer [see *active layer*]

annually thawed layer [see *active layer*]

Aufeis [see *icing*]

B

base of permafrost [see *permafrost base*]

baydzherakh [see *cemetery mound*]

beaded drainage [see *beaded stream*]

beaded stream [or, less desirable: *beaded drainage*, *button drainage*]
A drainage pattern of individual streams in which pools or small lakes are connected by short stream reaches.

COMMENT: In permafrost regions the "beads" or enlargements of the streams are caused by the melting of masses of *ground ice*. In some areas dry beds connect the pools. For this feature the term "beaded channel" is suggested. (See Figure 2.) REFERENCES: Brown, 1970*b*; Ferrians *et al.*, 1969; Péwé, 1954.

bi-modal flow [see *retrogressive thaw flow slide*]

bonding
The binding together of soil particles by the cementing action of ice. Poorly bonded or friable soils are those in which the particles are held together weakly by the ice. Well bonded soils are those in which the particles are held together strongly by the ice.

COMMENT: The degree of bonding depends among other factors on the volume and configuration of the ice. REFERENCE: Pihlainen and Johnston, 1973.

bottom of permafrost [see *permafrost base*]

buried ice [see *ice, buried*]

button drainage [see *beaded stream*]

C

cave ice [see *ice, cave*]

cave-in lake [see *thermokarst*]

cemetery mound [see also *thermokarst mound*]

A hillock caused by the melting of surrounding *ice wedges* in areas of *polygonal ground.*

COMMENT: Cemetery mounds, or *thermokarst mounds*, occur in groups forming a distinctive surficial network of regularly shaped mounds separated by trenches formed by the melting of *ice wedges.* The use of the descriptive term "cemetery mound" comes from the language of the Yakut (Siberia) people who use these permafrost features (Yakut—*baydzherakh*) for grave sites. (See Figure 3.) REFERENCES: Brown, 1970*b*; Péwé, 1954 (thermokarst mounds).

circle, nonsorted [see also *circle, sorted*]

Patterned ground feature, occurring in groups, whose mesh (interior surfaces) is dominantly circular and lacks a border of stones.

COMMENT: Nonsorted circles are characteristically surrounded by vegetation and occur singly or in groups. Common diameters are 0.5–3 m. The central areas tend to be slightly dome-shaped and cracked into small *nonsorted polygons.* Most nonsorted circles occur on nearly horizontal surfaces. The mineral soil normally has a high content of fines and may, or may not, contain stones. (See Figure 4.) REFERENCE: Washburn, 1973.

circle, sorted [see also *circle, nonsorted*]

Patterned ground features occurring in groups, whose mesh is dominantly circular and which has a sorted appearance commonly due to a border of stones surrounding finer material.

COMMENT: Like *nonsorted circles*, sorted circles occur singly or in groups; their range in size is also similar. Sorted circles are common on nearly horizontal surfaces. REFERENCE: Washburn, 1956.

clay boil [see *circle, nonsorted*]

climafrost [see *pereletok*]

closed-cavity ice [see *ice, closed-cavity*]

closed system pingo [see *pingo, closed system*]

closed talik [see *talik, closed*]

collapse scar

Generally circular, wet, treeless depression several metres long, adjacent to the slumping edge of a *peat plateau* or *palsa*, caused by the thawing of *ice-rich permafrost.*

COMMENT: The thawing permafrost edge commonly appears as a steep bank with leaning, mostly dead, trees (*drunken forest*). (See Figure 5.) REFERENCES: Tarnocai, 1970; 1973; Zoltai, 1971.

contemporary permafrost [see *permafrost, contemporary*]

continuous permafrost [see *permafrost, continuous*]

continuous permafrost zone [see *permafrost, continuous*]

cryopedology [see *geocryology*]

cryosphere

That part of the Earth's crust and the atmosphere subject for at least a part of each year to temperatures below 0°C.

COMMENT: Includes permafrost, glaciers, snow cover, and ice cover on bodies of water or on land. REFERENCE: Shvetsov, *in* Williams, 1965.

cryoturbation

A collective term to describe all soil movements due to frost action.

COMMENT: Cryoturbation encompasses frost heaving and all differential and mass movement including expansion and contraction due to temperature changes. Low temperatures alone are not enough to produce cryoturbation; the presence of water is necessary. It is one of the most important processes in *periglacial* geomorphology and is intimately connected with features resulting from *periglacial* processes. REFERENCES: Hamelin and Cook, 1967; Washburn, 1973.

degradation of permafrost [see *permafrost degradation*]

depressed centre polygon [see *polygon, low centre*]

depth of thaw [see also *active layer*]

The distance from the ground surface downward to *frozen ground* at any time during the thawing season.

depth of zero annual amplitude

The distance from the ground surface downward to the point beneath which there is virtually no annual fluctuation in ground temperature.

COMMENT: A change of no more than 0.1 C degree through the year is arbitrarily considered as virtually no annual fluctuation. The temperature at the depth (or level) of zero annual amplitude ranges from about $-0.1°C$ at the distal limit of the permafrost region to about $-20°C$ in the extreme polar reaches of the *continuous permafrost zone*. The depth of zero annual amplitude ranges widely but generally lies between 10 and 20 m depending upon climatic and terrain conditions such as amplitude of annual surface temperature variation, vegetation, snow cover, characteristics of the soil and rock including effective thermal diffusivity. REFERENCE: Grave, 1967.

depth to permafrost [see *permafrost table*]

discontinuous permafrost [see *permafrost, discontinuous*]

discontinuous permafrost zone [see *permafrost, discontinuous*]

disequilibrium permafrost [see *permafrost, disequilibrium*]

drunken forest

A group of trees leaning in a random orientation.

COMMENT: This condition is usually associated with *thermokarst topography*. In some cases it may be due to the poor support afforded the roots by the loose, irregular mounds of Sphagnum and other mosses, and numerous water-filled pits and channels in *peatlands*. (See Figure 6.)

dry permafrost [see *permafrost, dry*]

E

earth hummock [see *hummock, earth*]

East Greenland pingo [see *pingo, open system*]

epigenetic ice [see *ice, epigenetic*]

epigenetic permafrost [see *permafrost, epigenetic*]

equilibrium permafrost [see *permafrost, equilibrium*]

excess ice [see *ice, excess*]

F

fossil ice wedge [not recommended; see *ice wedge cast;* see also *soil wedge*]

freezing index [see also *thawing index*]

The number of degree-days (the difference between the mean temperature each day and 0°C, either positive or negative) between the highest point in the autumn and the lowest point the next spring on the cumulative degree-day time curve for one freezing season.

COMMENT: The freezing index is a measure of combined duration and magnitude of below-freezing temperatures during a year. REFERENCE: Boyd, 1973.

frost cracking

Fracturing of the ground by thermal contraction at temperatures below 0°C.

COMMENT: It is an important process in the initiation of both sorted and nonsorted *patterned ground.* Frost cracking is not restricted to a permafrost environment but it rarely forms well-defined and persistent features elsewhere.

frost-susceptible soil [see also *non-frost-susceptible soil*]

Soil in which significant detrimental *ice segregation* occurs when the requisite moisture and freezing conditions are present.

COMMENT: As a rough guide, soils with more than 10 per cent (by weight) of particles smaller than 20 microns (μ) are usually frost susceptible and will support *ice lens* growth. Well-graded soils require less fines (< 10 per cent) to make them frost susceptible than do uniform soils. REFERENCE: Penner, 1972.

frost table

Any frozen surface in the *active layer* which is moving downward towards the *permafrost table* due to thawing.

COMMENT: This term must not be confused with permafrost or the *permafrost table*. It is also applicable to a frozen surface in *seasonally frozen ground* where permafrost is not present.

frozen ground

Soil or rock having a temperature below 0°C.

COMMENT: The definition is based solely on temperature and is independent of water and ice content of the soil or rock. Thus *perennially frozen ground* remains at a temperature below 0°C continuously from year to year.

G

geocryology

The study of earth materials having a temperature below 0°C.

ground

Earth materials including all types of soil and rock and their constituents.

ground heave [see also *ground settlement*]

Upward movement of the ground causing a raising of the ground surface as a result of the formation of *ground ice* in excess of pore fillings.

COMMENT: Ground heave will occur if aggradation (increase) of *ice-rich permafrost* takes place. It also occurs annually during the winter when *excess ice* forms during freezing of the *active layer*.

ground ice [see *ice, ground*]

ground settlement [or, less desirable: *ground slumping, ground subsidence;* see also *ground heave, thaw settlement, thermokarst*]

Downward movement of the ground causing a lowering of the ground surface resulting from the melting of *ground ice* in excess of pore fillings.

COMMENT: Ground settlement will occur if thawing of *ice-rich permafrost* takes place. It also occurs annually during the summer when *excess ice* melts during thawing of the *active layer*. (See Figure 7.)

H

high centre polygon [see *polygon, high centre*]

hummock [see also *hummock, earth; hummock, turf*]

Special nonsorted form of *net*, also designated by the Icelandic term "thufur," characterized by a knob-like shape and vegetation cover.

COMMENT: Well developed hummocks are up to 1 m high and 1 to 2 m in diameter. They can occur in the presence or absence of permafrost and are associated with *frost-susceptible soils* that freeze seasonally. REFERENCE: Washburn, 1973.

hummock, earth

Hummocks having a core of mineral soil.

REFERENCE: Washburn, 1973.

hummock, turf

Hummocks consisting of vegetation with or without a core of mineral soil or stone.

(See Figure 8.) REFERENCE: Washburn, 1973.

hydrolaccolith [see *pingo, closed system; pingo, open system*]

I

ice

Water in the solid state.

COMMENT: In permafrost regions ice occupying voids in soils and rocks occurs or may develop in a variety of forms. Definitions of the various types of ice follow.

ice, aggradational

The additional newly formed or incorporated *ground ice* resulting from a raising of the *permafrost table* or a lowering of the *permafrost base.*

REFERENCE: Mackay, 1972*b*.

ice, buried

Ice formed at the surface and later covered with soil.

COMMENT: Includes glacier, lake, river and sea ice as well as icings and some snow turning with time into ice buried by wind-blown, water-laid, or gravity-transported masses of sediment.

ice, cave

Naturally formed ice in a closed or open cave.

REFERENCE: Gary *et al.*, 1972.

ice, closed-cavity

Ice formed in a completely closed space, cavity, or cave in permafrost.

COMMENT: Along the western Arctic Coast of Canada, for example, underground cavities, formed by pockets of methane gas, having been found filled with ice crystals. (See Figure 9.) REFERENCE: Mackay, 1972*b*.

ice, epigenetic [see also *ice, syngenetic*]

Ground ice that formed after the deposition of the earth material in which it occurs.

ice, excess [see also *ground heave, ground settlement*]

The ice in the ground which exceeds the total pore volume that the ground would have under natural unfrozen conditions.

COMMENT: In standard soils terminology the pore volume is that portion of a volume of soil, whether frozen or unfrozen, not occupied by mineral or organic particles. By this definition it is impossible to have an amount of ice which exceeds the pore volume of the *frozen ground.* The volume of ice can, however, exceed the volume of the pore spaces that this soil would have in its natural unfrozen condition. (It is the excess ice, causing *ground heave* and *ground settlement*, which gives rise to many of the foundation engineering problems associated with permafrost.)

ice, ground

Ice in pores, cavities, voids or other openings in soil or rock, including *massive ice.*

ice, injection [see *ice, intrusive*]

ice, interstitial [see also *ice, pore*]

Ice in interstices (pores, or small voids) in rocks and soils.

ice, intrusive

Ice formed from water intruded or injected under pressure into a porous earth material.

COMMENT: Ice formation may lift the ground above it, thereby producing topographic forms resembling those of igneous intrusions. Thus, a tabular mass of intrusive ice is the equivalent of a sill (see *ice, sill*) or dyke (see *ice, vein*) where the water was introduced or injected under pressure; the domed form is that of a laccolith (see *hydrolaccolith, pingo*). REFERENCE: Mackay, 1972*b*.

ice, lattice [see *ice, reticulate*]

ice, massive

A comprehensive term used to describe large (with dimensions measureable at least 10 - 100 cm) masses of underground ice including *ice wedges, pingo ice,* and *ice lenses.*

ice, needle

Relatively long (about 2.5 to 5 or 6 cm) thin, needle-like ice crystals which form during nights when there is extensive radiation cooling and when ice segregation occurs at the ground surface or just below it in moist soils.

