TEXT AND DESCRIPTION OF GEOLOGIC UNITS FOR THE MT. HAYES D-4 QUADRANGLE, ALASKA

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INTRODUCTION

The Mount Hayes D-4 quadrangle, an area of about 255 square miles, is in southeastern interior Alaska, approximately 150 miles west of the Canadian border and about 225 miles north of the Pacific coast. The area is crossed by the Alaska and Richardson Highways, which meet at the village of Delta Junction (directly north of the quadrangle boundary). Fairbanks is approximately 100 highway miles to the northwest, and Valdez is about 250 highway miles to the south. Fort Greely (U.S. Army) and a Federal Aviation Agency airfield lie in the northern part of the area. Much of the remainder of the quadrangle is withdrawn for Army use. The towns of Delta Junction and Big Delta, 3 miles and 13 miles to the north, respectively, have a total estimated population of 700.

The area has no mining or agricultural activities, and most of it is covered by a subarctic forest with small sections of alpine tundra. The forests bear the scars of extensive fires that have occurred during the past two centuries.

The quadrangle is largely mantled with unconsolidated deposits that are a source of construction material and provide the base for foundations; they are therefore emphasized on the geologic map (sheet 1). Most of these deposits and some of the bedrock are perennially frozen.

Data on the engineering properties of the geologic units were obtained from observation of their behavior in various engineering uses and from laboratory tests made by several agencies. Generalizations made from these data may be useful in preliminary planning and designing, but they are not intended to replace standard field and laboratory investigations required for the design of specific engineering structures.

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PHYSICAL SETTING

REGIONAL PHYSIOGRAPHY AND LANDFORMS

The quadrangle lies in two physiographic provinces: the Tanana lowland and the Alaska Range. Most of the mapped area is in the Tanana lowland, a northwest-trending plain, covered by moraines, outwash plains, terraces, and flood plains formed by glaciers and streams from the south. Granite Mountain and Donnelly Dome, foothills of the Alaska Range, lie in the southern part of the quadrangle.

CLIMATE

The Mount Hayes D-4 quadrangle has a continental climate, characterized by an extreme range between summer and winter temperatures. The extremes are caused by an inflow of Siberian polar continental air in winter and Pacific maritime air in summer (Holmes and Benninghoff, 1957, p. 46). Short calm periods of intense cold, with minimum temperatures of -40° to -60°F, occur occasionally during the long winters. These cold intervals commonly terminate either when Chinook winds blow from the south through the Delta River valley and over the range bringing temperatures as high as 50°F, or when strong winds blow down the Tanana Valley from the southeast causing a less abrupt temperature rise.

The minimum temperature on record is -65°F and the maximum 90°F. The average temperature for January is -5°F and for July 59°F. The mean annual temperature is 27°F (de Percin and others, 1955, p. 4, 17).

The mean annual precipitation is 11.4 inches, of which about 8 inches falls as rain during the warm season. The average annual snowfall is approximately 38 inches, but in one season as much as 66 inches was recorded.

The most curious climatological phenomena in the Big Delta area are the strong east-southeast surface winds blowing down the Tanana Valley (Ehrlich, 1953; Mitchell, 1956). These occur mainly in the winter and are the result of a strong pressure gradient from Northway to Big Delta. The velocity of the winds usually ranges from 25 to 45 miles per hour, but winds up to 97 miles per hour have been recorded. The stream of air often flows northwestward for more than 100 miles, gradually broadening and diminishing in velocity. In the Big Delta D-4 quadrange the stream is about 5 miles wide and generally extends approximately 2,000 feet upward (Mitchell, 1956, p. 15), although it has been reported as high as 4,000 feet above the ground (Péwé, 1951, p. 401).

South winds blow intermittently throughout the year, but are stronger in the summer. These winds result from a high-pressure area to the south from which a stream of air flows through the Delta River pass and then directly over the Alaska Range. In many instances the south and east winds converge in the Mount Hayes D-4 quadrangle, the south winds having less velocity on the average than the east winds.

Calms prevail about 13 percent of the time during the winter months, whereas in Fairbanks, 80 miles down the Tanana Valley, calms prevail more than 50 percent of the time (Mitchell, 1956, p. 15).

STREAMS AND LAKES

The two main streams in the quadrangle, Delta River and Jarvis Creek, are fed by glacial meltwater and flow on wide unvegetated braided flood plains. The flood plain of the Delta River is 1 to 2 miles wide and is bounded by terrace scarps as high as 175 feet. In summer the river flows in five or six major channels and several minor channels, and has Yazoo-type tributaries. Rough estimates of the extremes of discharge are 450 cubic feet per second in January and 9,000 cubic feet per second in July. In winter the Delta River flood plain in the southern part of the quadrangle is usually covered with a continuous sheet of overflow ice, but downstream bare areas of stream deposits are exposed to wind action.

Jarvis Creek flows on the surface of the ground throughout its entire length during the warm season, but the rest of the year it flows on the surface only in its middle course. Measurements made during the summer show that the creek loses water to its bed as it flows downstream over a widening flood plain (Holmes and Benninghoff, 1957, p. 243). Marked diurnal fluctuation in stage occurs as a result of changes in the rate of glacier melting. Short periods of high discharge follow periods of high temperature, strong wind, or exceptionally heavy rain. In winter, overflow icings cover the flood plain in the lower section and the flowing channels of the middle course. The lower section of Jarvis Creek is a source of windblown silt and sand throughout most of the year.

