TEI-753

Nuclear Explosions--Peaceful Applications

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGIC INVESTIGATIONS IN SUPPORT OF PROJECT CHARIOT IN THE VICINITY OF CAPE THOMPSON, NORTHWESTERN ALASKA--PRELIMINARY REPORT*

By

Reuben Kachadoorian, R. H. Campbell, G. W. Moore,
J. Y. Cole, A. H. Lachenbruch, G. W. Greene,
D. F. Barnes, R. M. Waller, W. L. Lamar,
and M. J. Slaughter

January 1960

Trace Elements Investigations Report 753

This report is preliminary
and has not been edited for
conformity with Geological
Survey format and nomenclature.

*This report concerns work done on behalf of San Francisco Operations Office, U. S. Atomic Energy Commission.

CONTENTS

CONTENTS--continued

ILLUSTRATIONS

TABLES

GEOLOGIC INVESTIGATIONS IN SUPPORT OF PROJECT CHARIOT IN THE VICINITY OF CAPE THOMPSON, NORTHWESTERN ALASKA--PRELIMINARY REPORT

By

Reuben Kachadoorian, R. H. Campbell, G. W. Moore,
J. Y. Cole, A. H. Lachenbruch, G. W. Greene,
D. F. Barnes, R. M. Waller, W. L. Lamar,
and M. J. Slaughter

ABSTRACT AND GENERAL INTRODUCTION

By

Reuben Kachadoorian

Abstract

The Chariot test site at Ogotoruk Creek in the vicinity of Cape Thompson, Alaska, is topographically and geologically well-situated for the construction of an experimental deep-water excavation as proposed by the Atomic Energy Commission.

The rocks of the area consist entirely of consolidated clastic and chemical sediments of marine and brackish water depositional environments. They include sandstone, calcitic and dolomitic limestone, chert, argillite, mudstone, siltstone, and graywacke. All the rocks have been highly deformed and very slightly metamorphosed. The rocks range in age from Early Mississippian to Jurassic(?) and Cretaceous.

The material to be excavated consists chiefly of mudstone, siltstone, and sandstone of the Tiglukpuk formation of Jurassic(?) age. Test holes Able and Baker indicate that the devices will be located entirely in frozen mudstone containing numerous small faults. The fault zones in the mudstone

are generally less than 1 foot thick. In Hole Baker, however, there is a 14.1-foot fault zone from 136.2 feet to 150.3 feet below the surface. Locally, the mudstone is so highly fractured that it occurs as splinters 1/8- to 1/4-inch thick, 1/2- to 1-inch wide, and about 3 inches long.

During the drilling program in 1959 the walls of the holes slumped into the bottom of the hole when the relatively warm drilling fluid thawed the permafrost in the mudstone. Slumping of debris into the hole will be one of the major problems during the construction of the device holes if proper techniques are not utilized. The greatest amount of slumping will take place in the fault zones and the unconsolidated materials that overlie the mudstone if they are allowed to thaw.

The moisture content of the rocks in place probably is much higher than that reported by the Corps of Engineers for samples of the rock. The reported moisture content (0.28 to 5.67 percent) was based on thawed core sent to the Corps of Engineers laboratory in Anchorage, Alaska, and no consideration could be given to the fact that the rocks are perennially frozen and that some of the fracture zones may contain ice. It is believed that the moisture content is in the vicinity of 10 percent in the rocks that underlie the test site.

On the basis of preliminary geothermal data the tentative depth of permafrost in Hole Able is at least 800 feet below the surface and at least 1,000 feet in Hole Baker. The absence of reliable data concerning the lower half of Hole Baker makes it difficult to determine the undisturbed geothermal gradient below the zone of climatic change.

Seismic measurements in the frozen Tiglukpuk rocks indicate velocities ranging from 11,500 to 14,500 fps and averaging about 13,500 fps. Surface refraction measurements suggest a slight increase of velocity with depth, but this increase with depth is not supported by the in-hole velocity logs. The drilling program planned for the summer of 1959 could not be completed, so that seismic velocities in the unfrozen mudstones beneath the permafrost could not be measured; therefore an attempt was made to measure by seismic refraction the depth to the high velocity chert and limestone that is believed to underlie the Tiglukpuk. However, this refraction work had not been planned previously and neither sufficient equipment nor time were available to obtain satisfactory results. Although a higher velocity was measured near the north end of a 7,500-foot profile, there is considerable doubt whether this higher velocity represents a deep refractor. If the high velocity does represent a deep refractor, its depth is somewhere between 1,000 and 1,750 feet.

The beach at the Chariot site is in a steady-state condition and is not advancing toward the land at a rate that is significant from an engineer's standpoint. Erosion behind the beach may be in the order of 1 or 2 feet a century. The net alongshore transport of sediments is approximately 5 cubic yards an hour to the southeast during the ice-free periods. However, during heavy storms the beach transport of sediments may be more than 1,000 cubic yards per hour. Therefore, jetties should be constructed on each of the excavated channels to accommodate the volume of material that may be moved during these storms.

Shallow and deep aquifers exist in the test site area. The shallow aquifers consist principally of unconsolidated material dependent upon recharge from surface sources during the summer. The deep aquifers are in permeable portions of bedrock and receive recharge water from distant sources. Both types of aquifers may be contaminated by any radioactive fallout from the proposed nuclear test. The shallow aquifers would receive contaminated surface water immediately, whereas it may take years for the deep aquifers to receive the contaminated surface water.

On the basis of data available the suspended sediment discharge of Ogotoruk Creek can be considered minor compared to the size of the proposed excavation. The chemical composition of the waters indicates springs as well as surface water exist in the vicinity of the test site. The radio-chemical levels of the fresh waters are low and in the same magnitude as are normally found. The highest beta activity of the fresh waters was found in the two ponds approximately 6 miles north of the test site, and might be ascribed to fallout which has accumulated from previous detonations and which has not been flushed out owing to lack of natural drainage. The chemical composition of the water of the larger control pond to the east is unusual for the area, in that it has a high mineral content.

For all practical purposes no flow occurred in Ogotoruk Creek from October 1, 1958 to late in May 1959. There may have been some flow on certain scattered days but amounts were too small to be considered of any importance in the overall surface water study. No definite conclusions can be drawn from the limited stream-flow records obtained thus far, except that little flow is likely between mid-October and mid-May.

General introduction

General statement

In 1958 the U. S. Geological Survey was requested by the Atomic Energy Commission to conduct geologic studies to develop data which will contribute to determining the feasibility and safety of detonating several nuclear explosives to create an excavation that could be used for a channel and harbor near the mouth of Ogotoruk Creek, northwest Alaska. The proposed test excavation is Project Chariot of the Atomic Energy Commission's Operation Plowshare Program.

Previous work

In the early spring of 1958 the U. S. Geological Survey was asked to undertake a study to evaluate the geologic and oceanographic factors relevant to the selection of a site between Point Barrow and Nome, Alaska. Later, an area between Cape Seppings and Cape Thompson, Alaska, was selected and the Survey prepared a report on this 20-mile area (Péwé, Hopkins, and Lachenbruch, 1959). Péwé, Hopkins, and Lachenbruch's work was based entirely on the study of published reports, manuscripts, field notes, and unpublished maps in the files of the U. S. Geological Survey. This information was supplemented by interviews with geologists who had visited the area, and the geologic interpretation of aerial photographs. On the basis of the above sources of information, 3 sites were selected in the 20-mile coastal strip from Cape Seppings to Cape Thompson. The report suggested that a geological field investigation of the 3 sites be made to determine the most suitable site for the test.

Accordingly, a Survey field party worked in the area from July 7, 1958 to August 25, 1958. The data collected on the 3 sites were discussed with representatives of the Atomic Energy Commission, Lawrence Radiation Laboratory, Sandia Corporation, U. S. Corps of Engineers, and Holmes and Narver, Inc., who visited the Survey party from July 17 , 1958 to July 19, 1958. On the basis of the Survey findings it was decided to conduct the test at the Ogotoruk Creek site. A report was prepared by the Geological Survey and transmitted to the Atomic Energy Commission during the winter of 1958 (Kachadoorian, Campbell, Sainsbury, and Scholl, 1958). This report and the report by Péwé, Hopkins, and Lachenbruch were placed on open-file in October 1959 by the U. S. Geological Survey.

Present work

This report includes the Geological Survey's participation in the investigation of the Ogotoruk Creek test site area during the 1959 field season. This entire phase of the investigative program is referred to as Chariot, Phase II, by the Atomic Energy Commission. The Survey investigation for 1959 consisted of 6 parts: (1) site geologic investigations, (2) areal geologic mapping, (3) coastal processes investigations, (4) geothermal investigations, (5) seismic velocity investigations, and (6) water resources investigations. The seismic velocity investigations, in turn, were in two categories: in-hole velocity and a seismic refraction investigation. The water resources investigation was in three categories: surface water, ground water, and quality of water investigations. The seismic refraction study was not in the original Geological Survey proposal for field work for 1959, but was begun in the field when it became apparent that in-hole velocity equipment could not provide needed information on seismic velocities of the rocks at depths to 1,500 feet because the diamond-drilling program would not give required depth of 1,500 feet.

All pertinent major problems that are associated with the Geological Survey investigations are considered in this preliminary report. Some revisions may be necessary when complete laboratory results have been obtained, but the authors believe that these revisions will be slight and will not materially affect the conclusions expressed in this report.

Acknowledgments

Field work was facilitated by the cooperation of the personnel of the Atomic Energy Commission, Wein Airlines, Holmes and Narver, Inc., Boyles Bros., and Lawrence Radiation Laboratory.

Location

The Chariot site area lies north of the Arctic Circle in northwestern Alaska at longitude 165°45'W. and latitude 68°06'N., at the mouth of Ogotoruk Creek (fig. 1). The area is approximately 125 miles northwest of the town of Kotzebue and about 24 miles southeast of the town of Point Hope. The coastal processes investigation included the coastline from Sheshalik Spit, 110 miles southeast of the test site, to the mouth of the Kukpuk River, 27 miles northwest of the site.

Accessibility

The only means of access to the Ogotoruk Creek area at the present time is by boat, light aircraft, or tracked vehicle. The Alaska highway system does not extend into northwestern Alaska. Light single-engine aircraft can land at the site on a 700-foot airstrip built by the U. S. Geological Survey personnel in 1958. Twin-engine aircraft can land on a 2,200-foot airstrip constructed by the contractor, Holmes and Narver, Inc., in 1959.

Methods of field work

Onshore field work by the Geological Survey consisted of a series of foot, tracked vehicle, and boat traverses, during which geological data were gathered and plotted on vertical aerial photographs of 1:40,000 and 1:12,000 scale and on surface photographs ranging in scale from 1:600 to 1:3,000. The information was later transferred to topographic maps of 1:4,800 and 1:48,000 scale (pls. 1 and 2, respectively). Information concerning the depth of permafrost and thickness of ice wedges was obtained from diamond-drill holes.

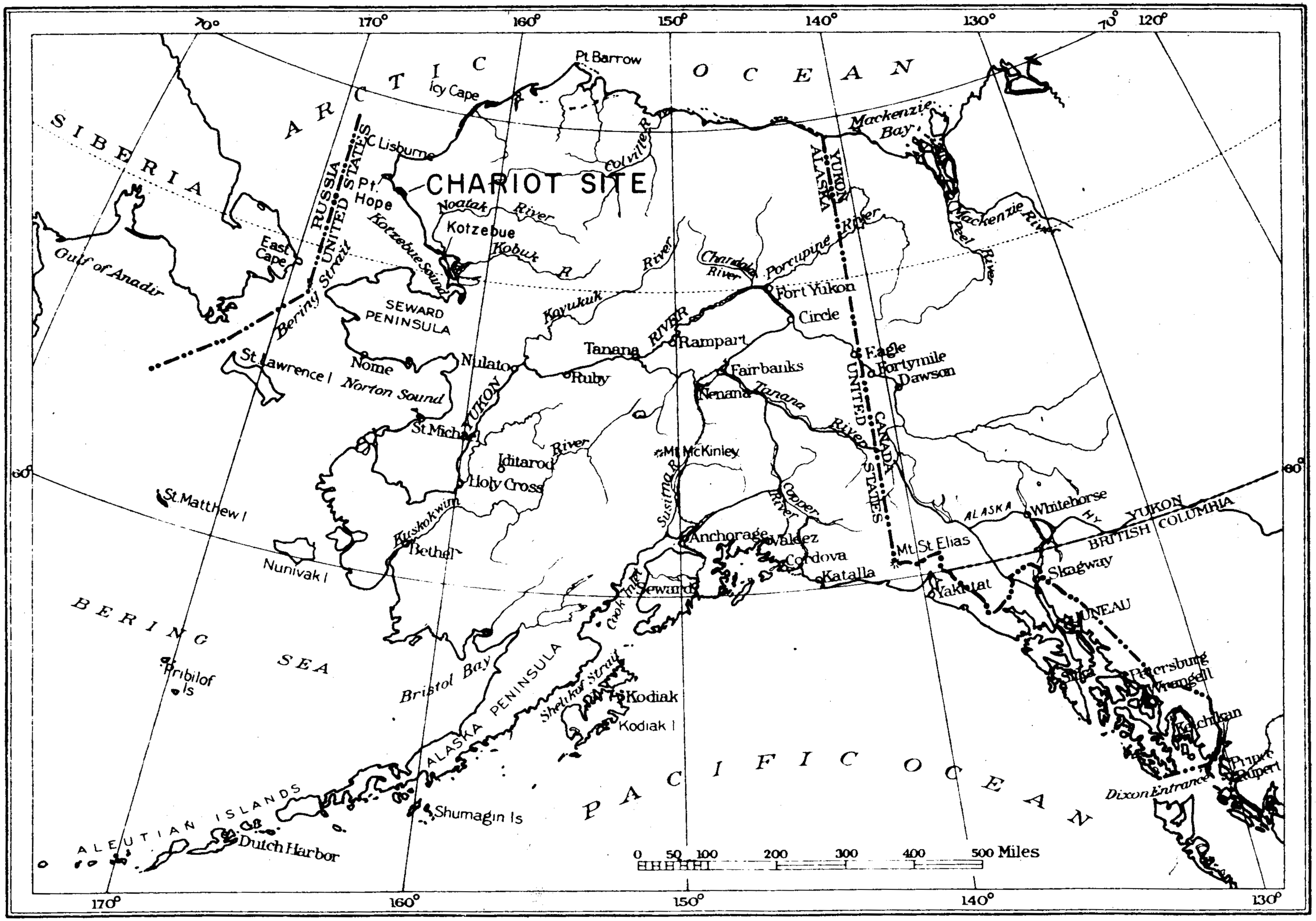

Figure 1...Index map showing location of Chariot site, northwestern Alaska

Data regarding submarine topography, marine geology, oceanography, and coastal processes were collected by teams using either a weasel, or a small boat equipped with an outboard motor.