COMMENT: The ice needles grow perpendicular to the ground surface and occur commonly in clusters. Silty and organic soils offer optimum conditions for the development of needle ice. The equivalent Swedish term (*pipkrake*) is also used in the English literature. REFERENCES: Hamelin and Cook, 1967; Lovell and Herrin, 1953.

ice, open-cavity

Frost formed in an open cavity or crack in the ground by sublimation of water vapour.

REFERENCE: Mackay, 1972*b*.

ice, pingo

Ice forming the core of a *pingo*.

COMMENT: Such ice may be nearly pure or admixed with sediment. (See Figure 10.) REFERENCE: Mackay 1972*b*.

ice, pore

Ice occurring in the pores of soils and rocks.

COMMENT: On melting, pore ice does not yield water in excess of the pore volume in contrast to *segregated ice*.

ice, reticulate

Network of horizontal and vertical *ice veins* forming a three-dimensional rectangular or square lattice commonly found in frozen glaciolacustrine sediments.

COMMENT: Field observations suggest that the reticulate *ice veins* grow in horizontal and vertical shrinkage cracks with much of the water being derived from the adjacent clay, in a semi-closed freezing system, rather than from an upward migration of water in an open system. REFERENCE: Mackay, 1974.

ice, segregated

Ice formed by the migration of pore water to the freezing plane where it forms into discrete lenses, layers, or seams ranging in thickness from hairline to greater than 10 m.

COMMENT: Segregated ice commonly occurs in alternating layers of ice and soil (see *ice lens*, 2). Some authors use the term broadly for any soil with a high ice content and do not restrict its use to the ice component alone. (See Figure 11.) REFERENCES: Mackay, 1966*a*; Penner, 1972.

ice, sill

Ice in a concordant, tabular mass formed by water intruded or injected under pressure into a porous earth material.

COMMENT: In general, sill ice freezes along bedding planes; in some places along the base of the *active layer* and parallel to the *permafrost table*. It is often difficult, or impossible, to determine whether a particular tabular body of ice grew as a sill or by *ice segregation*. (See Figure 12.) REFERENCE: Mackay, 1972*b*.

ice, single-vein

Ice formed in an open, generally vertical, crack penetrating into the permafrost, which became filled with surface water or hoarfrost.

COMMENT: Just below the *permafrost table* these ice-filled cracks occur in groups of criss-crossing veins ranging in thickness from paper-thin veinlets up to those 1 cm thick. REFERENCE: Mackay, 1972*b*.

ice, syngenetic [see also *ice, epigenetic*]

Ground ice that formed more or less simultaneously with the deposition of the earth material in which it occurs.

ice, tension-crack

Ice, banded or layered, which forms in cracks produced by tension or mechanical rupture of the ground, mostly resulting from the growth of *segregated* or *intrusive ice*. (See Figure 13.)

REFERENCE: Mackay, 1972*b*.

ice, thermal contraction

Ice formed in cracks in the ground caused by thermal contraction of the ground surface.

COMMENT: *Ice wedges* and *single vein ice* are both types of thermal contraction ice. REFERENCE: Mackay, 1972*b*.

ice, vein

A comprehensive term for ice in cracks where it occurs in bodies of various shapes, including tabular forms and wedges.

ice, wedge

Ice occurring in an *ice wedge*.

ice bonding [see *bonding*]

ice content

The ratio, expressed as a percentage, of the weight of the ice phase to the weight of dry soil.

REFERENCE: Hennion, 1955.

ice dyke

Intruded tabular ice body that cuts across bedding.

ice lens [see also *ice, segregated*]

1. A dominantly horizontal lens-shaped body of ice of any dimension.
2. Commonly used for layers of *segregated ice* that are parallel to the ground surface. The lenses may range in thickness from a hairline to as much as about 10 m.

ice-rich permafrost [see *permafrost, ice-rich*]

ice segregation [see also *ice, segregated*]

The process of formation of segregated ice by freezing of water in mineral or organic soil.

REFERENCE: Penner, 1972.

ice slump [see *retrogressive thaw flow slide; thaw slumping*]

ice vein [see also *ice, vein*]

A seam or vein of ice occupying a crack that cuts across rock or soil layers.

ice wedge

A massive, generally wedge-shaped body with its apex pointing downward, composed of foliated or layered, vertically oriented, commonly white ice; from less than 10 cm to 3 m or more wide at the top, tapering to a feather edge at the apex at a depth of 1 to 10 m or more. Some ice wedges may extend downward as far as 25 m and may have shapes dissimilar from wedges.

COMMENT: Ice wedges occur in permafrost where they commonly form in cracks in polygonal patterns originating in winter by thermal contraction of the ground and into which water from melting snow penetrates in the spring. Repeated annual contraction and subsequent cracking of the ice in the wedge, followed by freezing of water in the crack, lead to an increase in width and depth of the wedge and cause a layering of the ice mass. The surface expression of many ice wedges is generally a network of *polygons*. (See Figure 14.)
REFERENCES: Lachenbruch, 1966; Mackay and Black, 1973.

ice wedge, active

An ice wedge that is actively growing by repeated but not necessarily annual (winter) cracking.

COMMENT: Active ice wedges occur principally in the *continuous permafrost zone*. REFERENCES: Hamelin and Cook, 1967; Péwé, 1966.

ice wedge, inactive

An ice wedge that is no longer growing.

COMMENT: Inactive ice wedges occur mostly in the northern part of the *discontinuous permafrost zone*. REFERENCES: Hamelin and Cook, 1967; Péwé, 1966.

ice wedge cast [see also *soil wedge*]

An infilling of soil or sediment into the space formerly occupied by an *ice wedge*.

COMMENT: The term "fossil ice wedge" is not recommended because ice is no longer present. An ice wedge cast is one of the few acceptable criteria for former permafrost. REFERENCE: Washburn, 1973.

ice wedge polygon [see *polygon, ice wedge*]

icing

A sheet-like mass of ice either on the ground surface or on the surface of river ice.

COMMENT: Icings on the ground surface form by the freezing of spring water, and also water forced from unfrozen soil between the *seasonally frozen ground* and an underlying impervious layer which is commonly permafrost. Icings on rivers form by the freezing of overflow water or seepages from rivers; they may extend onto land surfaces and are therefore by some called floodplain icings. The longitudinal dimension of the largest icings may be 10 km or more and may be 1 m or more thick. The equivalent terms for icing in German (*Aufeis*) and Russian (*naled*) are in common use in the English literature.

inactive ice wedge [see *ice wedge, inactive*]

injection ice [see *ice, intrusive*]

interstitial ice [see *ice, interstitial*]

intrapermafrost water [see also *subpermafrost water; suprapermafrost water*]

Free water occurring in unfrozen zones within the permafrost.

REFERENCE: Williams, 1965.

intrusive ice [see *ice, intrusive*]

island permafrost [see *permafrost, sporadic*]

L

layered permafrost [see *permafrost, layered*]

low centre polygon [see *polygon, low centre*]

lower surface of permafrost [see *permafrost base*]

M

Mackenzie Delta pingo [see *pingo, closed system*]

marginal permafrost [see *permafrost, marginal*]

massive ice [see *ice, massive*]

muck

A dark brown to black soil, composed of a mixture of well-decomposed organic material and fine-grained soil, predominantly silt.

COMMENT: Muck has a higher proportion of mineral soil than *peat* and may be described as "organic silt."

muskeg [see *peatland*]

N

naled [see *icing*]

needle ice [see *ice, needle*]

net [see also *hummock*]

Patterned ground feature occurring in groups whose mesh (interior surfaces) is neither dominantly circular nor polygonal.

COMMENT: The size range and slope relation of most nets are similar to those of *circles* and *polygons*. The same nonsorted and sorted terminology applies and their relationship to permafrost is similar. REFERENCE: Washburn, 1973.

non-frost-susceptible soil [see also *frost-susceptible soil*]

A soil that does not display significant detrimental ice segregation during freezing. (See definition of *frost-susceptible soil* for quantitative limits imposed by particle size.)

nonsorted circle [see *circle, nonsorted;* see also *circle, sorted*]

nonsorted polygon [see *polygon, nonsorted;* see also *polygon, sorted*]

nonsorted stripe [see *stripe, nonsorted;* see also *stripe, sorted*]

O

offshore permafrost [see *permafrost, submarine*]

open-cavity ice [see *ice, open-cavity*]

open system pingo [see *pingo, open system*]

open talik [see *talik, open*]

organic terrain [see *peatland*]

oriented lake

One of a number of lakes having a parallel alignment and commonly elliptical or rectangular in plan.

COMMENT: In permafrost regions some *thermokarst lakes* show a preferred orientation. The precise mechanism of lake orientation remains uncertain although wind direction appears to be a factor. REFERENCES: Black and Barksdale, 1949; Mackay, 1963; Washburn, 1973.

P

palsa [see also *peat mound; peat plateau*]

A Fennoscandian term for a round or elongated hillock or mound, maximum height of about 10 m, composed of a *peat* layer overlying mineral soil. It has a perennially frozen core which extends from within the covering *peat* layer downward into or toward the underlying mineral soil.

COMMENT: Palsas appear to occur mainly in the *discontinuous permafrost zone*. Mounds resembling palsas have been observed in the *continuous permafrost zone* and may be genetically related. The layer of *peat* over the mineral soil may vary in thickness from 1 m or less to as much as 7 m, equivalent in thickness to the average of the surrounding *peatland* where there is no permafrost. Palsas commonly form by a build-up of *segregated ice*, mainly in the mineral soil. The apparently random distribution of individual palsas within a *peatland* is poorly understood. Some controversy exists whether palsas and *peat plateaus* are only morphological variations of the same feature or genetically different. It may be difficult or impossible to distinguish between the two types of features in some *peatlands*. (See Figure 15.) REFERENCES: Lundqvist, 1969; Railton and Sparling, 1973; Salmi, 1970; Sjors, 1959; Zoltai, 1971; 1972; Zoltai and Tarnocai, 1971.

patterned ground

A general term for any ground surface of surficial soil materials exhibiting a discernible, more or less ordered and symmetrical, micro-physiographic pattern.

COMMENT: Patterned ground is not confined to regions of permafrost but it is best developed in regions of present or past intensive frost action. It comprises such features as *nonsorted* and *sorted circles*, *polygons*, *solifluction features*, *steps*, *stone nets*, *nonsorted* and *sorted stripes*. Patterned ground occurs also in *peatland* in the form of *string bogs* and other features not listed in this terminology. Stanek (in preparation) should be consulted for a complete listing of these *peatland* features. REFERENCES: Stanek, in preparation; Washburn, 1956; 1973.

peat

An unconsolidated, compressible soil consisting of partially decomposed, semi-carbonized remains of plants such as mosses, sedges and trees, some animal residues, and commonly some mineral soil.

COMMENT: Peat must have an organic content of not less than 20 per cent of the total dry weight. It develops usually in a waterlogged environment but dry peats do exist in dry *tundra* sites. The plant structure is still recognizable in many peats but some with a high degree of decomposition have no recognizable structures. Most peats are dark brown to black but they can be quite light (orange) where there is little or no decomposition. The thickness of peat in permafrost regions has been observed to range from about 10 cm to 6 or 7 m. REFERENCE: Stanek, in preparation.

peat mound [see also *palsa*]

A mound or hillock in a *peatland* composed mainly of *peat* overlying mineral soil.

COMMENT: In permafrost literature the term is generally used to refer to a *palsa*. Peat mounds, which do not have a perennially frozen core and therefore are not *palsas*, are formed by a localized accumulation of *peat*.

peat plateau [see also *palsa*]

A low, generally flat-topped expanse of *peat*, rising one or more metres above the general surface of a *peatland*. A layer of permafrost exists in the peat plateau, which may extend into the peat below the general *peatland* surface and even into the underlying mineral soil.

COMMENT: Some controversy exists whether peat plateaus and *palsas* are only morphological variations of the same feature or genetically different. Some authors state that the perennially frozen cores of peat plateaus are confined to the peat layers and that the elevation of peat plateaus may be attributed to a combination of buoyancy of the perennially frozen mass and the upward volume expansion due to a phase change of the peat's water into ice. In some *peatlands* it may be difficult or impossible to distinguish peat plateaus from *palsas*. Peat plateaus are also found in *peatlands* south of the permafrost region where permafrost is not a factor in their formation. (See Figure 16.) REFERENCES: Brown 1970*a*; Zoltai, 1972.

peatland

Any terrain covered by a layer of peat.

