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Generalized Interpretation of Geologic Materials from Shot Holes Drilled for the Trans-Alaska Crustal Transect Project, Copper River Basin and Adjacent Regions, Alaska, May-June 1984

By

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INTRODUCTION

The Trans-Alaska Crustal Transect (TACT) project is designed as one of the first parts of the broader Trans-Alaska Lithosphere Investigation (TALI) program of coordinated geological and geophysical study of the structure and evolution of the crust and upper mantle of Alaska. The study focuses on a north-south corridor across the middle of the State and extends onto the continental margins (Page, 1984). Although the U.S. Geological Survey is the lead organization in the program, many other institutions are collaborating in this effort which will last for several years. The corridor of prime interest roughly parallels the trans-Alaska oil pipeline; of somewhat lesser interest are several subsidiary cross corridors. Work concentrated on southern areas of the prime corridor during 1984, which included reevaluation of bedrock and structural relationships in selected areas flanking the Copper River basin. In addition, magnetic, gravity, and seismic refraction studies were undertaken. Preliminary interpretations of geological and geophysical data have been presented (Page and others, 1984; Plafker and others, 1985; Fuis and others, 1985; Nokleberg and others, 1985a, b).

This report presents a generalized interpretation of geologic materials recovered from shot holes drilled as part of the study of deep geologic structure by seismic refraction methods. Holes were located (1) north-south over a distance of about 110 mi in the Copper River basin and adjacent mountain valleys, and in nearby parts of the Alaska Range and Chugach Mountains and (2) southwest-northeast over a distance of about 115 mi in the Copper River basin and its broad valley extensions (fig. 1).

DRILLING OPERATIONS AND SAMPLING

A total of 21 holes were drilled and steel-cased between May 30 and June 27, 1984. They ranged in depth from 140 to 185 ft; five were predominantly in bedrock and the remainder in unconsolidated materials. Most samples were collected and examined during the drilling operation. A few days after completion of a hole, temperature measurements, using thermistors, were taken through the casing by permafrost researchers working on projects designed by T. E. Osterkamp, Koji Kawasaki, J. K. Petersen, and George Walker, all of the University of Alaska at Fairbanks. Loading of the holes with explosives took place soon after temperature measurements were completed. Detonation of the explosives was accomplished a few weeks later.

The drill employed was a modified conventional- and percussion-type rotary Ingersoll-Rand TH 60 Cyclone Model, operated by M-W Drilling, Inc., Anchorage, Alaska. Air was the drilling medium for most of the percussion drilling in the bedrock holes, but during some of the bedrock drilling and