Granite Creek, a nonglacial stream, also loses water downstream and eventually disappears into its bed.

Scores of ponds and lakes lie on the moraines and are generally 10 to 20 feet deep and less than half a mile across. Many are bordered by marshes or bogs and are in various stages of being filled with vegetation and silt. Thickness of winter ice on lakes or ponds ranges from 3 to 4 feet, depending on the severity of the winter and the snow cover.

GEOLOGIC HISTORY

The oldest formation exposed in the Mount Hayes D-4 quadrangle is the Birch Creek Schist of Precambrian age. It consists of completely recrystallized and metamorphosed clastic sedimentary rocks in which nearly all evidence of the original sedimentary structure has been destroyed (Wahrhaftig and Hickcox, 1955, p. 356). The next recorded geologic event was intrusion of the granodiorite of Granite Mountain in Mesozoic time (Moffit, 1942, p. 126; G. W. Holmes and T. L. Péwé, unpublished data).

Continental coal-bearing Tertiary deposits were laid down on the flanks of the Alaska Range in early or middle Tertiary time. Following deformation and erosion of some of these rocks, the Nenana Gravel was deposited, and in turn was deformed and eroded (Wahrhaftig and Hickcox, 1955, p. 365).

The Quaternary history in this area is characterized by a series of advances of glacial ice from the Alaska Range. The earliest advance known in the Delta River area is the Darling Creek Glaciation (Péwé, 1952, p. 1289), recognized from high-level gravel remnants lying outside the quadrangle to the south. Perhaps the entire quadrangle was buried under glacial ice at this time.

The succeeding glacial advance is known as the Delta Glaciation (Péwé, 1952, p. 1289). The ice advanced from Delta Valley and Granite Mountain and covered all but the top of Donnelly Dome, the top of Granite Mountain, the knob west of Granite Creek, and a small lowland area northwest of Granite Mountain. Ice surrounded Donnelly Dome to an altitude of approximately 3,200 feet and the dome protruded as a nunatak. Ice along Granite Creek rose to an altitude of approximately 2,800 feet on the valley walls in the southern part of the quadrangle. This Granite Creek lobe of ice joined the Delta River lobe. Small alpine glaciers poured northwest from the cirques on Granite Mountain and spread as terminal bulbs on the lowlands but did not coalesce with the large Delta River and Granite Creek lobes.

An inner moraine west of Jarvis Creek indicates that the Delta Glaciation was perhaps compound. An alternate interpretation, however, is that this was a recessional moraine deposited as the main Delta River lobe retreated.

The Donnelly Glaciation, the latest major ice advance, followed a period of considerable erosion and some deposition of windblown sediments (Péwé, 1952, p. 1289). The ice of this glaciation was not as extensive as the earlier advances and a large lobe terminated along the Delta River valley on the west side of the quadrangle; an offshoot of this lobe terminated near Donnelly Dome. Small alpine glaciers from Granite Mountain barely reached the piedmont lowland, and the Granite Creek lobe did not coalesce with the Delta River lobe. Near the end of this major ice advance there appears to have been a readvance down the axis of the Delta River lobe. Ice overrode and grooved the moraine of Donnelly age and extended slightly beyond the major terminal moraine.

The glaciers then melted back to the south, and subsequent advances and retreats are not recorded in this quadrangle. Two prominent terrace levels on the Delta River and Jarvis Creek, however, reflect changes in stream regimen which perhaps are related to glacial activity in the Alaska Range in the upper Delta River area (Péwé and others, 1953; Péwé, 1961).

Concurrent with and subsequent to glacier withdrawal and terrace formation, silt was picked up by the wind from the flood of the Delta River and Jarvis Creek and deposited as loess on the adjacent terrain (Péwé, 1951). Included in the loess blanket is a ¼-inch layer of white to grayish-white volcanic ash which is exposed in many places in this and adjoining quadrangles. This layer consists mainly of volcanic glass.

Two prominent fault scarps about 10 to 15 feet high cut moraines of Donnelly age and attest to postglacial tectonic activity. One fault scarp trends east from Donnelly Dome in the southern part of the quadrangle, and the other trends northeast along the front of Granite Mountain in the southeast corner of the quadrangle.

In the absence of radiocarbon dates or continuous tracing of moraines to age-documented sequences, it is difficult to assign definite ages to the major glaciations in this quadrangle. The relatively fresh knob-and-kettle topography, the well-preserved striations and ice polish on boulders, and the lack of dissection of the moraines suggest that the Donnelly Glaciation is of Wisconsin age. However, the fact that there were subsequent glacial advances along the upper Delta River valley (Péwé and others, 1953; Péwé, 1961) indicates that the large, well-preserved festooned end moraines of Donnelly age in the Mount Hayes D-4 quadrangle are not of latest Wisconsin age.

The Delta Glaciation is thought by some to be pre-Wisconsin in age (Henry Coulter and others, unpublished data) because the morainal topography is considerably subdued and the moraines fragmentary, the number of boulders on the surface is low, kettle lakes are partly filled and modified, and many large glacial boulders on the moraine are deeply weathered. The percentage of recognizable mica schist fragments in the till of Delta ranges from 1 to 10, in contrast to 25 to 35 percent of such rock fragments in the less-weathered till of Donnelly age.

A detailed description of the geologic units is given in the table below. Special emphasis is placed on suitability for foundations and for use as construction material.