COMMENT: There is no universal agreement on the minimum thickness of *peat* required to be classed as "peatland." Islands of mineral soil without a *peat* cover may exist in a peatland. REFERENCE: Stanek, in preparation.

pereletok [not recommended; see *permafrost*]

A Russian term for a layer of ground, between the *active layer* above and the *permafrost* below, that remains frozen for one or several years and then thaws.

COMMENT: Use of this Russian term, which was introduced into the English literature, is not recommended. It presupposes arbitrarily that pereletok is not permafrost although the definition assigns a sufficient duration of time for it to be considered as permafrost.

Furthermore, the definition implies a basic difference in characteristics between pereletok, on the one hand, and permafrost of only a few years' duration, on the other hand, where in fact no difference exists. It is preferable to regard *frozen ground* as permafrost if it lasts at least from one winter through the succeeding thawing season to the next winter and as *seasonally frozen ground* if it lasts only through a part of the year. For the same reason, the use of the term *climafrost*, as a synonym of pereletok is not recommended. REFERENCE: Brown, 1966.

perennially frozen ground [see *permafrost*]

periglacial

1. The area, geomorphological processes, and deposits characteristic of the frost-affected immediate margins of existing and former glaciers and ice sheets.
2. The environment of cold regions in which frost action is important; the features resulting from frost action.

REFERENCES: Hamelin and Cook, 1967; Washburn, 1973.

permafrost

The thermal condition in soil or rock of having temperatures below 0°C persist over at least two consecutive winters and the intervening summer.

COMMENT: Permafrost, or *perennially frozen ground*, is defined purely as a thermal condition; moisture in the form of water and *ground ice* may or may not be present. Earth materials in this thermal condition may thus be described by the adjectives "perennially frozen" (e.g. perennially frozen silt, perennially frozen rock) irrespective of their water and ice content. The minimum time limit for permafrost is at least one year as it includes ground which reaches freezing temperatures in one winter and remains at freezing temperatures through the following summer and winter. At the other end of the time scale, permafrost may be thousands of years old. It is not *permanently frozen ground* because changes in climate and terrain may cause it to thaw and disappear. The thickness of permafrost may vary from less than 10 cm to 100–1000 m. Materials in a perennially frozen condition may be referred to as "permafrost-affected" materials. REFERENCE: Brown, 1970*b*.

permafrost, contemporary [see also *permafrost, relic*]

1. Permafrost in thermal equilibrium with current mean annual surface temperature and ground heat flux.

2. Newly formed permafrost in an area where surface temperatures have fallen below 0°C.

permafrost, continuous

Permafrost occurring everywhere beneath the exposed land surface throughout a geographic regional zone with the exception of widely scattered sites, such as newly deposited unconsolidated sediments, where the climate has just begun to impose its influence on the ground thermal regime and will cause the formation of continuous permafrost.

COMMENT: The *frozen ground* in the circumpolar zone of continuous permafrost thickens from 100 m or less at its distal limit to more than 1 km in more polar regions; the *active layer* varies from about 30 cm to 1 m and commonly extends to the *permafrost table;* the temperature at the *depth of zero annual amplitude* ranges from about −5°C at the boundary with the *discontinuous permafrost zone* to −20°C in areas closer to the pole. (See Figure 1.) REFERENCE: Brown 1970*b*.

permafrost, discontinuous

Permafrost occurring in some areas beneath the ground surface throughout a geographic regional zone where other areas are free of permafrost.

COMMENT: The zone of discontinuous permafrost lies between the more polar *continuous permafrost zone* and the distal limit of permafrost. Near its polar boundary, the permafrost in the discontinuous zone is widespread, whereas near its distal boundary it occurs in isolated patches and scattered islands. There is no sharp distinction between the *continuous permafrost zone* and the *discontinuous permafrost zone* but one grades into the other. The *frozen ground* in the circumpolar *discontinuous permafrost zone* generally thickens from 10 cm or less at its distal limit to 100 m or more at the boundary with the *continuous permafrost zone*. At certain locations, however, permafrost more than 100 m thick may be encountered. In the discontinuous zone, the *active layer* does not always extend to the *permafrost table* and unfrozen layers may occur between frozen ones (*permafrost, layered*); the temperature at the *depth of zero annual amplitude* ranges from a few tenths of a degree below 0°C at the distal border to about −5°C at the boundary with the *continuous permafrost zone*. (See Figure 1.) REFERENCE: Brown, 1970*b*.

permafrost, disequilibrium [see also *permafrost, equilibrium; permafrost, relic; permafrost, submarine*]

Permafrost that is not in thermal equilibrium with the existing negative mean annual surface or sea bottom water temperature and the heat flux from the interior of the Earth.

REFERENCE: Mackay, 1972*a*.

permafrost, dry

Perennially frozen soil or rock without ice or with an ice content lower than the pore volume so that it does not yield excess water on thawing.

permafrost, epigenetic [see also *permafrost, syngenetic*]

Permafrost that formed after the deposition of the earth material in which it occurs.

permafrost, equilibrium [see also *permafrost, disequilibrium; permafrost, relic; permafrost, submarine*]

Permafrost that is in thermal equilibrium with the existing negative mean annual surface or sea bottom water temperature and with the heat flux from the interior of the Earth.

REFERENCE: Mackay, 1972*a*.

permafrost, ice-rich

Perennially frozen ground that contains ice in excess of that required to fill pore spaces.

COMMENT: When ice-rich permafrost thaws, water in excess of that required to fill the pore spaces is released.

permafrost, island [see *permafrost, sporadic*]

permafrost, layered

Permafrost alternating with layers of unfrozen ground.

COMMENT: Layered permafrost may occur in the *discontinuous permafrost zone* and the *continuous permafrost zone*.

permafrost, marginal

Permafrost that is very close in space, temperature, or time to thawing, *i.e.*,

1. Permafrost at or near the southern limit of the permafrost region, or
2. Permafrost of which the temperature is very close to 0°C (a few tenths of a degree) anywhere in the permafrost region, or
3. Permafrost that lasts for only a few years and then dissipates.

COMMENT: There are no generally accepted quantitative values for the various types of marginal permafrost. REFERENCE: Brown, 1970*b*.

permafrost, relic [see also *permafrost, contemporary; permafrost, disequilibrium; permafrost, equilibrium; permafrost, submarine*]

Occurrences of permafrost that reflect past climatic conditions differing from those of today and which must have formed when the ground-surface temperature was different (usually lower) than it is now, as they are not in thermal equilibrium with the present mean annual ground-surface temperature.

COMMENT: The lower part of thick permafrost in the *continuous permafrost zone* and the northern part of the *discontinuous permafrost zone* can be considered as relic permafrost where the ground surface temperature at the time of formation was lower than it is now. Relic permafrost may be encountered in shafts and bore-holes at depths below those affected by the present climate along the distal limit of permafrost. It is also known from examination of *submarine permafrost* in arctic waters. The spelling "relic" is preferred to "relict." REFERENCE: Brown, 1967*b*.

permafrost, sporadic

Permafrost occurring in the form of scattered *permafrost islands.*

COMMENT: This term was used to refer to the most southerly permafrost zone in which permafrost exists only as scattered islands. The term *discontinuous permafrost zone* was used to refer to the permafrost belt lying between the sporadic zone and the *continuous permafrost zone*. Currently such a zone of sporadic permafrost is no longer recognized but is included in the more distal parts of the *discontinuous permafrost zone.*

permafrost, submarine [see also *permafrost, disequilibrium; permafrost, equilibrium; permafrost, relic*]

Permafrost occurring beneath the sea or ocean bottom.

COMMENT: It occurs either in response to negative sea bottom water temperatures or it formed in coastal areas, exposed to cold air temperatures, which were subsequently submerged. It is currently preserved because of negative sea bottom temperatures in saline water. REFERENCE: Mackay, 1972*a*.

permafrost, syngenetic [see also *permafrost, epigenetic*]

Permafrost that formed more or less simultaneously with the deposition of the ground in which it occurs.

COMMENT: The term "penecontemporaneous," sometimes used instead of syngenetic, is not recommended. Syngenetic contrasts with epigenetic, which is in common use, shorter, and less cumbersome.

permafrost, thaw stable [see also *permafrost, thaw unstable*]

Perennially frozen soils which do not, on thawing, show loss of strength below normal, long-time thawed values nor produce *ground settlement*.

REFERENCE: Linell and Kaplar, 1966.

permafrost, thaw unstable [see also *permafrost, thaw stable*]

Perennially frozen soils which show, on thawing, significant loss of strength below normal, long-time thawed values and/or significant settlement, as a direct result of the melting of the *excess ice* in the soil.

REFERENCE: Linell and Kaplar, 1966.

permafrost, widespread

Permafrost that is widely distributed but not continuous beneath the land surface.

COMMENT: It can be used to describe the distribution of permafrost where it underlies more than 50 per cent of the land surface. The widespread permafrost subzone refers to the northern portion of the *discontinuous permafrost zone* which is located generally north of the $-4°C$ mean annual air isotherm. It could be applied to the *continuous permafrost zone* where permafrost is indeed "widespread" but the term is not normally used in this sense. REFERENCES: Brown, 1967*b*; Brown, 1970*b*.

permafrost aggradation [see also *permafrost degradation*]

An increase in thickness and/or areal extent of permafrost because of natural or artificial causes as a result of climatic cooling and/or change of terrain conditions, such as vegetation succession or infilling of lake basins.

COMMENT: Permafrost aggradation may be expressed as a thinning of the *active layer* or a thickening of the permafrost, or an increase in areal extent.

permafrost base [see also *permafrost table*]

The lower boundary surface of permafrost above which temperatures are negative (below 0°C) and below which temperatures are positive (above 0°C).

permafrost boundary [see *permafrost limit*]

permafrost degradation [see also *permafrost aggradation*]

A decrease in thickness and/or areal extent of permafrost because of natural or artificial causes as a result of climatic warming and/or change of terrain conditions such as disturbance or removal of an insulating vegetation layer by fire or human means.

COMMENT: Permafrost degradation may be expressed as a thickening of the *active layer*, a lowering of the *permafrost table*, a raising of the *permafrost base*, or a reduction in areal extent.

permafrost island [see also *permafrost*, *sporadic*]

An isolated patch of permafrost surrounded by unfrozen ground.

COMMENT: Permafrost islands range in size from about 1 m^2 to several hectares and in thickness from less than 10 cm to 100 m or more. REFERENCE: Brown, 1970*b*.

permafrost limit

The geographical distal boundaries of the circumpolar *continuous* and *discontinuous permafrost zones*.

permafrost table [see also *permafrost base*]

The upper boundary of permafrost.

COMMENT: The depth of this boundary below the land surface, whether exposed or covered by a water body or glacier ice, is variable depending on such local factors as topography, exposure to the sun, insulating cover of vegetation and snow, drainage, grain size and sorting of the soil, and thermal properties of soil and rock. Freezing of the ground upward from the *permafrost table* in the fall has been observed frequently. This upward freezing may comprise 10–30 per cent of the thickness of the total *active layer*. REFERENCES: Hamelin and Cook, 1967; Washburn, 1973.

permafrost thickness

The vertical distance between the *permafrost table* and the *permafrost base*.

permanently frozen ground [not recommended; see *permafrost*]

pingo

An Eskimo term for a conical, commonly more or less asymmetrical mound or hill, with a circular or oval base and commonly fissured summit, occurring in the *continuous* and *discontinuous permafrost zones*, which has a core of massive *ground ice* covered with soil and vegetation, and which exists for at least two winters.

COMMENT: The term pingo was first applied to relatively large features with vertical dimensions of 10 m or more and horizontal dimensions of more than 100 m, but now smaller features only 1 m or so high are called pingos by some. Most pingos are fissured at the top and have star-shaped craters surrounded by escarpments. The fissures and craters open out as rupturing, which results from growth, progresses. Subsequent melting of the ice core leads to partial or total collapse. Pingos can be divided into *open system* and *closed system pingos*. REFERENCES: Mackay, 1962; 1973; Hamelin and Cook, 1967; Washburn, 1973.

pingo, closed system

A genetic term for a pingo, in flat, poorly drained terrain of the *continuous permafrost zone*, that originates where a water-bearing, unfrozen layer of soil, generally in a *thaw basin* underlying a lake, becomes enclosed by *permafrost aggradation* (as when a previously existing lake, which provided insulation, shallows or drains completely) causing the expulsion of pore water. The water may dome up

the overlying permafrost and inject water that freezes into that layer to form the ice-cored pingo, or the overlying permafrost may be domed up by the segregation of ice.

