DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF- 671-D
SHEET 2 OF 2

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 proper 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-1 SW quadrangle (Map I-949, Péwé and others, in press), the Map showing distribution of permafrost in the Fairbanks D-1 SW quadrangle (Map MF-671A, Péwé and Bell, 1975a), and the Map showing ground water conditions in the Fairbanks D-1 SW quadrangle (Map MF-671B, 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 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.

Six foundation units are defined: I, bedrock; II, river gravel; III, loess; IV, river silt; V, muck; VI, peat muck. Each unit poses different foundation problems depending upon 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 V and VI). Small ice wedges occur locally in some broad, river-silt deposits (unit IV) of the flood plain.

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)

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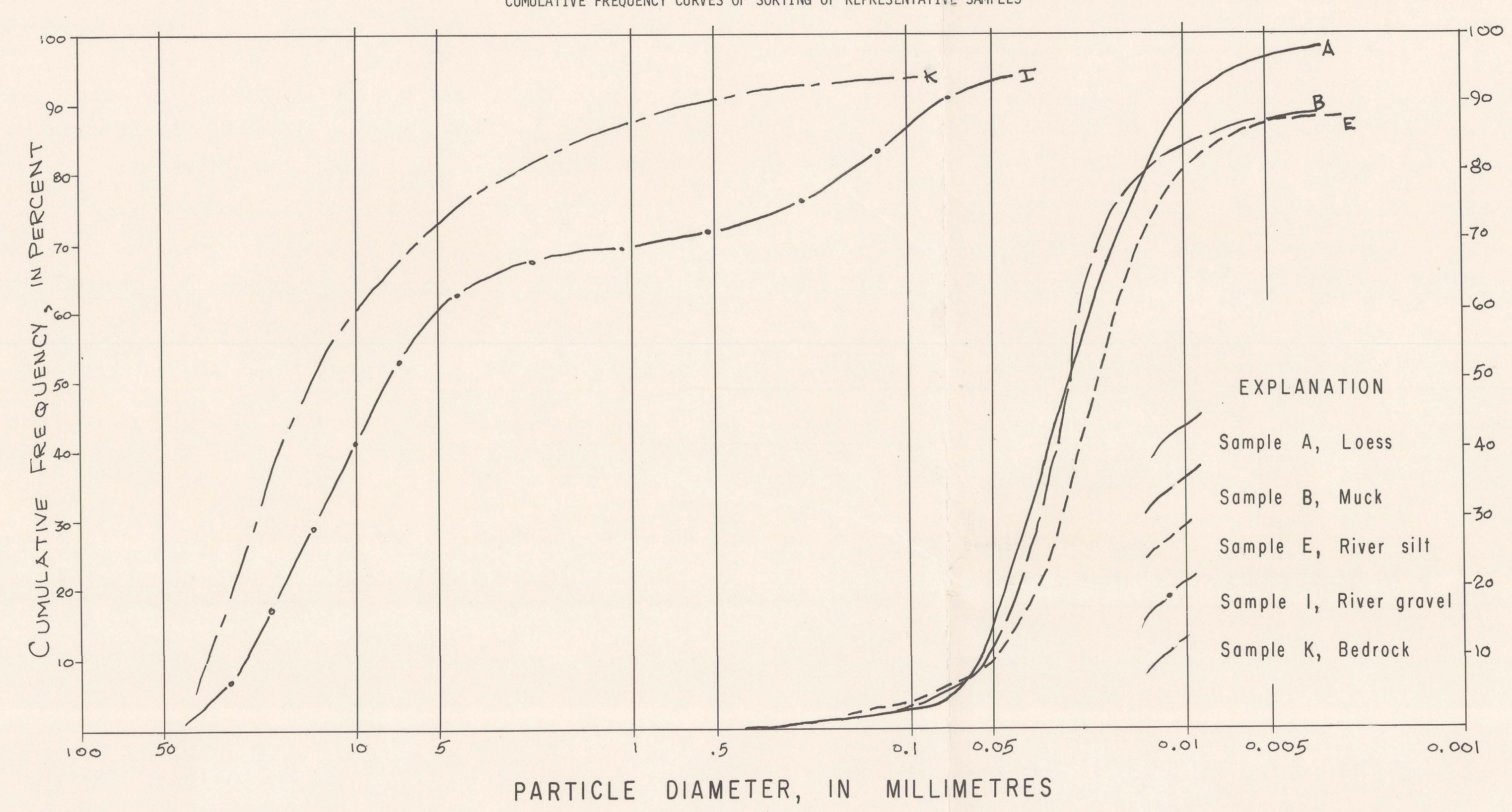
CUMULATIVE FREQUENCY CURVES OF SORTING OF REPRESENTATIVE SAMPLES



