Effect of Permafrost on Cultivated Fields Fairbanks Area Alaska

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EFFECT OF PERMAFROST ON CULTIVATED FIELDS, FAIRBANKS AREA, ALASKA

By TROY L. PÉWÉ

ABSTRACT

Permafrost affects agricultural development in many parts of Alaska. Its destructive effects on cultivated fields result chiefly from the thawing of large masses of clear ice in the frozen ground. If care is not exercised in selecting areas to be cleared for cultivation, thawing of permafrost may necessitate abandonment of fields or their reduction to pasture. The effects of permafrost on farming are well illustrated in the Fairbanks area, which lies in the Tanana Valley, the most extensive potential agricultural area in Alaska. Permafrost may be encountered nearly everywhere in the Fairbanks area except beneath hilltops and moderate to steep south-facing slopes. Sediments of the Tanana and Chena River flood plains (50 percent of the area) are perennially frozen to a depth of at least 265 feet, but not everywhere is permafrost encountered in a single layer. Permafrost on the flood plain affects soil drainage and temperature during the first few years after the clearing of the land, but this effect disappears after the permafrost table has been lowered. Because ground-ice masses are lacking, no undesirable mounds or pits are formed by thawing of frozen ground.

Alluvial fans, colluvial slopes, and lowlands, all consisting of silt, extend from the hills to the flood plain and are underlain by continuous permafrost, as much as 175 feet thick near the flood plain, but which thins toward the hills, pinching out at the base of steep south-facing slopes. Permafrost in the fans, slopes, and lowland is characterized by masses of clear ice as much as 50 feet in the largest dimension. Removal of vegetation cover causes thawing of this ice. The thawing of the ice masses creates thermokarst topography—an uneven topography characterized by mounds, sags, sinkholes, tunnels, caverns, and short ravines.

Thermokarst mounds are polygonal or circular hummocks 10 to 50 feet in diameter and 1 to 8 feet in height, separated by trenches 1 to 5 feet wide. The trenches are formed by the melting of a polygonal network of ground-ice masses and subsequent subsidence of the ground leaving mounds in the intervening areas. Mounds generally begin to form in a cultivated field within 2 or 3 years after clearing.

Thermokarst pits are steep-walled pits, 5 to 20 feet deep and 3 to 20 feet across, initiated by the melting of ground-ice. Twenty-four thermokarst pits were found in cultivated fields of the Fairbanks area.

Alluvial fans, colluvial slopes, and a small silt lowland comprise 27 percent of the Fairbanks area. Thermokarst mounds and pits are likely to form in culti-

vated fields on these slopes and lowland; these features may necessitate the abandonment of the field or reduction to pasture. In 1948, 32 of the 37 fields on the slopes and the lowland showed evidence of thermokarst action. Six of the 27 fields cleared before 1945 had been abandoned for more than 20 years, and in five others cultivation was attempted only on a part of the original cleared land. Mounds and pits had already begun to form in half of the 10 fields cleared between 1945 and 1948.

The northern part of the Fairbanks area (23 percent) consists of rounded, even-crested loess-covered hills 1,250 to 1,800 feet above sea level. Cultivated fields on the south-facing gentle slopes of the hills do not have mounds or pits because permafrost is absent.

The investment of labor and capital required for clearing land in Alaska makes careful selection of ground imperative. Where mounds develop, fields can be reclaimed by grading, and a field can continue to be used if the mounds are repeatedly leveled as they re-form. New pits can be filled as they appear. However, it is a costly fight and much time, money, and soil are wasted in such a perennial struggle. In permafrost areas land should be surveyed for its permafrost characteristics before development.

INTRODUCTION

Agriculture in Alaska began during the time of the early gold discoveries more than 50 years ago, and expanded with increased population, especially after World War II. By 1950 about 13,500 acres were cleared for crops in Alaska according to D. L. Irwin, Director, Alaska Agricultural Experiment Station (letter Dec. 11, 1952).

The presence of permafrost affects agricultural development in many parts of Alaska. Areas suitable for agriculture in the central Pacific coast district are not underlain by permafrost (fig. 69), but farther north permafrost is increasingly widespread and extends to increasing depths. Wherever present, permafrost affects land use by influencing water supply, soil drainage, the stability of roads and buildings, and the microtopography of land cleared for crops. The destructive effects of permafrost in cultivated fields result chiefly from the thawing of large masses of clear ice in the frozen ground. Pits and mounds develop after the vegetation cover is removed and the ice masses melt. Gullies form in silty soils on slopes where surface waters are channeled into pits initially formed by the melting of ground-ice masses.

If care is not exercised in selecting areas to be cleared for cultivation, thawing of permafrost may necessitate that fields be abandoned or reduced to pasture a few years after clearing. Thermokarst mounds and pits can be combatted and fields containing them can be still used, if repeatedly graded, but time, money, and soil are wasted in the struggle.

Fairbanks is one of the Alaskan agricultural areas seriously affected by the presence of permafrost, and the effects of permafrost on farming are well illustrated there. Several fields in the Fairbanks area have been abandoned or reduced to pasture, because they were under-

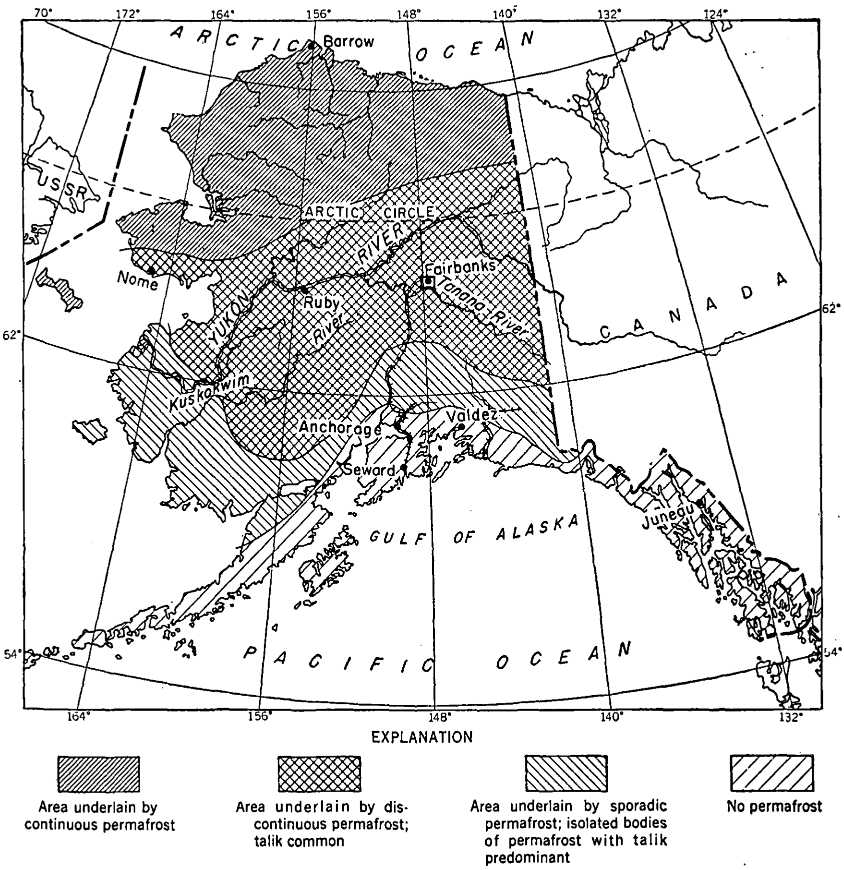

FIGURE 69.—Index map showing location of the Fairbanks area and generalized distribution of permafrost in Alaska.

lain by frozen ground containing large ice masses. These difficulties could have been anticipated and the undesirable areas avoided by settlers, had a proper survey of the permafrost characteristics of various districts in the Fairbanks area been available.

This report describes the destructive effect of permafrost on cultivated fields and delineates the parts of the Fairbanks area which are least suitable for agriculture because of the character of the underlying permafrost (pl. 9). Studies by the author indicate that agriculture will be affected by similar permafrost conditions throughout areas on the north side of the Tanana Valley within 100 miles of Fairbanks (fig. 69).

PREVIOUS INVESTIGATIONS

Intensive studies of frozen ground have been conducted in Russia since 1900, and the results have been applied profitably to agriculture, especially in Siberia (Nikiforoff, 1928, p. 73–74; Cressey, 1939, p. 488; and Tsiplenkin, 1944).

In North America, however, little attention has been given to the problems of agriculture in areas underlain by permafrost. Early homesteaders and the personnel of agricultural experiment stations in northern regions learned by trial and error the effects of permafrost on cultivated fields, but no systematic studies were made before 1945.

Rockie (1942, p. 128) pointed out that melting of ground-ice caused "pitting" in Alaskan farmlands, and that, ". . . pitting of his land would bankrupt any owner whose livelihood depended to an important degree on returns from that land." Kellogg and Nygard (1949, p. 74–78, 1951, p. 26–29) discuss the effects of permafrost and point out the need of ". . . principles to serve as reliable guides for avoiding areas subject to caving and settling after clearing for crops."

The author began systematic studies of permafrost in cultivated fields in the Fairbanks area in 1947 (Péwé, 1948b; 1950b). Later, reconnaissance studies of permafrost in a potential agricultural area were conducted at Dunbar, 35 miles west of Fairbanks by Péwé, (1949) and by E. W. Marshall in 1949 (report on file, U. S. Geol. Survey, Washington, D. C.) and along the Chena River, 15 miles east of Fairbanks, by Péwé and J. R. Williams in 1950 (reports in the files of the U. S. Geological Survey).

