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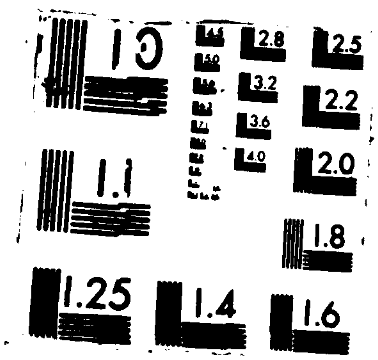
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Special Report 87-7

June 1987

US Army Corps of Engineers
Cold Regions Research & Engineering Laboratory

Preparation and description of a research geophysical borehole site containing massive ground ice near Fairbanks, Alaska

Allan J. Delaney

Prepared for
OFFICE OF THE CHIEF OF ENGINEERS

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A geophysical control site consisting of 27 holes drilled in permafrost and cased with ABS pipe has been completed near the USACRREL permafrost tunnel at Fox, Alaska. The site provides excellent control on a range of material types in permafrost terrain including frozen silt, gravel, bedrock, and all common ground-ice types such as wedge, lens, and pore ice. The holes delineate massive ground-ice features of which there is no surface manifestation. Ground temperature data is available from a small-diameter glycol-filled hole. This report describes the site, its preparation, and the soil logs and data obtained.

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PREFACE

This report was prepared by Allan Delaney, Physical Science Technician, of the Snow and Ice Branch, Research Division, U.S. Army Cold Regions Research and Engineering Laboratory.

Funding for this research was provided by the Navy EOD Technical Center at Indian Head, Maryland. A portion of the site development was also funded by DA Project 4A762730AT42, ***Design, Construction, and Operations Technology for Cold Regions***; Work Unit 011, ***Electromagnetic Geophysical Methods for Rapid Subsurface Exploration***. The report was technically reviewed by Paul V. Sellmann, Herbert Ueda, and Dr. Steven A. Arcone of CRREL.

The drilling was completed by Dan Dinwoodie, Sgt. Roy Weber, and Spec 4 Donny Piland of the CRREL Alaska Projects Office.

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ALLAN J. DELANEY

INTRODUCTION

During early November 1985 and January 1986, 27 holes were drilled in frozen, ice-rich silt near the USA CRREL permafrost tunnel at Fox, Alaska. This site was selected for current geophysical research projects at CRREL involving radio-wave propagation studies, determination of dielectric properties of frozen ground, and subsurface ordnance detection studies sponsored by the Naval EOD Technical Center at Indian Head, Maryland. The site provides excellent control on a range of material types and ground conditions found in permafrost terrain. This includes frozen silt, gravel, bedrock, and all common ground-ice types such as wedge, lens, and pore ice. The holes delineate massive ground ice features and provided samples for both detailed and general description of the sites. Seasonal temperature data can also be observed in a vertical temperature well. There is little disturbance at the site and no surface manifestation of the large buried ice features. The site will be useful for evaluation and calibration of other geophysical methods.

This report describes the site, its preparation, and the soil logs and data obtained. This information is provided for any future geophysical studies in this area as the installations are meant to be permanent.

SITE LOCATION AND DESCRIPTION

The site is located in perennially frozen ground near the CRREL permafrost tunnel at Fox, Alaska, on the margin of Goldstream Valley. It is situated on the lower slopes of a north-facing hillside. Fairbanks silt is the most abundant material in this area; it was exposed in all of the holes logged and reported here. The geology and permafrost conditions have been extensively described by Sellmann (1967, 1972) and Péwé (1958).

Figure 1 is a map showing the location of the area. It is accessible from the Steese Highway near Fox. Figure 2 is a detail of the site, which is divided into two arrays of holes spaced about 16 m (52 ft) apart. The deep array consists of 6 holes