EOLIAN DEPOSITS

The strong persistent winds and wide unvegetated flood plains of the present day, and the valley trains of the past, make this area ideal for observations on the action of wind as a geologic process. Winds from the south and east have blown great clouds of silt from the Delta River and Jarvis Creek flood plains, at least since the time of the Delta Glaciation, blanketing the adjacent terrain with loess (Lindholm and others, 1959). Silt is blown 1,000 to as much as 4,000 feet above the surface today and covers hundreds of square miles (Péwé, 1951). As might be expected, it is thickest to the leeward of the source areas. The area west of the Delta River is thickly covered with loess, as well as small areas on the east side of the Delta River where the regular flow of the wind is broken. A map showing the relation between the thickness of the loess and the source areas is shown on sheet 1.

The leaves and limbs of the trees near the river are covered with fine silt during much of the summer. When it rains the silt is washed down the trees and forms small cones at the base of the trunks. The accumulation of silt on the floor of the forest forces the white spruce, a shallow-rooted tree, to send out roots at higher and higher levels as the trunk is buried. This also requires a continuous regeneration of the forest-floor vegetation.

Deposits of loess are from 1 to 55 feet thick and consistently have much more buried forest vegetation in the upper part than in the lower. This suggests that the buried vegetation in the upper part has not yet had time to decay and disappear as it has in the lower. An alternative explanation may be that earlier vegetation decayed as the loess accumulated, but recent deposition was more rapid, and the vegetation was buried before it had a chance to decay. Radiocarbon dating of critical wood samples may refute or confirm this second explanation.

The upper few feet of loess contains fossil pulmonate snails (Péwé, 1955a, p. 714)—species that occur in the Pleistocene loess of Kansas (Leonard, 1952, p. 8). No pulmonate snails have yet been found in the extensive loess deposits in the Fairbanks area, and, except for the pulmonate snails in the loess near Manley Hot Springs (D. M. Hopkins, oral communication), the snails in the Mount Hayes D-4 quadrangle are the only ones reported in the Tanana Valley.

The age of the loess in the quadrangle ranges from pre-Wisconsin to recent. Radiocarbon data now available indicate that the ash bed along Jarvis Creek near the middle of most loess sections is between 2,000 and 4,600 years old (J. L. Kulp, Lamont Geological Observatory, written communication, 1954). This estimate is based on the dating of one wood specimen lying about a foot above the bed and of another specimen lying a few inches below the bed. A wood specimen found near the base of a 45-foot-thick section of loess on the east side of the Delta River on top of river gravel (section I-I on the geologic map) has a radiocarbon age of 7,000±275 years (Isotopes, Inc., 1962).

Wind action is also indicated by the presence of sand dunes on a low terrace on the west side of the Delta River in the northwest corner of the quadrangle. The sand fraction of the sediments blown from the Delta River flood plain was trapped and dropped first to form a sand dune belt approximately 1 mile wide and 5 miles long. The dunes are covered with a veneer of loess.

Well-developed ventifacts are widespread in the quadrangle. Grooved, pitted, and faceted boulders, cobbles, and pebbles of different composition occur commonly on the surface of the moraines of Delta age (Péwé and others, 1953). The stones are still being modified by wind action today, but the cutting and polishing was much more active during the Donnelly Glaciation. During this time, when perhaps the outwash plains were free of vegetation, the stones exposed on nearby moraines of Delta age were cut by sand and silt blown by strong winds.

No ventifacts are known from the moraines of the Donnelly Glaciation. This distribution of ventifacts was one criteria used to distinguish the multiple glaciations in the area (Péwé and others, 1953), and its use has been extended to other regions (Péwé, 1960).

Present-day wind action in the area has formed poorly developed boulder-pavement and lag-gravel surfaces on the treeless morainal knobs of both Delta and Donnelly age.

FOUNDATION CONDITIONS AND LAND USE

The Mount Hayes D-4 quadrangle contains large areas where foundation conditions are stable, good ground water is abundant, quantities of sand and gravel are available for construction, and few frozen-ground problems are encountered. However, special precautions must be taken against intense seasonal frost action for construction of roads, airfields, bridges, and unheated buildings in areas of colluvium, silt, and peat, and in poorly drained areas of the terraces and flood plains.

Selected subsurface data and measured stratigraphic sections from 40 localities in the quadrangle are shown on sheet 1 as an aid in evaluating foundation conditions. Six diagrams are also presented to show the percentages of gravel, sand, silt, and clay in the various units.

Permafrost, or perennially frozen ground, is one of the most important factors to consider when evaluating foundation conditions in the arctic and subarctic. This quadrangle lies in the zone of discontinuous permafrost (Péwé and Paige, 1963)—a zone in which permafrost is usually 1 to 300 feet thick and has a temperature of about $-\frac{1}{2}^\circ$ to -1°C. However, temperature data on permafrost in this area are scarce. Few ground temperature measurements have been made to determine the thickness and the temperature of permafrost, although some temperature measurements have been made to check the depth of seasonal frost.

Permeable coarse-grained sediments with large quantities of groundwater flow contain little or no permafrost; if frozen they do not contain segregations of ground ice. The presence of permafrost has not been proved in the flood plain of the river and the outwash-plain sediments near Fort Greely, although drillers have reported "frozen ground." Thermal records have indicated "relics" of permafrost, such as the one extending from 32 to 47 feet below the surface in glacial outwash sediments near Donnelly Dome (subsurface data at location X). Deep seasonal frost (20 feet) has been misinterpreted by drillers as permafrost in some places.