ACKNOWLEDGMENTS

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Roy Earling, retired vice-president of the United States Smelting, Refining, and Mining Co., generously made available records of subsurface materials and conditions. Many farmers supplied the dates they cleared their fields and the dates of the beginning of thermokarst phenomena in their fields. E. S. King, Jr., A. M. Gooding, and D. R. Loftus assisted in the field. Mary Jean Péwé accompanied the writer on the field and prepared many of the illustrations, including compilation of figure 70. J. D. Crawford, a vice-president of the United States Smelting, Refining and Mining Co., and Ernest Wolff, research associate at the University of Alaska, kindly reviewed the manuscript.

The writer wishes to extend special acknowledgment to G. S. Gasser, former Alaska Territorial Commissioner of Agriculture, who provided agricultural data on the Fairbanks area, reviewed the manu-

script, and contributed many helpful suggestions derived from his wide knowledge of agriculture in Alaska.

SETTLEMENT AND AGRICULTURE IN THE FAIRBANKS AREA

The Fairbanks area is in central Alaska, about 100 miles south of the Arctic Circle (fig. 69). Fairbanks, including the metropolitan area, having a population of 19,409 (1950), is the largest city in the interior of Alaska and the second largest in the Territory.

Felix Pedro discovered gold in 1902 about 12 miles north of a trading station named Fairbanks and, within a few years, the area became one of the greatest gold-producing regions in Alaska. Fairbanks today is the principal trade center of interior Alaska; the city is strategically located at the northern terminus of the Alaska and the Richardson Highways, and the Alaska Railroad, and is one of the main hubs for air travel. Important military centers are located in the vicinity, and the University of Alaska is 3 miles to the west.

Fairbanks is in the Tanana Valley, the largest area of potential agricultural land in Alaska (Gasser, 1948b, p. 80). Homesteads were first taken up and land cleared in the area in 1904. As agricultural activity increased, a U. S. Department of Agriculture experiment station was established in 1906, 4 miles west of the city. The station is now the oldest one still operating in the Territory.

Today the Fairbanks area (Tanana Valley) is second only to the Matanuska Valley in value of crops produced (table 1). Potatoes and garden vegetables are the principal cash crops; oats, barley, and spring wheat are the main cereal crops. There are two commercial dairies, and a few farmers raise hogs. Some poultry is raised, and poultry grains can be grown locally.

TABLE 1.—*Total value of agricultural products of Alaska,* 1951, *by localities*

[From "Alaska Market News", Alaska Dept. of Agriculture, v. 1, no. 8, p. 1 (1951)]

Matanuska Valley	$1,274,803	Kenai Peninsula	$66,600
Tanana Valley	495,630	Southeastern Alaska	349,200

Farming activities in the Fairbanks area are handicapped by the development of mounds and pits in fields underlain by large ice masses, by only moderately fertile soil which must be fertilized regularly (Gasser, 1946, p. 4, 9), by periods of low rainfall during the spring season in many years, and by the short growing season. Nevertheless, new farm land continues to be cleared every year. In 1948 Gasser estimated that 2,400 acres were under cultivation (1948a, p. 14). About 1,000 acres, comprising about 40 percent of the total cleared acreage, were cleared between May 1945 and September 1948.

Homesteading is still active (Miller, 1951, p. 247) but nearly all land within 10 miles of Fairbanks has been claimed. Since the end of World War II, there has been much land cleared on the Tanana-Chena River flood plain and in the hills at the headwaters of Steele and Columbia Creeks (pl. 9). Because most of the desirable land near Fairbanks has been preempted, however, many newcomers are clearing land in areas where permafrost conditions can be expected to cause serious problems. Thus, with the continued development of agriculture in the Fairbanks area, there is increased need for the evaluation of agricultural land and the recognition of areas that should be avoided.

PHYSICAL SETTING

CLIMATE

A U. S. Weather Bureau station was established at the U. S. Department of Agriculture experiment station in 1904, and its records represent climatic conditions on the south-facing permafrost-free slopes. Since 1929, when the Weather Bureau station was moved to Fairbanks, the records represent conditions on the Tanana-Chena River flood plain.

The Fairbanks area has a continental climate, characterized by an extreme range between summer and winter temperatures (fig. 70). The absolute minimum recorded temperature is −66 F.; the absolute maximum is 99 F. The mean annual number of days with freezing temperatures is 233, and freezing temperatures have been reported during every month except July (U. S. Weather Bureau, 1943).

Interior Alaska has the warmest summers in the Territory, a fact of major importance to agriculture. The mean summer temperature (June, July, and August) is 57.8 F. at Fairbanks. The average length of the growing season on the flood plain is 97 days; the longest recorded is 137 days and the shortest 22 days. The mean date of the last killing frost in the spring is May 22; August 31 is the mean date of the first killing frost in the autumn. The growing season is about 2 weeks longer on south-facing hill slopes, ranging in duration from 105 days for tender plants to 123 days for field crops (Sundborg, 1944, p. 12).

Interior Alaska has more hours of possible summer sunshine than any other agricultural area in the Territory. The long days during June and July shorten the period required for the maturing of the crops and increase the size of individual plants by speeding the process of photosynthesis (Gasser, 1948a, p. 2). More than half of the summer days are cloudy, however, so that the hours of actual sunshine are much fewer than hours of possible sunshine.

The mean annual precipitation is 11.7 inches. Thunderstorms are frequent during the summer, but most of the precipitation during the

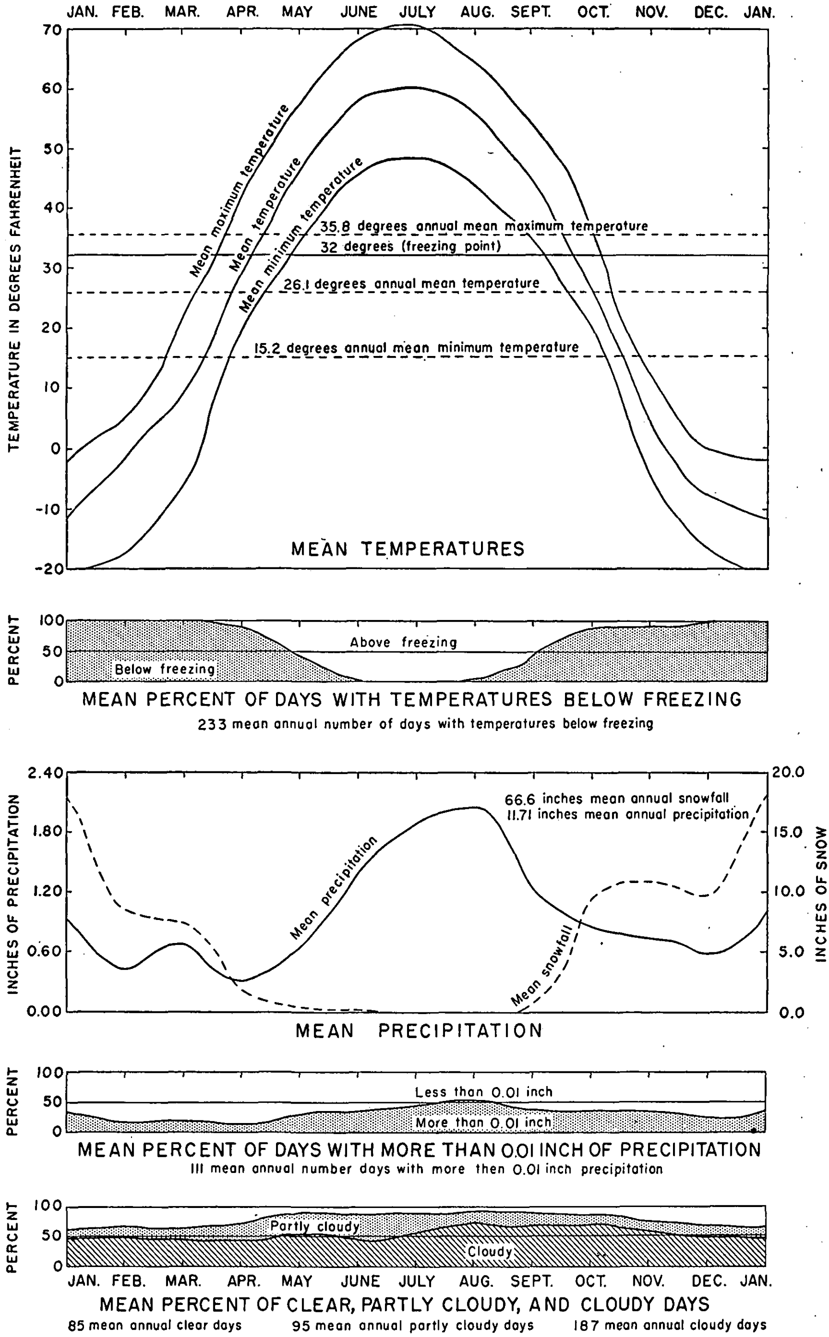

FIGURE 70.—Climatic data for Fairbanks, Alaska.

growing season falls in light showers. Sixty-three percent of the annual precipitation is concentrated in the period May through September.

Evaporation rates probably are relatively high in the Fairbanks area during summer, but no quantitative data are available. Tests at Norman Wells in northwestern Canada reveal that summer evapotranspiration rates are high (Sanderson, 1950). Norman Wells, at the same latitude as Fairbanks, has a similar summer climate.

PHYSIOGRAPHY AND GEOLOGY

Fairbanks lies on the north side of the broad Tanana River valley at the base of hills comprising part of the Yukon-Tanana Upland. The southern half of the area discussed in this report lies within the Tanana River flood plain at an altitude of 400 feet (pl. 9), and the rest lies within the Upland.

The flood plain, an area of nearly flat topography extending along the Tanana and Chena Rivers, is underlain by alternating lenses and beds of silt, sand, and gravel which have a total thickness of several hundred feet.