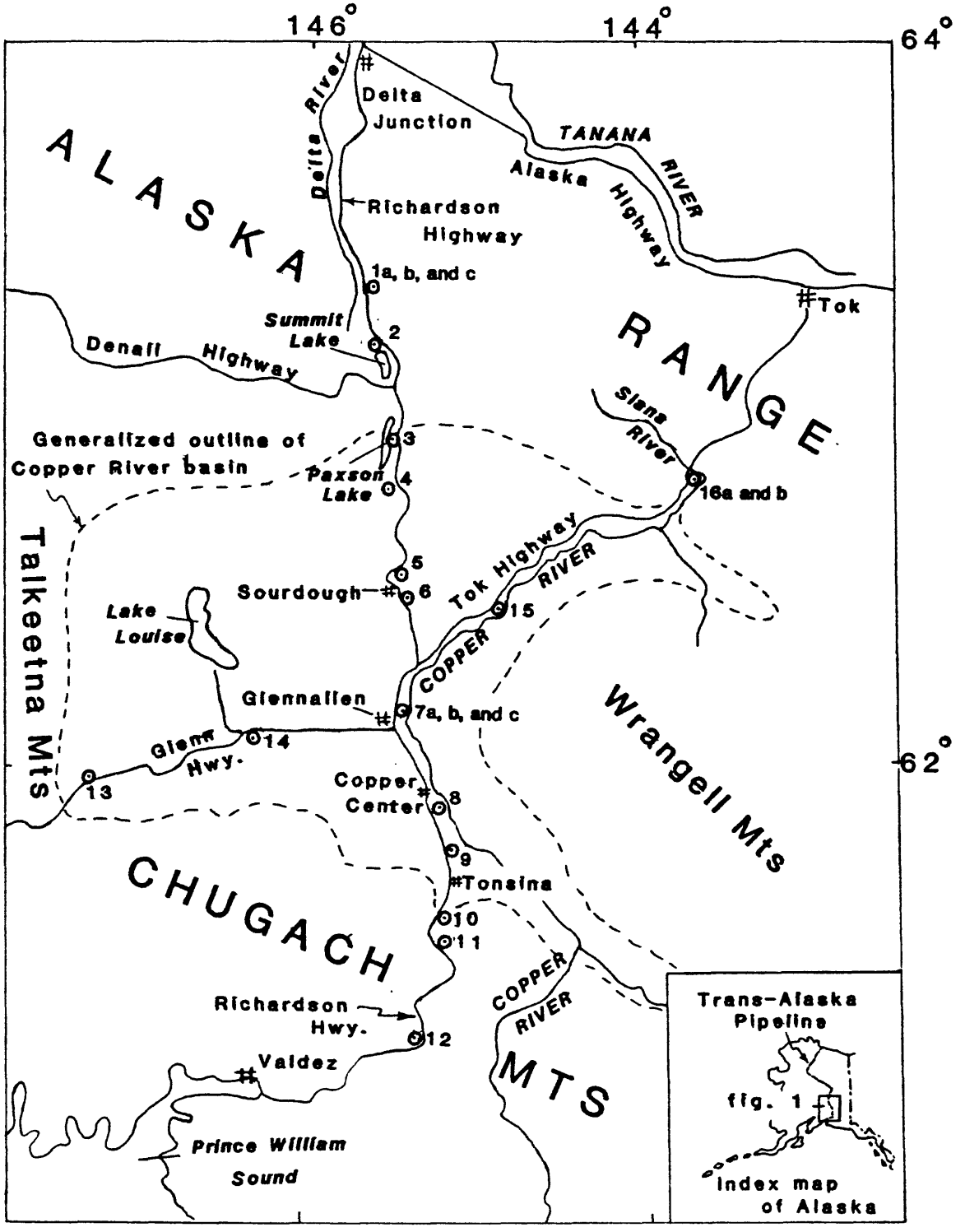

Figure 1.--Location map showing U.S. Geological Survey drill holes CRB 84-1a, b, and c through CRB 84-16a and b, Copper River basin and adjacent regions, Alaska. Scale, approximately 1:2,000,000.

during all of the conventional rotary drilling of unconsolidated materials, ground water from the hole itself was used as the drilling medium where the quantity of water in a particular geologic horizon was adequate. Where inadequate, water was supplied from a truck-mounted, closed tank filled from a variety of sources ranging from stagnant ponds to glacial streams. The sources contained inorganic and organic materials. Occasionally a foaming agent, Quik Foam, was added to the water used in drilling. In no instances was ground-water flow so great that a hole had to be abandoned as a shot hole. Casing of a nominal 8-in. interior diameter was driven after approximately each 5-ft increment of drilling.

The collection of representative, but disturbed, fine-grained and some medium-grained unconsolidated samples is possible from rotary-drill operations, but any geologic materials coarser than about medium-sized pebbles become broken during drilling, and thus, samples are not representative of the in situ material. Procedures for collection of samples were not uniform because samples are ejected at speeds varying from slow, to very fast, from a nozzle about 10 ft long and 0.5 ft in diameter onto the ground behind the drill rig. As drilling progressed during any one section of hole, the nozzle height above ground surface decreased from an initial maximum of about 22 ft, depending on the length of the casing used for each drilled 20-ft increment to a final minimum of about 1.5 ft. Commonly there was a sizing of material in the drop zone depending upon the height of the nozzle that emitted the ejecta plume and the velocity of the plume. The drop zone varied from about 100 to 3 ft behind the drill rig, depending on the type of material and amount of water in the plume. Sizing resulted in relatively smaller, drier, and less cohesive particles being ejected the farthest and relatively coarser and wetter materials being ejected intermediate distances. With relatively lower velocity of the ejecta, all materials, especially more cohesive ones, were found close to the drill rig.

Observed and inferred contaminants in the samples may include the following, in likely decreasing order of abundance: 1) bits of material from previously collected samples that were not cleaned from the sample-catching device, 2) foam or other agents used to thicken the drilling medium, 3) particles in the source water collected for use in drilling and subsequently stored in a closed water tank and consisting of scum, insects, and plant fragments, 4) other particles in the drilling water resulting from the drilling operation itself and consisting of hydraulic oil, grease, rust, paint, paper, and miscellaneous metallic fragments, and 5) air-fall particles from nearby vegetation that blew onto the sample before collecting or packaging could be completed.

INTERPRETATION OF MATERIALS

The types of geologic materials encountered in the drill holes as deduced by visual examination and the interpretation of these materials in the field are given in the next section. Holes containing chiefly unconsolidated materials are treated in some detail while those predominantly in bedrock are considered only generally. Grain sizes are estimated and follow the classification of Wentworth (1922). It has been noted on the logs where collected materials are thought to vary from the deposits in situ. The largest clasts not broken during the drilling process were all smaller than

about 0.45 in. The breaking of coarser clasts during conventional rotary drilling makes characterization of unconsolidated deposits difficult; even more destructive is percussion drilling which pulverizes bedrock to silt- and clay-sized particles. Where in situ clasts larger than about 0.45 in. are abundant, descriptions relate largely to broken fragments. Grain-size descriptions are presented in order of estimated decreasing abundance. Great uniformity of some of the materials is evident, especially those materials considered to be lake or glacial lake deposits. Where lithologic similarities or differences of clasts were readily apparent, this was noted. An example is the lithologic uniformity of clasts of volcanic rock observed in hole CRB 84-8 near Copper Center (fig. 1) from which a possible volcanic debris flow at least 40 ft thick was interpreted. Similar volcanic deposits are present along the nearby Copper River bluffs. These volcanic materials may form part of the Dadina volcanic debris flow that originated in the volcanic Wrangell Mountains (fig. 1; Nichols and Yehle, 1985).

Information presented on possible permafrost conditions is sketchy and based on sporadic observations of the relative coldness of materials higher in a particular hole. In one hole, CRB 84-3 in the northern Copper River basin, small pieces of ice were present in the materials from the interval between 45 and 80 ft.

We suggest possible depositional environments and age of unconsolidated deposits as interpreted from materials recovered from the holes and a knowledge of the regional geology. All unconsolidated deposits are of Quaternary age. Except for materials that constitute the possible volcanic debris flow and the terrace alluvium along the Copper River, most deposits are related directly or indirectly to an extensive former lake, glacial Lake Atna (Nichols, 1965; Ferrians, 1971; Williams and Johnson, 1980; Yehle, 1980, 1981), that, along with ancestral lakes, covered much of the Copper River basin during long periods of the Quaternary. Other deposits commonly observed are thought to be alluvial sequences, some of which may be related to non-glacial intervals or the advance and retreat of glaciers. Few of the deposits penetrated are interpreted with certainty as diamictons of primary glacial (till) origin. These deposits were in holes CRB 84-3, -10, and -14 in or near the northern, southern, and western parts of the Copper River basin, respectively.