The Survey party included three two-man field teams. One team worked from Sheshalik Spit to the Kukpuk River doing the coastal processes investigation; the second team did the areal mapping; and the third team did the site investigation study. In addition to the three two-man field teams, Survey personnel doing the geothermal, ground water, surface water, and seismic investigations were also at the site from time to time.

Climate

The climate of the Ogotoruk Creek area is characterized by long cold winters and short cool summers. Data from weather stations at Kotzebue Airport, and Cape Lisburne about 70 miles north of Ogotoruk Creek, are shown in tables 1 and 2. Additional data for dates of freeze-up and breakup of ice are available for Kivalina, 30 miles southeast of Ogotoruk Creek, and Point Hope, and are shown in table 3.

Weather data have been collected by the Geological Survey at Ogotoruk Creek for the past two field seasons. Wind direction, maximum and minimum temperatures, and precipitation were recorded. The summary of these data is shown in table 4.

Literature cited

Kachadoorian, Reuben, Campbell, R. H., Sainsbury, C. L., and Scholl, D. W., 1958, Geology of the Ogotoruk Creek area, northwestern Alaska: U. S. Geol. Survey TEM-976; also, U. S. Geol. Survey open-file report.

(Text continued on p. 19)

Table 1.--Climatological data for Kotzebue Airport, Alaska 1/

Month	Average temperature °F	Average precipitation inches
January	-6.6	.47
February	-4.7	.32
March	-1.6	.27
April	13.8	.36
May	29.6	.33
June	43.3	.49
July	52.6	1.53
August	50.7	1.95
September	40.9	.94
October	25.5	.58
November	7.5	.43
December	-3.7	.35
Annual	20.6	8.02

1/ U. S. Weather Bureau, 1958, Climatological data, Alaska Annual Summary, 1957, v. XLIII, no. 13

Years of record:

Precipitation, 15 years

Temperature, 15 years

Table 2.--Climatological data for Cape Lisburne, Alaska 1/

Month	Average temperature °F		Average precipitation inches	
January	-9.5		.27	
February	-10.6		.13	
March	-8.7		.25	
April	20.9		.21	
May	30.3		.02	
June	41.6		.44	Partly estimated (June–September)
July	46.0		2.12	
August	44.9		3.50	
September	35.8		2.61	
October	28.2		1.94	
November	5.9		.44	
December	-8.2	(1-10 days record missing)	.12	
Annual	19.7		12.05	Partly estimated

1/ U. S. Weather Bureau, 1958, Climatological data, Alaska Annual Summary, 1957, v. XLIII, no. 13

Years of record:

Precipitation, 3 years

Temperature, 4 years

Table 3.--Miscellaneous climatological data for Kotzebue, Cape Lisburne, Point Hope, and Kivalina, Alaska, 1957 1/

Station	Rivers and harbors	Date unsafe for man 2/	Break-up	Departure 3/	First ice	Date safe for man 4/	Departure 3/	Highest temp (°F)	Date	Lowest temp (°F)	Date	Total snow fall (in.)	Freezing temp		Number of days temperature			
													Last date in spring	First date in autumn	Max. 70°F or above	Max. 32°F or below	Min. 32°F or below	Min. 0°F or below
Kotzebue	Kotzebue Sound	May 25	May 26	-6	Sept. 25	Oct. 31	+8	81	June 8	-47	Dec. 26	77.2	May 31 (30°)	Sept. 19 (32°)	5	183	243	90
Cape Lisburne	---	5/	5/	5/	5/	5/	5/	72	July 11	-37	Feb. 13	30.3	June 20 (32°)	Sept. 17 (28°)	1	195	247	104
Kivalina	Walik River	6/	6/	6/	Oct. 4	Oct. 8	-18	5/	5/	5/	5/	5/	5/	5/	5/	5/	5/	5/
Point Hope	Marit Inlet	May 30	June 9	6/	Sept. 26	Oct. 3	-8	5/	5/	5/	5/	5/	5/	5/	5/	5/	5/	5/

1/ U. S. Weather Bureau, 1958, Climatological Data, Alaska Annual Summary, 1957, v. XLIII, no. 13.
2/ Date man cannot travel on ice.
3/ Departures are days from average date of breakup or freeze up based on five or more years of record. Earlier-than-average dates are indicated as minus and later-than-average dates are indicated as plus.
4/ Date man can travel on ice.
5/ No data reported by Weather Bureau.
6/ No record.

Table 4.--Summary of weather data for the Ogotoruk Creek area collected during 1958 and 1959 field seasons

	July 7-31 1958	July 13-31 1959	August 1-27 1958	August 1-31 1959
Total precipitation	0.4 in.	0.8 in.	4.4 in.	1.4 in.
Maximum precipitation in 24 hours	0.2 in. (July 9)	0.7 in. (July 23)	1.0 in. (Aug. 10 and 11)	0.5 in. (Aug. 22)
Maximum temperature	80°F (July 10)	79°F (July 20)	70°F (Aug. 27)	81°F (Aug. 13)
Average maximum daily temperature	63.5°F	57.9°F	60.2°F	59.3°F
Minimum temperature	35°F (July 27)	31°F (July 27)	34°F (Aug. 19)	34°F (Aug. 24 and 25)
Average minimum daily temperature	44.4°F	47.0°F	42.7°F	41.0°F
Average daily wind velocity	14 mph	14 mph	17 mph	16 mph
Maximum wind velocity	30 mph SE	30 mph NE	60 mph N	50 mph N
Average daily cloud cover	60 percent	55 percent	65 percent	50 percent
Number of essentially cloudless days	7	7	7	7

Literature cited--continued

Péwé, T. L., Hopkins, D. M., and Lachenbruch, A. H., 1959, Engineering geology bearing on harbor site selection along the northwest coast of Alaska from Nome to Point Barrow: U. S. Geol. Survey, TEI-678; also, U. S. Geol. Survey open-file report.

U. S. Weather Bureau, 1958, Climatological data: Alaska Annual Summary, 1957, v. XLIII, no. 13

ENGINEERING GEOLOGY OF THE CHARIOT SITE NEAR CAPE THOMPSON, NORTHWESTERN ALASKA

By

Reuben Kachadoorian

Introduction

General statement

During the 1959 field season a two-man Geological Survey field party worked at Ogotoruk Creek, Alaska doing site engineering geology investigations. In addition, the party in cooperation with U. S. Coast and Geodetic Survey and Holmes and Narver, Inc. personnel, selected several seismic recording stations. The site investigation consisted chiefly of logging core from diamond-drill holes Able and Baker, giving geologic advice and counsel to other participants in the Chariot Program, and evaluating the site geologic investigations conducted by the Survey in 1958. In addition to the site investigation studies the engineering geology team at the Chariot site collected the water samples at Ogotoruk Creek and elsewhere, collected daily weather data, and performed and provided a coordination and liaison function with other participants in the program.

Geology

Bedrock

The site is located entirely in highly deformed and fractured mudstone, siltstone, and graywacke of the Tiglukpuk formation of Jurassic(?) age (pl. 1). Locally these rocks are so highly fractured that they occur as splinters 1/8- to 1/4-inch thick, 1/2- to 1-inch wide, and about 3 inches long. The mudstone, siltstone, and graywacke are frozen to depths of at least 800 to 1,000 feet. The permafrost problem is analyzed by Lachenbruch and Greene in a later chapter of this report.

Two diamond-drill holes were drilled during the summer of 1959. Tables 5 and 6 are detailed lithologic logs of these holes, Able and Baker, respectively. The drill cores indicate that the bedrock is mudstone at the site of the drill holes. Thin-section and X-ray analyses of the mudstone show that it consists of about 70 percent detrital grains (0.2 mm to 0.04 mm in diameter) and 30 percent matrix (grains less than 0.04 mm in diameter). Grains larger than 0.2 mm were not observed in the thin sections analyzed. However, as indicated in the lithologic logs, pyrite crystals as much as a quarter of an inch in diameter were noted in the core. The detrital material consists chiefly of subangular to angular grains of quartz, muscovite, feldspar, and chlorite. The matrix consists chiefly of mica, and probably includes clay minerals of the illite and kaolinite groups as very minor constituents. The mudstone was analyzed specifically for clays of the montmorillonite group and none was observed.

(Text continued on p. 32)

Table 5.--Lithologic log of Hole Able, Chariot site, northwestern Alaska

Depth (feet)	Description
0.0-2.1	Concrete (note: depths were measured from top of concrete block, 2.1 feet above original ground).
2.1-9.6	Sand and silt; top of permafrost 4.5 feet; ice wedge at 4.5-5.8 feet; local small ice lenses at 5.8-9.6 feet.
9.6-22.4	Gravel, subrounded to rounded, 1/4-inch to 3 inches long, locally contains sand layers or pockets as much as 2 feet thick; deposit may be beach gravel.
22.4-45.0	Mudstone, dark-gray, highly fractured into average length of 1 inch; fracturing chiefly due to drilling; core contains vertical fracture cleavage.
45.0-50.3	Mudstone, dense, dark-gray; core broken into average lengths of 4 inches, except between 46.0-47.7 feet, where highly fractured into pieces 2-1/2 by 2 by 1/2-inches; tight joints at 45°, average spacing 0.7-foot.
50.3-51.3	Mudstone, crumbles and forms clay and silt balls when wet; fault gouge.
51.3-60.4	Mudstone, medium dark-gray, massive, core pieces averaging 1 foot long; interbedded with crumbled mudstone at 51.7-52.0 feet, 54.5-55.0 feet, and 57.7-58.0 feet; joints at 50°, generally loose, locally healed with quartz, average spacing 0.4 foot; vertical fracture cleavage.

Table 5.--Lithologic log of Hole Able, Chariot site, northwestern Alaska--continued

Depth (feet)	Description
60.4-96.1	Mudstone, medium dark-gray, dense, massive; highly fractured by drilling at 65.8-67.5 feet, 79.9-80.2 feet, 80.8-81.4 feet, and 84.9-85.5 feet; crumbled mudstone at 67.8-68.2 feet, may be small fault zone; joints at 70° and 45° loose, locally filled with quartz.
96.1-104.0	Mudstone, dark-gray; interbedded massive mudstone and thin-bedded mudstone; fractured zones at 96.0-98.3 feet, and 101.7-103.0 feet in thin-bedded mudstone; joints at 70°, tight, locally loose; average spacing 0.8-foot; vertical fracture cleavage.
104.0-108.5	Mudstone, dark-gray; highly fractured pieces that average 1 inch in length; vertical fracture cleavage.
108.5-136.2	Mudstone, gray-black, fissile, thinly bedded, highly fractured by drilling; 50 percent of core fractured into pieces less than 1 inch in length, some core 18 inches long; joints at 60°, loose; vertical fracture cleavage is tight and contains soft clay material.
136.2-138.6	Mudstone, gray-black; crumbles into small fragments, clayey in spots; fault zone; hole started caving here because of permafrost thawing and gouge slumping into hole.
138.6-150.3	Mudstone, gray-black, highly fractured and crumbled; core pieces locally 0.5-foot long, more commonly less than 1 inch; locally appears to have high content of clay-size

Table 5.--Lithologic log of Hole Able, Chariot site, northwestern Alaska--continued

Depth (feet)	Description
	particles; caving in this interval during drilling between 136.2-150.3 feet.
150.3-177.0	Mudstone, gray-black; generally massive core as much as 3.4 feet long, more commonly 4 inches; joints at 40° and 60°, generally tight, average spacing 0.8-foot.
177.0-203.7	Mudstone, gray-black, thin-laminated, interbedded with massive mudstone; thin-laminated mudstone crumbles easily into pieces generally less than 1/2-inch in length, constitutes 65 percent of core; joints at 75°, tight and healed with quartz; vertical fracture cleavage.
203.7-222.9	Mudstone, dark-gray, massive, core pieces as much as 2.0 feet long, generally 1.0 foot; at 220.9-222.9 feet core more broken; joints at 70°, tight, some healed by quartz; horizontal joints, all healed by quartz; average spacing 0.6-foot; vertical fracture cleavage; core contains quartz veins as much as 1/4-inch thick.
222.9-246.8	Mudstone, dark-gray; highly fractured and crumbled, pieces generally less than 1/2-inch in length, locally as much as 3 inches; vertical fracture cleavage, locally healed with fine silt.
246.8-277.5	Mudstone, thin-laminated, laminae range from 45° to parallel to core; at 254.1-258.5 feet core relatively massive; at 269.9-272.5 feet core is mud, appears to be fault zone;

Table 5.--Lithologic log of Hole Able, Chariot site, northwestern Alaska--continued

Depth (feet)	Description
	stringers of quartz throughout core, chiefly at 254.1-258.5 feet; joints at 60°, open.
277.5-317.5	Mudstone, dark-gray, massive; core pieces generally more than 1 foot and less than 3 feet long; at 315.7-316.0 feet core broken by drilling; joints at 45°, healed with quartz, spaced 1-3 feet apart.
317.5-333.5	Mudstone, dark-gray; moderately fractured, most fractures along joints; joints at 70°, open to tight, spaced 0.3-0.6 foot apart, locally healed by quartz; vertical fracture cleavage.
333.5-408.7	Mudstone, dark-gray; massive with local highly fractured zones at 341.3-342.8 feet, 379.6-380.4 feet, 395.5-395.7 feet, and 399.4-400.5 feet, fractured zones caused by drilling; joints at 70°, tight, spaced 0.4-1.0 foot apart; at 45°, tight and occur only occasionally; horizontal joints, spaced 2 feet apart, filled with quartz; vertical fracture cleavage; lenses and pods of quartz throughout core.
408.7-430.7	Mudstone, dark-gray, generally highly fractured; longest core piece 1.6 feet, pieces more commonly less than 0.8 foot; core highly fractured at 409.1-410.7 feet, 411.9-412.3 feet, and 418.5-420.5 feet; joints at 70°, tight, spaced 1.0-1.5 feet apart; vertical fracture cleavage; stringers and pods of quartz throughout core.

