DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

ENVIRONMENTAL GEOLOGY AND FOUNDATION PROBLEMS

In the Fairbanks area, the effects of development on the geologic environment must be considered in determining proper land use. Persons concerned with the land, especially land planners, developers, public officials, engineers, architects, financial advisors, and educators, must be aware of recognizable geologic features that may prove hazardous; only then can correct and economical land use be insured.

To provide a background for people concerned with the land, basic data from the Geologic map of the Fairbanks D-2 NE quadrangle (Map I-950, Péwé and others, in press), the Map showing distribution of permafrost in the Fairbanks D-2 NE quadrangle (MF 670A, Péwé and Bell, 1975a), and the Map showing ground-water conditions in the Fairbanks D-2 NE quadrangle (MF-670B, Péwé and Bell, 1975b) have been recast into this foundation map. The description of units outlines in simple and basic terms the major problems and the various foundation conditions in the quadrangle.

Not only do conventional foundation and constructional problems occur, but unique problems related to permafrost and seasonal frost action complicate the otherwise normal land use. The bedrock is, in general, a solid foundation that presents no major problem. Most of the unconsolidated sediments would provide fair to good foundations in more temperate latitudes. In the Fairbanks area, however, the widespread blanket of silt is very susceptible to intense seasonal frost action, especially where poorly drained. Theoretical frost-heaving forces are given below. To prevent frost heaving, special precautions must be taken in the construction of roads, air fields, bridges, unheated buildings, and structures on piers or pilings. At some places, the silt can be removed; in others, drainage must be improved. It is also possible to anchor structures in the underlying permafrost to eliminate the effects of frost heaving.

Permafrost is critical in evaluating land use. Permafrost, or perennially frozen ground, is defined as soil or bedrock that remains at or below 32°F for two or more years. In this area, as well as in other parts of the North, many types of structures have been extensively damaged because the existence and nature of the frozen ground were little understood.

The first step in preparing the land for construction or farming is usually the stripping of the vegetative cover, an operation that disturbs the natural thermal equilibrium and causes thawing of the permafrost if present. As the ground thaws, the ground surface and anything on it settle differentially, sometimes producing severe damage. The type and extent of permafrost vary, and the consequences of building on ice-rich ground vary as well.

The foundation map presents as much data as possible on engineering problems that would be found in any particular area. Information is presented on frost heaving and permafrost and on general ground stability and soil properties.

Five foundation units are defined: I, bedrock; II, tailings; III, loess; IV, muck; V, peat muck. Each unit poses different foundation problems, depending on the presence and type of permafrost, the mechanical properties of the material whether or not it is consolidated, and its characteristics upon thawing. The conditions within a unit are generalized and may vary locally, especially near contacts.

The most critical foundation problem is the existence of large, massive ground-ice masses in the reworked valley-bottom silts (units IV and V).

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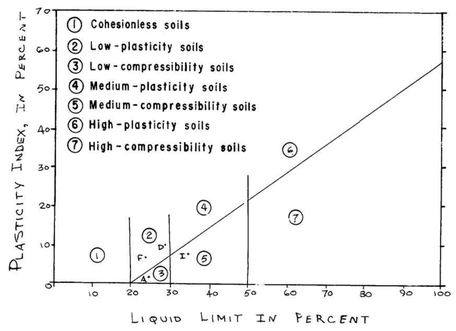
PLASTICITY AND COMPRESSIBILITY CHART