The graph shows the frequency of occurrence of particles of various sizes in several types of foundation materials from the Fairbanks D-1 SW 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-1 SW QUADRANGLE

Type of material	Sample letter	Township	Range	Section	1/4 Section	1/4 of 1/4 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	Laboratory tests[1]: AASHO class.	Specific gravity	Max. density lb/cu. ft.	Unit weight lb/cu. ft.: Loose	Dry rodded	Adsorption 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	Frozen, seasonal frost: percent by dry weight	Depth of sample	Date collected
Soils	A	1S	1E	14	SW	SW	Loess	Windblown upland silt	100	96	39	4(3)	A-4(8)							ND	ND	ND							
Soils	B	1N	1E	36	NE	SE	Muck	Retransported valley bottom silt	100	95	33	13	A-4(8)	2.69						NV	NP	NP			30.6	31-32 ft	45.5	1-2 ft	4-70
Soils	C	1N	1E	36	SE	SE	Muck	Retransported valley bottom silt	Peat																522.5	1-4 ft			4-70
Soils	D	1S	2E	5	NW	NW	Muck	Retransported valley bottom silt	A4 silt											ND	ND	ND			152.6	7-8 ft			4-70
Soils	E	1S	2E	7	NE	NE	River silt	River slough and top silt	100	94	53	13	A-4(8)	2.67		54	71			NV	NP	NP					35.2	2-4 ft	4-70
Soils	F	1S	2E	7	SW	SW	River silt	River slough and top silt	99	83	64	22	A-4(8)	2.74						NV	NP	NP	36.5	10-11 ft					4-70
Soils	G	1S	2E	7	NE	SE	River silt	River slough and top silt	100	61	24	8	A-4(6)	2.68	34.7					NV	NP	NP			43.9	7-8 ft			4-70

Type of material	Sample letter	Township	Range	Section	1/4 Section	1/4 of 1/4 Section	Map unit	Description of material	50.8 (2")	38.10 (1½")	25.40 (1")	19.05 (3/4")	12.70 (½")	9.39 (3/8")	4.76 (#4)	2.0 (#10)	.417 (#40)	.074 (#200)	AASHO class.	Specific gravity	Max. density lb/cu. ft.	Loose	Dry rodded	Adsorption percent	L.A. abrasion % loss	Liquid limit
Aggregates (before crush)	H	1S	2E	18	NW	NW	River gravel	River gravel	100		91	78	56	39	19	14	13	4	A-1-a	2.70				0.5	27	NV
Aggregates (before crush)	I	1S	2E	7	NW	NW	River gravel	River gravel	100		90	79	65	59	38	32	27	9	A-1-a	2.69					24	NV
Aggregates (before crush)	J	1S	1E	12	NE	NE	River gravel	River gravel	100		99	97	90	79	49	37	24	8	A-1-a	2.67		109	122	0.6	24	NV
Aggregates (before crush)	K	1S	1E	14	SW	SW	Bedrock	Basalt (after crush)		93.0	74.6	53.2	45.6		25.0		9.7	6.5	A-1-a	2.47		90.0	109.2	2.36	19.0	NV

HEAVY MINERAL ANALYSIS OF TYPICAL LOESS[2]

Mineral	Numerical frequency in percent
Opaque	37.0
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 Alaska Department of Highways.
2. Analysis by Troy L. Péwé.
3. Analyses by Rock Island Office, Corps of Engineers, U.S. Army, Rock Island, Ill.