Table 5.--Lithologic log of Hole Able, Chariot site, northwestern Alaska--continued

Depth (feet)	Description
430.7-457.0	Mudstone, gray-black to 438.0 feet, dark-gray to 444.5 feet, gray-black to 457.0 feet, massive with local highly fractured zones at 435.0-435.5 feet, 437.5-438.3 feet, 448.0-448.3 feet, 449.8-450.3 feet, and 453.2-453.5 feet; joints at 45°, tight, average spacing 0.7-foot; 70°, tight, average spacing 1.2 feet; quartz pods and stringers 1/2-inch in maximum thickness throughout core, locally contain pyrite.
457.0-522.3	Mudstone, dark-gray, massive, with local highly fractured zones at 470.2-471.0 feet, 491.0-491.5 feet, 502.3-502.4 feet, and 511.0-511.5 feet; joints at 45°, tight, average spacing 0.7-foot, locally healed with quartz; at 70°, tight, 1.5-foot apart, locally healed with quartz; quartz pods and stringers as much as 1/2-inch thick throughout core, numerous quartz stringers less than 1 mm.
522.3-530.8	Mudstone, dark-gray, highly fractured; continuously fractured from 525.3-530.8 feet, core makes mud balls when wet, especially at 525.3-526.0 feet, which is probable fault zone; joints at 45° and 70°, tight, spaced 0.5-0.7-foot apart, locally healed by quartz; core contains minute stringers and pods of quartz.
530.8-534.0	Mudstone, dark-gray, massive, contains quartz pods and stringers; joints at 45° and 70°, 0.8-foot apart, tight.

Table 5.--Lithologic log of Hole Able, Chariot site, northwestern Alaska--continued

Depth (feet)	Description
534.0-546.0	Mudstone, dark-gray, at 540.4-541-6 feet core gray-black, thin-laminated; highly fractured core, pieces generally less than 0.6-foot long, average length 0.1-foot; joints at 45° spaced 0.3-foot apart, tight; at 70°, spaced 1.2 feet apart, tight.
546.0-598.0	Mudstone, gray-black; core pieces generally less than 1.0-foot long, highly fractured by drilling; from 566.6-567.7 feet, 564.4-564.7 feet core thinly laminated; fault zone at 586.0-586.9 feet; joints at 70°, 0.1-1.0-foot apart, tight, some healed by quartz; at 45°, average spacing 0.5-foot, tight, some healed by quartz; at 549.2-549.4 feet quartz pods 1 inch or less in thickness; at 572.0 feet 1-inch quartz stringer.

Table 6.--Lithologic log of Hole Baker, Chariot site, northwestern Alaska

Depth (feet)	Description
0.0-12.2	Silt and sand; permafrost from 2.1 feet.
12.2-17.2	Gravel; generally less than 1 inch in diameter.
17.2-41.0	Mudstone, no core; drilling with rock bit.
41.0-85.2	Mudstone, dark-gray, highly fractured, longest core piece 8 inches, locally fissile, chiefly fractured by drilling; joints at 60°, spaced 0.3-foot apart, tight; vertical fracture cleavage; bedding at 75°; at 41.0-55.7 feet quartz veins and vugs throughout core.
85.2-125.5	Mudstone, medium dark-gray to dark-gray, massive; core broken by drilling; core pieces 0.1-1.2 feet long; joints at 65°, spaced 0.8-foot apart, tight; vertical fracture cleavage; quartz veins common at 86.6-88.9 feet, 94.0-95.3 feet, and 120.0-121.8 feet.
125.5-130.7	Mudstone, massive; bedding at 70°; joints along bedding locally healed by quartz.
130.7-160.4	Mudstone, dark medium-gray, massive; core pieces as much as 2.6 feet long, average 0.5-foot; quartz veins, vugs scattered throughout core, 1/2-inch quartz vein at 143.4 feet containing crystals; pyrite crystals to 1/32-inch at 142.4-142.8 feet; joints at 45°, spaced 2 feet apart, generally tight.
160.4-193.0	Mudstone, dark-gray, massive; locally fractured at 164.0-165-7 feet, at 164.0-178.0 feet core generally in 0.2-foot pieces; from 178.0-193.0 feet core in 1-foot pieces; joints

Table 6.--Lithologic log of Hole Baker, Chariot site, northwestern Alaska--continued

Depth (feet)	Description
	at 75°, tight, occur along bedding planes, healed by fine quartz veins.
193.0-215.1	Mudstone; appears to be chiefly fault gouge; at 193.0-209.5 feet series of fault zones with chief fault zone at 209.5-215.1 feet.
215.1-239.7	Mudstone, dark-gray; highly fractured at 220.3-222.6 feet, core thin-laminated; bedding at 70°; core pieces 0.3-0.8-foot long; small quartz veins throughout core, at 227.4-229.0 feet quartz veins 1/4-inch or less in thickness; at 215.0-218.1 feet massive mudstone is faulted against thin-laminated mudstone; fault is nearly vertical.
239.7-254.0	Mudstone with clay gouge; movement along fault later than injection of quartz that occurs in the core.
254.0-279.5	Mudstone, medium dark-gray to dark-gray, massive; core pieces 1 foot long or less; healed breccia zone at 267.3-267.8 feet; joints at 45°, spaced 0.5-foot apart, generally tight; quartz veins throughout core, except in breccia zone.
279.5-448.3	Mudstone; contains several fault zones; quartz has healed fractures at irregular intervals; fault zones at 279.5-289.7 feet, 305.3-313.3 feet, 326.8-333.5 feet, 347.5-350.4 feet, 367.5-379.2 feet, 388.6-391.5 feet, 419.8-432.0 feet, and 442.2-442.6 feet.
	Note: from 41.0 to 422.0 feet drilling done by NC bit; NX bit used from 422.0 feet to bottom of hole.

Table 6.--Lithologic hole of Hole Baker, Chariot site, northwestern Alaska--continued

Depth (feet)	Description
448.3-477.0	Mudstone, dark-gray; highly fractured, core pieces less than 0.4-foot long; high percentage of quartz veins scattered throughout core; bedding at 60°; locally zones of soft core indicate movement.
477.0-532.0	Mudstone, massive; fractured by drilling; quartz veins 1/2-inch or less in thickness throughout core; joints at 70°, spaced 3 feet apart, tight, some joints healed by quartz; small brecciated zones at 501.8-502.3 feet, 511.8-512.1 feet, and 516.3-518.5 feet; small pyrite crystals at 518.9 feet.
532.0-565.8	Mudstone, dark-gray, relatively soft and highly fractured from 538.6-540.9 feet; core pieces generally less than 0.3-foot long except at 532.0-535.4 feet where they are about 1.6 feet long; quartz veins and vugs 1/4-inch or less in thickness throughout core; bedding at 60°; brecciated zone at 540.8-541.8 feet.
565.8-613.3	Mudstone, dark-gray, highly fractured, core pieces averaging 0.2-foot long, some 0.5-foot long; local quartz veins in core; bedding at 65°; fault gouge at 605.1-607.5 feet; joints at 45°, spaced 0.1-0.6-foot apart, tight; local vertical fracture cleavage.
613.3-637.7	Mudstone, dark medium-gray; highly fissile at 620.0-621.3 feet, 624.6-625-7 feet, massive elsewhere, especially at 625.6-637.7 feet; fault gouge at 625.3-625.7 feet; vertical

Table 6.--Lithologic log of Hole Baker, Chariot site, northwestern Alaska--continued

Depth (feet)	Description
	fracture cleavage at 615.2-618.0 feet and 622.3-627-1 feet.
637.7-662.0	Mudstone, highly fractured, dark-gray; core contains quartz veins and vugs 1/4-inch or less in thickness; vertical fracture cleavage; joints at 45°, where discernible, tight; fault gouge at 640.1-643.3 feet, 647.3-647-9 feet, and 658.7-662.0 feet.
662.0-692.5	Mudstone, dark medium-gray, massive; core generally in 0.5-foot pieces; fracturing caused by drilling; bedding appears to be at 70°; at 680.1-692.5 feet core highly fractured, also by drilling.
692.5-777.0	Mudstone, dark-gray; highly fractured mudstone and gouge at 699.6-701.2 feet, 709.2-710.0 feet, 725.1-725.4 feet, and 760.9-761.7 feet; quartz veins 1/4-inch or less in thickness throughout core; joints at 45°, spaced 0.1-1.0-foot apart, tight, appear to be along bedding.
777.0-825.6	Mudstone, medium dark-gray, massive except at 777.0-781.2 feet and 791.7-792.6 feet; fracturing chiefly by drilling; fault gouge at 786.7-787.0 feet; core fissile at 791.8-792.3 feet and 793.9-794.3 feet; bedding generally at 55°-60°, locally vertical.
825.6-856.7	Mudstone, dark-gray, generally massive; core contains quartz stringers and vugs 1/4-inch or less in width; core highly fractured into 0.1-foot pieces at 849.5-849.0 feet; bedding at 60° to 80°.

Table 6.--Lithologic log of Hole Baker, Chariot site, northwestern Alaska--continued

Depth (feet)	Description
856.7-1109.6	Drilled with NX plug bit; no core; bedrock is Tiglukpuk formation.
1109.5-1111.9	Mudstone, dark-gray, highly fractured; core broken into 0.1-foot pieces by drilling.
1111.9-1172.0	Drilled with NX plug bit, no core; bedrock is Tiglukpuk formation.

As seen in thin section, the Tiglukpuk rocks appear to contain scattered graphite or carbonaceous material. Tests were conducted to determine whether the material was graphitic or carbonaceous. Graphite was not detected in x-ray diffraction analyses of several specimens of core from holes Able and Baker. Carbonaceous material was indicated, however, when several specimens heated to a red heat color in a platinum crucible turned from the characteristic dark gray color to a buff brown color when the sample cooled.

The Corps of Engineers reports that the average moisture content of samples of mudstone ranges from 0.28 to 5.67 percent (personal communication, 1959). Moisture content was determined by drying the specimens of core, sent to the Anchorage laboratories of the Corps of Engineers, to a constant weight at a temperature of 220°F. This technique does not consider the moisture that is chemically bound or the ice in the fractures of the mudstone. F. W. Clarke (1924) reports that the total moisture content of a composite sample of 51 Paleozoic shales was 4.71 percent. The mudstone of the test site area contains permafrost, and locally accumulation of ice in the fractures would undoubtedly make the moisture content of the rocks in place higher than that reported by the Corps of Engineers for the thawed samples. On the basis of the Corps of Engineers' results, plus the chemically bound moisture and the ice in the fractures it is estimated that the moisture content of the Tiglukpuk mudstones that underlie the test site is about 10 percent. Locally, it may be higher or lower depending upon the pattern of fractures that may contain ice. Because of the nature of the drilling program, it is difficult to determine to what extent the mudstone is fractured, or to what extent the fractures are open and contain frozen moisture.

Structure

Fault zones are numerous in the core from Hole Able and Hole Baker. At least 6 zones were observed in Hole Able and about 26 zones in Hole Baker (tables 5 and 6). Most of the fault zones were less than 1 foot thick. In Hole Baker a 14.3-foot zone exists between depths of 239.7 and 254.0 feet. It is difficult to determine the true thickness of this fault zone because the attitude of the fault was not established, but undoubtedly the true thickness is less than the 14.3-foot vertical component that was measured in the core. Relative displacement along the fault zones could not be determined in the core. It was determined, however, that movement occurred after the deposition of the quartz in the core.

At least two sets of conjugate joints were noted: one at 70° and the second generally at 45°. The spacing of the joints varies from 0.1 foot to 3 feet. Most of the joints were tight and commonly healed by quartz. The subsurface characteristics of these joints do not vary from their surface expression except that a higher percentage of joints are loose instead of tight at the surface.

Unconsolidated deposits

Unconsolidated deposits of Quaternary age overlie the Tiglukpuk rocks (pl. 1). They consist of ancient beach deposits (Qab), terrace deposits (Qt), silt and sand (Qss), colluvium (Qco), alluvial fan deposits (Qaf), swamp deposits (Qs), flood plain deposits (Qfp), and modern beach deposits (Qb). Although the unconsolidated deposits are locally as much as 30 feet thick in the area included in plate 1, they are generally only a thin veneer 5 to 12 feet thick. These deposits, as well as the bedrock, are only briefly discussed in this report. For a more detailed discussion the reader is referred to an earlier report (Kachadoorian and others, 1958).

Permafrost

Permafrost, or perennially frozen ground, exists in the test site area. The depth to permafrost is unknown in areas of bedrock and modern beach deposits (Qb), but is believed to be about 10 feet in bedrock areas and as much as 25 feet in modern beach deposits. In unconsolidated deposits, except modern beach deposits and marine deposits, permafrost lies 1 foot to 3 feet below the surface. Ice layers or lenses as much as 3 feet thick were measured in silt and sand deposits (Qss) during the 1958 investigations by the Geological Survey. Permafrost was encountered 2.4 feet below the original ground surface in Hole Able and 2.1 feet below the original ground surface in Hole Baker. During the drilling of Hole Able a 1.3-foot ice-wedge was encountered at 2.4 feet.

Depths indicated in the lithologic log of Hole Able (table 5) were measured not from the original ground surface, but from the top of a 2.1-foot concrete block placed by the drilling contractor in order to spud in the hole more easily. Unless otherwise indicated, all depths in Hole Able used in this report will be from the top of the concrete block.

Ice-wedge polygons are common in parts of the test site area (pl. 1). All of the polygonal ground in the area included in plate 1 is confined to silt and sand (Qss) areas. Ice wedges as much as 3 feet thick were observed along the edges of the polygons. Ice is generally no more than 1 foot and locally as little as 3 inches below the surface in areas underlain by polygonal ground.

