INTERNATIONAL PERMAFROST ASSOCIATION

MULTI-LANGUAGE GLOSSARY of

PERMAFROST and

RELATED GROUND-ICE TERMS

in

Chinese, English, French, German, Icelandic, Italian

Norwegian, Polish, Romanian, Russian, Spanish, and Swedish

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INTRODUCTION

Background

During the 5th International Conference on Permafrost, held in Trondheim (Norway) in August 1988, the Council of the International Permafrost Association (IPA) authorized the establishment of a Terminology Working Group with the mandate "to develop a set of internationally accepted permafrost terms for use in engineering and science, with equivalents in various languages, and to disseminate and encourage the use of such terminology". The Terminology Working Group was established in the fall of 1988, with members from Argentina, Canada, China, Finland, France, Germany, the USA, and the (former) USSR. Members from Italy, Norway and Sweden were added later.

The Working Group agreed to use as the basis for its work the "Glossary of Permafrost and Related Ground-Ice Terms", which had just been published (Permafrost Subcommittee, 1988). The initial effort was directed towards the preparation of a multi-language listing incorporating the primary and secondary terms from the 1988 Glossary, and a number of synonyms. The languages to be covered by the glossary were to be English, French, German, Spanish, and Russian. By the end of 1994, Italian, Norwegian, and Swedish were included. The effort was coordinated by the Chair of the Working Group, at the Arctic Institute of North America.

In December 1994 a pre-publication version was printed for limited distribution to solicit comments and corrections. Corrections were made and some additional terms incorporated in 1995, 1996, and 1998. In addition, Chinese, Icelandic, Polish, and Romanian were included.

In order to avoid possible confusion of entries such as "ice, wedge" and "ice wedge", all multi-word terms have been entered using the natural word sequence (i.e. "wedge ice" and "ice wedge" for the above example). The elimination of commas also improves the readability.

Version 2

"Version - 2 (1998)" of the Glossary, published in 1998 at the IPA International Permafrost Conference in Yellowknife, Canada, should be regarded as the latest stage of a work in progress, because the terminology in permafrost science and engineering is continuing to evolve, and the Glossary should evolve with it.

Chinese

Listings of Chinese equivalents were provided by Cheng Guodong, Qiu Guoqing, Zhao Xiufeng and Zhou Youwu. The search for appropriate software delayed the inclusion of Chinese terms in the Glossary database until late 1996. Word-processing for the Chinese entries by Zhao Xiufeng is gratefully acknowledged.

Pinyin Version of Chinese

Pinyin conversions of the Chinese terms have been added to the Glossary for the convenience of non-Chinese users.

French

At the time of publication of the 1988 Glossary (Permafrost Subcommittee, 1988), a French translation was also published (Sous-comité de Pergélisol, 1988). From this, most of the French equivalents of the primary and secondary terms were incorporated in the database without change. Changes were made for 46 of the terms, following suggestions from the French Commission for the Study of Periglacial Phenomena (Commission Française pour l'Étude des Phénomènes Périglaciaires), which were received from J.-P. Lautridou in January 1991. Examples of the changes include: "couche active" instead of "mollisol"; "géli-adhérence" instead of "congélation adhérente"; and "frange gelante" instead of "frange gelée". Corrections and a few additions, provided by B. van Vliet-Lanoe, were incorporated in 1993, 1996, and 1998.

German

A German translation of "Permafrost Terminology" (Brown and Kupsch, 1974) had been prepared in 1982 by J. Karte. The German equivalent terms from that translation were incorporated in the database, with a number of corrections and additions provided by J. Karte and L.King, in 1991. Additional terms were added in 1994, 1996, and 1998.

Icelandic

Preparation of a listing of Icelandic terms for the glossary was undertaken by H. Pétursson in the spring of 1995. The list of Icelandic terms was received in December 1996, and the terms were incorporated in the database. Corrections were made, and additional terms incorporated in 1997 and 1998.

Italian

Italian translations of the terms from the 1988 Glossary were prepared by C. Ottone and F. Dramis in 1992, and incorporated in the database after they were formally accepted in November 1992 by the Italian adhering body for IPA. Translations for a few additional terms were included in early 1994, in 1996, and in 1998.

Norwegian

Preparation of a listing of Norwegian terms for the glossary was undertaken by O. Gregersen and O. Salvigsen in the fall of 1992. The list of Norwegian terms was received in April 1993, and the terms were incorporated in the database before the 6th International Conference on Permafrost in Beijing, July 1993. Translations for additional terms were included in March 1994, in 1996, and in 1998.

Polish

Preparation of a listing of Polish terms for the glossary was started by K. Pekala in the spring of 1995, with the cooperation of J. Repelewska-Pękalowa, S. Kozarsky, and L. Marks. The list of Polish terms was received in July 1995, and the terms were incorporated in the database shortly thereafter. A few additional terms were incorporated in 1996 and 1998.

Romanian

Preparation of a listing of Romanian terms for the glossary was undertaken by

P. Urdea in 1996, and a list of Romanian terms was received later that year. A few additional terms were added in 1998.

Russian

A copy of the Russian translation of the whole 1988 Glossary, prepared by N. N. Romanovskiy, G. Rozenbaum, and V. N. Konishchev (Moscow, Russia), was received in February 1991. The Russian equivalents of the primary and secondary terms have been incorporated in the multi-language database. Corrections and translations for a number of additional terms were provided by the same authors in early 1994. Further revisions were made in the fall of 1995 during a visit by N. N. Romanovsky to The Arctic Institute of North America. Additional Russian terms were incorporated in 1996 and 1998.

Transliterated Russian

Transliterations of Russian equivalent terms, from the Cyrillic alphabet to the Latin alphabet, using the Library of Congress system, have been added to the multi-language database for the convenience of non-Russian users.

Spanish

The Spanish translation of the terms from the 1988 Glossary was prepared by A. E. Corte, E. Buk, and D.Trombotto (Argentina). Their listing of the Spanish equivalents of the primary terms was received in February 1990; secondary terms were added in May 1990, some additions and corrections were made in June and July 1993, in July 1995, and in 1996.

Swedish

Preparation of a listing of Swedish terms for the glossary was started by H. J. Åkerman in the fall of 1992. The list of Swedish terms was received in April 1993, and the terms were incorporated in the database before the 6th International Conference on permafrost in Beijing, July 1993. Translations for additional terms were included in late 1993, in 1996, and in 1998.

Synonyms

A number of synonyms (including terms designated as "not recommended" in the 1988 Glossary) are included in the current multi-language database, because many of these terms are found in the early permafrost literature.

Definitions

Definitions for most of the primary terms in the multi-language glossary were adopted, without change, from the 1988 Glossary (Permafrost Subcommittee, 1988). Permission for this was obtained from the copyright holder (National Research Council of Canada). Minor changes for some of the definitions, as well as definitions for the additional terms, have been prepared by O. J. Ferrians, S.A.Harris, J.A. Heginbottom, B. Ladanyi, N. N. Romanovsky , Y. Shur, and R. O. van Everdingen.

In the Definitions section, terms defined elsewhere in the text are printed in ***italics.***

Illustrations

Photographs and diagrams illustrating the meaning of various terms were also adopted from the 1988 Glossary (Permafrost Subcommittee, 1988). Permission for this was obtained from the copyright holder (National Research Council of Canada). The original Figure 1, showing the distribution of permafrost in Canada, has been replaced by a new Figure 1 showing the distribution of permafrost in the northern hemisphere, kindly supplied by J. A. Heginbottom. Figures 2 and 3 were modified slightly, and a new Figure 17i (from Mackay, 1990, Fig.3) was added to illustrate the three main types of ice wedges.

Revision - 2005

In 1998 and 2003 an English-only digital version was included on the CAPS versions 1 and 2 CD-ROMS prepared for the IPA by the National Snow and Ice Data Centre. The current "Revision - 2005" digital version has been prepared to enable computer access to the complete text of the Glossary, without the necessity to have Cyrillic and Chinese fonts installed on the computer. Minor corrections have also been incorporated.

2. **active air-cooled thermal pile**

A foundation pile on which a cold air refrigeration system has been installed to remove heat from the ground.

COMMENT:

The refrigeration system may be fastened to, or form part of the pile or, if the pile is a sealed unit (e.g. steel pipe), the pile itself may serve as both a heat-removal device and a structural unit.

REFERENCES: Heuer, 1979; Johnston, 1981.

3. **active construction methods in permafrost**

Special design and construction methods used for engineering works in permafrost areas where *permafrost degradation* cannot be prevented.

COMMENT:

Two main approaches are possible. Unfavourable foundation materials can be thawed and compacted or replaced with more suitable materials before the structure is erected. Alternatively, the foundations and structure may be designed to accommodate any *thaw settlement* that will occur.

REFERENCES: Andersland and Anderson, 1978; Linell and Lobacz, 1980; Johnston, 1981.

5. **active ice wedge**

An *ice wedge* that is growing as a result of repeated (but not necessarily annual) winter cracking.

COMMENT:

Active ice wedges developed in mineral soil occur primarily in areas of *continuous permafrost*.

6. **active layer**

The layer of ground that is subject to annual thawing and freezing in areas underlain by permafrost (see Figure 2).

COMMENT:

In the zone of *continuous permafrost* the active layer generally reaches the *permafrost table*; in the zone of *discontinuous permafrost* it often does not.

The active layer includes the uppermost part of the permafrost wherever either the *salinity* or clay content of the permafrost allows it to thaw and refreeze annually, even though the material remains cryotic (T < 0°C).

The active layer is sometimes referred to as the "active zone"; the term "zone," however, should be reserved for the zones of *discontinuous* and *continuous permafrost*.

In Russian and Chinese literature, the term active layer covers two distinct types: (1) the *seasonally thawed layer* overlying permafrost, and (2) the *seasonally frozen layer* overlying *unfrozen ground* inside or outside permafrost areas.

REFERENCES: Muller, 1943; Williams, 1965; Brown, 1971; van Everdingen, 1985.

7. **active-layer failure**

A general term referring to several forms of slope failures or failure mechanisms commonly occurring in the active layer overlying permafrost (see Figure 21a).

COMMENT:

These include *detachment failures* but not *retrogressive thaw slumps* and *thaw slumping* since these involve permafrost.

SYNONYM: (not recommended) skin flow.

9. active-layer thickness

The thickness of the layer of the ground that is subject to annual thawing and freeing in areas underlain by permafrost.

COMMENT:

The thickness of the *active layer* depends on such factors as the ambient air temperature, vegetation, drainage, soil or rock type and *total water content*, *snowcover*, and degree and orientation of slope. As a rule, the active layer is thin in the High Arctic (it can be less than 15 cm) and becomes thicker farther south (1 m or more).

The thickness of the active layer can vary from year to year, primarily due to variations in the mean annual air temperature, distribution of soil moisture, and *snowcover*.

The thickness of the *active layer* includes the uppermost part of the permafrost wherever either the *salinity* or clay content of the permafrost allows it to thaw and refreeze annually, even though the material remains cryotic (T < 0°C).

Use of the term "depth to permafrost" as a synonym for the thickness of the *active layer* is misleading, especially in areas where the *active layer* is separated from the permafrost by a *residual thaw layer*, that is, by a thawed or noncryotic (T > 0°C) layer of ground.

REFERENCES: Muller, 1943; Williams, 1965; van Everdingen, 1985.

10. active liquid refrigerant pile

A foundation pile on which a liquid coolant refrigeration system has been installed to remove heat from the ground.

COMMENT:

The refrigeration system may be fastened to, or form part of the pile or, if the pile is a sealed unit (e.g. steel pipe), the pile itself may serve as both a heat-removal device and a structural unit.

REFERENCES: Heuer, 1979; Johnston, 1981.

11. active rock glacier

A mass of rock fragments and finer material, on a slope, that contains either an ice core or interstitial ice, and shows evidence of present movement.

COMMENT:

Active rock glaciers possess steep fronts with slope angles that may exceed the angle of repose. Gradual elimination of such oversteepening of the frontal portion

may suggest some movement long after the ice has melted and the main body of the rock glacier has stopped moving.
REFERENCES: White, 1976b; Washburn, 1979.

12. active thermokarst

The process by which characteristic landforms are currently developing as a result of thawing of *ice-rich permafrost* or melting of *massive ice*.COMMENT:

The occurrence of active thermokarst indicates the presence of *disequilibrium permafrost*.
REFERENCES: French, 1976; Washburn, 1979.

14. adfreeze/adfreezing

The process by which two objects are bonded together by ice formed between them.

COMMENT:

Adfreezing is the process that anchors piles or buried foundations in permafrost, so that they can be unaffected by *frost heave* occurring in the *active layer*.
SYNONYM: frost grip.
REFERENCE: Muller, 1943.

15. adfreeze strength

The tensile or shear strength which has to be overcome to separate two objects that are bonded together by ice.

COMMENT:

The term is usually used to describe the resistance to the force that is required to separate *frozen ground* or an ice mass from an object (frequently a foundation unit) to which it is frozen. The shear stress required to separate an object from *frozen ground* is frequently referred to as the "tangential adfreeze strength".
REFERENCES: Muller, 1943; Johnston, 1981.

18. aggradational ice

The additional *ground ice* formed as a direct result of *permafrost aggradation* (see Figure 10a).

COMMENT:

Ice lenses form seasonally, especially in the lower part of the *active layer*, and can be incorporated into the permafrost if they do not melt over a period of years.
REFERENCES: Mackay, 1972b, 1983; Cheng, 1983.

19. air freezing index

The cumulative number of *degree-days* below 0°C for the air temperature during a given time period.

COMMENT:

The air freezing index differs from the corresponding *surface freezing index* (see *n-factor*).

20. air thawing index

The cumulative number of *degree-days* above 0°C for the air temperature during a given period.

COMMENT:

The air thawing index differs from the corresponding *surface thawing index* (see *n-factor*).

21. alas/alass

A large depression of the ground surface produced by thawing of a large area of very thick and exceedingly *ice-rich permafrost*.

COMMENT:

Typically, alasses are large depressions ranging from 0.5 to more than 100 km^2 in area and from 5 to 20 m in depth. In the early stages of formation, a shallow (≤ 2 m) circular "alas lake" forms in a steep-sided depression. Enlargement and ultimate drainage of a number of such lakes may leave low interalas plateaus (termed "mezhalasye" in Russian). Ultimately, the plateaus disappear and *mass wasting* produces gentle side slopes. The term is of Yakut origin. The term is of Yakut origin. An analogous term of Nenets (northwestern Siberia) origin is "khasyrey".

REFERENCES: Czudek and Demek, 1970; Soloviev, 1973.

22. albedo

Albedo is a measure of the reflecting power of a surface, expressed as the fraction of the incoming solar radiation reflected by the surface.

COMMENT:

The albedo of natural land surfaces varies over a wide range, and it changes with the seasons, primarily due to changes in vegetation and *snowcover*.

25. altitudinal limit of permafrost

The lowest altitude at which *mountain permafrost* occurs in a given highland area outside the general *permafrost region*.

COMMENT:

The altitudinal limit of *mountain permafrost* generally rises progressively with decreasing latitude.

REFERENCE: Brown, 1967b.

26. altitudinal zonation of permafrost

The vertical subdivision of an area of *mountain permafrost* into *permafrost zones*, based on the proportion of the ground that is perennially cryotic.

COMMENT:

As mean annual temperatures decrease with increasing elevation, *mountain permafrost* can normally be expected to be more extensive, thicker and colder at higher elevations, although exposure and the extent of vegetation and snow cover will moderate this effect. A noteable exception is found in the southwestern portion of Yukon, where (1) the high St. Elias Mountains block the circulation of moist and warm maritime air from the Pacific Ocean, particularly in winter, and (2) the deeply dissected nature of the terrain promotes cold-air drainage and ponding in

the valleys. As a result, permafrost is more extensive, thicker and colder in valley bottoms than at higher elevations.
REFERENCE: Burn, 1994.

29. anti-syngenetic ice wedge

An ice wedge that grows progressively downwards into a receding slope, in a direction normal to the surface (see Figure 17i).

COMMENT:

The younger portions of the wedge extend farthest down. The downward rate of growth is a function of the rate of slope recession and the rate of formation of new ice veinlets.

REFERENCE: Mackay, 1990.

30. apparent heat capacity

The amount of heat required to raise the temperature of a unit mass of *frozen ground* by one degree.

COMMENT:

Because the phase change in *frozen ground* often occurs gradually over a range of temperatures, the apparent heat capacity (which is the sum of the *specific heat capacity* and the *latent heat* released) may vary significantly with temperature. Apparent heat capacity is commonly expressed in Joules per kg per degree K.

31. approximate freezing index

The cumulative number of *degree-days* below 0°C for a given time period, calculated from the mean monthly temperatures for a specific station without making corrections for positive *degree-days* in spring and fall.

REFERENCES: Boyd, 1973, 1979.

32. approximate thawing index

The cumulative number of *degree-days* above 0°C for a given time period, calculated from the mean monthly temperatures for a specific station without making corrections for negative *degree-days* in spring and fall.

REFERENCES: Boyd, 1973, 1979.

33. artificial ground freezing

The process of inducing or maintaining a frozen condition in earth materials by artificial means.

COMMENT:

The frozen condition can be induced or maintained by natural convection movement of air, gases or liquids (e.g., through or in ventilation ducts, *thermal piles, thermosyphons*), or by forced (mechanical) circulation of cold air or a refrigerant through a system of ducts or freeze pipes in the ground.

REFERENCES: Jumikis, 1977; Johnston, 1981.

35. banded cryogenic fabric

A distinct soil micromorphology, resulting from the effects of freezing and thawing processes, in which soil particles form subhorizontal layers (see Figure 8c).
COMMENT:
This fabric, found in *cryosols*, results from freeze-thaw processes accompanied by eluviation.
REFERENCES: Brewer and Pawluk, 1975; Pawluk and Brewer, 1975; Fox, 1983.

36. barrens
Areas of discontinuous vegetation cover in the polar semi-desert of the High Arctic.COMMENT:
Unvegetated areas of polar desert may be caused by climatic factors (too cold and/or too dry), or edaphic factors (low soil nutrients or toxic substrate), or a combination of those.

37. basal cryopeg
A layer of *unfrozen ground* that is perennially cryotic (T < 0°C), forming the basal portion of the permafrost (see Figures 2, 4 and 11).
COMMENT:
In a basal cryopeg, freezing is prevented by *freezing-point depression* due to the dissolved-solids content of its *pore water*.
REFERENCE: Tolstikhin and Tolstikhin, 1974.

38. basal cryostructure
The cryostructure of a frozen deposit of boulders that is saturated with ice (see Figure 9e).
REFERENCE: Kudryavtsev, 1978.

40. basal-layered cryostructure
The cryostructure of a frozen layered deposit of gravel and boulders that is saturated with ice (see Figure 9e).
REFERENCE: Kudryavtsev, 1978.

44. beaded stream
A stream characterized by narrow reaches linking pools or small lakes (see Figure 22a).
COMMENT:
A characteristic pattern of small streams in areas underlain by *ice wedges*. The course of the stream channel is controlled by the pattern of the wedges, with the beads (pools) occurring at the junctions of the wedges. When the intervening channels are dry, they may be called "beaded channels".
SYNONYMS: (not recommended) beaded drainage, button drainage.
REFERENCES: Péwé, 1954; Hopkins et al., 1955; Ferrians et al., 1969; Brown, 1970b; Lawson and Brown, 1978.

47. block field

A surficial layer of angular shattered rocks formed in either modern or Pleistocene *periglacial* environments.
SYNONYMS: stone field and (not recommended) felsenmeer, blockmeer.
REFERENCES: French, 1976; Washburn, 1979.

49. bottom temperature of snow cover (BTS)
Temperature measured at the base of the snow cover during mid- to late-winter (February/March).
COMMENT:
Such measurements are used in the *BTS method* to predict the presence or absence of permafrost in mountain areas where the winter snow cover is thicker than about 1.0 m
REFERENCES: Haeberli, 1973; Hoelzle et al., 1993.

51. BTS method
Method to predict the presence or absence of permafrost in a mountain area, using measurements of the *bottom temperature of snow cover* in mid- to late-winter.
COMMENT:
Snow cover, with its low thermal conductivity, insulates the soil from short-term fluctuations in air temperature. In those mountain areas where snow-cover thickness equals or exceeds 1 m and surface melting is still negligible in mid- to late-winter, BTS values remain virtually constant, mainly controlled by heat transfer from the upper ground layers, which in turn is strongly influenced by the presence or absence of permafrost. According to published data, BTS values below -3°C, between -3°C and -1.7°C, and above -1.7C° suggest, respectively, the presence, possible presence, and absence of permafrost.
REFERENCES: Haeberli, 1973; Hoelzle et al., 1993.

54. buried ice
Ice formed or deposited on the ground surface and later covered by sediments.
COMMENT:
Buried ice likely represents buried glacier ice or snowbanks; or less likely, lake, river or sea ice, or *icings*.

56. cave ice
Ice formed in a closed or open cave.
COMMENT:
Cave ice can form and persist in an area of temperate climatic conditions where the configuration of the cave or cave system permits an influx of cold winter air by gravity flow but limits access of warm summer air.
REFERENCE: Harris, 1979.

61. closed-cavity ice
Ice formed in a closed space, cavity or cave in permafrost.

COMMENT:
Along the western Arctic coast of Canada for example, underground cavities, apparently formed by pockets of methane gas, have been found filled with ice crystals. The water from which the crystals have grown probably entered the cavities through vapour diffusion.
REFERENCES: Mackay, 1965, 1972b.

62. closed-system freezing

Freezing that occurs under conditions that preclude the gain or loss of any water by the system (see Figure 7).
COMMENT:
Pure closed-system conditions, in which water is neither added to nor removed from the system, are sometimes referred to as "in situ freezing". Closed-system freezing of water-saturated soil causes expansion equal to about 9 percent of the original pore volume of the unfrozen soil. Inside closed systems, some redistribution of water may take place during freezing.

63. closed-system pingo

A *pingo* formed by doming of *frozen ground* due to freezing of injected water supplied by expulsion of *pore water* during *permafrost aggradation* in the *closed talik* under a former water body (see Figures 18 and 19a).
COMMENT:
Most closed-system pingos are found in flat, poorly-drained terrain in the zone of *continuous permafrost*. Repeated injections of expelled water into the overlying permafrost, followed by freezing of the injected water, cause progressive doming, and produce the *massive ice* forming the core of the *pingo*. Progressive formation of *segregated ice* and *dilation crack ice* can also contribute to the process.
SYNONYMS: hydrostatic pingo and (not recommended) Mackenzie Delta pingo.
REFERENCES: Mackay, 1973b, 1979, 1985.

64. closed talik

A layer or body of *unfrozen ground* occupying a depression in the *permafrost table* below a lake or river (see Figure 11).
COMMENT:
The temperature of closed *lake taliks* and *river taliks* remains above 0°C because of the heat storage effect of the surface water.
REFERENCES: Williams, 1965; Washburn,1973; van Everdingen, 1976.

65. coefficient of compressibility

The volume change per unit volume of a substance per unit increase in effective compressive stress, under isothermal conditions.
COMMENT:
Frozen soils are usually considered to be practically incompressible, and volume-change deformations can therefore be neglected. Numerous investigations have shown, however, that the compressibility of frozen soils can be significant and should not be neglected in some cases, especially when large areas are to be loaded.

Compressibility and its time dependence in frozen soils are due to several causes, such as instantaneous compression of the gaseous phase, creep of the *pore ice* due to shear stresses at the grain contacts, and hydrodynamic consolidation due to the expulsion of unfrozen water under stress, the amount of which varies with the applied pressure.

66. collapse scar

That portion of a *peatland* where the whole or part of a *palsa* or *peat plateau* has thawed and collapsed to the level of the surrounding *peatland* (see Figures 14 and 15e).

COMMENT:

A collapse scar is not a depression but is marked by vegetation different from the peatland that did not contain permafrost. Irregular topography (hence *thermokarst terrain*) may be present on the *peatland* as a whole but the collapse scars are only part of that *thermokarst terrain*, marked by the absence of permafrost, and by vegetation different from that on both the previously unfrozen *peatlands* and the remnant permafrost *peat* landforms.

REFERENCE: Zoltai, 1971.

68. composite wedge

A wedge showing evidence of both primary and secondary filling.

COMMENT:

When used with reference to *thermal contraction crack* phenomena in permafrost, it describes a wedge filled by a combination of ice and soil (usually sand). The term is also frequently used to describe Pleistocene *sand wedges* and *ice-wedge casts*. Typically, composite wedges are filled with material very similar in structure and texture to sands in a typical fissure of primary filling (i.e., *sand wedge*). However, there may be inclusions of material from the fissure walls and some distortion of the adjacent sediments bordering the wedge, reflecting the presence of ice in the original fill material.

REFERENCES: Black and Berg, 1966; Goździk, 1973; French, 1976; Washburn, 1979.

72. conglomeric cryogenic fabric

A distinct soil micromorphology, resulting from the effects of freezing and thawing processes, in which coarser soil particles form compound arrangements (see Figure 8f).

COMMENT:

This fabric, found in *cryosols*, results from freeze-thaw processes probably accompanied by *cryoturbation*.

REFERENCES: Brewer and Pawluk, 1975; Pawluk and Brewer, 1975; Fox, 1983.

73. construction methods in permafrost

Special design and construction procedures required when engineering works are undertaken in permafrost areas.

COMMENT:

Design and construction of engineering works on permafrost normally follow one of two broad principles which are based on whether or not the frozen foundation soil or rock is thaw-stable (*thaw-stable permafrost*) or thaw-unstable (*thaw-sensitive permafrost*).

Permafrost conditions can be neglected, and conventional designs and construction methods used when foundation materials are stable upon thawing. When the foundation materials are *thaw-sensitive*, however, then either the "passive" or "active" design and construction method is selected.

The passive method maintains the foundation materials in a frozen state. Preservation of the frozen condition or *permafrost aggradation* can be accomplished using *thermal piles* or *thermosyphons*, or by using either a ventilation or an insulation construction technique; often a combination of these techniques is used.

The ventilation technique requires that there is a clear space left between the bottom of the structure and the ground surface, or that the structure is placed on a fill pad with ducts incorporated in the pad or the floor system. Movement of cold air through the air space or ducts dissipates heat from the structure above and removes heat from the ground below.

Using the insulation technique, a relatively thick fill (sometimes containing a layer of insulation) is placed on the ground surface to prevent thawing or to reduce or control the *depth of thaw* below the original ground surface.

When *permafrost degradation* cannot be prevented, then one of the active methods must be considered. Two main approaches are possible. Unfavourable foundation materials are thawed and compacted or replaced with more suitable materials before the structure is erected. Alternatively, the foundations and structure are designed to accommodate the *thaw settlements* that will occur.
REFERENCES: Andersland and Anderson, 1978; Linell and Lobacz, 1980; Johnston, 1981.

76. continuous permafrost

Permafrost occurring everywhere beneath the exposed land surface throughout a geographic region 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 *thermal regime of the ground,* causing the development of continuous permafrost (see Figure 1).

COMMENT:

For practical purposes, the existence of small *taliks* within continuous permafrost has to be recognized. The term, therefore, generally refers to areas where more than 90 percent of the ground surface is underlain by permafrost.
REFERENCE: Brown, 1970b.

77. continuous permafrost zone

The major subdivision of a *permafrost region* in which permafrost occurs everywhere beneath the exposed land surface with the exception of widely scattered sites.

COMMENT:

Taliks associated with rivers and lakes may occur in the continuous permafrost zone.
REFERENCE: Brown, 1970b.

79. creep of frozen ground

The slow deformation (or time-dependent shear strain) that results from long-term application of a stress too small to produce failure in the frozen material.

COMMENT:

In frozen soils, creep deformations are due mainly to the creep of *pore ice* and the migration of unfrozen *pore water*. In ice-saturated frozen soils, most creep deformations are distortional with little or no volume change. In frozen soils with large *unfrozen water contents* or in unsaturated frozen soils, slow deformations due to consolidation, and creep due to volume change, may also occur. Usually, a large portion of the creep deformation is permanent.
REFERENCES: Vyalov, 1959; Ladanyi, 1972, 1981.

80. creep strength

The failure strength of a material at a given strain rate or after a given period under deviatoric stress.

COMMENT:

Under high confining stress and at relatively high freezing temperatures, most frozen soils creep and eventually fail in a plastic manner.

83. crust-like cryostructure

The cryostructure of a frozen deposit of angular blocks that are coated with ice, whereas large spaces between the blocks are not filled with ice (see Figure 9e).

COMMENT:

A deposit with a crust-like cryostructure has a relatively low *ice content*.
REFERENCE: Kudryavtsev, 1978.

87. cryofront

The boundary between *cryotic* and *noncryotic ground* as indicated by the position of the 0°C isotherm in the ground (see Figures 4 and 5).

COMMENT:

The *permafrost base* and the boundaries between noncryotic and cryotic portions of the *active layer* constitute cryofronts. As a result of *freezing-point depression*, the *freezing front* usually lags behind the cryofront as it moves downwards during annual freezing of the *active layer*.
REFERENCE: van Everdingen, 1976.

88. cryogenesis

The combination of thermophysical, physico-chemical and physico-mechanical processes occurring in freezing, frozen and thawing earth materials.

COMMENT:

Specific processes of cryogenesis include water migration during freezing and thawing of the ground, *frost heave*, heat and mass (moisture) exchange, regelation and *gelifluction*. In the Russian permafrost literature, cryogenesis includes mainly processes that lead to development of permafrost *cryostructure* and landforms.

REFERENCE: Poppe and Brown, 1976.

89. cryogenic aquiclude

A layer of ground which, because of its frozen state, has a low enough permeability to act as a confining bed for an aquifer.

COMMENT:

Annual freezing can turn the *active layer* into a cryogenic aquiclude.

REFERENCE: Fotiev, 1978.

90. cryogenic fabric

The distinct soil micromorphology resulting from the effects of freezing and thawing processes (see Figure 8).

COMMENT:

The following cryogenic fabrics, found in *cryosols*, can be distinguished under a microscope:

1. *granic* and *granoidic* fabrics - soil particles form discrete loosely packed units. These fabrics are generally attributed to freeze-thaw processes and the formation of *needle ice* near the ground surface.

2. *fragmic* and *fragmoidal* fabrics - soil particles form discrete units that are either densely packed or coalescing. These fabrics commonly occur in subsurface soil horizons, usually close to the *freezing front* where soil material is subject to *ice lens* formation.

3. *banded* and *isoband* fabrics - soil particles form subhorizontal layers which result from freeze-thaw processes accompanied by eluviation.

4. *orbiculic*, *suscitic* and *conglomeric* fabrics - coarser soil particles form circular to ellipsoidal patterns (orbiculic), vertical or near-vertical orientation (suscitic), and compound arrangements (conglomeric), probably as a result of *cryoturbation* activity.

REFERENCES: Brewer and Pawluk, 1975; Pawluk and Brewer, 1975; Fox, 1983.

95. cryogenic temperature

In international materials science, this term refers to temperatures generally below -50°C, but usually to temperatures within a few degrees of absolute zero (-273°C).

101. cryolithology

The study of the genesis, structure and lithology of frozen earth materials.

COMMENT:

This is a Russian term not widely used in North America. It is a branch of *geocryology* in which lithological and ground-ice conditions are emphasized.

106. cryopedology

The study of soils at temperatures below 0°C, with particular reference to soils subject to intensive *frost action*, and to soils overlying permafrost.

COMMENT:

As originally defined (Bryan, 1946), the term comprised the whole science of *geocryology*, including the civil engineering methods used to overcome difficulties resulting from intensive *frost action* and the existence of permafrost.

REFERENCES: Bryan, 1946; Canada Soil Survey Committee, 1978.

107. cryopeg

A layer of *unfrozen ground* that is perennially cryotic (forming part of the permafrost), in which freezing is prevented by *freezing-point depression* due to the dissolved-solids content of the *pore water* (see Figures 2, 4 and 11).

COMMENT:

Three types of cryopeg can be distinguished on the basis of their position with respect to permafrost:

1. a *basal cryopeg* forms the basal portion of the permafrost;

2. an *isolated cryopeg* is entirely surrounded by perennially *frozen ground*;

3. a *marine cryopeg* is found in coastal or subsea perennially *frozen ground*; marine cryopegs may also be basal and/or isolated.

In Russian literature cryopegs are defined as lenses of "cryosaline water" (supercooled brine) found within saline cryotic soils or rock.

REFERENCE: Tolstikhin and Tolstikhin, 1974.

108. cryoplanation

The process through which *cryoplanation terraces* form.

COMMENT:

Cryoplanation occurs most frequently in *periglacial* areas of moderate aridity underlain by permafrost, under conditions of intense *frost wedging* associated with snowbanks.

109. cryoplanation terrace

A step-like or table-like bench cut in bedrock in cold climate regions.

COMMENT:

Cryoplanation terraces may occur as both hillside benches or bevelled summit surfaces and often lack structural control. They are thought to form under conditions of intense *frost wedging* associated with snowbanks. Cryoplanation terraces are more frequently reported from *periglacial* areas of moderate aridity. As these areas are usually underlain by permafrost, cryoplanation terraces are regarded by some as diagnostic landforms of permafrost terrain.

REFERENCES: Eakin, 1916; Demek, 1969; French, 1976; Reger and Péwé, 1976; Washburn, 1979.

110. cryosol

Soil formed in either mineral or organic materials having permafrost either within 1 m below the surface or, if the soil is strongly cryoturbated, within 2 m below the surface, and having a *mean annual ground temperature* below 0°C.

COMMENT:

This is a pedological term for a major soil order. Cryosols are divided into three groups:

1. *organic cryosols* developed in organic (peat) materials;
2. *static cryosols* developed in mineral soils and showing little or no evidence of *cryoturbation*;
3. *turbic cryosols* developed in mineral soils and showing strong evidence of *cryoturbation*.

SYNONYMS: (not recommended) cryosolic soil, pergelic soil.

REFERENCE: Canada Soil Survey Committee, 1978.

112. cryosphere

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

COMMENT:

The cryosphere may be divided into the cryoatmosphere, the cryohydrosphere (snowcover, glaciers, and river, lake and sea ice) and the cryolithosphere (perennially and seasonally *cryotic ground*). Some authorities exclude the earth's atmosphere from the cryosphere; others restrict the term "cryosphere" to the regions of the earth's crust where permafrost exists.

REFERENCE: Baranov, 1978.

114. cryostructure

The structural characteristics of frozen earth materials (see Figure 9).

COMMENT:

The cryostructure is determined by the amount and distribution of *pore ice* (or ice cement) and lenses of *segregated ice*. The type and arrangement of ice in the frozen material will depend largely on the initial *total water content* of the material and the extent of moisture migration during subsequent freezing.