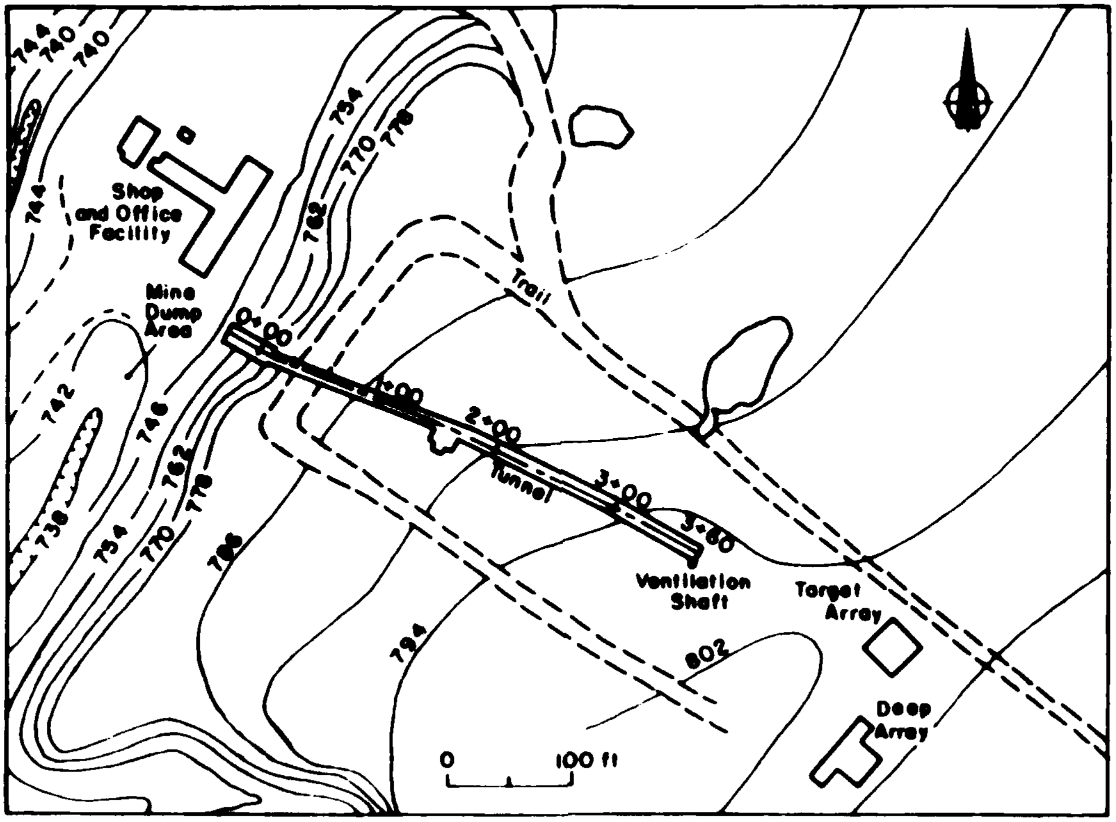


Figure 1. Topographic map of the Fox tunnel site and location of the arrays of holes drilled during this investigation (after Sellmann 1967).

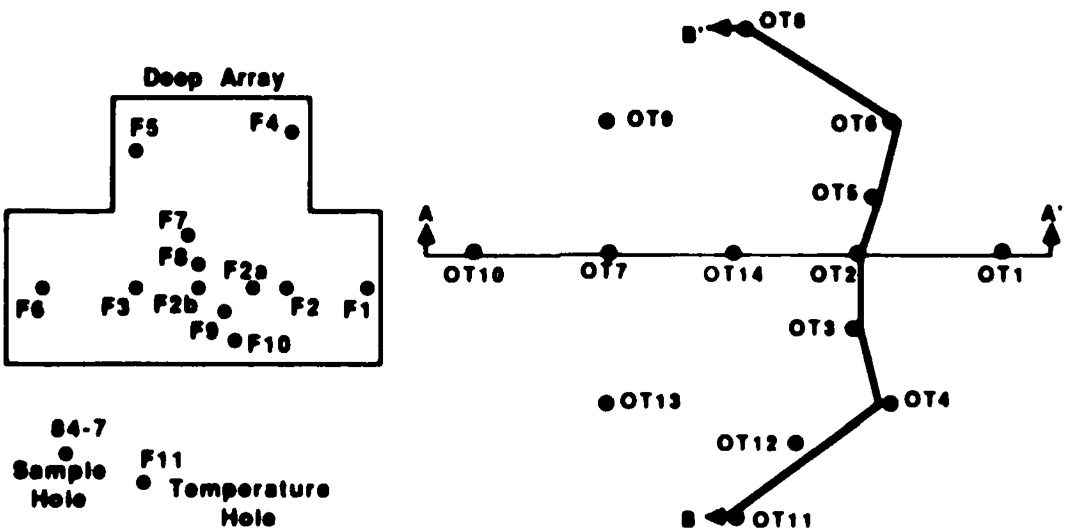


Figure 2. Detail hole location for the two arrays and location of the buried ordnance. The temperature and core sample holes are also shown.

drilled to depths of 24 m (78 ft) through frozen silt and frozen gravel sections into the top of bedrock. An additional 6 uncased holes were drilled to further delineate massive ice features encountered during the deep drilling. The target array consists of 12 cased holes drilled to a depth of 6.1 m (20 ft) on a grid around two buried targets placed in two additional uncased holes. The casing used in all holes is 3-in. I.D. ABS pipe with sealed bottom caps. The fluid-filled temperature hole was cased with 1½-in. ABS pipe. Data on material properties were obtained in 1984 when a hole was cored and continuously sampled at this site.

The top of massive ground ice was encountered in several holes at depths between 3.4 m (11 ft) and 4.6 m (15 ft) and was continuous to depths as great as 12.1 m (39 ft). A second, deeper zone of massive ice was encountered in the 12.2 to 13.7-m (39.7 to 44.5 ft) depth range. Frozen gravels and bedrock were encountered beneath the frozen silt.