The thawing of permafrost presented many problems during the construction of the camp and drilling of the diamond-drill holes during the 1959 field season. When the camp supplies were brought from the beach to the camp site by heavy equipment the ground was dug up and the protective vegetation mat destroyed. The loss of the vegetation allowed the permafrost to thaw. This thawing will continue until a protective mat is placed upon the ground or until thawing reaches such great depths that the summer heat will cease to thaw the ground.

The chief difficulty from thawing permafrost occurred during the drilling of Holes Able and Baker. The heat of the drilling fluid thawed the permafrost in the bedrock and overlying surficial deposits. When this occurred, slumping of the thawed debris into the hole made it increasingly difficult to continue drilling. In Hole Able considerable caving occurred in the 14.1-foot interval between 136.2 and 150.3 feet. As a result of this caving and minor caving deeper in the hole, drilling was discontinued at a depth of 598 feet, or at an actual depth below the original ground surface of 595.9 feet. Caving because of thawing permafrost also prevented drilling Hole Baker to its planned depth of 1,500 feet. This hole was discontinued at a depth of 1,172 feet. Caving in both Holes Able and Baker occurred chiefly in zones of weakness marked by faults and closely spaced joints.

Summary and conclusions

According to present plans, the nuclear devices will be placed in frozen mudstone of the Tiglukpuk formation of Jurassic(?) age. The mudstone contains numerous faults, of unknown displacement. The fault zones are generally less than 1 foot thick, with the exception of a fault zone in Hole Baker of unknown true thickness but extending 14.3 feet in the hole.

The drilling or digging of the large holes for devices in 1960 will present the chief engineering problem in the Phase III program. The extensive slumping that was experienced in the drilling of Holes Able and Baker indicates that similar difficulty can be expected in a large-diameter hole or shaft. The greatest amount of slumping will occur in the fault zones and the unconsolidated material that overlies the mudstone. Consideration should be given either to drilling the holes with refrigerated fluids, such as diesel oil, or to casing the hole as drilling progresses. The use of drilling mud did not prevent the slumping of the thawed bedrock into the hole during the drilling of Holes Able and Baker in 1959. Unless a drilling mud is used that has "holding" characteristics materially greater than that of the "mud" used during the summer of 1959, it is doubtful that slumping of the walls of the device holes can be prevented without drilling with a refrigerated fluid.

The moisture content of the rocks in situ probably is much more than reported. The writer believes that the total moisture content is about 10 percent in the rocks that underlie the test site.

The construction and maintenance of facilities such as roads, airfields, and living quarters will require some precautions because of frost heaving and thawing of permafrost. If structures are to be built that will require critical tolerances in connection with the test, special precautions will be necessary during their construction. Roads and airstrips should be placed on areas that are not susceptible to frost action and that do not contain appreciable perennial ice. If the structures are placed on unconsolidated deposits some frost heaving of the structures will occur, and heated buildings may settle as a result of thawing of permafrost. If it is necessary to place structures, roads, and airstrips on areas susceptible to frost heaving and thawing of permafrost, construction techniques should be adopted to minimize their effects. Fortunately, the unconsolidated deposits are only a few feet thick and the foundations of structures can easily be placed on bedrock.

Literature cited

Clarke, F. W., 1924, The data of geochemistry: U. S. Geol. Survey Bull. 770.

Kachadoorian, Reuben, Campbell, R. H., Sainsbury, C. L., and Scholl, D. W., 1959, Geology of the Ogotoruk Creek area, northwestern Alaska: U. S. Geol. Survey TEM-976; also, U. S. Geol. Survey open-file report.

AREAL GEOLOGY OF THE OGOTORUK CREEK CHARIOT TEST SITE AND ADJACENT AREAS TO THE WEST AND NORTH, NORTHWESTERN ALASKA

By

R. H. Campbell

Introduction

The purpose of the areal mapping study in the Ogotoruk Creek area, Alaska, is to determine the general geologic setting for the proposed nuclear test excavation at the mouth of Ogotoruk Creek. The chief objective of this study is to provide a mile-to-the-inch (1:63,360) geologic map within an area of about a 15-mile radius of the test site. The data from this map will serve as a general basis for consideration of engineering geology problems in the immediate vicinity of the site and should provide data fundamental to considerations of the distribution of environments for the local plant and animal life; it should also provide background for evaluation of water resources, determination of sources of materials involved in the coastal processes, and other related geologic studies.

The area in the immediate vicinity of the Chariot test site was mapped in detail by the Geological Survey during the summer of 1958. For detailed maps and discussion the reader is referred to the resulting report (Kachadoorian and others, 1958). During July and August 1959, the mapping was extended to the west and north by the author, assisted by D. R. Currey.

The first half of the 1959 summer season was spent in a detailed examination of sea cliff exposures west of the test site. The remainder of the summer was spent in areal geologic mapping at a scale of 1:48,000 by means of weasel and foot traverses. The traverses were generally in an east-west direction, across the general structural grain of the rocks. Photointerpretation was used to project geologic units and structures between traverses (pl. 2). Geologic mapping during the 1959 field season was confined chiefly to the west and north of the test site because this area provides the best outcrop control and is the best area for study of the stratigraphy and structure of the rocks that underlie the test site.

Geology

Stratigraphy

The rocks of the area consist chiefly of consolidated clastic and chemical sediments. They include sandstone, calcitic and dolomitic limestone, chert, argillite, mudstone, siltstone, and graywacke. All the rocks have been highly deformed and very slightly metamorphosed. The limestones have been converted to marble locally, and the siliceous cement of siltstones and graywackes has been recrystallized to microcrystalline quartz.

The rocks range in age from Early Mississippian to Jurassic(?) and Cretaceous. Unconsolidated deposits of Quaternary age, consisting chiefly of colluvium, stream gravel, beach gravel, wind-deposited sand and silt, and gravel of uncertain origin, conceal the bedrock in more than 50 percent of the area. They are as much as 50 feet thick locally but most commonly are less than 20 feet thick. The distribution of the various types of surficial deposits is shown on plates 1 and 2. Undisturbed outcrops of bedrock are generally exposed only in stream cutbanks and sea cliffs. Away from such areas of active erosion bedrock is generally covered by 1 to 6 feet of rubble composed of frost-heaved fragments derived from the underlying rock units.

The distribution and structure of the bedrock units is shown on plate 2; the sequence and lithologies of the layered sedimentary rocks are described on plate 3. The sequences illustrated by the columnar section (pl.3) are based on reliable measurements for the rocks of the Lisburne group, the upper 400 feet of the Lower Mississippian sandstone-shale unit, the Siksikpuk and Shublik formations, and the lower 700 feet of the Tiglukpuk formation. The lower part of the Lower Mississippian sandstone-shale unit is highly deformed and largely covered, and the upper part of the Tiglukpuk formation and the undifferentiated Jurassic(?) and Cretaceous rocks are highly deformed; therefore, the sequence illustrated by the columnar section for these rocks is largely diagrammatic (see also cross-sections, pl. 2).

The oldest rocks exposed in the area (pl. 2) are the sandstone-shale beds of an unnamed formation of Early Mississippian age (Dutro, J. T., Jr., Sable, E. G., and Bowsher, A. L., written communication, 1958). The unit is generally noncalcareous and carbonized plant remains are present in the lower part of the formation; however, a few limestone and calcareous sandstone beds containing marine fossils are present in the upper 300 feet of the unit. The sandstone-shale sequence is overlain conformably (the contact is gradational) by about 5,700 feet of marine limestone with minor amounts of shale of the Lisburne group that probably ranges in age from Early to Late Mississippian. The Lisburne group has been divided into 5 map units that are generally recognizable in the area of plate 2.

The Lisburne group is overlain by about 400 feet of greenish-gray argillite and chert with some black shale near the base, that have been assigned to the Siksikpuk formation of Permian age. The rocks are generally noncalcareous but a few calcareous argillite beds in the lower part of the unit contain marine fossils. The Siksikpuk formation is generally in fault contact with rocks of the Lisburne group in areas of good exposure.

The Siksikpuk formation is overlain by about 200 feet of limestone, chert, and shale assigned to the Shublik formation of Triassic age. The Siksikpuk-Shublik contact is apparently conformable, but may be a very slight angular unconformity.

The Shublik formation is overlain by more than 2,500 feet of interbedded mudstone, siltstone, and graywacke that are tentatively assigned to the Tiglukpuk formation and are probably Jurassic in age. These rocks grade upward almost imperceptibly to beds of similar lithology but in which sandstone is generally more abundant. These consolidated rocks grade upward into rocks containing marine fossils of Cretaceous age.

Structure

The general strike of the beds is north and the dips are generally west, but because of thrust and high-angle reverse faulting and overturning of many beds, there is a general progression from older rocks on the west to younger rocks on the east. North-trending thrust faults usually with older rocks thrust over younger rocks from west to east are prominent along Emmikroak Creek and parts of the west side of the valley of Ogotoruk Creek. Although thrust faults dominate the structure, folding and high-angle faulting have also deformed the rocks intensively. One thrust fault has a dip slip of at least 2 miles and its total dip slip may be more than twice that amount. Displacements on other thrusts are probably of the same order of magnitude.

The folding is generally more intense in the weaker rocks of the Siksikpuk and younger formations than in the relatively competent Lisburne group. As a result, the Tiglukpuk rocks of the test site area are intensely contorted and broken by many small faults (see tables 5 and 6). In Ogotoruk Creek valley there appear to be 2 or 3 major folds and innumerable minor folds. The cross-sections on plate 2 indicate that the test site is located on the east flank near the crest of one of these major folds.

Literature cited

Kachadoorian, Reuben, Campbell, R. H., Sainsbury, C. L., and Scholl, D. W., 1958, Geology of the Ogotoruk Creek area, northwestern Alaska: U. S. Geol. Survey TEM-976; also, U. S. Geol. Survey open-file report.

COASTAL PROCESSES IN THE VICINITY OF CAPE THOMPSON, ALASKA

By

G. W. Moore and J. Y. Cole

Introduction

Objectives of the coastal processes study in connection with the Chariot project in the Ogotoruk Creek area, Alaska, are: (1) to aid in determining what protective measures are necessary to prevent filling of the artificial harbor by beach sediment moving along the shore under wave action; and (2) to ascertain whether radioactive solid material, if any, would move along the beach at a significant rate toward Kivalina and other villages. In addition to these objectives, which are connected with the success and safety of the project, the description of the physical aspects of beaches and adjacent areas under Arctic climates may be of value to biological studies being conducted concurrently by other investigators.

Work during the summer of 1959 was a reconnaissance investigation of the coast from Sheshalik Spit, 110 miles southeast of the Chariot site, to the mouth of the Kukpuk River, 27 miles northwest of the site. Richard Watson assisted in this work during short periods and kept records of surf statistics at the Chariot site during times when the authors were working along other parts of the coastline.

Distribution of beach sediment

Along most of the coastal region studied, the beach is in a steady-state condition. The shoreline is neither prograding toward the sea as a result of permanent deposition of beach material, nor is it encroaching rapidly toward the land because of wave erosion. The energy available in the waves is principally expended in moving beach sediment first toward the sea during times of heavy surf and then restoring it to the beach during the longer periods of relative calm.

Permanent deposition is taking place, however, along approximately 7 percent of the coastline, namely, on the south side of Point Hope, on the south side of Cape Krusenstern, and at Sheshalik Spit. Likewise, especially active erosion is occurring along approximately 9 percent of the coastline, principally on the north side of Point Hope, at the Cape

Thompson cliffs, and on the west side of Cape Krusenstern.

The width of the steady-state beaches is related to their exposure to wave action. Sheltered beaches, such as the one fronting the Chariot site, are wide, and exposed beaches tend to be narrow.

Sediment related to the present beaches extends only to a depth of water of approximately 30 feet. The sediment grades downward from fine gravel in the surf zone to very fine grained sand. Finer grain sizes are missing and have evidently been swept away by offshore currents, the velocity of which may be as much as 100 feet a minute in the Cape Thompson area.

Lithology of beach sediment

Part of the energy available in waves may cause movement of beach material parallel to the shoreline. As an approach to the problem of learning the direction of the net alongshore beach transport, counts were made of the proportion of grains formed from different rock types in beach samples collected at many points along the coast. Typical data are plotted in figure 2 and illustrate that a systematic difference exists between the various grain counts. Limestone is a principal constituent of the beach material northwest of Kivalina, whereas it is nearly absent southeast of Kivalina (fig. 2).