Till and thick deposits of fine-grained material may be perennially frozen. Depth to permafrost in the colluvium, silt, and peat deposits is 1 to 3 feet, and the sediments are ice rich. These frozen deposits present foundation problems.

Large thermal contraction polygons (30 to 40 feet in diameter) occur in restricted areas of the gravel outwash plain of the Donnelly Glaciation. This pattern is best developed on the west side of the Richardson Highway northeast of Donnelly Dome. In cross section the trenches outlining the polygons are underlain by "fossil" ice wedges. Without a critical analysis of all features of the landscape, these polygons might easily be misinterpreted as ice-wedge polygons which, in interior Alaska, are indicative of ice-rich perennially frozen fine-grained sediments, whereas actually they are "fossil" thermal-contraction-crack polygons. Erroneous interpretation of this polygonal pattern might lead to rejection of these areas as possible sources of gravel or good places for construction, because they were mistakenly believed to be fine grained.

A large amount of good ground water is available in the flat to gently sloping gravel deposits in the area. Much of this water is derived from mountain streams that recharge the gravel in the higher, southern part of the area. Ground water issues from springs at the north end of the outwash plain near Big Delta, 15 miles north of the quadrangle (Péwé, 1955b, p. 130).

The supply of water from the outwash plain upon which Fort Greely is built is very large, and only slight seasonal fluctuation of the water table occurs. A 400-foot well at Fort Greely was pumped at the rate of 1,000 gallons per minute for several days with no measurable depression of the water level. A 275-foot well at Fort Greely has provided as much as 217,980 gallons per day of good water (Holmes and Benninghoff, 1957, p. 173).

Agriculture is possible on the low terraces and flood plains of the Delta River and Jarvis Creek as well as on the outwash plains and the gravel apron north of Granite Mountain. The loess soils, if properly fertilized and cultivated, should be productive except where they are too thin or poorly drained. These soils are similar with respect to grain-size distribution and fertility to those in the Fairbanks region (Péwé, 1954) and in the Matanuska Valley (Trainer, 1953; Stump and others, 1959). These are the principal argricultural areas of Alaska; but strong winds, short growing season, and periodically dry summers are drawbacks. The loess soil also is very susceptible to erosion by wind when freshly tilled.

The Mount Hayes D-4 quadrangle lies in a major earthquake zone; consequently buildings should be designed to withstand the shocks. In 1937 and again in 1947 severe earthquakes shook the area. The epicenter of the 1937 earthquake was at Salcha about 50 miles northwest of the quadrangle (Bramhall, 1938) and in 1947 the epicenter was near Clear on the railroad about 110 miles west of this quadrangle. The intensity of the 1947 quake at the epicenter was 8+ on the Mercalli scale; at Fort Greely it was estimated to be 6+ (St. Amand, 1948). The radius of the area through which the 1947 shock was felt was about 500 miles. The 1937 shock was slightly less intense and was felt throughout a slightly smaller area. In addition to historic records, the post-Wisconsin fault scarps in this quadrangle indicate that major earthquake activity has taken place in the last few thousand years.

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DESCRIPTION OF GEOLOGIC UNITS