The Upland consists of rounded, even-crested groups of hills with summits 1,250 to 1,800 feet above sea level. Local relief ranges from 50 to 700 feet. The bedrock consists chiefly of schist but includes local masses of basalt, and quartz diorite. Loess, wind-blown silt, (Péwé 1951), ranging in thickness from a few feet on summits to more than 100 feet on middle slopes, blankets the ridges (Péwé, 1950a). The valleys are filled with 10 to 100 feet of gravel overlain by 10 to 300 feet of colluvial silt.

The Fairbanks area has not been glaciated, but glaciers from the Alaska Range on the south probably approached to within 50 miles (Capps, 1932, pl. 1; Péwé, 1952a). During glacial advances a total of several hundred feet of sand and gravel was deposited in the Tanana Valley by the heavily loaded Tanana River. Aggradation of the trunk valley raised base level and caused clear-water tributaries from the unglaciated upland to the north to aggrade their lower valleys. More than 300 feet of sediment was deposited in creek valleys of the Upland in the Fairbanks area.

A transitional area of gently sloping alluvial fans of silt separates the hills from the Chena-Tanana River flood plain. In stream valleys farther from the Tanana flood plain the transported silt forms colluvial deposits on the lower parts of slopes; the colluvial deposits from opposite slopes coalesce in the narrow valley bottoms.

Despite the small rainfall, the Fairbanks area has abundant lakes, swamps, and marshes. Except on hill tops, steep slopes, and cultivated land the ground is wet almost everywhere during early and middle summer and sometimes throughout the summer. Drainage is poor because underlying perennially frozen ground prevents downward percolation of water. A luxuriant spongy mat of low vegetation, mosses with sedges or small shrubs, restricts surface-water movement and acts as a reservoir. Summer thawing of the frozen ground releases additional water.

PERMAFROST

DEFINITIONS

Several terms dealing with permafrost may be unfamiliar to some readers, and others have not been clearly defined in previous papers. The writer's usage of these terms is given below.

"Permafrost" as originally defined by Muller (1945, p. 3) is

> a thickness of soil or other surficial deposit or even of bedrock, at a variable depth beneath the surface of the earth in which a temperature below freezing has existed continuously for a long time (from two to tens of thousands of years).

A widely used synonym is "perennially frozen ground" (Taber, 1943).

"Permafrost table" is the upper limit of permafrost.

"Active layer" is the layer of ground above permafrost which thaws in summer and freezes again in winter. The active layer may extend down to the permafrost table.

"Talik" is unfrozen ground between the active layer and the permafrost; it also applies to unfrozen ground within or beneath permafrost (Muller, 1945, p. 223).

"Ground-ice" consists of grains or bodies of more or less clear ice in permafrost. The term generally is not applied to ice of glacial origin.

"Polygonal ground" is ground with a polygonal surface pattern caused by the subsidence of the surface over ground-ice that is arranged in a polygonal network. Also called "tundra polygons" or "Taimyr" polygons. Not to be confused with polygonal surface markings of small scale produced by frost heaving (Black, 1952).

"Cave-in lake" is a lake formed in a collapse depression formed by the thawing of frozen ground that contains ground-ice (Muller, 1945, p. 214). The lake is enlarged by thawing and subsequent caving of the banks (fig. 71) (Wallace, 1948): Synonymous with "thaw lake" (Hopkins, 1949, p. 124).

"Beaded drainage" is the characteristic pattern of small streams in areas underlain by polygonal ground-ice. The stream paths are angular due to partial control by depressions associated with the polygonal distribution of ground-ice. Small cave-in lakes occur at intervals along the stream generally at the junctions of ice wedges. The lakes, when connected by the stream, resemble beads on a string.

"Thermokarst topography" is an irregular land surface containing depressions and caverns formed by melting of ground-ice. It resembles the uneven "karst" topography formed by the solution of lime-

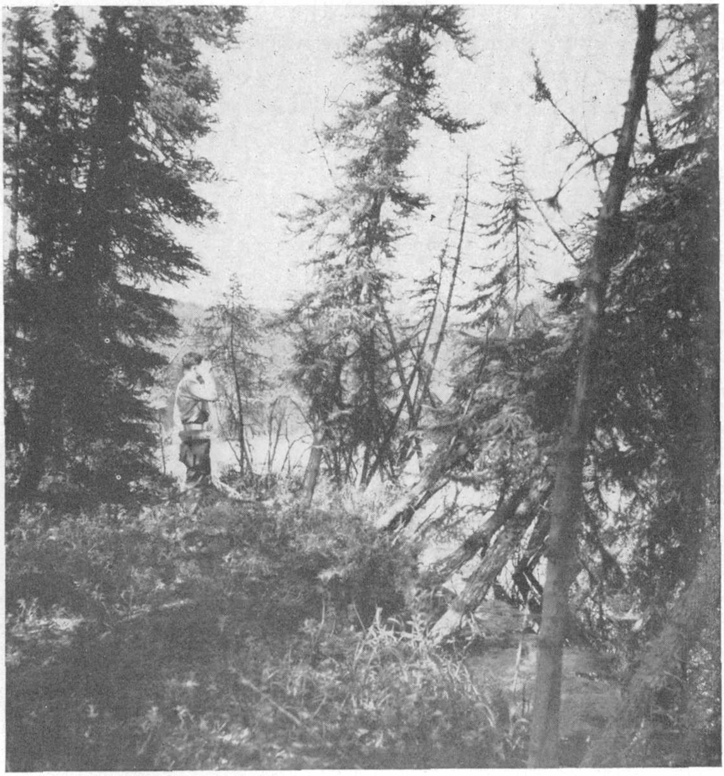

FIGURE 71.—Spruce slumping into a cave-in lake in the silt lowland as bank retreats by thawing of permafrost. (Center Sec. 29, T. 1 N., R. 1 W.) Photograph by T. L. Péwé, July 25, 1948.

stone. "Cryokarst" has been suggested as an alternate term by Ahlmann (1952).

"Muck" is silt rich in organic material. It is gray to black when wet or frozen and fetid upon thawing. Muck in permafrost ground generally contains more ice than either perennially frozen loess or flood plain silt.

GENERAL DISTRIBUTION OF PERMAFROST

Permafrost is a widespread phenomenon in the northern part of North America and Asia; it is estimated to underlie one-fifth of the land surface of the world (Muller, 1945, p. 1).

Permafrost is present throughout most of Alaska but is more widespread and extends to greater depths in the north than in the south. Alaska can be divided arbitrarily into three generalized permafrost zones, the continuous, discontinuous, and sporadic permafrost zones (fig. 69). In the continuous zone of the north, permafrost is nearly everywhere present and extends to depths of 1,000 feet or more. Southward, in the discontinuous zone of central Alaska, the thickness of permafrost progressively decreases, and nonfrozen areas are more and more abundant. Permafrost conditions at Fairbanks are probably typical of this zone. In the sporadic zone to the south perennially frozen ground is confined to local areas.

PERMAFROST IN THE FAIRBANKS AREA

Permafrost may be encountered nearly everywhere in the Fairbanks area except beneath hilltops and moderate to steep south-facing slopes (fig. 72). The Tanana River flood plain is underlain by zones of perennially frozen ground interspersed and interstratified with zones in which the sediments are unfrozen. Large ice masses are lacking. The gently sloping alluvial fans and colluvial slopes which extend from the upland to the flood plain are underlain by continuous permafrost containing abundant large ground-ice masses.

PERMAFROST OF THE FLOOD PLAIN

Sediments of the flood plain are perennially frozen to depths of at least 265 feet [1] but not everywhere is permafrost encountered in a single layer. The thickness of the frozen layer varies widely and in many areas permafrost is lacking (fig. 72). Thawed areas occur beneath existing or recently abandoned river channels, sloughs, or lakes. Elsewhere layers of frozen sand and silt are intercalated with unfrozen layers of gravel. The gravel layers are commonly lenslike so that no single unfrozen layer of broad lateral extent exists. The unfrozen areas are connected with the unfrozen layer to comprise irregular unfrozen passages throughout the permafrost of the flood plain.

The depth to permafrost in undisturbed areas ranges from 2 or 3 feet in the older parts of the flood plain to more than 4 feet on the inside of meander curves near the rivers. As the river meander advances, permafrost forms in the new deposits on the slip-off side (Péwé, 1947). Fires, clearings, and construction since 1903 have increased the depth to permafrost to 25 to 40 feet in many places.

Ice in the perennially frozen sediments of the flood plain consists of granules and cement between mineral grains. Large ice masses, common beneath the colluvial slopes, are lacking in the flood plain. This condition may be due in part to the coarseness of the flood plain sediments, which are less favorable for growth of large ice masses than is the well-sorted silt of the slopes and creek valley bottoms.

PERMAFROST OF THE SILT FANS, COLLUVIAL SLOPES, AND SILT LOWLAND

Permafrost in the alluvial fans, colluvial slopes, and silt lowland probably extends continuously from the flood plain to the hills. The

[1] Well drilled in 1953 at Club "11", at mile 11 on the Richardson Highway, 3 miles outside of mapped area (pl. 9).