For engineering purposes, the structure of frozen soil may be described as massive, layered or reticulate, based on the type and distribution of ice in the soil. A massive structure (not to be confused with massive ground-ice forms) is characterized by the predominant presence of *pore ice* and by a relatively low total *ice content*. In soils with a reticulate structure, *ice veins* generally form a random net, whereas in those with a layered structure, well-oriented horizontal *ice lenses* alternate with soil layers having a massive structure. In both cases their total *ice content* is relatively high.

Russian permafrost scientists identify ten cryogenic structures or cryostructures: basal, basal-layered, crust-like, layered, lens-type, massive-agglomerate, massive, massive-porous, reticulate and reticulate-blocky.

REFERENCES: U.S.S.R., 1969, 1973; Poppe and Brown, 1976; Kudryavtsev, 1978.

115. cryosuction

A suction developed in freezing or partially frozen fine-grained materials as a result of temperature-dependent differences in *unfrozen water content*.

COMMENT:

Cryosuction occurs where gradients of the temperature-dependent *unfrozen water content* in a freezing or partially frozen fine-grained earth material cause hydraulic gradients large enough to induce migration of *pore water* from unfrozen soil into the partially frozen soil via unfrozen water films.

SYNONYM: (not recommended) frost suction.

REFERENCES: Blanchard and Frémond, 1982.

117. cryotexture

The textural characteristics of frozen, fine-grained organic and mineral earth materials cemented together with ice.

COMMENT:

Cryotextures may be useful in determining the nature of the freezing process and the conditions under which the sediments accumulated.

REFERENCES: Poppe and Brown, 1976; Kudryavtsev, 1978.

118. cryotic ground

Soil or rock at temperatures of 0°C or lower.

COMMENT:

The terms "cryotic" and "noncryotic" were introduced to solve a major semantic problem identified by Brown and Kupsch (1974), namely the lack of specific separate terms to designate "above 0°C" and "below 0°C" as opposed to "unfrozen" (not containing ice) and "frozen" (containing ice) (see Figure 3). Cryotic and noncryotic refer solely to the temperature of the material described, independent of its water or *ice content*. Perennially cryotic ground refers to ground that remains at or below 0°C continuously for two or more years and is therefore synonymous with permafrost.

REFERENCES: Brown and Kupsch, 1974; van Everdingen, 1976.

119. cryoturbate

A body of earth material moved or disturbed by *frost action*.

COMMENT:

The process of *cryoturbation* results in the disruption and distortion of soil horizons and structures, the formation of *patterned ground*, the growth of involutions, and the redistribution of organic-rich subsurface masses and layers. Downslope soil movements are more properly termed *solifluction, gelifluction* and *frost creep*, although many authors include the products of *solifluction* within the term cryoturbate.

SYNONYMS: cryoturbations and (not recommended) congeliturbate.

120. cryoturbation

1. (Singular) **A collective term used to describe all soil movements due to *frost action*.**
2. (Plural) **Irregular structures formed in earth materials by deep *frost penetration* and *frost action* processes, and characterized by folded, broken and dislocated beds and lenses of unconsolidated deposits, included organic horizons and even bedrock.**

COMMENT:

Cryoturbation encompasses *frost heave*, *thaw settlement* and all differential movements, including expansion and contraction due to temperature changes and the growth and disappearance of *ground ice* bodies, whether perennial or seasonal. Low temperatures alone are not enough to produce cryoturbation; the water-ice phase change is necessary. Cryoturbation is an important process in the development of *patterned ground*.

SYNONYMS: 1. (not recommended) congeliturbation, frost churning, frost stirring; 2. cryoturbates.

REFERENCES: French, 1976; Washburn, 1979.

121. debris flow

A sudden and destructive variety of landslide, in which loose material on a slope, with more than 50 percent of particles larger than sand size, is mobilized by saturation and flows down a channel or canyon.

COMMENT:

The water content of debris flows may range from 10 to over 50 percent by volume. They may transport huge boulders for great distances down gentle slopes. Debris flows also occur in non-permafrost areas.

122. deformability

The ability of a material to change its shape or size under the influence of an external or internal agency, such as stress, temperature, or pore pressure.

123. degree-day (C or F)

A derived unit of measurement used to express the departure of the mean temperature for a day from a given reference (or base) temperature.

COMMENT:

The *freezing index* and the *thawing index* are expressed in degree-days with respect to a reference temperature of 0°C (32°F); units: degree-day Celsius or degree-day Fahrenheit.

REFERENCE: Boyd, 1979.

124. degree of saturation

1. **The total degree of saturation of frozen soil is the ratio of the volume of ice and unfrozen water in the soil pores to the volume of the pores.**
2. **The degree of saturation of frozen soil by ice is the ratio of the volume of ice in the soil pores to the volume of the pores.**

COMMENT:
Neither definition is the equivalent of the standard definition used in soil mechanics where the degree of saturation is the ratio of the volume of water in a soil to the volume of the pores.

125. delayed strength
The failure strength of a material at a given strain rate or after a given period under deviatoric stress.

126. density of frozen ground
The mass of a unit volume of frozen soil or rock.

129. depth of seasonal frost penetration
The maximum thickness of the *seasonally frozen layer*.
COMMENT:
This term is primarily used in areas without permafrost, but also in areas with permafrost where the *seasonal frost* does not reach the *permafrost table*.

130. depth of thaw
The minimum distance between the ground surface and *frozen ground* at any time during the thawing season in an area subject to seasonal freezing and thawing (see Figure 4).
COMMENT:
When no *frozen ground* remains, thawing is complete, and depth of thaw cannot be determined.

131. depth of zero annual amplitude
The distance from the ground surface downward to the level beneath which there is practically no annual fluctuation in ground temperature (see Figure 2).
COMMENT:
A change of no more than 0.1°C throughout the year is arbitrarily considered as "practically no annual fluctuation". The temperature at the *depth* (or level) *of zero annual amplitude* ranges from about -0.1°C at the southern limit of the *permafrost region* to about -15°C in the extreme polar reaches of the zone of *continuous permafrost*. The *depth of zero annual amplitude* varies widely but generally lies between 10 and 20 m below the ground surface, depending on climatic and terrain conditions such as amplitude of annual surface temperature variation, vegetation, *snowcover* and characteristics of the soils and rocks including *thermal diffusivity* (see *thermal properties of frozen ground*).
SYNONYMS: (not recommended) zone of minimum annual amplitude, zone of zero annual amplitude.
REFERENCE: Muller, 1943.

133. desiccation crack

Crack or fissure developed in fine-grained soil material as a result of shrinkage during drying.

134. desiccation polygon

Closed, multi-sided *patterned-ground* feature formed by *desiccation cracks* in fine-grained soil material. Usually less than 2 m in diameter.

135. design depth of frost penetration

1. (North-American usage) **The mean of the three largest *depths of seasonal frost penetration* measured during the past thirty years, or the largest *depth of seasonal frost penetration* beneath a snow-free soil surface measured during the past ten years**.
2. (Russian usage) **The mean of the *depths of seasonal frost penetration* measured during at least the last ten years with the ground surface free of snow and the groundwater level below the *depth of seasonal frost penetration***.

136. design freezing index

The cumulative number of *degree-days* below 0°C, calculated by taking the average of the *seasonal freezing indices* for the three coldest winters in the most recent 30 years of record.

COMMENT:

If data for 30 years are not available, then the index is based on the coldest winter in the latest 10-year period of record.

REFERENCE: U.S. Army/Air Force, 1966.

137. design thawing index

The cumulative number of *degree-days* above 0°C, calculated by taking the average of the *seasonal thawing indices* for the three warmest summers in the most recent 30 years of record.

COMMENT:

If data for 30 years are not available, then the index is based on the warmest summer in the latest 10-year period of record.

REFERENCE: U.S. Army/Air Force, 1966.

138. detachment failure

A slope failure in which the thawed or thawing portion of the *active layer* detaches from the underlying frozen material (see Figure 21b).

COMMENT:

Detachment failures are common on colluvial slopes in areas of fine-grained, ice-rich deposits. They occur more frequently during warm summers or following disturbance of the vegetation or ground surface by, for example, tundra or forest fires or engineering activity, when the *depth of thaw* is greater than normal. Detachment failures that expose *massive ice* or icy sediments can develop into *retrogressive thaw slumps*.

SYNONYMS: (not recommended) skin flow, active-layer glide.

REFERENCES: Hughes, 1972; McRoberts and Morgenstern, 1974.

139. dielectric constant

The dielectric constant of a soil is a measure of the ability of the soil to store electrical energy in the presence of an electrostatic field.

COMMENT:

The dielectric constant is calculated as the ratio of the permittivity of the soil to the permittivity of a vacuum. It varies with soil type, temperature, *unfrozen water content*, and the dissolved-solids content of the *pore water*.

SYNONYM: *relative permittivity*.

140. dilation crack

A tensile fracture in a frozen material due to surface extension caused by doming.

COMMENT:

This usually occurs during the growth of *frost mounds*.

141. dilation crack ice

Ice that forms in *dilation cracks* (see Figure 10b).

COMMENT:

Dilation crack ice may form a significant component of the total *ice content* of features such as *pingos*. The ice is vertically banded and may be discoloured by inclusions of mineral soil and organic matter. Individual bands may be up to 20 cm wide.

REFERENCES: Mackay, 1979, 1985.

142. discontinuous permafrost

Permafrost occurring in some areas beneath the exposed land surface throughout a geographic region where other areas are free of permafrost (see Figure 1).

COMMENT:

Discontinuous permafrost occurs between the *continuous permafrost zone* and the southern *latitudinal limit of permafrost* in lowlands. Depending on the scale of mapping, several subzones can often be distinguished, based on the percentage of the land surface underlain by permafrost, as shown in the following table.

English usage	% Permafrost	Russian Usage	% Permafrost
Extensive	65-90%	Massive Island	70-80%
Intermediate	35-65%	Island	40-60%
Sporadic	10-35%	Sporadic	5-30%
Isolated Patches	0-10%	?	0-5%

SYNONYMS: (not recommended) insular permafrost; island permafrost; scattered permafrost.

REFERENCES: Brown, 1970b; Kudryavtsev, 1978; Heginbottom, 1984; Heginbottom and Radburn, 1992; Brown et al., 1997.

143. discontinuous permafrost zone

The major subdivision of a *permafrost region* in which permafrost occurs in some areas beneath the exposed land surface, whereas other areas are free of permafrost.

COMMENT:

The zone of discontinuous permafrost lies between the *continuous permafrost zone* and the southern *latitudinal limit of permafrost* in lowlands. Near its northern boundary, *discontinuous permafrost* is extensive, whereas near its southern boundary it occurs as *isolated patches of permafrost*, and *sporadic permafrost*. There is no sharp distinction, or boundary, between the continuous and discontinuous permafrost zones.

REFERENCE: Brown, 1970b.

144. disequilibrium permafrost

Permafrost that is not in thermal equilibrium with the existing *mean annual surface* or sea-bottom *temperature* and the *geothermal heat flux*.

REFERENCE: Mackay, 1972a.

145. drunken forest

Trees leaning in random directions.

COMMENT:

A descriptive term for trees usually growing on ice-rich terrain and subject to repeated differential *frost heave* or *thermokarst* subsidence. Active, forested *rock glaciers* may also exhibit this phenomenon due to differential movements.

REFERENCES: Muller, 1943; Zoltai, 1975.

146. dry density

The mass of a unit volume of dried material (e.g. soil).

COMMENT:

To determine the dry *density of frozen ground*, a measured volume of the material has to be thawed and then dried and weighed.

147. dry frozen ground

Frozen ground with a very low *total water content* consisting almost completely of *interfacial water,* and not cemented by ice.

COMMENT:

The compressibility of dry frozen ground is the same as that of *unfrozen ground* of the same composition, *total water content*, and density.

REFERENCE: van Everdingen, 1976.

148. dry permafrost

Permafrost containing neither *free water* nor ice.

COMMENT:

A negligible quantity of moisture in the form of *interfacial water* may be present. Dry permafrost is *thaw-stable*.
REFERENCE: van Everdingen, 1976.

149. dynamic modulus of elasticity
The ratio of stress to strain for a material under dynamic loading conditions.

150. dynamic Poisson's ratio
The absolute value of the ratio between the linear strain changes, perpendicular to and in the direction of a given uniaxial stress change, respectively, under dynamic loading conditions.

151. earth hummock
A hummock having a core of silty and clayey mineral soil which may show evidence of *cryoturbation* (see Figure 20a, b).
COMMENT:
Earth hummocks are a type of *nonsorted circle* (see also *patterned ground*) commonly found in the zone of *continuous permafrost*. They develop in materials of a high silt and clay content and/or of high *ice content*. Earth hummocks found outside the southern limit of present-day permafrost are believed to have formed during a previous period of cooler climate when the area was underlain by permafrost.
SYNONYMS: mud hummock and (not recommended) earth mound, tundra hummock.
REFERENCES: Tarnocai and Zoltai, 1978; Washburn, 1979.

154. electrical conductivity
The inverse of electrical resistivity.
COMMENT:
The electrical conductivity of unfrozen soils decreases slightly with a decrease in temperature. A significant decrease in conductivity occurs when a soil freezes, but this change is directly related to the decreasing *unfrozen water content* of the *frozen ground*, and it may be affected by *cryostructure*. Available data show that the conductivities of *frozen ground* may be from 1 to more than 2 orders of magnitude smaller than those of the same material when unfrozen. The conductivity of frozen soils decreases further with further decreases in temperature.

155. electrical properties of frozen ground
The *dielectric constant* (or *relative permittivity*), *electrical conductivity* and *electrical resistivity* are the major electrical properties governing the flow of electric current through frozen ground.
COMMENT:
The *dielectric constant* of a soil is a measure of the ability of the soil to store electrical energy in the presence of an electrostatic field; it is the ratio of the soil's

permittivity to the permittivity of a vacuum. The electrical conductance of a soil is the inverse of the resistance offered by a soil to current flow.

Current flow under an electrical gradient in a frozen soil occurs almost entirely through the unfrozen water films. Electrical conduction is related to the thickness of these water films and their degree of interconnection; it decreases with decreasing temperature and increases with increasing pressure. As a consequence, all these electrical properties are influenced by soil type, density, *salinity*, temperature and, in particular, the *unfrozen water content*.

For example, the resistivity of unfrozen soils increases slightly with decrease in temperature. A significant increase in resistivity occurs when the soil freezes; this change is directly related to the decreasing *unfrozen water content* of the *frozen ground*. Available data show that the resistivities of frozen soils and rocks may be from 10 to more than 100 times larger than those of the same materials when unfrozen.

Electromagnetic geophysical techniques for mapping permafrost, and the electrical grounding of various types of machines and electrical equipment, power transmission systems and radio transmitting antennae in permafrost areas, require a knowledge of the electrical properties of frozen ground.

REFERENCE: Johnston, 1981.

156. electrical resistivity

The property of a material that determines the electrical current flowing through a centimetre cube of the material when an electrical potential is applied to opposite faces of the cube.

COMMENT:

The electrical resistivity of unfrozen soils increases slightly with a decrease in temperature. A significant increase in resistivity occurs when a soil freezes, but this change is directly related to the decreasing *unfrozen water content* of the *frozen ground*, and it may be affected by *cryostructure*. Available data show that the resistivities of *frozen ground* may be from 10 to more than 100 times larger than those of the same material when unfrozen. The resistivity of frozen soils increases further with further decreases in temperature.

157. epigenetic ice

***Ground ice* developed in *epigenetic permafrost*, or in previously formed *syngenetic permafrost*.**

COMMENT:

If epigenetic ice occurs in the form of *ice lenses* in which the volume of ice to soil is large, the more descriptive term *segregated ice* is preferred. Examples of epigenetic ice also include *wedge ice* and *intrusive ice*.

REFERENCE: Mackay, 1972b.

158. epigenetic ice wedge

An *ice wedge* developed in *epigenetic permafrost*, or in previously formed *syngenetic permafrost* (see Figure 17i).

COMMENT:

Epigenetic ice wedges grow progressively wider, rather than deeper, and are characteristically wedge-shaped. The ice of an epigenetic ice wedge is oldest on the outside edges.

REFERENCES: Romanovskii, 1973; Mackay, 1990.

159. epigenetic permafrost

Permafrost that formed through lowering of the *permafrost base* in previously deposited sediment or other earth material.

160. equilibrium permafrost

Permafrost that is in thermal equilibrium with the existing *mean annual surface* or sea-bottom *temperature* and with the *geothermal heat flux*.

SYNONYM: contemporary permafrost.

REFERENCE: Mackay, 1972a.

161. excess ice

The volume of ice in the ground which exceeds the total pore volume that the ground would have under natural unfrozen conditions (see Figure 7).

COMMENT:

In standard geotechnical terminology, a soil is considered normally consolidated when its total pore volume or its *total water content* is in equilibrium with the acting gravity stresses. Due to the presence of *ground ice*, the *total water content* of a frozen soil may exceed that corresponding to its normally consolidated state when unfrozen. As a result, upon thawing, a soil containing excess ice will settle under its own weight until it attains its consolidated state.

162. extensive discontinuous permafrost

1. (North-American usage) **Permafrost underlying 65 to 90 percent of the area of exposed land surface.**
2. (Russian usage) **Permafrost underlying 70 to 80 percent of the area of exposed land surface.**

COMMENT:

It is suggested that this term be used as a replacement for "widespread" discontinuous permafrost, because the word "widespread" can mean either "extensively distributed" or "widely spaced".

SYNONYM: widespread discontinuous permafrost.

REFERENCE: Heginbottom and Radburn, 1992.

163. fabric

Soil micromorphology.

175. fragmic cryogenic fabric

A distinct soil micromorphology, resulting from the effects of freezing and thawing processes, in which soil particles form discrete units that are densely packed.

COMMENT:

This fabric, found in *cryosols*, commonly occurs in soil horizons close to the *freezing front*, where soil material is subject to *ice lense formation*.
REFERENCES: Brewer and Pawluk, 1975; Pawluk and Brewer, 1975; Fox, 1983.

176. fragmoidal cryogenic fabric

A distinct soil micromorphology, resulting from the effects of freezing and thawing processes, in which soil particles form discrete units that are coalescing (see Figure 8b).

COMMENT:

This fabric, found in *cryosols*, commonly occurs in soil horizons close to the *freezing front*, where soil material is subject to *ice lense formation*.
REFERENCES: Brewer and Pawluk, 1975; Pawluk and Brewer, 1975; Fox, 1983.

177. free water

Free water is that portion of the *pore water* that is free to move between interconnected pores under the influence of gravity.

COMMENT:

The term free water also covers water in fissures, solution channels, and other openings in soils or rocks. The temperature at which free water will change phase depends primarily on its dissolved-solids content, which determines the *freezing-point depression*.

179. freeze-thaw cycle

Freezing of a material followed by thawing.

COMMENT:

Natural freeze-thaw cycles consist of the freezing and subsequent thawing during a freezing season and the following thawing season. In laboratory experiments and geotechnical testing, freeze-thaw cycles are usually much shorter (several days to a few months).

180. freezeback

Refreezing of thawed materials.

COMMENT:

This term is used to describe:

1. seasonal refreezing of the thawed *active layer* (see Figure 4), or

2. refreezing of soil thawed as a result of construction activity or drilling of a well in permafrost, and of soil placed as backfill or a slurry around foundations or engineering facilities buried or embedded in *frozen ground*, e.g., pipelines, piles or shallow foundations in permafrost.

REFERENCE: Johnston, 1981.

181. freezing (of ground)

The changing of phase from water to ice in soil or rock.

COMMENT:

The temperature at which ground freezing starts may be lower than 0°C as a result of *freezing-point depression*.

183. freezing front

The advancing boundary between *frozen* (or *partially frozen*) *ground* and *unfrozen ground* (see Figures 4 and 5).

COMMENT:

In the usual case, where the *active layer* extends to the *permafrost table*, two freezing fronts will be present during annual freezing of the ground, one moving downward from the ground surface, the other moving upward from the *permafrost table*.

The freezing front may not coincide with the 0°C isotherm (*cryofront*).

SYNONYMS: (not recommended) freezing plane, frost front.REFERENCES: Corte, 1962; Mackay, 1974a; van Everdingen, 1976.

184. freezing index

The cumulative number of *degree-days* below 0°C for a given time period.

COMMENT:

Four main types of air freezing indices have been used:

1. *approximate freezing index* - calculated from the mean monthly air temperatures for a specific station without making corrections for positive *degree-days* (T > 0°C) in spring and fall (Boyd, 1973, 1979);

2. *total annual freezing index* - calculated by adding all the negative mean daily air temperatures (°C) for a specific station during a calendar year (Harris, 1981);

3. *seasonal freezing index* - calculated as the arithmetic sum of all the negative and positive mean daily air temperatures (°C) for a specific station during the time period between the highest point in the fall and the lowest point the next spring on the cumulative *degree-day* time curve (Huschke, 1959);

4. *design freezing index* - calculated by taking the average of the seasonal freezing indices for the three coldest winters in the most recent 30 years of record. If data for 30 years are not available, then the index is based on the coldest winter in the latest 10-year period of record (U.S. Army/Air Force, 1966).

The *total annual freezing index* has been used to predict permafrost distribution, and the *design freezing index* is commonly used in engineering to estimate the maximum thickness of lake ice and the maximum *depth of frost penetration* in the ground.

A *surface* (ground, pavement, etc.) *freezing index* differs from the *air freezing index* (see *n-factor*).

187. freezing point

1. **The temperature at which a pure liquid solidifies under atmospheric pressure**.
2. **The temperature at which a ground material starts to freeze**.

COMMENT:

See also *freezing-point depression*.

188. freezing-point depression

The number of degrees by which the freezing point of an earth material is depressed below 0°C (see Figures 2 and 3).

COMMENT:

The highest temperature at which soil, water, ice and air can coexist at equilibrium. In soils, the freezing-point depression is due mainly to capillarity and surface adsorption. It depends on soil particle effects (curvature and nature of soil particle surfaces), pressure, and the effects of dissolved solids in the *pore water*.

The freezing-point depression can often be determined from the ground *temperature profile* where it is the difference between the temperature at the base of the *ice-bearing permafrost* and 0°C.

REFERENCES: Anderson and Morgenstern, 1973; van Everdingen, 1976; Osterkamp and Payne, 1981.

189. freezing pressure

The positive pressure developed at ice-water interfaces in a soil as it freezes.

COMMENT:

It is also known to result in a *heaving pressure* or frost-heave pressure that is responsible for the heaving of utilities, foundations and pavements. Ice-water interfaces occur at the contact between *ice lenses* and the *frozen fringe*.

REFERENCES: Jumikis, 1977; Andersland and Anderson, 1978; Johnston, 1981; Gilpin, 1982.

190. friable permafrost

***Permafrost* in which the soil particles are not held together by ice**.

191. frost

The occurrence of air temperatures below 0°C.

COMMENT:

An alternative definition states that "frost is the condition existing when the surface temperature falls below freezing (0°C)". In British usage, "ground frost" is recorded when a minimum thermometer just above a grass surface reads less than 30.4°F.

192. frost action

The process of alternate freezing and thawing of moisture in soil, rock and other materials, and the resulting effects on materials and on structures placed on, or in, the ground.

COMMENT:

Frost action in soils describes the detrimental processes of *frost heave* that occurs in the ground during the freezing period, and *thaw weakening* (followed by *thaw settlement*) that occurs as the *seasonally frozen ground* thaws.

Although it normally refers to *seasonal freezing* and *thawing* processes and effects, the term "frost action" has also been used to describe the long-term heaving that occurs when soils are subjected continuously to a freezing temperature over a long period of time (years), e.g., under cold storage plants and buried chilled pipelines.

Frost action contributes to the mechanical weathering (i.e., disintegration or breakdown) of soil and rock materials, by *frost wedging*, *cryoturbation* activity, and to the development of *cryotexture* and *cryogenic fabric* in soils.
REFERENCES: Hennion, 1955; Washburn, 1979; Johnston, 1981.

193. frost blister

A seasonal *frost mound* produced through doming of *seasonally frozen ground* by a subsurface accumulation of water under elevated hydraulic potential during progressive *freezing* of the *active layer* (see Figures 12 and 13).

COMMENT:

Freezing of the accumulated subsurface water produces a domed layer of clear ice beneath the overlying *frozen ground*. Frost blisters are formed in a single winter; their decay may take more than a year. They are distinguished from *icing blisters* by the layer of *seasonally frozen ground* overlying the ice layer.
SYNONYMS: (not recommended) cryolaccolith, hydrolaccolith, seasonal pingo, winter pingo.
REFERENCES: Muller, 1943; van Everdingen, 1978; Pollard and French, 1984.

194. frost boil

A small mound of soil material, presumed to have been formed by *frost action* (see Figure 16c, d).

COMMENT:

A type of *nonsorted circle*; they are commonly found in fine-grained sediments underlain by permafrost, but also occur in non-permafrost areas.
SYNONYM: mud boil.
REFERENCES: Thorn, 1976; Shilts, 1978.

195. frost bulb

A more or less symmetrical zone of *frozen ground* formed around a buried chilled pipeline or beneath or around a structure maintained at temperatures below 0°C (see Figure 23).

COMMENT:

Heaving of the ground and/or of a structure or facility may occur as the frost bulb forms.
REFERENCES: Andersland and Anderson, 1978; Johnston, 1981.

200. frost creep

The net downslope displacement that occurs when a soil, during a freeze-thaw cycle, expands normal to the ground surface and settles in a nearly vertical direction.

REFERENCES: Benedict, 1970; Washburn, 1979.

204. frost heave

The upward or outward movement of the ground surface (or objects on, or in, the ground) caused by the formation of ice in the soil (see Figure 7).

COMMENT:

Frost action in fine-grained soils increases the volume of the soil not only by freezing of in situ *pore water* (≈ 9% expansion) but also by drawing water to the *freezing front* where *ice lenses* form. Soils that have undergone substantial heaving may consist of alternate layers of ice-saturated soil and relatively clear *ice lenses*. The lenses are formed normal to the direction of heat flow and when freezing penetrates from the ground surface (which may be horizontal, sloping or vertical), they form parallel to that surface. When unrestrained, the amount of surface heave may be almost as much as the total thickness of the *ice lenses*. Frost heave can occur seasonally or continuously if freezing of the ground proceeds without interruption over a period of years.

Differential, or non-uniform, frost heaving is one of the main detrimental aspects of the *frost action* process and reflects the heterogeneous nature of most soils, or variations in heat removal rate and groundwater supply over short distances.

Depending on the degree of restraint, large *freezing pressures* (up to 1 MPa) can be developed as the ground freezes. These can be transmitted to a foundation, structure or other object placed on the ground surface, or embedded or buried in the ground, as basal (i.e., vertical) forces acting on their underside, or through *adfreezing* of the soil to the sides of the foundation, structure or object.

REFERENCES: Penner, 1967, 1968; Washburn, 1979; Linell and Lobacz, 1980; Chamberlain, 1981; Johnston, 1981.

205. frost-heave extent

The difference between the elevations of the ground surface before and after the occurrence of *frost heave*.

208. frost jacking

Cumulative upward displacement of objects embedded in the ground, caused by *frost action*.

COMMENT:

Frost jacking results from basal or vertical *freezing pressures* acting on the underside of a foundation, structure or object, or from *adfreezing* of soil to the sides of these objects. The cumulative upward movement over a period of time (one or several *freeze-thaw cycles*) may result in the foundation unit or object being ejected from the ground.

Fence posts and utility poles or towers are commonly affected, and both deep (pile) and shallow (post) foundations (e.g., used for bridges, wharves, unheated or lightweight buildings) have been seriously affected by frost jacking.

Blocks of jointed or fractured bedrock have also been displaced upward by frost jacking.

SYNONYM: (not recommended) upfreezing.
REFERENCE: Linell and Lobacz, 1980.

209. frost mound

Any mound-shaped landform produced by ground freezing combined with accumulation of *ground ice* due to groundwater movement or the migration of soil moisture.

COMMENT:

Various types of frost mounds, (e.g., *frost blisters*, *icing blisters*, *palsas* and *pingos*) can be distinguished on the basis of their structure and duration, and the character of the ice contained in them.

SYNONYMS: (not recommended) bugor, bulgunniakh, cryogenic mound, earth mound, frost hummock, ground-ice mound, tundra hummock.

REFERENCES: Porsild, 1938; Muller, 1943; van Everdingen, 1978; Pollard and French, 1984.

210. frost penetration

The movement of the *freezing front* into the ground during freezing.

211. frost phenomena

Effects on earth materials and on structures placed in or on the ground, resulting from *frost action*.

216. frost shattering

The mechanical disintegration of rock by the pressure of the freezing of water in pores and along grain boundaries.

COMMENT:

Frost shattering is the process of grain loosening and rock disintegration by the *freezing pressure* of water in films of varying thickness on the surfaces of individual mineral grains. Freezing of the water drawn between the grains by various particle surface forces exerts sufficient differential pressure to loosen and separate the grains.

217. frost sorting

The differential movement of soil particles of different size ranges as a result of *frost action*.

COMMENT:

Frost sorting often accompanies *cryoturbation*.

REFERENCE: Washburn, 1979.

219. frost-stable ground

Ground (soil or rock) in which little or no *segregated ice* forms during *seasonal freezing*.

COMMENT:

Significant cumulative *ice segregation* and *frost heave* may occur even in seasonally frost-stable ground (e.g., gravels and rock) under conditions of continuous freezing and plentiful water supply.
SYNONYM: (not recommended) non-frost-susceptible ground.
REFERENCES: van Everdingen, 1976; Chamberlain, 1981; Konrad and Morgenstern, 1983.

220. frost-stable soil

Soil in which little or no *segregated ice* forms during *seasonal freezing*.
SYNONYM: (not recommended) non-frost-susceptible soil.

223. frost-susceptible ground

Ground (soil or rock) in which *segregated ice* will form (causing *frost heave*) under the required conditions of moisture supply and temperature.
COMMENT:
Frost-susceptible ground will eventually become *ice-rich*, regardless of its initial *total water content*, if the appropriate moisture supply and temperature conditions persist. By implication, frost-susceptible ground may also be susceptible to *thaw weakening* effects when it thaws.
SYNONYM: (not recommended) frost-sensitive ground.
REFERENCES: van Everdingen, 1976; Chamberlain, 1981; Konrad and Morgenstern, 1983.

224. frost-susceptible soil

Soil in which *segregated ice* will form (causing *frost heave*) under the required conditions of moisture supply and temperature.
SYNONYM: (not recommended) frost-sensitive soil.

226. frost weathering

The disintegration and break-up of soil or rock by the combined action of *frost shattering*, *frost wedging* and hydration shattering.
COMMENT:
Hydration shattering is the process of grain loosening and soil or rock disintegration by the wedging pressure of water in films of varying thickness on the surfaces of silicate minerals. Water is drawn between the grains by various particle surface forces and exerts sufficient differential pressure to loosen and separate the grains. The process can act in all climates without the aid of freezing and thawing. When combined with freezing and thawing (*frost shattering* and *frost wedging*), however, the resulting process of frost weathering can be a very efficient mechanism for the break-up of soil or rock.
SYNONYM: (not recommended) rock shattering.
REFERENCES: White, 1976a; Washburn, 1979.

228. frost wedging

The mechanical disintegration, splitting or break-up of rock by the pressure of the freezing of water in cracks, crevices, pores, joints or bedding planes.

COMMENT:

A wide variety of terms has been used to describe what appears to be a single process.

SYNONYMS: congelifraction, frost bursting, frost prying, frost riving, frost splitting, gelifraction.

REFERENCE: Washburn, 1979.

229. frozen fringe

The zone in a freezing, *frost-susceptible* soil between the warmest isotherm at which ice exists in pores and the isotherm at which the warmest *ice lens* is growing (see Figure 5).

COMMENT:

The temperature at the growing *ice lens* is slightly below 0°C.

REFERENCES: Miller, 1972; Konrad and Morgenstern, 1983.

230. frozen ground

Soil or rock in which part or all of the *pore water* has turned into ice.

COMMENT:

Perennially and *seasonally frozen ground* can vary from being partially to extensively frozen depending on the extent of the phase change. It may be described as *hard frozen ground*, *plastic frozen ground*, or *dry frozen ground*, depending on the *pore ice* and *unfrozen water contents* and its *compressibility* under load. Hard-frozen soils are firmly cemented by ice, are subject to brittle failure, and exhibit practically no consolidation under load. Plastic-frozen soils are cemented by ice but have viscous properties due to their high *unfrozen water content* and therefore will compress under load. Dry-, or friable-frozen, soils have a very low *total water content* and are not cemented by ice; their compressibility is the same as for unfrozen soils having the same composition, *total water content* and density.

REFERENCES: U.S.S.R., 1969, 1973; van Everdingen, 1976.

232. gas hydrate

A special form of solid clathrate compound in which crystal lattice cages or chambers, consisting of host molecules, enclose guest molecules.

COMMENT:

Gas hydrates are formed under special temperature and pressure conditions. The host molecules are water, and the guest molecules may be a variety of gases, including argon, nitrogen, carbon dioxide, hydrogen sulfide, methane, ethane, halogens and other small molecules. In *permafrost regions*, gas hydrates are commonly found near the *permafrost base* and may lead to unexpected problems during drilling for hydrocarbons.

REFERENCES: Bily and Dick, 1974; Kaplan, 1974; Judge, 1982.

233. gelifluction

The slow downslope flow of unfrozen earth materials on a frozen substrate.

COMMENT:

Gelifluction is a type of *solifluction* implying the presence of either *seasonal frost* or permafrost.

REFERENCE: Washburn, 1979.

235. geocryology

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

COMMENT:

The term is derived from the Russian word "geokriologiya". Although glaciers are not excluded, the term is usually applied to the study of *frozen ground*, including *seasonally frozen ground* as well as permafrost.

REFERENCES: Fyodorov and Ivanov, 1974; Poppe and Brown, 1976; Washburn, 1979.

236. geothermal gradient

The rate of temperature increase with depth in the subsurface (see Figure 2).

COMMENT:

Commonly expressed as °C per metre depth.

237. geothermal heat flux

The amount of heat moving steadily outward from the interior of the earth through a unit area in unit time.

COMMENT:

Commonly expressed as joules per square metre per second.

238. granic cryogenic fabric

A distinct soil micromorphology, resulting from the effects of freezing and thawing processes, in which soil particles form discrete loosely packed units (see Figure 8a).

COMMENT:

This fabric, found in *cryosols*, is generally attributed to freeze-thaw processes and the formation of *needle ice* near the ground surface.

REFERENCES: Brewer and Pawluk, 1975; Pawluk and Brewer, 1975; Fox, 1983.