For conversion of measurements to metric, use 1 in. equal to 254 mm, 1 ft equal to 0.3048 m, and 1 mi equal to 1.609 km.

DESCRIPTION OF DRILL SITES AND HOLES

CRB 84-1a, b, and c

These three 180-ft-deep holes are located in NE1/4NE1/4 sec. 19, T. 18 S., R. 11 E., Fairbanks Meridian, of the Mount Hayes B-4 quadrangle at an altitude of about 2,700 ft. About 0.75 mi to the west is Richardson Highway mileage point about 213 mi north from Valdez (fig. 1). The holes are situated adjacent to an unmaintained road possibly built in the 1960's. The drill site lies at the east margin of the floor of an abandoned bedrock-walled channel, informally named Red Rock Canyon, that formed by differential glacial erosion, and later was deepened by outwash streams. At the surface, the channel exposes outwash derived from one of the late Holocene advances of Canwell Glacier 1.5 mi northeast of the holes. Because of the present retreat of the glacier, the channel no longer is receiving outwash.

Bedrock of the channel area is volcaniclastic and volcanic in origin and probably consists of andesite or dacite of the lower volcaniclastic member (not formalized) of the Slana Spur Formation of middle Pennsylvanian to early Permian age; faulting is extensive (Nokleberg and others, 1982). Along the canyon walls, bedrock is well jointed; locally, zones of hydrothermal alteration are prominent and narrow dikes are present.

From a composite of the three holes, drilling indicated about 20 ft of outwash gravel and some rubble overlying bedrock. Rock was pulverized by the percussion bit used for drilling.

CRB 84-2

This 150-ft-deep hole is located in NE1/4SE1/4 sec. 24, T. 20 S., R. 11 E., Fairbanks Meridian, of the Mount Hayes A-4 quadrangle at an altitude of about 3,215 ft. To the east about 0.2 mi is Richardson Highway mileage point about 196.5 mi north from Valdez (fig. 1). The hole is situated adjacent an unmaintained, narrow road possibly built in the 1940's. The drill site lies on the brush-covered outwash delta of ancestral glacier-fed Gulkana River which prograded into the north end of Summit Lake. The present lakeshore is about 0.3 mi southwest of the hole. The 1954 glacier terminus was about 6 mi northeast of Summit Lake.

[Leaders (---) indicate no entry]

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-5	5	Sandy silt to silty clay.	Light tan to brown, moist.	Alluvial, Holocene.
5-20	15	Silty, very fine sand.	Gray to dark gray moist.	Do.
20-40	20	Clayey silt.....	Dark gray, moist, sticky.	Shallow water deltaic, Holocene.
40-50	10	Clayey silt to sandy silt.	Gray.....	Do.
50-55	5	Silty sand, coarsens downward.	---	Deltaic, Holocene.
55-60	5	Sandy pebble gravel..	---	Do.
60-80	20	Coarse sand with some small pebbles; rare detrital wood fragments.	Gray, loose.....	Do.
80-100	20	Coarse sand; some wood fragments.	---	Do.
100-110	10	Granules and coarse medium sand; in some small pebbles.	---	Do.

CRB 84-2--Continued

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
110-115	5	Sand and some silt, very fine sand, and lignitized wood; rare pebbles.	Grayish, olive green.	Deltaic, Holocene.
115-120	5	Coarse to medium sand; some silt and very fine sand.	Probably thin beds.	Do.
120-125	5	Silt and some clay...	Gray.....	Deeper water deltaic, Holocene.
125-135	10	Silt and clay.....	Very wet.....	Do.
135-140	5	Medium to fine sand with many tiny lignitized wood fragments.	....do.....	Deltaic, Holocene.
140-145	5	Coarse to very fine sand.	....do.....	Do.
145-150	5	Medium to fine sand with rare silt lenses.	....do.....	Do.

CRB 84-3

This 140-ft-deep hole is located in NW1/4NW1/4 sec. 18, T. 13 N., R. 1 W., Copper River Meridian, of the Gulkana D-5 quadrangle at an altitude of about 2,600 ft. To the east about 0.3 mi is Richardson Highway mileage point about 176.5 mi north from Valdez (fig. 1). The hole is situated several feet north of a small creek on the embankment of an abandoned road possibly built in the 1930's and not maintained since the 1950's. The embankment was constructed on the lower slope of an alluvial fan cut through gently sloping glacial moraines (Ferrians, 1971). The area is lightly forested.

[Leaders (---) indicate no entry]

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-20	20	Pebbly sand with some silt.	Road embankment...	---
20-35	15	Fine sand and silt, some pebbles and clay, slightly organic; clay may increase with depth.	Dark gray, wet....	Alluvial, Holocene.
35-40	5	Organic pebbly silt with some clay and sand.	Very dark to light gray, very wet.	Glacial or glaciolacustrine, Pleistocene.
40-45	5	Silty fine sand with some pebbles and granules (in situ?: includes coarser clasts, diamicton).	Light gray, slurry.	Glacial, Pleistocene.
45-50	5	Silty fine sand with granules and pebbles (in situ?: includes coarser clasts, diamicton).	Very wet, several ice particles.	Do.
50-55	5	Pebbles, silt and clay, sand and granules (in situ?: contains coarser clasts, diamicton).	Very moist, rare ice particles.	Do.
55-60	5	....do.....	Wet, rare ice particles.	Do.
60-70	10	Silty sand with some very small pebbles.	Medium gray, tiny ice particles.	Glaciofluvial, Pleistocene.
70-75	5	Sand and silt, rare very small pebbles.	Some tiny ice particles.	Do.