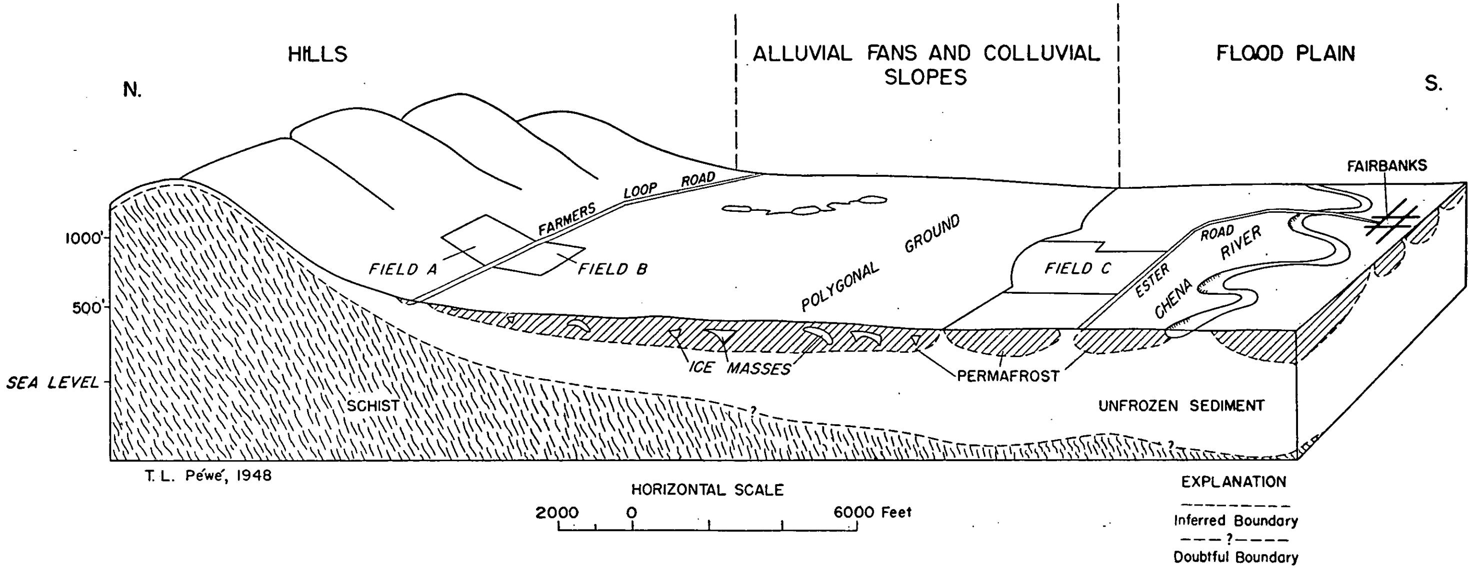

FIGURE 72.—Diagrammatic sketch showing character and distribution of permafrost in the Fairbanks area, Alaska. Field *A* is not underlain by permafrost. Field *B* is underlain by permafrost containing large ice masses; mounds and pits may form in the field when the ice melts. Field *C* is underlain by permafrost which does not contain large ice masses; mounds and pits will not form at the surface.

apices of the broad, gently sloping, coalescent alluvial fans extend well into the upland valleys, in some places almost reaching the crests of the hills. Low-angle colluvial slopes form silt aprons around the hills, between the alluvial fans. In addition to the silt and slopes there is a small silt lowland, underlain with continuous permafrost, which extends from the toe of the fans to the flood plain and lies just north of Ester Road (pl. 9).

Perennially frozen ground in the silt fans and slopes reaches a thickness of at least 175 feet near the flood plain but decreases toward the hills, pinching out at the base of steep south-facing slopes but extending nearly to the summit of north-facing slopes. The permafrost may consist of a few isolated, small bodies where it becomes very thin near the contact with permafrost-free slopes.

Permafrost lies at a depth ranging from 3 to 4 feet on the lower slopes and in creek valley bottoms and at a depth ranging from 5 to 20 feet near the contact with the permafrost-free slopes. Depth to permafrost is 1 to 3 feet in the silt lowland north of Ester Road.

Permafrost in the fans, slopes, and lowland is characterized by large masses of clear ice occurring as horizontal sheets, vertical sheets, wedges, and saucer-shaped and irregular masses (fig. 73). The ice masses range from less than 1 foot to more than 15 feet in thickness and from 1 to 50 feet in length. The ice in some masses is clear but other masses contain many silt particles that give the ice a gray color. Much of the ice is arranged in a polygonal or honeycomblike network that encloses silt polygons 10 to 40 feet in diameter. The ice masses lie at depths of 5 to 25 feet in the fans and colluvial slopes and 1½ to 5 feet in the silt lowland. Large masses of ground-ice are not unique to the Fairbanks area and have been reported from other localities in Alaska (Kotzebue, 1821, v. 1; Leffingwell, 1919; Taber, 1943; Péwé, 1949; Black, 1951).

BOUNDARIES BETWEEN AREAS WITH AND WITHOUT PERMAFROST

The boundary between permafrost and permafrost-free areas is determined by plotting ground temperature measurements, well log data, the distribution of thermokarst features in cleared fields, and changes in plant cover. The most accurate criteria for determining this boundary are temperature measurements and well data, which can reliably indicate the presence of permafrost even though it may underlie a thawed layer 20 or 25 feet thick. Less reliable indicators for determining the boundary are thermokarst features and vegetation.

Ground temperatures have been measured in only three wells, in sections 13, 30, and 36 (R. 1 W., T. 1 N.). The well in section 13 is in unfrozen ground. Temperatures below 32 F. have been recorded for periods of two or more years in the wells in sections 30 and 36

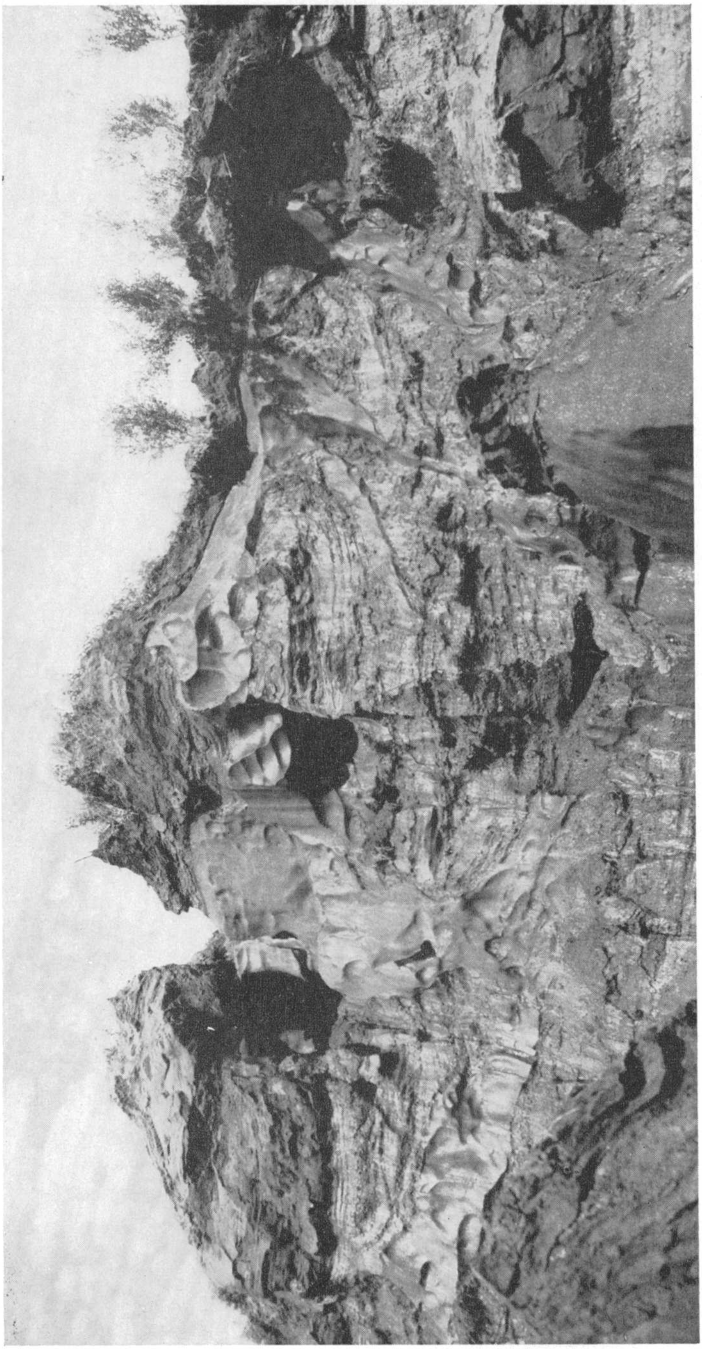

FIGURE 73.—Panoramic view of ground-ice in muck exposed in the east wall of a placer gold mining excavation at Fairbanks creek, 15 miles northeast of Fairbanks. Photograph by Troy L. Péwé, July 16, 1948.

thereby establishing the presence of permafrost. Permafrost generally can be recognized in drilled or dug wells without making temperature measurements. Driller's records of wells along the Farmers Loop road permit delineation of the permafrost boundary in that area.

Thermokarst mounds or pits in cleared fields help to define the boundary. Absence of thermokarst phenomena does not necessarily mean the absence of permafrost, however; permafrost without ice masses may be present or permafrost with ice masses may lie below the depth of seasonal thawing.

A well-defined boundary between two vegetation types generally lies near the boundary between slopes underlain by permafrost and slopes that are permafrost-free. A scrubby woods of stunted black spruce (*Picea mariana*), with knee-high shrubs of dwarf birch (*Betula nana*), Labrador tea (*Ledum decumbens*), and blueberry (*Vaccinium uliginosum*), and a thick moist carpet of cranberry (*Vaccinium vitis-idaea*), cottongrass (*Eriophorum* sp.), and much peat-moss (*Sphagnum* spp.) and caribou-moss lichen (*Cladonia* spp.) grows on gentle slopes having poor drainage where permafrost generally lies at a depth of 2 to 4 feet. Willows (*Salix* spp.) and alders (*Alnus* spp.) are found in faintly developed water courses.

White spruce (*Picea glauca*), birch (*Betula papyrifera*), quaking aspen (*Populus tremuloides*), and alder (*Alnus* sp.) are found on slightly steeper slopes having better drainage where permafrost is lacking or lies at a depth of more than 4 feet. The boundary between the black spruce scrub forest and the white spruce-birch-aspen forest is distinct and is readily recognized (fig. 74). Generally, permafrost, with or without ice masses, extends a short distance upslope past the line marking the border between these two vegetation types.