239. granoidic cryogenic fabric

A distinct soil micromorphology, resulting from the effects of freezing and thawing processes, in which soil particles form more or less discrete loosely packed units.

COMMENT:

This fabric, found in *cryosols*, is generally attributed to freeze-thaw processes and the formation of *needle ice* near the ground surface.

REFERENCES: Brewer and Pawluk, 1975; Pawluk and Brewer, 1975; Fox, 1983.

241. gravimetric (total) water content

The ratio of the mass of the water and ice in a sample to the dry mass of the sample, commonly expressed as a percentage.

COMMENT:

Because of the way it is defined, the gravimetric total water content can greatly exceed 100 percent. During thawing of a sample of *frozen ground* the gravimetric total water content remains constant, unless excess water is allowed to drain out of the sample.

REFERENCE: Anderson and Morgenstern, 1973.

243. ground ice

A general term referring to all types of ice contained in freezing and *frozen ground* (see Figure 10).

COMMENT:

Ground ice occurs in pores, cavities, voids or other openings in soil or rock and includes *massive ice*. It generally excludes *buried ice*, except in Russian usage. Ground ice may be epigenetic or syngenetic, contemporaneous or relict, aggrading or degrading, perennial or seasonal. It may occur as lenses, wedges, veins, sheets, seams, irregular masses, or as individual crystals or coatings on mineral or organic particles. Perennial ground ice can only occur within permafrost bodies.

REFERENCES: Mackay, 1972b; Pollard and French, 1980.

251. hard frozen ground

***Frozen ground* (soil or rock) which is firmly cemented by ice**.

COMMENT:

Hard frozen ground is subject to brittle failure, and exhibits practically no consolidation under load.

REFERENCE: U.S.S.R., 1969, 1973.

252. heat capacity

The amount of heat required to raise the temperature of a unit mass of a substance by one degree.

COMMENT:

This term is a commonly used abbreviation of *specific heat capacity*, which does not include the effects of changes in latent heat due to the melting of ice or the freezing of water with changes in temperature. Because the phase change in a frozen soil often occurs gradually over a range of temperatures, the *apparent heat capacity* (covering both sensible and *latent heat* contents) may vary significantly with temperature. Heat capacity is commonly expressed in Joules per kg per degree K.

254. heaving pressure

Upward pressure developed during freezing of the ground.

COMMENT:
Heaving pressure develops during the formation of both *pore ice* and *ice lenses*. It is responsible for the heaving of utilities, foundations, pavements etc.

256. high-centre polygon
An *ice-wedge polygon* in which melting of the surrounding *ice wedges* has left the central area in a relatively elevated position.

258. hydraulic conductivity
The volume of fluid passing through a unit cross section in unit time under the action of a unit hydraulic potential gradient.
COMMENT:
The hydraulic conductivity is a function of the viscosity and density of the fluid, which in turn depend on the fluid temperature. In practice it is commonly expressed in cm per second or m per day.

259. hydraulic diffusivity
The ratio of the *hydraulic conductivity* and the storage capacity of a groundwater aquifer.
COMMENT:
The hydraulic diffusivity expresses the facility with which an aquifer will undergo a pressure change.

261. hydraulic thawing
Artificial thawing (and removal) of *frozen ground* by the use of a stream or jet of water under high pressure.
COMMENT:
Hydraulic thawing (hydraulicking) is a common method of working frozen placer deposits in North America.

262. hydrochemical talik
A layer or body of *cryotic* (but *unfrozen*) *ground* in a permafrost area, maintained by moving mineralized groundwater (see Figure 11).
COMMENT:
In a hydrochemical talik, freezing is prevented by *freezing-point depression* due to the dissolved-solids content of mineralized groundwater moving through the talik.
REFERENCE: van Everdingen, 1976.

267. hydrothermal talik
A layer or body of *noncryotic unfrozen ground* in a permafrost area, maintained by moving groundwater (see Figure 11).
COMMENT:
In a hydrothermal talik, the temperature is maintained above 0°C by the heat supplied by moving groundwater.
REFERENCE: van Everdingen, 1976.

268. ice

Water in the solid state.

COMMENT:

Ice commonly occurs as hexagonal crystals. In *permafrost regions*, ice may occupy voids in soils and rocks and may develop in a variety of forms. Ice may be colourless to pale blue or greenish-blue. It may appear white due to included gas bubbles; in exposures, *ground ice* may also appear black. Various types of *ground ice* are defined elsewhere in this Glossary.

269. ice-bearing permafrost

Permafrost that contains ice.

271. ice-bonded permafrost

***Ice-bearing permafrost* in which the soil particles are cemented together by ice**.

COMMENT:

Frozen soils may be *partially-bonded*, *poorly-bonded* or *friable*, if the soil particles are held together (cemented) weakly by the ice. If ice bonding is strong, the soil is said to be *well-bonded*. The distinction between ice-bonded permafrost and permafrost that contains ice but in which the ice does not act as a cement, is particularly important in *subsea permafrost*, where the dissolved-solids content of the *pore water* affects the ability of ice to act as a cement. Acoustic geophysical methods can be used to delineate ice-bonded permafrost, but use of the term "acoustically-defined permafrost" is not recommended except as a modifier to describe the method used to determine the permafrost conditions.

REFERENCES: Pihlainen and Johnston, 1963; Linell and Kaplar, 1966; Johnston, 1981; Hunter, 1984; Sellmann and Hopkins, 1984.

273. ice content

The amount of ice contained in frozen or partially frozen soil or rock.

COMMENT:

Ice content is normally expressed in one of two ways:

1. on a dry-weight basis (gravimetric), as the ratio of the mass of the ice in a sample to the mass of the dry sample, expressed as a percentage, or

2. on a volume basis (volumetric), as the ratio of the volume of ice in a sample to the volume of the whole sample, expressed as a fraction.

The volumetric ice content cannot exceed unity whereas the gravimetric ice content can greatly exceed 100 percent.

REFERENCES: Penner, 1970; Anderson and Morgenstern, 1973; Johnston, 1981.

274. ice-cored topography

Topography that is due almost solely to differences in the amount of *excess ice* underlying its surface.

COMMENT:

The relief may be totally or partially due to *thermokarst*, or to irregular development of *ground ice*, primarily *segregated ice*, or to buried glacier ice. An example is the "involuted hill" near Tuktoyaktuk, N.W.T.
REFERENCES: Rampton, 1974; Rampton and Walcott, 1974.

276. ice lens

A dominantly horizontal, lens-shaped body of ice of any dimension.

COMMENT:

The term is commonly used for layers of *segregated ice*. Ice lenses may range in thickness from hairline to more than 10 m. Very thick and extensive ice lenses are better termed *massive ice* beds.
REFERENCES: Mackay, 1971, 1973a; Rampton and Walcott, 1974.

278. ice-nucleation temperature

The temperature at which ice first forms during freezing of a soil/water system that does not initially contain ice.

COMMENT:

The ice-nucleation temperature may be lower than 0°C due to *freezing-point depression* caused by the dissolved-solids content of the *pore water*.

279. ice-rich permafrost

Permafrost containing *excess ice*.

COMMENT:

A qualitative term. Ice-rich permafrost is *thaw-sensitive*.

280. ice segregation

The formation of discrete layers or lenses of *segregated ice* in freezing mineral or organic soils, as a result of the migration (and subsequent freezing) of *pore water*.

COMMENT:

The migration of *pore water* to the *frozen fringe* is caused by *cryosuction*.
REFERENCES: Miller, 1972; Penner, 1972.

282. ice vein

An ice-filled crack or fissure in the ground.

284. ice wedge

A massive, generally wedge-shaped body with its apex pointing downward, composed of foliated or vertically banded, commonly white, ice (see Figure 17).

COMMENT:

The size of ice wedges varies from less than 10 cm to more than 3 m in width at the top, commonly tapering to a feather edge at a depth of 1 to more than 10 m. Some ice wedges may extend downward as much as 25 m and may have shapes dissimilar to wedges. *Epigenetic ice wedges* are characteristically wedge-shaped, whereas *syngenetic ice wedges* and *anti-syngenetic ice* wedges are generally wedge-shaped but with more irregular sides (see also *epigenetic permafrost*, *syngenetic permafrost*).

Ice wedges are formed in *thermal contraction cracks* in which hoar frost (see *open-cavity ice*) forms and into which water from melting snow penetrates in the spring. Repeated annual contraction cracking of the ice in the wedge, followed by freezing of water in the crack, gradually increases the width (and possibly the depth) of the wedge and causes vertical banding of the ice mass. The surface expression of ice wedges is generally a network of *polygons*. Ice wedges growing as a result of repeated (but not necessarily annual) winter cracking are called *active ice wedges*. They occur primarily in areas of *continuous permafrost* when developed in mineral soil. *Inactive ice wedges* can be stable and remain for many centuries without changing.

REFERENCES: Dostovalov and Popov, 1966; Lachenbruch, 1966; Mackay and Black, 1973; French, 1976; Washburn, 1979; French et al., 1982; Mackay and Matthews, 1983; Mackay, 1990.

285. ice-wedge cast

A filling of sediment in the space formerly occupied by an *ice wedge*.

COMMENT:

An ice-wedge cast is a wedge of secondary filling. When the permafrost thawed, the *ice wedge* melted and the enclosing and overlying sediments collapsed into the resulting trough.

An ice-wedge cast is one of the few acceptable criteria indicating the earlier presence of permafrost.

The term "fossil ice wedge" is not recommended because ice is no longer present.

SYNONYM: (not recommended) ice-wedge pseudomorph.

REFERENCES: Washburn, 1979, 1980.

286. ice-wedge polygon

A *polygon* outlined by *ice wedges* underlying its boundaries.

COMMENT:

Ice-wedge polygons occur in both mineral terrain and *peatland*, commonly in poorly drained permafrost areas.

288. iciness

A qualitative term describing the quantity of ice in *frozen ground*.

COMMENT:

In Russian literature, the equivalent term is used to describe volumetric ice content of frozen, or partially frozen, soil or rock. The "relative iciness" is expressed as the ratio of the mass of ice to the total mass of water (ice and unfrozen water) present.

REFERENCE: U.S.S.R., 1969.

289. icing

A sheetlike mass of layered ice formed on the ground surface, or on river or lake ice, by freezing of successive flows of water that may seep from the ground, flow from a spring or emerge from below river or lake ice through fractures.

COMMENT:

Icings also occur in non-permafrost areas. Many icings incorporate snow. In North America the term "icing" is gradually replacing a variety of terms used in the past. Aufeis (German), flood ice, flood-plain icing, ice field, naled (Russian) and overflow ice usually indicated icings formed on river ice and floodplains. Chrystocrene (or crystocrene), ground icing, groundwater icing and spring icing usually indicated icings formed by freezing of ground-water discharge. Use of the term "glacier" to describe icings, which is common in Alaska and the Yukon, is inappropriate and should be avoided.

REFERENCES: Muller, 1943; Carey, 1970, 1973.

290. icing blister

A seasonal *frost mound* consisting of ice only and formed at least in part through lifting of one or more layers of an *icing* by injected water (see Figures 12 and 13).

COMMENT:

Freezing of the injected water will produce a layer of clear ice, contrasting with the overlying thinly layered ice of the *icing*. Rupture and draining of an icing blister may leave an empty cavity. Icing blisters are distinguished from *frost blisters* by the absence of a covering layer of *seasonally frozen ground*; they are distinguished from *icing mounds* by the layer of clear ice, and in some cases by the presence of an empty cavity. They have also been termed "ice blisters" (not recommended).

REFERENCE: van Everdingen, 1978.

291. icing glade

An area kept clear of trees and shrubs by the annual occurrence of *icings*.

COMMENT:

Icing glades along streams may also show the effects of lateral erosion occurring along the edges of the *icings* during and after the *snowmelt*.

292. icing mound

A seasonal *frost mound* consisting exclusively of thinly layered ice, formed by freezing of successive flows of water issuing from the ground or from below river ice.

COMMENT:

Icing mounds may incorporate snow.

SYNONYM: (not recommended) ice mound.

REFERENCES: Muller, 1943; van Everdingen, 1978.

294. inactive ice wedge

An *ice wedge* that is no longer growing.

COMMENT:
Inactive ice wedges can be stable and remain unchanged for decades or centuries.

295. inactive rock glacier

A mass of rock fragments and finer material, on a slope, that contains either an ice core or interstitial ice, and shows evidence of past, but not present, movement.

COMMENT:
Rock glaciers are said to be inactive when their main body ceases to move, and they show no evidence of very recent movement.
REFERENCES: White, 1976b; Washburn, 1979.

298. interfacial water

Interfacial water forms transition layers at mineral/water and mineral/water/ice interfaces in *frozen ground*.

COMMENTS:
The intermolecular forces involved are such that interfacial water does not move under the influence of gravity. The temperature at which any portion of the interfacial water will change phase depends on the total energy of the various adsorption forces, which in turn depends on the distance from the mineral surface, the type of mineral, and the solute content of the water.
REFERENCE: Anderson and Morgenstern, 1973.

299. intermediate discontinuous permafrost

1. (North-American usage) **Permafrost underlying 35 to 65 percent of the area of exposed land surface**.
2. (Russian usage) **Permafrost underlying 40 to 60 percent of the area of exposed land surface**.

REFERENCE: Heginbottom and Radburn, 1992.

301. intrapermafrost water

Water occurring in unfrozen zones (*taliks* and *cryopegs*) within permafrost (see Figure 11).

COMMENT:
Intrapermafrost water includes water in *open*, *lateral* and *transient taliks* and in *basal*, *isolated* and *marine cryopegs*. Sometimes erroneously called interpermafrost water.
REFERENCES: Williams, 1965, 1970; Tolstikhin and Tolstikhin, 1974.

302. intrusive ice

Ice formed from water injected into soils or rocks (see Figure 10c).

COMMENT:
Freezing of injected water will normally lift the ground above it, thereby producing topographic forms somewhat resembling those of igneous intrusions in rocks. Thus, a tabular mass of intrusive ice is analogous to a sill or a dyke (see *ice*

vein) whereas the domed form is analogous to a laccolith (see *frost blister, pingo*). Use of terms such as "sill ice" or "hydrolaccolith," however, is not recommended.

Intrusive ice may develop in porous unconsolidated sediments and in jointed or fractured bedrock. Fractures may become enlarged by hydraulic fracturing or *frost wedging* processes. For the greatest effect, water must become trapped in the joints or fractures and be subjected to relatively rapid freezing.

SYNOMYM: (not recommended) injection ice.

REFERENCES: Mackay, 1972b; Dyke, 1981, 1984.

304. isoband cryogenic fabric

A distinct soil micromorphology, resulting from the effects of freezing and thawing processes, in which soil particles form subhorizontal layers of similar thickness.

COMMENT:

This fabric, found in *cryosols*, results from freeze-thaw processes accompanied by eluviation.

305. isolated cryopeg

A body of *unfrozen ground,* that is perennially cryotic (T < 0°C) and entirely surrounded by perennially *frozen ground* (see Figure 11).

COMMENT:

In an isolated cryopeg, freezing is prevented by *freezing-point depression* due to the dissolved-solids content of its *pore water*.

REFERENCE: Tolstikhin and Tolstikhin, 1974.

306. isolated patches of permafrost

Permafrost underlying less than 10 percent of the exposed land surface.

COMMENT:

Individual areas of permafrost are of limited areal extent, widely separated, and are completely surrounded by *unfrozen ground*.

SYNONYMS: (not recommended) insular permafrost; island permafrost; scattered permafrost.

REFERENCES: Heginbottom and Radburn, 1992.

307. isolated talik

A layer or body of *unfrozen ground* entirely surrounded by perennially *frozen ground* (see Figure 11).

COMMENT:

Isolated taliks are commonly cryotic (see *isolated cryopeg*), but they may be noncryotic (see *transient talik*).

REFERENCE: van Everdingen, 1976.

308. kurum

A general term for all types of coarse clastic formations on slopes of 2-3 to 40 degrees, moving downslope mainly due to creep.

COMMENT:

This Russian term, used extensively in Siberia, covers "stone streams", "rock streams", "rock covers", and "rock fields".
REFERENCE: Tiurin, Romanovskii and Poltev, 1982.

309. lake talik

A layer or body of *unfrozen ground* occupying a depression in the *permafrost table* beneath a lake.

COMMENT:

The temperature of a lake talik remains above 0°C due to the heat storage effect of the lake water. Depending on the *permafrost thickness* and the size of the lake, such taliks may be either open or closed.
REFERENCES: Williams, 1965; Washburn, 1973; van Everdingen, 1976.

310. latent heat (of fusion)

The amount of heat required to melt all the ice (or freeze all the *pore water*) in a unit mass of soil or rock.

311. lateral talik

A layer or body of *unfrozen ground*, overlain and underlain by perennially *frozen ground* (see Figure 11).

COMMENT:

Lateral taliks may be cryotic (see *hydrochemical talik*) or noncryotic (see *hydrothermal talik*).
REFERENCE: van Everdingen, 1976.

312. latitudinal limit of permafrost

The southernmost (northernmost) latitude at which permafrost occurs in a lowland region in the northern (southern) hemisphere.

313. latitudinal zonation of permafrost

The subdivision of a *permafrost region* into *permafrost zones*, based on the percentage of the area that is underlain by permafrost.

314. layered cryostructure

The cryostructure of frozen silt or loam in which ice layers alternate with mineral layers that have a *massive cryostructure* (see Figure 9e).

COMMENT:

Silt or loam with a layered cryostructure has a relatively high *ice content*.
REFERENCE: Kudryavtsev, 1978.

315. lens ice

Ground ice* occurring as *ice lenses.

316. lens-type cryostructure

The cryostructure of frozen silt or loam containing numerous *ice lenses* (see Figure 9e).

COMMENT:
Silt or loam with a lens-type cryostructure has a relatively high *ice content*.
REFERENCE: Kudryavtsev, 1978.

319. long-term strength
The failure strength of a material after a long period of creep deformation.
COMMENT:
It is sometimes defined in practice as the *creep strength* (or the *delayed strength*) related to the service life of a structure, but its general definition is the failure strength attained when the strain rate tends to zero or time tends to infinity.

320. low-centre polygon
An *ice-wedge polygon* in which thawing of *ice-rich permafrost* has left the central area in a relatively depressed position.

322. macro-scale polygons
Macro-scale polygons are closed, multi-sided, roughly equidimensional patterned-ground features, typically 15 to 30 m across, commonly resulting from thermal contraction cracking of the ground.
COMMENT:
Macro-scale polygons form random or oriented polygonal patterns in both mineral terrain and *peatland* in permafrost areas.
REFERENCES: Rapp and Clark, 1971; Washburn, 1979.

323. marine cryopeg
A layer or body of *unfrozen ground*, that is perennially cryotic (T < 0°C), forming part of coastal or *subsea permafrost* (see Figure 11).
COMMENT:
Freezing of a marine cryopeg is prevented by *freezing-point depression* due to the high dissolved-solids content of its *pore water*.
REFERENCE: Tolstikhin and Tolstikhin, 1974.

324. mass wasting
Downslope movement of soil or rock on, or near, the earth's surface under the influence of gravity (see Figure 21).
COMMENT:
Mass wasting includes slow displacements such as *frost creep*, *gelifluction* or *solifluction*, and more rapid movements such as earthflows or *active-layer failures*. It does not include crustal displacements resulting from tectonic activity or those movements where material is carried directly by an active transporting medium, such as glacial ice, snow, water or air. In permafrost areas, mass wasting is not limited to the *active layer*; it can include displacements caused by the formation and creep of *ground ice* within permafrost. When *frost heave* is a component of *frost creep*, it is a mass wasting process.
REFERENCES: Hutchinson, 1968; Savage, 1968; Washburn, 1979.

325. massive-agglomerate cryostructure

The cryostructure of frozen silt or loam in which ice veins form an irregular three-dimensional network (see Figure 9e).

COMMENT:

Massive-agglomerate cryostructure is characterized by a relative high *ice content*.

REFERENCE: Kudryavtsev, 1978.

326. massive cryostructure

The cryostructure of frozen sand in which all mineral particles are bonded together by ice, and all pore spaces completely filled with ice (see Figure 9e)**.**

COMMENT:

Massive cryostructure is characterized by the predominance of *pore ice*.

REFERENCE: Kudryavtsev, 1978.

327. massive ice

A comprehensive term used to describe large masses of *ground ice*, including *ice wedges, pingo ice, buried ice* and large *ice lenses* (see Figure 10d, e, f).

COMMENT:

Massive ice beds typically have an *ice content* of at least 250 percent (on an ice-to-dry-soil weight basis). If the *ice content* is less than 250 percent, the beds are better termed "massive icy beds". Some massive ice beds are more than 40 m thick and 2 km in horizontal extent, and some are responsible for prominent topographic rises.

REFERENCES: Rampton and Mackay, 1971; Mackay, 1971, 1973a; Rampton and Walcott, 1974.

328. massive-porous cryostructure

The cryostructure of frozen sand and gravel in which all mineral particles are bonded together with ice, but larger pore spaces are not completely filled with ice (see Figure 9e).

COMMENT:

Massive-porous cryostructure is characterized by the predominance of *pore ice* and a relatively low *ice content*.

REFERENCE: Kudryavtsev, 1978.

329. mean annual ground-surface temperature (MAGST)

Mean annual temperature of the surface of the ground.

COMMENT:

Permafrost exists if the mean annual ground-surface temperature is perennially below 0°C. Although the mean annual surface temperature may be below 0°C, the surface temperature will fluctuate during the year, causing a layer of ground immediately beneath the surface to thaw in the summer and freeze in the winter (the *active layer*). Small changes in the annual range of surface temperature and in the mean annual surface temperature from year to year, or over a period of a few years, may cause a layer of ground between the bottom of the *active layer* and the *permafrost table* to remain at a temperature above 0°C, creating a *talik* or *residual thaw layer*.

330. mean annual ground temperature (MAGT)

Mean annual temperature of the ground at a particular depth.

COMMENT:

The mean annual temperature of the ground usually increases with depth below the surface. In some northern areas, however, it is not uncommon to find that the mean annual ground temperature decreases in the upper 50 to 100 metres below the ground surface as a result of past changes in surface and climate conditions. Below that depth, it will increase as a result of the *geothermal heat flux* from the interior of the earth. The mean annual ground temperature at the *depth of zero annual amplitude* is often used to assess the *thermal regime of the ground* at various locations.

331. mechanical properties of frozen ground

The properties of *frozen ground* governing its *deformability* and strength.

COMMENT:

1. Properties under quasi-static loading:

The behaviour of frozen soils under quasi-static loading is usually different from that of unfrozen soils because of the presence of ice and unfrozen water films. In particular, frozen soils are more susceptible to creep and relaxation effects, and their behaviour is strongly affected by temperature change. In addition to creep, volumetric consolidation may also develop in frozen soils with large *unfrozen water contents*.

As with unfrozen soils, the strength of frozen soils depends on interparticle friction, particle interlocking and cohesion. In frozen soil, however, bonding of particles by ice is the dominant strength factor. This is complicated by the unfrozen water films surrounding the soil particles, which reduce interparticle bonding. The strength of ice in frozen soil is dependent on many factors, such as temperature, pressure, strain rate, grain size, crystal orientation and density. At very high *ice contents*, frozen soil behaviour under load is similar to that of ice. At low *ice contents*, however, when interparticle forces begin to contribute, the unfrozen water films play an important role, especially in fine-grained frozen soils.

(a) *Deformability* and strength:

The *deformability* and strength of a frozen soil can be studied by specially designed tests either in a cold room or in situ. Quasi-static elastic parameters usually determined in such tests are: *Young's modulus* and *Poisson's ratio* for short-term response, and creep parameters (used in a creep equation) for long-term response. In addition, the variation of strength with time or with strain rate is also determined from the tests. The strength is usually found to vary from a high short-term value to a much smaller long-term value, which is considered to govern the behaviour of frozen soil under sustained loading. Under high confining stresses and at relatively high freezing temperatures, most frozen soils creep and eventually fail in a plastic manner. On the other hand, under compression at low confining stresses, or at tensile stresses combined with low temperatures, many frozen soils fail in a brittle manner by tensile crack propagation.

(b) *Compressibility* of frozen soils:

Although frozen soils are usually considered to be practically incompressible, and volume change deformations can therefore be neglected, investigations show, however, that the *compressibility* of frozen soils can be significant and should not be neglected in some cases, especially when large areas are loaded.

Compressibility and its time dependence in frozen soils are due to several causes, such as instantaneous compression of the gaseous phase, creep of the *pore ice* due to shear stresses at the grain contacts, and hydrodynamic consolidation due to the expulsion of *unfrozen water* under stress, the amount of which varies with the applied pressure.

2. Dynamic properties of *frozen ground*:

Information on the dynamic properties of frozen soils is important with regard to the behaviour of structures subjected to seismic or vibratory loads, and the evaluation of results of seismic field surveys in permafrost areas.

Dynamic properties are expressed either in terms of two dynamic elastic parameters: the *dynamic modulus of elasticity* and the *dynamic Poisson's ratio*, or in terms of the propagation velocities of compressional waves and shear waves in the material. The two sets of dynamic parameters are uniquely related by the theory of elasticity.

The dynamic elastic parameters deduced from wave propagation velocities are different from those obtained from any type of static loading tests because the latter contain the additional effects of elastic relaxation and creep. Parameters that influence the compressional and shear wave velocities in soils and rocks include grain size, lithology, *total water content*, porosity and pore structure, the nature, temperature and degree of freezing of the interstitial water, degree of cementation, and confining pressure.

Due to the *ice content*, seismic velocities are generally higher in frozen soils or rocks than in the same unfrozen materials. The change in velocity can occur gradually as temperatures decrease below 0°C, if *freezing point depression* conditions exist in the soil.

REFERENCES: Garg, 1973; Tsytovich, 1973; King et al., 1974; Vinson, 1978; Johnston, 1981.

332. mechanical strength

The failure strength of a material under given loading conditions.

334. micro-scale polygon

Micro-scale polygons are closed, multi-sided, roughly equidimensional patterned-ground features, less than 2 m in diameter, usually caused by desiccation cracking of fine-grained soil materials.

335. minerogenic palsa

A *palsa* in which the frozen core extends below the peat into underlying mineral material.

COMMENT:

Palsas were originally regarded as having developed completely in peat (Fries and Bergström, 1910). Later it was found that such true *palsas* are relatively rare, and that the frozen core in most palsa-like landforms extends down into mineral layers (Lundqvist, 1962; Lundqvist and Mattsson, 1965; Wramner, 1965). Fosgren (1966) and Åhman (1977) also reported "palsas" developed entirely in mineral soil, and they called both types "minerogenic palsas". Harris (1993) described a sequence of stages in the development of palsa-like mounds developed entirely in mineral soils in the Fox Lake area (Yukon), for which he proposed the name "lithalsa". He suggested a new name was needed, because the heat- and moisture-transport processes in mineral soils differ from those in peat (Brown, 1970a).

REFERENCES: Åhman, 1977; Fosgren, 1966, 1968; Fries and Bergström, 1910; Harris, 1993; Lundqvist, 1962; Lundqvist and Mattsson, 1965; Wramner, 1965.

338. mountain permafrost

Permafrost existing at high altitudes in high, middle, and low latitudes (see Figure 1).

COMMENT:

Mountain permafrost may show some degree of *altitudinal zonation*. Mountain permafrost grades into the permafrost of high latitudes in areas such as the North American Cordillera. Plateau permafrost is a subdivision of mountain permafrost but use of this term is not recommended.

SYNONYMS: alpine permafrost, high-altitude permafrost.

REFERENCES: Fujii and Higuchi, 1978; Harris and Brown, 1978, 1982; Péwé, 1983.

340. mud circle

A type of nonsorted circle developed in fine-grained materials.

SYNONYM: mud boil

343. multiple retrogressive slide

A type of mass movement associated with shear failure in unfrozen sediments underlying permafrost, leading to detachment of blocks of *frozen ground* that move downslope.

COMMENT:

A degree of back-tilting or rotation of the failure components may be involved.

REFERENCE: McRoberts and Morgenstern, 1974.

344. n-factor

The ratio of the *surface freezing* or *thawing index* to the *air freezing* or *thawing index*.

COMMENT:

At any site, (standard) air temperatures are seldom the same as surface (air/substrate boundary) temperatures. Because air temperatures (measured at weather stations) are usually available and surface temperatures are not, the n-factor (an empirically determined coefficient) is used to relate air temperatures to surface temperatures in order to establish the thermal boundary condition at the surface, particularly for engineering purposes.

The difference between air and surface temperatures at any specific time and location is greatly influenced by climatic, surface and subsurface conditions (e.g., latitude, cloud cover, time of day or year, relative humidity, wind speed, type of surface--wet, dry, moss, snow, natural vegetated terrain, mineral soil, pavements--and *thermal properties of the ground*). The average surface temperature and n-factor may vary significantly from year to year, even for a given surface and location, as well as for different sites, surfaces and soil systems.

Values of the freezing and thawing n-factors have been determined for a large number of sites and surfaces and are widely used for predicting surface temperatures and the *thermal regime of the ground*. The data vary widely, however, and indicate that a rigorous value of n for a given site cannot simply be chosen from these data. Direct determination of the n-factor for a specific location is much better and requires concurrent observations of air and surface temperatures throughout at least one and preferably several complete freezing and thawing seasons.

REFERENCES: Carlson and Kersten, 1953; Lunardini, 1978, 1981.

346. needle ice

Thin, elongated ice crystals that form perpendicular to the ground surface (see Figure 10g).

COMMENT:

Needle ice forms during nights when there is extensive radiative cooling, causing *ice segregation* in the surface layer of the soil. The needles can form under stones, soil peds, moss or other surface vegetation and are best developed in alpine areas with maritime temperate climates where silty or organic soils are present. They can also form on coarse-grained, porous volcanic ejectamenta (e.g., in British Columbia and Iceland). The Swedish term "pipkrake" is sometimes used to describe needle ice.

REFERENCES: Krumme, 1935; Mackay and Mathews, 1974; Washburn, 1979.

349. noncryotic ground

Soil or rock at temperatures above 0°C (see Figures 2 and 3).

COMMENT:

Noncryotic ground is not synonymous with *thawed ground* (which implies an earlier frozen state), nor with *unfrozen ground* (the temperature of which may be below 0°C).
REFERENCE: van Everdingen, 1976.

350. nonsorted circle

A nonsorted circle is a *patterned ground* form that is equidimensional in several directions, with a dominantly circular outline which lacks a border of stones.

COMMENT:

Nonsorted circles characteristically have margins of vegetation; they occur singly or in groups; their diameter is commonly between 0.5 and 3.0 m. Their central areas tend to be slightly dome-shaped and may be cracked into small *nonsorted polygons*. In places, the long axes of stones and sand particles tend toward vertical. The term covers both *mud circles*, developed in fine-grained materials, and *stony earth circles*, developed in gravelly materials.
REFERENCE: Washburn, 1979.

351. nonsorted net

A nonsorted net is a type of *patterned ground* with cells that are equidimensional in several directions, neither dominantly circular nor polygonal, and lacking borders of stones.

COMMENT:

Nonsorted nets occur on nearly horizontal surfaces. Diameters of individual cells range from 0.5 to as much as 10 m. Where vegetation is sparse, it is generally concentrated in furrows bordering the individual cells of the net, emphasizing the pattern.
REFERENCE: Washburn, 1979.

352. nonsorted polygon

A nonsorted polygon is a *patterned ground* form that is equidimensional in several directions, with a dominantly polygonal outline which lacks a border of stones.

COMMENT:

Nonsorted polygons commonly occur in extensive patterns, most frequently on nearly horizontal surfaces (although small forms have been found on slopes up to 27°; large ones have been found on slopes as steep as 31° in polar regions). *Micro-scale polygons* range in size from 5 cm to about 1 m; *macro-scale polygons* may be more than 100 m in diameter. Where vegetation is sparse, it is generally concentrated in furrows along the borders between the polygons, emphasizing the pattern. The mineral soil can be well-sorted fines, sand, gravel, or a mixture.
REFERENCE: Washburn, 1979.

353. nonsorted step

A nonsorted step is a *patterned ground* feature with a step-like form and a downslope border of vegetation embanking an area of relatively bare ground upslope.

COMMENT:

Nonsorted steps are only found on slopes, commonly ranging from 5° to 15°; their downslope border forms a low riser fronting a tread whose slope is less than the general slope. Nonsorted steps are assumed to be derived from *nonsorted nets* or hummocks or *nonsorted polygons*, rather than to develop independently.

REFERENCE: Washburn, 1979.

354. nonsorted stripe

Nonsorted stripes form *patterned ground* with a striped and nonsorted appearance, due to parallel strips of vegetation-covered ground and intervening strips of relatively bare ground, oriented down the steepest available slope.

COMMENT:

Nonsorted stripes, both large and small, occur on slopes of 5-6°, downslope from *nonsorted polygons* or *nonsorted nets*. In some places the vegetated and non-vegetated strips are equally wide; in other places vegetated strips of 0.3-0.6 m are spaced from 3 to 4.5 m apart. They can be several hundred metres long.

REFERENCE: Washburn, 1956.

356. onshore permafrost

Permafrost occurring beneath exposed land surfaces.

COMMENT:

Often used to indicate permafrost in coastal land areas, as contrasted with *subsea permafrost*.

SYNONYM: continental permafrost.

357. open-cavity ice

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

COMMENT:

Open-cavity ice is similar to hoar frost, except that the ice crystals grow in cavities rather than on the surface. It is common in *thermal contraction cracks*, mine workings, ice caves and ice cellars in permafrost.

SYNONYM: *sublimation ice*.

REFERENCE: Mackay, 1972b.

358. open-system freezing

Freezing that occurs under conditions that allow gain or loss of water by the system. (see Figure 7).

COMMENT:

The effects of open-system freezing can be quite different for different soil materials. During freezing of clean, medium- to coarse-grained materials, some *pore water* may be expelled ahead of the *freezing front* (compensating for the volume increase during phase change) thus reducing *frost heave*. During freezing of fine-grained materials, however, water often migrates to the *freezing front*, contributing to the formation of *segregated ice*, thus causing increased *frost heave*.

359. open-system pingo

A *pingo* formed by doming of *frozen ground* due to freezing of injected water supplied by groundwater moving downslope through *taliks* to the site of the *pingo*, where it moves towards the surface (see Figure 19b).

COMMENT:

Most open-system pingos are found in or near areas of marked relief, mainly in the *discontinuous permafrost zone*. High hydraulic potential, due to water originating in elevated areas, causes repeated injection of water into the weakest portion of the permafrost, followed by freezing. This leads to the development of the *massive ice* forming the core of the *pingo*.

SYNONYMS: hydraulic pingo and (not recommended) East Greenland pingo.

