

## CHAPTER 4 DEEP SEASONAL FROST AND PERMAFROST

### 4-1. Distribution

a. Areas of deep seasonal frost penetration may be defined arbitrarily for engineering as seasonal frost areas with design air freezing indexes of 1500 Fahrenheit degree-days or more. An air freezing index of 1500 Fahrenheit degree-days corresponds to a depth of seasonal frost penetration of about 7 feet into very well drained clean gravel under a bituminous surface kept clear of snow and ice. The actual frost penetration at a given point will depend on soil and surface conditions, and other factors as discussed in chapter 5. If the soil is saturated silt, the frost penetration may be about half of that in a very well drained clean gravel for otherwise identical conditions. Design freezing indexes of 1500 Fahrenheit degree-days exist well south of the Subarctic in the northern temperate zone. However, there are also lower values in a few locations within the Subarctic, such as in northern Iceland. As the freezing index increases with increasing latitude, or increasingly cold geographic location or topographic position, the depth of seasonal freezing increases; it may reach as much as about 20 feet in very well drained clean gravel under a bituminous surface kept clear of snow and ice, without development of permafrost. When a point is reached, however, where the depth of winter freezing exceeds the depth of summer thaw, permafrost results if frozen ground persists over at least two consecutive winters and the intervening summer. As one travels northward, permafrost, which in the more southerly part of the permafrost zone is discontinuous, becomes gradually continuous, except under some large water bodies that are deep enough to prevent freezing temperatures from reaching the bottom, and the depth of summer thaw becomes progressively smaller. In areas of continuous permafrost, lateral heat flow may cause permafrost to extend partly or entirely under bodies of water, even though there is a layer of unfrozen soil immediately below the water. Along the seacoast, permafrost may extend for a substantial distance offshore, either as relic permafrost or as permafrost formed as a result of seawater temperatures below 32°F.

b. Figures 4-1 and 4-2 show the approximate extent of permafrost areas in North America and Eurasia respectively. Islands of permafrost are also found in mountains south of the Subarctic.

### 4-2. Characteristics of permafrost

The following summary of the characteristics of permafrost should be considered merely introductory.

a. *Structure.* Depending on local conditions, permafrost may exist as (see figure 4-3):

-A continuous layer with its upper surface at the bottom of the annual frost zone (active layer). This is common in arctic regions.