The boundary between the permafrost and the permafrost-free areas is at a higher altitude on north-facing slopes, which receive less solar heat than the south-facing slopes. Permafrost locally reaches to the summit of low-angle north-facing hillslopes. Generally, however, the contact is near a break in slope such as the contact between erosional and depositional slopes; where the steeper angle of the hillside gives way to a more gentle slope, drainage becomes sluggish and the water-saturated ground is frozen.

THERMOKARST PHENOMENA

GENERAL FEATURES

The thawing of permafrost creates thermokarst topography (Sumgin, 1940, Chapter 10; Liverovsky and Morozov, 1941, p. 56), an uneven surface which contains mounds, sink holes, tunnels, caverns, and short ravines caused by melting of ground-ice. Thawing may

FIGURE 74.—Aerial view of the central part of the Fairbanks area showing physiographic units: (*f*) Floodplain with permafrost with no ice masses; (*sl*) silt lowland and (*af*) alluvial fans with permafrost with ice masses; and the hills with no permafrost. Chena River at extreme left. View toward west from an elevation of 10,000 feet. Photograph by U. S. Army Air Corps, 1946.

result from artificial or natural removal of the vegetation or from warming of the climate. Removal of the insulating blanket of vegetation by forest fire or by man allows the ground to absorb more solar heat. Ground-ice melts and segments of the ground surface settle or cave. Cultivation probably causes more rapid and extensive thawing than forest fires because, before cultivation, man completely removes the vegetative cover and thereafter exposes the bare ground annually. Thawing and caving proceed most rapidly and deeply, therefore, in artificially cleared areas. Thermokarst landforms also develop, however, when permafrost is destroyed by a warming of the climate; this has been reported in Europe by Halicki (1951). Caverns, sink holes, and depressions then may become filled with silt or other sediment to form casts of these thermokarst features. Such "fossil" thermokarst features can be recognized in stream banks and mining cuts in Alaska and are valuable for interpretation of the geologic history (Péwé, 1952b).

The development of thermokarst features is influenced by several factors in addition to the removal of the vegetation. Large masses of ground-ice must lie near the surface; thermokarst features seldom form where ground-ice consists only of an ice cement between grains of sediment. Cavities and caverns are more readily preserved in thick deposits of thawed silt or clay than in well-sorted, thawed gravel. Loess, especially, is capable of standing in steep banks and perhaps is the best sediment for the development of extensive thermokarst topography.

On gentle slopes, ground water circulation aids in the formation of caverns and pits by thawing ice masses and by enlarging the resulting cavities by erosion. Surface water has two effective roles: on slopes it is diverted underground where it contributes to thawing and subterranean erosion, and on horizontal surfaces, it forms lakes in the depressions, the borders of which cave constantly and retreat under the thawing effects of water and waves.

Thermokarst phenomena in the Fairbanks area are found only in the alluvial fans, colluvial slopes, and lowlands underlain by silt (pl. 9) because only here does the permafrost contain large ground-ice segregations. Cave-in lakes are the most conspicuous thermokarst features in the silt lowland north of Ester road, and thermokarst mounds and pits are the predominant forms produced on the silt fans and colluvial slopes.

THERMOKARST MOUNDS

Thermokarst mounds in the Fairbanks area are polygonal or circular hummocks 10 to 50 feet in diameter (fig. 75) 1 to 8 feet in height (fig. 76), and are composed of loess. They are commonest in cultivated fields but a few are found in abandoned fields now reforested. In some fields the mounds are separated by trenches 1 to 5 feet wide, but in others the trenches are poorly developed and the mounds are not completely separated one from another (fig. 77).

The trenches are formed by the melting of a network of ice masses in the ground (Péwé, 1948a, p. 295) leaving mounds in the intervening areas. The ground surface sinks as ice near the surface melts. Local, disconnected depressions appear at first; surface water collects in the depressions and probably speeds thawing. Surface water also may enter cavities left by melting ice and enlarge them. Eventually, if the underlying ice is distributed in a polygonal pattern, ground in the center of the polygon is left standing in relief. The silt in the mounds is not deformed, indicating that the mounds do not originate by frost heaving.

FIGURE 75.—Low-angle oblique aerial view of mounds in field 7 (pl. 9 and fig. 76) at U. S. Department of Agriculture experiment farm near Fairbanks, Alaska. The mounds are about 10 to 30 feet across. Photograph by R. F. Black and T. L. Péwé, Sept. 10, 1948.

Thermokarst mounds first begin to form within 2 or 3 years after a field is cleared, according to the writer's survey of the Fairbanks area in 1947 and 1948 (table 2 and pl. 9). Mound formation ceases only after the ice is completely melted, or after the thawed layer has become thick enough to insulate against further melting, and after subterranean water erosion stops.

A field on a gentle north-facing slope at the U. S. Department of Agriculture experiment farm (field 7 on pl. 9; see also fig. 75) has the best developed mounds and the most detailed record in the Fairbanks area. The surface of the field was smooth before clearing in 1908. By 1922 pronounced individual and connected depressions had formed and by 1926 some trenches between mounds were as much as 5 feet

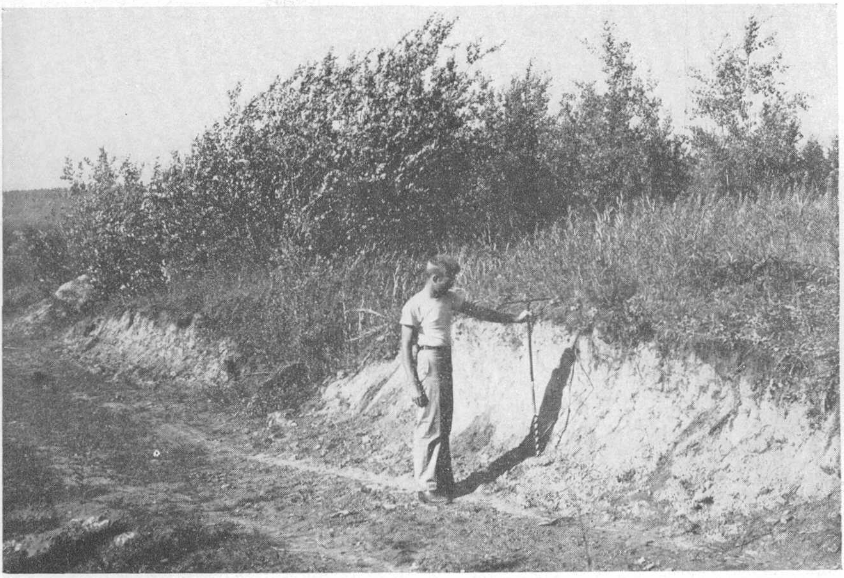

FIGURE 76.—A close-up of the mounds shown in figure 75. Relief is about 6 feet; the sediment is loess. Photograph by T. L. Péwé, July 23, 1947.

deep. Cultivation stopped a year or two later because the irregular topography formed by the pits and mounds was dangerous to the operation of farm machinery. The field then was seeded to pasture. By 1938 the mounds were 3 to 8 feet high and about 20 to 50 feet in diameter (fig. 78). Rockie studied the field in November 1938, and in order to determine whether the ice still was actively melting "a tractor bulldozer was used to remove the upper part of every hummock and fill each pit until the land surface assumed approximately a uniform slope" (1942, p. 132). The surface remained smooth for nearly a year but in July 1939 irregularities began to form. In succeeding years polygonal mounds formed as the ground surface subsided over melting ice.

Mounds in the test area smoothed in 1938 were as large and as high as those in the part of the field that had not been smoothed when the writer first studied in the field in 1947. Maximum mound height was 8 feet. Comparisons of aerial photographs with those taken 10 years earlier (figs. 78 and 79) reveal that in 1948 mounds were about the same size and shape and in the same position as in 1938. Probing with a soil auger on July 14, 1948, revealed no ice or frozen ground at a depth of 9 feet below the surface of a trench in field 7.

THERMOKARST PITS

Thermokarst pits are steep-walled pits 5 to 20 feet deep and 3 to 29 feet across. Commonly, they are larger at depth than at the

FIGURE 77.—Vertical aerial photograph of field 23 near the Farmers Loop Road on the colluvial slope. A well-developed network of mounds about 30 feet in diameter and 6 feet in height occurs in the L-shaped part of the field. Many of the mounds are not completely separated because the dividing trench is not fully developed. Black spots in the field are water-filled depressions. The black bar on the left represents about 1,000 feet. Photograph by U. S. Army Air Corps, May 9, 1947.

FIGURE 78.—Vertical aerial photograph of mounds in fields of the U. S. Department of Agriculture experimental farm near Fairbanks, Alaska as they appeared in 1938. This photograph was taken before part of field no. 7 (field in the center of the view with well-developed mounds) was smoothed. Compare this photograph of the mounds with figure 79 taken in 1948. The black bar on the lower left represents about 1,000 feet. Photograph by Pacific Aerial Surveys, July 22, 1938.

surface. They occur in cultivated fields on the alluvial fans and colluvial slopes near the contact with the permafrost-free slopes (pl. 9).

The pits are started by melting of ground-ice, and commonly are enlarged and modified by surface water that is diverted into small cracks and subterranean passageways and then flows 6 to 20 feet beneath the surface. Additional well-sorted, fine-grained silt then can be removed in suspension through small openings by small quantities of water moving over low gradients. Linear pits result where running water enlarges the surface opening of a pit by eroding headward along a rut in a road or a furrow in a cultivated field.

The passageways do not collapse readily because of the structural properties of the loess, and, consequently, such caverns may exist un-

FIGURE 79.—Stereopair of aerial photographs of mounds in four fields of the U. S. Department of Agriculture experimental farm near Fairbanks, Alaska. (Fields 3, 6, 7, and 8 on plate 9.) Mounds shown in figures 75 and 76 are in the center field 7 of this photograph. Parts of the three largest fields have been abandoned for cultivation. The white bar on the lower left represents about 1,000 feet. Photograph by U. S. Army Air Corps 1948.