CRB 84-3--Continued

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
75-82.5	7.5	Coarse sand with some silt.	Rare ice particles(?).	Glaciofluvial, Pleistocene
82.5-90	7.5	Silt and clay with some pebbles (diamicton).	Light gray, very wet, no ice particles visible, warmer than above sample.	Glacial, Pleistocene.
90-100	10	Silt, clay, and sand with some granules and pebbles (in situ?: includes some coarser clasts).	Very wet, no ice apparent.	Glacial or glaciolacustrine, Pleistocene.
100-110	10	Pebbles, granules, silt, clay, and sand (diamicton?).	Medium gray, wet..	Do.
110-120	10	Pebbles, granules, clay, silt, and sand.	Wet.....	Do.
120-130	10	Very pebbly sand with silt and granules.	Very wet.....	Alluvial, Pleistocene.
130-140	10	Granuly gravel and sandy small pebble gravel, (in situ?: includes coarser clasts).	....do.....	Do.

CRB 84-4

This 151-ft-deep hole is located in NW1/4SE1/4 sec. 30, T. 12 N., R. 1 W., Copper River Meridian, of the Gulkana D-3 quadrangle at an altitude of about 2,550 ft. Eastward about 0.1 mi is Richardson Highway mileage point about 167.5 mi north from Valdez (fig. 1). The hole is situated adjacent an abandoned, narrow road probably built in the 1930's and not maintained since the 1950'squadrangle at an altitude of about 2,550 ft. Eastward about 0.1 mi is Richardson Highway mileage point about 167.5 mi north from Valdez (fig. 1). The hole is situated adjacent an abandoned, narrow road probably built in the 1930's and not maintained since the 1950's. The drill site lies about 0.3 mi north of a small creek on gently sloping ground underlain by glacial lake deposits (Ferrians, 1971). The area is lightly forested.

[Leaders (---) indicate no entry]

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-5	5	Sandy gravel and some silt.	Road embankment...	---
5-10	5	Sandy silt with a few small pebbles.	Grayish brown, moist.	Large glacial lake, Pleistocene.
10-20	10	Silt and sand with pebbles.	....do.....	Do.
20-50	30	Silt and very fine sand, with some pebbles.	....do.....	Do.
50-55	5	Clayey silt with a few pebbles.	Gray.....	Do.
55-60	5	Silt and clay with some sand, numerous small pebbles.	---	Do.
60-85	25	Silty clay with pebbles.	Compact(?).....	Do.
85-90	5	Silt and sand with much clay; granules(?) and pebbles (in situ?: includes coarser clasts).	Medium to dark gray, wet.	Do.
90-95	5	Fine to medium sand with some silt, very few pebbles.	Greenish gray, very wet.	Large glacial lake, Pleistocene.

CRB 84-4--Continued

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
95-100	5	Fine to medium sand..	Greenish dark gray, very wet, liquefiable in sample.	Do.
100-105	5	Sand and some granules.	Very wet.....	Do.
105-110	5	Medium sand with some fine sand.	....do.....	Do.
110-115	5	Fine to medium sand and granules, some small pebbles.	Very wet, cold....	Do.
115-125	10	Very fine sand.....	Slurry, very cold.	Do.
125-130	5	Silt with some sand and clay, a few pebbles (in situ?: includes coarser clasts).	....do.....	Do.
130-135	5	Granuly to pebbly sand with some silt.	....do.....	Do.
135-140	5	Coarse sand with pebbles.	....do.....	Do.
140-150	10	Fine to medium sand..	....do.....	Do.
150-151	1	Very fine sand.....	....do.....	Do.

CRB 84-5

This 140-ft-deep hole is in NW1/4NW1/4 sec. 8, T. 9 N., R. 1 W., Copper River Meridian, of the Gulkana C-3 quadrangle at an altitude of about 2,200 ft. To the west about 0.6 mi is Richardson Highway mileage point about 244 mi north from Valdez; Sourdough is about 4 mi to the southwest (fig. 1). The hole lies adjacent an abandoned, narrow road probably built in the 1930's and not maintained since the 1950's. The area of the drill site is moderately forested and very gently sloping. Underlying geological materials consist of glacial lake deposits (Ferrians, 1971) probably part of glacial Lake Atna (Nichols, 1965).

[Leaders (---) indicate no entry]

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-15	15	Very fine to silty sand.	Brown, moist.....	Large glacial lake, Pleistocene.
15-30	15	....do.....	Brown, wet.....	Do.
30-35	5	Medium sand.....	....do.....	Do.
35-40	5	Silty, medium to coarse sand with very small pebbles; silt near base.	Brown, cold.....	Do.
40-45	5	Clayey silt with a few pebbles (in situ?: includes coarser clasts).	Hard.....	Do.
45-50	5	Clayey silt.....	---	Do.
50-55	5	Clayey silt with some pebbles (in situ?: includes coarser clasts).	Slurry, hard drilling.	Do.
55-70	15	Clayey silt with very few pebbles (in situ?: includes coarser clasts).	....do.....	Do.
70-75	5	Very fine to silty sand.	....do.....	Do.
75-80	5	Very fine to silty sand, some granules.	....do.....	Do.
80-90	10	Very fine to silty sand.	Slurry, hard drilling.	Large glacial lake, Pleistocene.