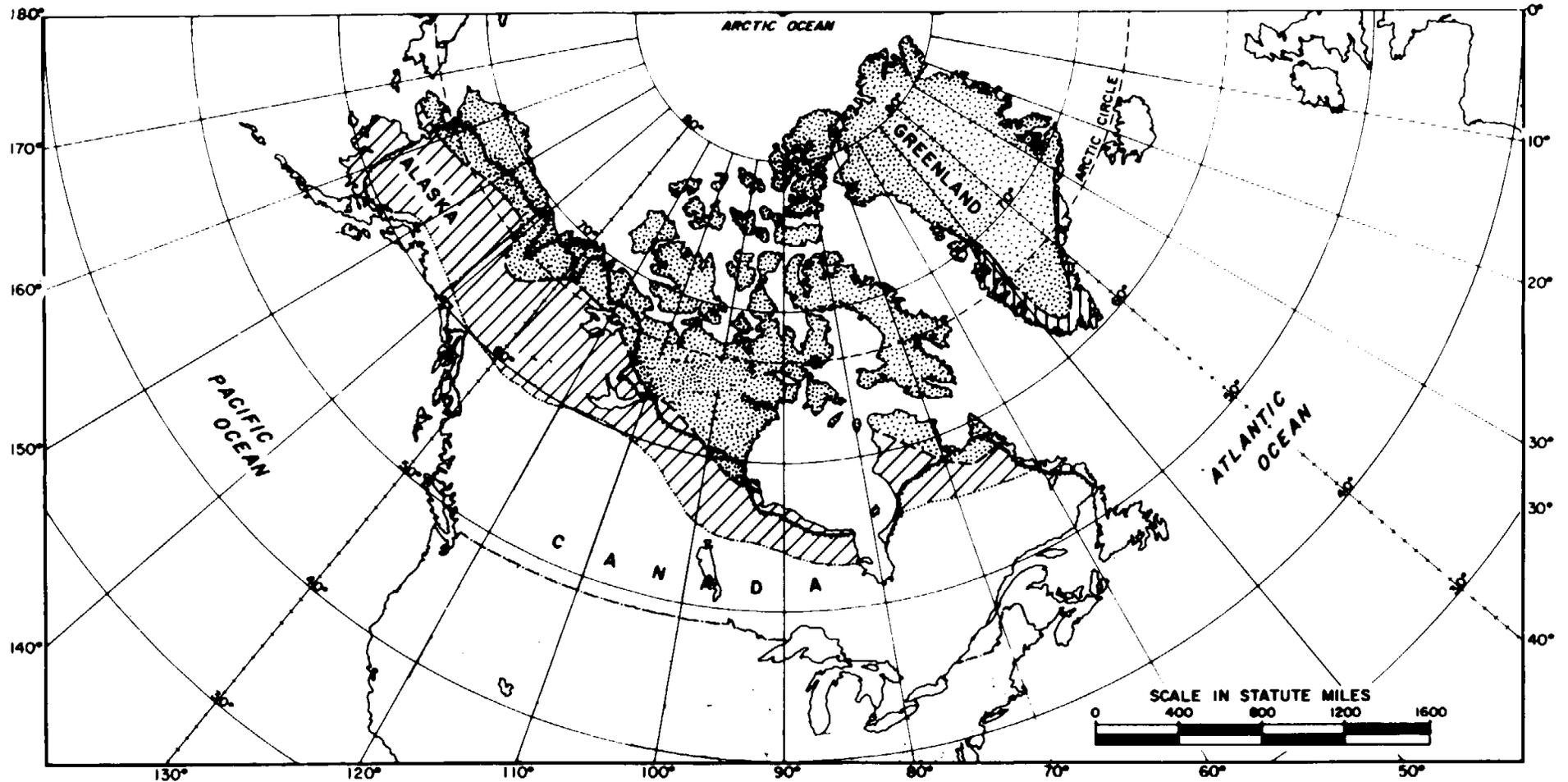
-A continuous layer with its upper surface separated from the annual frost zone (active layer) by a residual thaw layer. If the permafrost table is lowering progressively, this is a degrading condition.

-Frozen layers separated by layers of unfrozen material.

-Inclusions of remnants of permafrost in unfrozen ground.

b. *Depth to surface.* The depth to the permafrost table is dependent primarily on the magnitude of the air thawing index, the amount of solar radiation that reaches the surface, the surface cover conditions that have existed for the previous several years, and the water content and dry unit weight of the soil. See table 4-1 for typical depths to the permafrost layer. For comparison, in a subarctic area without permafrost, a well-graded sandy gravel that is relatively dry ( $w = 5\%$ ) and seasonally frozen would have an annual thaw penetration of about 16 feet. Methods for estimating depths of freeze and thaw penetration are discussed in TM 5-852-4/AFM 88-19, Chap. 4 and TM 5-852-6/AFR 88-19, Volume 6.

c. *Factors affecting existence and distribution.* Under natural, undisturbed ground cover conditions, the *mean annual air temperature* must usually be 21° to 30°F for permafrost to exist, although exceptions are possible on either side of this range. If temperatures at the ground surface could be used, more precise correlation could be obtained. However, surface temperatures have not been generally available in the past from meteorological records. The existence of ground temperatures perennially below freezing is a function of many factors other than air temperatures, as discussed in chapter 5, including solar radiation, surface cover, snow cover, wind, soil type, soil moisture content, groundwater flow and presence of stationary or moving surface water. Forest fires or meandering of streams may cause alterations of permafrost conditions extending over many years.