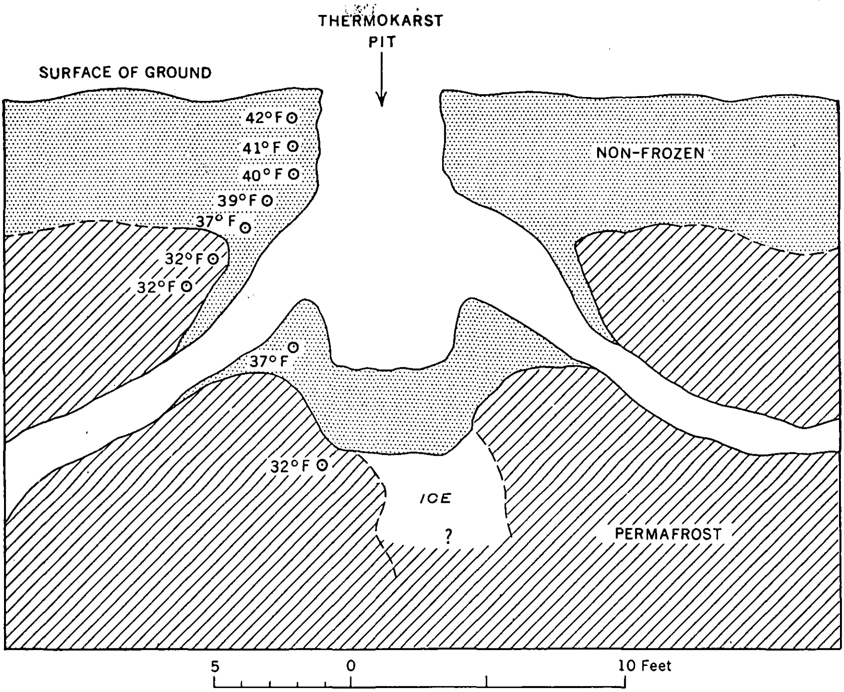

FIGURE 80.—Diagram of a thermokarst pit in frozen ground of field 11. Note how the opening simulates the shape of irregular ice masses shown in figure 73. Temperature measurements taken by Ansel Gooding on September 4, 1948.

detected for many years before the roof collapses or surface water wears a small opening through the roof.

Twenty-four thermokarst pits were found in cultivated fields of the Fairbanks area; some were in frozen ground and some in thawed ground. Cavities in frozen ground are irregular in shape, and indicate the space formerly occupied by the ice mass (fig. 80). The openings generally are circular and 3 to 4 feet in diameter through the active layer. The walls are vertical in the thawed surface layer, but spread outward and downward in frozen ground. The main cavity is as much as 10 feet across; small passageways extend downward at angles of 45 degrees to undetermined depths. The frozen silt of the roof and walls characteristically spalls off in layers 2 to 3 inches thick. The top of an ice mass was visible in the bottom of the main cavity of one of the pits investigated in field 11 on September 4, 1948 (fig. 80).

The largest pit observed in thawed ground, in field 2, is 8 feet wide, 15 feet long, and 20 feet deep. Horizontal, tubelike passageways 3 feet wide and 2 feet high branch from both ends of the pit (fig. 81). Current markings and water-deposited silt on the flat floors

FIGURE 81.—Thermokarst pit in thawed silt, Fairbanks, Alaska, (field 2, table 2). The semicircular dark area at the base of the wall at the far side of the pit is an opening to a passageway extending from the pit. Photograph by T. L. Péwé, June 23, 1948.

of the passageways indicate an intermittent subterranean stream (fig. 82).

All of the known thermokarst pits in the Fairbanks area in 1948 were in cultivated or formerly cultivated fields near the boundary between permafrost-free slopes and slopes underlain by large ice masses. The distribution of permafrost in thin isolated masses and the low water table, 15 to 100 feet below the surface, in this zone provide the favorable conditions which localize the pits. Water from melting ice masses and surface water funneled down from above can circulate freely through the passageways as it progresses down to the water table. The water table is nearer the surface at low elevations on the slopes and in the silt lowland north of Ester road, and consequently the melting of ice masses in these areas creates cave-in lakes (fig. 71) instead of pits.

Pits appear within 3 to 30 years after clearing of the fields (table 2). Most openings first appear within 8 to 10 years after clearing. Cavities probably form within 3 years after clearing, but may not open to the surface until many years later.

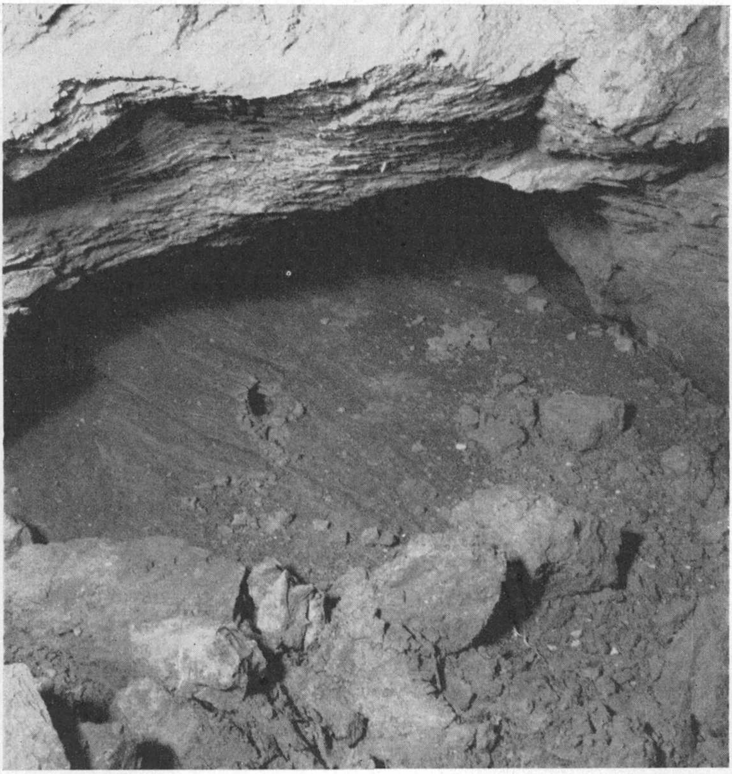

FIGURE 82.—Current water markings in underground passage leading from the thermokarst pit in thawed silt shown in figure 81. Passageway is about 1 foot high and 2½ feet wide at this point and partly filled with water-deposited tan silt. Photograph by T. L. Péwé, June 23, 1948.

PERMAFROST CONDITIONS IN THE PHYSIOGRAPHIC UNITS

FLOOD PLAIN

Description.—The Chena and Tanana River flood plain lies at an altitude of about 440 feet and covers 71 square miles in the southern part of the area mapped. The city of Fairbanks (pl. 9) is on the flood plain. This unit, commonly referred to as the "flat" or "bottom" lands by the farmers, extends to the bases of Birch Hill, Chena Ridge, and the hill at the University; but elsewhere it is separated from the hills by alluvial fans and colluvial slopes. Crescentic markings and lakes indicating former positions of rivers and sloughs are characteristic of the flood plain (fig. 73). Much of the flood plain is underlain by permafrost but no cave-in lakes or polygonal ground (tundra polygons) have been found.

Topography.—The only surface irregularities on the flood plain are broad linear swales 3 to 4 feet deep marking former meander paths of sloughs; these do not interfere seriously with cultivation.

Lithology.—Sediments of the flood plain consist of silt, sand, and gravel deposited by shifting streams and occur, therefore, as lenses rather than as beds of broad lateral extent. Micaceous sandy silt underlies the surface to a depth of 1 to 15 feet, and a sandy gravel layer of variable thickness underlies the silt. Alternating lenses or beds of silt, organic silt, sand, and gravel extend to a depth of at least 364 feet.[2] Sandy loam, silt loam, and fine sand are the main soil types recognized on the flood plain (Gasser, 1946, p. 4).

Vegetation.—Cottonwood, white spruce, birch, and tall willows grow where depth to permafrost is 4 feet or more. Stunted black spruce and larch grow in parts where depth to permafrost is less than 4 feet. Most of the wet areas are treeless, but support a shrub growth of alder, dwarf birch, Labrador tea, blueberry, cranberry, and a thick moss and lichen cover. Horsetail (*Equisetum*) is common throughout the flood plain. Much of the original vegetation has been destroyed in the last 45 years by fires and clearing and only a few old dense stands of white spruce and birch remain.

Suitability for agriculture.—Most of the land along the roads leading out on the flood plain from Fairbanks has been claimed for homesteading, and by 1948 about 800 acres had been cleared (pl. 9). Farmers report that during the first or second year of cultivation, before the permafrost level has receded much, the moisture content of the soil is higher than in the succeeding years. The additional moisture is valuable because of the low rainfall in the Fairbanks area. Perhaps in those areas of Alaska where the depth to permafrost after clearing the surface is not as great as in the Fairbanks area, the melting of frozen ground would supply extra moisture for many years (Benninghoff, 1952, p. 43). This fact has been reported by farmers in Siberia (Nikiforoff, 1928, p. 73). However, no facts support the startling statement by Aamodt and Savage (1949, p. 104) that "melting ground ice often provides running water for livestock and power development" in the interior of Alaska.

Drainage is poor in most areas of the flood plain that have not been cleared. After the insulating vegetation cover has been stripped away, however, the permafrost table is lowered, and in most places drainage is improved so much that farm crops can be raised successfully. In the summer, soil temperatures in flood plain areas underlain by permafrost are well above freezing after clearing. The chilling effect of permafrost, which retards germination of field crops, is largely eliminated after lowering of the permafrost table.