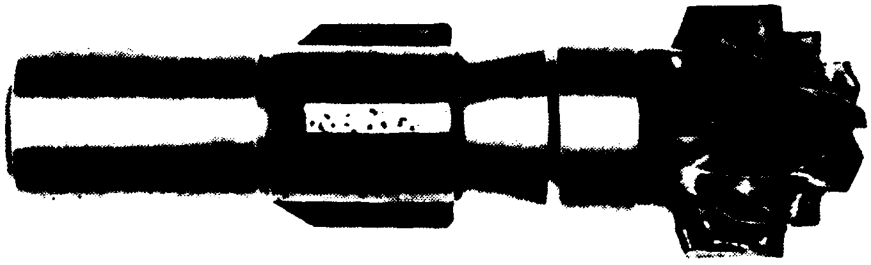
SITE PREPARATION

Drilling

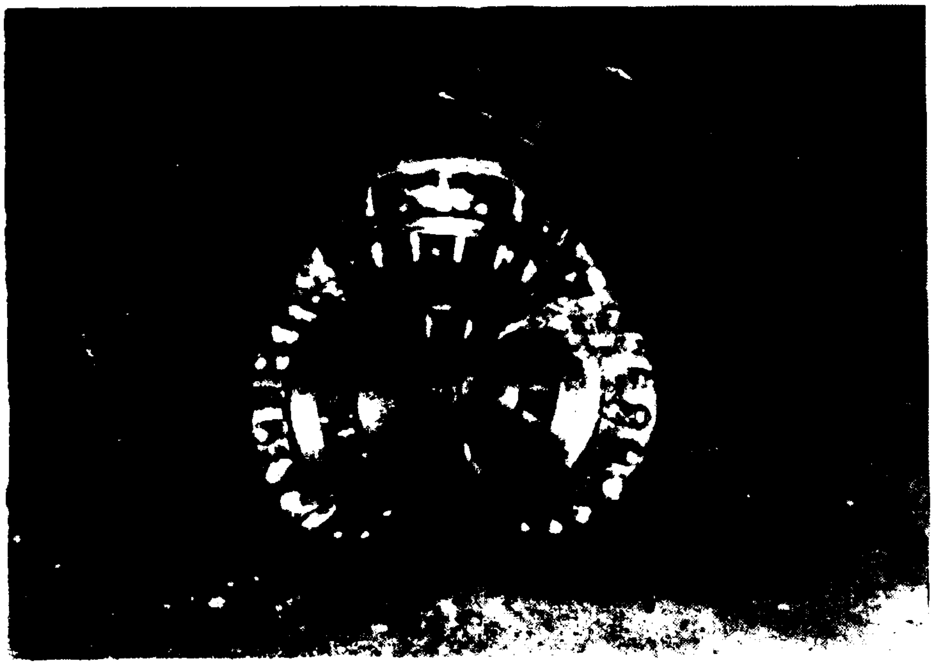
The drilling was done with both a large auger and a rotary drill that used chilled, compressed air for circulation. Ice wedge sampling was performed with a hand-operated CRREL core barrel on extensions.

All of the small-diameter holes were drilled using the rotary equipment. The rotary rig was a Failing Model 43 mounted on a 2 ½-ton truck. Compressed air was provided by a Sullair 750 ft^3/min compressor. During the drilling operations, ambient air temperatures averaged -23°C. The compressed air was chilled by passing it through a heat exchanger with a gas-engine-driven fan for moving the air. This cooled the compressed air to temperatures below freezing, which prevented melt in the hole.

The bits used on the rotary equipment (Fig. 3) included a 4 ¾ three-wing carbide-face Hawthorne drag bit; a 4 ¼-in. tricone roller rock bit; a 5-in. three-wing, step face, carbide bit manufactured by Sprague & Henwood; and an 8-in. three-wing hard-face drag bit provided with the original Failing drill equipment. The 4 ¾-in. carbide Hawthorne bit was used for drilling in the frozen silt and showed very little wear after 203 m (660 ft) of hole. The bit was advanced at the maximum rate of the drill rig hydraulics (approximately 5-6 ft/min), and the cuttings consisted of fragmented pieces of frozen material. The last hole (F11) was completed to 18.5 m (60 ft) in a total of 20 minutes drilling time. An attempt to use the 5-in. diameter step-face carbide bit for drilling in frozen silt proved unsatisfactory. The cuttings produced were very fine, resulting in slow penetration. Silt blew from the hole and covered the drill rig. An inspection of this bit (Fig. 3) revealed that the shoulders behind the cutters, particularly the center cutters, extended beyond the radius of the path cut. This prevented penetration and also produced the effect of an inefficient secondary cutter (Sellmann, personal com-



a. 4 3/4 in. Hawthorne bit.



b. 4 1/4 in. roller rock bit.

Figure 3. The drill bits used with the rotary equipment.

munication). The 8-in. diameter drag bit was used to drill a shallow target hole in frozen silt. The cuttings were large pieces of fragmented frozen material and the bit was advanced at about 2 ft/min. A well-worn, 4 1/4-in. roller rock bit was used for drilling in the frozen gravel and bedrock. Drilling rates were about 3 in./min in the frozen gravel and approximately 12 in./min in the bedrock. Generally, average drilling rates with the Failing 43 varied greatly depending on material type, air temperature, and various cold-related equipment operating problems.

Two persistent problems encountered during drilling were sporadic operation of the engine driving the heat exchanger blower and compressed-air-line icing with ice buildup often occurring at the swivel head. The air lines were cleared by

c. 5 in. step-face bit

d. 8 in. hard-face bit.