**LEGEND**



AREA OF CONTINUOUS PERMAFROST



AREA OF DISCONTINUOUS AND SPORADIC PERMAFROST



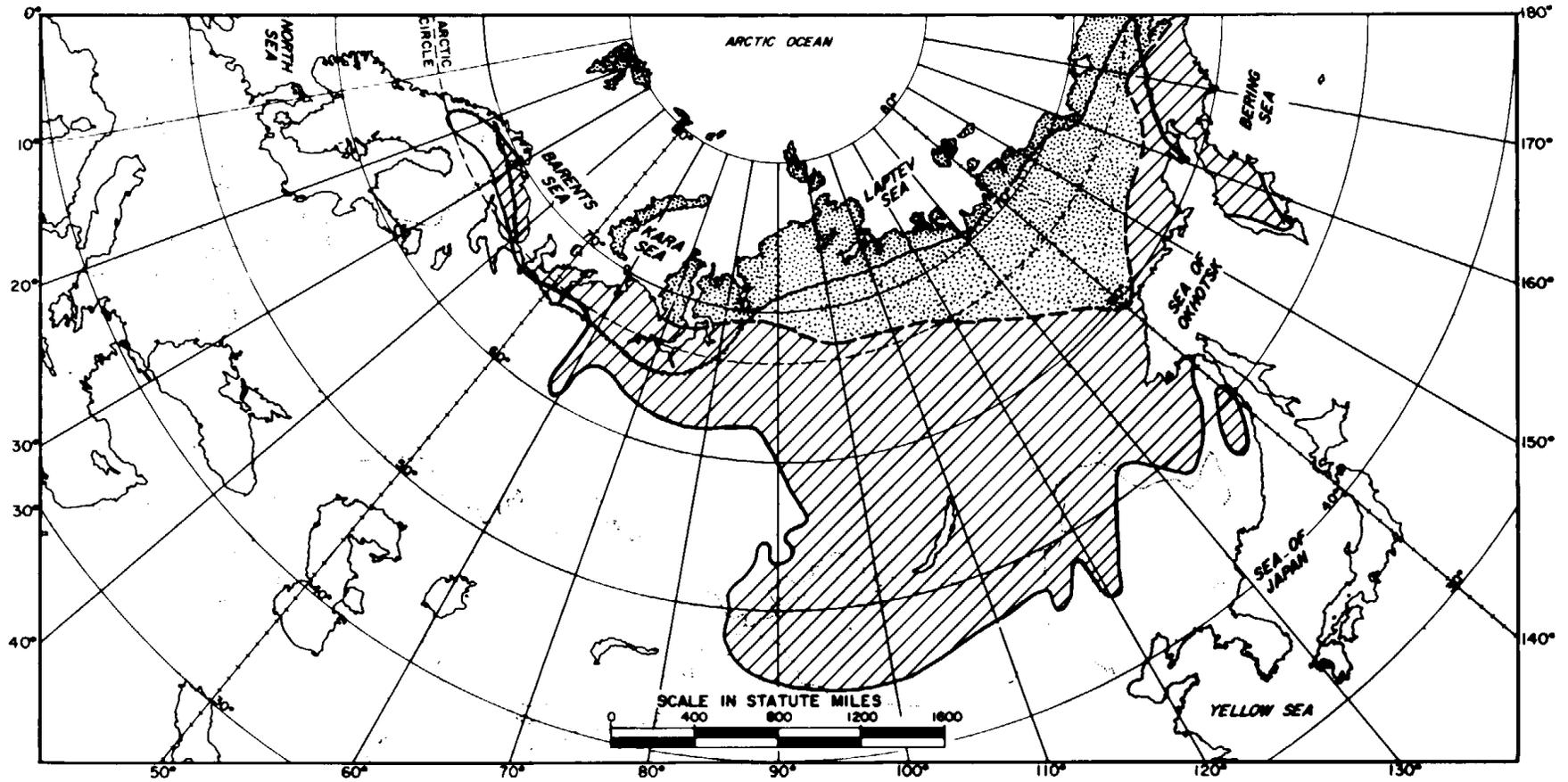
APPROXIMATE LIMIT OF TREES

**NOTE**

*Patches and islands of permafrost may be found in areas south of cross hatched zone, particularly in elevated mountain locations.*

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Figure 4-1. Approximate distribution of permafrost in North America.



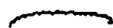
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AREA OF CONTINUOUS PERMAFROST