REFERENCES: Müller, 1959; Hughes, 1969.

360. open talik

A body of *unfrozen ground* that penetrates the permafrost completely, connecting *suprapermafrost* and *subpermafrost water* (see Figure 11).

COMMENT:

Open taliks can be found below large rivers (see *river talik*) and lakes (see *lake talik*). They may be noncryotic (see *hydrothermal talik*) or cryotic (see *hydrochemical talik*).

SYNONYMS: (not recommended) through talik, penetrating talik, perforating talik, piercing talik.

REFERENCES: Williams, 1965; Washburn, 1973; van Everdingen, 1976.

361. orbiculic cryogenic fabric

A distinct soil micromorphology, resulting from the effects of freezing and thawing processes, in which coarser soil particles form circular to ellipsoidal patterns (see Figure 8d).

COMMENT:

This fabric, found in *cryosols*, results from freeze-thaw processes probably accompanied by *cryoturbation*.

REFERENCES: Brewer and Pawluk, 1975; Pawluk and Brewer, 1975; Fox, 1983.

362. organic cryosol

An organic soil having a surface layer containing more than 17% organic carbon by weight, with permafrost within 1 m below the surface..

COMMENT:

Organic cryosol is more than 40 cm thick, or more than 10 cm thick over a lithic contact, or more than 10 cm thick over an ice layer that is at least 30 cm thick. Organic cryosols have *mean annual ground temperatures* below 0°C.

REFERENCE: Canada Soil Survey Committee, 1978.

364. oriented lake

One of a group of lakes possessing a common, preferred, long-axis orientation (see Figure 22b).

COMMENT:

Oriented lakes appear to develop by differential erosion of permafrost shorelines formed in fine-grained, homogeneous sediments under the influence of predominant winds. In some cases, bedrock structural control may also determine lake orientation. Oriented lakes also occur in non-permafrost environments.

REFERENCES: Black and Barksdale, 1949; Rex, 1961; Carson and Hussey, 1962; Price, 1968; Sellman et al., 1975; Harry and French, 1983.

366. palsa

A peaty permafrost mound possessing a core of alternating layers of *segregated ice* and *peat* or mineral soil material (see Figures 14 and 15a).

COMMENT:

Palsas are typically between 1 and 7 m in height and a few metres to 100 m in diameter. The term is of Fennoscandian origin, originally meaning ".... a hummock rising out of a bog with a core of ice" (Seppälä, 1972). Implicit in this definition are their constructional nature, their origin in wetlands (fens or *peat* bogs), and that *ice segregation* in mineral soil beneath *peat* is the process responsible for growth. Most, but not all, palsas occur in the *discontinuous permafrost zone*.

A more general definition has been proposed by Washburn (1983) in which the term is applied in a descriptive sense to a broader range of permafrost mounds that may include *intrusive* as well as *segregated ice*: "Palsas are peaty permafrost mounds, ranging from about 0.5 to about 10 m in height and exceeding about 2 m in average diameter, comprising (1) aggradation forms due to *permafrost aggradation* at an *active-layer*/permafrost contact zone, and (2) similar-appearing degradation forms due to disintegration of an extensive peaty deposit". The disadvantage of this broader definition is that mounds of entirely different origins (e.g., those including *intrusive ice*) are grouped under one term. It is proposed, therefore, that the term "palsa" be restricted to those features where the internal structure shows the presence of *segregated ice* and where the environment lacks high hydraulic potentials, provided that other parameters (size, shape, location in wetlands) are also satisfied. The term "*frost mound*" should be used as a non-genetic term to describe the range of morphologically similar, but genetically different, features that occur in permafrost terrain.

SYNONYMS: peat hummock; peat mound.

REFERENCES: Fries and Bergström, 1910; Lundqvist, 1969; Seppälä, 1972; Zoltai and Tarnocai, 1971, 1975; Washburn, 1983.

367. palsa bog

A poorly-drained lowland underlain by organic-rich sediments, which contains perennially frozen peat bodies (*peat plateaux*) and occasionally *palsas*.

COMMENT:

Palsa bogs occur in subarctic lowlands and are characteristic of the zone of *discontinuous permafrost*.

SYNONYM: palsa mire.

REFERENCE: Sollid and Sorbel, 1974.

369. partially-bonded permafrost

***Ice-bearing permafrost* in which some of the soil particles are not held together by ice**.

370. passive construction methods in permafrost

Special design and construction methods used for engineering works in permafrost areas where preservation of the frozen condition is feasible.

COMMENT:

Passive methods should maintain the foundation materials in a frozen state. Preservation of the frozen condition or *permafrost aggradation* can be accomplished using *thermal piles* or *thermosyphons*, or by using either a ventilation or an insulation construction technique; often a combination of these techniques is used.

The ventilation technique requires that there is a clear space left between the bottom of the structure and the ground surface, or that the structure is placed on a fill pad with ventilation ducts incorporated in the pad or the floor system. Movement of cold air through the air space or ducts dissipates heat from the structure above and removes heat from the ground below.

Using the insulation technique, a relatively thick fill (sometimes containing a layer of insulation) is placed on the ground surface to prevent thawing or to reduce or control the *depth of thaw* below the original ground surface.

371. passive single-phase thermal pile

A foundation pile provided with a single-phase natural convection cooling system to remove heat from the ground.

COMMENT:

Natural convection cooling systems consist of self-powered devices, commonly referred to as *thermosyphons*, or heat pipes, which operate only when air temperatures are lower than the ground temperature.

Passive single-phase thermal piles usually contain a sealed tube with a small radiator above the ground surface, and are filled with a liquid or gas which does not change phase. During the winter, heat from the soil surrounding the embedded portion of the pipe is absorbed by and thus warms the working fluid, which rises to the above-ground radiator section of the pipe exposed to the cooler air and loses its heat by conduction and natural convection.

372. passive two-phase thermal pile

A foundation pile provided with a two-phase natural convection cooling system to remove heat from the ground.

COMMENT:

Natural convection cooling systems consist of self-powered devices, commonly referred to as *thermosyphons*, or heat pipes, which operate only when air temperatures are lower than the ground temperature.

Passive two-phase thermal piles usually contain a sealed tube with a small radiator above the ground surface, and are filled with a substance which can be in the liquid or vapour phase, depending on its temperature. When the air temperature falls below the ground temperature, the vapour condenses in the radiator section of the tube, the pressure in the tube is reduced and the liquid in the lower section starts to boil. The resulting cycle of boiling, vapour movement up the tube, condensation, and return of the condensate by gravity flow is an effective way of transferring heat up the tube, thus cooling the ground.

373. patterned ground

A general term for any ground surface exhibiting a discernibly ordered, more or less symmetrical, morphological pattern of ground and, where present, vegetation (see Figure 16).

COMMENT:

Some patterned ground features are not confined to *permafrost regions* but they are best developed in regions of present or past intensive *frost action*. A descriptive classification of patterned ground includes such features as *nonsorted and sorted circles, nets, polygons, steps and stripes, and solifluction features*. In *permafrost regions*, the most ubiquitous macro-form is the *ice-wedge polygon*, and a common micro-form is the *nonsorted circle*. The latter includes *mud boils, mud hummocks, frost boils, stony earth circles, earth hummocks, turf hummocks, thufa* and (not recommended) tundra hummocks. *Nonsorted circles* are not all of the same origin. Some, such as mud and *earth hummocks* and *frost boils*, involve *cryoturbation* activity and differential heave of *frost-susceptible* materials. Others, such as *mud boils*, involve hydraulic pressures and diapiric displacements of water-saturated sediments. The genesis of many types of patterned ground phenomena is not clearly understood.

Patterned ground also occurs in *peatland* in the form of *string fens* and other *peatland* features (see Stanek, 1977 and Stanek and Worley, 1983).

REFERENCES: Washburn, 1956, 1979; Mackay and MacKay, 1976; Tarnocai and Zoltai, 1978; Shilts, 1978; Mackay, 1980.

374. peat

A deposit consisting of decayed or partially decayed humified plant remains.

COMMENT:

Peat is commonly formed by the slow decay of successive layers of aquatic and semi-aquatic plants in swampy or water-logged areas, where oxygen is absent.

375. peat hummock

A hummock consisting of *peat*.

377. peat plateau

A generally flat-topped expanse of *peat*, elevated above the general surface of a *peatland*, and containing *segregated ice* that may or may not extend downward into the underlying mineral soil (see Figures 14 and 15b).

COMMENT:

Some controversy exists as to whether peat plateaus and *palsas* are morphological variations of the same features, or genetically different. Layers or

lenses of *segregated ice* occur especially in the mineral soil but they are thinner and less extensive in peat plateaus than in *palsas*. Flat-topped, somewhat raised *peatlands* without an icy core occur in non-permafrost environments but are not peat plateaus.
SYNONYM: (not recommended) palsa plateau.
REFERENCES: Brown, 1970a; Zoltai, 1972; Zoltai and Tarnocai, 1975.

378. peatland

Peat-covered terrain.

COMMENT:

Stanek (1977) and Stanek and Worley (1983) should be consulted for definitions and information on *peat* and peatland and associated features.

There is no international agreement on the minimum thickness of *peat* required for the terrain to be classified as "peatland". In Canada, peatland is defined as a type of wetland formed by the accumulation of plant remains with negligible decomposition.

In the *discontinuous permafrost zone*, especially near the southern limit, peatland is often underlain by permafrost, reflecting the thermal insulating qualities of *peat*. *Palsas*, *peat plateaus* and *polygonal peat plateaus* are permafrost-related peatland features (see Figure 15).
SYNOMYMS: (not recommended) muskeg; organic terrain.
REFERENCES: Zoltai and Tarnocai, 1975; Stanek, 1977; Tarnocai, 1980; Stanek and Worley, 1983.

381. pereletok

A layer of *frozen ground* which forms as part of the *seasonally frozen ground* (in areas free of permafrost or with a lowered *permafrost table*), remains frozen throughout one or several summers, and then thaws.

COMMENT:

Use of this Russian term 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 part of a year. For the same reason, the use of the term "climafrost" as a synonym for pereletok is not recommended.
REFERENCE: Brown, 1966.

386. periglacial

The conditions, processes and landforms associated with cold, nonglacial environments.

COMMENT:

The term was originally used to describe the climatic and geomorphic conditions of areas peripheral to Pleistocene ice sheets and glaciers. Modern usage refers, however, to a wider range of cold climatic conditions regardless of their proximity to a glacier, either in space or time. Many, but not all, periglacial environments possess permafrost; all are dominated by *frost action* processes.
REFERENCES: Dylik, 1964; French, 1976; Washburn, 1979.

387. periglacial phenomena

Landforms and soil characteristics produced by *periglacial processes*.

COMMENT:

Periglacial phenomena include landforms like seasonal and perennial *frost mounds*, as well as the *cryotextures*, *cryostructures* and *cryogenic fabrics* found in soils.

388. periglacial processes

Processes associated with *frost action* in cold, nonglacial environments.

COMMENT:

Periglacial processes include *frost jacking*, *frost sorting*, *frost wedging*, *cryoturbation*, and the development of *cryotextures*, *cryostructures* and *cryogenic fabrics* in soils.

389. permacrete

An artificial mixture of frozen soil materials cemented by *pore ice*, which forms a concrete-like construction material used in cold regions.

COMMENT:

When soils of appropriate gradation are brought to their saturation moisture content, mixed and compacted to maximum density and then frozen, a material of relatively high strength is obtained so long as it is kept frozen. Permacrete has been moulded in brick or block form or placed in forms and used for construction (e.g., of walls and columns, both underground in tunnels, mines, etc., and on the ground surface in a freezing environment).
REFERENCE: Swinzow, 1966.

390. permafrost

Ground (soil or rock and included ice and organic material) that remains at or below 0°C for at least two consecutive years (see Figure 2).

COMMENT:

Permafrost is synonymous with perennially *cryotic ground*: it is defined on the basis of temperature. It is not necessarily frozen, because the freezing point of the included water may be depressed several degrees below 0°C; moisture in the form of water or ice may or may not be present. In other words, whereas all perennially *frozen ground* is permafrost, not all permafrost is perennially frozen. Permafrost should not be regarded as permanent, because natural or man-made changes in the climate or terrain may cause the temperature of the ground to rise above 0°C.

Permafrost includes perennial *ground ice*, but not glacier ice or icings, or bodies of surface water with temperatures perennially below 0°C; it does include man-made perennially frozen ground around or below chilled pipelines, hockey arenas, etc.

Russian usage requires the continuous existence of temperatures below 0°C for at least three years, and also the presence of at least some ice. (see *pereletok*).
SYNONYMS: perennially *frozen ground*, perennially *cryotic ground* and (not recommended) biennially frozen ground, climafrost, cryic layer, permanently frozen ground.
REFERENCES: Muller, 1943; van Everdingen, 1976; Kudryavtsev, 1978.

391. permafrost aggradation

A naturally or artificially caused increase in the thickness and/or areal extent of permafrost.

COMMENT:

Permafrost aggradation may be caused by climatic cooling or by changes in terrain conditions, including vegetation succession, infilling of lake basins and a decrease in *snowcover*. It can also occur under ice arenas, road and airfield embankments, etc. It may be expressed as a thinning of the *active layer* and a thickening of the permafrost, as well as an increase in the areal extent of permafrost.

392. permafrost base

The lower boundary surface of permafrost, above which temperatures are perennially below 0°C (cryotic) and below which temperatures are perennially above 0°C (noncryotic) (see Figures 2, 4 and 11).

393. permafrost boundary

1. **The geographical boundary between the *continuous* and *discontinuous permafrost zones***.
2. **The margin of a discrete body of permafrost.**

395. permafrost degradation

A naturally or artificially caused decrease in the thickness and/or areal extent of permafrost.

COMMENT:

Permafrost degradation may be caused by climatic warming or by changes in terrain conditions, such as disturbance or removal of an insulating vegetation layer by fire, or by flooding caused by a landslide-blocked stream, or by human activity. It 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 the areal extent or the complete disappearance of permafrost.

396. permafrost limit

Outermost (latitudinal) or lowest (altitudinal) limit of the occurrence of permafrost (see Figure 1).

398. permafrost region

A region in which the temperature of some or all of the ground below the seasonally freezing and thawing layer remains continuously at or below 0°C for at least two consecutive years.

COMMENT:

The permafrost region is commonly subdivided into *permafrost zones* (see Figure 1).

399. permafrost table

The upper boundary surface of permafrost (see Figures 2, 4 and 11).

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 degree of sorting of the soil, and thermal properties of soil and rock.

REFERENCES: Muller, 1943; Stearns, 1966; Washburn, 1979.

400. permafrost thickness

The vertical distance between the *permafrost table* and the *permafrost base* (see Figures 2 and 4).

COMMENT:

The thickness of permafrost may range from less than 1 m to more than 1000 metres.

401. permafrost zone

A major subdivision of a *permafrost region* (see Figure 1).

COMMENT:

A *permafrost region* is commonly subdivided into permafrost zones based on the proportion of the ground that is perennially *cryotic*. The basic subdivision in high latitudes is into zones of *continuous permafrost* and *discontinuous permafrost*.

REFERENCES: Muller, 1943; Brown, 1967b, 1978; Washburn, 1979; Péwé, 1983.

404. pingo

A perennial *frost mound* consisting of a core of *massive ice,* produced primarily by injection of water, and covered with soil and vegetation.

COMMENT:

Pingos occur in both the *continuous* and *discontinuous permafrost zones*. The term "pingo," a local Inuktitut term used in the Mackenzie Delta, Canada, was applied to relatively large features with heights of 10 m or more and horizontal dimensions of more than 100 m. Most pingos are conical, somewhat asymmetric, and have a circular or oval base and a fissured top that may be cratered. The fissures and craters are the result of rupturing of the soil and vegetation cover during doming due to progressive development of the ice core (see *dilation crack*). Seasonal *frost mounds* (e.g., *frost blisters*), should not be called pingos.

SYNONYMS: (not recommended) bulgunniakh, hydrolaccolith.

REFERENCES: Porsild, 1938; Mackay, 1973b, 1979; Washburn, 1979.

405. pingo ice

Massive ice* forming the core of a *pingo (see Figure 10h).

COMMENT:

The ice in a *pingo* may be nearly pure or mixed with sediment. It includes *intrusive ice*, *segregated ice* and *dilation crack ice*.

REFERENCES: Rampton and Mackay, 1971; Mackay, 1973b, 1985; Pissart and French, 1976.

406. pingo remnant

A collapsed *pingo* (see Figure 19c).

COMMENT:

In contemporary permafrost environments, a pingo remnant is commonly represented by a low, circular or arcuate ridge of material resulting from the slumping of the sides of the *pingo* during thawing. The former centre is marked by a depression which may be filled with water.

SYNONYM: (not recommended) fossil pingo.

REFERENCES: Black, 1969; Washburn, 1979.

407. pingo scar

A *pingo remnant* in a contemporary non-permafrost environment.

COMMENT:

Their occurrence provides evidence of former permafrost conditions.

REFERENCE: Flemal, 1976.

409. planetary permafrost

Permafrost occurring on other planetary bodies (planets, moons, asteroids).

COMMENT:

The most extensive suite of permafrost-related features known is from Mars, where large volumes of water and/or ice are believed to exist beneath the planet's surface. Water ice, alone or in combination with methane ice and/or *gas hydrates*, is also believed to occur on moons of Jupiter (Callisto, Ganymede and Europa) and Saturn (Titan). Most of the moons and asteroids of the solar system are characterized by permafrost (temperature perennially below 0°C), but in the absence of any water they are all unfrozen, although *cryotic*. All the planetary bodies noted above include some frozen material.

REFERENCES: Anderson et al., 1973; Fanale and Clark, 1983.

410. plastic frozen ground

Fine-grained soil in which only a portion of the *pore water* has turned into ice.

COMMENT:

Plastic frozen ground is cemented by ice, but it has viscous properties due to its high *unfrozen water content* and will therefore indergo plastic deformation under load, rather than brittle failure.

REFERENCE: U.S.S.R., 1969, 1973.

412. Poisson's ratio

The absolute value of the ratio between linear strain changes, perpendicular to and in the direction of a given uniaxial stress change, respectively.

413. polygon

Polygons are closed, multi-sided, roughly equidimensional *patterned-ground* features, bounded by more or less straight sides; some of the sides may be irregular (see Figure 16a, b).

COMMENT:

Macro-scale polygons, typically 15 to 30 m across, result from thermal contraction cracking of the ground and form random or oriented polygonal patterns. They occur in both mineral terrain and *peatland* (see *polygonal peat plateau*). *Ice-wedge polygons* are common in poorly drained areas and may be either *high-centred or low-centred*. *Sand-wedge polygons* occur where wedges of primary mineral infill underly the polygon boundaries. Some polygons may be formed by seasonal frost cracking in areas of deep *seasonal frost*.

*Micro-scale polygon*al patterns, usually less than 2 m in diameter, are normally caused by desiccation cracking.

SYNONYMS: frost polygon, frost-crack polygon, and (not recommended) depressed-centre polygon, fissure polygon, raised-centre polygon, Taimyr polygon, tundra polygon

REFERENCES: Rapp and Clark, 1971; Washburn, 1979.

415. polygon trough

The narrow depression surrounding a *high-centre polygon*.

COMMENT:

A polygon trough develops as a result of thawing of the *ice wedges* surrounding an *ice-wedge polygon*.

417. polygonal pattern

A pattern consisting of numerous multi-sided, roughly equidimensional figures bounded by more or less straight sides.

418. polygonal peat plateau

A *peat plateau* with *ice-wedge polygons* (see Figure 15c).

COMMENT:

Polygonal peat plateaus are commonly found near the boundary between the zones of *discontinuous* and *continuous permafrost*.

REFERENCES: Zoltai and Tarnocai, 1975; Zoltai and Pollett, 1983.

419. poorly-bonded permafrost

***Ice-bearing permafrost* in which few of the soil particles are held together by ice**.

420. **pore ice**

Ice occurring in the pores of soils and rocks.

COMMENT:

Pore ice does not include *segregated ice*. On melting, pore ice does not yield water in excess of the pore volume of the same soil when unfrozen.

SYNONYMS: ice cement, interstitial ice.

REFERENCES: Brown and Kupsch, 1974; Johnston, 1981.

421. **pore water**

Water occurring in the pores of soils and rocks.

COMMENT:

Pore water includes *free water* and *interfacial* (adsorbed) water.

Free water is that portion of the pore water that is free to move between interconnected pores under the influence of gravity. The temperature at which *free water* will change phase depends primarily on its dissolved-solids content, which determines *freezing-point depression*. It should be noted that the term "*free water*" also covers water in fissures, solution channels and other openings in soils or rocks.

Interfacial water forms transition layers at mineral/water and mineral/water/ice interfaces. The intermolecular forces involved are such that this water does not move under the influence of gravity. The temperature at which any portion of the *interfacial water* will change phase depends on the total energy of the various adsorption forces, which in turn depend on distance from the mineral surface, type of mineral and solute content of the water.

REFERENCE: Anderson and Morgenstern, 1973.

422. **pressure-melting**

Lowering the melting point of ice by applying pressure.

COMMENT:

Application of pressure increases the *unfrozen water content* by a small amount in frozen soils at a given temperature. Ice in soils is more easily melted by this process than bulk ice, because of stress concentrations at the soil intergranular contacts.

REFERENCES: Anderson and Morgenstern, 1973; Glen, 1974.

424. **relative permittivity**

The relative permittivity of a soil is the ratio of the permittivity of the soil to the permittivity of a vacuum.

COMMENT:

The relative permittivity varies with soil type, temperature, *unfrozen water content*, and the dissolved-solids content of the *pore water*.

SYNONYM: *dielectric constant*.

425. **relict active layer**

A layer of ground, now perennially frozen, lying immediately below the modern *active layer*. Its thickness indicates the greater annual *depth of thaw* that occurred during a previous period.

COMMENT:

The base of the relict active layer is a *thaw unconformity*, which may be recognized by differences in *ice contents*, stable isotope contents, and heavy mineral and pollen assemblages above and below the unconformity, and by the truncation of ice bodies.

REFERENCES: Delorme et al., 1978; Mackay, 1978.

426. relict ice

Ice formed in, and remaining from, the geologically recent past.

COMMENT:

Relict ice may include *ground ice* preserved in cold regions such as the coastal plains of western Arctic Canada and northern Siberia, where *relict permafrost* of Pleistocene age has been preserved. In Russian literature the term is usually associated with *buried ice*.

SYNONYM: (not recommended) fossil ice.

REFERENCES: Mackay et al., 1972; Mackay, 1975.

427. relict permafrost

Permafrost existing in areas where permafrost can not form under present climatic conditions.

COMMENT:

Relict permafrost (including *relict ice*) formed when the *mean annual surface temperature* was lower than at present; it is in disequilibrium with the present *mean annual surface temperature*. This permafrost persists in places where it could not form today.

SYNONYM: (not recommended) fossil permafrost.

REFERENCE: Mackay et al., 1972.

428. residual stress

The effective stress generated in a thawing soil if no volume change is permitted during thaw.

REFERENCES: Morgenstern and Nixon, 1971; Nixon and Morgenstern, 1973.

429. residual thaw layer

A layer of *thawed ground* between the *seasonally frozen ground* and the *permafrost table* (see Figure 4).

COMMENT:

This layer may result from thawing of the permafrost which causes a lowering of the *permafrost table*, or from incomplete freezing of the *active layer* during a mild winter after a very warm summer, or during a winter in which an unusually heavy snowfall (providing a thick insulating cover on the ground surface) occurs before extreme cold sets in. It may exist for one year or for several years, or it may be permanent if permafrost is degrading due to climatic warming or changes in

terrain conditions resulting from natural or human disturbance or activity. This layer does not exist where the *seasonal frost* extends to the *permafrost table*.
REFERENCE: Linell and Kaplar, 1966.

430. reticulate-blocky cryostructure

The cryostructure in which horizontal and vertical *ice veins* form a three-dimensional, irregular rectangular lattice (see Figure 9e).

COMMENT:

The mesh size in reticulate-blocky cryostructure is larger and more irregular than that in *reticulate cryostructure*. It is found in frozen loam, silt and clay deposits with a high *ice content*.

REFERENCE: Kudryavtsev, 1978.

431. reticulate cryostructure

The cryostructure in which horizontal and vertical *ice veins* form a three-dimensional, rectangular or square lattice (see Figure 9e).

COMMENT:

Reticulate cryostructure is often found in frozen glaciolacustrine sediments with a high *ice content*.

REFERENCE: Kudryavtsev, 1978.

432. reticulate ice

A network of horizontal and vertical *ice veins* forming a three-dimensional, often rectangular or square lattice (see Figure 9c, d).

COMMENT:

Field observations suggest that reticulate *ice veins* grow in horizontal and vertical shrinkage cracks with much of the water coming from the adjacent material in a semi-closed freezing system, rather than from migration of water in an open system. It is commonly found in frozen glaciolacustrine sediments.

REFERENCE: Mackay, 1974b.

434. retrogressive thaw slump

A slope failure resulting from thawing of *ice-rich permafrost* (see Figure 21c, d).

COMMENT:

Retrogressive thaw slumps consist of a steep headwall that retreats in a retrogressive fashion due to thawing, and a *debris flow* formed by the mixture of thawed sediment and meltwater that slides down the face of the headwall and flows away. Such slumps are common in ice-rich glaciolacustrine sediments and fine-grained diamictons.

SYNONYMS: (not recommended) bi-modal flow, ground-ice slump, ice slump, retrogressive-thaw flow slide, thermocirque, thermo-erosional cirque.

REFERENCES: Mackay, 1966; Rampton and Mackay, 1971; Hughes, 1972; McRoberts and Morgenstern, 1974; Washburn, 1979.

436. river talik

A layer or body of *unfrozen ground* occupying a depression in the *permafrost table* beneath a river.

COMMENT:

The temperature of a river talik remains above 0°C due to the heat storage effect of the river water. Depending on the *permafrost thickness* and the size of the river, such taliks may be either open or closed.

REFERENCES: Williams, 1965; Washburn, 1973; van Everdingen, 1976.

437. rock glacier

A mass of rock fragments and finer material, on a slope, that contains either interstitial ice or an ice core and shows evidence of past or present movement.

COMMENT:

Rock glaciers do not form where there is insufficient moisture to form the interstitial ice that permits movement of the mass. Some are believed to have been formed, at least partly, by burial of glacier ice. *Active rock glaciers* move at speeds up to 50 m per year and possess steep fronts with slope angles greater than the angle of repose. Rock glaciers are said to be inactive when the main body ceases to move. Most rock glaciers have transverse ridges and furrows on their surface.

REFERENCES: Capps, 1910; White, 1976b; Washburn, 1979.

439. saline permafrost

Permafrost in which part or all of the *total water content* is unfrozen because of *freezing-point depression* due to the dissolved-solids content of the *pore water*.

COMMENT:

Saline permafrost is found in *cryopegs*. At temperatures below the *ice-nucleation temperature*, a higher than normal *unfrozen water content* will persist due to increased dissolved-solids content of the remaining *pore water*.

440. salinity

1. **A general property of aqueous solutions caused by the alkali, alkaline earth, and metal salts of strong acids (Cl, SO_4 and NO_3) that are not hydrolyzed**.
2. **In soil science, the ratio of the weight of salt in a soil sample to the total weight of the sample.**

COMMENT:

Often used, inappropriately, as a synonym for the dissolved-solids content of aqueous solutions.

441. sand wedge

A wedge-shaped body of sand produced by filling of a *thermal contraction crack* with sand either blown in from above or washed down the walls of the crack (see Figure 17h).

COMMENT:

Sand wedges are wedges of primary filling since, at the time of their formation, they are filled with mineral soil. Upon thawing of the permafrost, there is little or no void space left, and any subsequent downward movement of material into the wedge is negligible.

A sand wedge is not a replacement feature (or *ice-wedge cast*) associated with the melting of an *ice wedge*. It is a type of *soil wedge* showing marked vertical fabric and laminations.

SYNONYM: (not recommended) tesselation.

REFERENCES: Berg and Black, 1966; Black, 1976; Washburn, 1979; Mackay and Matthews, 1983.

442. sand-wedge polygon

A *polygon* outlined by *sand wedges* underlying its boundaries.

COMMENT:

Sand-wedge polygons may be formed by seasonal thermal contraction cracking in areas of deep *seasonal frost*.

REFERENCE: Washburn, 1979.

445. seasonal freezing index

The cumulative number of *degree-days* below 0°C, calculated as the arithmetic sum of all the negative and positive mean daily air temperatures (°C) for a specific station during the time period between the highest point in the fall and the lowest point the next spring on the cumulative *degree-day* time curve.

REFERENCES: Huschke, 1959.

446. seasonal frost

The occurrence of ground temperatures below 0°C for only part of the year.

SYNONYMS: (not recommended) active frost, winter frost.

448. seasonal thawing index

The cumulative number of *degree-days* above 0°C, calculated as the arithmetic sum of all the positive and negative mean daily air temperatures (°C) for a specific station during the time period between the lowest point in the spring and the highest point the next fall on the cumulative *degree-day* time curve.

REFERENCE: Huschke, 1959.

449. seasonally-active permafrost

The uppermost layer of the permafrost which undergoes seasonal phase changes due to a lowered thawing temperature (see Figures 2 and 4).

COMMENT:

Seasonally-active permafrost can occur wherever its *salinity* or clay content allows it to thaw and refreeze annually, even though the materials remains cryotic (T < 0°C). It forms part of the *active layer*.
REFERENCE: van Everdingen, 1985.

450. seasonally frozen ground
Ground that freezes and thaws annually (see Figures 2 and 4).
COMMENT:
In Russian and Chinese literature, seasonally frozen ground forms the "active layer" in areas without permafrost or with a deep *permafrost table*.

451. seasonally frozen layer (SFL)
"Active layer" in areas without permafrost.
COMMENT:
In Chinese and Russian literature, the seasonally frozen layer is synonymous with the "active layer" in areas without permafrost or with a deep *permafrost table*. It is underlain by unfrozen ground and usually has a positive *mean annual ground temperature.* Freezing progresses from the surface downward, whereas thawing progresses both downward from the surface, and upward from the bottom of the seasonally frozen layer.

452. seasonally thawed ground
Ground that thaws and refreezes annually (see Figures 2 and 4).
COMMENT:
In areas with permafrost, seasonally thawed ground forms the *active layer*; it can include the uppermost portion of the permafrost in places where annual thawing takes place at temperatures slightly below 0°C, due to high *salinity* or a high clay content.

453. seasonally thawed layer (STL)
The *active layer* in permafrost areas.
COMMENT:
The seasonally thawed layer is synonymous with the *active layer* in areas with permafrost where seasonal freezing commonly reaches the *permafrost table*. Thawing progresses from the surface downward, whereas freezing progresses both downward from the surface and upward from the *permafrost table*. The seasonally thawed layer usually has a negative *mean annual ground temperature*.

454. segregated ice
Ice in discrete layers or *ice lenses,* formed by *ice segregation* (Figure 9a).
COMMENT:
Segregated ice can range in thickness from hairline to more than 10 m. It commonly occurs in alternating layers of ice and soil (see *ice lens*).
SYNONYMS: (not recommended) ice gneiss, sirloin ice and Taber ice.
REFERENCES: Taber, 1929; Mackay, 1966; Penner, 1972.

455. **segregation potential**

The ratio of the rate of moisture migration to the temperature gradient in a frozen soil near the 0°C isotherm.

COMMENT:

An engineering parameter that couples mass (water) flow and heat flow in a freezing soil. It is used by some workers to predict amounts of *frost heave*.

REFERENCES: Nixon, 1982; Konrad and Morgenstern, 1983, 1984.

456. **short-term strength**

The failure strength of a material under a short-term loading (e.g. up to about 10 minutes in a uniaxial compression test).

458. **single-phase thermosyphon**

A passive heat transfer device, filled with either a liquid or a gas, installed to remove heat from the ground (see Figure 24).

COMMENT:

A single-phase thermosyphon usually consists of a sealed tube, with a small radiator above the ground surface, containing a fluid (liquid or gas) which does not change phase. These devices have no moving parts, and they require no external power for operation.

During the winter, heat from the soil surrounding the embedded portion of the pipe is absorbed by and thus warms the working fluid, which rises to the above-ground radiator section of the pipe exposed to the cooler air and loses its heat by conduction and natural convection.

461. **snow**

Ice crystals precipitated from the atmosphere, mainly in complex hexagon (plate, column or needle) form, often agglomerated into snowflakes.

COMMENT:

Meteorologically, snow also includes snow grains (opaque granular ice particles). Snow pellets are aggregations of supercooled water droplets collected on an initial ice crystal.

462. **snowcover**

The accumulation of fallen snow covering the ground.

463. **snowdrift**

An accumulation of wind-blown snow, commonly considerably thicker than the surrounding *snowcover*.

464. **snowline**

The lower boundary of a highland region in which snow never melts.

465. **snowmelt**

Melting of the *snowcover*, and also the period during which melting of the *snowcover* occurs at the end of the winter.

467. snowpatch

Relatively small area of *snowcover* remaining after the main *snowmelt* period.

COMMENT:

Such areas commonly represent remnants of *snowdrifts*.

469. soil wedge

A wedge-shaped body of soil that is different in structure and texture from the surrounding soil (see Figure 17g).

COMMENT:

A soil wedge may be an *ice-wedge cast* (i.e., a feature of secondary filling), or a *sand wedge* (i.e., a feature of primary filling), or it may be produced by repeated formation of *thermal contraction cracks* in *seasonally frozen ground* followed by filling of the crack with soil. It is usually difficult to distinguish between soil wedges in the *active layer*, soil occupying cracks in *seasonally frozen ground* (i.e., in a non-permafrost environment), soil as original fillings in cracks in permafrost, and soil replacing *ice wedges*.

REFERENCES: Jahn, 1975; Black, 1976; Washburn, 1979.

470. solifluction

Slow downslope flow of saturated unfrozen earth materials (see Figure 16d).

COMMENT:

The presence of a frozen substrate, or even freezing and thawing is not implied in the original definition (Andersson, 1906). However, one component of solifluction can be the *creep of frozen ground*. Rates of flow vary widely. The term is commonly applied to processes operating in both *seasonal frost* and permafrost areas.

REFERENCES: Andersson, 1906; Washburn, 1979.

471. solifluction apron

A fan-like deposit at the base of a slope, produced by *solifluction*.

REFERENCES: Brown, 1969; Benedict, 1970; Washburn, 1979.

473. solifluction features

Geomorphological features of varying scale produced by the process of *solifluction* (see Figure 16d).