Figure 3 (cont'd).

applying heat and pouring 2-3 gallons of isopropyl alcohol into a tee at the compressor. The blower engine has since been rebuilt.

The auger drill used for this work was a Williams HD-50. This rig can be used to auger holes from 8 to 48 in. in diameter to depths of 15.4 m (50 ft). The hole augered at this site was 48 in. in diameter and 4.3 m (14 ft) deep. Total augering time was 6 hours. The auger essentially stopped cutting when the top of massive ice was encountered. The very slow penetration rate with this large bit resulted from worn carbide cutters. Because of the inefficient cutting, some melting occurred, which caused problems when this material refroze on the auger flights.

Additional support equipment included a Caterpillar D-7 tractor, 6x6 wrecker, 5-ton tractor and low-boy trailer, crane (to load the compressor on the low-boy), Herman-Nelson heater, and two 4x4 pickup trucks for equipment and delivering fuel. All of this equipment is maintained and operated by CRREL-Alaska. This site installation and associated research would not have been possible without these facilities because of the prohibitive cost of contracting this type of work.

Casing

The holes were cased with 3 in. I.D. ABS pipe with a cemented end cap and a removable top cap to allow insertion of borehole-compatible antennas for research purposes. The joints were cemented while holding the suspended pipe coupling with a specially fabricated slip plate. All of the holes were backfilled around the casing with a mixture of drill cuttings and water. Enough material was placed around each casing string to prevent buoyancy when spring meltwater ran into the annulus. The casings extend 0.9 m (3 ft) above the ground surface and are identified with white markings.

Target placement

Two metallic radar targets were buried in the target array. The targets consist of inert ordnance items provided by the Naval EOD Technical Center at Indian Head, Maryland. A 155-mm projectile was buried vertically, at hole location OT12 (Fig. 4). The tip of the shell is pointed down and is 1.5 m (4.9 ft) below the surface. The end of the shell is 0.97 m (3.2 ft) below the ground surface. At hole location OT14, an MK82 500-lb bomb was buried at a 45° angle (Fig. 5). The tip and tail end of the bomb are 3.63 and 2.54 m (11.8 and 8.25 ft) respectively below the ground surface. The long axis of the bomb is oriented between holes OT2 and OT7 with the tip towards OT2. Figure 6 shows the bomb being placed. The target holes were backfilled with frozen silt cuttings and covered with pieces of the organic mat to aid in natural freeze-back of the site.

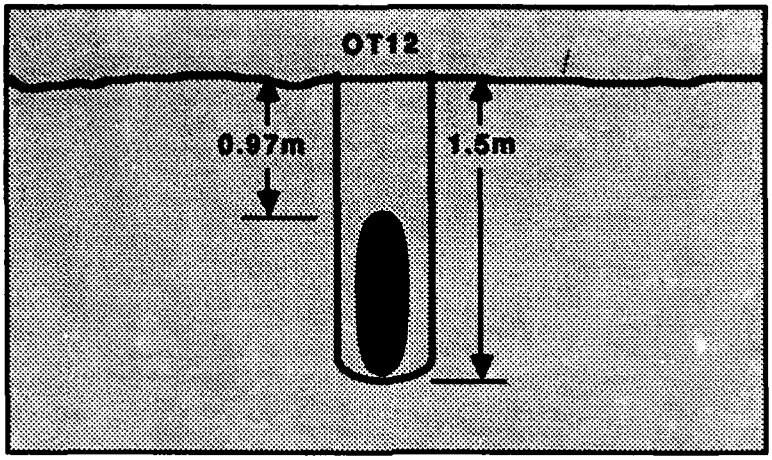


Figure 4. The installation of the 155-mm shell in hole OT12.