AREA OF DISCONTINUOUS AND SPORADIC PERMAFROST



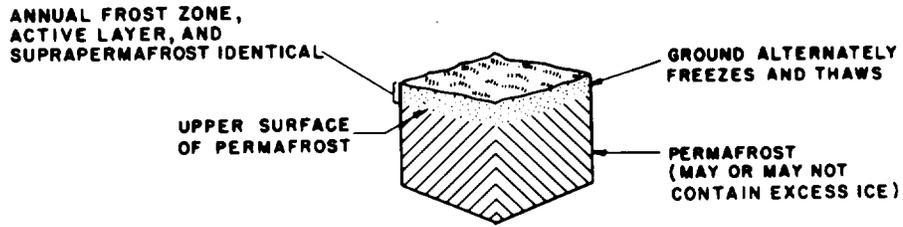
APPROXIMATE LIMIT OF TREES

**NOTE**

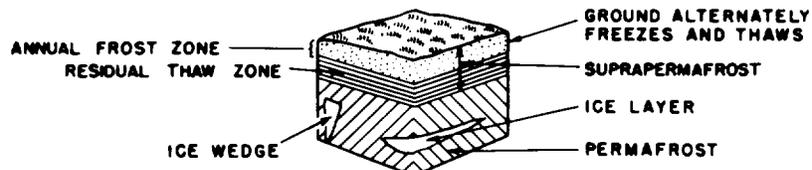
*Patches and islands of permafrost may be found in areas south of cross hatched zone, particularly in elevated mountain locations.*

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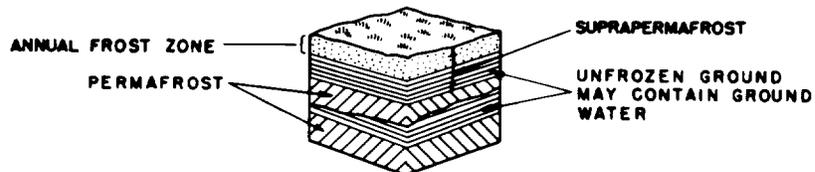
*Figure 4-2. Approximate distribution of permafrost in Eurasia.*



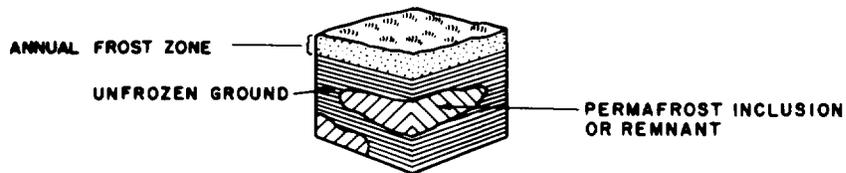
(A) ANNUAL FROST ZONE EXTENDS TO PERMAFROST



(B) RESIDUAL THAW ZONE OVER PERMAFROST



(C) LAYERED PERMAFROST



(D) INCLUSIONS OR REMNANTS PERMAFROST IN UNFROZEN GROUND

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Figure 4-3. Typical sections through ground containing permafrost.

Table 4-1. Depths to the permafrost layer at the end of the thawing period of two typical locations.

Surface and subsurface conditions	Depth to surface of permafrost layer (ft)	
	Arctic: mean annual temp. 10 to 12°F, mean thawing index 500-600 degree-days (°F)	Subarctic: mean annual temp. 26cF, mean thawing index 3200 degree-days (°F)
Treeless area with 6-inch-thick moss cover over silt soil (w = 30-40%) <sup>a</sup>	1.5 to 2.0	5.0 to 6.0
Asphalt pavement over 8 feet of sandy gravel base (w = 4%) and silt subgrade (w = 30-40%)	7.0 to 8.0	12.0 <sup>b</sup>

<sup>a</sup>w = water content in percent of dry w-eight of soil.

<sup>b</sup>Six years after construction, a degrading condition.

d. *Thickness.* The thickness of the permafrost layer generally increases with increasing latitude, being greater in arctic than in subarctic regions. The greatest depths of permafrost occur in the nonglaciaded areas of the continuous zone. In Siberia, a record depth of 4900 feet to the permafrost base has been reported. It has been estimated that the maximum thickness of permafrost in arctic Canada may exceed 3000 feet, and in arctic Alaska it may be over 2000 feet. The greatest depth so far measured in Canada is about 1700 feet at Winter Harbour, Melville Island. A depth of 1600 feet has been estimated at Thule, Greenland. Other observed depths are about 1300 feet south of Barrow, Alaska, and at Resolute, Northwest Territories; about 920 feet at Umiat, Alaska; and about 170 feet at Northway, Alaska.

e. *Soil factors.* As a rule, the characteristics of permafrost will depend upon the texture, water content and temperature of the soil. Relatively clean sands and gravels located in well-drained positions may not present serious engineering construction problems if they do not contain appreciable amounts of excess ice. Conversely, permafrost consisting of fine-textured soils such as silt often contains large formations of ice in lenses, layers, wedges, veins or other shapes. TM -852-4/AFM 88-19, Chap. 4 presents information on the strength and other properties of frozen soils. MIL-STD-619B presents a standard system for classification of frozen soils.