CRB 84-5--Continued

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
90-95	5	Silt with some very fine sand, rare granules.	Slurry.....	Do.
95-100	5	Silt.....	Gray, slurry.....	Do.
100-115	15	Silt and very fine sand.	Greenish gray, slurry.	Do.
115-120	5	Very fine sand and silt.	....do.....	Do.
120-130	10	Very fine sand.....	Slurry.....	Do.
130-140	10	Fine sand.....	....do.....	Do.

CRB 84-6

This 140-ft-deep hole is located in SE1/4NE1/4 sec. 7, T. 8 N., R. 1 W., Copper River Meridian, of the Gulkana B-3 quadrangle at an altitude of about 1,960 ft. To the northwest about 200 ft is Richardson Highway mileage point about 144.5 mi north from Valdez; to the northwest about 3 mi is Sourdough (fig. 1). The hole is on an abandoned, narrow road probably built in the 1930's and not maintained since the 1950's. Underlying geologic materials consist of glacial lake deposits (Ferrians, 1971) probably a part of glacial Lake Atna (Nichols, 1965). The area is forested and very gently sloping.

[Leaders (---) indicate no entry]

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-5	5	Sandy gravel with some silt.	Road embankment...	---
5-20	15	Clayey silt with a few pebbles.	Gray, gummy to wet.	Large glacial lake, Pleistocene.
20-40	20	Probably silty clay with a small amount of sand and rare clasts.	(Material not observed directly.)	Do.
40	about 1	Clay with some silt.	Dark gray.....	Do.
40-140	100	Probably silty clay with a small amount of sand and rare clasts.	(Material not observed directly).	Do.

CRB 84-7a, b, and c

These three holes, two of which are 150 ft deep and one of which is 132 ft deep, lie in SE1/4SW1/4 sec. 33, T. 5 N., R. 1 W., Copper River Meridian, of the Gulkana A-3 quadrangle at an altitude of about 1,325 ft. To the west about 1.5 mi is Richardson Highway mileage point about 119 mi north from Valdez; to the southwest about 4.5 mi is Glennallen (fig. 1). The holes were drilled in the floor of a large borrow pit developed probably early in the 1970's. The area forms a sparsely forested muskeg that overlies gravelly terrace alluvium (Nichols and Yehle, 1969). The Copper River is 0.25 mi to the east and 50 ft lower than the floor of the pit.

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-15	15	Pebble gravel, and sand (in situ?: includes cobbles), wood pieces near base.	Wet, varied lithologies; upper 10 ft probably disturbed by borrow-pit operation.	Alluvial, Holocene.
15-20	5	Silty sand with some pebbles and granules (in situ?: includes coarser clasts; diamicton).	Gray, moist.....	Large glacial lake, Pleistocene.
20-25	5	Fine sandy silt and clay, some granules and rare pebbles, becomes finer with depth.	....do.....	Do.
25-40	15	Silt and very fine sand, some granules and pebbles.	Slurry.....	Do.
40-60	20	Silt, clay, and sand with some granules and rare pebbles.	Bluish gray, very moist.	Do.
60-65	5	Silty clay.....	Bluish gray.....	Large glacial lake, Pleistocene.
65-75	10	Silty clay with some granules and sand.	Firm.....	Do.

CRB 7a, b, and c--Continued

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
75-105	30	Silty clay with some rare granules and rare pebbles (in situ?: includes coarser clasts).	Bluish gray to very dark gray, some slickensides on clay pieces.	Do.
105-110	5	Sand.....	Loose.....	Alluvial, Pleistocene.
110-115	5	Pebble gravel and sand.	High percentage of volcanic rock types; water under pressure, seltzer-water taste.	Do.
115-120	5	Pebble gravel (in situ?: includes coarser clasts).	High percentage of volcanic rock types.	Do.
120-125	5	Pebble gravel and sand (in situ?: includes coarser clasts).	....do.....	Do.
125	about 1	Gravelly sand.....	....do.....	Do.
125-140	15	Pebble gravel (in situ?: includes coarser clasts).	....do.....	Do.

CRB 84-8

This 141-ft-deep hole is located in NE1/4SE1/4 sec. 19, T. 2 N., R. 1 E., Copper River Meridian, of the Valdez D-4 quadrangle at an altitude of about 1,050 ft. To the west 0.7 mi is Richardson Highway mileage point about 99.4 mi north from Valdez; to the northwest 0.75 mi is Copper Center (fig. 1). The hole lies about 25 ft north of an unimproved, narrow road. The area is underlain by gravelly alluvium of a terrace of the Copper River (Nichols and Yehle, 1969), which is about 0.25 mi to the east and 75 ft lower than the drill site. Forest covers the terrace.

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-15	15	Pebble gravel (in situ?: includes cobbles).	Dry, various lithologies.	Alluvial, Holocene.
15-25	10	Pebble gravel and sand (in situ?: includes cobbles).	Olive gray, damp, various lithologies but high percent of volcanic rock types.	Alluvial, Pleistocene.
25-40	15	Pebbly sand.....	Various lithologies high percent volcanic rocks.	Do.
40-63	23	Silty clay with a few granules and rare pebbles.	Grayish blue, slightly moist to dry.	Large glacial lake, Pleistocene.
63	Less than 1.	Fine sand.....	Very light gray, maximum size of pieces, 0.5 in.; possibly a volcanic ash.	Air-fall volcanic ash(?) into glacial lake, Pleistocene.
63-75	12	Silt and clay with a few granules and rare pebbles.	Gray, various lithologies, naturally angular to subangular and not broken by drilling.	Large glacial lake, Pleistocene.
75-80	5	Silty clay with a few granules and rare pebbles.	Dark gray.....	Large glacial lake, Pleistocene.
80-95	15	Coarse sand with granules, possibly coated by clay.	Gray, wet.....	Alluvial, Pleistocene.