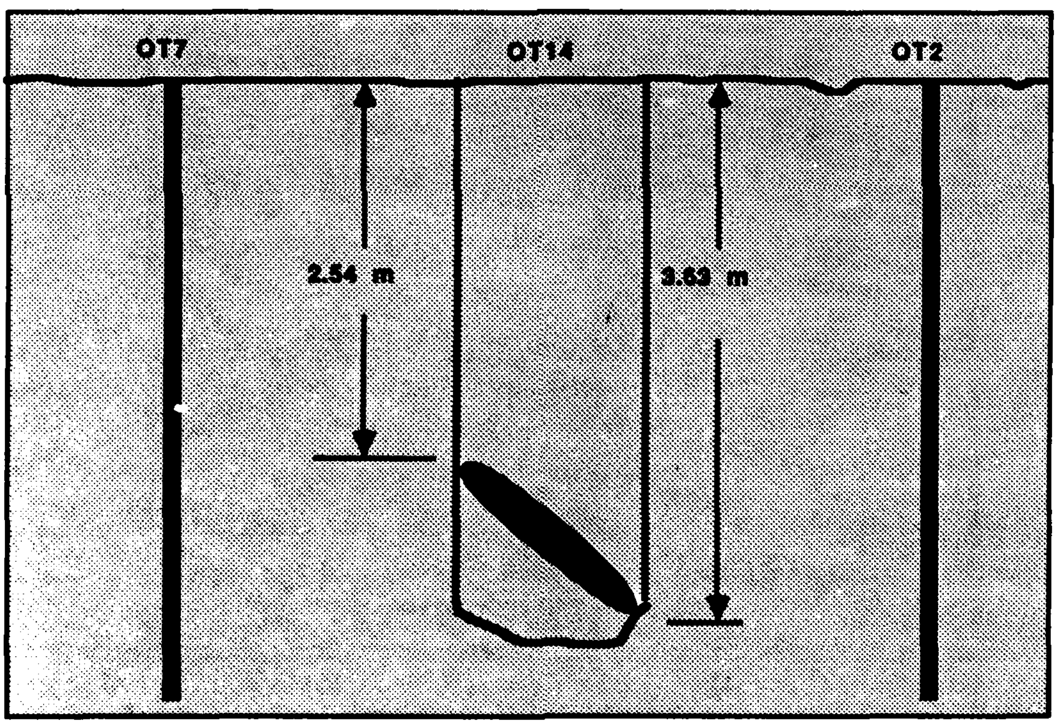


Figure 5. The installation of the MK82 bomb in hole OT14.

Temperature hole

Hole F11 was drilled to provide site temperature data. The total depth was 18.3 m (59.5 ft) (top of the gravel). The hole was cased with 1 1/2-in. I.D. ABS pipe, which was filled with ethylene glycol. The remaining annulus was backfilled with drill cuttings and water. Temperature was recorded by lowering a thermis-

Figure 6. The MK82 bomb being lowered into the 48-in.-diameter hole.

tor, calibrated to 0.01°C, down the fluid-filled casing and recording the resistance at discrete intervals. The thermistor was held at one location until resistance variations became minimum.

LOGGING RESULTS

Sample hole 84-7

All of the boreholes drilled in 1985-86 were logged from the drill cuttings; so only gross changes in material type were recorded. However, material properties at this site are well known and additional property data is available from a hole outside of both arrays that was cored and continuously sampled to 15 m (49 ft) in March 1984 by Brockett and Delaney. It was drilled with a prototype portable drill developed at CRREL (Brockett and Lawson 1985) and sampled using a modified CRREL core barrel. The frozen core was cut into 10-cm (4-in.) lengths and processed to determine volumetric ice content, ice type, and material type. Figure 7 shows the volumetric ice content of this silt section as a function of depth. Al-

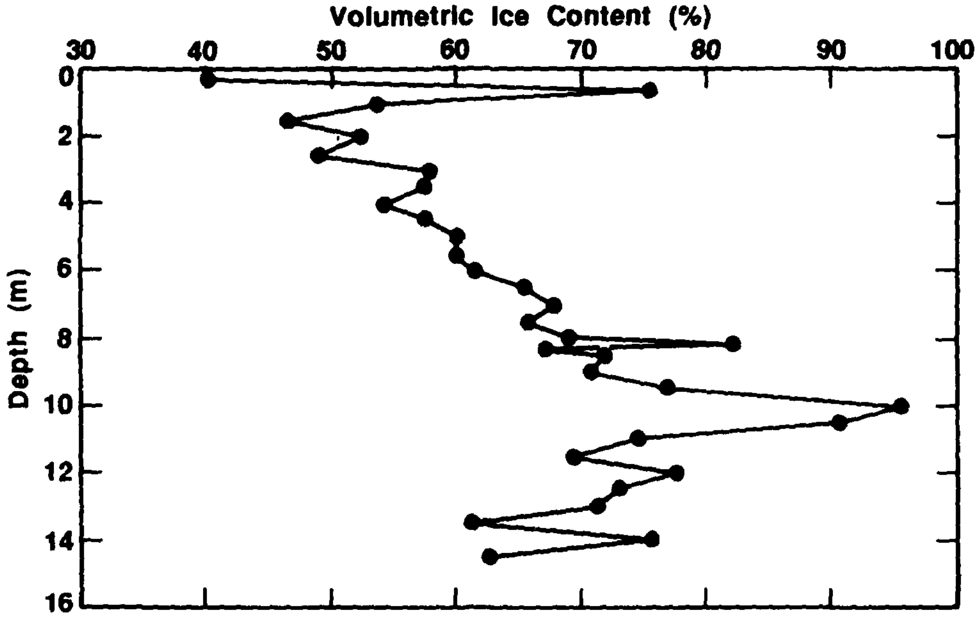


Figure 7. The volumetric ice content of samples from hole 84-7 plotted as a function of depth.

though no massive ice feature was encountered, the data reveal the percentage volumetric ice content with depth to be found in this area.

Deep array

The drill logs for the deep array are shown in Table 1. Holes F1 through F6 were drilled to the top of bedrock with an average depth of 23.8 m. A vertical cross section of this site shows (Fig. 8) that it consists of ice-rich frozen silt, massive foliated ground ice, frozen gravel, and frozen bedrock (schist) at depth. Drilling was discontinued within 10 ft of the top of bedrock because of a potential aquifer.