Ground-ice masses are absent, and cultivated fields do not become

[2] Well "B" of U. S. Smelting, Refining, and Mining Co., Fairbanks, Alaska, 1927.

pitted or bumpy as do some fields on the silt alluvial fans and colluvial slopes.

In many places on the flood plain, permafrost is lower than the water table and water is available in shallow wells. Water in larger quantities is available from wells penetrating gravelly beds below the permafrost at depths of 50 to 200 feet or even at shallower depths where permafrost is absent (Péwé, 1948c, p. 9).

In summary, permafrost affects soil drainage and temperature during the first few years after the clearing of cultivated fields in the flood plain of the Fairbanks area, but this effect soon disappears. Because large ground-ice masses are lacking, no undesirable microtopography is formed by thawing of frozen ground in the flood plain.

ALLUVIAL FANS, COLLUVIAL SLOPES AND THE SILT LOWLAND

Description.—Gently sloping alluvial fans and colluvial slopes extend from the flood plain to the hills and increase in altitude from 450 feet at the toe to 900 feet in the creek valley heads (pl. 9). A silt lowland separates the toes of the fans from the flood plain, just north of Ester road at an altitude of about 450 feet (pl. 9).

Fans and slopes cover 35 square miles and may be recognized by the following characteristics: (1) gentle slopes of $\frac{1}{2}°$ to 1°, (2) absence of crescentic scroll-like sloughs of flood plain stream markings, (3) presence of poorly developed polygonal ground, cave-in lakes, and beaded drainage, and (4) vegetation characterized on the lower parts of the fans by black spruce, some dwarf birch, willow, alders, Labrador tea, blueberry, cranberry, and a mat of mosses and lichens. Near the contact with the permafrost-free slopes, the well-drained upper parts of the fans have much white spruce and birch.

The silt lowland is 4 miles in diameter and is characterized by (1) little or no slope, (2) absence of crescentic sloughs or flood plain stream markings, (3) well-developed polygonal ground, cave-in lakes (fig. 71), and beaded drainage (fig. 83), and (4) vegetation characterized by stunted black spruce, larch, willow, dwarf birch, much Labrador tea, blueberry, and cranberry. Locally, the moss-lichen mat is 12 to 18 inches thick. This silt lowland is easily recognized on aerial photographs (fig. 83). The well-developed polygonal ground pattern, cave-in lakes, and beaded drainage of the lowland are features that enable one to detect the presence of permafrost by use of aerial photographs (Hopkins and Karlstrom, 1954).

Topography.—The surface of the fans and slopes is initially smooth, and, before thawing of permafrost, is topographically suited to agriculture. Before clearing, the only relief in the silt lowland consists of lake-filled depressions and a polygonal pattern of trenches 1 to 2 feet deep.

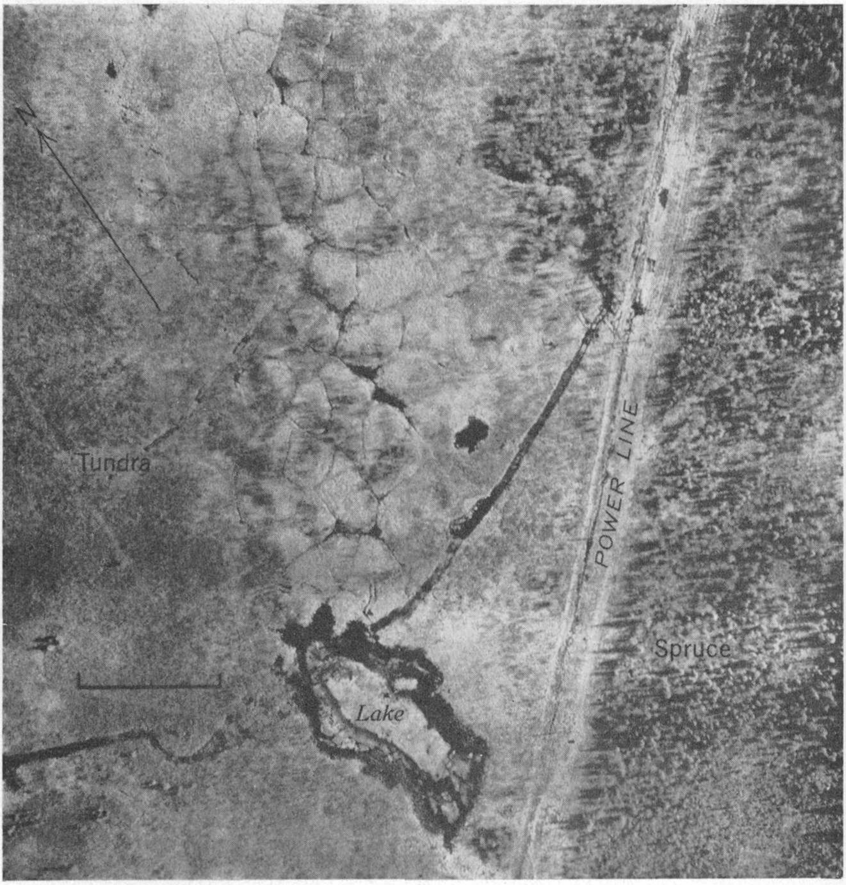

FIGURE 83.—Aerial view of polygonal ground pattern in the silt lowland near the junction of the Farmers Loop road and Steese Highway about 1 mile northeast of Fairbanks. Ground-ice occurs in a polygonal net, giving rise to these polygonal markings. The polygons are 40 to 60 feet across. Small lakes have formed at the junction of the polygons forming beaded drainage. Vegetation on the right is mostly scrubby birch-spruce forest with some larch and on the left is cotton-grass-shrub tundra. Black strips 8 feet wide trending diagonally across photograph are water-filled caterpillar tractor tracks. The horizontal bar in the lower left represents a distance of about 150 feet. Photograph by U. S. Army Air Corps, 1947.

Lithology.—The upper parts of the fans and colluvial slopes are composed of loess and reworked loess (Péwé, 1950a) underlain by muck (organic silt). The lower parts of the fans and slopes and the silt lowland are composed of muck. The muck in the lowland reaches a thickness of at least 175 feet and contains many layers and lenses of peat. Coarse creek gravel underlies the lower slopes and the silt lowland at depths of 50 to 200 feet.

The soil on the upper parts of the fans and colluvial slopes is a subarctic brown forest soil; this grades into half-bog and bog soils at lower altitudes.

Suitability for agriculture.—Land underlain by ground-ice near the surface is satisfactory for cultivation for only the first few years after clearing. The melting of ground-ice masses and the subsequent formation of thermokarst topography has a serious effect on cultivated fields on alluvial fans, colluvial slopes, and silt lowland (Mimms, Paschal, and Fuhriman, 1950). Permafrost with large ground-ice masses underlies 27 percent (39 square miles) of the Fairbanks area, and fields located there may develop thermokarst pits and mounds. Mounds appear less dramatically and suddenly than pits, but they probably constitute a more widely distributed obstacle to cultivation in this area.

In 1948, 32 of the 37 fields examined on the alluvial fans, colluvial slopes, and silt lowland showed evidence of thermokarst action. Six of the 27 fields cleared prior to 1945 (fields 24, 25, 26, 28, 29, and 31), have been abandoned for more than 20 years (see table 2). In five others cultivation was attempted only on part of the original cleared land.

None of the 10 fields cleared between 1945 and 1948 has been abandoned due to excessive thermokarst development; however, mounds and pits had already begun to form in many of them. No mounds or pits had formed in the two fields cleared in 1948.

In 1948 about 400 acres of land was under cultivation on the alluvial fans and colluvial slopes, but no land was under cultivation in the silt lowland.

In summary, farmers who consider clearing land in this zone of the Fairbanks area should be aware of the difficulty caused by melting ground-ice and the probability of having to abandon fields and buildings. Tsiplenkin (1944), in describing the influence of permafrost on agriculture in Siberia, states that ground which contains thick masses of ice is absolutely unfit for agriculture.

PERMAFROST-FREE SLOPES

Description.—Hilltops and most well-drained south-facing slopes in the Fairbanks area are permafrost-free. These permafrost-free areas are largely confined to the northern part of the mapped area (pl. 9), and extend from about 500 feet to 2,000 feet above sea level. Permafrost also is lacking on the crests and steep slopes of three small bedrock hills which protrude 50 to 100 feet above the flood plain 4 to 5 miles east of Fairbanks.