COMMENT: Closed system pingos are common in parts of the Mackenzie River Delta region, and hence are referred to by some authors as *Mackenzie Delta pingos*. (See Figure 17.) REFERENCES: Mackay, 1962; 1966*b*; 1973; Müller, 1963.

pingo, open system

A genetic term for a pingo in areas of marked relief mainly in the *discontinuous permafrost zone*. An open system pingo originates where the hydrostatic pressure of water circulating from higher ground to beneath a frozen layer causes injection of water which freezes into a weakened part of the overlying layer to form the ice-cored pingo.

COMMENT: Open system pingos are common in Eastern Greenland, hence they are referred to by some authors as *East Greenland pingos*. (See Figure 18.) REFERENCE: Müller, 1963.

pingo ice [see *ice, pingo*]

pipkrake [see *ice, needle*]

polygon

A type of *patterned ground* consisting of a closed, roughly equidimensional figure bounded by several sides, commonly more or less straight but some, or all, of which may be irregularly curved.

COMMENT: Polygons commonly occur in groups forming a type of *patterned ground* referred to as *polygonal ground*. Polygons may be classed as *nonsorted* or *sorted* depending on the nature of the borders and interior surfaces (mesh). They occur in mineral terrain and *peatland*.

polygon, depressed centre [see *polygon, low centre*]

polygon, high centre [or, less desirable: *polygon, raised centre*]

A polygon having a centre that is higher than its margins.

COMMENT: In the case of *ice wedge polygons* where erosion, deposition, or thawing proceeds at a higher rate than the heaving of the soil within the polygon adjacent to the *ice wedges*, the low ridges will be absent and there may be either no obvious polygons or the polygons may be higher in the centre than the troughs over the enclosing *ice wedges*. Such polygons may also be called "depressed edge polygons." By some they are erroneously termed *raised centre polygons*. The purely descriptive term *high centre polygon* is preferred. (see Figure 19.) REFERENCES: Péwé, 1966; Washburn, 1973.

polygon, ice wedge [see also *polygon, tundra*]

Any polygon surrounded by troughs underlain by *ice wedges*.

COMMENT: The dimensions of ice wedge polygons may vary from small (diameter $\leqq$ 3 m) to large (maximum diameter $\leqq$ 100 m). The margin may or may not be turned up. Ice wedge polygons may be composed of soil or vegetation or a combination of both.

polygon, low centre [or, less desirable: *polygon, depressed centre*]

A polygon having a centre that is lower than its margins.

COMMENT: In the case of *ice wedge polygons* the soil adjacent to the *ice wedges* is turned up by the growth of the *ice wedges* and also by expansion and shearing of the ground in summer to create a soil ridge on each side of the wedges enclosing the polygon. Such polygons may also be called "raised edge polygons." By some they are erroneously termed "depressed centre polygons." The purely descriptive term "low centre polygon" is preferred. (See Figure 20.) REFERENCES: Péwé, 1966; Washburn, 1973.

polygon, nonsorted [see also *polygon, sorted*]

Patterned ground whose mesh is dominantly polygonal and lacks a border of stones.

COMMENT: Mesh diameter varies widely from less than 1 m to more than 100 m. Nonsorted polygons have a variety of origins, the largest in permafrost regions being associated mainly with thermal contraction and cracking of the ground in extremely cold winter air temperatures. The shape or configuration of the polygons caused by the induced stresses is a function of the type of earth material and other factors. REFERENCES: Lachenbruch, 1966; Washburn, 1973.

polygon, raised centre [see *polygon, high centre*]

polygon, sorted [see also *polygon, nonsorted*]

A polygon having a fine-textured centre surrounded by margins of stones.

COMMENT: Mesh size ranges from about 10 cm to 10 m. They are not confined to permafrost environments but the largest forms are found there. REFERENCE: Washburn, 1973.

polygon, stone [see *polygon, sorted*]

polygon, tundra

Ice wedge polygon covered entirely with *tundra* vegetation.

COMMENT: The polygon may be either the *high centre* or *low centre* type. REFERENCE: Hamelin and Cook, 1967.

polygonal ground [see *polygon*]

poorly bonded [see *bonding*]

pore ice [see *ice, pore*]

R

raised centre polygon [see *polygon, high centre*]

relic permafrost [see *permafrost, relic*]

residual thaw layer [see also *talik*]

The layer of thawed or unfrozen ground between the *seasonally frozen ground* and the *permafrost table.*

COMMENT: This layer may result from thawing of the permafrost which causes a lowering of the *permafrost table.* REFERENCE: Linell and Kaplar, 1966.

retrogressive thaw flow slide [see also *thaw slumping*]

A slide that consists of a steep headwall, containing ice or ice rich sediment, which retreats in a retrogressive fashion through melting, and a debris flow formed from the mixture of thawed sediment and ice, which slides down the face of the headwall to its base.

COMMENT: The term *bi-modal flow* for this feature is preferred by some. REFERENCES: McRoberts and Morgenstern, in press; Rampton and Mackay, 1971.

S

sand wedge [see also *soil wedge*]

A generally wedge-shaped downward tapering body of sand produced by repeated *frost cracking* and infilling with sand.

COMMENT: It may be considered as one type of *soil wedge* but it is not a replacement feature associated with the melting of an *ice wedge*. REFERENCE: Washburn, 1973.

seasonal frost [see also *active layer*]

Seasonal temperatures causing frost (below 0°C temperatures) that affect earth materials and keep them frozen only during the winter.

seasonally frozen ground [see also *active layer*]

Ground affected by *seasonal frost*.

COMMENT: In permafrost areas *seasonally frozen ground* can be equated with the *active layer*.

seasonally thawed ground [see also *active layer*]

Ground affected by seasonal thaw during the summer and *seasonal frost* during the winter.

COMMENT: In permafrost areas seasonally thawed ground can be equated with the *active layer*.

segregated ice [see *ice, segregated*]

sill ice, [see *ice, sill*]

single-vein ice [see *ice, single-vein*]

soil wedge [see also *ice wedge cast; sand wedge*]

A generally wedge-shaped, downward tapering body of soil different in structure (and possible texture) from the surrounding soil, which may be an *ice wedge cast* or produced by repeated *frost cracking* and infilling with soil where no *ice wedge* was ever present.

COMMENT: Soil wedges are found in *periglacial* regions and areas formerly subjected to *periglacial* conditions. (See Figure 21.) REFERENCE: Washburn, 1973.

solifluction

The process of slow, gravitational, downslope movement of saturated, nonfrozen earth material behaving apparently as a viscous mass over a surface of frozen material.

COMMENT: Although applied occasionally in a wider sense than the concept of soil movement caused by freezing and thawing, the term is here regarded as applicable to cold climates only although the process is not confined to permafrost regions. The slowness of the movement is expressed by rates of flow in the order of 0.5 to 10 cm or so per year. REFERENCES: Gary *et al.*, 1972; Washburn, 1973.

solifluction features

Physiographic features of varying scale produced by the process of *solifluction* which include:

lobe—isolated, tongue-shaped feature, up to 25 m wide and 150 m or more long, formed by more rapid *solifluction* on certain sections of the slope showing variations in gradient, commonly with a steep (15° to 25°) front and a relatively smooth upper surface (see Figure 22).

REFERENCE: Gary *et al.*, 1972.

stripe—one of alternating, differently textured or structured, soil bands produced on a sloping surface. [See also *stripe, sorted; stripe, nonsorted*].

sheet—broad deposit of nonsorted, water-saturated, locally derived material which has moved downslope.

REFERENCE: Gary *et al.*, 1972.

terrace—low step or bench commonly with a lobate front, reflecting differences in rates of flow, and having bare mineral soil on the up-slope part and folded-under organic matter in both the seasonally thawed and the frozen soil.

REFERENCE: Brown, 1969.

southern limit of permafrost [see *permafrost limit*]

sporadic permafrost [see *permafrost, sporadic*]

spot medallion [see *nonsorted circle*]

step

Patterned ground feature occurring in groups displaying a step-like form and downslope border of vegetation or stones embanking an area of relatively bare ground up-slope.

COMMENT: Steps are restricted to slopes, mainly 5° to 15°, and are derived from *circles*, *polygons*, or *nets*, rather than having developed independently. They can be nonsorted or sorted. Like their parent forms, they originate in both permafrost and non-permafrost environments. REFERENCE: Washburn, 1973.

stone net [see also *nets*]

A type of *patterned ground* characterized by a textural differentiation caused by frost action between fine-grained soils in the centre and coarse-grained, stony materials forming the rims of an irregular network of features intermediate between *sorted circles* and *sorted polygons*.

COMMENT: The diameter of the *sorted polygons* forming the net varies from 1 cm or more to as much as 10 m. REFERENCE: Washburn, 1956.

stone polygon [see *polygon, sorted*]

stone stripe [see *stripe, sorted*]

stony earth circle [see *circle, nonsorted*]

string bog

Boggy area marked by serpentine ridges of *peat* and vegetation, interspersed with depressions many of which contain shallow ponds.

COMMENT: The ridges or "strings" are 1 to 3 m wide, up to about 1 m high, and may be 10 m or more long. There is a gentle regional slope, but string bogs occur mainly on gradients of less than 2°. There is considerable controversy over the origin of string bogs and their relation to permafrost. They are best developed in the *discontinuous permafrost zone* near the *southern limit of permafrost* and immediately to the south of the permafrost region. REFERENCE: Washburn, 1973

stripe, nonsorted [see also *stripe, sorted*]

Patterned ground with a striped pattern and a nonsorted appearance owing to parallel lines of vegetation-covered ground and intervening strips of relatively bare ground oriented down the steepest slope.

COMMENT: The width of the vegetated strips or stripes is generally 1 m or less and the stripes are spaced 1 m or more apart on slopes of up to 5° or so. They are not confined to permafrost regions but the largest forms are found there. REFERENCE: Washburn, 1973.

stripe, sorted [see also *stripe, nonsorted*]

Patterned ground feature occurring in groups displaying a striped pattern and a sorted appearance due to parallel lines of stones and intervening strips of finer material oriented down the steepest available slope.

COMMENT: The stony strips or stripes may be 1 cm or more to 1.5 m or more wide, and the intervening finer stripes tend to be several times wider than the coarser ones. Sorted stripes can be up to 120 m long on slopes ranging mainly from 3° to 7°. The largest forms are commonly associated with permafrost although they occur in many environments. REFERENCE: Washburn, 1973.

submarine permafrost [see *permafrost, submarine*]

subpermafrost water [see also *intrapermafrost water; suprapermafrost water*]

Free water in the ground below the *permafrost base.*

REFERENCE: Williams, 1965.

suprapermafrost water [see also *intrapermafrost water; subpermafrost water*]

Free water in the ground above the permafrost.

COMMENT: The *permafrost table* forms the floor for such water. This water is recharged directly from the ground surface and is wholly or in part subject to freezing in winter. It occurs commonly beneath lakes, rivers, some parts of flood plains, terraces, slopes of southern exposure, and hilltops. Locally, suprapermafrost water may become confined and subjected to increasing pressure by the downward extension of *seasonal frost* toward the *permafrost table.* REFERENCES: Williams, 1965; Williams and Walter, 1966.

syngenetic ice [see *ice, syngenetic*]

syngenetic permafrost [see *permafrost, syngenetic*]

T

talik [see also *residual thaw layer*]

A layer or body of unfrozen ground within the permafrost.

COMMENT: It is also used to refer to the layer or body of unfrozen ground between the *seasonally frozen ground* and the permafrost although the term *residual thaw layer* is preferred in this context. REFERENCE: Washburn, 1973.

talik, closed

Talik, or unfrozen ground, entirely surrounded by permafrost.

talik, open

Talik, or unfrozen ground, not entirely surrounded by permafrost.

tension-crack ice [see *ice, tension-crack*]

thaw basin

A depression of the *permafrost table* created by natural or artificial thawing.