Two possible sources of limestone that would denote beach transport to the southeast past the Chariot site are the beach area north of Point Hope and the cliffs at Cape Thompson. On the other hand, if the limestone grains were derived from the Kivalina and Wulik Rivers, beach transport to the northwest would be implied. The river gravels contain less than 20 percent limestone, however, so this last possibility may be excluded, and beach transport to the southeast past the Chariot site therefore seems indicated

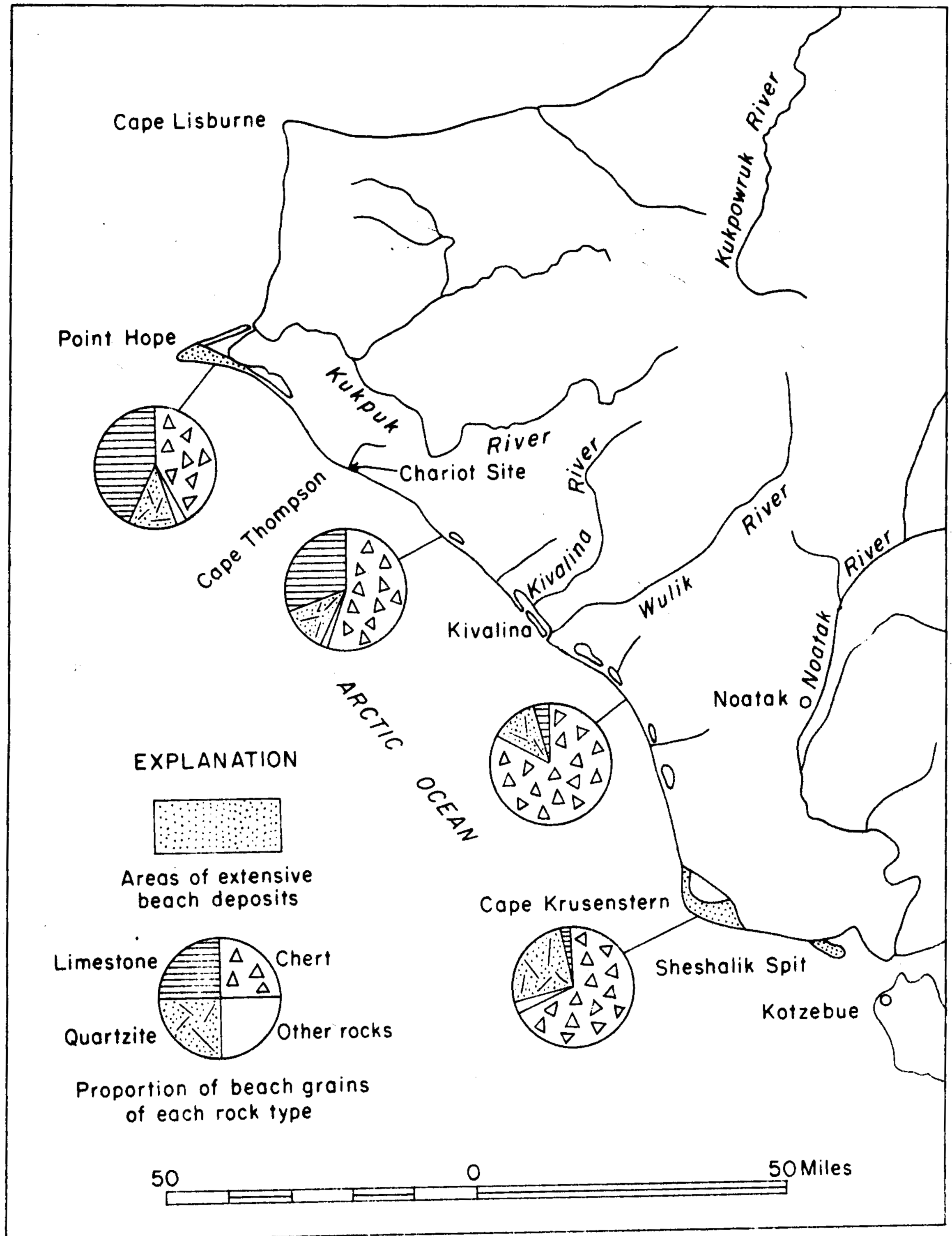

Figure 2.-‑Composition of beach material in the vicinity of Cape Thompson, Alaska

by the lithologic evidence. Such transport would be accompanied by slow destruction of the soft limestone grains by attrition and solution.

Alongshore transport is not inhibited by rocky promontories (Trask, 1955). In fact, it has been demonstrated in Australia (Baker, 1956) that the rate of alongshore movement of individual grains around cliffed headlands similar to those at Cape Thompson is much more rapid than on open beaches. The beach at the Chariot site is therefore not naturally protected against material moving around the cliffs from the northwest.

The rate of sediment movement is more difficult to determine than its direction. One method of measuring the rate of alongshore transport that has been tried by several investigators employs grains that are marked by radioactivity, luminescent dyes, or other means. The most comprehensive study of this type is that of Medvedev and Aybulatov (1958). Although a small percent of the marked grains can be followed for significant distances, the method has not yet proved successful in determining the rate of total transport because it has not been possible to determine the thickness of the layer of sediment in motion.

Rate of alongshore beach transport estimated from surf statistics

Two general methods were used to determine the average rate of alongshore beach transport. One entailed measurement of actual transport under specific surf characteristics with the results applied to the relative frequency of different surf conditions. The other involved measurement of long-term sediment accumulation on a large spit.

Only two previous attempts to relate alongshore beach transport in the field to specific surf conditions have come to our attention, although there have been numerous small-scale laboratory experiments. Watts (1953) studied the relationship of local surf characteristics to the movement of sand pumped from a stationary sand bypassing plant on the east coast of Florida. Caldwell (1956) related surf conditions to the rate of dispersal of an artificial sand accumulation in southern California.

In the Cape Thompson area, a potential method presented itself when large lagoons overtopped and breached their barrier beaches during heavy rains. As soon as flow from the lagoons had ceased, spits began to build in the direction of beach transport across the newly formed outlets. Several plane-table surveys of these spits gave a measure of the rate of transport which could be related to surf conditions existing at the time the spits were formed.

Figure 3 is a series of maps of the outlet of Tasaychek Lagoon which is 12 miles north of Cape Krusenstern. The lagoon has a surface area of approximately half a square mile. On July 11, 1959, it began to drain at 7:00 a.m., and by 11:10 a.m. the lake level had been lowered approximately 6 feet to sea level, and outward flow had virtually ceased. At 1:30 p.m. the spit which formed across the outlet was surveyed, and at 4:30 p.m. a second survey was made. During this three-hour period, a total of 585 cubic yards of material had moved onto the spit. By 10:00 a.m. the following day, when a final survey was made, the spit had reached the opposite shore, and beach material was bypassing the outlet.

During the interval between the first two surveys, the wave height was 5.5 feet, the wave period was 5.5 seconds, the angle between the wave crest and the beach was 25°, open to the south, and the longshore current was 126 feet per minute to the south. The median grain size of material being transported was 1 millimeter. By chance, these waves were among the

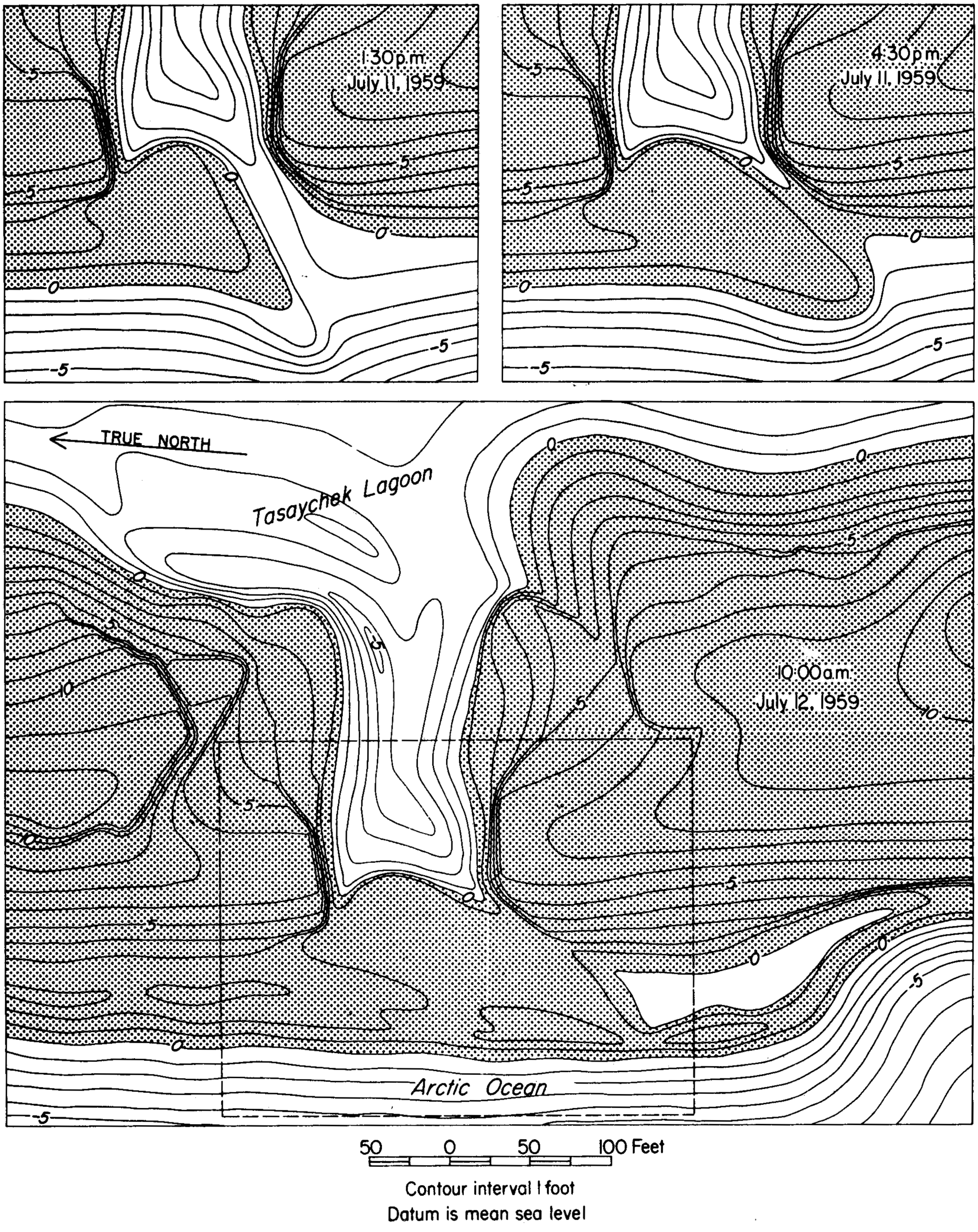

Figure 3.--Growth of a spit across the outlet of Tasaychek Lagoon, 12 miles north of Cape Krusenstern, Alaska

highest that existed in the Cape Thompson area during the summer.

Previous field studies by Watts (1953) and Caldwell (1956) have shown that alongshore beach transport (Q) is probably directly proportional to the alongshore component of total wave energy (E):

$$Q = k\ E \tag{1}$$

where k is a constant.

In shallow water near the shore, the energy of each wave (E_s) is approximately proportional to the wave length (L) times the square of the wave height (h) (Beach Erosion Board, 1954):

$$E_s \propto L\ h^2. \tag{2}$$

Empirical studies in the Cape Thompson area indicate that the wave length may be related to the wave period (T) and wave height in the following way:

$$L \propto T\ h^{0.5}. \tag{3}$$

Combining equations (2) and (3) gives

$$E_s \propto T\ h^{2.5}. \tag{4}$$

The portion of the energy that is directed along the shore is dependent on the angle (ϕ) between the wave crest and the beach. From vector analysis, the alongshore component of energy in each wave (E_{sa}) is

$$E_{sa} \propto T\ h^{2.5}\ \sin\phi\ \cos\phi. \tag{5}$$

The total alongshore energy per day (E) is

$$E \propto \frac{E_{sa}}{T}, \tag{6}$$

hence

$$E \propto h^{2.5}\ \sin\phi\ \cos\phi. \tag{7}$$

Combining equations (1) and (7) gives

$$Q = k\ h^{2.5}\ \sin\phi\ \cos\phi. \tag{8}$$

Inserting our data in this formula provides the following tentative relationship for the Cape Thompson area:

$$Q = 7.1\ h^{2.5}\ \sin\phi\ \cos\phi, \qquad (9)$$

where

Q = alongshore beach transport in cubic yards per hour,

h = wave height in feet,

ϕ = angle between wave crest and beach in degrees.

Equation (9) may be used to evaluate the surf statistics of the summer of 1959 in an effort to determine the direction and amount of alongshore beach transport.

Figure 4 presents the wave height plotted against the angle between the wave crest and beach for the period July 7, 1959, to September 7, 1959. On two-thirds of the days of the summer, transport was to the southeast, but, because of the exponential relationship to wave height, almost all the significant transport occurred during a relatively few storm days. The high waves are approximately equally divided between those causing drift to the southeast and those causing it to the northwest. The evidence from surf statistics therefore indicates that the net alongshore beach transport during the period of surf observation was approximately zero.

But on the basis of our investigation in 1959, it is apparent that, during a single storm day, waves with suitable surf angle can move the equivalent of several cubic yards an hour for the whole year. Moreover, independent evidence, to be given in the next section, suggests that the true net beach transport is not zero. These results therefore point to the necessity for collecting additional surf statistics, especially during storms, for the entire period that the region is ice free.

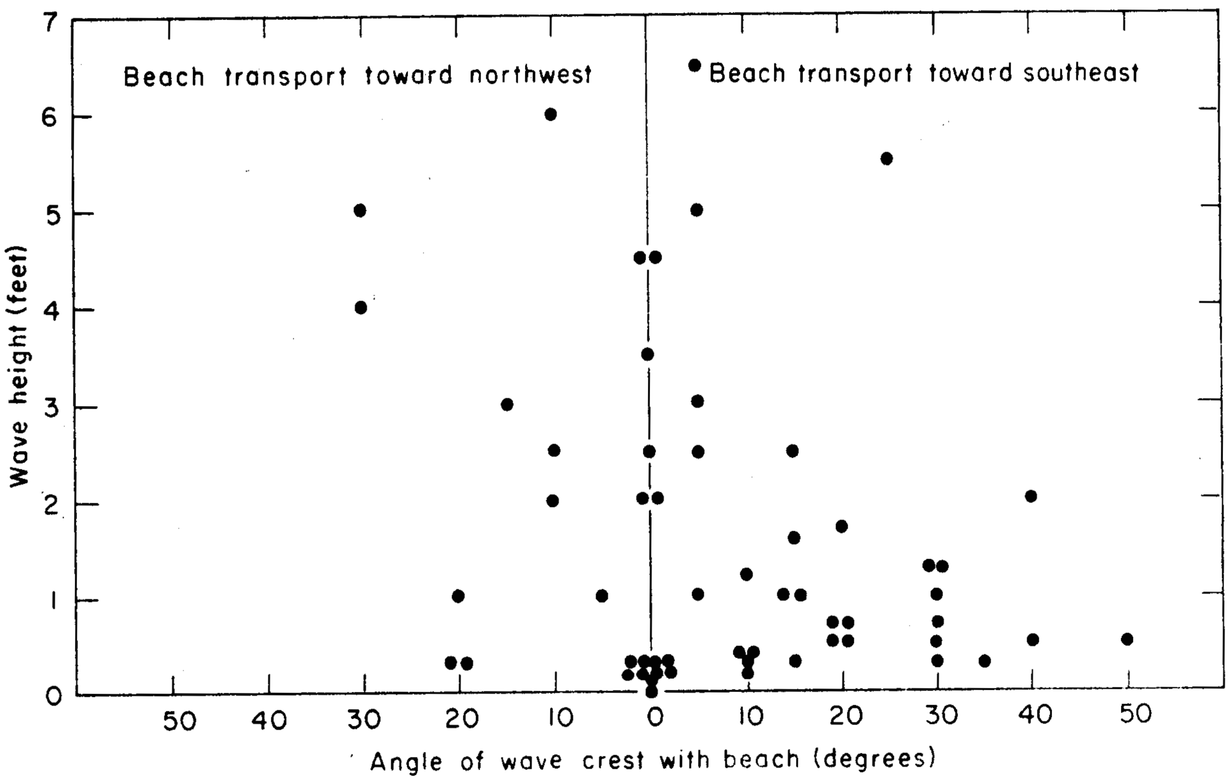

Figure 4.--Daily surf characteristics at Chariot site, July 7, 1959 to September 7, 1959

Rate of alongshore beach transport estimated from permanent beach deposits

In the absence of artificial structures along the beach, the three areas of natural permanent deposition of beach material were studied to see if they possibly would give a measure of the average rate of beach transport. Point Hope, Cape Krusenstern, and Sheshalik Spit each consist of areas of beach ridges that have built seaward from the shore, and the age of human habitation of certain of the ridges at each locality is known from archeological and radiocarbon dates.