In addition to its higher elevation and form, the permafrost-free area differs from the fans, colluvial slopes, and flood plain in the following respects: (1) it is well drained, (2) it has no lakes or streams, (3) it has a vegetation cover characterized by dense stands of white spruce, birch, and aspen. Usually, aspen is predominant if the stand

TABLE 2.—*Fields exhibiting thermokarst phenomena in the Fairbanks area, Alaska, 1948**

[*See pl. 9 for location of fields*]

Field no.	Date cleared	Date of appearance of		Field use, 1948	Remarks
		Mounds	Pits		
3	1908	1915(?)	1915	Grain crop	Lower half of the field has depression 5 feet deep in poorly developed polygonal arrangement. Large pit in upper half has been filled (fig. 79).
7	1908	1918	1918	Mostly abandoned	Mounds 30 feet in diameter and 8 feet high. Pits have formed; some are artifically filled (figs. 75, 76, 78, 79).
23	1908(?)	1910	Date unknown	Lower part of field reduced to pasture: upper part in hay	Well-developed network of mounds 30 feet in diameter and 6 feet high (fig. 77).
24	1908(?)	1910–11	do	Abandoned	Many mounds 4 to 6 feet high, now covered with trees.
25	1908(?)	1910–11	do	do	Many mounds 4 to 6 feet high, now covered with black spruce-aspen scrub.
26	1908(?)	1910–11	do	do	Do.
6	1909	1915(?)		Cultivated	Several irregular depressions 1 to 2 feet deep on the west edge of the field (fig. 79).
9	1909(?)		1942	do	Three pits present. One opened by tractor falling through roof of thermokarst cavern. This pit in thawed ground has enlarged continually since 1942 and is 20 feet deep. One trench 3 feet wide, 20 feet long and 6 feet deep.
8	1910	1920		do	Mounds 30 to 50 feet in diameter and 2 to 3 feet high (fig. 79).
11	1910		1936, 1946, 1949	Partly abandoned	This field has more pits than any other in the Fairbanks area. Two pits are reported to have been 3 feet in diameter when they originated in 1936. The openings were 20 feet in diameter in 1948. Two other pits 5 feet in diameter were exposed in 1946. Three new pits 10 to 15 feet in diameter opened in 1949. Two old pits occur in an abandoned grown-over part of the field (fig. 80).
13	More than 20 years ago	Existed for many years.	1943	Cultivation still attempted	Several small pits present; one is 4 feet in diameter, more than 10 feet deep. Prominent depressions 5 feet deep occur in which water sometimes stands.
27	Many years ago	Many years ago	Many years ago	Partly abandoned	Large depression 20 feet in diameter in lower half of the field.
28	do	do	do	Abandoned	Well-formed mounds 30 feet in diameter and 6 feet high. One large pit reported.
29	do	do	do	do	Trees reestablished over mounds and pits. Cabin in field has subsided 4 feet.
31	1913(?)	20(?) years ago	20(?) years ago	Abandoned years ago	Large mounds 4 feet high and old, half-filled pits 5 feet deep.
16	1936		1939	Cultivated	Mounds 20 to 30 feet in diameter and 3 to 4 feet high. One owner fought mound and pit formation for 10 years but finally moved. Cabin settled unevenly each year.
32	1936	1938–39		Potato crop	Mounds 1 to 1½ feet high on lower side of field.
21	1937	1940	1946		Many depressions and small pits forming.
12	1939	1943 (?)		Golf course	Broad, undulating mounds 50 feet to 100 feet in diameter and 2 to 4 feet high still active. Radio transmitter building settling.

19	1940	Between 1942 and 1945.			Depressions 2 to 3 feet deep.
20	1940		1947	Cultivated	Tractor collapsed roof of thermokarst cavern near road between field 17 and 19.
36	1940		1948	Potato crop	Two pits 6 feet deep exposed in thawed ground when tractor collapsed roof.
30	1943		1947	do	Tractor collapsed roof over pit 5 feet in diameter in valley on east side of field.
34	1944	1945	1944	Not in current use	Two pits about 4 feet deep in field. Two pits 8 feet deep adjacent to farm road in heavily wooded area. These pits have deepened 5 feet from 1940 to 1948. Future of cleared field uncertain.
2	1945	1947	1948–49	Partly abandoned	Prominent linear depression. A pit 8 feet by 15 feet in thawed ground next to depression appeared in 1946 (fig. 81). A circular pit 20 feet across and 15 feet deep formed in 1949.
4	1945	1947		Cultivated	Gentle depressions.
5	1945	1947		do	Gentle irregular and some downhill linear depressions. No serious interference with cultivation. Henhouse has settled unevenly.
15	1946			do	No irregularities yet but probably will appear soon.
17	1946	1948			Irregularities in surface beginning to form 1948.
35	1946	1948		Pasture	Well log indicated permafrost from depth 12 feet to 52 feet.
14	1947			Cultivated	No depressions yet but probably will appear soon.
33	1947	1948		do	Few small depressions 2 feet deep. Poorly drained.
18	1948				No irregularities in surface yet but can be expected in a few years.
22	1948				No depressions yet, but can be expected.
1	Unknown	Date unknown	Date unknown	Not in current use	Faint outlines of polygonal ground. Trenches 3 feet deep, and one pit 10 feet deep and 2 feet in diameter. Two small pits near the road.
10	Unknown	do		Cultivated	Small mounds on the downslope edge of field.

*With a few additional notes in 1949.

is less than 10 or 20 years old. The moss and lichen mat is thin, and forest undergrowth is predominantly wild rose, bunchberry or dwarf dogwood, and horsetail. Alder and willow grow along drainage paths.

Topography.—The upper slopes are generally too steep for cultivation and many have parallel gullies and ridges 50 to 70 feet wide, 200 to 300 feet long, and with a relief of 10 to 20 feet. However, the gentler (½° to 4°) middle and lower slopes are satisfactory for agriculture.

Soil erosion is a serious hazard on cultivated slopes in the permafrost-free area. The soft loess is easily gullied and if plowed parallel to the slope, runoff is channeled down the furrows. Gullies 30 feet long, 4 feet wide, and 4 feet deep have formed in freshly plowed fields during a single heavy rainstorm. Especially serious gullying may occur if runoff from roadside ditches is channeled into a field. Such gullies may resemble modified thermokarst pits.

Lithology.—Loess as much as 100 feet thick covers the middle slopes but thins to a few inches or may be missing on the hilltops and upper slopes.

More than 70 percent of the loess particles are silt size and range in diameter from 0.01 to 0.05 millimeter. Little clay is present (fig. 84).

Subarctic brown forest soils are formed on the loess (Kellogg and Nygard, 1951, p. 59; Michaelson (unpublished manuscript, Alaska Agricultural Experiment Sta., Palmer, Alaska). This slope soil is termed the Fairbanks silt loam (Bennett and Rice, 1919, p. 131–148) and is similar in physical characteristics to the brown loessial soils of the midwestern United States.

Suitability for agriculture.—The first farms in the Fairbanks area were established almost 50 years ago on the south-facing permafrost-free slopes. By 1948 approximately 1,200 acres had been cleared for agriculture on these slopes (pl. 9), and most of the 34 square miles of the permafrost-free area near Fairbanks was claimed for homesteading.

South-facing slopes are desirable for agriculture because more solar heat is received on them. The soil warms more rapidly in the spring, and the growing season is about 2 weeks longer than on the floodplain. Permafrost is absent and no thermokarst topography is formed.

Cultivated fields on these slopes are subject to severe soil erosion, but perhaps the most critical handicap to agriculture is the relative depth to ground water. Depth to ground water is generally more than 100 feet and only small quantities are available. Consequently, water supply is a much more critical problem there than on the flood plain, where ground water is available in abundance at depths of 20 to 200 feet.

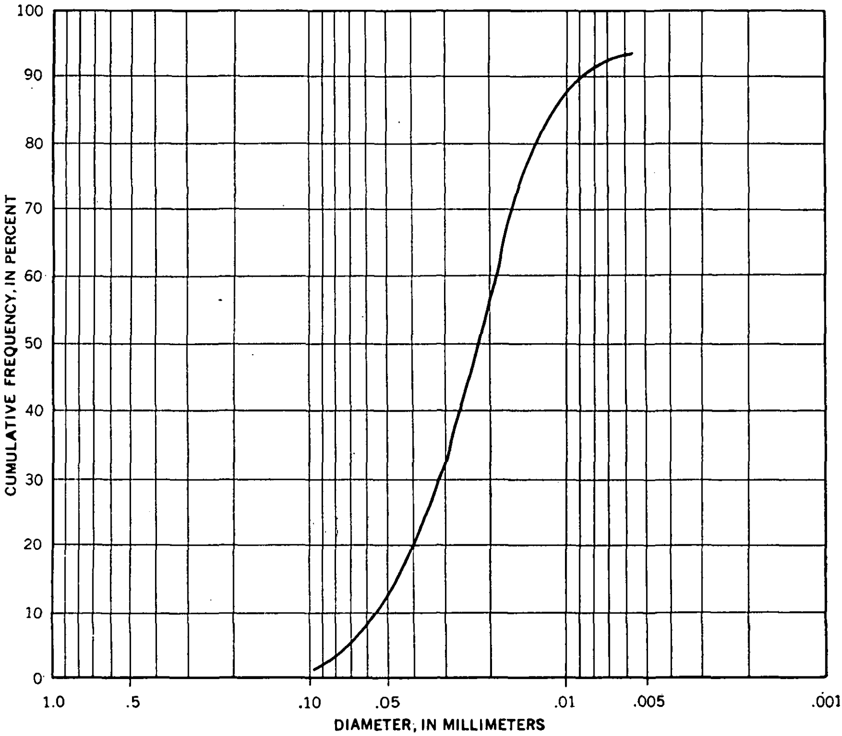

FIGURE 84.—Average cumulative-frequency curve of 17 samples of loess from the Fairbanks area, Alaska

CONCLUSIONS

Permafrost containing large ice masses underlies 27 percent of the Fairbanks area. When the surface is cleared, the ice melts and thermokarst mounds and pits form. As a result, the new field may eventually become difficult or impossible to cultivate. Consequently, some fields in the area underlain by large ground-ice masses can be cultivated only a few years after clearing and then must be abandoned or put into pasture. Clearing represents a big investment in labor and capital, and abandonment of a cultivated field is a serious loss. It is recognized that a field can be used if the mounds are repeatedly leveled and the pits filled as they appear. However, it is a costly fight and much time, money, and soil are wasted in such a perennial struggle.

Most of the suitable agricultural land on the flood plain and permafrost-free slopes near Fairbanks has already been claimed by homesteaders. In the future, many new settlers are likely to clear and attempt to cultivate fields on the alluvial fans and silt lowland where large masses of ground-ice are present. Large masses of ground-ice are not unique to the Fairbanks area and occur in the upper Tanana

Valley, the middle Yukon Valley, the Seward Peninsula, northern Alaska and other localities. Farmers seeking new land in the Fairbanks area or elsewhere should find out which areas are unfavorable because of permafrost conditions. They should realize the probable necessity that fields in the area underlain by ground-ice may have to be abandoned eventually.

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