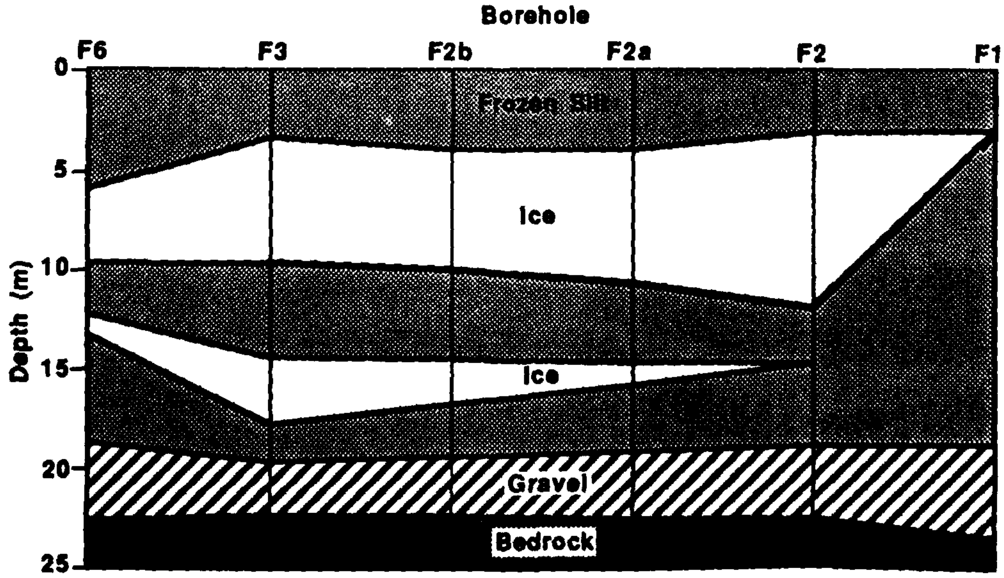


Figure 8. A cross section of the deep array.

Table 1. Well logs from the deep array.

Hole	*Depth (ft)*	*Material description*	
F1	0–62	Ice-rich silt	3-in. I.D. ABS casing
	62–77	Frozen gravel	
	77–80	Bedrock	
F2	0–10	Ice-rich silt	3-in. I.D. ABS casing
	10–39	Wedge ice	
	39–48	Ice-rich silt	
	48–48.5	Ice	
	48.5–62.5	Ice-rich silt	
	62.5–74	Frozen gravel	
	74–77.5	Bedrock	
F2a	0–13	Ice-rich silt	Uncased
	13–20	Wedge ice	
F2b	0–13	Ice-rich silt	Uncased
	13–20	Wedge ice	
F3	0-11	Ice-rich silt	3-in. I.D. ABS casing
	11–31.5	Wedge ice	
	31.5-47	Ice-rich silt	
	47–58	Wedge ice	
	58–64.5	Ice-rich silt	
	64.5–73	Frozen gravel	
	73–	Bedrock	
F4	0–41.5	Ice-rich silt	3-in. I.D. ABS casing
	41.5–45.5	Ice	
	45.5–50	Dirty ice	
	50–64	Ice-rich silt	
	64–84.5	Frozen gravel	
	84.5	Bedrock	
F5	0–62.5	Ice-rich silt	3-in. I.D. ABS casing
	62.5–71	Frozen gravel	
	71	Bedrock	
F6	0–19.5	Ice-rich silt	3-in. I.D. ABS casing
	19.5–31.5	Wedge ice	
	31.5–40	Ice-rich silt	
	40–43.5	Ice	
	43.5–61.5	Ice-rich silt	
	61.5–74	Frozen gravel	
	74–78	Bedrock	

Table 1 (cont'd). Well logs from the deep array.

Hole	*Depth (ft)*	*Material description*	
F7	0–21	Ice-rich silt	Uncased
F8	0–15	Ice-rich silt	Uncased
	15–20	Wedge ice	
F9	0–14	Ice-rich silt	Uncased
	14–	Wedge ice	Sample at 14 ft
F10	0–16	Ice-rich silt	Uncased
	16–	Wedge ice	Sample at 16 ft
F11	0–13	Ice-rich silt	1 1/2-in. I.D. ABS casing
	13–23	Wedge ice	Glycol filled
	23–60	Ice rich silt	
	60	Frozen gravel	

Figure 9. An ice-wedge sample obtained with a CRREL core barrel from hole F9 at a depth of 3.5 m.

A hole drilled to 33 m (107 ft), approximately 150 m (487 ft) south of this array, was reported by the drill operator to have produced a flowing well.

Six additional holes (F2a, F2b, F7-F10) were drilled 6.1 m (198 ft) deep within this array to further define the massive ice feature. The top of the massive ice was sampled at two locations with a hand-operated CRREL core barrel on extensions to determine the character and origin of the ice. The foliated appearance of the ice indicates that the feature is an ice wedge. A photograph of one of these samples is shown in Figure 9. The top of the upper buried ice wedge is repeatedly encoun-

Table 2. Well logs from the target array.