COMMENT: Thaw basins exist beneath bodies of water in permafrost regions, such as lakes or rivers, which do not freeze to the bottom in winter. They may be 10 m to 100 m or more in depth. They can develop also beneath buildings which emit heat into the ground, reservoirs, and hot oil pipelines. REFERENCE: Lachenbruch, 1970.

thaw bulb [see *thaw basin*]

thaw consolidation

1. The process by which a reduction in volume and increase in density of a soil mass occurs, following thaw, in response to the escape of water under the weight of the soil itself and/or an applied load.
2. The process by which settlement due to thaw (*thaw settlement*) is impeded by the flow of water from the soil.

COMMENT: It is a time-dependent phenomenon that is not governed exclusively by the rate of thaw or position of the thaw front. Thaw consolidation may proceed for many years.

thaw flowing [see *thaw slumping*]

thaw lake [see *thermokarst*]

thaw settlement [see also *thermokarst*]

The generally differential downward movement of the ground surface resulting from escape of water on melting of *excess ice* in the soil and the *thaw consolidation* of the soil mass.

thaw slumping

A type of mass movement caused by the conversion of ice into water in a soil by ground thaw, creating the kind of landslide that most closely resembles the more temperate climate earth flow, with a well-developed breakaway scarp front.

COMMENT: Because thaw slumping is not characterized by an independent mass of earth material moving as a unit along a curved slip surface, and because therefore the typical morphological features of what are called slumps in temperate climates (such as a backward tilted slump surface or lunate tension cracks) are absent, it is deemed advisable to substitute "flowing" and "flow" for "slumping" and "slump."' Thaw flowing differs from *solifluction* in that it has a generally faster rate of movement and a pronounced breakaway scarp; but a gradation exists and the terms are not clearly separable.

REFERENCE: Mackay, 1966*a*.

thaw stable permafrost [see *permafrost, thaw table;* see also *permafrost, thaw unstable*]

thaw unstable permafrost [see *permafrost, thaw unstable;* see also *permafrost, thaw stable*]

thawing index [see also *freezing index*]

The number of degree-days (the difference between the mean temperature each day and 0°C, either positive or negative) between the lowest point in the spring and the highest point the next autumn on the cumulative degree—a day time curve for one thawing season.

COMMENT: It is a measure of combined duration and magnitude of above-freezing temperatures during a year. REFERENCE: Boyd, 1973.

thermal contraction ice [see *ice, thermal contraction*]

thermokarst (topography)

The irregular topography resulting from the process of differential *thaw settlement* or caving of the ground because of the melting of ground ice in *thaw unstable permafrost.*

COMMENT: Thermokarst is so named because of superficial resemblance to the karst topography typical of limestone regions subject to solution by surface and ground waters. In thermokarst, however, there is little or no underground drainage. The annual thawing of the *active layer* does not produce thermokarst which only results where ice in permafrost melts following such events as forest fires, fissuring or breaking of the surface, destruction of an insulating vegetational cover by animals, man, or any other natural or man-made disturbance of the thermal regime including the acceleration of the rate of thawing by moving surface water. Morphological features of thermokarst topography include:

depression [see also *alas*]—also called "thaw depression."

lake—also called *thaw lake* or *cave-in lake*, occupying *thermokarst depressions* (Figure 23).

mound [see also *cemetery mound*]—residual polygonal hummock bordered by depressions.

pit—small, equidimensional depression.

REFERENCES: Hamelin and Cook, 1967; Péwé, 1954; Rampton and Walcott, 1974; Washburn, 1973.

thufur [see *hummock*]

tundra

A treeless, generally level to undulating, region of lichens, mosses, sedges, grasses, and some low shrubs, including dwarf willows and birches, which is characteristic of both the Arctic and higher alpine regions outside of the Arctic.

COMMENT: The term is used to refer to both the region and the vegetation association growing in it.

tundra polygon [see *polygon, tundra*]

turf hummock [see *hummock, turf*]

U

unfrozen water content

The ratio, expressed as a percentage, of the weight of unfrozen water to the weight of dry soil.

COMMENT: Total water content = ice content + unfrozen water content. The main factors thought to control the amount of unfrozen water in frozen soils are specific surface area of mineral particles, mineral type, kind of exchangeable ions, soluble salt content of the soil water, and pore size distribution. The unfrozen water content is highest in clays and it decreases with temperature. Some clays may have 20 per cent of their moisture in the liquid state at about −2.5°C and 15 per cent at −10°C. REFERENCES: Corte, 1969; Penner, 1970; Williams, 1968.

upper surface of permafrost [see *permafrost table*]

V

vein ice [see *ice, vein*]

W

wedge ice [see *ice, wedge*]

well bonded [see *bonding*]

widespread permafrost [see *permafrost, widespread*]

Z

zero curtain

The zone immediately above the *permafrost table* where zero temperature (0°C) lasts a considerable period of time during freezing and thawing of the overlying ground.

COMMENT: The zero curtain is caused by the latent heat of fusion of water, which retards freezing and thawing by several weeks. The higher the moisture content at the *permafrost table*, the greater the delay. REFERENCES: Muller, 1947; Washburn, 1973.

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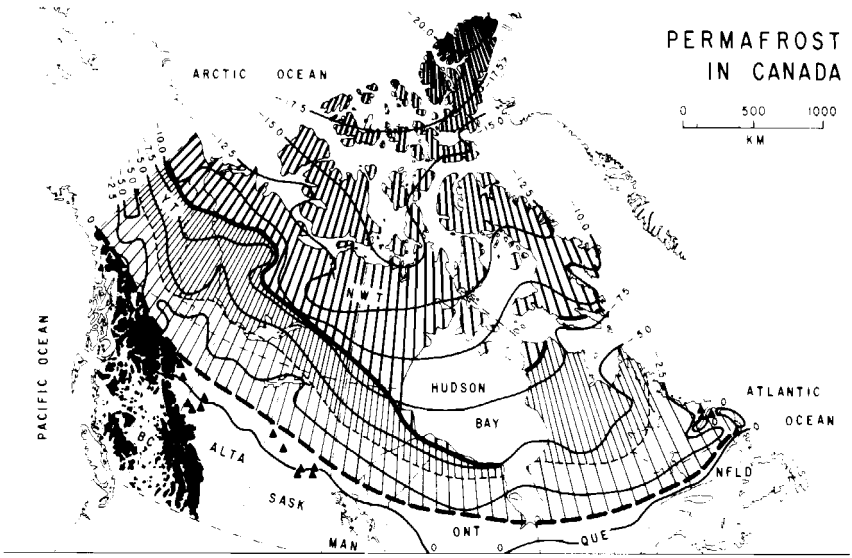


PERMAFROST

CONTINUOUS PERMAFROST ZONE

Southern limit of continuous permafrost zone

DISCONTINUOUS PERMAFROST ZONE

Widespread permafrost

Southern fringe of permafrost region

Southern limit of permafrost

Patches of permafrost observed in peat bogs south of permafrost limit

Permafrost areas at high altitude in Cordillera, south of permafrost limit

Mean annual air temperature, °C

Figure 1. *Permafrost* in Canada. (*From* Brown, 1970*b*. © University of Toronto Press 1970.)

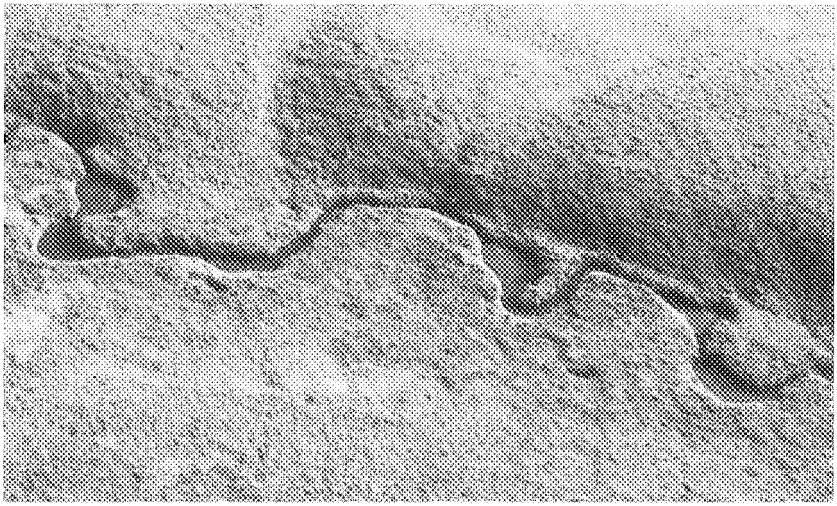


Figure 2. *Beaded stream.* Air view from an altitude of about 300 m in continuous permafrost zone near Tuktoyaktuk, N.W.T. (*From* Brown, 1970*b*. © University of Toronto Press 1970.)

Figure 3. *Cemetery mound.* Mounds 1 to 2 m high on Aldan River, Siberia in discontinuous permafrost zone. (*From* Brown, 1967*a*. Reproduced by permission from *Polar Record*, Vol. 13, 1967.)

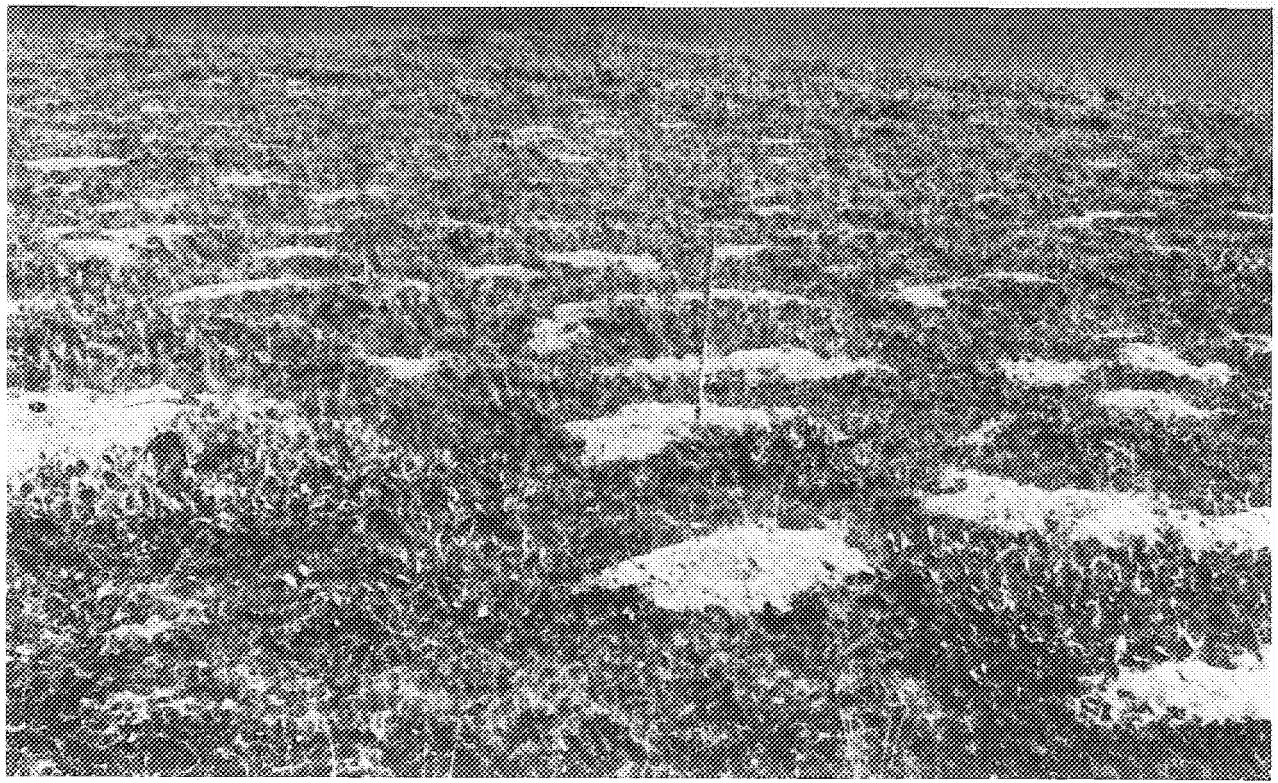


Figure 4. *Circle, nonsorted.* Circles up to 1 m in size on Arctic Coast near Coppermine, N.W.T. in continuous permafrost zone. (Division of Building Research, National Research Council of Canada.)