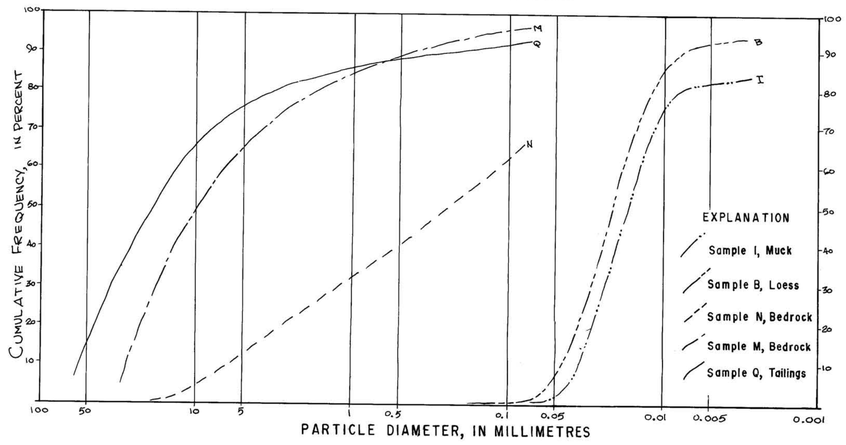
Relation of plasticity and compressibility to plasticity index and liquid limit for samples (indicated by letters) in the Fairbanks D-2 NE quadrangle. Although none of the samples fall into groups 4, 6, or 7, it does not necessarily mean that these groups are absent from the area. After Legget (1967, fig. 5).

Date	Depth of frost penetration, in feet	Maximum force pushing upward, in pounds
November 1	1	21,600
December 1	1.5	32,400
January 1	2	43,200
February 1	3	64,800
March 1	4	86,400
April 1	4.5	97,200

POSSIBLE EFFECTS OF FROST HEAVING

Hypothetical example of seasonal frost penetration into silt in central Alaska and possible upward push on 40-inch-perimeter pile (ground temperature constant) (Péwé and Paige, 1963, table 6)

CUMULATIVE FREQUENCY CURVES OF SORTING OF REPRESENTATIVE SAMPLES



The graph shows the frequency of occurrence of particles of various sizes in several types of foundation materials from the Fairbanks D-2 NE quadrangle. The slope of a curve indicates the degree of sorting of the material--the steeper the slope, the higher the degree of sorting.