COMMENT:

Typical solifluction features include:

1. *solifluction apron* - a fan-like deposit at the base of a slope;
2. *solifluction lobe* - an isolated, tongue-shaped feature, up to 25 m wide and 150 m or more long, formed by more rapid *solifluction* on certain sections of a slope showing variations in gradient; commonly has a steep (15°-60°) front and a relatively smooth upper surface. Fronts covered by a vegetation mat are called "*turf-banked lobes*" whereas those that are stony are called "*stone-banked lobes*".

SYNONYM: (not recommended) mud-debris tongue.

3. *solifluction sheet* - a broad deposit of nonsorted, water-saturated, locally derived materials that is moving or has moved downslope. *Sorted* and/or *nonsorted stripes* are commonly associated with solifluction sheets.
SYNONYM: solifluction mantle.

4. *solifluction terrace* - a low step, or bench, with a straight or lobate front, the latter reflecting local differences in rate of flow. A solifluction terrace may have bare mineral soil on the upslope part and 'folded-under' organic matter in both the *seasonally thawed ground* and the *frozen ground*. Those covered with a vegetation mat are called "*turf-banked terraces*"; those that are stony are called "*stone-banked terraces*".
SYNONYMS: solifluction bench, solifluction step and (not recommended) soliflual garland terrace.

REFERENCES: Brown, 1969; Benedict, 1970; Washburn, 1979.

474. solifluction lobe

An isolated, tongue-shaped *solifluction feature*, up to 25 m wide and 150 m or more long, formed by more rapid *solifluction* on certain sections of a slope showing variations in gradient.

COMMENT:

Commonly has a steep (15°-60°) front and a relatively smooth upper surface. Solifluction lobes with fronts covered by a vegetation mat are called "*turf-banked lobes*" whereas those that are stony are called "*stone-banked lobes*".
SYNONYM: (not recommended) mud-debris tongue.
REFERENCES: Brown, 1969; Benedict, 1970; Washburn, 1979.

476. solifluction sheet

A broad deposit of nonsorted, water-saturated, locally derived materials that is moving or has moved downslope.

COMMENT:

Sorted and/or *nonsorted stripes* are commonly associated with solifluction sheets.
SYNONYM: solifluction mantle.
REFERENCES: Brown, 1969; Benedict, 1970; Washburn, 1979.

478. solifluction terrace

A low step, or bench, with a straight or lobate front, the latter reflecting local differences in the rate of *solifluction* movement.

COMMENT:

A solifluction terrace may have bare mineral soil on the upslope part and 'folded-under' organic matter in both the *seasonally thawed ground* and the *frozen ground*. Those covered with a vegetation mat are called "*turf-banked (solifluction) terraces*"; those that are stony are called "*stone-banked (solifluction) terraces*".
SYNONYMS: solifluction bench, solifluction step and (not recommended) soliflual garland terrace.
REFERENCES: Brown, 1969; Benedict, 1970; Washburn, 1979.

479. sorted circle

A sorted circle is a *patterned ground* form that is equidimensional in several directions, with a dominantly circular outline, and a sorted appearance commonly due to a border of stones surrounding a central area of finer material.

COMMENT:

Sorted circles occur singly or in groups; their diameter is commonly between 0.5 and 3.0 m. Their central areas have a concentration of fines, with or without stones. The stones of the borders surrounding the central areas tend to increase in size with the size of the circles. Tabular stones tend to stand on edge, with their long axes in the vertical plane parallel to the border.

REFERENCE: Washburn, 1956.

480. sorted net

A sorted net is a type of *patterned ground* with cells that are equidimensional in several directions, neither dominantly circular nor polygonal, with a sorted appearance commonly due to borders of stones surrounding central areas of finer material.

COMMENT:

Sorted nets occur most frequently on nearly horizontal surfaces. Diameters of individual cells range from 0.5 to as much as 10 m. Central areas have a concentration of fines, with or without stones. The bordering stones tend to increase in size with the size of the net.

REFERENCE: Washburn, 1979.

481. sorted polygon

A sorted polygon is a *patterned ground* form that is equidimensional in several directions, with a dominantly polygonal outline, and a sorted appearance commonly due to a border of stones surrounding a central area of finer material.

COMMENT:

Sorted polygons commonly occur in extensive patterns, most frequently on nearly horizontal surfaces, and on slopes of less then 20°. They range in size from 10 cm to about 10 m. In places, small sorted polygons occur in the central areas of larger polygons. Central areas have a concentration of fines, with or without stones. The bordering stones tend to increase in size with the size of the polygons, but to decrease with depth, regardless of the size of the polygons.

REFERENCE: Washburn, 1956.

482. sorted step

A sorted step is a *patterned ground* feature with a step-like form and a downslope border of stones embanking an area of relatively fine-grained bare ground upslope.

COMMENT:

Sorted steps are only found on slopes ranging from 5° to 15°; their downslope border forms a low riser fronting a tread whose slope is less than the general slope. Sorted steps are presumed to be derived either from *sorted circles* or from *sorted polygons*, rather than to develop independently. Some sorted steps clearly form an intermediate stage between *sorted polygons* and *sorted stripes*.
SYNONYM: *stone garland*.
REFERENCE: Washburn, 1979.

483. sorted stripe

Sorted stripes form *patterned ground* with a striped and sorted appearance, due to parallel strips of stones and intervening strips of finer material, oriented down the steepest available slope.

COMMENT:

Sorted stripes, both large and small, occur on slopes of more than 3°, downslope from *sorted polygons* or *sorted nets*; they are derived by downslope extension of *sorted polygons* or *sorted nets*. They can be several hundred metres long. The stones of the coarse stripes can range from pebbles to boulders, depending on the size of the stripes. The intervening finer material can be stone-free or contain stones and be a diamicton.
REFERENCE: Washburn, 1956.

484. specific heat capacity

The amount of heat required to raise the temperature of a unit mass of a substance by one degree.

COMMENT:

Specific heat capacity is commonly expressed in Joules per kg per degree K.

485. sporadic discontinuous permafrost

1. (North-American usage) **Permafrost underlying 10 to 35 percent of the exposed land surface**.
2. (Russian usage) **Permafrost underlying 5 to 30 percent of the exposed land surface**.

COMMENT:

Individual areas of permafrost are completely surrounded by *unfrozen ground*.
SYNONYMS: (not recommended) insular permafrost; island permafrost; scattered permafrost.
REFERENCES: Muller, 1943; Brown, 1967b; Heginbottom and Radburn, 1992.

487. static cryosol

A mineral soil showing little or no evidence of *cryoturbation*, with permafrost within 1 m below the surface .

COMMENT:

Static cryosols occur most commonly in coarse-textured materials, and *patterned ground* features may or may not be present. They have *mean annual ground temperatures* below 0°C.
REFERENCE: Canada Soil Survey Committee, 1978.

488. **stone-banked (solifluction) lobe**

A *solifluction lobe* with a stony front.

REFERENCES: Brown, 1969; Benedict, 1970; Washburn, 1979.

489. **stone-bankeded (solifluction) terrace**

A *solifluction terrace* with a stony front.

REFERENCES: Brown, 1969; Benedict, 1970; Washburn, 1979.

492. **stone garland**

A stone garland is the downslope border of stones along a *sorted step*, embanking an area of relatively fine-grained bare ground upslope.

493. **stony earth circle**

A type of nonsorted circle developed in gravelly materials.

REFERENCE: Thorn, 1976.

495. **string fen**

A *peatland* with roughly parallel narrow ridges of *peat* dominated by fenland vegetation interspersed with slight depressions, many of which contain shallow pools (see Figure 15d).

COMMENT:

The ridges or strings are arranged at right angles to the slope, which is usually less than 2°. They are typically 1 to 3 m wide, up to 1 m high and may be over 1 km long. Although the ridges are usually parallel to one another, they may interconnect at acute angles. On nearly level fens the ridges are farther apart but shorter; and they interconnect frequently, giving a roughly polygonal appearance. Since the strings are elevated, they are better drained and allow shrubs and trees to grow on them. String fens are composed of sedge-fen *peat* with some woody shrub remains. The ridges are composed of moss-sedge or moss *peat*. They are best developed in the zone of *discontinuous permafrost* and immediately to the south of the *permafrost region*. In the central and northern parts of the zone of *discontinuous permafrost*, the ridges are often perennially frozen. Permafrost conditions may extend into the underlying soil.

SYNONYMS: string bog, ribbed fen.

REFERENCES: Zoltai, 1971; Zoltai and Tarnocai, 1975; Tarnocai, 1980; Zoltai and Pollett, 1983.

497. **subglacial permafrost**

Permafrost beneath a glacier.

498. **subglacial talik**

A layer or body of *unfrozen ground* beneath a glacier in an area with permafrost.

499. **sublimation ice**

Ice formed by reverse sublimation of water vapour onto cold surfaces.

COMMENT:

Hoar frost and *open-cavity ice* are examples of sublimation ice.

501. subpermafrost water

Water occurring in the *noncryotic ground* below the permafrost (see Figure 11).

COMMENT:

This term does not include the water in *basal cryopegs*, i.e., the unfrozen zones that may occur in the basal portion of the permafrost (see *intrapermafrost water*).

REFERENCES: Williams, 1965, 1970; Tolstikhin and Tolstikhin, 1974.

502. subsea permafrost

Permafrost occurring beneath the sea bottom (see Figures 1 and 11).

COMMENT:

Subsea permafrost either occurs in response to negative sea-bottom water temperatures, or it formed in now submerged coastal areas that were exposed previously to air temperatures below 0°C (*relict permafrost*).

Much of the *ice-bonded permafrost* that has been found beneath the sea bottom has been inferred from acoustic geophysical surveys, and the term "acoustically-defined permafrost" has been used to describe such permafrost found in areas where temperature records or visual confirmation of ice bonding are not available.

SYNONYMS: offshore permafrost, and (not recommended) sea-bed permafrost, submarine permafrost, sub-seabed permafrost.

REFERENCES: Mackay, 1972a; Hunter et al., 1976.

503. subsea talik

A layer or body of *unfrozen ground* beneath the seabottom, and forming part of the *subsea permafrost*.

COMMENT:

Subsea taliks are usually cryotic (T < 0°C). See also *marine cryopeg*.

505. supercooling

Cooling of a liquid to a temperature below its *freezing point,* without causing solidification.

506. suprapermafrost water

Water occurring in *unfrozen ground* above perennially *frozen ground* (see Figure 11).

COMMENT:

Suprapermafrost water occurs in the *active layer*, between the *active layer* and the *permafrost table*, and in *taliks* below rivers and lakes. It is replenished by infiltration of rain, *snowmelt* or surface waters, or from *intra-* or *subpermafrost water* via *open taliks*. Much of the suprapermafrost water in the *active layer* may freeze in the winter; the remainder can temporarily become confined and subjected

to increasing pressure during progressive freezing of the *active layer* (see *cryogenic aquiclude*).
REFERENCES: Williams, 1965, 1970; Tolstikhin and Tolstikhin, 1974.

507. surface freezing index

The cumulative number of *degree-days* below 0°C for the surface temperature (of the ground, pavement, etc.) during a given time period.

COMMENT:

The surface freezing index differs from the corresponding *air freezing index* (see *n-factor*).

508. surface thawing index

The cumulative number of *degree-days* above 0°C for the surface temperature (of the ground, pavement, etc.) during a given period.

COMMENT:

The surface thawing index differs from the corresponding *air thawing index* (see *n-factor*).

509. suscitic cryogenic fabric

A distinct soil micromorphology, resulting from the effects of freezing and thawing processes, in which coarser soil particles have vertical or near-vertical orientation (see Figure 8e).

COMMENT:

This fabric, found in *cryosols*, results from freeze-thaw processes probably accompanied by *cryoturbation*.
REFERENCES: Brewer and Pawluk, 1975; Pawluk and Brewer, 1975; Fox, 1983.

510. syngenetic ice

Ground ice* developed during the formation of *syngenetic permafrost.

SYNONYM: (not recommended) penecontemporaneous ice.

511. syngenetic ice wedge

An *ice wedge* developed during the formation of *syngenetic permafrost* (see Figure 17i).

COMMENT:

Syngenetic ice wedges grow both wider and higher, more or less simultaneously with the deposition of additional sediment or other earth material on the ground surafce. Hence the ice on the outside edges decreases in age from bottom to top. Syngenetic ice wedges are generally wedge-shaped but with more irregular sides than *epigenetic ice wedges*.
REFERENCES: Romanovskii, 1973; Mackay, 1990.

512. syngenetic permafrost

Permafrost that formed through a rise of the *permafrost table* during the deposition of additional sediment or other earth material on the ground surface.

515. talik

A layer or body of *unfrozen ground* occurring in a permafrost area due to a local anomaly in thermal, hydrological, hydrogeological, or hydrochemical conditions (see Figure 11).

COMMENT:

Taliks may have temperatures above 0°C (noncryotic) or below 0°C (cryotic, forming part of the permafrost). Some taliks may be affected by seasonal freezing. Several types of taliks can be distinguished on the basis of their relationship to the permafrost (closed, open, lateral, isolated and transient taliks), and on the basis of the mechanism responsible for their unfrozen condition (hydrochemical, hydrothermal and thermal taliks):

1. *closed talik* - a noncryotic talik occupying a depression in the *permafrost table* below a lake or river (also called "*lake talik*" and "*river talik*"); its temperature remains above 0°C because of the heat storage effect of the surface water;

2. *hydrochemical talik* - a cryotic talik in which freezing is prevented by mineralized groundwater flowing through the talik.

3. *hydrothermal talik* - a noncryotic talik, the temperature of which is maintained above 0°C by the heat supplied by groundwater flowing through the talik;

4. *isolated talik* - a talik entirely surrounded by perennially *frozen ground*; usually cryotic (see *isolated cryopeg*), but may be noncryotic (see transient talik);

5. *lateral talik* - a talik overlain and underlain by perennially *frozen ground*; can be noncryotic or cryotic;

6. *open talik* - a talik that penetrates the permafrost completely, connecting *suprapermafrost* and *subpermafrost water*, (e.g., below large rivers and lakes). It may be noncryotic (see hydrothermal talik) or cryotic (see hydrochemical talik).

SYNONYMS: (not recommended) through talik, penetrating talik, perforating talik, piercing talik;

7. *thermal talik* - a noncryotic talik, the temperature of which is above 0°C due to the local *thermal regime of the ground*;

8. *transient talik* - a talik that is gradually being eliminated by freezing, e.g., the initially noncryotic closed talik below a small lake which, upon draining of the lake, is turned into a transient isolated talik by *permafrost aggradation* (see also *closed-system pingo*).

REFERENCES: Williams, 1965; Washburn, 1973; van Everdingen, 1976.

518. temperature profile

The graphic or analytical expression of the variation in ground temperature with depth.

521. thaw basin

A depression of the *permafrost table* created by naturally induced thawing.

COMMENT:

In *permafrost regions*, thaw basins exist beneath bodies of water such as lakes or rivers that do not freeze to the bottom in winter. They may be quite extensive both in depth (from a few metres to more than a 100 m) and in areal extent (from several tens of metres to more than 2 km) and they may be irregular in shape. Their depth, areal extent and shape depend on the size of the water body, the type and properties of earth material underlying it, and the presence of *ground ice* and groundwater.

SYNONYMS: *closed talik* and (not recommended) thaw depression.

522. thaw bulb

A zone of *thawed ground* below or surrounding a man-made structure placed on or in permafrost and maintained at temperatures above 0°C (see Figure 23).

COMMENT:

Construction and operation of structures usually lead to alteration of the *thermal regime of the ground*. Where permitted, the development of a thaw bulb under a structure is taken into account and controlled as part of the engineering design. It is frequently nearly symmetrical in form and limited in size under structures such as buildings. Beneath linear structures or facilities built in permafrost areas, such as road embankments or buried warm pipelines, the thaw bulb may extend for the full length of the structure. Settlement of the ground and the structure or facility may occur as the thaw bulb forms.

A thaw bulb may also form when a structure or facility, around which a *frost bulb* has developed, is abandoned and the ground is no longer maintained at a temperature below 0°C.

REFERENCES: Andersland and Anderson, 1978; Johnston, 1981.

523. thaw consolidation

Time-dependent compression resulting from thawing of *frozen ground* and subsequent draining of excess water.

COMMENT:

If during thaw, the flow of water from the *thawed ground* is unimpeded, then the variation of *thaw settlement* with time is controlled solely by the position of the *thawing front*. If the *thawed ground* is not sufficiently permeable, and flow is impeded, however, the rate of settlement with time is also controlled by the *compressibility* and permeability of the *thawed ground*.

In the case of thawing fine-grained soils, if the rate of thaw is sufficiently fast, water is released at a rate exceeding that at which it can flow from the soil, and pore pressures in excess of hydrostatic will be generated. These excess pore pressures may cause severe instability problems in slopes and foundation soils.

It has been found that excess pore pressures and the degree of consolidation in thawing soils depend principally on the *thaw consolidation ratio*.

REFERENCES: Morgenstern and Nixon, 1971; Andersland and Anderson, 1978; Johnston, 1981.

524. thaw consolidation ratio

A dimensionless ratio describing the relationship between the rate of thaw and the rate of consolidation of a thawing soil, which is considered to be a measure of the relative rates of generation and expulsion of excess water during thaw.

COMMENT:

According to Morgenstern and Nixon (1971), a value of the ratio greater than unity would predict the danger of sustained substantial pore pressures at the *thawing front* and hence the possibility of instability due to the reduction of shear strength at that plane.

REFERENCES: Morgenstern and Nixon, 1971; Johnston, 1981.

528. thaw penetration

The downward movement of the *thawing front* during thawing of *frozen ground*.

COMMENT:

The rate of thaw penetration depends on the rate of heat conduction and on the *ice content* of the ground.

530. thaw-sensitive permafrost

Perennially *frozen ground* which, upon thawing, will experience significant *thaw settlement* and suffer loss of strength to a value significantly lower than that for similar material in an unfrozen condition.

COMMENT:

Ice-rich permafrost is thaw-sensitive.

SYNONYM: (not recommended) thaw-unstable permafrost.

REFERENCES: Linell and Kaplar, 1966; van Everdingen, 1976.

531. thaw settlement

Compression of the ground due to *thaw consolidation* (see Figure 7).

COMMENT:

In coarse-grained and dense soils, the amount of thaw settlement is usually small because it is governed mainly by the melting of *pore ice*. In *ice-rich permafrost*, and *seasonally frozen ground* containing *excess ice*, however, the amount of thaw settlement may be quite substantial.

In general, on thawing, any *frozen ground* will settle both under its own weight and under applied stresses. The settlement will continue as long as the *thawing front* advances and until the pore pressures generated during thawing are dissipated.

In relatively permeable coarse-grained soils, where draining of *pore water* is rapid, the thaw settlement rate will usually follow closely the rate of thaw, and development of pore pressures will be negligible during the thaw period. On the other hand, if a relatively impermeable fine-grained soil is thawed rapidly, then excess pore pressures will be generated. If these excess pore pressures are sustained for any length of time, then severe problems may develop (e.g., slopes

may become unstable, dam foundations may fail, and differential settlements may be aggravated).
REFERENCES: Andersland and Anderson, 1978; Johnston, 1981.

532. thaw sink

A closed *thaw basin* with subterranean drainage.

SYNONYMS: (not recommended) thaw hole, thaw pit.
REFERENCES: Wallace, 1948; Hopkins, 1949.

533. thaw slumping

A slope failure mechanism characterized by the melting of *ground ice*, and downslope sliding and flowing of the resulting debris.

COMMENT:

The resulting landform is a *retrogressive thaw slump*.

SYNONYM: (not recommended) ice slump.
REFERENCES: Mackay, 1966; McRoberts and Morgenstern, 1974; Washburn, 1979.

535. thaw-stable permafrost

Perennially *frozen ground* which, upon thawing, will not experience either significant *thaw settlement* or loss of strength.

COMMENT:

Thaw-stable permafrost may have the same mineral and particle-size compositions as *thaw-sensitive permafrost*. It may be *frost-susceptible*. *Dry permafrost* is thaw-stable.

REFERENCE: Linell and Kaplar, 1966.

536. thaw strain

The amount that *frozen ground* compresses upon thawing.

COMMENT:

The thaw strain is equal to the *thaw settlement* divided by the original thickness of the *frozen ground* before thawing. When freezing of the ground occurred in a closed system, the thaw strain is due only to the 9 percent volume contraction associated with the melting of *pore ice*.

537. thaw unconformity

A boundary sometimes identified in perennially *frozen ground*, representing the base of a *relict active layer*, as well as the corresponding earlier *permafrost table*.

COMMENT:

A thaw unconformity may be recognized by differences in *ice contents*, stable isotope contents, and heavy mineral and pollen assemblages above and below the unconformity, and by the truncation of ice bodies.

REFERENCES: Delorme et al., 1978; Mackay, 1978.

539. thaw weakening

The reduction in shear strength due to the decrease in effective stresses resulting from the generation and slow dissipation of excess pore pressures when frozen soils containing ice are thawing.

COMMENT:

Thaw weakening, although generally used with respect to the thawing of *seasonally frozen ground* when melting of *ice lenses* and *pore ice* occurs, is equally applicable to thawing of *ice-bearing* and *ice-rich permafrost*. The usual effects of thaw weakening are a significant decrease in bearing capacity and an increase in stability problems (e.g., on road embankments, natural slopes, etc.).

SYNONYM: thaw softening.

REFERENCE: Johnston, 1981.

540. thawed ground

Previously *frozen ground* in which all ice has melted.

COMMENT:

Unfrozen ground is thawed ground only if it were previously frozen. Thawed ground is commonly noncryotic, but it may be cryotic.

REFERENCE: van Everdingen, 1976.

541. thawing (of frozen ground)

Melting of the ice in *frozen ground*, usually as a result of a rise in temperature.

543. thawing front

The advancing boundary between *thawed ground* and *frozen ground* (see Figure 4).

COMMENT:

The thawing front may be advancing into either seasonally or perennially *frozen ground* during progressive thawing. In non-permafrost areas there will be two thawing fronts during the annual thawing period, one moving downward from the surface, the other moving upward from the bottom of the *seasonally frozen ground*. The thawing front usually coincides more closely with the position of the 0°C isotherm than the *freezing front*, except in *saline permafrost*.

SYNONYM: frost table.

544. thawing index

The cumulative number of *degree-days* above 0°C for a given time period.

COMMENT:

Four main types of air thawing indices have been used:

1. *approximate thawing index* - calculated from the mean monthly air temperatures for a specific station without making corrections for negative *degree-days* (T < 0°C) in spring and fall (Boyd, 1973, 1979);

2. *total annual thawing index* - calculated by adding all the positive mean daily temperatures (°C) for a specific station during a calendar year (Harris, 1981);

3. *seasonal thawing index* - calculated as the arithmetic sum of all the positive and negative mean daily air temperatures (°C) for a specific station during the time period between the lowest point in the spring and the highest point the next fall on the cumulative *degree-day* time curve (Huschke, 1959);
4. *design thawing index* - calculated by taking the average of the seasonal thawing indices for the three warmest summers in the most recent 30 years of record. If data for 30 years are not available, then the index is based on the warmest summer in the latest 10-year period of record (U.S. Army/Air Force, 1966).

The *total annual thawing index* has been used to predict permafrost distribution, and the *design thawing index* is commonly used in engineering design to estimate the maximum *depth of thaw* in *frozen ground*.

A *surface* (ground, pavement, etc.) *thawing index* differs from the *air thawing index* (see *n-factor*).

545. thermal conductivity

The quantity of heat that will flow through a unit area of a substance in unit time under a unit temperature gradient.

COMMENT:

Commonly expressed in joules per second per metre per degree K.

546. thermal-contraction crack

A tensile fracture resulting from thermal stresses in *frozen ground*.

COMMENT:

Tensile stresses caused by a reduction in ground temperature are probably a major factor in thermal contraction cracking, but it is usually difficult to prove that desiccation is not also involved. *Ice wedges, sand wedges, soil wedges* and *ice veins* form in thermal contraction cracks.

SYNONYMS: frost crack, frost fissure, and (not recommended) frost wedge, contraction crack.

REFERENCES: Lachenbruch, 1962, 1966; Washburn, 1979.

547. thermal-contraction-crack ice

Ice formed in *thermal contraction cracks* in the ground (see Figure 17).

COMMENT:

Both *wedge ice* and some kinds of *vein ice* are types of thermal contraction crack ice. *Open-cavity ice* may be a constitutent of thermal contraction crack ice.

REFERENCE: Mackay, 1972b.

548. thermal diffusivity

The ratio of the *thermal conductivity* to the *volumetric heat capacity*.

COMMENT:

The thermal diffusivity expresses the facility with which a material will ondergo a temperature change.

549. thermal erosion

The erosion of *ice-bearing permafrost* by the combined thermal and mechanical action of moving water.

COMMENT:

Thermal erosion is a dynamic process involving the wearing away by thermal means (i.e., the melting of ice), and by mechanical means (i.e., hydraulic transport). Thermal erosion is distinct from the development of *thermokarst terrain*, which results from thermal melting followed by subsidence of the ground but without hydraulic transport of earth materials. An example of the combined thermal and mechanical effects of moving water is the formation of a *thermo-erosional niche*.

REFERENCES: Walker and Arnborg, 1966; Mackay, 1970; French, 1976; Are, 1978; Newbury et al., 1978.

550. thermal expansion (or contraction) coefficient

The volume change per unit volume of a substance due to a one degree change in its temperature.

551. thermal pile

A foundation pile on which natural convection or forced circulation cooling systems or devices have been installed to remove heat from the ground (see Figure 24).

COMMENT:

There are two basic types of thermal piles. Passive or natural convection systems use self-powered devices, commonly referred to as *thermosyphons*, or heat pipes, which operate only when air temperatures are lower than the ground temperature. Forced circulation refrigeration systems require external power and mechanical equipment to circulate refrigerants, such as antifreeze liquids, chilled gases or cool air, and may be operated throughout the year or only during the winter. Both types may be fastened to, or form part of, the pile, or, if the pile is a sealed unit (e.g., a steel pipe), the pile itself may serve as a heat-removal device as well as a structural unit.

Thermal piles are used to decrease the time for and ensure *freezeback* of the slurry and ground around piles, to prevent or control long-term *permafrost degradation*, and to decrease the existing ground temperatures around piles, particularly in warm temperature permafrost areas.

REFERENCES: Heuer, 1979; Johnston, 1981.

552. thermal properties of frozen ground

The properties of the ground governing the flow of heat through it, and its freezing and thawing conditions.

COMMENT:

The position of the interface between thawed and frozen soil with respect to the ground surface, for a given surface-temperature regime, depends on the thermal properties of the strata located above and immediately below the interface. The basic thermal properties of frozen ground are *thermal conductivity*, *heat capacity* and *latent heat of fusion*.

Thermal conductivity is a measure of the quantity of heat that will flow through a unit area of a substance in unit time under a unit temperature gradient.

Heat capacity (specific heat) is the amount of heat required to raise the temperature of a unit mass of a substance by one degree (sensible heat capacity). *Volumetric heat capacity* is the amount of heat required to raise the temperature of a unit volume of a substance by one degree. It is equal to the *heat capacity* multiplied by the density. Because the phase change in frozen soils is often gradual and continuous, the term "*apparent heat capacity*" is introduced to designate the rate of change of the total heat content (sensible plus *latent heat*) with temperature.

The *volumetric latent heat of fusion* is the amount of heat required to melt the ice (or freeze the water) in a unit volume of soil. When phase change occurs over a temperature range, the *latent heat* manifests itself as an apparent (large) increase in *heat capacity*.

Thermal diffusivity is defined as the ratio of the *thermal conductivity* to the *volumetric heat capacity*. It expresses the facility with which a material will undergo temperature change.

These thermal properties vary with phase composition and hence temperature, soil type, *total water content*, porosity, *degree of saturation*, density and organic content.

REFERENCE: Johnston, 1981.

553. thermal regime of the ground

A general term encompassing the temperature distribution and heat flows in the ground and their time-dependence (see Figure 2).

COMMENT:

Permafrost exists as a result of thermal conditions that maintain a ground temperature that does not rise above 0°C for at least two years. The ground temperature distribution is complicated, varying with depth from the surface and with time. Ground temperatures fluctuate in cyclical patterns on a daily and a yearly basis, in response to the heat losses and gains at the ground surface. The heat balance at the ground surface (which is indicated by the surface temperature) is highly variable with time, being affected by terrain and climate conditions as well by as the *thermal properties of the ground* itself.

Changes in surface temperature impose a response that decays while travelling downwards. The rate of decay depends on the time scale involved, on the soil thermal properties and on the occurrence of freezing and thawing phenomena. The depth beyond which ground temperature fluctuations can be considered insignificant is the *depth of zero annual amplitude*. The effects of daily temperature variations at the ground surface penetrate to only a few centimetres; those due to weekly variations (e.g., transient weather systems) penetrate to perhaps several metres; and annual variations penetrate to a depth of about 10 to 20 metres. Longer-term changes in surface temperature caused by changes in climate and surface conditions may modify the thermal regime of the ground to much greater depths.

Permafrost exists if the *mean annual surface temperature* is perennially below 0°C. Although the *mean annual surface temperature* may be below 0°C, the surface temperature will fluctuate during the year, causing a layer of ground immediately beneath the surface to thaw in the summer and freeze in the winter (the *active layer*). Small changes in the annual range of surface temperature and in the *mean annual surface temperature* from year to year, or over a period of a few years, may cause a layer of ground between the bottom of the *active layer* and the *permafrost table* to remain at a temperature above 0°C, creating a *talik* or *residual thaw layer*.

The *mean annual ground temperature* usually increases with depth below the surface. In some northern areas, however, it is not uncommon to find that the *mean annual ground temperature* decreases in the upper 50 to 100 metres below the ground surface as a result of past changes in surface and climate conditions. Below that depth, it will increase as a result of heat flow from the interior of the earth. The rate of change of temperature with depth in the earth is known as the *geothermal gradient*

The *geothermal gradient* at a specific location can be determined from accurate measurements of ground temperature made at several depths to obtain the *temperature profile* over a period of time. A rough approximation of the *mean annual surface temperature* can be made by extrapolating the *geothermal gradient* to the ground surface. In permafrost areas, extrapolation of the gradient downwards to the point where the ground temperature changes from below to above 0°C will provide an estimate of the depth to the *permafrost base*. The thermal regime of the ground at various locations is often assessed using the *mean annual ground temperature* at the *depth of zero annual amplitude*.

The *geothermal heat flux* is the amount of heat moving steadily outward from the interior of the earth by conduction through a unit area in unit time. It is generally calculated as the product of the *geothermal gradient* and the *thermal conductivity* of the earth materials at a given depth; its value is very small.
REFERENCES: Lachenbruch, 1959; Gold, 1967; Gold and Lachenbruch, 1973; Goodrich, 1982.

554. thermal talik

A layer or body of *unfrozen ground* (in a permafrost area) in which the temperature is above 0°C due to the local *thermal regime of the ground*.

COMMENT:

The *seasonally thawed ground* in the *active layer* is a thermal talik.
REFERENCE: van Everdingen, 1976.

555. thermo-erosional cirque

The usually steep, horseshoe-shaped headwall of a *retrogressive thaw slump*.

556. thermo-erosional niche

A recess at the base of a river bank or coastal bluff, produced by *thermal erosion* of *ice-bonded permafrost* (see Figure 22d).

COMMENT:

A niche may extend more than 10 m into a river bank or coastal bluff. Subsequently, the undercut sediments may collapse along a line of weakness, such as an *ice wedge*, destroying the niche. Niche development and bank/bluff collapse is a unique mechanism of erosion in *permafrost regions*. Very rapid coastal or bank retreat can occur if collapse debris is removed by waves or water currents.
REFERENCES: Walker and Arnborg, 1966; Czudek and Demek, 1970; French, 1976; Are, 1978; Newbury et al., 1978; Harry et al., 1983.

558. thermokarst

The process by which characteristic landforms result from the thawing of *ice-rich permafrost* or the melting of *massive ice*.

COMMENT:

Landforms found in *thermokarst terrain* include *alasses*, *thermokarst lakes*, and *thermokarst mounds*.
REFERENCES: French, 1976; Washburn, 1979.

559. thermokarst lake

A lake occupying a closed depression formed by settlement of the ground following thawing of *ice-rich permafrost* or the melting of *massive ice* (see Figure 22c).

COMMENT:

Thermokarst lakes are generally shallow. The depressions may expand by *active-layer failure* processes (see *alas*); the lakes may expand by *thermokarst* processes (see also *oriented lake*). In glaciated terrain they may be similar in appearance to kettle lakes.
SYNONYMS: (not recommended) thaw lake, cave-in lake.
REFERENCES: Wallace, 1948; Hopkins, 1949.

560. thermokarst mound

A hummock remaining after melting of the *ice wedges* surrounding an *ice-wedge polygon* (see Figure 22e).

COMMENT:

Thermokarst mounds occur in groups forming a distinctive surficial network of regularly shaped mounds separated by troughs formed by the melting of *ice wedges*.
SYNONYMS: (not recommended) baydzherakh, cemetery mound, graveyard mound.
REFERENCES: Péwé, 1954; Brown, 1967a; French, 1975.

561. thermokarst terrain

The often irregular topography resulting from the melting of excess *ground ice* and subsequent *thaw settlement* (see Figure 22).

COMMENT:

Thermokarst terrain is so named because of its superficial resemblance to the karst topography typical of limestone regions.

The melting of *ground ice* may be initiated by climatic change, destruction of an insulating vegetation cover by fire, animals or man, or by any other disturbance of the *thermal regime of the ground*, including the acceleration of the rate of thawing by moving water. Annual thawing of the *active layer* does not produce thermokarst terrain.

Morphological features of thermokarst topography include depressions (see *alas*); lakes (see *oriented lake; thermokarst lake*); mounds (see *thermokarst mound*); and small, more or less equidimensional depressions or pits.

Thermokarst landforms may be divided into active and inactive forms. Inactive thermokarst indicates that thermal equilibrium has been regained, whereas *active thermokarst* indicates continuing thermal disequilibrium.

Except for *thaw sinks* there may be little underground drainage in thermokarst terrain.

REFERENCES: Hopkins, 1949; Czudek and Demek, 1970; French, 1976.

563. thermosyphon

A passive heat transfer device installed to remove heat from the ground (see Figure 24).

COMMENT:

A thermosyphon, also called thermotube, or heat pipe, usually consists of a sealed tube, with a small radiator above the ground surface, containing a liquid and/or gas. These devices have no moving parts, require no external power for operation, and function only when air temperatures are lower than the ground temperature. They may be either single- or two-phase systems.

A *single-phase thermosyphon* is usually *liquid- or air-filled*. During the winter, heat from the soil surrounding the embedded portion of the pipe is absorbed by and thus warms the working fluid, which rises to the above-ground radiator section of the pipe exposed to the cooler air and loses its heat by conduction and natural convection.