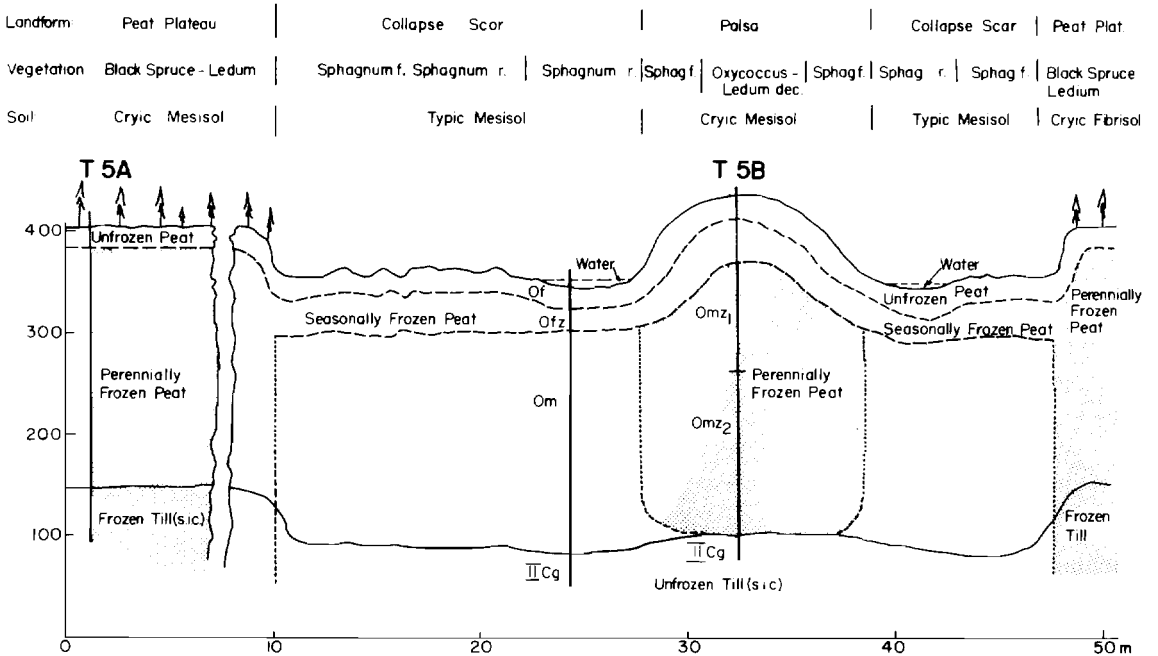


Figure 5. *Collapse scar.* Cross-section of a peat plateau-collapse scar area with a young palsa and of a wooded palsa-fen area in discontinuous permafrost zone. (*From* Tarnocai, 1973. Reproduced with permission of Environmental-Social Program, Northern Pipelines.)

Figure 6. *Drunken forest*. Leaning spruce trees on palsa near Snow Lake, northern Manitoba in discontinuous permafrost zone. (Division of Building Research, National Research Council of Canada).

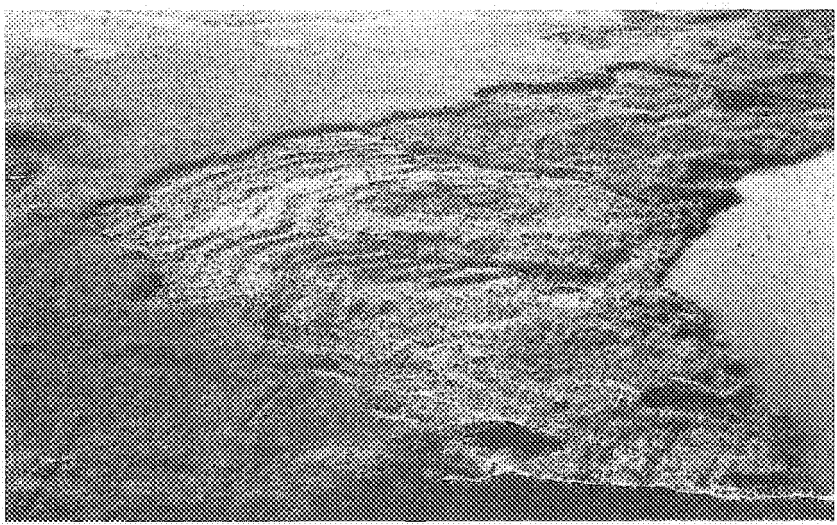


Figure 7. *Ground Settlement*. Air view from an altitude of about 300 m near Tuktoyaktuk, N.W.T. in continuous permafrost zone. (Division of Building Research, National Research Council Canada.)

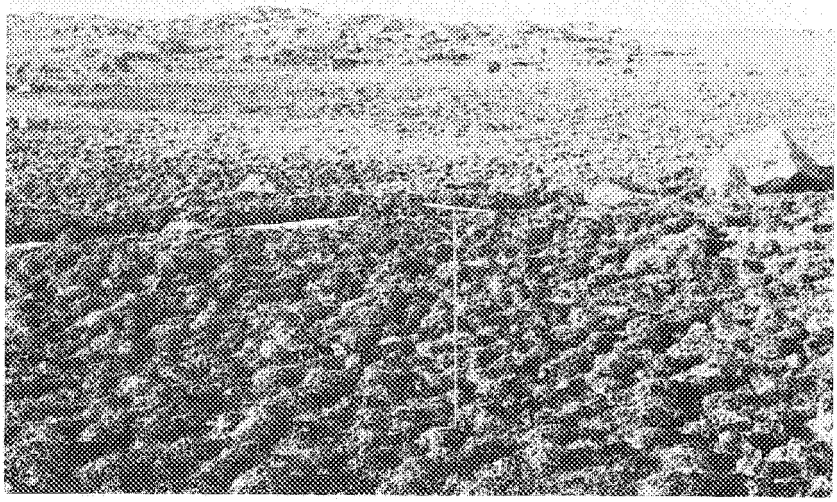


Figure 8. *Hummock, turf.* Hummocks 10 to 15 cm high on north coast of Devon Island, Arctic Archipelago in continuous permafrost zone. (*From* Brown, 1972. Reproduced by permission from *Zeitschrift für Geomorphologie*, Suppl. Bd. 13, July 1972.)

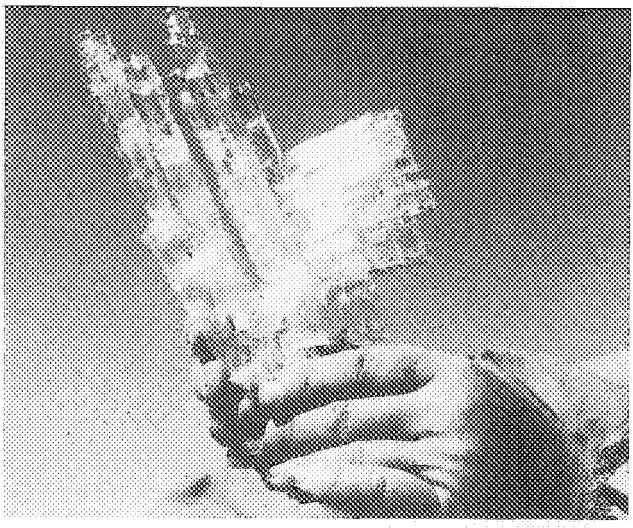


Figure 9. *Ice, closed-cavity.* Ice crystals from the ceiling of a cavity in permafrost, Mackenzie River Delta region in continuous permafrost zone. (*From* Mackay, 1972*b*. Reproduced by permission from the *Annals* of the Association of American Geographers, Volume 62, 1972.)

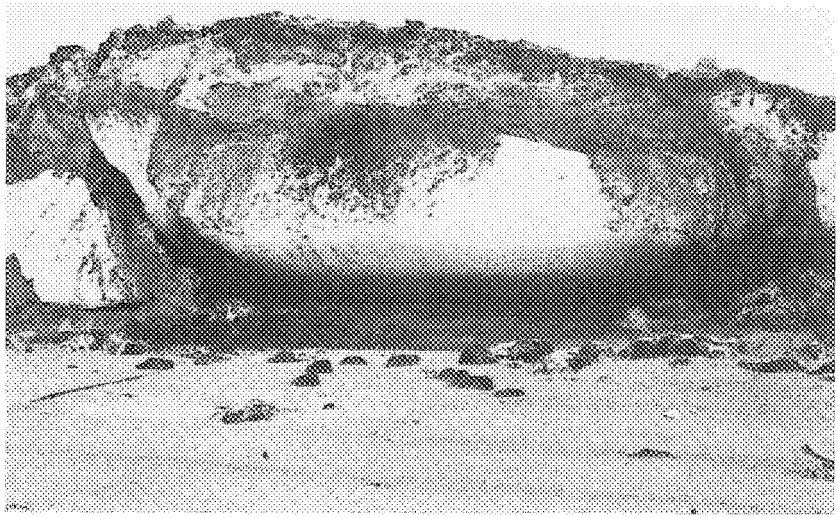


Figure 10. *Ice, pingo.* Pingo ice core exposed by coastal erosion. Original pingo height estimated at 7 to 10 m. Near Tuktoyaktuk, N.W.T. in continuous permafrost zone. (*From* Mackay, 1972*b*. Reproduced by permission from the *Annals* of the Association of American Geographers, Volume 62, 1972.)

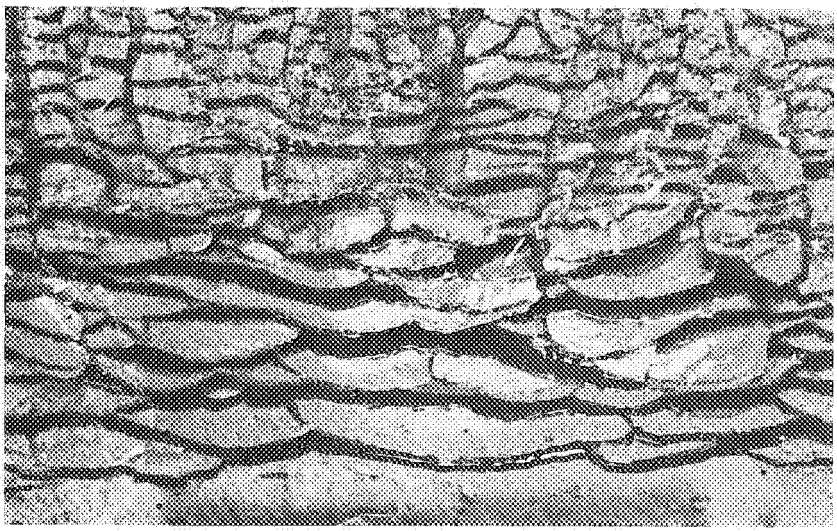


Figure 11. *Ice, segregated.* Ice layers (black), mainly horizontal up to 5 mm thick in grey silty clay. (*From* Penner, 1972.)

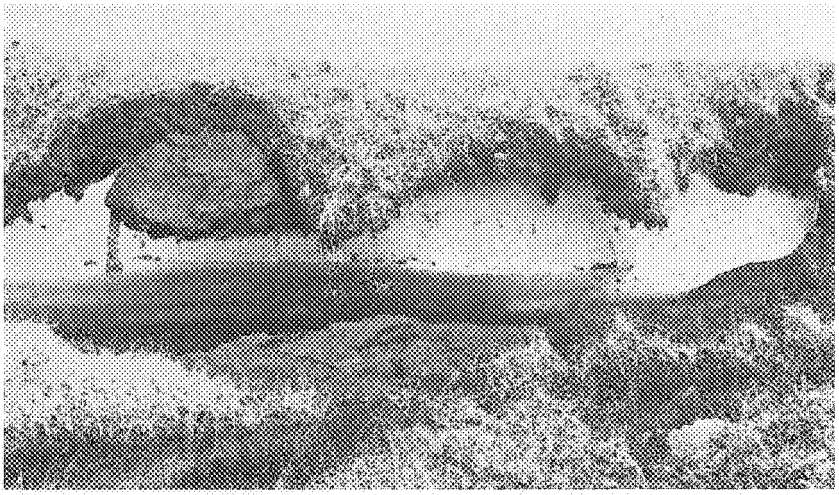


Figure 12. *Ice, sill.* Tabular sheet of pure ice at least 1.2 m thick in Brock River Delta, N.W.T. near Mackenzie River Delta in continuous permafrost zone. (*From* Mackay, 1972*b*. Reproduced by permission from the *Annals* of the Association of American Geographers, Volume 62, 1972.)