Geologic unit	Lithology	Drainage and permeability	Permafrost	Susceptibility to frost action	Bearing strength and slope stability	Distribution and thickness	Terrain and natural slopes	Seasonal changes and dynamic processes	Excavation and compaction	Possible use
Loess	Blanket of massive, homogeneous, unconsolidated eolian silt; well sorted, locally calcareous, and containing gastropod shells; light brown to brown gray when dry, brown when wet. Locally mottled by iron stains, and poor stratification delineated by peat and wood fragments. Contains a white volcanic-ash bed ¼ inch thick.	Good surface drainage. Lateral permeability poor to fair; vertical permeability good. Average moisture content of 51 unfrozen samples is 40 percent by dry weight.	Depth to permafrost ½ to 3 ft; deeper near scarps.	Generally mild; locally intense if drainage is poor.	Bearing strength high when frozen or when dry and in original position, very low when wet. Will stand in nearly vertical cliffs. Extremely susceptible to gullying; freshly exposed surfaces susceptible to wind erosion.	Blanket a few inches to 55 ft thick; see isopach map.	Gently rolling hillslopes and low rounded hills. Slightly subdued parallel gullies and ridges at right angles to contours are characteristic of most upper slopes.	Extremely variable depending on location and landform.	Easily excavated except where perennially frozen. Difficult to compact.	Source of fine material; possible source of impervious fill. Good foundation for heated buildings if protected against gullying. Unsurfaced roads unstable and powdery when dry, plastic and sticky when wet. Good agricultural soil if fertilized.
Flood-plain gravelly alluvium (Qag)	Well-stratified layers and lenses of unconsolidated light yellowish brown silt, sand, and rounded river gravel. Delta River: gravel consists mostly of quartzite, quartz, gneiss, and diorite and ranges from ¼ inch to 3 inches in diameter. Jarvis Creek: gravel consists mostly of gneiss, quartz and quartzite, and ranges from 1-inch pebbles to 7-foot boulders; boulders are mainly granitic in southern half of this quadrangle. Granite Creek: gravel consists of more than 90 percent granitic rocks, and ranges from 1- to 8-inch diameter cobbles in lower reach, to 2- to 4-foot diameter boulders in extreme southern part of quadrangle.	Drainage and permeability excellent except locally where perennially frozen. Infiltration of stream flow into the flood plain occurs throughout the year. Good surface drainage. Lateral and vertical permeability good.	Local channel deposits of sand or silt may be frozen perennially.	Sand and gravel is unsusceptible. Frost action in silt is mild to intense.	Bearing strength high. Scarps of abandoned channels are stable.	Active flood plain of Delta River, Jarvis Creek and Granite Creek; thickness unknown but probably at least equal to depth of large channels (15 ft in Delta River and 6 ft in Jarvis Creek).	Braided channels and paralleling (Yazoo-type) tributaries, with gravel-covered or sand- and silt-covered islands. Enclosed by terraces up to 175 ft high. Gradients range from 25 ft per mile on Delta River to 90 ft per mile on Granite Creek. Mantled by isolated active dunes and sand sheets.	Winter: covered by thick, rough, discontinuous icings, and marked by water holes and patches of exposed gravel. Break-up: slow increase in flow in channels cut through icings; no flood. Summer: gradual increase in flow and number of channels; migration and cutting of channels is rapid and erratic. Diurnal fluctuation on Delta River and Jarvis Creek. Freeze-up: gradual decrease of flow and complete infiltration of lower section of Jarvis and Granite Creeks; beginnings of icings. Silt removed by wind throughout the year.	Easily excavated or moved by power equipment. Difficult to compact.	Good foundation for temporary structures and emergency aircraft landing sites. Excellent source of good gravel for subgrade and base-course material, and, if crushed and screened, for road metal and concrete aggregate. Source of enormous quantities of ground water.
Flood-plain sandy alluvium (Qas)	Well-stratified layers and lenses of unconsolidated light yellowish brown to gray, medium- to fine-grained sand and silty sand; locally interbedded with thin peat layers and wood fragments.	Good to fair drainage and permeability; locally poor in bogs.	Perennially frozen in bogs and other silty areas, especially in forested sections. Permafrost less than 5 ft thick. Low to high ice content.	Moderate to intense, especially in silty facies.	Bearing strength high except in bogs. Bog deposits can normally be removed to expose stable gravel.	Extensive areas on Delta River and on small islands or abandoned channels on Jarvis Creek. Thickness 0.5 to 3 ft.	Crossed by active tributaries and marked by meander scars. Stabilized by forest or shrub vegetation. A few bogs. Gradients same as Qag.	Winter: encroached by icings late in winter or not at all. Break-up: subject to flooding from local snow melt. Summer: moderate runoff, less than in main channels. Freeze-up: low stage or dry channels.	Easily excavated except where frozen. Difficult to compact.	Good foundation for temporary structures. Good source of silty sand. Source of enormous quantities of ground water.