Deposition is occurring very rapidly on the south shore of Point Hope. The archaeological sites at the Ipiutak ruins, which are now 3,500 feet from the south shore, have been dated by radiocarbon methods at A. D. 340 ± 200 (Rainey and Ralph, 1959, p. 370). The Ipiutak people subsisted principally on marine mammals, and it is inferred that their village was originally on the south coast of Point Hope near the shoreline. If so, land is being added at a rate of approximately 200 feet a century. A difficulty with the Point Hope data for our present purposes, however, is that we are not certain whether the beach material is coming from the cliffs at Cape Thompson, from the area north of Point Hope, or from both areas.

Southeast of the cliffs at Cape Thompson, however, the evidence is somewhat less ambiguous. Cape Krusenstern was originally a spit which built from the northwest and, without question, was formed by material moving southeastward. Dated beach ridges indicate that several thousand years ago the tip of the former Krusenstern spit arched back toward the coast until it impinged against the shore again. Since that time, permanent deposition at Cape Krusenstern has been reduced and most beach material has bypassed the cape and is being deposited at Sheshalik Spit, 20 miles farther southeast.

The shape of Sheshalik Spit is such that no sediment can pass it, and all material moving onto the spit is permanently deposited.

A beach ridge on the spit (fig. 5) contains ruins of the Western Thule culture which has been dated culturally at about A. D. 1000 by comparison with neighboring sites dated by the radiocarbon method and by tree-ring analysis (J. L. Giddings, personal communication). The area of the spit that has formed since that time is equal to approximately 1.4 square miles. The thickness of the beach material is not definitely known, but a similar deposit at Kotzebue, 10 miles to the southeast, is 23 feet thick (Cederstrom, 1952, p. 35). Using this thickness for Sheshalik Spit, the authors calculated that a total of 33 million cubic yards of sediment has been deposited since A. D. 1000. This means that deposition has taken place at an average rate of 1.9 cubic yards per hour during the whole year, or 5.7 cubic yards per hour for the 4-month period that the area is ice free.

The material at Sheshalik Spit has moved to the southeast and evidently moved past the Chariot site. An uncertainty remains because we do not know the contribution of the intervening Kivalina and Wulik rivers. Until further data are available, however, we shall neglect this contribution and assume that the average alongshore beach transport at the Chariot site is of the order of 5 cubic yards an hour to the southeast during the ice-free months.

Summary and recommendations

The steady-state beach at the Chariot site is not advancing toward the land at a rate that will affect an artificial harbor. Erosion behind the beach may be of the order of one or two feet a century. The beach itself is in a dynamic state, however, and during a large storm it might be swept

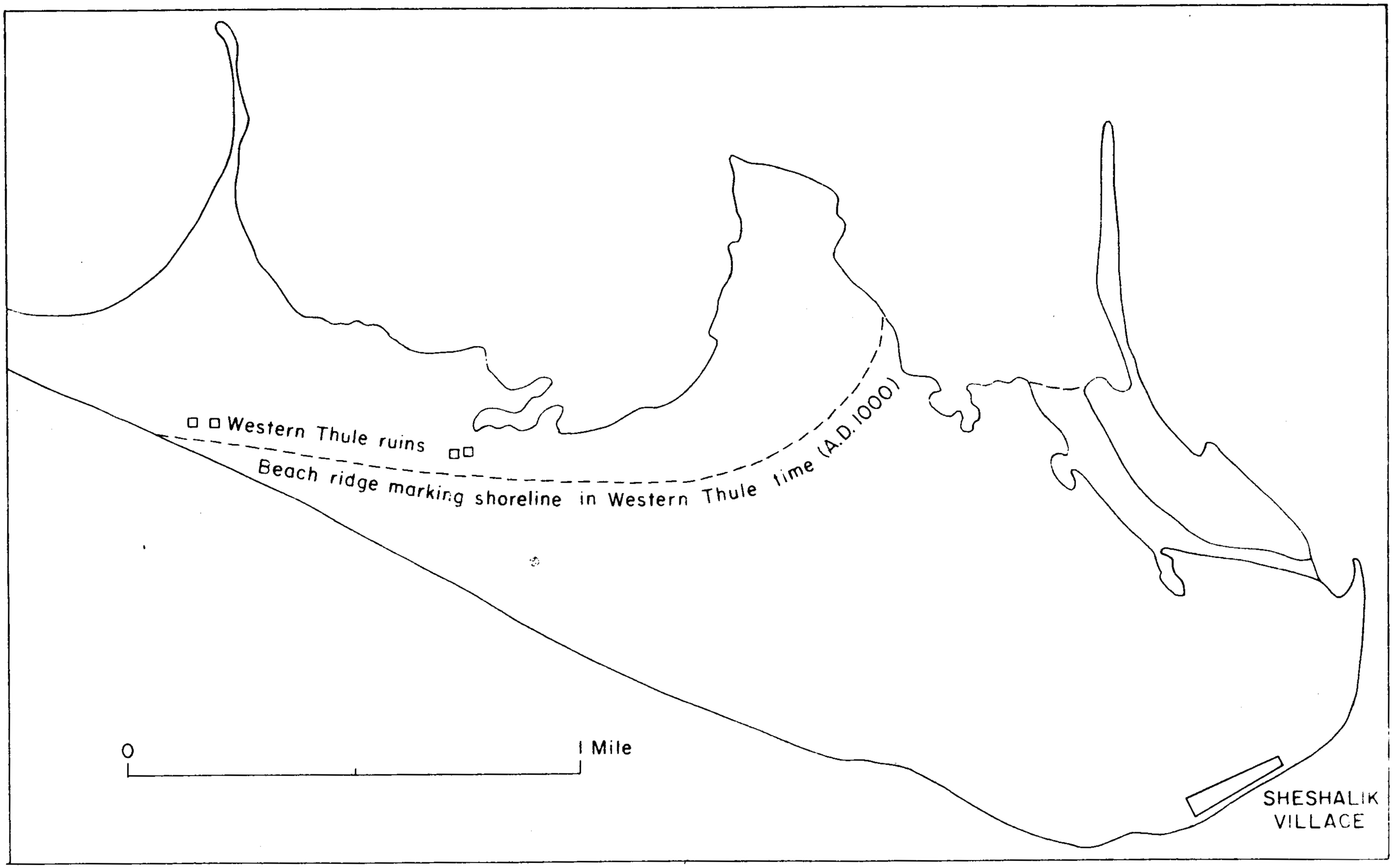

Figure 5.--Sheshalik Spit, Alaska, showing area of beach sediment deposited since A.D. 1000

entirely out to sea, only to be restored again during the waning period of the storm.

Plans for measures to protect the artificial harbor against filling by beach material must consider two aspects of the problem: (1) short-term movement of sediment during periods of heavy surf; and (2) the net alongshore beach transport.

The lateral component of beach transport during a storm generating 10-foot waves (the supposed maximum for the area) may be as much as 27,000 cubic yards a day (equation 9). Jetties should be constructed on each side of the harbor entrance that will retain volumes of material of this general order of magnitude or greater.

The net alongshore beach transport is believed to be approximately 5 cubic yards an hour to the southeast during the ice-free months. It may be considered desirable to install a small sediment bypassing plant to pump beach material from the northwest side of the harbor to the southeast side. Such an installation would prohibit sediment from entering the harbor around the northwest jetty and would also prevent erosion of the beach to the southeast by restoring material whose movement in that direction was arrested by the harbor entrance.

Literature cited

Baker, G., 1956, Sand drift at Portland, Victoria: Royal Soc. Victoria Proc., v. 68, p. 151-197.

Beach Erosion Board, 1954, Shore protection, planning, and design: Beach Erosion Board Tech. Rept., no. 4.

Caldwell, J. M., 1956, Wave action and sand movement near Anaheim Bay, California: Beach Erosion Board Tech. Memo., no. 68, 21 p.

Cederstrom, D. J., 1952, Summary of ground-water development in Alaska, 1950: U. S. Geol. Survey Cir. 169, 37 p.

Medvedev, V. S., and Aybulatov, N. A., 1958, Ezuchenie dinamiki otmelogo peschanolo berega pri pomoshchi lyuminoforov i podvesnoy dorogi (A study of sand-shore dynamics using luminescent sand grains and an aerial tramway): Akad. Nauk SSSR Inst. Oceanology Trudy, v. 28, p. 37-55.

Rainey, F., and Ralph, E., 1959, Radiocarbon dating in the Arctic: Am. Antiquity, v. 24, p. 365-374.

Trask, P. D., 1955, Movement of sand around southern California promontories: Beach Erosion Board Tech. Memo., no. 76, 60 p.

Watts, G. M., 1953, A study of sand movement at South Lake Worth Inlet, Florida: Beach Erosion Board Tech. Memo., no. 42, 24 p.

PRELIMINARY REPORT OF GEOTHERMAL STUDIES AT THE OGOTORUK CREEK CHARIOT SITE, NORTHWESTERN ALASKA

By

A. H. Lachenbruch and G. W. Greene

Introduction

A geothermal study at Ogotoruk Creek was undertaken to supply information on distribution of permafrost and its relation to the shoreline. To obtain this information it was judged necessary to measure temperatures in two 1,000-foot holes, one within a few hundred feet of the shoreline, and the second a few thousand feet inland. To interpolate between these two holes and to extrapolate seaward and landward from them it is necessary first to use geothermal data that are obtained to reconstruct the history of shoreline movements during the past several thousand years. The effect of such shoreline movements on permafrost distribution is then calculated (Lachenbruch, 1957). The shoreline history, therefore, is a useful by-product of the permafrost-distribution study. It provides helpful background for the coastal processes studies. In addition, the thermal study yields information about climatic change in the last few centuries, including that probably occurring at present. Such information is pertinent to ecological studies of the area.

In the process of drilling the holes, the natural thermal regime is profoundly disturbed, and many months may pass before the pre-drilling temperatures are approached at each depth (Lachenbruch and Brewer, 1959). The thermal cables must be left in the holes and allowed to freeze in place. They are read periodically until the drilling anomaly is dissipated.

Field work

Hole Able was started July 13 and abandoned July 30 after attaining a depth of 598 feet. Thermistor cable no. 336 (U. S. Geological Survey designation) was installed to a depth of 584 feet on July 30, 1959, and allowed to freeze in place. The hole is about 300 feet from the shoreline and about 100 feet from Ogotoruk Lagoon.

Hole Baker was drilled to a depth of 1,172 feet between August 3 and September 1, 1959. Thermistor cable no. 249 (U. S. Geological Survey designation) was installed to a depth of 1,015 feet on September 2, 1959, and the hole was back-filled with gravel (to prevent convection) on September 3, 1959. At various depths below 500 feet, the walls of the hole were caving when it was abandoned. This caused serious problems during installation of the cable and resulted in damage to the lower half of the cable. Hole Baker is about 2,000 feet from the ocean.

The cables in Holes Able and Baker were read periodically until September 4, 1959, the last date on which project personnel were at the site. An additional set of readings was provided on September 22, 1959 by Harry Spencer, radio operator and winter resident of the Ogotoruk Creek camp. This is the first of a series of bimonthly readings to be taken throughout the winter by Mr. Spencer.

The 1959 field work was less successful than anticipated, inasmuch as Hole Able was bottomed at 598 feet (402 feet short of the required depth), and Hole Baker was not clean enough so that critical parts of the cable were damaged during installation.