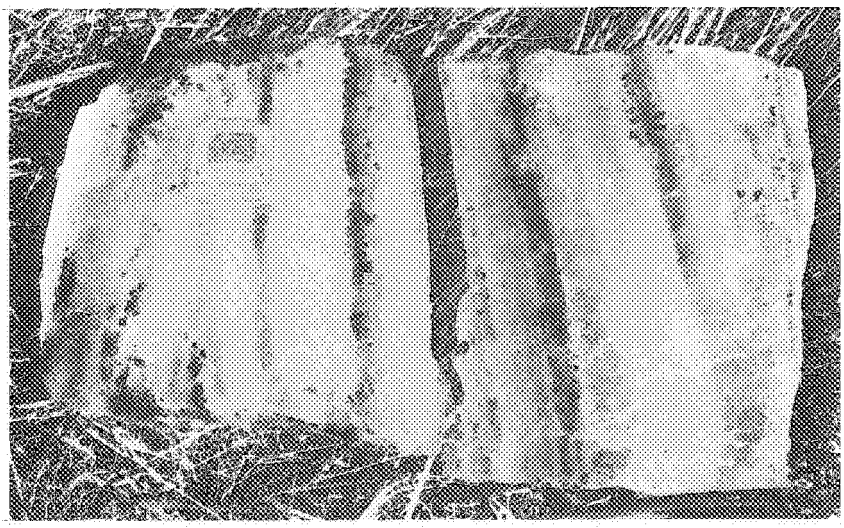


Figure 13. *Ice, tension-crack.* Ice from top of a pingo near Tuktoyaktuk, N.W.T. in continuous permafrost zone. (*From* Mackay, 1972*b*. Reproduced by permission from the *Annals* of the Association of American Geographers, Volume 62, 1972.)

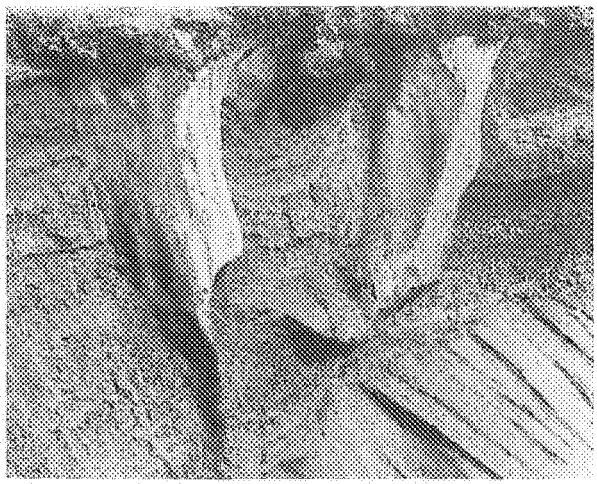


Figure 14. *Ice wedge*. The ice wedge on the left is about 4.5 m wide at the top. Mackenzie River Delta region in continuous permafrost region. (*From* Mackay, 1972*b*. Reproduced by permission from the *Annals* of the Association of American Geographers, Volume 62, 1972.)

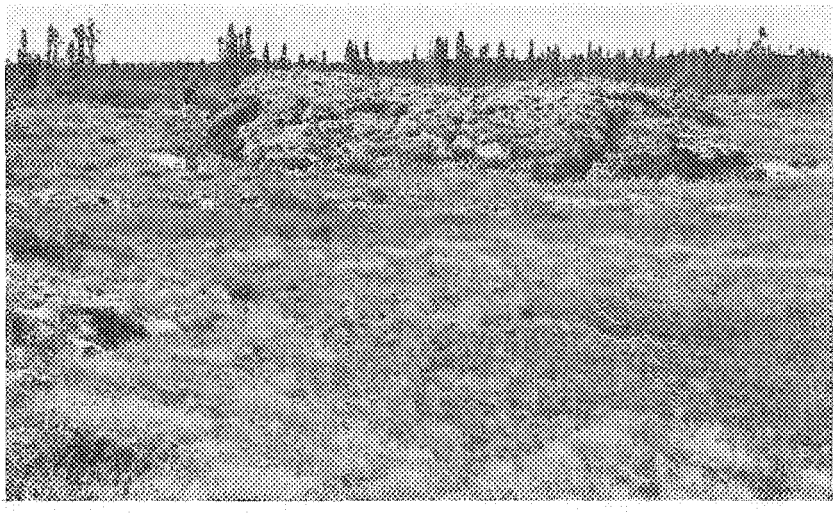
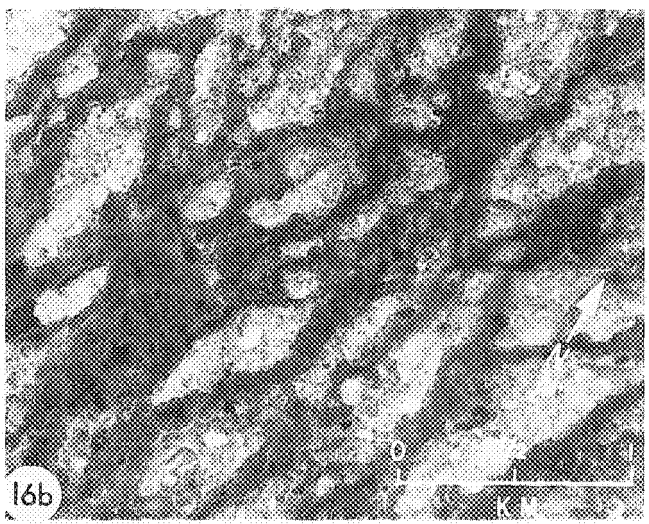


Figure 15. *Palsa*. Palsa about 3 m high on east coast of Hudson Bay near Great Whale River, P.Q. in discontinuous permafrost zone. (Division of Building Research, National Research Council of Canada.)

Figure 16. *Peat plateau.*
(a) Air view from an altitude of about 120 m of forested peat plateau (top of photograph). Wet sedge-covered treeless depression with no permafrost (middle of photograph). (*From* Brown, 1970*b*. © University of Toronto Press, 1970.)



(b) Aerial photograph (A14188-119; National Air Photo Library) of peat plateaus (light grey toned areas) and wet sedge-covered depressions (dark grey toned areas). Northern Manitoba near Gillam in discontinuous permafrost zone. (*From* Brown, 1970*b*. © University of Toronto Press 1970.)

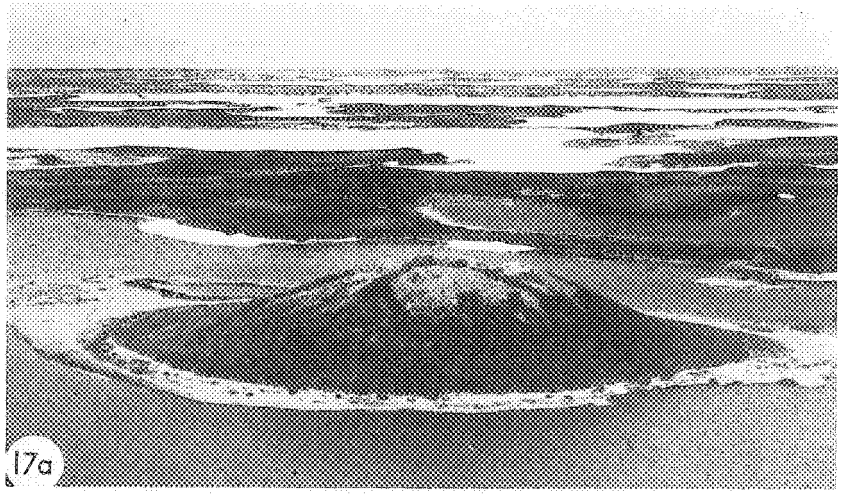
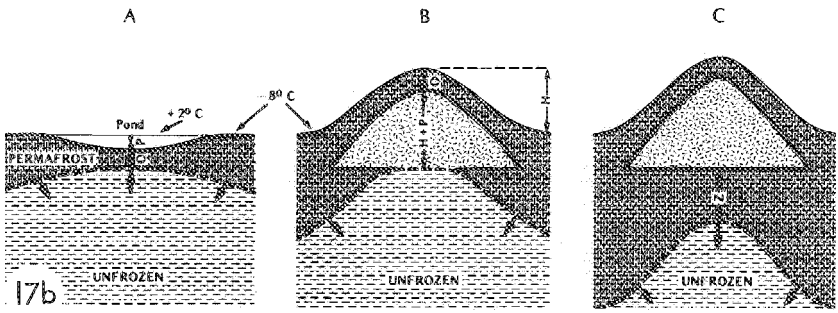
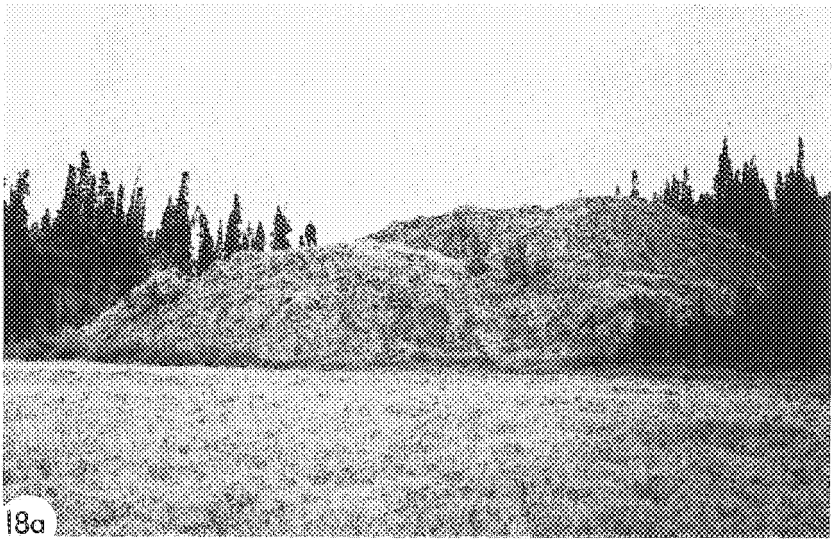


Figure 17. *Pingo, closed system.*

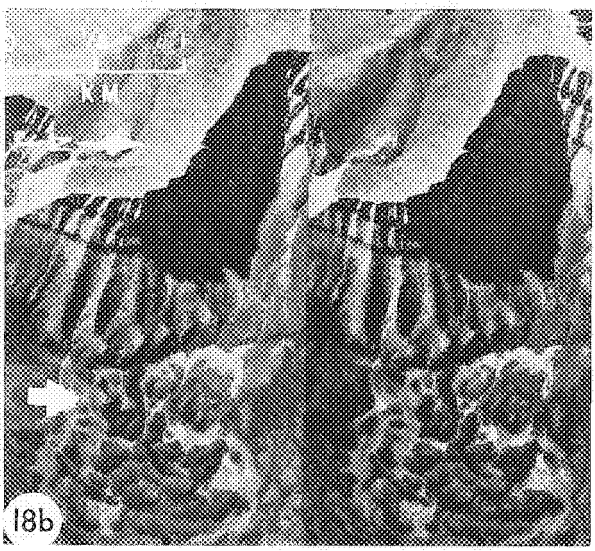
(a) Pingo, 27 m high, in centre of shallow lake near Tuktoyaktuk, N.W.T. in continuous permafrost zone. (*From* Mackay, 1972*b*. Reproduced by permission from the *Annals* of the Association of American Geographers. Volume 62, 1972.)

(b) Schematic diagram of growth of pingo. Diagram A shows a residual pond of depth P and permafrost beneath it at the moment that pingo growth commences. As the ice core grows, the freezing plane remains stationary, and the permafrost becomes uplifted to form the overburden thickness above the ice core. Diagram B shows a pingo with the freezing plane at the bottom of the ice core. There is no overburden; the height of the pingo above the lake bottom is H; and the maximum height of the ice core is H + P. Diagram C shows a pingo with the freezing plane at a depth z below the ice core. The pingo can continue to grow from ice segregation and the freezing of pore water in a confined system. (*From* Mackay, 1973. Reproduced by permission of the National Research Council of Canada from the Canadian Journal of Earth Sciences, Volume 10, pp. 979-1004, 1973.)