A *two-phase thermosyphon* contains a working fluid that can be in either the liquid or vapour phase, depending on its temperature. When the air temperature falls below the ground temperature, the vapour condenses in the radiator section of the tube, the pressure in the tube is reduced and the liquid in the lower section starts to boil. The resulting cycle of boiling, vapour movement up the tube, condensation, and return of the condensate by gravity flow is an effective way of transferring heat up the tube, thus cooling the ground.

REFERENCES: Long, 1966; Heuer, 1979; Johnston, 1981; Hayley, 1982; Hayley et al., 1983.

566. thufur

Perennial hummocks formed in either the *active layer* in permafrost areas, or in the *seasonally frozen ground* in non-permafrost areas, during freezing of the ground (see Figure 20d).

COMMENT:

Thufur (an Icelandic term, plural of "thufa") can be formed in the warmer part of the zone of *discontinuous permafrost* and also under conditions of maritime

seasonal frost. The hummocks may be as much as 50 cm in height and 160 cm in diameter and can reform within 20 years following destruction. Growth is favoured by silty sediments, a maritime climate and reasonably good drainage.
REFERENCES: Thorarinsson, 1951; Schunke, 1975; Scotter and Zoltai, 1982.

567. total annual freezing index

The cumulative number of *degree-days*, calculated by adding all the negative mean daily air temperatures (°C) for a specific station during a calendar year.
REFERENCE: Harris, 1981.

568. total annual thawing index

The cumulative number of *degree-days*, calculated by adding all the positive mean daily air temperatures (°C) for a specific station during a calendar year.
REFERENCE: Harris, 1981.

569. total water content (of frozen ground)

The total amount of water (unfrozen water plus ice) contained in soil or rock (see Figure 3).
COMMENT:

When no ice is present, the total water content is usually referred to as "water content" or "moisture content". The total water content of a soil or rock sample includes *free water*, *interfacial* (adsorbed) *water*, and water absorbed by organic material. Water of crystallization or hydration (e.g., in gypsum) is usually not included.

The total water content is normally determined in one of two ways:

1. on a dry-weight basis (*gravimetric total water content*), as the ratio of the mass of the water and ice in a sample to the dry mass of the sample, expressed as a percentage; or

2. on a volume basis (*volumetric total water content*), as the ratio of the volume of water and ice in a sample to the volume of the whole sample, expressed as a fraction (or, less commonly, as a percentage).

Because of the way in which it is defined, the *volumetric total water content* cannot exceed unity, whereas the *gravimetric total water content* can greatly exceed 100 percent. During thawing of a sample of *frozen ground* the *volumetric total water content* decreases, but the *gravimetric total water content* remains constant.
REFERENCE: Anderson and Morgenstern, 1973.

570. transient talik

A layer or body of *unfrozen ground* (in a permafrost area) that is gradually being eliminated by freezing (see Figure 11).
COMMENT:

An example is the initially noncryotic *closed talik* below a small lake which, upon draining of the lake, is turned into a *transient, isolated talik* by *permafrost aggradation*.
REFERENCE: van Everdingen, 1976.

571. tundra

Treeless terrain, with a continuous cover of vegetation, found at both high latitudes and high altitudes.

COMMENT:

Tundra vegetation comprises lichens, mosses, sedges, grasses, forbs and low shrubs, including heaths, and dwarf willows and birches. This vegetation cover occurs most widely in the zone immediately north of the boreal forest including the treeless parts of the forest-tundra ecotone adjacent to the treeline. In high altitudes, tundra occurs immediately above the forest zone, and the upper altitudinal timberline.

The term "tundra" is used to refer to both the region and the vegetation growing in the region. It should not be used as an adjective to describe lakes, *polygons* or other physiographic features.

Areas of discontinuous vegetation in the polar semi-desert of the High Arctic are better termed *barrens*. Unvegetated areas of polar desert may be caused by climatic (too cold or too dry) or edaphic (low soil nutrients or toxic substrate) factors or a combination of both.
REFERENCE: Polunin, 1951.

574. turbic cryosol

A mineral soil showing marked evidence of *cryoturbation*, as indicated by broken horizons and displaced material.

COMMENT:

Turbic cryosols generally occur on *patterned ground*. They have *mean annual ground temperatures* below 0°C, with permafrost within 2 m below the surface.
REFERENCE: Canada Soil Survey Committee, 1978.

575. turf-banked (solifluction) lobe

A *solifluction lobe* with its front covered by a vegetation mat.
REFERENCES: Brown, 1969; Benedict, 1970; Washburn, 1979.

576. turf-banked (solifluction) terrace

A *solifluction terrace* with its front covered by a vegetation mat.
REFERENCES: Brown, 1969; Benedict, 1970; Washburn, 1979.

577. turf hummock

A hummock consisting of vegetation and organic matter with or without a core of mineral soil or stones (see Figure 20c).
REFERENCES: Raup, 1966; Washburn, 1979.

578. two-layer permafrost

Ground in which two layers of permafrost are separated by a layer of *unfrozen ground*.

COMMENT:

In two-layer permafrost, the lower permafrost layer may represent *relict permafrost* remaining from an earlier cold period, whereas the upper permafrost layer represents more recent development of *epigenetic permafrost*. The intervening unfrozen layer could be a *hydrothermal talik* or a *hydrochemical talik*.

579. two-phase thermosyphon

A passive heat transfer device, filled with a temperature-dependent liquid/vapour combination, installed to remove heat from the ground (see Figure 24).

COMMENT:

A two-phase thermosyphon consists of a sealed tube with a small radiator above the ground surface, containing a working fluid that can be in either the liquid or vapour phase, depending on its temperature. These devices have no moving parts, and they require no external power for operation.

When the air temperature falls below the ground temperature, the vapour condenses in the radiator section of the tube, the pressure in the tube is reduced and the liquid in the lower section starts to boil. The resulting cycle of boiling, vapour movement up the tube, condensation, and return of the condensate by gravity flow is an effective way of transferring heat up the tube, thus cooling the ground.

580. unfrozen ground

Soil or rock that does not contain any ice.

COMMENT:

Unfrozen ground can be cryotic ($T \leq 0°C$) if *freezing-point depression* prevents freezing of the *pore water* (see Figures 2 and 3), or if no water is available to freeze (e.g., in *dry permafrost*). It should not be called *thawed ground*, unless it is known that the ground has previously contained ice.

REFERENCE: van Everdingen, 1976.

581. unfrozen water content

The amount of unfrozen (liquid) water contained in frozen soil or rock (see Figure 3).

COMMENT:

The unfrozen water content can include *free water* that can be moved by gravity, and/or *interfacial* (adsorbed) *water* that cannot be moved by gravity.

The main factors controlling the unfrozen water content in *frozen ground* (or in partially frozen ground) are temperature, specific surface area of mineral particles, mineral type, pore size distribution, dissolved-solids content of the *pore water*, and kind of exchangeable ions. The unfrozen water content at temperatures below 0°C is highest in clays and decreases with decreasing temperature, clay content, and dissolved-solids content, and with increasing particle size. Unfrozen water content, like *total water content*, can be determined either gravimetrically or volumetrically.

SYNONYM: (not recommended) liquid water content.
REFERENCES: Williams, 1967; Penner, 1970; Anderson and Morgenstern, 1973; van Everdingen, 1976.

584. upward freezing

The advance of a *freezing front* upwards from the *permafrost table* during annual freezing of the *active layer*.

COMMENT:

Upward freezing can only occur where the *active layer* extends to the *permafrost table*.

585. vein ice

A comprehensive term for ice of any origin occupying cracks in permafrost.

COMMENT:

Vein ice occurs in various forms, including horizontal layers or lenses, tabular sheets, wedges and reticulate nets.
REFERENCES: Mackay, 1972b; Washburn, 1979.

586. volumetric heat capacity

The amount of heat required to raise the temperature of a unit volume of a substance by one degree.

COMMENT:

The volumetric heat capacity of a material is equal to its *(specific) heat capacity* multiplied by the density of the material.

587. volumetric latent heat of fusion

The amount of heat required to melt all the ice (or freeze all the *pore water*) in a unit volume of soil or rock.

COMMENT:

When the phase change occurs over a range of temperature, then the latent heat manifests itself as an apparent (large) increase in the *heat capacity*.

588. volumetric (total) water content

The ratio of the volume of the water and ice in a sample to the volume of the whole sample, expressed as a fraction (or, less commonly, as a percentage).

COMMENT:

Because of the way it is defined, the volumetric total water content cannot exceed unity (or 100 percent). During thawing of a sample of *frozen ground* the volumetric total water content decreases.
REFERENCE: Anderson and Morgenstern, 1973.

589. waterbody encircling a palsa

A water-filled depression surrounding a *palsa*.

591. wedge ice

Ice occurring in an *ice wedge* (see Figure 17).

COMMENT:

Wedge ice comprises a series of *ice veins* formed in *thermal contraction cracks* at the same location over a period of time. The ice is vertically to subvertically banded and may be discoloured by sediments and contain air bubbles that tend to be arranged in nearly vertical bands. The presence of many small bubbles may give the ice a milky appearance. Individual bands of ice are a few millimetres to a centimetre in width.

REFERENCES: Gell, 1978; Washburn, 1979.

592. well-bonded permafrost

***Ice-bearing permafrost* in which all the soil particles are held together by ice**.

596. Young's modulus

The ratio of increase in stress acting on a test specimen, to the resulting increase in strain, under constant transverse stress.

COMMENT:

Limited to materials having a linear stress-strain relationship over the range of loading applied.

SYNONYM: elastic modulus.

597. zero curtain

The persistence of a nearly constant temperature, very close to the *freezing point*, during annual freezing (and occasionally during thawing) of the *active layer* (see Figure 6).

COMMENT:

The zero curtain results from the dissipation of the *latent heat of fusion* of water during freezing or thawing of the ground. It can persist for several hours or several weeks depending largely on the *total water content* of the ground, *snowcover* and air temperatures. Although the zero curtain can occur in non-permafrost areas, it is most pronounced in permafrost areas, especially during freezing of the *active layer*.

The zero curtain is not only evident in freezing and thawing of undisturbed natural terrain but is also an important factor with respect to *frost action*, refreezing of the ground (backfill or slurry) around foundations, etc. and can have a major effect on the thermal regime of the *active layer* and of the permafrost.

REFERENCES: Sumgin et al., 1940; Brewer, 1958; French, 1976; Washburn, 1979; Outcalt et al., 1990.

598. zone of gas-hydrate stability

That portion of the subsurface where the conditions of temperature and pressure are suitable for the formation and preservation of *gas hydrates*.

COMMENT:

In *permafrost regions*, the zone of gas-hydrate stability is commonly found near the *permafrost base*.

INTERNATIONAL PERMAFROST ASSOCIATION

MULTI-LANGUAGE GLOSSARY of PERMAFROST and RELATED GROUND-ICE TERMS

in

Chinese, English, French, German, Icelandic, Italian

Norwegian, Polish, Romanian, Russian, Spanish, and Swedish

ILLUSTRATIONS

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1998
(revised 2005)

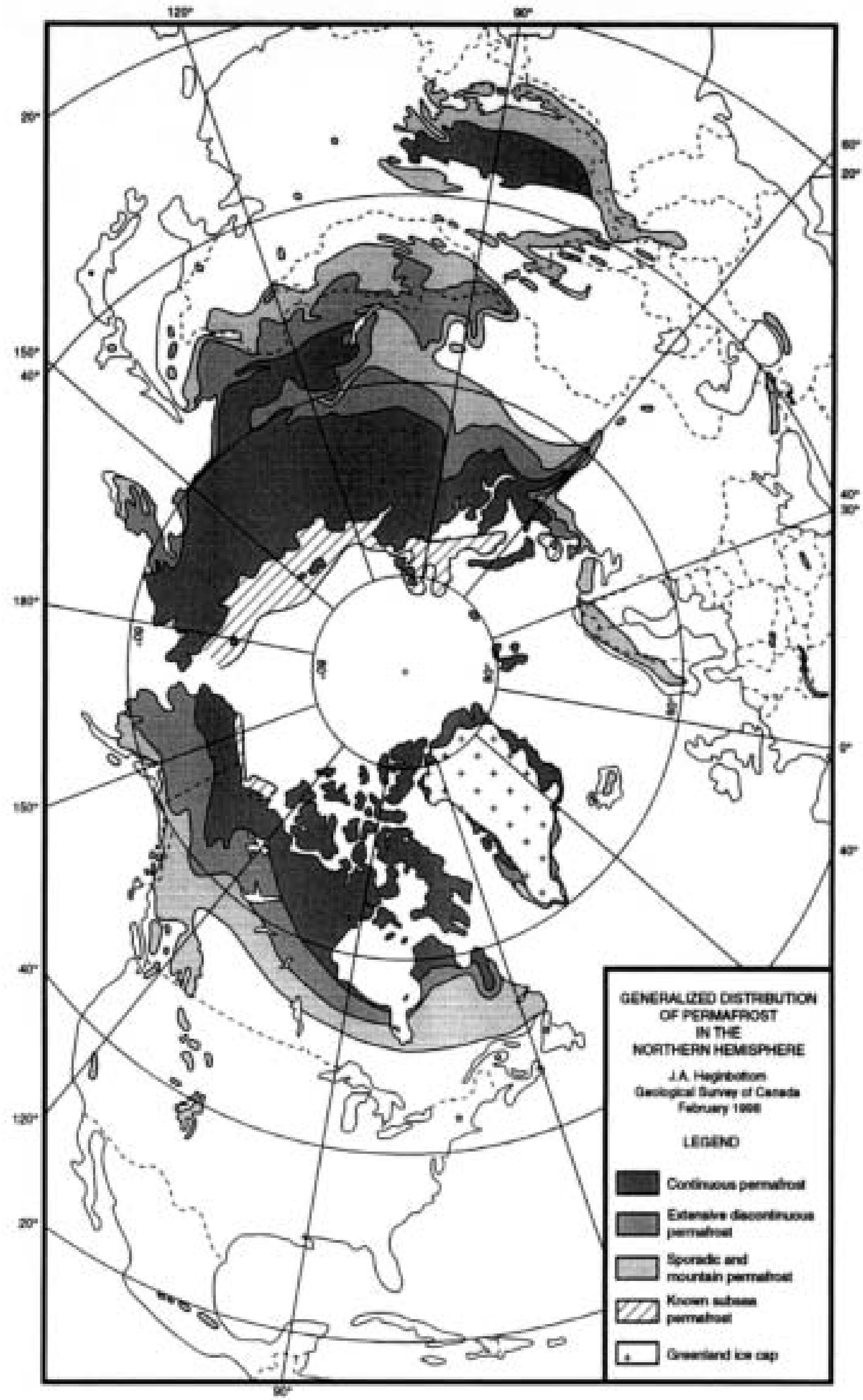

Figure 1. General distribution of permafrost in the Northern Hemisphere (by J. A. Heginbottom, February 1998).

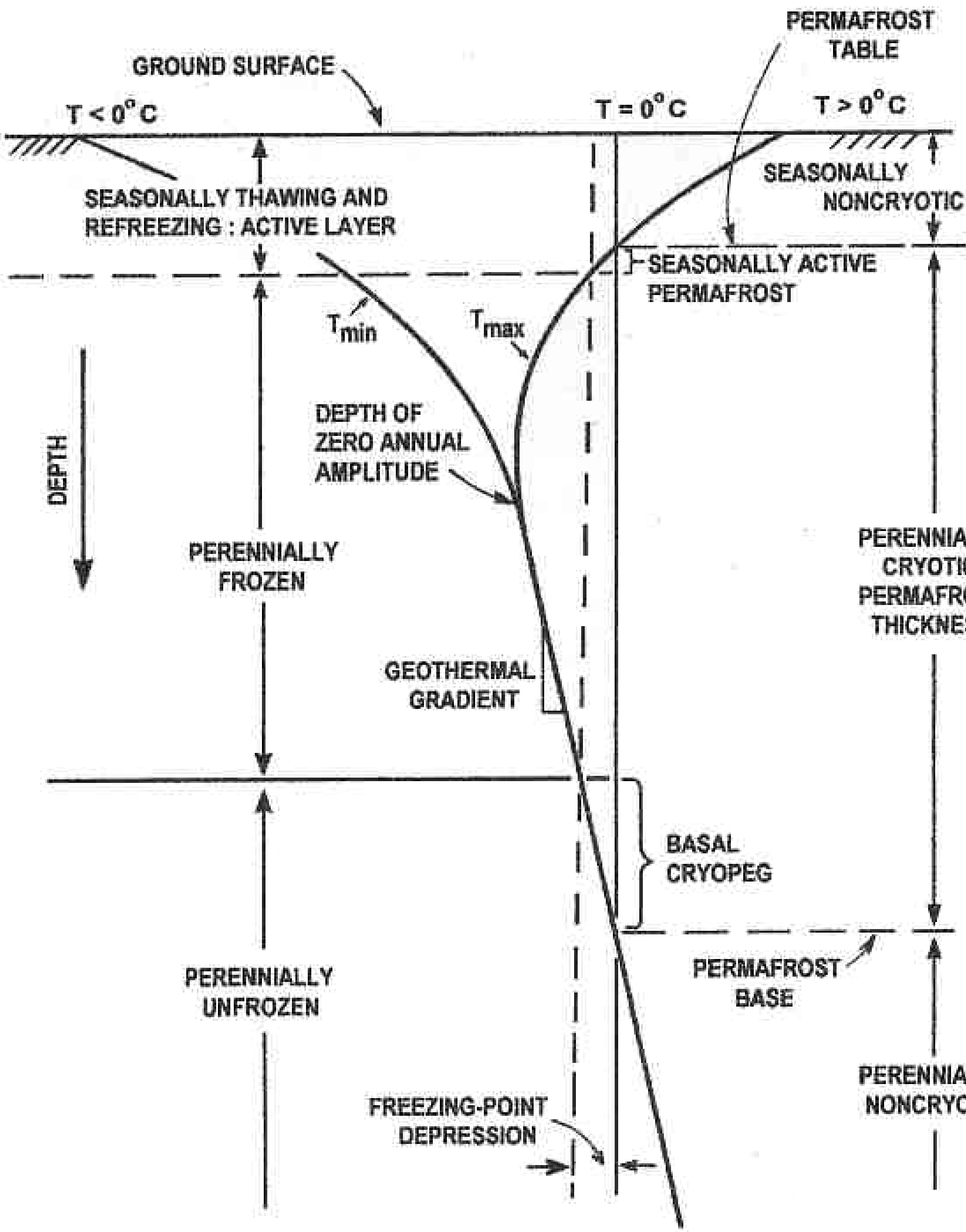

Figure 2. Terms used to describe the ground temperature relative to 0°C, and the state of the water versus depth, in a permafrost environment (modified from van Everdingen, 1985}

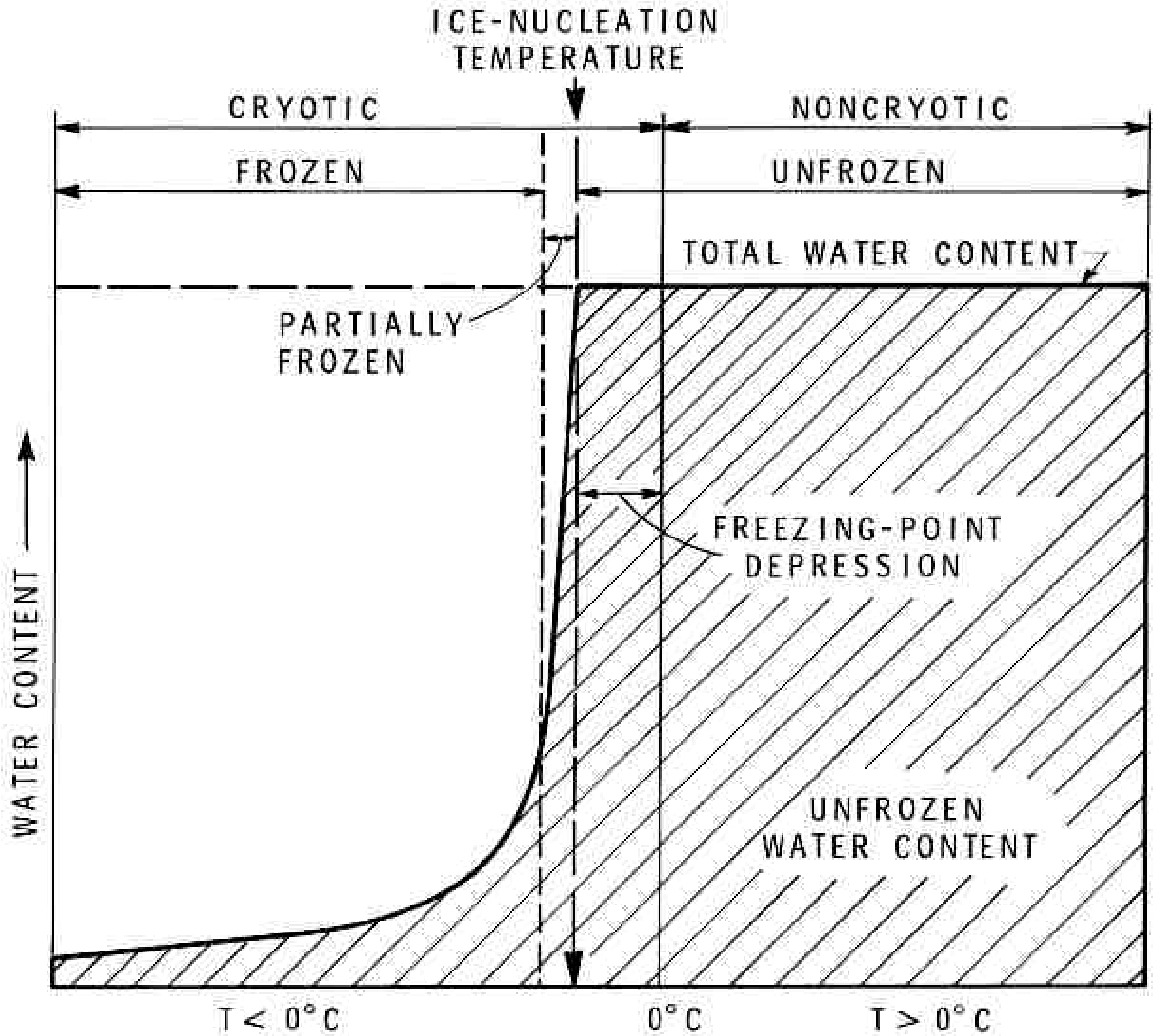

Figure 3. Terms used to describe the state of the water relative to ground temperature in soil materials subjected to freezing temperatures (modified from van Everdingen, 1985)

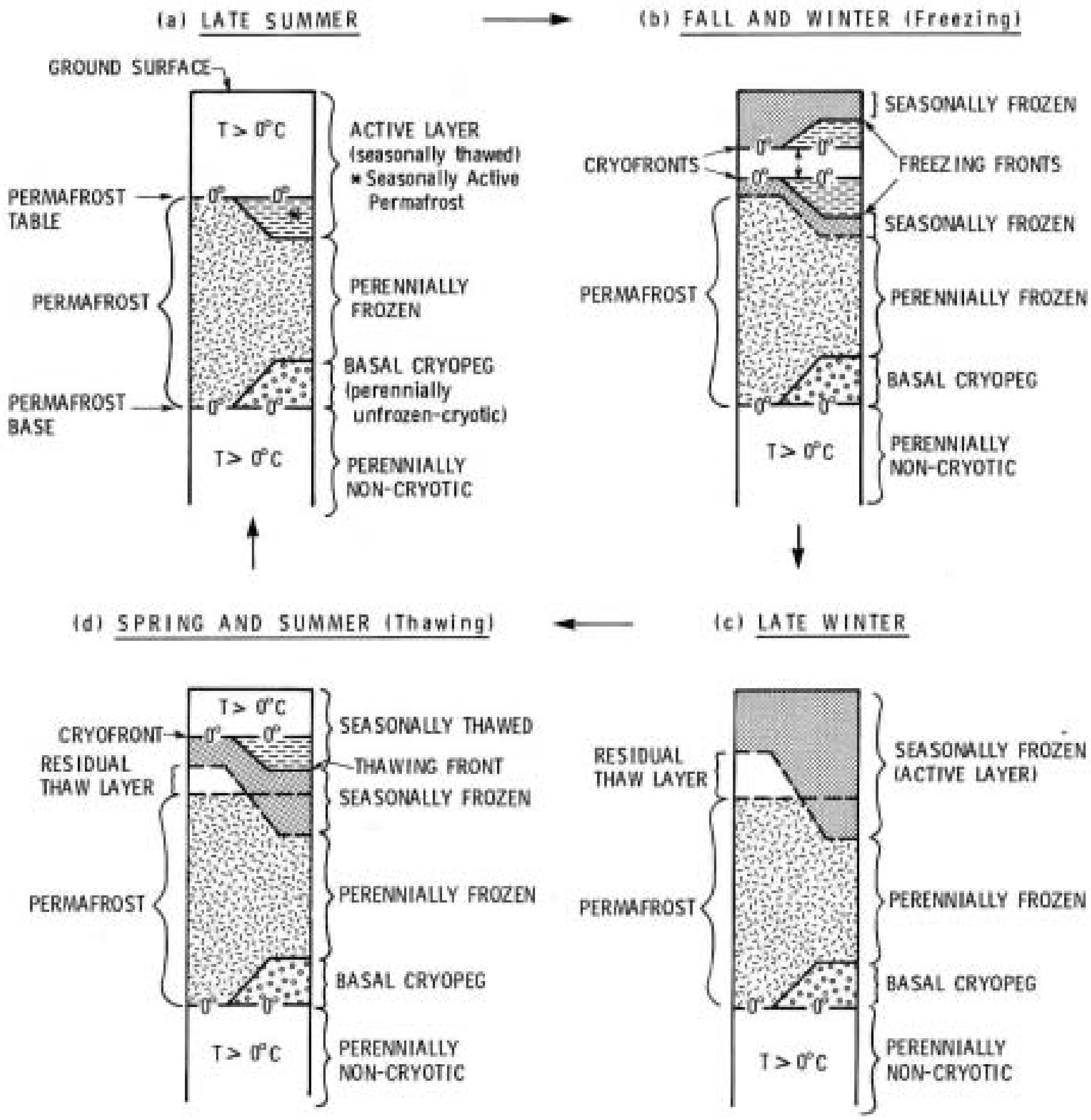

Figure 4. Terms used to describe seasonal changes in the ground temperature relative to 0°C, and in the state of the water versus depth, in a permafrost environment (modified from van Everdingen, 1985)

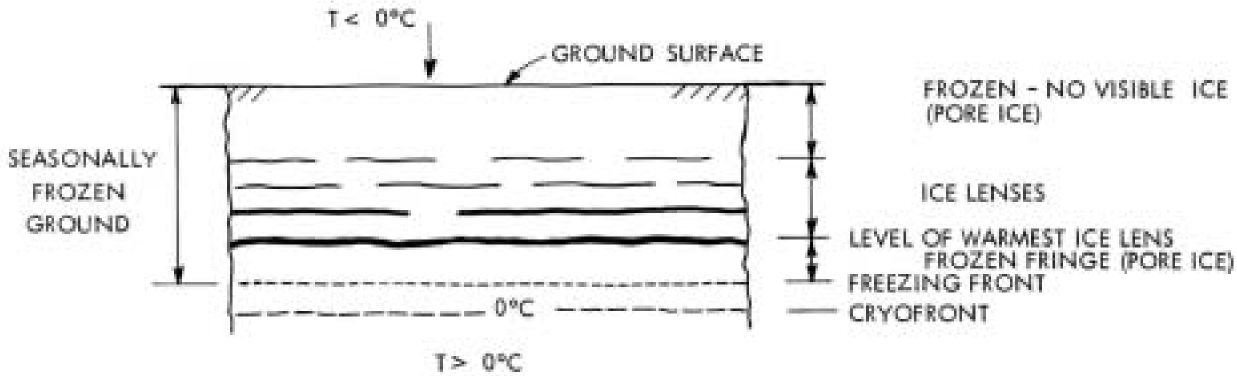

Figure 5. Diagram showing the relative positions of the *frozen fringe*, the *freezing front* and the *cryofront* during freezing of a fine-grained, *frost-susceptible soil*

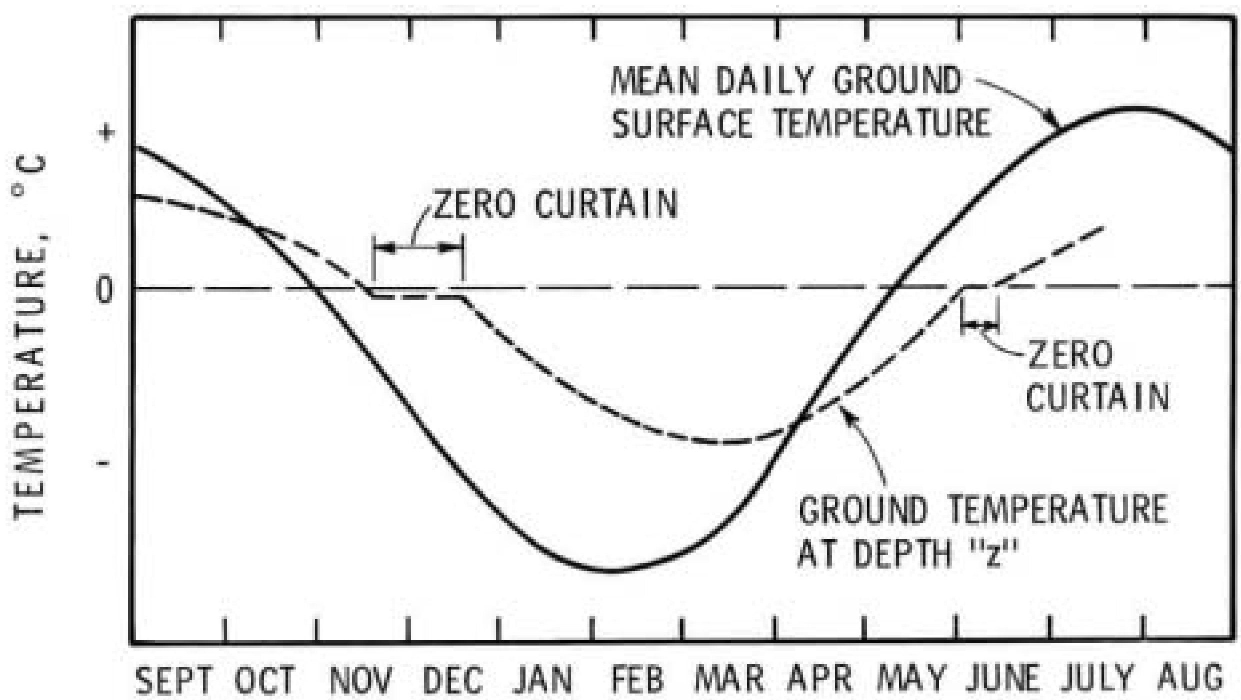

Figure 6. Diagram illustrating the zero curtain

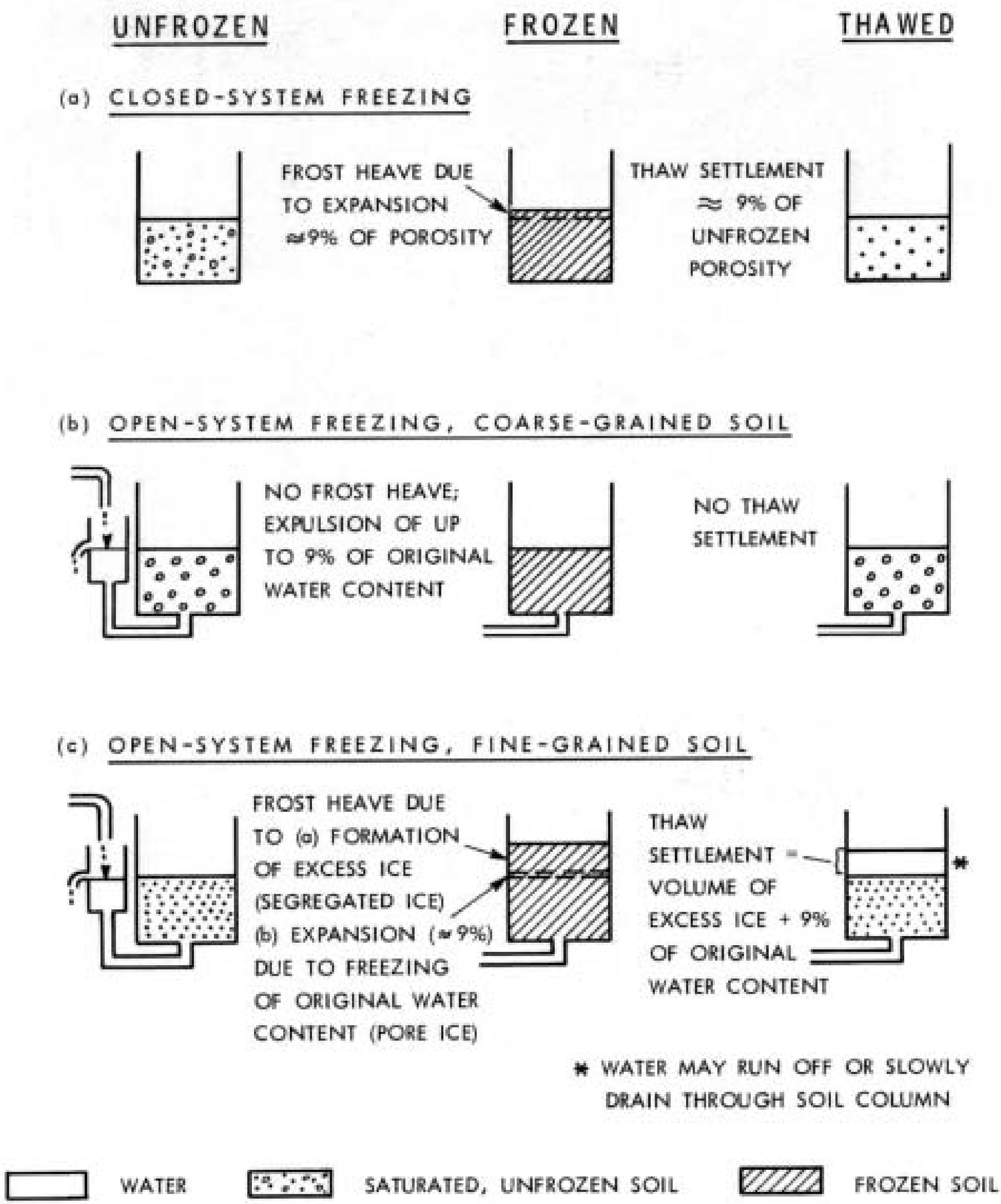

Figure 7. Diagrams illustrating frost heave and thaw settlement resulting from closed- and open-system freezing of soil materials and the formation of excess ice

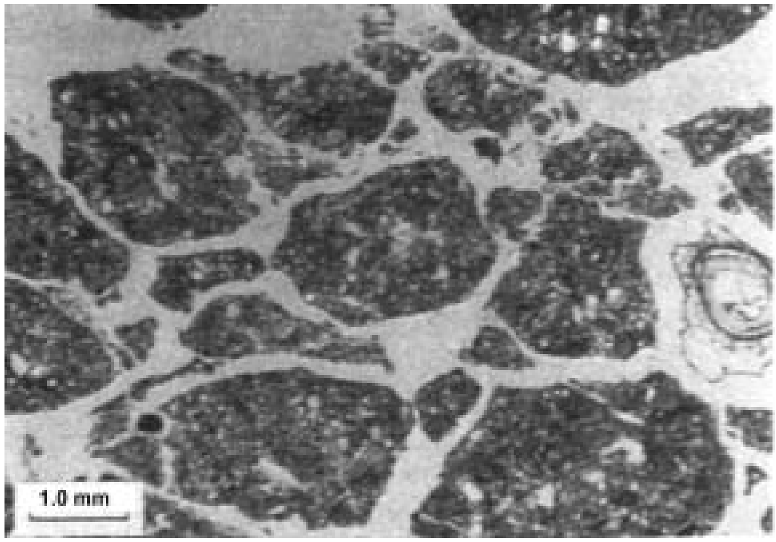

Figure 8a

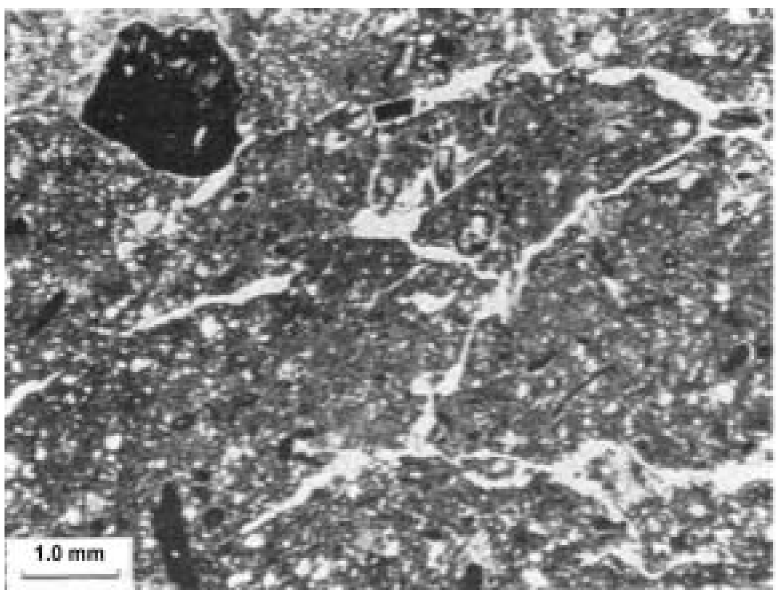

Figure 8b

Figure 8. *Cryogenic fabrics*, as seen in thin sections (Photos by C.A. Fox, Agriculture Canada, except for (c) by C. Tarnocai, Agriculture Canada).