ANALYSES OF SAMPLES FOR FAIRBANKS D-2 NE QUADRANGLE

Type of material	Sample number	Township	Range	Section	¼ Section	¼ of ¼ Section	Map unit	Description of material	Mechanical analyses: Percent smaller than size units in millimeters (U.S. Standard Sieve Size) .417 (#40)	.074 (#200)	.022	.005	AASHO class.	Laboratory tests[1] Properties: Specific gravity	Max. density lb/cu ft	Unit weight lb/cu ft: Loose	Dry Rodded	Absorption percent	L.A. Abrasion % loss	Liquid limit	Plastic limit	Plasticity index	Moisture content: Unfrozen: Percent by dry weight	Depth of sample	Frozen: Permafrost: Percent by dry weight	Depth of sample	Seasonal frost: Percent by dry weight	Depth of sample	Date collected
Soils	A	1N	1W	36	NE	NW	Loess	Windblown upland silt		98.6	36.0	13.0 (3)	A-4(8)	2.60	102.0					24.7	22.9	1.8 (3)	11.4	2 ft 6 in					
	B	1N	1E	30	NE	NE	Loess	Windblown upland silt	100	99	53	7	A-4(8)	2.70		61	69			NV	NP	NP	12.3	3-7 ft					10-69
	C	2N	1E	35	SW	SW	Loess	Windblown upland silt	100	98	41	6 (4)	A-4(8)	ND						ND	ND	ND	ND	ND					
	D	2N	1W	33	SE	NE	Muck	Reworked valley bottom silt	90	80	22	0	A-4(8)	2.73		70	70.6			28.9	18.9	10	23.7	16-17 ft					8-26-66
	E	2N	1W	35	SW	SW	Muck	Reworked valley bottom silt	ND	ND	ND	ND	A-4(8)												27.8.3	15-17 ft			8-29-66
	F	1N	1E	18	NW	NE	Muck	Reworked valley bottom silt	81	53	32	18	A-4(8)	2.74		67	80			24.1	17.1	7.0			ND	ND			12-69
	G	1N	1W	25	SE	SW	Muck	Reworked valley bottom silt	100	98	40	13	A-4(8)	2.69		70	78			NV	NP	NP			ND	ND	53.0	1-3 ft	2-70
	H	1N	1W	36	NE	NW	Muck	Reworked valley bottom silt	100	99	51	9	A-4(8)	2.56		56	65			NV	NP	NP			97.6.0	15-19 ft			10-69
	I	1N	1W	36	NW	NW	Muck	Reworked valley bottom silt		99.1	65.6	17.0 (3)	A-4(8)	2.00	85.2					34.3	26.8	7.5 (3)	42.6	1 ft	93.9	1 ft 6 in	56.32	10 in.	1-24-56
	J	1N	1W	35	NE	NE	Peat-muck	Reworked organic valley bottom silt	80.0	44.0				0.35	22.0	Organic content (ignition loss) 54 1/4							27.6.5	1 ft	141.0	1 ft 8 in	315.0	1 ft	1-24-56
Aggregates (after crush)									50.8 (2")	38.10 (1½")	25.40 (1")	19.05 (3/4")	12.70 (1/2")	9.53 (3/8")	4.76 (#4)	2.0 (#10)	.417 (#40)	.074 (#200)											
	K	1N	1E	20	NW	SW	Bedrock	Hard brown schist w/soft layers				98	96	91	81	57	44	31	22	A-1-b	2.74	130.0	93	103	1.8	ND	NV					
	L	1N	1E	19	NE	NE	Bedrock	Weathered mica schist				100	99	97	83	66		39	18	A-1-b	2.75	ND	88	98	4.3	ND	NV					
	M	1N	1E	18	SW	SE	Bedrock	Blocky, compact sericitic schist, light gray with iron staining	100	100	86.0	71.39	60.32	47.13	33.08			10.54	4.55	A-1-a	2.33	ND	89.0	106.0	3.50	38.75	NV					
	N	1N	1E	7	SW	SE	Bedrock	Weathered schist				100	98	95	85	75	58	31		A-2-4	2.74	ND	83	89	2.8	ND	NV					
	O	2N	1W	36	SE	SE	Bedrock	Fine to coarse grained limestone	100	100	100	98.6	86.2	51.0	21.5		5.8	3.1		A-1-a	2.87	ND	ND	ND	ND	23.8	NV					
	P	1N.	2W	1	NW	SE	Tailings	Coarse grained dredge tailings	80	57	33	21	15	13	11	9	6	4		A-1-a	2.80	ND	ND	ND	ND	4.5	NV					
	Q	1N	2W	1	SE	NW	Tailings	Coarse grained dredge tailings	86	73	59	50	39	32	24	19	12	6		A-1-a	2.82	ND	112	114	ND	42	NV					
	R	1N	1W	1	SE	SW	Tailings	Coarse dredge tailings; schist 45%, quartz 29%, gneiss 26%				94.7	90.7	76.9	56.7	29.9		5.7	2.3	A-1-a	2.57	137.7	98.0	112.0	1.17	38	NV					

Heavy Mineral Analysis of Typical Loess[2]

Mineral	Numerical frequency in percent
Opaque	57.0
Zoisite	10.3
Hornblende	10.1
Garnet	9.6
Epidote	7.2
Unknown fragments	6.0
Clinozoisite	3.8
Augite	3.1
Sphene	3.1
Tourmaline	2.8
Hypersthene	2.6
Zircon	1.9
Apatite	1.4
Rutile	0.7
Enstatite	0.2
Tremolite	0.2

Separation made with acetylene tetrabromide; permanent mount made in Canada balsam; 415 grains counted. Opaque minerals approximately 70% magnetite and ilmenite. All isotropic grains listed as garnet.