Stream terrace deposits (Qts_1, Qts_2, Qtb)	Well-stratified layers and lenses of unconsolidated silt, sand, and gravel, in part glaciofluvial. Silt cover is both eolian and alluvial. Older deposits, Qts , silt and fine- to medium-grained light yellowish brown sand underlying surface of terrace. Younger deposits, Qts_2, silt and fine-grained yellowish-brown sand overlying gravel in places. Deposits containing boulders, Qtb, coarse brown sand and gravel with well-rounded granitic boulders up to 7 ft in diameter; locally includes lenses of clay-sized material, silt, peat, and orange sand and gravel.	Good to fair surface drainage and permeability. Locally poor in bogs.	Permafrost table at approximately 3 ft where silt cover is more than 3 to 9 ft. Low to high ice content.	Intense to mild under wet to moist conditions respectively.	Bearing strength high if silt cover is removed. Stable slopes.	Qts_2, discontinuous deposits on Delta River, 15 to 25 ft thick. Qts_2, narrow, discontinuous deposits on Delta River, 3 ft thick, and on Jarvis Creek, 2 to 15 ft thick. Qtb, irregular terraces 5 to 45 ft thick.	Qts_1, gently undulating surfaces approximately parallel to stream gradient, and 15 to 25 ft above stream. Qts_2, nearly flat surfaces approximately parallel to stream gradient and 3 to 5 ft above stream. Qtb, irregular flights of terraces, channelled and covered with large boulders; slope is greater than stream gradient, and terraces are 5 to 45 ft above stream.	Winter: discontinuous snow cover. Break-up: local flooding, especially in silt-filled swales. Summer and freeze-up: moist to dry, varies with cover and rainfall.	Easily excavated except where frozen. Difficult to compact.	Gravel beneath silt cover is excellent foundation for construction.
Alluvial fan deposits (Qaf, Qafm)	Qaf, poorly to fairly well stratified layers and lenses of unconsolidated well-rounded, poorly-sorted light yellowish brown sand; mantled with 1 ft to 40 ft of loess, locally stratified with peat and wood layers. Qafm, poorly stratified layers and lenses of coarse sand with angular to subangular granitic fragments of 1 inch to 12 inches in diameter.	Drainage normally good. Permeability of Qaf fair to poor. In mountains, frozen at shallow depths, permeable only where dissected.	Depth to permafrost 3 to 5 ft. Low to high ice content.	Intense in loess mantle. Abundant water and slopes encourage frost churning and solifluction.	Bearing strength fair if dry, poor if moist. Mountain fans subject to solifluction unless forested.	Large fans on Delta River, more than 40 ft thick, including loess mantle; small fans in mountain canyons, estimated 10 to 20 ft thick.	Fans on the river cut by narrow gullies as deep as 40 ft at river's edge, with slopes as much 10 percent. Fans in mountain canyons dissected with slopes as much as 100 percent.	Fans on river continuously receive large quantities of loess from Delta flood plain; disssected by stream during break-up and summer. Fans in mountains actively eroded by melt water at break-up.	Easily excavated except where frozen. Loess difficult to compact.	Poor foundation. Gravel deeply buried or inaccessible.
Eolian sand (Qe)	Light yellowish brown, well sorted medium-grained dune sand.	Well drained. Permeable except when frozen or covered by silt.	Permafrost probably present in places. Low ice content.	Intense with silt cover; unsusceptible in clean sand.	Bearing strength high. Slope stability of exposed or active dunes low.	On low terrace, Qts_2, west of Delta River. Small unmapped dunes on flood plains. Estimated thickness 1 to 20 ft.	Stabilized by vegetation and marked by steep-sided pits and irregular ridges generally trending NW. Isolated dunes have low slopes.	Dune depressions are drifted full of snow in winter, ponded at break-up, and dry in summer and at freeze-up. Receive loess from flood plain at all seasons. Dunes on flood plains are active.	Easily excavated with hand tools except where frozen. Easily compacted.	Fair to good foundation for construction. Excellent source of clean sand.
Silt and peat (Qsp)	Poorly-stratified lenses and layers of black, gray, or brown organic-rich eolian, alluvial, lacustrine, or bog silt; well sorted with little clay-sized particles; locally contains peat lenses and is mantled with a few inches of peat.	Impermeable substratum of permafrost and organic soil creates very poor drainage; marshy, boggy, or flooded in summer; land clearing produces summer quagmire. Permeability poor.	Depth to permafrost 1 to 3 ft. High ground-ice content in small segregations.	Intense	Bearing strength high when frozen, very low when thawed. Slopes in cuts are subject to sloughing and landsliding upon thawing.	In kettle depressions on moraines, especially those of Delta Glaciation; on glacial gravel beyond and behind the moraines, especially in swales and old channels; or, rarely, on flood plains and terraces. Thickness from 2 to more than 14 ft.	On floors of steep-sided to shallow kettles; other occurrences on flat or gently sloping surfaces. Covered with frost-produced hummocks or tussocks.	Winter: frost forms buried by snow. Break-up: flooded by melt water. Summer: moist or partially inundated. Freeze-up: dry to slightly moist on surface. Freezing of surface layer over weak, unfrozen subsurface silt creates hazardous bearing condition.	Very difficult to excavate unless thawed; blasting only moderately successful. Differential subsidence of ground upon thawing of permafrost.	Poor foundation for construction of any sort. Minor source for fine material.
Colluvium (Qc, Qca)	Qc, colluvium, poorly-stratified layers and lenses, and unstratified unconsolidated, angular to rounded, poorly-sorted detrital bedrock fragments and gravel 1 inch to 6 inches in diameter in a matrix of organic-rich sand or silt. Qca, alpine colluvium, unconsolidated angular to rounded, poorly-sorted granitic colluvium, with mixtures of alluvium, till, and talus.	Well drained except on moderate slopes, on treads of some lobes, and in frost scars and other depressions. Low permeability.	Depth to permafrost 2 to 5 ft. Moderate to high ice content.	Intense	Bearing strength high when frozen, low when thawed. Slopes in cuts subject to sloughing and landsliding upon thawing.	On slopes of foothills and in mountain valleys. Estimated thickness 1 to 20 ft.	Moderate to steep slopes. May occur as single or coalescing solifluction lobes, marked by terracettes, frost scars, festoons, stone stripes, and hummocks.	Winter: discontinuous snow cover. Break-up, summer, and freeze-up: moist or very moist and subject to frost action and mass movement.	Difficult to excavate or compact.	Poor foundation for construction. Poor source of construction material.