Hole	*Depth (ft)*	*Material description*	
OT1	0–15	Ice-rich silt	3-in. I.D. ABS casing
	15–20	Wedge ice	
OT2	0–14	Ice-rich silt	3-in. I.D. ABS casing
	14–20	Wedge ice	
OT3	0–14	Ice-rich silt	3-in. I.D. ABS casing
14–20	Wedge ice		
OT4	0–17	Ice-rich silt	3-in. I.D. ABS casing
	17–19	Wedge ice	
	19–20	Ice-rich silt	
OT5	0–14	Ice-rich silt	3-in. I.D. ABS casing
	14–20	Wedge ice	
OT6	0–20	Ice-rich silt	3-in. I.D. ABS casing
OT7	0–14	Ice-rich silt	3-in. I.D. ABS casing
	14–19	Wedge ice	
	19–20.5	Ice-rich silt	
OT8	0–20	Ice-rich silt	3-in. I.D. ABS casing
OT9	0–20	Ice-rich silt	3-in. I.D. ABS casing
OT10	0–15	Ice-rich silt	3-in. I.D. ABS casing
15–20	Wedge ice		
OT11	0–20	Ice-rich silt	3-in. I.D. ABS casing
OT12	0–6	Ice-rich silt	8-in.-dia. uncased
OT13	0–15	Ice-rich silt	3-in. I.D. ABS casing
15–20	Wedge ice		
OT14	0–13	Ice-rich silt	48-in.-dia. uncased

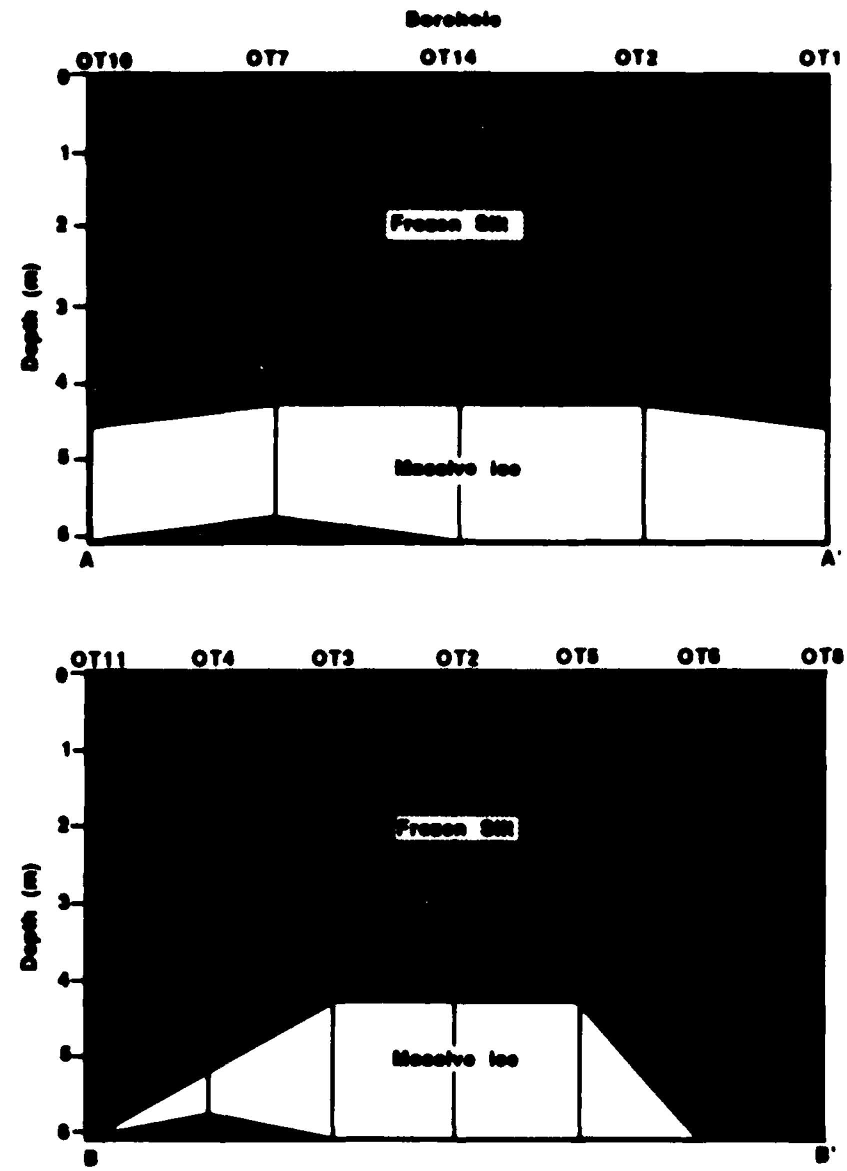


Figure 10. Cross sections from the target array.

tered between 3.4 and 4.6 m (11 and 15 ft) with an organic-rich section directly above. A second massive ice feature was encountered between 12.2 and 13.7 m (39.6 and 44.5 ft) corresponding with ice wedges exposed in the CRREL permafrost tunnel. A fetid, ice-rich organic section was also encountered directly above the gravels.