Footnotes

1. All laboratory tests, unless otherwise noted, by the Fairbanks District of the Alaska Road Commission, Dept. of Interior, and its successor.
2. Analysis by Troy L. Péwé.
3. Analyses by Frost Effects Laboratory, Corps of Engineers, U.S. Army, Fairbanks, Alaska.
4. Analyses by Permafrost Division, St. Paul Office, Corps of Engineers, U.S. Army, Fairbanks, Alaska.

NV: Not viscous
NP: Not plastic
ND: No data

DESCRIPTION OF MAP UNITS

Map unit	Distribution and thickness	Terrain and natural slopes	Drainage and permeability	Permafrost	Susceptibility to frost action	Bearing strength and slope stability	Excavation and compaction	Possible use
Bedrock (I)	Exposed on hilltops and steep slopes where loess cover less than 3 ft thick. Upper weathered layer 1-2 ft thick on upper slopes; more than 75 ft thick on lower slopes.	Rounded gently rolling topography; moderately steep north-facing slopes common in some places.	Surface drainage good to excellent. Joints, faults, fracture cleavage, and foliation result in poor to fair permeability. Upper weathered layer has low permeability.	Locally perennially frozen under muck and tailings in creek valley bottoms and on north-facing slopes. Depth to permafrost on north-facing slopes 1-4 ft; locally 1-100 ft thick. Low ice content as interstitial ice in unweathered bedrock; low to moderate ice content as seams and interstitial ice in weathered bedrock. Water table generally deep.	Moderately susceptible in weathered bedrock.	High bearing strength in fresh bedrock; generally high in weathered bedrock if ice content low or absent. Highest bearing strength on horizontal or vertical dipping beds. Susceptible to sliding and slumping along joints, cleavage, and foliation planes, especially the mica-laden planes.	Weathered bedrock easily excavated with hand or power tools, except where frozen. Unweathered schist is generally easily excavated with power tools with only little to moderate blasting; some varieties, especially the quartzite facies and vein quartz, may require additional blasting. Resistant layers more easily excavated where interbedded with schistose rocks. Loosened rock easily compacted with power tools; unweathered granite requires blasting. Difficult to moderately difficult to compact both unweathered and weathered bedrock.	Schist varieties good for unclassified embankment fill; fair for selected use such as base course if processed; breaks down to silt with repeated traffic and frost action. Softer varieties, such as the quartzite facies and vein quartz, good for rip rap and ballast, and coarser aggregate; if processed, good for base course and asphalt aggregate. Many varieties, especially the marble facies, are good as decorative rocks.
Tailings (II)	Placer mine dredge tailings at Goldstream Creek, Engineer Creek and Pedro Creek. Thickness 3-50 ft.	Steep, imbricate, parabolic, symmetrical gravel piles forming rough terrain with some undrained depressions. Leveled in places.	Material loose, porous, and slightly compacted. Excellent drainage and permeability except where locally perennially frozen.	Locally perennially frozen; low ice content; primarily interstitial.	Unsusceptible.	High bearing strength. Slopes generally stable at 1:1:1.	Easily excavated by power tools, except where frozen. Relatively easily compacted.	Good foundation for any structure if tailing piles leveled. Good for subgrade, ballast, rip rap, pervious fill, and if crushed and screened, good for base course and aggregate. Possible sites for sanitary landfill.
Loess (III)	Widespread on middle and upper slopes and on lower hillsides. Thickness range from 3 ft on upper slopes to a maximum of over 200 ft on middle slopes. Not mapped where less than 3 ft thick.	Gently rolling terrain with low rounded hills. Old, slightly subdued parallel gullies and ridges at right angles to contours; characteristic of most upper slopes.	Good surface drainage. Lateral permeability poor to fair; vertical permeability good.	Generally permafrost free. Permafrost may be present on north-facing slopes with little or no ice content. Water table deep.	Moderate to unsusceptible; locally high if drainage poor.	High bearing strength when dry and in original position; very low when wet. Will stand in nearly vertical slopes. Extremely susceptible to gullying; freshly exposed surfaces susceptible to wind erosion.	Easily excavated with hand tools, except where frozen. Difficult to compact.	Source of fine-grained sediment, possible source of impervious fill and unclassified embankment fill. Good foundation for heated structures if protection is provided against gullying. Dessicated roads unstable; powdery when dry, plastic and sticky when wet. Good agricultural soil if fertilized. Possible sites for sanitary landfill.