(a) Discrete, rounded to subangular, units of soil material, granic fabric, at the 0 to 30 cm depth of a Brunisolic Turbic Cryosol developed in an *earth hummock* formed on an undulating morainal till deposit in the Mackenzie Plain, N.W.T. Plane-polarized light, vertical section.

(b) Planar voids resulting from the coalescence of discrete units at their contact points (fragmoidic fabric). Observed within permafrost at a depth of 25 to 38 cm in an Orthic Turbic Cryosol developed in an *earth hummock* formed on a rolling morainal till in the Mackenzie Plain near Carcajou River, N.W.T. Plane polarized light, vertical section.

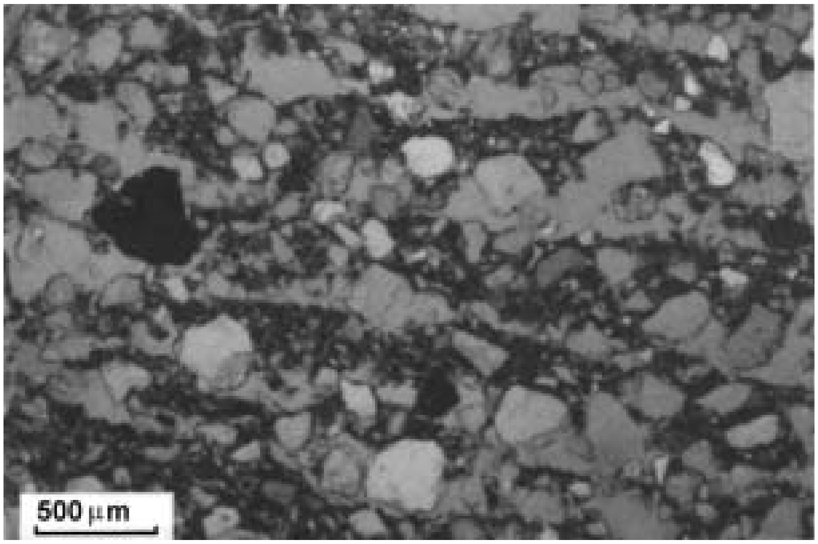

Figure 8c

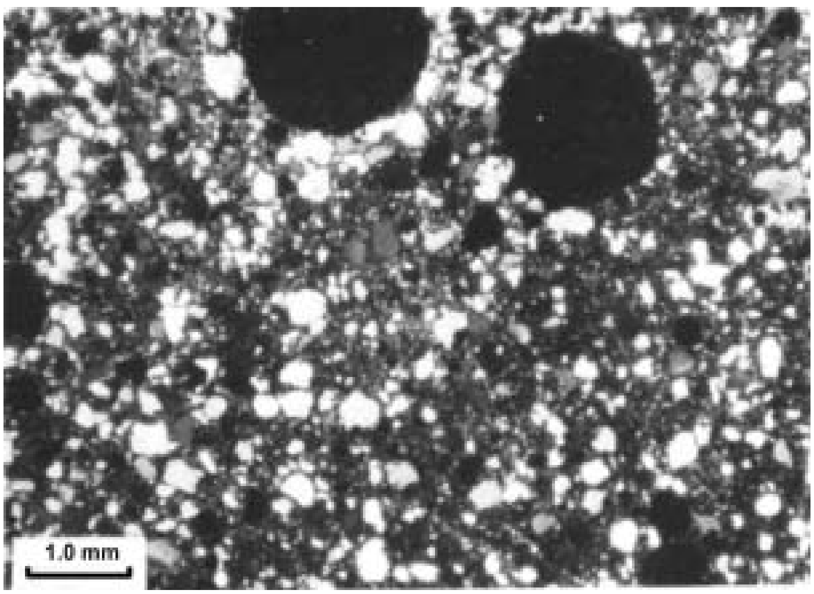

Figure 8d

Figure 8 (continued).

(c) Banded fabric showing a gradation of fine-to-coarse particle sizes within each layer. Observed within the *active layer* at approximately 30 cm in an Orthic Turbic Cryosol. This soil was developed in a small *polygon* formed on rolling terrain near Goodsir Inlet, Bathurst Island, N.W.T. Partially crossed nicols, vertical section.

(d) Coarse-sized particles form a circular to ellipsoidal pattern referred to as orbiculic fabric. The large circular black regions are pore space (vesicular pores). Observed at a depth of 0 to 20 cm in an Orthic Turbic Cryosol developed in a non-sorted circle on an unglaciated colluvial deposit of the Carcajou Range (Mackenzie Mountains) N.W.T. Crossed nicols, vertical section.

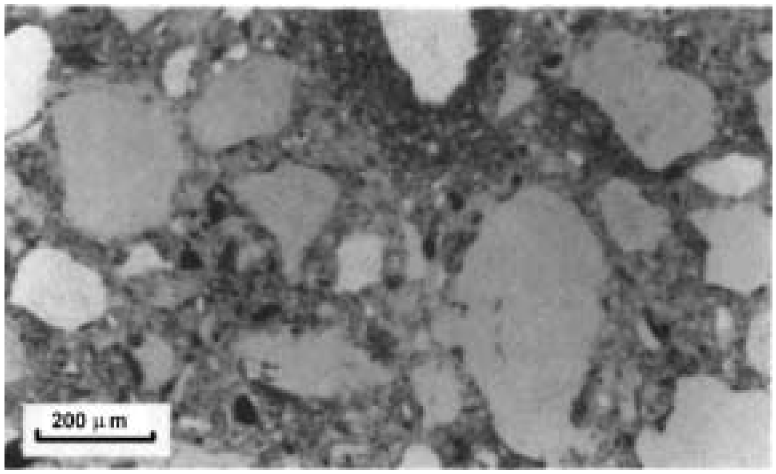

Figure 8e

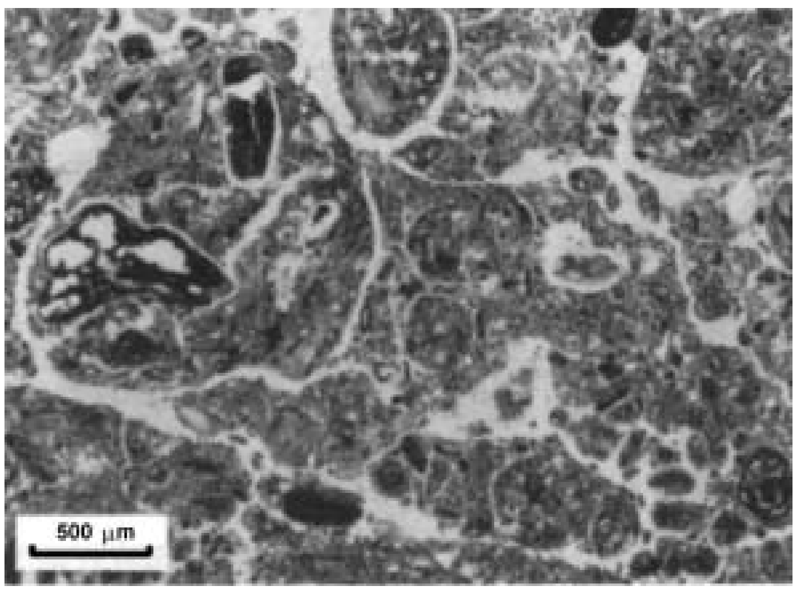

Figure 8f

Figure 8 (continued).

(e) Coarse-sized particles showing a tendency to be vertically or nearly vertically aligned (suscitic fabric). Some of the particles are also associated with surface accumulations of finer material. Observed at a depth of 0 to 20 cm in an Orthic Turbic Cryosol in a non-sorted circle on an unglaciated colluvial deposit of the Carcajou Range (Mackenzie Mountains) N.W.T. Partially crossed nicols, vertical section.

(f) Cryogenic processes have formed a complex morphology (conglomeric fabric) in which discrete fragments and rounded units are displaced, then enclosed by finer material and subjected to ice lens formation as evidenced by the associated planar voids. Observed within permafrost at a depth of 31 to 65 cm in a Gleysolic Turbic Cryosol developed in an *earth hummock* on a morainal till deposit in the Horn Plateau Region, N.W.T. Plane-polarized light, vertical section.

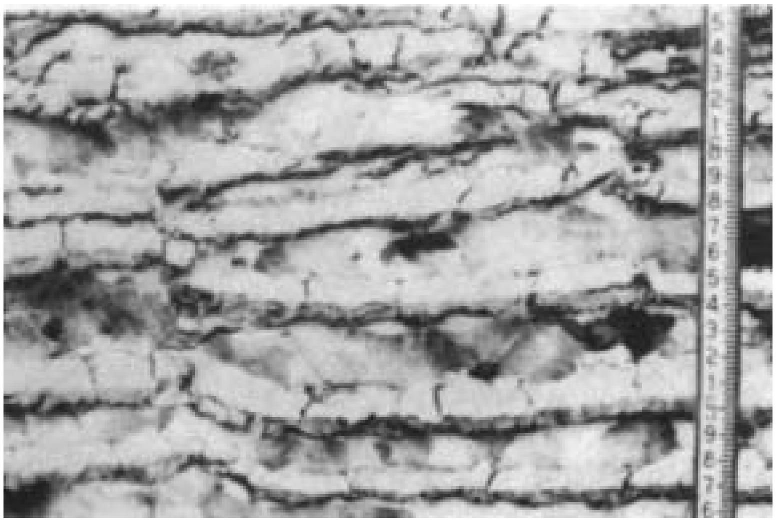

Figure 9a

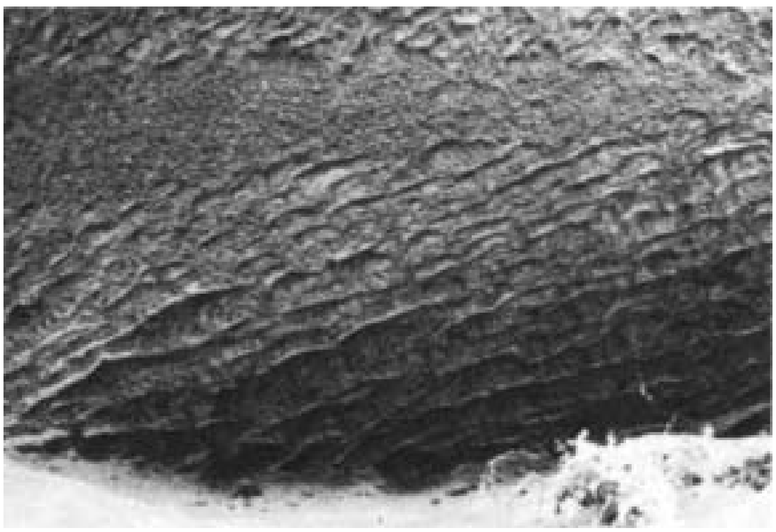

Figure 9b

Figure 9. Examples of *cryostructures* in frozen ground

(a) *Segregated ice* in varved glaciolacustrine silty clay, Thompson, Manitoba (Photo by G.H. Johnston, National Research Council of Canada)

(b) Inclined *ice lenses,* 30 to 80 cm long and 5 to 10 cm thick, formed by subaqueous syngenetic freezing of glaciolacustrine silty clay near Mayo, Yukon Territory (Photo by H.M. French, University of Ottawa)

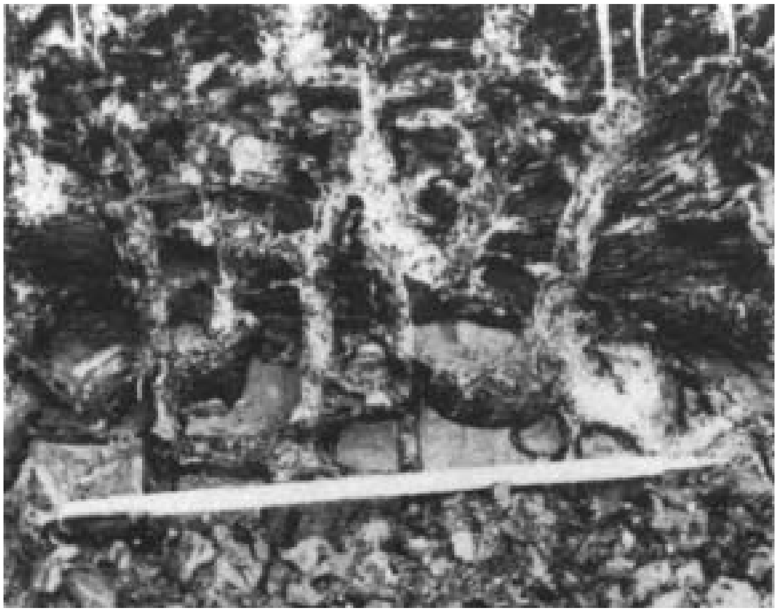

Figure 9c

Figure 9d

Figure 9 (continued).

(c) Coarse reticulate network of *ice veins* formed in glaciolacustrine clay, Sabine Point, Beaufort Sea coastal plain, Yukon Territory (Photo by D.G. Harry, Geological Survey of Canada)

(d) Fine reticulate network of *ice veins* formed in silty clay diamicton, Pelly Island, Mackenzie Delta, N.W.T. (Photo by H.M. French, University of Ottawa)

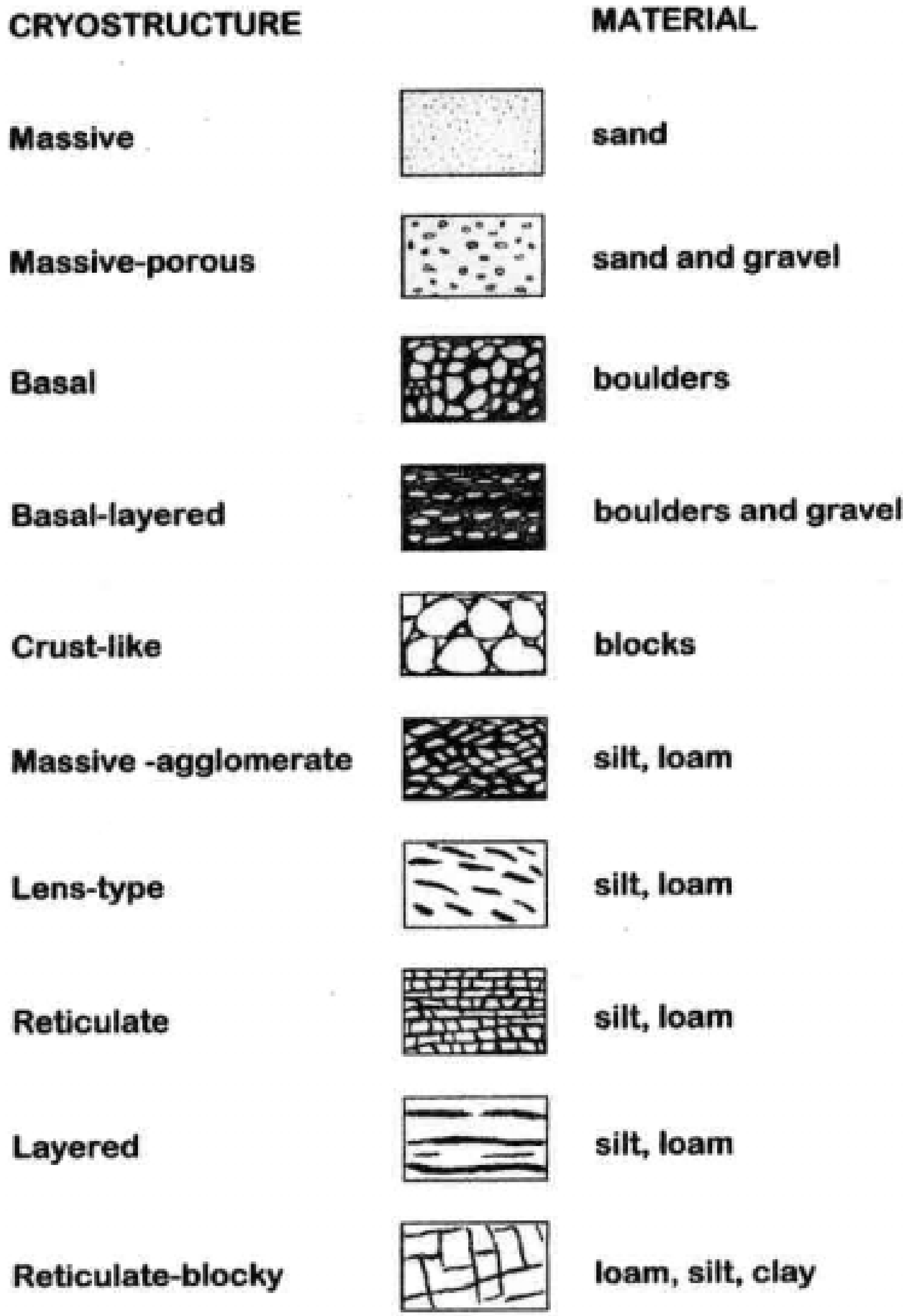

Figure 9e. Schematic drawings illustrating various cryostructure terms (after hand-drawn sketches by N. N. Romanovskii, 1995).

Figure 10a

Figure 10b

Figure 10. Examples of types *of ground ice*

(a) *Aggradational ice* at the top of permafrost and exposed at the 2 m depth in a pipeline trench, approximately 98 km south of Norman Wells, N.W.T. (Photo by D.G. Harry, Geological Survey of Canada)

(b) Ice *(dilation crack ice?)* between the ice core and heaved, silty, gravelly overburden of a collapsed *pingo*, Thomsen River, north central Banks Island, N.W.T. (Photo by H.M. French, University of Ottawa)

Figure 10c

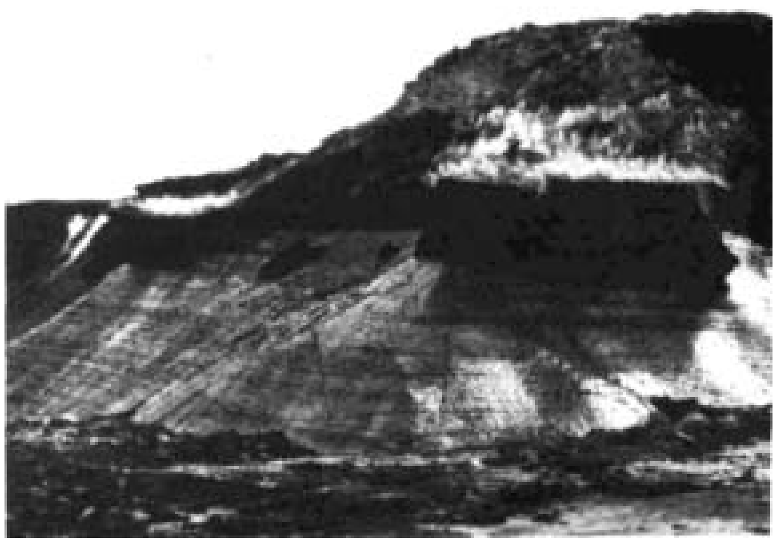

Figure l0d

Figure 10 (continued).

(c) Columnar ice crystals in a 10 to 20 cm thick layer of *intrusive ice* from within a seasonal *frost blister*, North Fork Pass, Ogilvie Mountains, Yukon Territory (Photo by W.H. Pollard, Memorial University)

(d) *Massive ice* exposed at Peninsula Point, 5 km southwest of Tuktoyaktuk, Mackenzie Delta, N.W.T. (Photo by H.M. French, University of Ottawa)

Figure 10e

Figure 10f

Figure 10 (continued).

(e) Glacially deformed *massive ice* exposed on north coast of Pelly Island, Mackenzie Delta, N.W.T. The exposure is approximately 7 to 10 m high. (Photo by D.G. Harry, Geological Survey of Canada)

(f) *Massive ice* body near Sabine Point, Beaufort Sea coastal plain, Yukon Territory. (Photo by H.M. French, University of Ottawa)

Figure 10g

Figure 10h

Figure 10 (continued).

(g) *Needle ice* exposed after removal of a stone, Boutillier Pass, Alaska Highway, Yukon Territory. (Photo by S.A. Harris, University of Calgary)

(h) Large body *of pingo ice* exposed near summit of a small growing *pingo*, 3 km west of Tuktoyaktuk, Mackenzie Delta, N.W.T. (Photo by H.M. French, University of Ottawa)

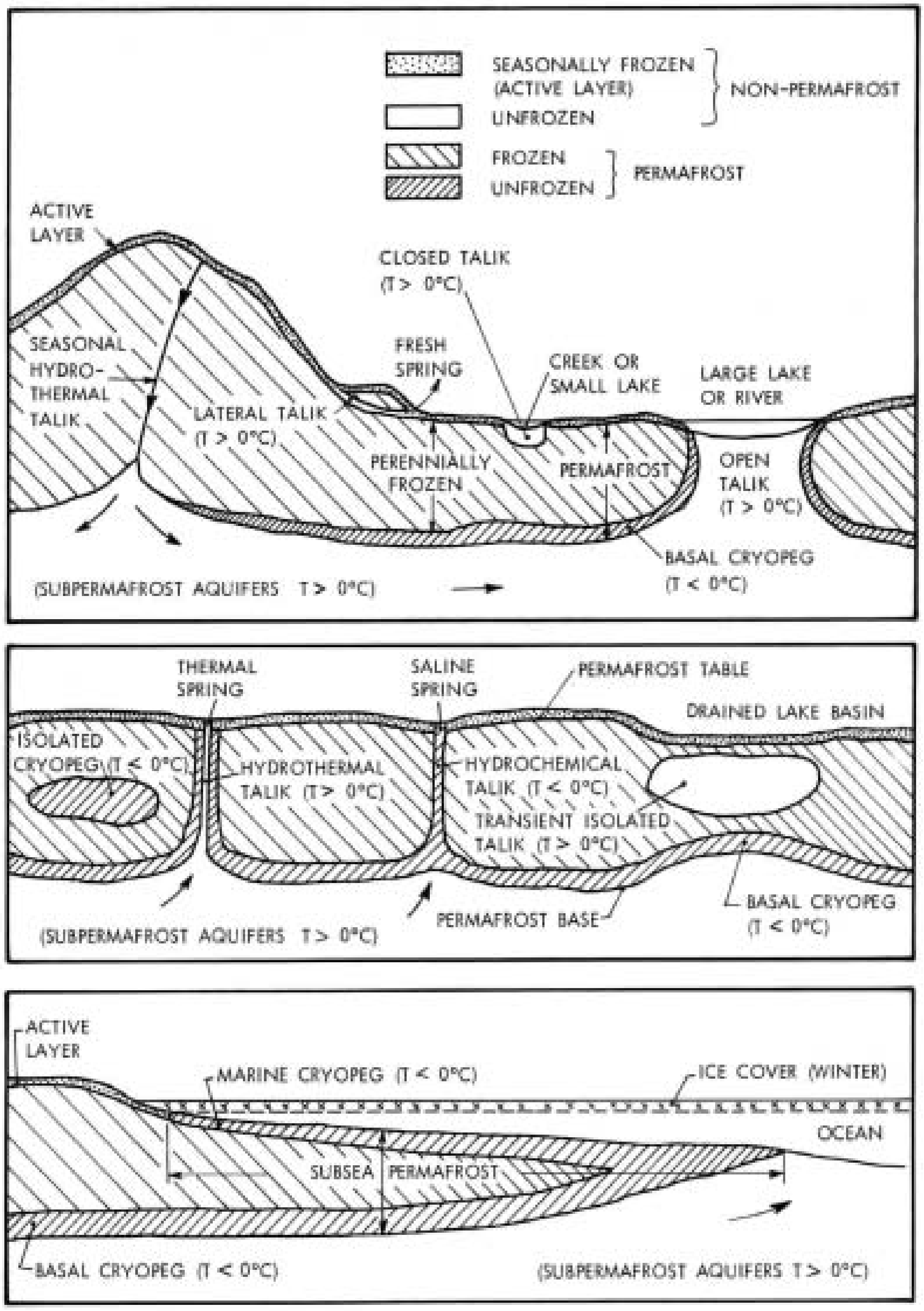

Figure 11. Cross sections illustrating terms used to describe unfrozen zones in a permafrost environment, and their relationships with surface water and groundwater flow (modified from van Everdingen, 1976)

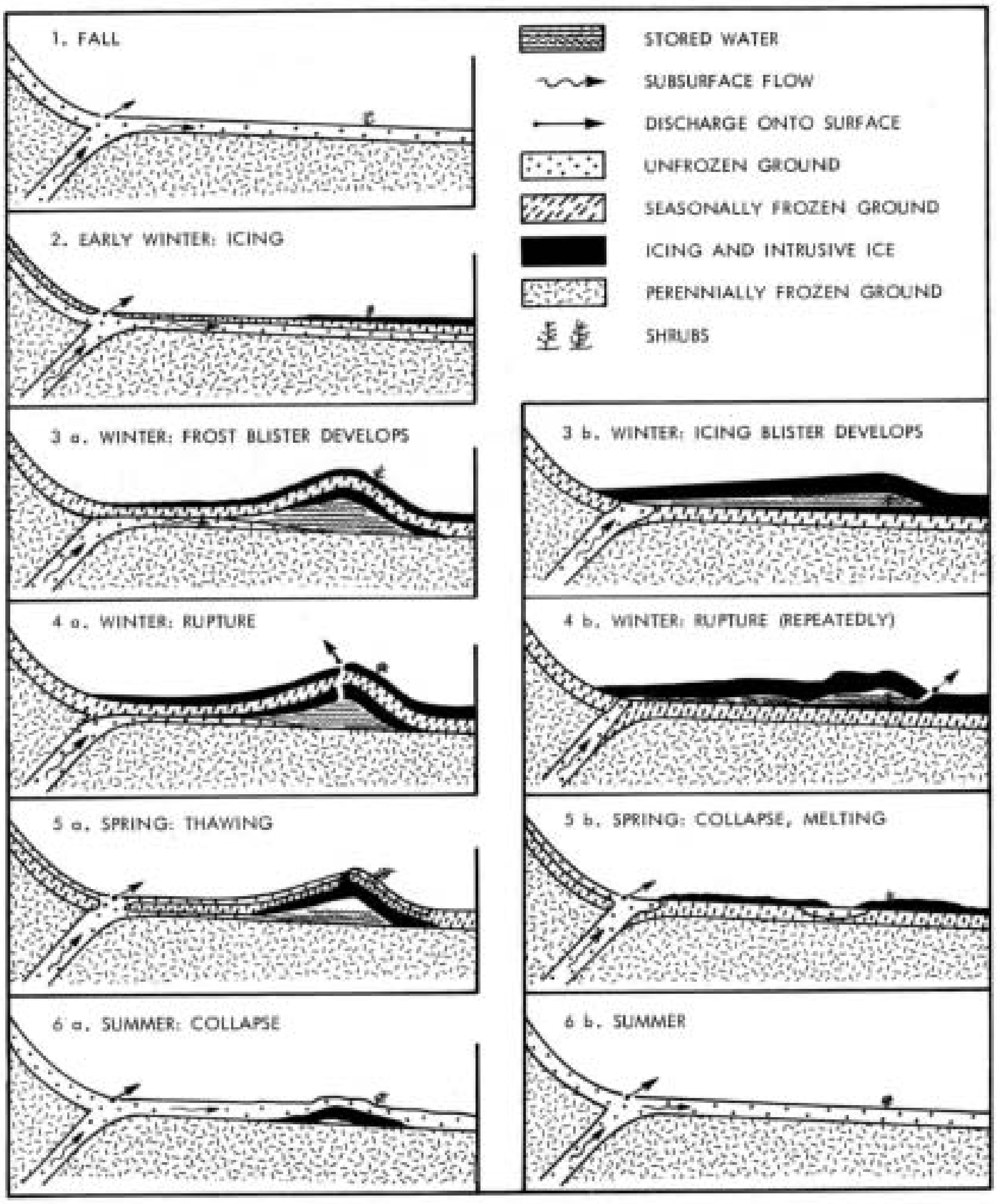

Figure 12. Sequence of events in the formation and decay of *frost blisters* and *icing blisters* (modified from van Everdingen, 1978)

Figure 13a

Figure 13b

Figure 13c

Figure 13. *Seasonal frost mounds* at Bear Rock, near Ft. Norman, N.W.T. (Photos by R.O. van Everdingen, Environment Canada)

(a) *Frost blister* in early July, after melting of snow and the surrounding *icing*

(b) The *same frost blister* in early September, after thawing of the seasonally frozen soil cover and partial collapse of the *intrusive ice* into the drained cavity

(c) Drained cavity (up to 40 cm high) exposed below cut-away *intrusive ice* in one of the *frost blisters* (cut at left is about 60 cm high)

Figure 13d

Figure 13e

Figure 13 (continued).

(d) Ruptured and partially collapsed *icing blister* in March (drained cavity was 90 cm high); note smaller *icing blister* in foreground

(e) Block of layered icing ice and massive *intrusive ice* from a ruptured *icing blister* (top is at left; tape shows centimetres)

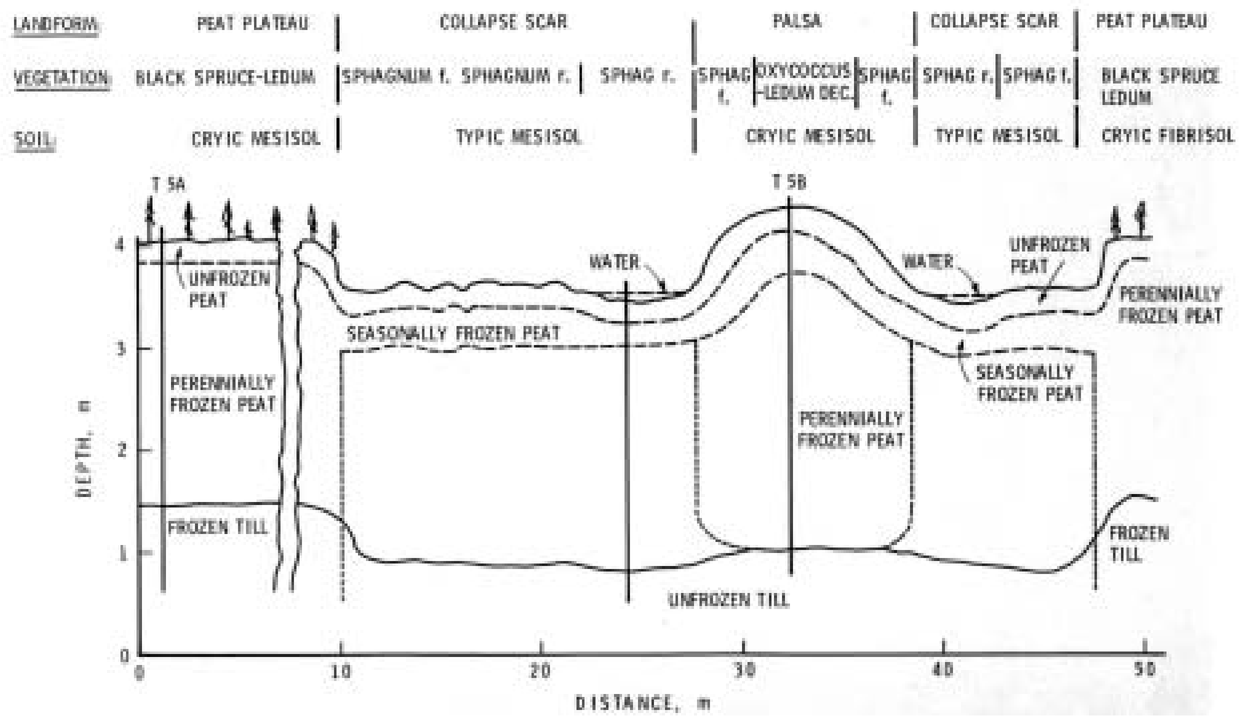

Figure 14. Cross section of a *peat plateau* - *collapse scar* area with a young *palsa* in the discontinuous permafrost zone (modified from Tarnocai, 1973)

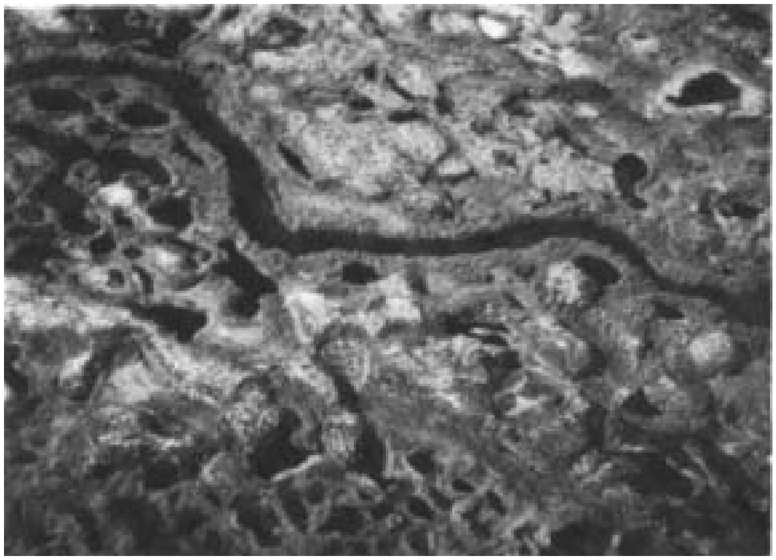

Figure 15a

Figure 15b

Figure 15. Examples of permafrost landforms developed in *peatlands*

(a) *Palsa* and *peat plateau* complex, Sheldrake Lake area, Quebec (Photo by M.K. Seguin, Universit~ Laval)

(b) *Peat plateaus* occurring as islands in an unfrozen *string fen*, Nelson River area, Manitoba (Photo by S.C. Zoltai, Environment Canada)

Figure 15c

Figure 15d

Figure 15 (continued).