Target array

The holes for the second, target array are labeled OT1 through OT14; general information on material types is listed in Table 2. Materials logged were mainly ice-rich frozen silt and massive ground ice. Massive wedge ice was encountered at 4.6 m (15 ft) depth. Two cross sections are shown in Figure 10. In section A-A',

(Fig. 2) wedge ice is continuous below 4.6 m (15 ft) in all holes. In section B-B', wedge ice is present in 4 holes below 4.6 m (15 ft). The ice wedge encountered in this array has the same orientation as the wedge encountered in the deep array. These ice features are probably part of a buried polygonal network, which are common in the area.

Ground temperature

Five sets of temperature data were recorded during the period between December 1985 and September 1986 (Fig. 11). Although this is not a full year, the period probably covered the largest annual ground temperature fluctuation. The coldest ground temperature, -5.8°C, occurred at a depth of 1 m (3.25 ft) during the March reading. Below 6.1 m (19.8 ft) the ground is marginally but permanently frozen at -0.76°C.

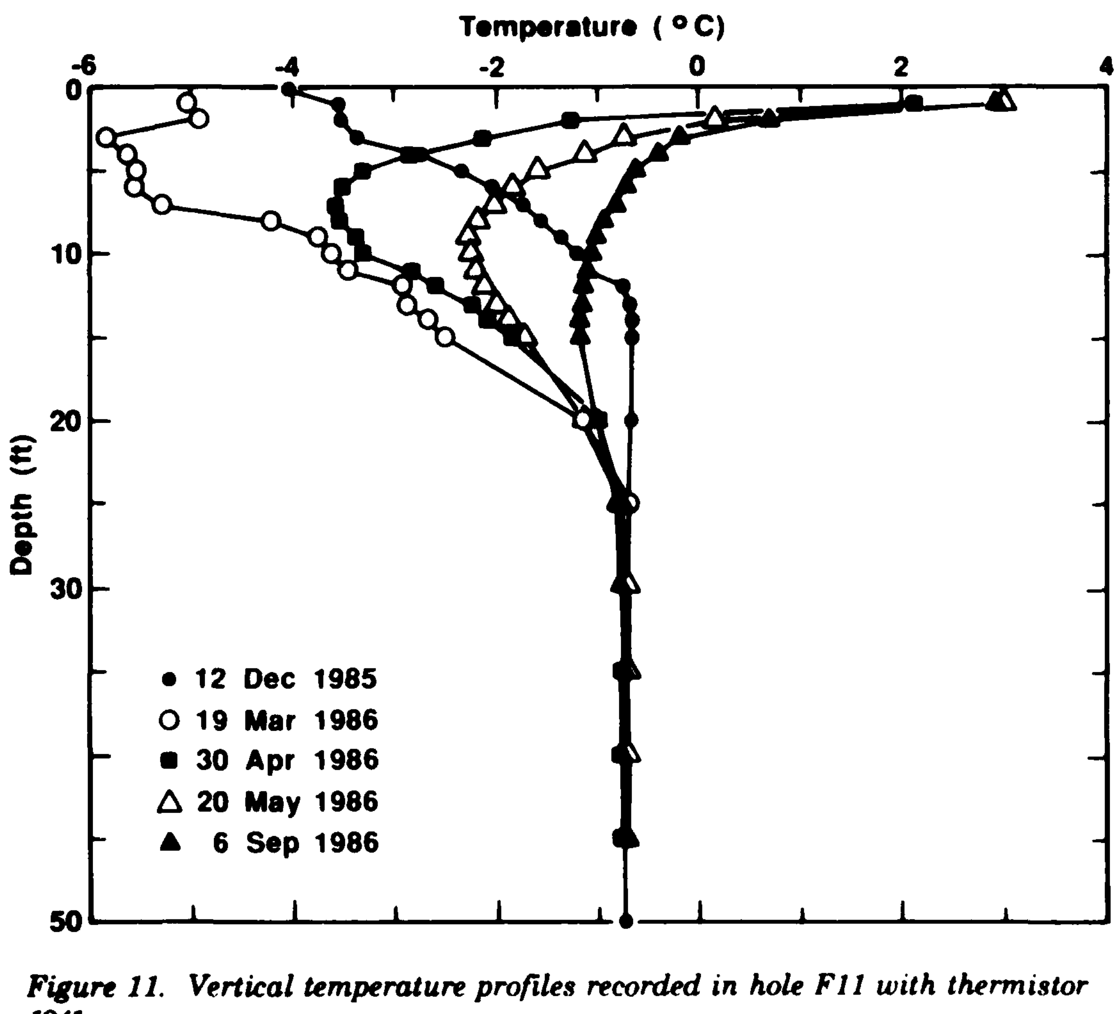


Figure 11. Vertical temperature profiles recorded in hole F11 with thermistor 1941.

SUMMARY

A site consisting of two arrays of cased boreholes drilled through massive ice wedges and a variety of material types has been established in interior Alaska for geophysical research. There is a hole for monitoring ground temperatures, detailed measurements of the volumetric ice content of the frozen silt have been conducted, and literature is available on the geology of the site. Present geophysical studies include cross-borehole propagation measurements of dielectric properties and evaluation of methods for detecting buried ordnance. Future plans include surface remote-sensing observations coordinated with ground control, and the attenuation of low-frequency radio-wave propagation.

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