Muck (IV)	Widespread on lower slopes and valley bottoms. Thickness 3-30 ft.	Very gently sloping alluvial fans and colluvial slopes; broad alluviated creek valley bottoms with small lakes.	Impermeable substratum of permafrost, especially in valley bottoms, creates poor drainage; marshy and undrained in summer. Land clearing and thawing of permafrost table improves drainage near contact with the loess; produces quagmire in valley bottoms. Permeability low to moderate.	Depth to permafrost 1½-3 ft on lower slopes and valley bottoms; 5-20 ft near the contact with the loess; 10-25 ft under cleared areas. Seasonal frost layer 1½-3 ft thick. Permafrost 3-30 ft thick; patches not spongy; continuous except under lakes and near contact with the loess. Ice content high as seams and lenses; content high in underlying unit V as seams, lenses, and massive ice. Commonly arranged in polygonal pattern. Water table below permafrost. Permafrost temperature averages 31-32°F. Pingos occur locally.	High.	High bearing strength when frozen or dry; very low when wet or thawed. May stand in nearly vertical abutments cut near contact with the loess. Subject to sloughing and sliding upon thawing; when drained stable at 2/3:1:1. Very susceptible to gullying.	Very difficult to excavate unless thawed; blasting only moderately successful. When thawed, viscous sediment slides into excavation except near contact with loess or on low hills. Difficult to compact. Great differential subsidence when thawed.	Poor foundation for construction. Upon thawing of permafrost thermokarst mounds 10-50 ft in diameter and 1-10 ft high and pits 3-30 ft in diameter and 5-20 ft deep form on the surface. Condition may improve near contact with the loess where permafrost table lower and permafrost sporadic. Can serve as solid foundation if permafrost prevented from thawing and structures designed to absorb frost-heaving effects. Source of fine-grained sediment; possible source of impervious fill. Good for agricultural use if fertilized. Unsatisfactory for sanitary landfill sites unless permafrost prevented from thawing or landfill frozen.
Peat-muck (V)	Occurs in valley bottoms. Thickness 10 to more than 300 ft.	Flat fens with small steep sided caves in lakes and a pattern of trenches 1-4 ft deep and 2-5 ft wide in polygonal network.	Impermeable substratum of permafrost and organic material creates very poor drainage; marshy and undrained in summer. Land clearing produces summer quagmire. Permeability poor.	Depth to permafrost 1½-3 ft. Seasonal frost layer 1½-3 ft. Permafrost 1-140 ft thick; continuous except under lakes. Ground-ice content high as seams, lenses, and massive ice. Water table 1½-10 ft below the surface. Water table below permafrost. Pingos occur locally.	High.	High bearing strength when frozen; very low when thawed. Slopes in cuts subject to sloughing and sliding upon thawing.	Very difficult to excavate unless thawed; blasting only moderately successful. When thawed, viscous sediment slides into excavation. Difficult to compact. Great differential subsidence when thawed.	Very poor foundation for construction of any sort. Thawing of permafrost results in formation of thermokarst mounds 1-10 ft high and 10-50 ft in diameter and pits 3-30 ft in diameter and 5-20 ft deep. Can serve as solid foundation only if permafrost prevented from thawing and structures designed to absorb frost-heaving effects. Poor for agriculture. Poor for sanitary landfill sites. Good for mosquito studies!!!

SUPPLEMENTARY DATA TO ACCOMPANY

MAP SHOWING FOUNDATION CONDITIONS IN THE FAIRBANKS D-2 NE QUADRANGLE, ALASKA

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1975

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