Results

Selected thermal data from Holes Able and Baker are presented in figures 6 and 7 respectively. From figure 6, it is seen that Hole Able cooled rapidly at first, but that only small changes occurred between September 3 and September 22, 1959. On the last date (September 22, 1959) the post-drilling period was about four times as great as the drilling period, and it is evident that these temperatures are approaching their natural values. In contrast, the data from Hole Baker show very rapid cooling between September 3 and September 22. This is to be expected when it is realized that the post-drilling time on September 22 was still less than

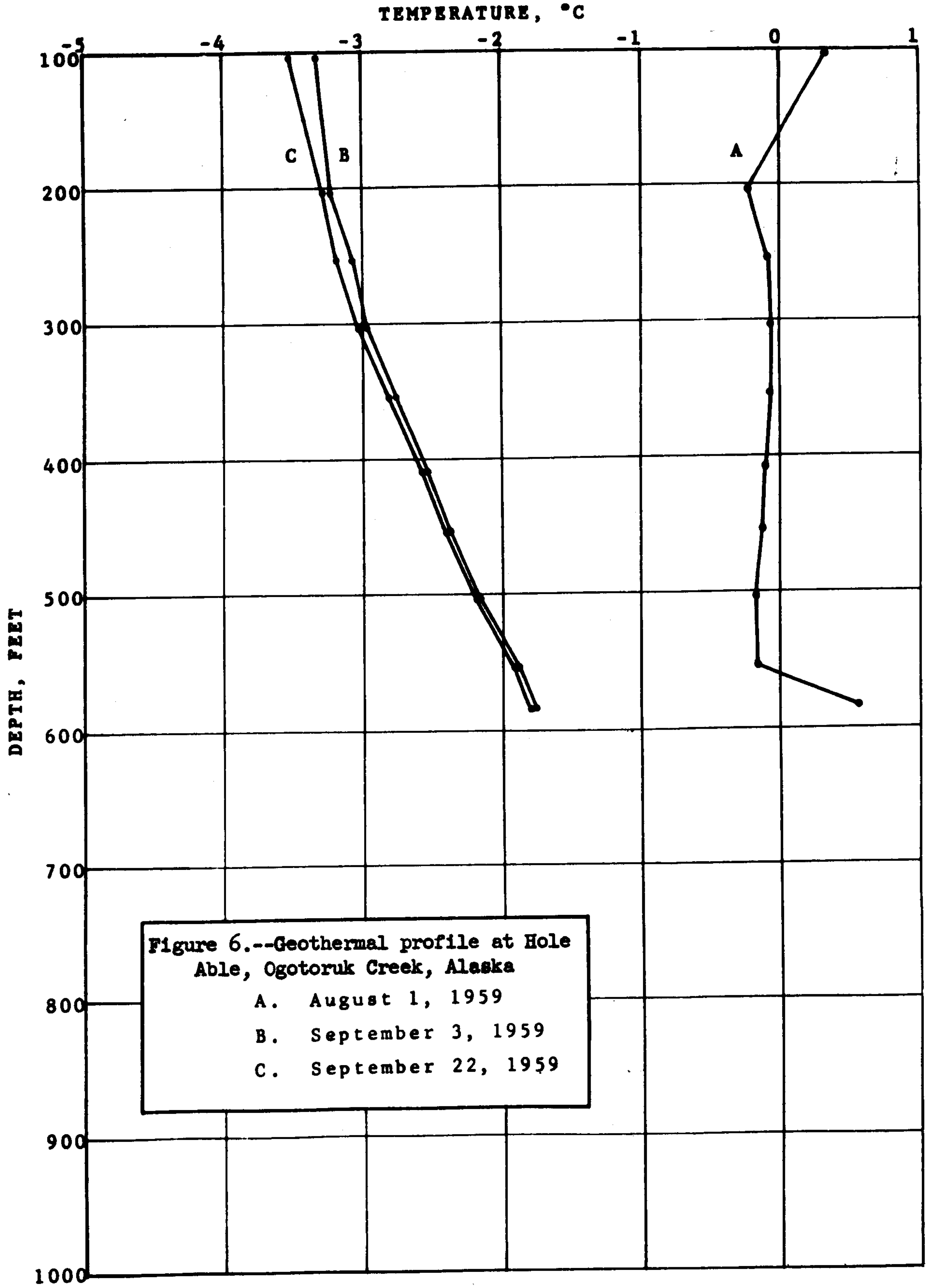

Figure 6.--Geothermal profile at Hole Able, Ogotoruk Creek, Alaska

A. August 1, 1959

B. September 3, 1959

C. September 22, 1959

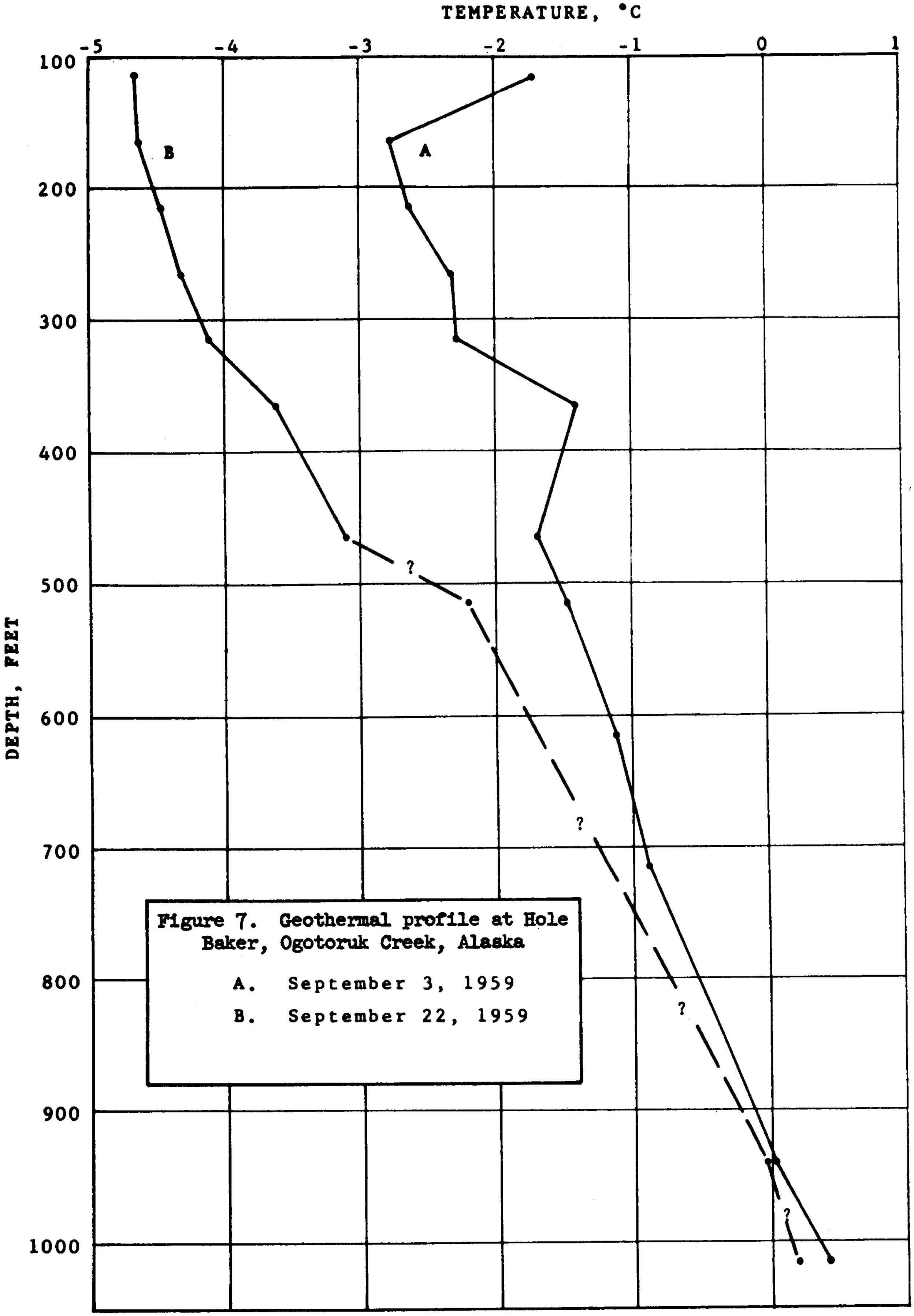

Figure 7. Geothermal profile at Hole Baker, Ogotoruk Creek, Alaska

A. September 3, 1959

B. September 22, 1959

the duration of the disturbance. (It took about a month to drill Hole Baker.) A few remarks about these preliminary data follow:

1. Although Hole Baker is still far from equilibrium, the temperatures in the upper 500 feet are already substantially below those at Hole Able. On the basis of a theoretical extrapolation formula (Lachenbruch and Brewer, 1959) it is estimated that the equilibrium temperatures at about 100 feet in Holes Able and Baker are roughly -4°C and -6°C respectively. The mean annual surface temperature in the area is, therefore, probably close to -6°C at present.

2. The thermal effects of the ocean and lagoon evidently cause anomalously high temperatures in the upper portion of Hole Able. However, it is the behavior of these anomalies at depth that plays the central role in problems of interest. The thermal anomaly introduced by the lagoon is expected to reach a maximum in the upper 300 or 400 feet and then to diminish with increasing depth. If the shoreline is in equilibrium, the anomaly caused by the ocean should increase progressively with increasing depth. However, if recent shoreline movements have occurred, the ocean anomaly, too, is expected to reach a maximum in the upper 500 or so feet. Clearly, temperature information over the full 1,000-foot range is required to untangle the effects of these two bodies of water.

3. Although Hole Baker was far from equilibrium on September 22, the curvature in the upper part of the thermal profile for that date strongly suggests that a significant climatic warming change has occurred at Ogotoruk Creek in the past century. It is likely that it is still in progress.

4. At depths below 465 feet in Hole Baker the data are unreliable owing to damage to the thermistors in installation. From the data at 940

feet and 1,015 feet, however, it seems reasonable to infer that the permafrost depth is probably somewhat greater than 1,000 feet at Hole Baker.

The absence of reliable data in the lower half of Hole Baker makes it difficult to determine the undisturbed geothermal gradient below the zone of climatic change, a quantity fundamental to all aspects of the study.

5. Linear extrapolation of the data of figure 6 to 0°C would seem to yield a permafrost depth of Hole Able comparable to that at Hole Baker. Such extrapolation, however, is not justified inasmuch as the thermal regime at Hole Able is evidently anomalous, and its behavior at depth is uncertain. It seems likely, however, that there is at least 800 feet of permafrost at Hole Able.

6. Preliminary appraisal of these data does not exclude the possibility that a significant marine transgression occurred in the last few thousand years. Such an event would have profound effects on the present distribution of permafrost beneath the ocean, and on temperatures 500 to 1,000 feet beneath the land surface.

The above comments are highly tentative, qualitative inferences based upon early trends in the data. A more precise story should emerge in the course of the next few months as the thermal disturbance caused by drilling dissipates. However, inasmuch as the holes drilled last summer did not permit adequate study of the critical 500 to 1,000 feet depth range, conclusions based upon data from existing installations are expected to be highly uncertain. Further work next summer has been recommended to eliminate this uncertainty.

Literature cited

Lachenbruch, A. H., 1957, Thermal effects of the ocean on permafrost: Geol. Soc. America Bull., v. 68, p. 1515-1530.

Lachenbruch, A. H., and Brewer, M. C., 1959, Dissipation of the temperature effect of drilling a well in Arctic Alaska: U. S. Geol. Survey Bull. 1083-C.

SEISMIC VELOCITY MEASUREMENTS AT THE OGOTORUK CREEK CHARIOT SITE, NORTHWESTERN ALASKA

By

D. F. Barnes

In-hole velocities

In the late spring of 1959 the Geological Survey was asked to measure the velocity of sound through 50-foot depth intervals at the test holes Able and Baker drilled at the Chariot test site at Ogotoruk Creek. These velocity measurements were made with a standard in-hole velocity geophone cable 1,000 feet long and having six geophones spaced at 50-foot intervals on its lower 250 feet. The time of arrival of the sound energy was recorded by a 12-channel portable refraction seismograph. The first test hole was logged on July 30 and 31, 1959. One man and his seismic equipment remained at the site from August 17 to September 7, 1959, awaiting completion of the drilling of Hole Baker, but this hole was not logged because its walls were so unstable that caving would probably have jammed the geophone cable in the hole, thereby preventing insertion of the thermistor cable.

In logging the first hole most of the charges were fired in two 3-foot holes dug in the muskeg approximately 50 feet east of the test hole and almost level with its collar. Charges of dynamite as large as $1\frac{1}{2}$ pounds were fired in these muskeg holes, but these did not always provide sufficient signal to be detected clearly over the large amount of noise caused by the high wind which blew continuously during the tests. Accordingly, a second series of $3\frac{1}{2}$-pound shots was fired in the lagoon formed by Ogotoruk Creek 115 feet west of the hole and 16 feet below it. Four cable positions were used for each shot position, in which the bottom geophone was 250, 350, 475, and 575 feet deep, respectively, so that there was either 100 or 125 feet of overlap between each cable position. A reference geophone was placed at the collar of the hole, and was used to compute corrections of as much as 0.005 second to compensate for variations in depth and form of the muskeg shot holes. The energy arrival times are plotted versus geophone depth in figures 8 and 9, which show both the observed, slant times, and the vertical arrival times computed by the method of Dix (1952).

Both curves show a vertical velocity of about 14,200 feet per second throughout the lower 450 feet of the hole, but there is a slight velocity decrease in the upper 125 feet. This high velocity definitely indicates that the rocks surrounding the hole are frozen throughout its depth. The velocity of unfrozen Tiglukpuk rocks is unknown, but rocks of similar geologic age and lithology were logged farther east during the exploration of Naval Petroleum Reserve No. 4; and velocities of 9,200 and 12,800 fps were obtained where these rocks were present at depths of 2,000 and 6,200 feet, respectively (Payne, 1951; Legge, 1948; Gilbert, 1949). Even where deeply buried the velocity of the unfrozen rocks was not as high as the