CRB 84-8--Continued

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
95-105	10	Coarse sand, granules, and small pebbles.	Wet, clasts entirely volcanic and almost exclusively of a gray, relatively vesicular rock with a chiefly hornblende and some orthopyroxene-flecked groundmass and phenocrysts of whitish plagioclase (S. F. Diehl, written commun., 1985).	Volcanic debris flow, Pleistocene.
105-110	5	Granules, coarse sand, and small pebbles (in situ?: includes coarser clasts).	Loose, clasts as above.	Do.
110-130	20	Pebble gravel with granules and coarse sand (in situ?: includes coarser clasts).	Very wet, clasts as above.	Do.
130-141	11	Coarse sand and granules, with some pebbles (in situ?: includes coarser clasts).	....do.....	Do.

CRB 84-9

This 140-ft-deep hole lies in SW1/4NW1/4 sec. 13, T. 2 S., R. 1 E., Copper River Meridian, of the Valdez C-4 quadrangle at an altitude of about 2,000 ft. To the west about 0.4 mi is Richardson Highway mileage point about 81.6 mi north from Valdez; to the south about 2.5 mi is Tonsina (fig. 1). The hole is situated on an abandoned, large area of artificial fill developed early in the 1970's for equipment storage. Cutting of forest land preceded emplacement of the fill. The drill site is on gently sloping ground underlain by deposits of glacial Lake Atna (Nichols, 1965; Nichols and Yehle, 1969).

[Leaders (---) indicate no entry]

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-10	10	Sand and gravel.....	Artificial fill...	---
10-30	20	Sand with some silt and rare pebbles.	Olive gray, wet...	Large glacial lake, Pleistocene.
30-40	10	Sand with silt.....	Olive gray, wet to slurry, cold.	Do.
40-50	10	Fine to medium sand with some silt.	Olive gray, wet to dry.	Do.
50-55	5	Fine sandy silt.....	Moist to wet.....	Do.
55-58	3	Silt and fine to very fine sand with some clay, granules, and small pebbles.	Dry.....	Do.
58-60	2	Fine sand.....	Olive gray.....	Do.
60-70	10	Silt and very fine sand with rare granules.	Dark greenish gray, dry.	Do.
70-80	10	Silt and very fine sand, rare coarse sand; rare tan colored granule-sized pieces of fine sand.	Medium gray, dry; possible rare volcanic ash in very thin lenses.	Large glacial lake, Pleistocene.
(80)	---	---	(Driving of casing very hard, then easy, possibly caused by passing through base of permafrost).	---

CRB 84-9--Continued

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
80-90	10	Silt and very fine sand with rare coarse sand, granules, and pebbles.	Medium gray, moist.	Do.
90-100	10	Silt and very fine sand with pebbles.	Medium gray, very wet to slurry.	Do.
100-115	15	Very fine sand.....	Olive to greenish gray; very wet, liquefiable.	Do.
115-120	5	Silt with some very fine sand.	Dark gray, dry....	Do.
120-122	2	Very clayey silt with some very fine sand and small pebbles.	....do.....	Do.
122-125	3	Sandy silt.....	Dark gray, moist.	Do.
125-130	5	Clayey silt and very fine sand with some pebbles.	....do.....	Do.
130-140	10	Silt and very fine sand with some granules and rare pebbles.	Dark gray, dry....	Do.

CRB 84-10

This 145-ft-deep hole is in NE1/4SE1/4 sec. 28, T. 3 S., R. 1 E., Copper River Meridian, of the Valdez C-4 quadrangle at an altitude of about 1,750 ft. West about 200 ft is Richardson Highway mileage point about 73.2 mi north from Valdez; to the north-northeast about 6 mi is Tonsina (fig. 1). The hole is situated on the floor of a borrow pit used since at least the early 1950's. Geologic mapping of the area indicates glacial lake and colluvial deposits at the surface (Nichols and Yehle, 1969).

[Leaders (---) indicate no entry]

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-2	2	Gravel.....	Floor of borrow pit.	---
2-18	16	Silty sand.....	Dark gray, dry....	Lake, Pleistocene.
18-20	2	Silty to sandy pebble gravel (in situ?: includes coarser clasts, diamicton).	Wet.....	Delta of glacial lake, Pleistocene.
20-22	2	Silty, coarse sand...	---	Do.
22-25	3	Clayey to silty pebble gravel (in situ?: includes coarser clasts).	---	Glacial, Pleistocene.
25-60	35	Clayey pebble gravel (in situ?: includes coarser clasts, toward base clasts may decrease in size).	Drills as if material is hard.	Do.
60-85	25	Pebble gravel, sand, silt, and clay (in situ?: includes coarser clasts, diamicton.	Dark gray, compact.	Do.
85-95	10	Silt and clay with granules, sand, and some pebbles.	Wet.....	Do.
95-110	15	Clay and silt with granules and pebbles (in situ?: includes coarser clasts).	Medium gray; wet, rather cold but no ice particles visible.	Glacial, Pleistocene.