18a



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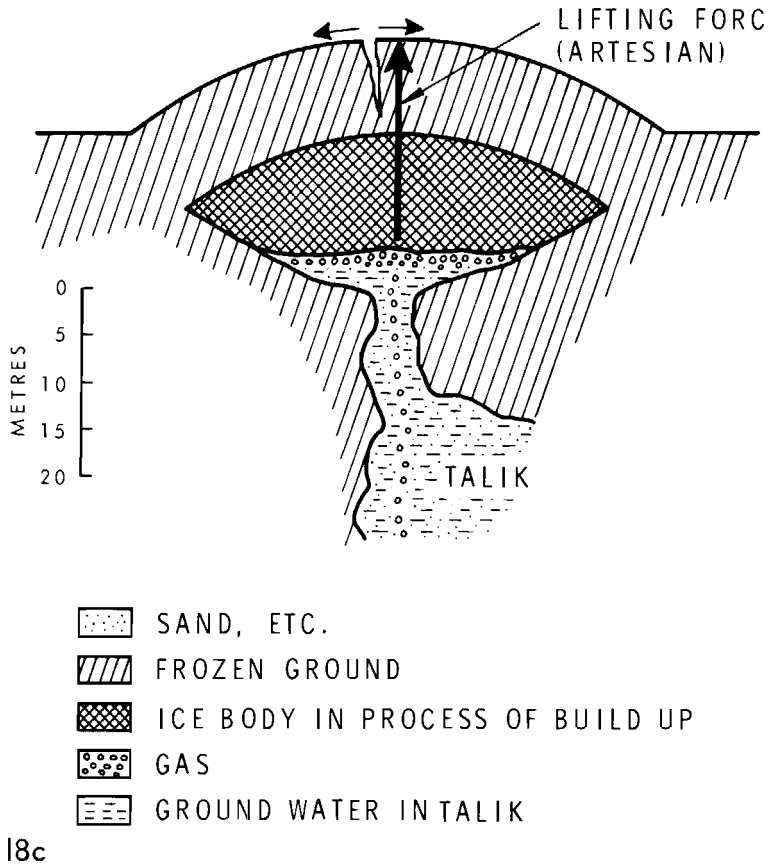

Figure 18. *Pingo, open system.*

(a) Pingo about 12 m high at base of Richardson Mountains west of Mackenzie River Delta. (*From* Fraser, 1956. Reproduced by permission of *Canadian Geographer*, No. 8, p. 18-23, 1956.)

(b) Stereo pair of aerial photographs (A12861-188 and 189; National Air Photo Library) of pingo (white arrow) in landslide area on alluvial fans at base of Richardson Mountains. (Division of Building Research, National Research Council of Canada).

(c) Schematic diagram of growth of open system pingo. (Müller, 1968. *From* Fairbridge: ENCYCLOPEDIA OF GEOMORPHOLOGY, published by Van Nostrand Reinhold Co., copyright 1968 by Litton Educational Publishing, Inc.)

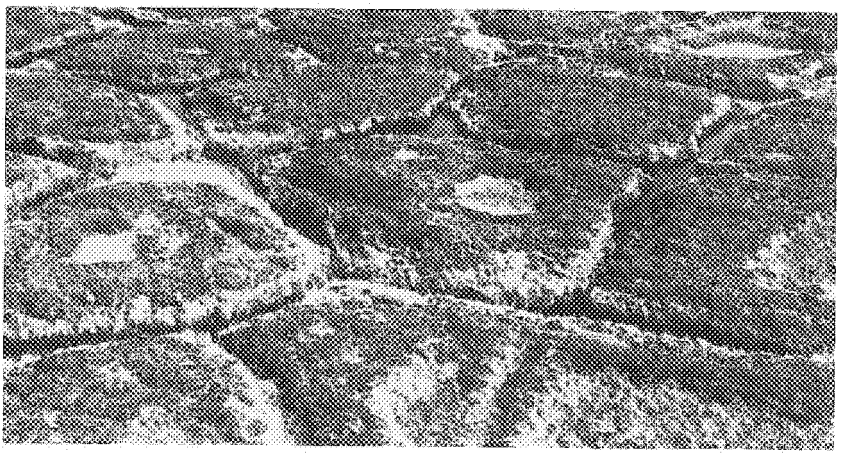

Figure 19. *Polygon, high centre.* Mainly high centre polygons near Tuktoyaktuk, N.W.T. in continuous permafrost zone. Some of the polygons in the foreground still have small depressions in the centre, and are in the transitional stage from low to high centre polygons. The water in the troughs is 30 to 60 cm deep. The average polygon is about 8 to 12 metres in diameter. (Reproduced with permission of J.R. Mackay, Department of Geography, University of British Columbia.)

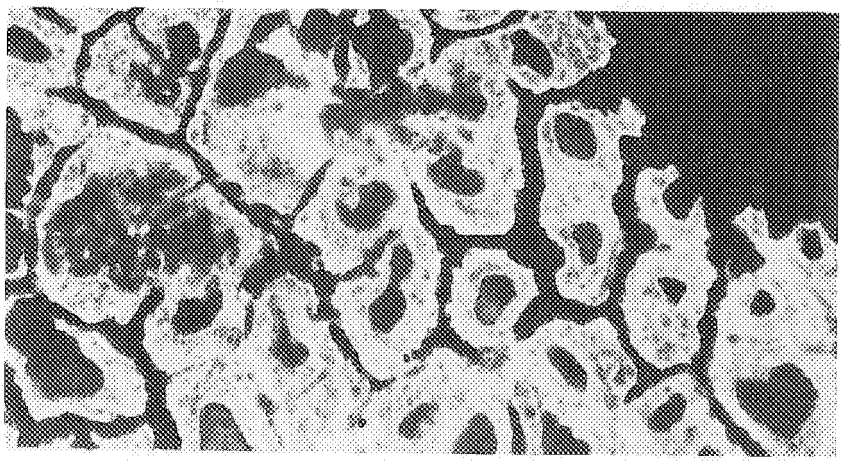

Figure 20. *Polygon, low centre.* Air view of low centre polygons having rims which enclose a saucer-like central depression near Tuktoyaktuk, N.W.T. in continuous permafrost zone. The central depressions are saturated and usually have standing water for much of the summer. The polygons are encroaching onto a shallow lake. The smallest polygons are about 5 metres in diameter, the largest, about 15 m. (Reproduced with permission of J.R. Mackay, Department of Geography, University of British Columbia.)

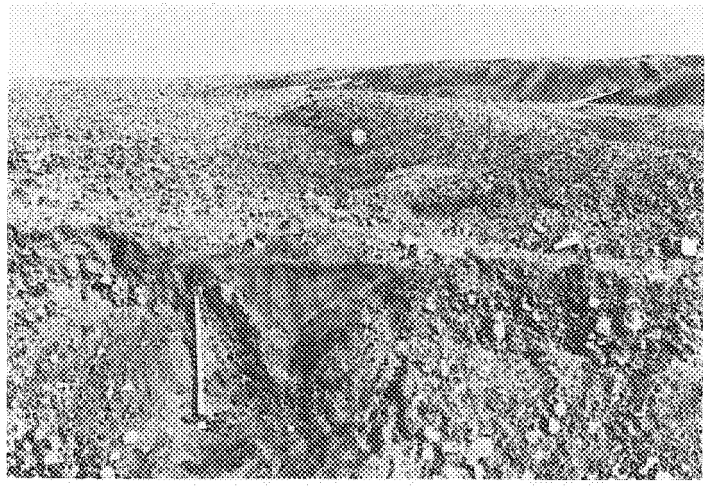

Figure 21. *Soil wedge.* Wedge consists of sand and layers of organic material beneath polygonal trench in glaciofluvial deposits at Mary River, northern Baffin Island, Arctic Archipelago, in continuous permafrost zone. Active layer is 1.7 m thick. (*From* Brown, 1972. Reproduced by permission from *Zeitschrift für Geomorphologie*, Suppl. Bd. 13, July 1972.)

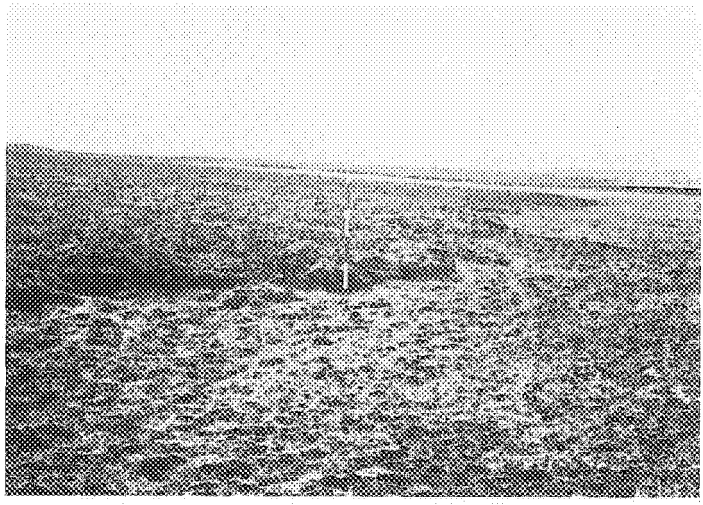

Figure 22. *Solifluction lobe.* Lobe on very gentle slope on Banks Island, Arctic Archipelago, in continuous permafrost zone. (*From* Brown, 1972 *Zeitschrift für Geomorphologie*, photograph by H.M. French, Department of Geography, University of Ottawa.)

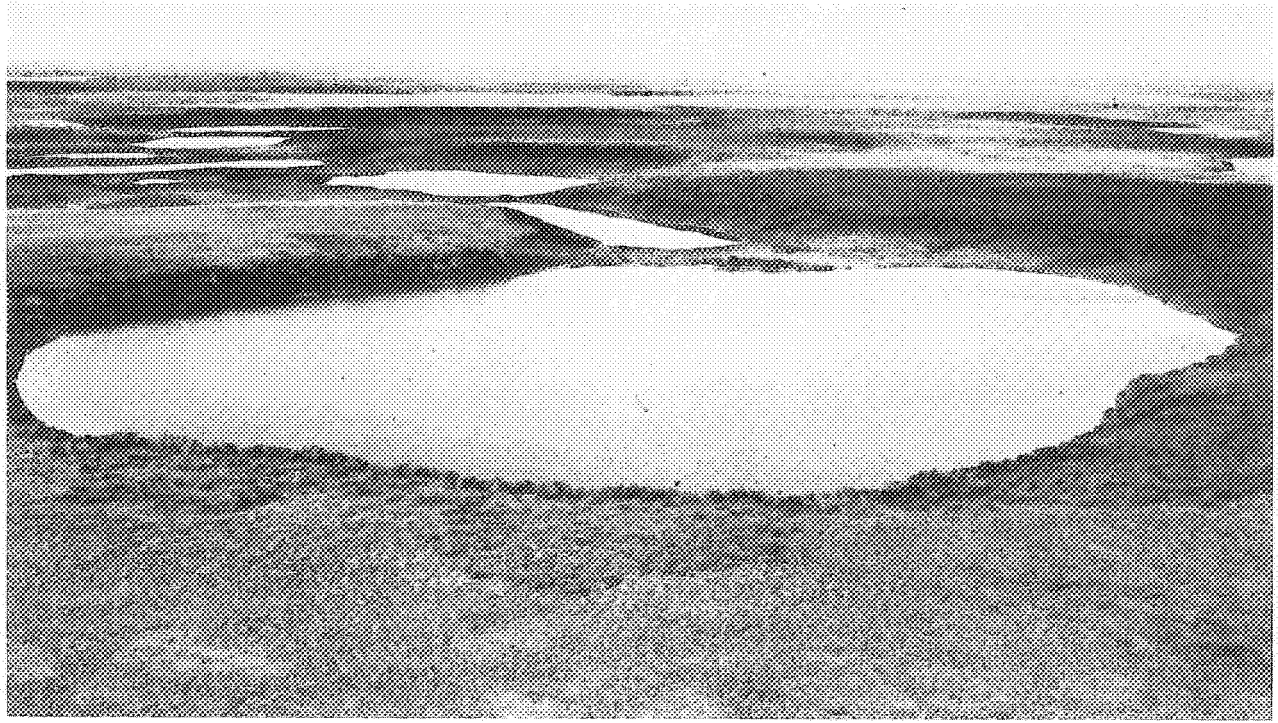

Figure 23. *Thermokarst lake.* Coalescing lake-filled thermokarst depressions in outwash plain at eastern end of Eskimo Lakes near Tuktoyaktuk N.W.T. The surface of the 450-m diameter lake in foreground lies about 15 m below the surface of the plain; its depth is about 5.4 m. Nearby exposures show massive ground ice underlying 15 m of glaciofluvial sand and silt. (Reproduced with permission of V.N. Rampton, Geological Survey of Canada, Department of Energy, Mines and Resources.)