Glacial and non-glacial stream deposits undifferentiated (Qgp, Qgb)	Qgp, well-stratified layers and lenses of unconsolidated moderately to well rounded, light yellowish brown to gray sandy stream gravel. Gravel consists mostly of granitic rocks and ranges from ¼-inch pebbles to 12-inch boulders covered with ½ to 3 ft of gray to reddish-orange granitic sand; locally covered with organic-rich silt or eolian sand. Qgb, granitic boulder gravel: Boulders ½ to 4 ft in diameter, covered with a few inches of sand or silt.	Good surface drainage. Permeable except in frozen bogs near mountain front.	Permafrost at shallow depth beneath bogs, especially near mountain front. Elsewhere permafrost table is probably deeper than 20 ft. Low ice content except in bogs.	Unsusceptible except in mantle of silt.	Bearing strength high. Slopes generally unstable.	Composes piedmont of Granite Mountain, 30 to more than 100 ft thick. Merges westward with Delta outwash apron.	Moderate to gentle piedmont slopes; channelled; locally covered with large-diameter boulders, and sand or silt, Qgb.	Winter: discontinuous snow cover. Break-up: local flooding, especially in silt-filled swales. Summer and freeze-up: moist to dry, varies with cover and rainfall.	Easily excavated where thawed. Easily compacted.	Good source of gravel and coarse fill except where perennially frozen. Abundant ground water.
Rubble (Qr)	Unstratified unconsolidated sheets 1 to 4 ft thick of angular granitic or schistose fragments; locally contains matrix of sand or silt and somewhat sorted by frost action.	Fair to poor surface drainage. Impermeable substratum of permafrost.	Perennially frozen at 2 to 4 ft. Moderate to high ice content.	Coarse rubble unsusceptible; intense in fine fractions.	Bearing strength high when frozen or dry; fair to poor when thawed, unstable.	Small deposits on summits of Granite Mountain and higher foothills. Thickness estimated 1 to 4 ft.	Rests on flat or nearly flat upland surfaces; locally marked by a pattern of shallow trenches in a polygonal network.	Winter: discontinuous snow cover. Break-up, summer, and freeze-up: surface layers moist to wet.	Difficult to excavate or compact. Contains ice masses.	May be removed with difficulty for foundations on bedrock. Source of coarse ballast and aggregate, but generally inaccessible and poor source of construction material.
Glaciofluvial deposits (Qf_2, Qf_1)	Moderately well-stratified layers and lenses of well-rounded poorly to moderately well-sorted unconsolidated light yellowish brown silty or sandy gravel with lenses of well-sorted sand; gravel consists mostly of gneiss, granitic rocks, quartzite, and diorite and ranges from ½ inch to 12 inches in diameter. Qf_2, locally mantled by erratics, lake deposits, organic-rich silt; peat, and thin deposits of till.	Surface drainage poor to good. Excellent permeability except locally in silt or where perennially frozen.	Permafrost table more than 25 ft deep, except beneath silt-mantled areas where it occurs from 3 to 9 ft. Low ice content except in silt deposits.	Gravel unsusceptible; intense in fine fractions.	Bearing strength high except in local areas of silt and peat on the younger glacio-fluvial deposits. Steep slopes unstable.	Widespread older glacio-fluvial deposits Qf_1, stretch north of moraines on Delta River and Jarvis Creek. Younger deposits, Qf_2, lie behind the older moraine deposits, Qm_1, east of the Delta River. Maximum thickness of about 150 ft exposed on Delta River.	Outwash aprons merge with moraines; little or no relief. Younger deposits form scattered low hills of till and glaciofluvial deposits.	Winter: discontinuous snow cover. Break-up: local flooding, especially in silt-filled swales. Summer and freeze-up: moist to dry, varies with cover and rainfall.	Easy to excavate and compact with power tools except where perennially frozen.	Excellent foundation for structures and aircraft landing sites. Excellent source of gravel for subgrade and base-coarse material, and, if crushed and screened, for road metal and concrete aggregate. Source of enormous quantities of ground water.
Glacial-moraine deposits (Qm_2, Qm_1, Qmg, c)	Qm_1 and Qm_2, unstratified, poorly sorted, unconsolidated, gray to light yellowish brown sandy till consisting mostly of gneiss, granitic rocks, quartz, quartzite, and small amounts of mica schist and dark volcanic rocks; gravel particles range from angular to well-rounded and from 1 inch to 7 ft in diameter; includes sandy to gravelly stratified drift as lenses, kames, or channel fillings. Qm_2, till of younger advance. Qmg, moraines of Granite Mountain consist of gray to grayish-yellow bouldery sandy till largely composed of granitic rocks. c, channelled and eroded till.	Excellent to good surface drainage and permeability on slopes; poor surface drainage locally in swales, bogs, and other depressions where perennially frozen.	Permafrost table 3 to 5 ft in swales; estimated 10 to 25 ft on dry slopes and ridges. Ice content low to high.	Moderate to mild. Of samples tested 76 percent were susceptible to frost action.	Bearing strength high when frozen or dry; low in swales. Stable slopes when frozen, subject to sloughing, solifluction, and landsliding where thawed.	Large moraines along Delta River, east of Donnelly Dome, and on Jarvis Creek; small moraines at mouths of valleys in Granite Mountain. Thickness of largest moraines at least 175 ft.	Slightly modified knob and kettle topography, with closely spaced steep hillocks and ridges, and ponds; a few melt-water channels, kames and eskers. Poorly developed drainage system. Slopes 5 to 33 percent; relief from 50 to 175 ft.	Winter: normally bare wind-swept knobs, and drifted lee slopes and swales. Break-up, summer, and freeze-up: dry slopes and wet to moist swales.	Moderately difficult to excavate. Fairly easy to compact.	Good to poor for foundation and source of fill. Kames and other stratified drift good sources of construction material.