CRB 84-10--Continued

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
110-118	8	Silt and clay with granules, sand, and pebbles (in situ?: includes coarser clasts).	Medium greenish gray, slurry.	Do.
118-122	4	Granules, coarse sand, and small pebbles (in situ?: includes coarser clasts).	Wet, various lithologies.	Alluvial, Pleistocene.
122-125	3	Granules and small pebbles (in situ?: includes coarser clasts).	Wet, possible water inflow.	Do.
125-130	5	Coarse sand and granules.	....do.....	Do.
130-140	10	Granules and sand with some silt.	....do.....	Do.

CRB 84-11

This 145-ft-deep hole is located in SE1/4NE1/4 sec. 16, T. 4 S., R. 1 E., Copper River Meridian, of the Valdez C-4 quadrangle at an altitude of about 1,815 ft. To the west about 20 ft is Richardson Highway mileage point 69.5 mi north from Valdez; to the north-northeast about 9.7 mi is Tonsina (fig. 1). The hole is situated in a mixed brush and lightly forested area on gently sloping ground. The area is underlain chiefly by glacial lake deposits (Nichols and Yehle, 1969).

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-15	15	Silty find sand with rare small pebbles (in situ?: includes coarser clasts as evident on ground surface).	Greenish gray, moist.	Clast concentration in shore zone of lake, Pleistocene.
15-30	15	Very fine to fine sand.	Liquefiable.....	Glacial lake, Pleistocene.
30-90	60	Silty clay with rare small pebbles.	Blue gray to medium gray.	Do.
90-95	5	Silty clay with a very small percent of sand, and rare granules.	Medium gray, very wet.	Do.
95-115	20	Clay with a very small percentage of silt.	Dark gray to greenish gray, very wet.	Do.
115-135	20	Clay with a very small percentage of silt and very rare pebbles.	Greenish to olive gray, very wet.	Do.
135-145	10	Clay with a very small percentage of silt and sand (in situ?: partly a laminated interval identified by fragments of material that had relatively thicker, very dark gray finer laminae and relatively thinner, medium to light gray coarser laminae).	Very wet.....	Glacial lake, Pleistocene.

CRB 84-12

This 180-ft-deep hole is located in NE1/4NE1/4 sec. 19, T. 7 S., R. 1 E., Copper River Meridian, of the Valdez B-4 quadrangle at an altitude of about 1,250 ft. To the southeast about 250 ft is Richardson Highway mileage point about 45.1 mi north from Valdez; to the north-northeast about 28.5 mi is Tonsina (fig. 1). The drill hole is situated on hummocky ground adjacent to steep terrain differentially eroded by glaciers and high-energy streams. Bedrock in the area is metamorphosed sandstone and subordinate argillite of Cretaceous age (Winkler and others, 1980). Near the hole, bedrock was observed to be well jointed with quartz-filling narrow fractures. Drilling indicated about 8 ft of peat and some rubble overlying bedrock. Rock was pulverized by the percussion bit used for drilling.

CRB 84-13

This 180-ft-deep hole is located in SE1/4NE1/4 sec. 36, T. 21 N., R. 11 E., Seward Meridian, of the Anchorage D-1 quadrangle at an altitude of about 3,200 ft. To the east about 400 ft is Glenn Highway mileage point 69.4 mi west from Glennallen (fig. 1). The hole is situated on the floor of a borrow pit probably developed in the 1950's. Adjacent to the pit are moderately steep slopes underlain by thin glacial drift deposits that in turn are underlain by siltstone of the Matanuska Formation of Cretaceous age (Grantz, 1951). Drilling indicated about 15 ft of brownish, oxidized siltstone over gray, unoxidized siltstone.

CRB 84-14

This 140-ft-deep hole is located in NE1/4NE1/4 sec. 33, T. 4 N., R. 6 W., Copper River Meridian, of the Gulkana A-5 quadrangle at an altitude of about 2,425 ft. About 300 ft to the north is Glenn Highway mileage point about 28 mi west from Glennallen; the highway's junction with the Lake Louise road is 1.1 mi to the west (fig. 1). The hole is situated near the east end of the floor of a borrow pit developed in the 1960's on gently sloping forested terrain. The area is underlain by glacial lake including shore deposits (J. R. Williams, oral commun., 1984) probably of glacial Lake Atna (Nichols, 1965).

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-15	15	Silty, very fine sand with pebbles (in situ?: includes coarser clasts as evident on ground surface).	Tan, moist.....	Clast concentration in shore zone of large glacial lake, Pleistocene.
15-30	15	Silt and fine sand, with a few pebbles.	Tan, slurry.....	Large glacial lake, Pleistocene.
30-50	20	Pebble gravel and sand (in situ?: includes coarser clasts).	Gray, wet.....	Glaciofluvial, Pleistocene.
50-60	10	Pebble gravel, very fine sand, and silt, with granules (in situ?: includes coarser clasts, diamicton).	....do.....	Glacial, Pleistocene.
60-70	10	Sand and silt.....	Olive gray, slurry.	Glacial lake, Pleistocene.
70-80	10	Silty, medium to coarse sand.	Gray, slurry.....	Do.
80-95	15	Sand and silt with granules and pebbles (in situ?: includes coarser clasts).	Gray, slurry.....	Glacial lake, Pleistocene.
95-105	10	Silty, medium to fine sand.	....do.....	Do.

CRB 84-14--Continued

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
105-140	35	Silty, medium to fine sand with some pebbles (in situ?: includes coarser clasts).	....do.....	Do.