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 1-3 ft thick on upper slopes; more than 75 ft thick on lower slopes.	Rounded gently sloping topography. Steep slopes adjacent to river flood plain.	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 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 horizontally or vertically dipping beds. Schist varieties susceptible to sliding and slumping along joint, cleavage, and foliation planes, especially mica-laden planes.	Weathered bedrock easily excavated with hand or power tools, except where frozen. Unweathered schist is generally easily excavated with 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. Weathered basalt easily excavated with power tools; unweathered basalt may require 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. Harder varieties, such as the quartzite facies and vein quartz, good for rip rap and ballast and coarse aggregate; if processed, good for base course and road metal. Basalt excellent for subgrade, base course, or pervious fill without crushing and good for road metal and concrete aggregate if crushed. Many varieties, especially the marble variety, are good as decorative rocks.
River gravel (II)	Covers most of the quadrangle. Surface layer of silt 1-15 ft thick. Total thickness of alluvium adjacent to bedrock hills 1-200 ft; thickness as much as 400 ft near Tanana River.	Flat plain with meandering streams and complex network of shallow swales.	Drainage excellent and permeability high except locally in silt or where perennially frozen. Drainage improves with land clearing and lowering of permafrost table. Subject to flooding.	Depth to permafrost 2-4 ft in older parts of flood plain and more than 4 ft on inside of meander curves near river. Depth to permafrost 25-40 ft in some cleared areas. Permafrost absent or deep beneath lakes, rivers, and creeks. Seasonal frost layer 2-9 ft thick. Permafrost 2-275 ft thick. Permafrost discontinuous; unfrozen lenses, layers, and vertical zones. Low ground-ice content and mostly interstitial in sand and gravel; ice content low to moderate in top silt layer. Water table 10-15 ft where permafrost absent or deep.	Silt, moderate to high; sand and gravel, unsusceptible.	High bearing strength when frozen; sand and gravel high when thawed, silt moderate to high when thawed and well drained; low when poorly drained. Slopes may stand at 1:1 to 2/3:1 except in unfrozen sand.	Easily excavated with power equipment, except where frozen. Difficult to compact. Slight subsidence in silt when thawed; very little or no subsidence in sand and gravel when thawed.	Good foundation for structures; upper silt layer should be removed if structure is unheated to prevent frost heaving. Gravel good for subgrade, base course, and if crushed and screened, for road metal and concrete aggregate. Source of tremendous quantities of groundwater. Surface silt fair to good for agriculture if fertilized. Generally unsatisfactory for sanitary landfill sites because of high water table.
Loess (III)	Widespread on middle and upper slopes and on lower hilltops. Thickness ranges 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. Unsurfaced roads unstable; powdery when dry, plastic and sticky when wet. Good agricultural soil if fertilized. Possible sites for sanitary landfill.
River silt (IV)	Widely distributed in a complex drainage network on flood plain in southern three-fourths of the quadrangle as broad basin-like areas and elongate, sinuous meander scars. Thickness generally less than 15 ft; maximum probably more than 30 ft.	Elongate, sinuous, flat-floored meander and slough scars and wide shallow basin-like areas. Some intermittent streams present.	Impermeable substratum of permafrost and organic silt in broad basin-like depressions creates poor drainage; marshy and undrained in summer. Drainage slightly better in linear scars. Drainage in both types improves slightly to moderately with land clearing and lowering of permafrost table. Subject to flooding.	Depth to permafrost 1½-4 ft. Active layer 1½-4 ft. Permafrost 5-30 ft thick; continuous in broad basins; discontinuous in meander scars, generally absent in young sloughs. May be in contact with underlying permafrost of river sand and gravel. Moderate to high ice content as thin seams and lenses. Water table 10-15 ft where permafrost absent or deep.	High.	High bearing strength when frozen; very low when thawed. Slopes subject to sloughing and sliding when thawed until well or moderately well drained.	Very difficult to excavate unless thawed. When thawed, viscous sediment slides into excavation. Difficult to compact. Moderate subsidence when thawed.	Poor for construction foundation or fill. Should be removed prior to construction. Possible source of clayey silt. Unsatisfactory for sanitary landfill sites because of high water table and permafrost.
Muck (V)	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 lowering of permafrost table improves drainage near contact with 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; pinches out upslope; continuous except under lakes and near contact with the loess. Ice content high as seams and lenses; content high in underlying unit VI as seams, lenses, and large foliated ice masses 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 shallow cuts near contact with the loess. Subject to sloughing and sliding when thawed; when drained stable at 2/3:1. Very susceptible to gullying.	Very difficult to excavate unless thawed; blasting 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 10-15 ft in diameter and 1-10 ft high and pits 3-30 ft in diameter and 5-20 ft deep form on surface. Condition may improve near contact with the loess where permafrost table is 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. Poor to fair for agriculture if fertilized. Unsatisfactory for sanitary landfill sites unless permafrost prevented from thawing or landfill frozen.
Peat-muck (VI) (Shown in cross section only)	Occurs in valley bottoms. Thickness 10 to more than 300 ft.	Flat fans with small steep-sided cave-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 large foliated ice masses 1½-10 ft below the surface. Water table below the permafrost. Pingos occur locally.	High.	High bearing strength when frozen; very low when thawed. Slopes in cuts subject to sloughing and sliding when thawed.	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 the structure is 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-1 SW QUADRANGLE, ALASKA

TROY L. PÉWÉ AND JOHN W. BELL
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