Glaciofluvial deposits (Qgf)	Moderately well-stratified layers and lenses of well-rounded poorly to moderately well-sorted unconsolidated yellowish gray-brown silty or sandy gravel with lenses of well-sorted sand; gravel consists mostly of gneiss, granitic rocks, quartzite, quartz, and diorite; particles range from ½ inch to 12 inches in diameter.	Excellent to good surface drainage and permeability except locally where perennially frozen.	Permafrost table 3 to 5 ft beneath silt covered area and probably more than 25 ft elsewhere. Low ice content.	Mild to unsusceptible. Of samples tested 13 percent were susceptible to frost action.	Bearing strength high. Scarps and steep slopes unstable.	Small deposits in or adjacent to morainal deposits; merges eastward with Qgp. Thickness 10 ft to more than 100 ft.	Small outwash aprons gently slope to the north; truncated by mountain creeks.	Winter: discontinuous snow cover. Break-up: local flooding, especially in silt-filled swales. Summer and freeze-up: moist to dry, depending on silt cover and rainfall.	Easily excavated and compacted except where perennially frozen.	Limited areas excellent foundation for structures and aircraft landing sites. Excellent source of gravel for subgrade and base-course material, and, if crushed and screened, for road metal and concrete aggregate.
Glacial-moraine deposits (Qgl, Qgg, Qge)	Qgl, unstratified, poorly sorted, unconsolidated yellowish-gray to grayish-brown sandy till locally perennially frozen with low ice content. Till consists mostly of gneiss, granitic rocks, quartz, and diorite; small coal particles occur locally. Gravel particles range from angular to well-rounded and from 1 inch to 12 inches in diameter. Includes sandy to gravelly stratified drift as lenses, kames, and channel fillings. Qgg, moraines of Granite Mountain consist of gray to grayish-yellow bouldery sandy till largely composed of granitic rocks. Qge, erratics of gneiss, schist, quartz, quartzite, and granitic rocks ½ to 4 ft in diameter.	Excellent to good surface drainage and permeability on slopes; poor surface drainage locally in swales, bogs, and areas where perennially frozen.	Permafrost table 3 to 4 ft in swales and muskeg-covered slopes; probably 25 ft deep on dry slopes and knobs. Ice content low to high.	Moderate to mild. Of samples tested 78 percent were susceptible to frost action.	Bearing strength high when frozen or dry. Slopes stable when frozen; subject to sloughing, solifluction, and landsliding when thawed.	Large moraines, Qgl, cover the lowland; small moraines, Qgg, exist along front of Granite Mountain. Maximum thickness probably 225 ft.	Gently rolling knob and swale topography with shallow ponds; partially developed drainage system. Slopes 1 to 20 percent.	Winter: bare wind-swept knobs, and drifted lee slopes and swales. Break-up: moist slopes and wet or inundated swales. Summer and freeze-up: dry to moist slopes and moist to wet swales.	Moderately difficult to excavate. Fairly easy to compact.	Limited amount of good to poor foundation material and fill available under silt cover. Kames and other stratified material good sources of construction material.
Nenana Gravel (Tn)	Poorly consolidated moderately well-sorted yellowish conglomerate and sandstone; particles consist chiefly of iron-oxide stained quartz, quartzite, and gneiss, ¼ to 8 in. in diameter.	Unknown	Probably present.	Unsusceptible	Bearing strength high. Slopes stable.	Small exposures in Jarvis Creek above its junction with Ober Creek. Maximum exposed thickness 30 ft.	Vertical cliffs and gentle slopes.	Not significant.	Moderately difficult to excavate. Difficult to compact.	Unimportant and inaccessible source of gravel and sandstone.
Coal-bearing rocks (Tc)	Lenses and layers of poorly consolidated sandstone, siltstone, claystone, conglomerate, and lignitic coal.	Good surface drainage and good to poor permeability.	Probably present.	Moderate to intense.	Bearing strength high. Steep slopes unstable.	Small outcrops occur high on west side of hill between Delta River and Donnelly Dome. Maximum vertical section approximately 71 ft.	Gentle to steep slopes on small spurs facing Delta River.	Winter: bare wind-swept spurs. Break-up, summer, and freeze-up: possible mass movement, especially when saturated.	Easy to difficult excavation with hand tools. Difficult to easy to compact.	Good to poor foundation for structures. Coal beds too thin and limited for commercial use.
Granodiorite (gr, grx)	gr, gray, medium- to coarse-grained, locally porphyritic granodiorite. grx, near contact with p€bc, locally gneissic and intimately intercalated with schist.	Good surface drainage. Poor permeability.	Probably present.	Intense frost riving.	Bearing strength high. Steep slopes stable.	Granite Mountain.	Glaciated alpine topography, with cirques and U-shaped valleys. Steepest slopes 170 percent.	Winter: snow covered except on steepest slopes. Break-up, summer, and freeze-up: short period of active gullying by snow melt, frost riving and heaving, and some stream erosion after heavy rains.	Requires blasting to quarry. Difficult to compact.	Weathered mantle good for base-course material, road metal, and concrete aggregate, without crushing. Fresh rock good for riprap or pervious fill.
Birch Creek Schist (p€bc)	Light-gray to greenish-gray or brown quartz-sericite schist, quartzite, slate, and gneiss with many quartz stringers. Original sedimentary structures essentially obliterated.	Good to excellent surface drainage. Joints, faults, fracture cleavage, and foliation result in poor to fair permeability. Upper weathered layer has very poor permeability.	Probably present.	Locally moderately susceptible in weathered rock. Mild to moderate frost riving on fresh outcrops.	Gneissic facies, bearing strength high; stands in vertical cuts. Schistose facies, bearing strength high in horizontal or vertical beds, moderate in dipping beds. Susceptible to *sliding and slumping* along joint, cleavage, and *foliation* planes, especially sericite-laden planes.	Hill west of Donnelly Dome, Donnelly Dome, and hill between Ober Creek and Jarvis Creek.	Glacially modified bedrock foothills. Slopes range between 60 and 100 percent.	Winter: discontinuous snow cover. Break-up, summer, and freeze-up: subject to frost riving, creep, and deep weathering.	Easily excavated with power tools with little to moderate blasting. Difficult to moderately difficult to compact.	Gneissic facies good for base-course material and road metal; schist poor.

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