CRB 84-15

This 185-ft-deep hole is located in NE1/4SW1/4 sec. 15, T. 8 N., R. 3 E., Copper River Meridian, of the Gulkana B-2 quadrangle at an altitude of about 1,735 ft. To the northwest about 0.25 mi is the Tok Highway mileage point about 23.5 mi northeast from its junction with the Richardson Highway (fig. 1). The hole is situated on the floor of a large borrow pit probably developed extensively in the 1950's. The area is forested and underlain by gravelly alluvium of a terrace of the Copper River which is 400 ft to the south and 25 ft lower than the pit floor.

[Leaders (---) indicate no entry]

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
0-15	15	Sandy pebble gravel, (in situ?: includes coarser clasts).	---	Alluvial, Holocene.
15-18	3	Clayey to silty, medium sand.	Wet.....	Alluvial or colluvial, Holocene or Pleistocene.
18-20	2	.....do.....	Medium gray, gummy, very cold (permafrost?).	Do.
20-40	20	Clay and silt with rare small pebbles.	Medium to medium dark gray, harder than material above (permafrost?), sticky in part.	Large glacial lake, Pleistocene.
40-60	20	Silty clay.....	Sticky.....	Do.
60-100	40	Very fine sand and silt.	Medium dark gray, slurry.	Large glacial lake, Pleistocene.
100-120	20	Fine sand, includes rare flecks of woody material.	Nearly black to very dark gray.	Large glacial lake, Pleistocene.
120-145	25	Very fine to fine sand with rare clay fragments; includes rare flecks of wood and pumice(?).	Nearly black, slurry.	Do.
145-155	10	Fine sand with rare flecks of wood and pumice(?).	Very dark gray to black, slurry.	Do.

CRB 84-15--Continued

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
155-165	10	Medium sand with rare small pebbles, percentage of pebbles increases downward.	Olive gray, slurry.	Do.
165-170	5	Fine to medium sand with very small fragments of silt.	....do.....	Do.
170-180	10	Granules and some coarse sand.	....do.....	Alluvial, Pleistocene.
180-185	5	Pebble gravel, coarse sand, and granules (in situ?: includes coarser clasts).	....do..... Clast lithologies varied.	Do.

CRB 84-16a and b

These two 180-ft-deep holes within 30 ft of each other are located in SW1/4NE1/4 sec. 3, T. 12 N., R. 9 E., Copper River Meridian, of the Nabesna D-6 quadrangle at an altitude of about 2,250 ft. To the northwest about 200 ft is the Tok Highway mileage point about 75.2 mi northeast from its junction with the Richardson Highway (fig. 1). The hole is situated on the floor of a borrow pit about 0.3 mi southwest of the Slana River bridge of the Tok Highway and 55 ft higher than the level of the river. Probably the pit was developed in the 1950's. The area is forested, hummocky, and underlain by pitted glacial drift deposits (H. R. Schmoll, oral commun., 1984).

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
		Composite of two drill holes		
0-25	25	Sandy pebble gravel (in situ?: includes coarser clasts).	Brown, moist, clast lithologies varied.	Pitted glacial drift possibly a kame field, Pleistocene.
25-30	5	Sand with a few pebbles.	Moist.....	Glacial lake, Pleistocene.
30-35	5	Medium to coarse sand, becomes finer downward.	Wet.....	Do.
35-40	5	Medium sand.....	Brown, wet.....	Do.
40-45	5	Medium to fine sand..	Brown to tan, slurry.	Do.
45-55	10	Silty, fine to very fine sand.	Slurry.....	Do.
55-70	15	Sandy pebble gravel, (in situ?: includes coarser clasts), becomes less sandy downward.	Wet, various lithologies.	Alluvial, Pleistocene.

CRB 84-16a and b--Continued

[Leaders (---) indicate no entry]

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
70-75	5	Silty, very fine sand.	---	Glacial lake, Pleistocene.
75-80	5	Clayey silt.....	Gummy.....	Do.
80-85	5	Very fine to fine sand and silt.	Medium gray, gummy.	Do.
85-95	10	Fine to medium sand, becomes finer downward.	Slurry.....	Do.
95-100	5	Coarse sand, granules, and small pebbles (in situ?: includes coarser clasts).	....do.....	Do.
100-110	10	Medium to fine sand, becomes finer downward.	Medium gray to black, slurry.	Do.
110-120	10	Fine to medium sand with rare small wood fragments.	Slurry.....	Do.
120-122	2	Silty, very fine sand.	Dark gray, slurry.	Do.
122-130	8	Sandy pebble gravel, (in situ?: includes coarser clasts).	Very dark gray to black, slurry.	Do.
130-135	5	Medium to coarse sand with pebbles (in situ?: includes coarser clasts).	Slurry.....	Do.
135-140	5	Medium sand with rare small fragments of wood.	....do.....	Do.
140-155	15	Sandy pebbly gravel with some granules and rare small fragments of wood (in situ?: includes coarser clasts).	Slurry, various lithologies.	Alluvial, Pleistocene.
155-160	5	Sandy pebble gravel with silt, becomes coarser downward (in situ?: includes coarser clasts).	....do.....	Do.

CRB 84-16a and b--Continued

Depth (ft)	Thickness (ft)	Recovered material (if in situ material thought to be different, so indicated)	Partial description, remarks	Inferred environment of deposition and age
160-170	10	Sandy pebble gravel (in situ?: includes numerous coarser clasts).	Very wet.....	Do.
170-180	10	Sandy pebble gravel, (in situ?: includes coarser clasts).	....do.....	Do.

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