(c) *Polygonal peat plateau* near the tree line, Richardson Mountains, N.W.T. (Photo by S.C. Zoltai, Environment Canada)

(d) A *string fen*, looking upstream, Lac La Ronge, Saskatchewan (Photo by S.C. Zoltai, Environment Canada)

Figure 15 (continued).

(e) *Collapse scars*, some with remnant *peat plateaus* marked by tall trees, near Wabowden, Manitoba (Photo by S.C. Zoltai, Environment Canada)

Figure 16. Examples of *patterned ground*

(a) Oblique aerial view of high-centre *polygons* on sediments of the Deer Bay Formation, northern Fosheim Peninsula, Ellesmere Island, N.W.T. (Photo by M.F. Nixon, Geological Survey of Canada)

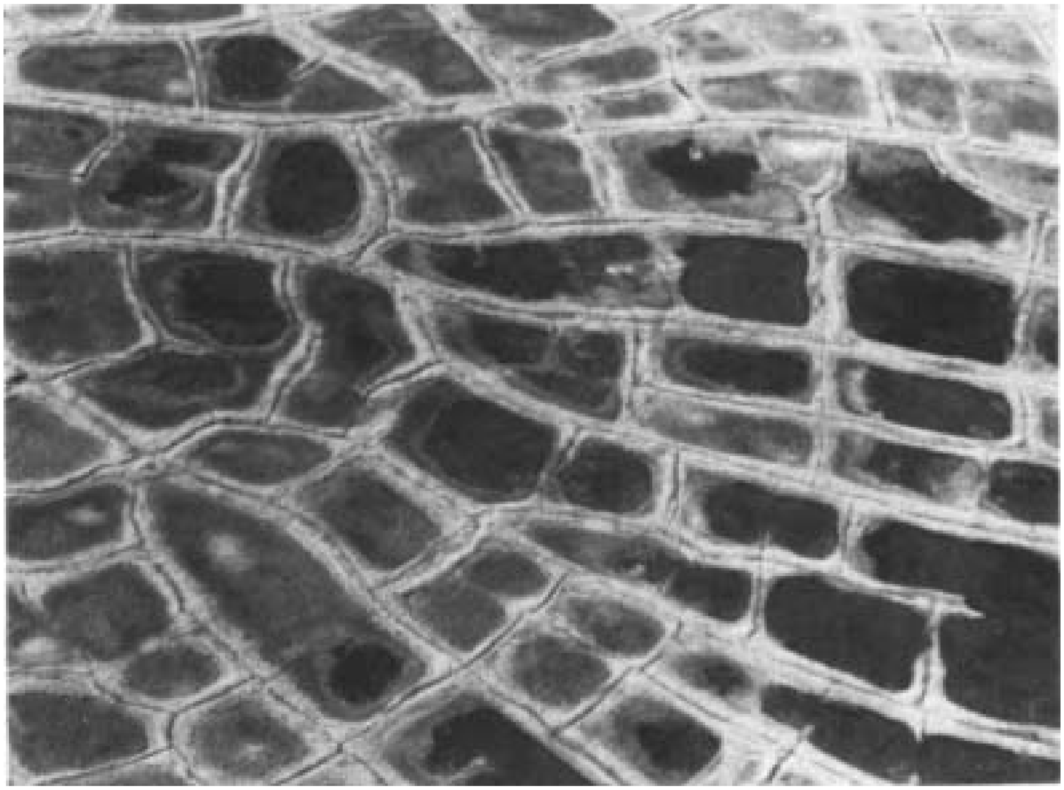

Figure 16 (continued).

(b) Oblique aerial view of low-centre *polygons* on a river terrace north of Raddi Lake, southwestern Banks Island, N.W.T. (Photo by J-S. Vincent, Geological Survey of Canada)

Figure l6 (continued).

(c) *Frost boils* on shallow lacustrine silts overlying till, on the west side of Irene Bay, central Ellesmere Island, N.W.T. (Photo by D.A. Hodgson, Geological Survey of Canada)

Figure 16 (continued).

(d) *Solifluction* of till across marine-limit raised beaches near Kaminak Lake, N.W.T. *Frost boils* can be seen on the till, thermal contraction crack *polygons* are seen on the raised beaches, and solifluction stripes are visible on the till in the middle-right of the field of view. The downslope edge of the solifluction sheet forms a turf-banked terrace. The white bar is the antenna of the helicopter. (Photo by W.W. Shilts, Geological Survey of Canada)

Figure 16 (continued).

(e) Non-sorted stripes in thin till overlying Cretaceous sandstones, eastern Banks Island, N.W.T. (Photo by H.M. French, University of Ottawa)

Figure 16 (continued).

(f) Sorted stripes on fissile sandstone of Jurassic age, near Mould Bay, Prince Patrick Island, N.W.T. (Photo by H.M. French, University of Ottawa)

Figure 17. *Ice, sand* and *soil wedges*

(a) *Ice wedge,* about 4 m wide at the top, in postglacial lake silts that overlie truncated glacially deformed. ice-rich Pleistocene sediments more than 40,000 years old. Garry Island, N.W.T. (Photo by J.R. Mackay, University of British Columbia)

Figure 17b

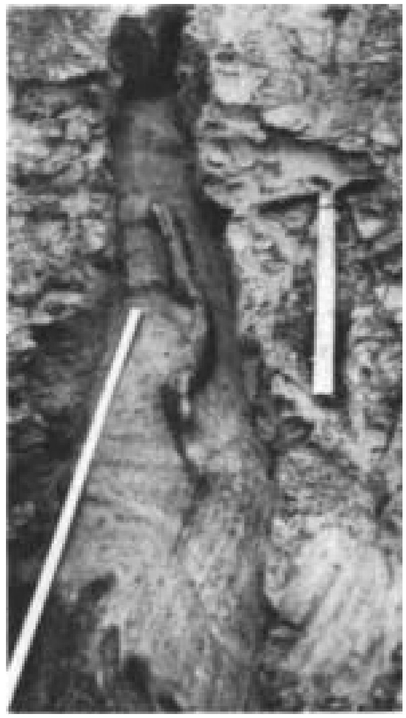

Figure 17c

Figure 17d

Figure 17 (continued).

(b) Inactive *ice wedge* formed in silty clay, Sachs River lowlands, Southern Banks Island, N.W.T. (Photo by D.G. Harry, Geological Survey of Canada)

(c) Small syngenetic *ice wedge* formed in silty sand of late-Quaternary age, Sachs River lowlands, southern Banks Island, N.W.T. (Photo by D.G. Harry, Geological Survey of Canada)

(d) Rejuvenated *ice wedge* showing primary and secondary wedge exposed in coastal bluff 3 km west of Sachs Harbour, southern Banks Island, N.W.T. (Photo by H.M. French, University of Ottawa)

Figure 17e

Figure 17f

Figure 17 (continued).

(e) Epigenetic *ice wedge* exposed in coastal bluff 3 km west of Sachs Harbour, southern Banks Island, N.W.T. (Photo by D.G. Harry, Geological Survey of Canada)

(f) *Ice-wedge ice* showing foliated nature, southern Banks Island, N.W.T. (Photo by H.M. French. University of Ottawa)

Figure 17g

Figure 17h

Figure 17 (continued).

(g) *Soil wedge* in "Wounded Moose" paleosol developed on pre-Reid till, Willow Hills, Yukon Territory (Photo by K. Valentine, Agriculture Canada)

(h) *Sand wedge* beneath polygonal trench in glaciofluvial deposits, Mary River area, northern Baffin Island, N.W.T. (Photo by G.H. Johnston, National Research Council of Canada)

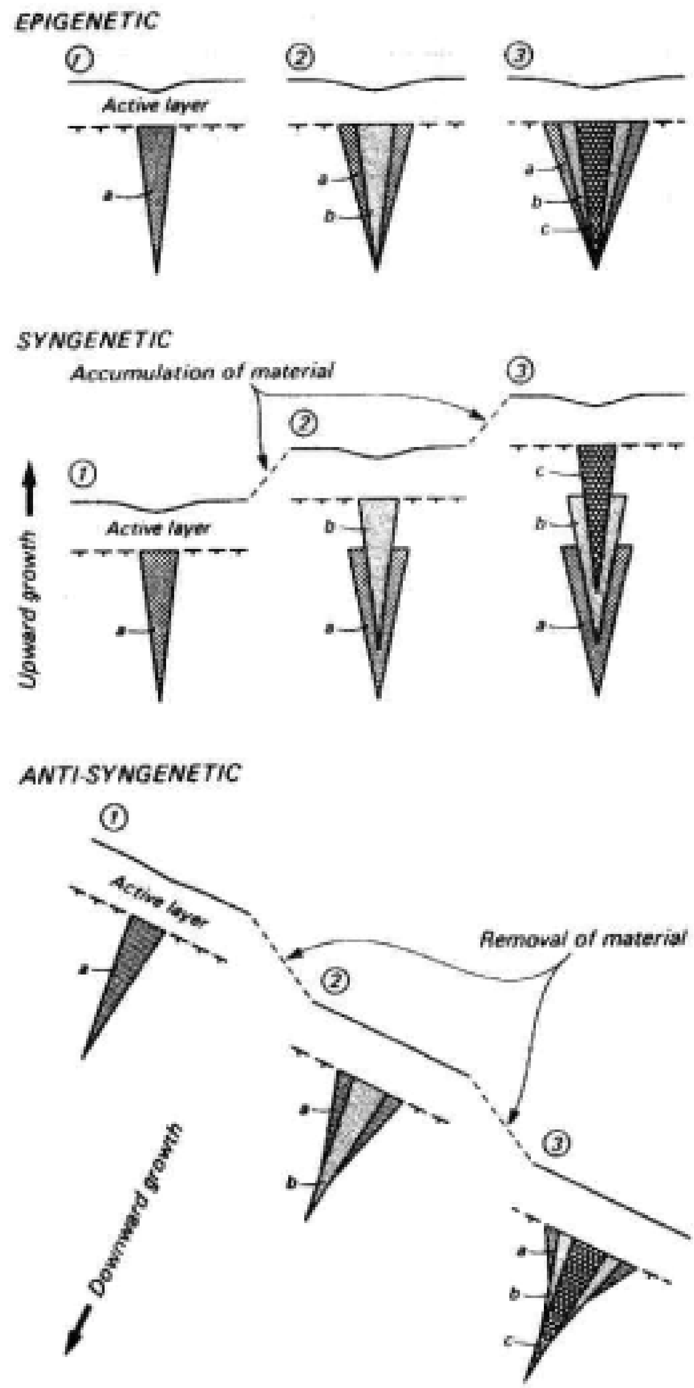

Figure 17 (continued).

(i) Schematic diagram showing three stages in the growth of epigenetic, syngenetic, and anti-syngenetic ice wedges: 1 - early, 2 - intermediate, and 3 - late (from Mackay, 1990, Fig.3). In an epigenetic ice wedge the ice on the sides is the oldest (a). In a syngenetic ice wedge the ice on the sides decreases in age from the bottom to the top. In an anti-syngenetic ice wedge the ice on the sides decreases in age from the top to the bottom.

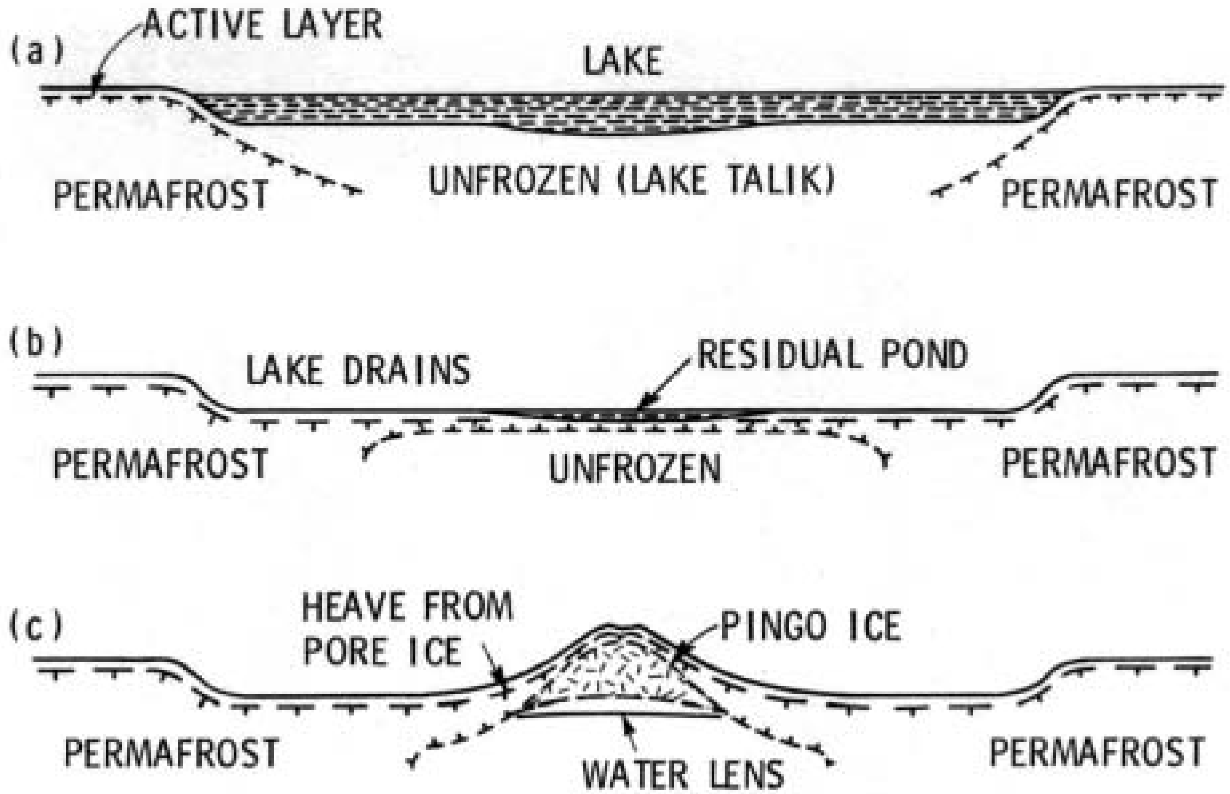

Figure 18. Illustration of the growth of a *closed-system pingo* (modified from Mackay, 1985)

Figure 19. *Pingos*

(a) *A closed-system pingo* (Ibyuk Pingo), 49 m high and 300 m in basal diameter, in the bottom of a drained lake near Tuktoyaktuk, N.W.T. The flats in the foreground are just above sea level and are flooded during storm surges. The pingo overburden is 15 m thick, the underlying sediments are sands and the pingo is still growing at the top at a rate of about 2 cm/year. (Photo by J.R. Mackay, University of British Columbia)

Figure 19b

Figure 19c

Figure 19 (continued).

(b) An *open-system pingo* on the alluvial fan in the Mala River Valley, Borden Peninsula, Baffin Island, N.W.T. (Photo by G.W. Scotter, Canadian Wildlife Service)

(c) A *pingo remnant* near Tuktoyaktuk, N.W.T. The basal diameter is about 300 m, which is almost identical with that of Ibyuk Pingo (see (a) above). The pond in the pingo is 5.4 m deep. The pingo probably grew at least several thousand years ago; the time of collapse is unknown. (Photo by J.R- Mackay, University of British Columbia)

Figure 20a

Figure 20b

Figure 20. Examples of *earth hummocks*

(a), (b) *Earth hummocks* near Inuvik, N.W.T., on a clay-silt colluvium, overlying outwash gravels. Individual hummocks are 1 to 2 m in diameter, and the troughs between the hummocks are 25 to 50 cm deep. Many hummocks have exposed mineral soil on the top; the troughs are commonly filled with moss and underlain by ice, year round. Figure 20(a) shows the natural terrain, with an open woodland of black spruce and alder. Figure 20(b) shows the same area following a forest fire in 1968. (Photos by H.M. French. University of Ottawa)

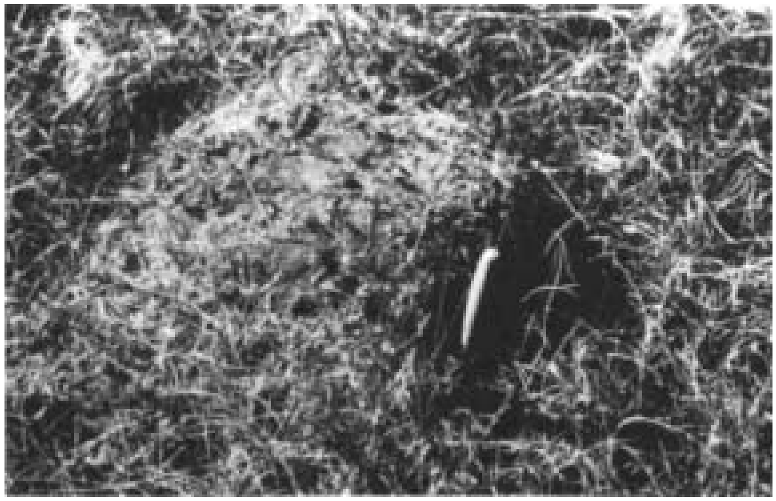

Figure 20c

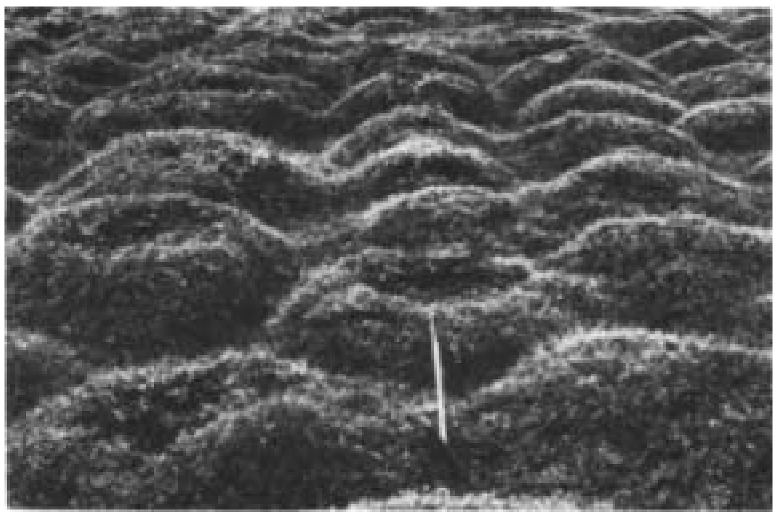

Figure 20d

Figure 20 (continued).

(c) *Turf hummock* consisting of living and dead *Sphagnum fuscum,* District of Keewatin, N.W.T. (Photo by S.C. Zoltai, Environment Canada)

(d) *Thufa* in volcanic ash soils, Sunshine Meadows, near Banff, Alberta. (Photo by S.C. Zoltai, Environment Canada)

Figure 21a

Figure 21b

Figure 21. Examples of *mass wasting* in permafrost areas

(a) Ac*tive-layer failure* in the upper Ramparts River area, Mackenzie Valley, N.W.T. (Photo by O.L. Hughes, Geological Survey of Canada)

(b) Active-layer detachment failure, Mackenzie Valley, N.W.T. (Photo by O.L. Hughes, Geological Survey of Canada)

Figure 21c

Figure 21d

Figure 21 (continued).

(c) *Retrogressive thaw slumping* in a borrow pit on the Dempster Highway near Ft. McPherson, N.W.T. (Photo by O.L. Hughes, Geological Survey of Canada)

(d) *Retrogressive thaw slumping* on the Yukon coastal plain near King Point, Yukon Territory. (Photo by J-S. Vincent, Geological Survey of Canada)

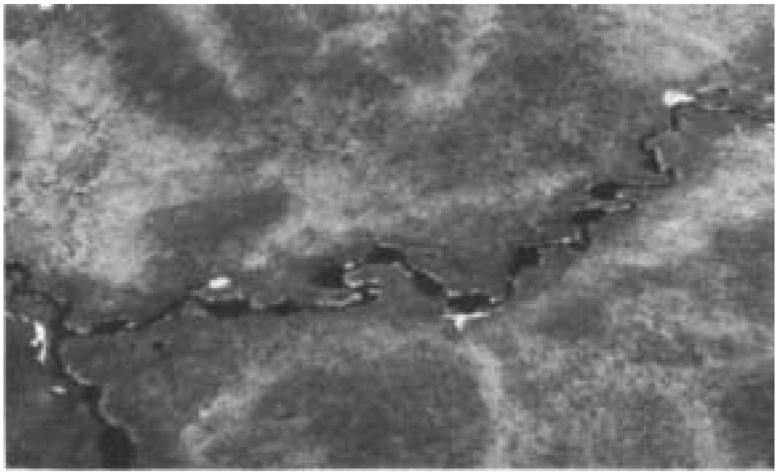

Figure 22a

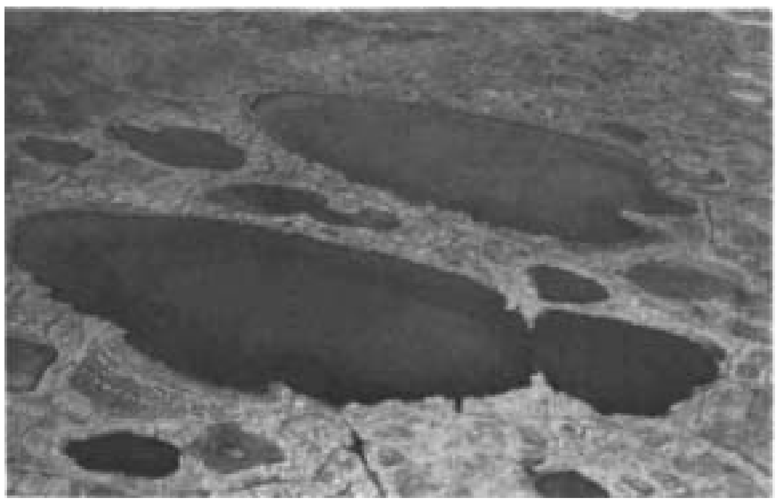

Figure 22b

Figure 22. Examples of thermokarst features in permafrost areas

(a) *Beaded stream*, Mackenzie Delta area, N.W.T. (Photo by H.M. French, University of Ottawa)

(b) *Oriented lakes,* Bathurst Peninsula, N.W.T. The large lake in the foreground is 250 m long. The long axes of the lakes are oriented normal to the strongest prevailing summer wind. (Photo by J.R. Mackay, University of British Columbia)

Figure 22c

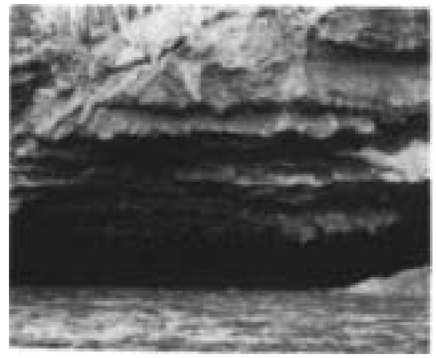

Figure 22d

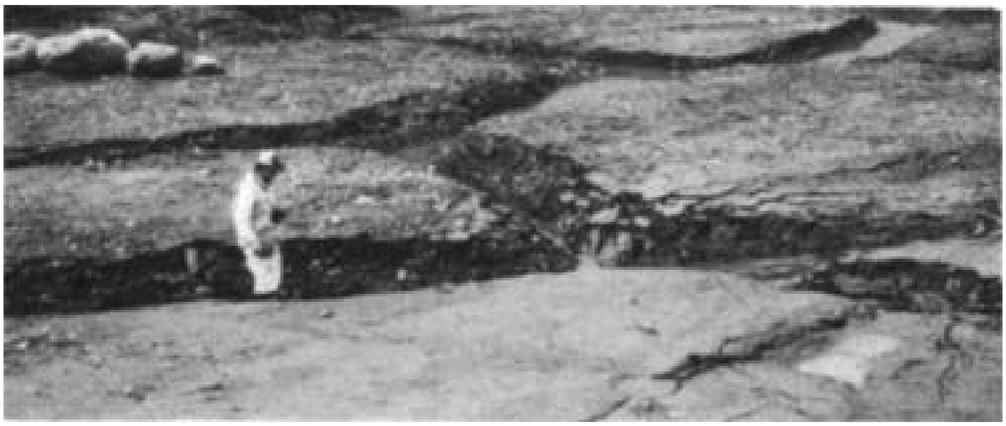

Figure 22e

Figure 22 (continued).

(c) *Thermokarst lake* showing shoreline erosion; shore of a typical expanding lake on overgrown pasture, west of Takhini River Crossing, Alaska Highway, Yukon Territory. (Photo by R.W. Klassen, Geological Survey of Canada)

(d) *Thermo-erosional niche* along the bank of the Rock River, Yukon Territory. (Photo by O.L. Hughes, Geological Survey of Canada)

(e) Fresh *thermokarst terrain* developing as a result of thawing of *ice wedges* in a borrow pit on the Dempster Highway near the crossing of the Blackstone River, Yukon Territory. (Photo by O.L. Hughes, Geological Survey of Canada)

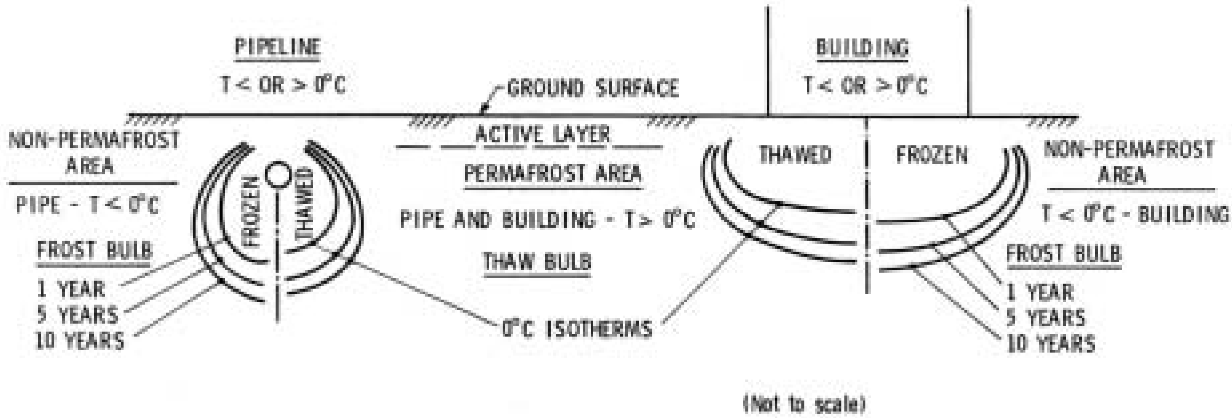

Figure 23. Illustration of the development *of frost* and *thaw bulbs* around buried pipelines and under buildings placed on the ground surface in permafrost and non-permafrost areas. For pipelines, the diagram illustrates a chilled pipeline in a non-permafrost area and a warm pipeline in a permafrost area. For buildings, the diagram illustrates a cold structure (e.g., an ice rink) in a non-permafrost area and a warm structure (e.g., a powerhouse) in a permafrost area. In all cases the pipelines and buildings are operated at temperatures either above or below 0°C, continuously for several years.

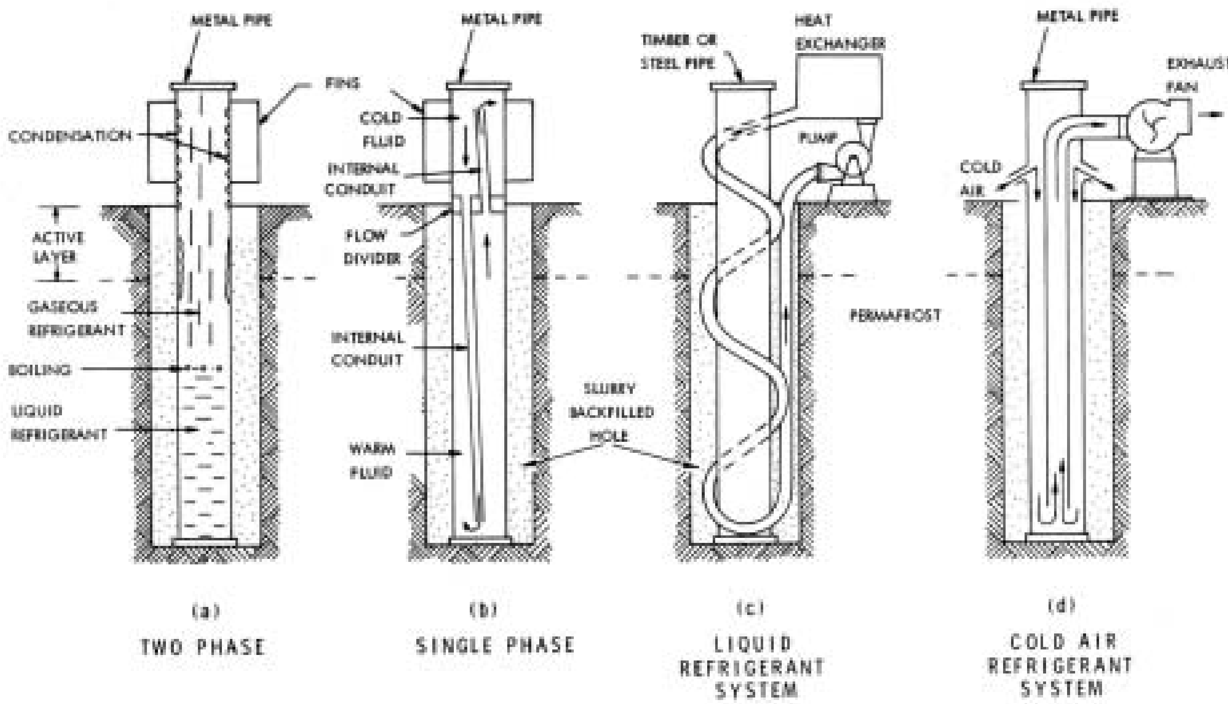

Figure 24. Representation of several *thermal pile* systems (after Johnston, 1981)

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IPA Multi-Language Glossary of Permafrost and Related Ground-Ice Terms

ERRATA for the 1998 printed Version - 2

1. On page iv add:
   P. Urdea, West University of Timisoara, Timisoara, Romania after the entry for F. Ugolini

2. On INTRODUCTION page 4, para 1, line 6, change: wdges to w**e**dges

3. On INTRODUCTION page 4, para 5, first line, change: twelf to **twelve**

4. On FRENCH page 1, in the right-hand column, change:
   crohydrosphère to cr**y**ohydrosphère
   and move to after the entry for cryogenèse **(88)**

5. On ITALIAN page 1, in the left-hand column, change:
   capacitá termica (252) to capacit**à** termica (also on ENGLISH page 20)

6. On ITALIAN page 4, in the left-hand column, change:
   profonditá di penetrazione .... (128) to profondit**à** ... (also on ENGLISH page 10)
   and profonditá di progetto .... (135) to profondit**à** ... (also on ENGLISH page 11)

7. On RUSSIAN page 1, in the right-hand column change:
   .. raprostraneniia ...(25) to ra**s**prostraneniia ... (also on ENGLISH page 3)

8. On RUSSIAN page 3, in the right-hand column, after (161) change:
   .., пастущая .. to .. **р**астущая .. and
   .. пклоне… (29) to .. **с**клоне ... (also on ENGLISH page 3)

9. On RUSSIAN page 4, in the left-hand column, change:
   [kratkovremennyi... (570) to [kratkovremenn**o**... (also on ENGLISH page 49)

10. On RUSSIAN page 14, in the left-hand column, add:
    хасырей (→ алас) [khasyrei (→ alas)]
    after the entry for фронт протаивания [front protaivaniia]**(543)**

11. On SPANISH page 2, in the right-hand column, change:
    cuña de hielo fosil to .... f**ó**sil

12. On SPANISH page 4, in the left-hand column, change:
    hielo fosil to .... f**ó**sil

13. On SPANISH page 5, in the left-hand column, change:
    permafrost fosil to .... f**ó**sil

14. On SPANISH page 6, in the right-hand column, change:
    termocarst fosil to .... f**ó**sil

15. On DEFINITIONS page 3, at the end of the COMMENT of entry 21, add:
An analogous term of Nenets (northwestern Siberia) origin is "khasyrei".

16. On DEFINITIONS page 12, at the end of the COMMENT of entry 107 add:
In Russian literature cryopegs are defined as lenses of "cryosaline water" (supercooled brine) found within saline cryotic soils or rock.