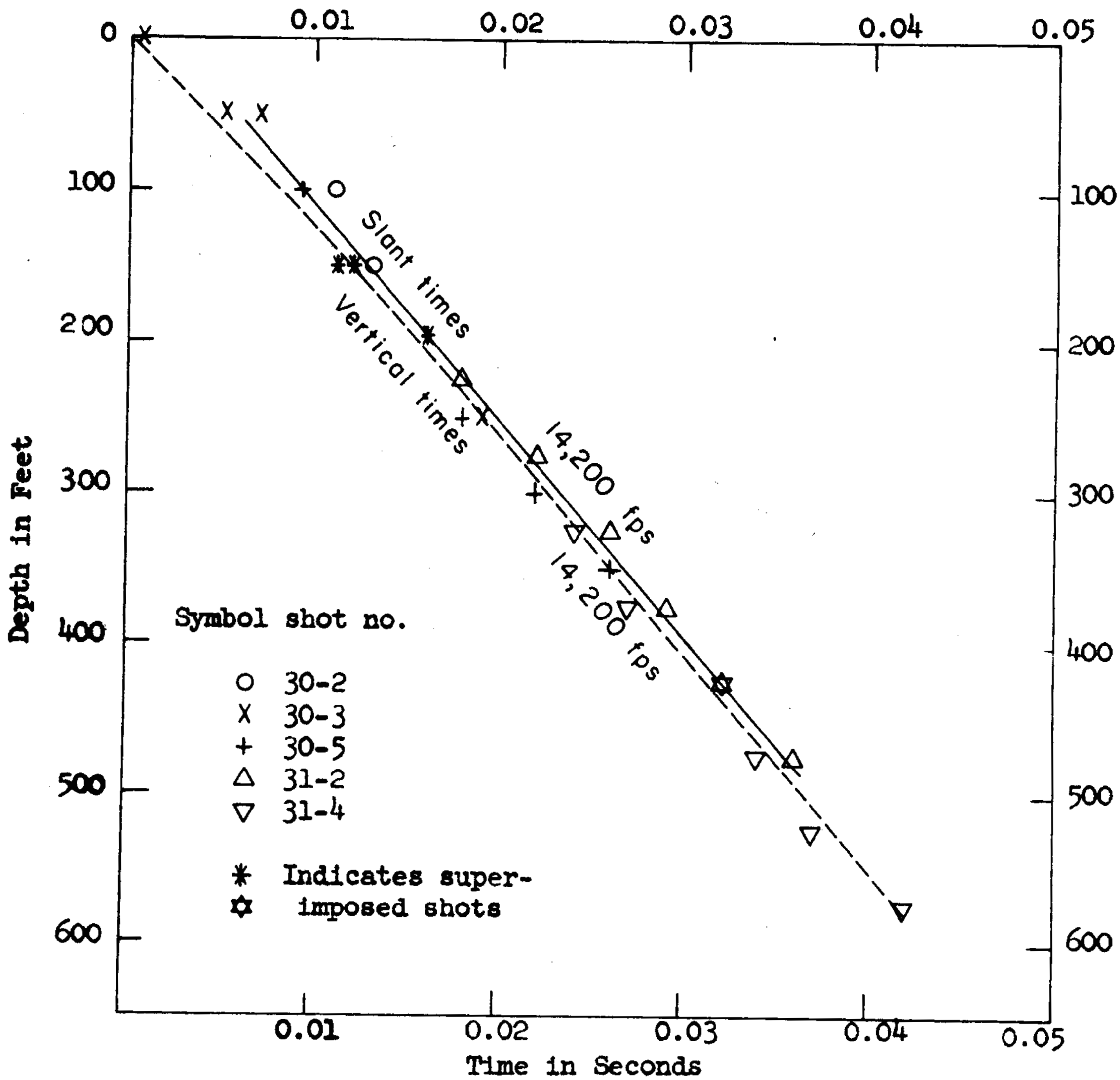

Figure 8. Travel-time curves with shots placed in muskeg, Ogotoruk Creek, Alaska

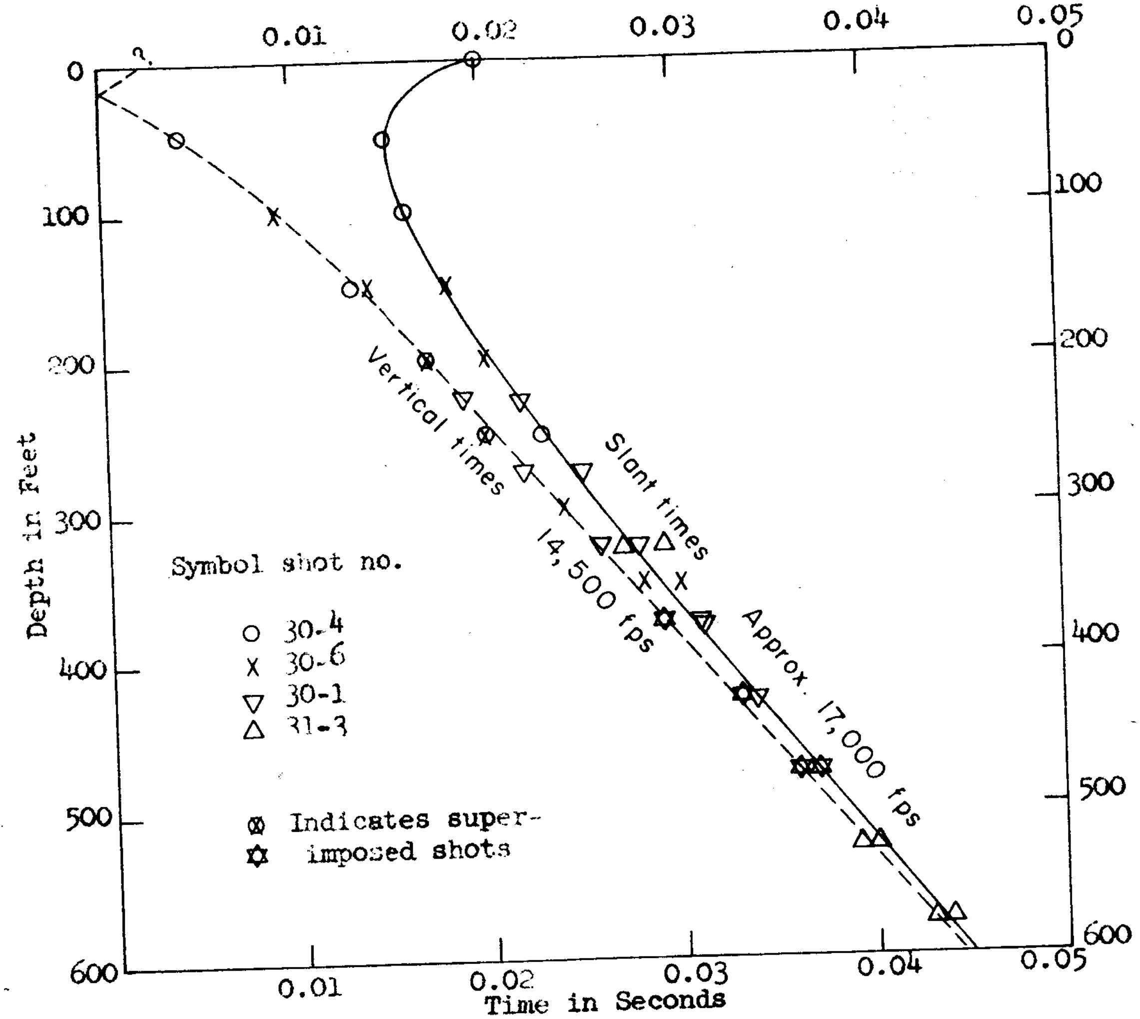

Figure 9. **Travel-time curves with shots placed in Ogotoruk Creek Lagoon, Alaska**

velocity of the frozen rocks measured at Ogotoruk Creek.

No large-size thawed zone or other marked velocity change is indicated by the velocity logs, but the resolution of these measurements is poor. The accuracy with which a seismic refraction arrival may be picked off on an oscillograph record varies from 0.001 to 0.002 second depending on the record quality. The lagoon shots gave good records and all arrival times lie within 0.001 second of the velocity line (fig. 9); the muskeg shots gave poorer records and the scatter amounts to as much as 0.002 second (fig. 8). A thawed layer 30 feet thick representing a velocity decrease from 15,000 fps to 10,000 fps would be indicated by a variation of only 0.001 second, and a thawed zone would have to be at least 50 feet thick in order to be detected.

One other pair of shots was fired to determine whether there was any anisotropism in the velocity of the sediments. The results suggested that the velocity might be somewhat greater parallel to the strike than perpendicular to it, but this apparent anisotropism is more probably the result of a greater thickness of low-speed unconsolidated material at one shot point than at the other.

Surface refraction measurements

To supplement the in-hole velocity information obtained in Hole Able, and to obtain desired subsurface information when it became apparent that Hole Baker would not attain the required depth of 1,500 feet, the Survey began a seismic refraction study. This study was designed to obtain subsurface information to a depth of 1,500 feet in the vicinity of Hole Baker. This work had not been planned, and the proper supplies and equipment were not available at Ogotoruk Creek. Although some additional items were later sent to the site from Fairbanks, the work could not receive proper support on such short notice. The results are therefore preliminary and largely inconclusive.

The locations of the seismic refraction spreads are shown on the map (fig. 10). All spreads consisted of 12 geophones separated by either 25- or 100-foot intervals. Charges ranging from 1 to 100 pounds were fired at various distances from the ends of these spreads. Charges were fired in the lagoon of Ogotoruk Creek, in the ocean, and in shallow holes dug in the tundra. Because of the shortage of explosives many of the profiles could not be fired from both ends, and the indicated velocities may be subject to errors caused by the slope of the refracting surface.

The refraction profiles indicate velocities in the frozen Tiglukpuk rocks that range from 11,000 to 14,500 fps. In general the surface refraction measurements gave slightly lower velocities than the in-hole velocity measurements; this discrepancy cannot be easily explained. There is some indication from the surface measurements that the velocities increase slightly with depth, but this increase would not extend below the bottom of the permafrost.

The major refraction effort was a 7,500-foot profile made along the valley of Ogotoruk Creek in the hope of determining the depth to a layer of high-velocity Triassic limestone and chert that is believed to underlie the Tiglukpuk rocks at the test site. The profile could not be completed because of lack of explosives. No shots were made to determine variations in surface geology, and no reverse shot was fired at the opposite end of the profile. These additional shots are generally considered standard aids

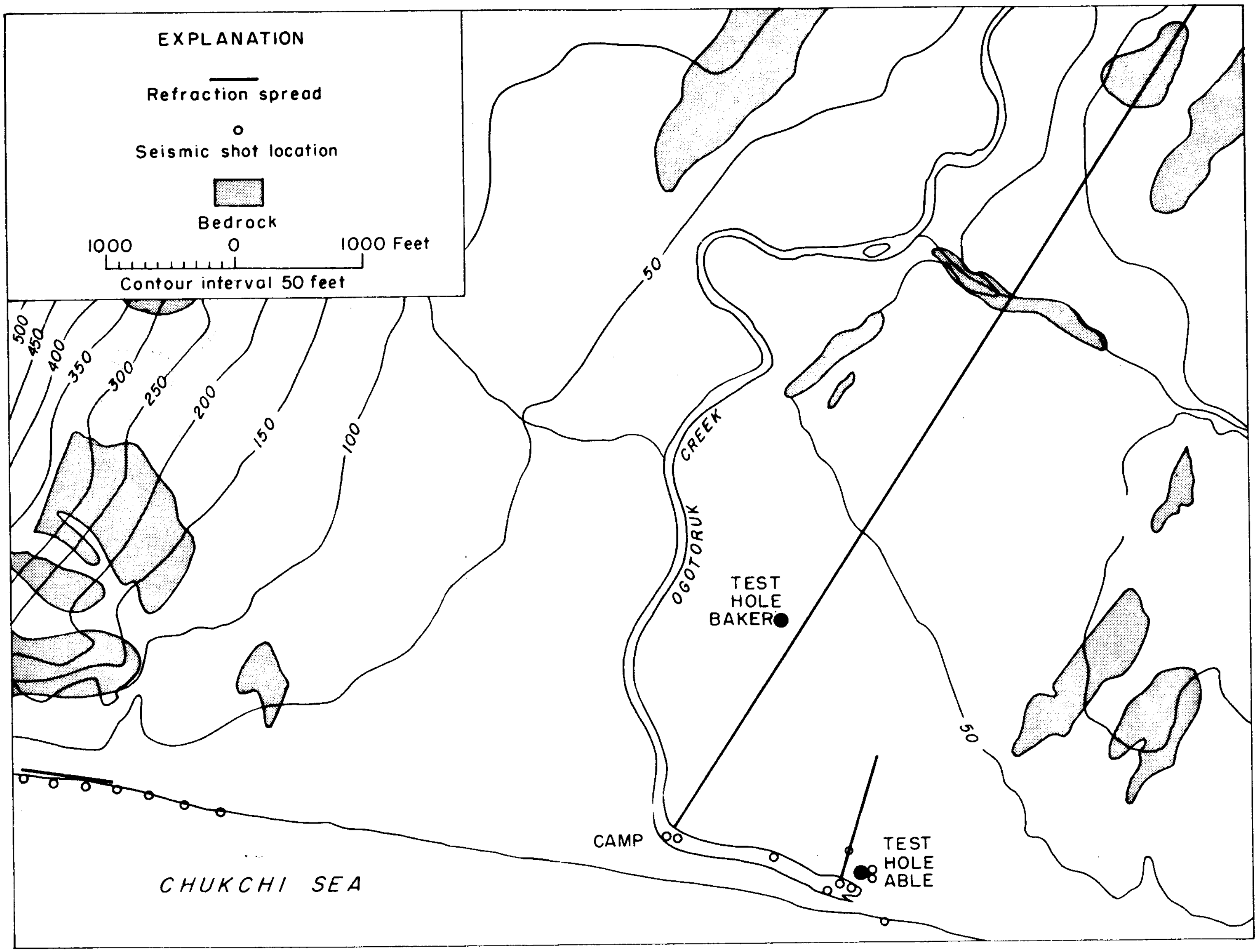

Figure 10. Map showing locations of seismic studies, Ogotoruk Creek, Alaska

for the interpretation of seismic refraction surveys, and their absence severely hinders the analysis of the results.

Dynamite charges for the 7,500-foot profile ranged from 2 to 100 pounds and were fired in the lagoon of Ogotoruk Creek. The shot instant was transmitted to the recording instruments by wire for the first 2,200 feet of the profile and by radio for the last 2,200 feet, but no shot instant was recorded for the middle spreads covering the distances between 2,200 and 5,400 feet. The arrival times in the middle portion of the profile are therefore uncertain, although the velocities recorded by the individual spreads should be accurate.

The location of the profile is shown in figure 10 and the travel-time curve in figure 11. The velocity throughout the first 6,400 feet of the profile averages 13,200 feet per second, but between 6,400 and 7,000 feet the indicated velocity is more than 16,000 feet per second. However, for the last 500 feet of the profile the velocity decreases again to about 13,000 feet per second, but this last part of the record is very hard to read because only a small amount of energy was recorded by these geophones. The interpretation of the profile depends on the significance attached to the velocity recorded between 6,400 and 7,500 feet. The velocity increase could represent either a deep, high-velocity refracting layer or a decrease in thickness of an unfrozen, unconsolidated surficial layer.

The surface layer of most of the Ogotoruk Creek Valley consists of a 1- to 3-foot veneer of unfrozen unconsolidated sand, soil, peat, or alluvium that overlies either frozen unconsolidated material or bedrock shale. The velocity of the unfrozen, unconsolidated layer is very low and sound energy generally requires about 0.01 second to pass through it. A reduction in the thickness of this layer causes an apparent increase in velocity for a short

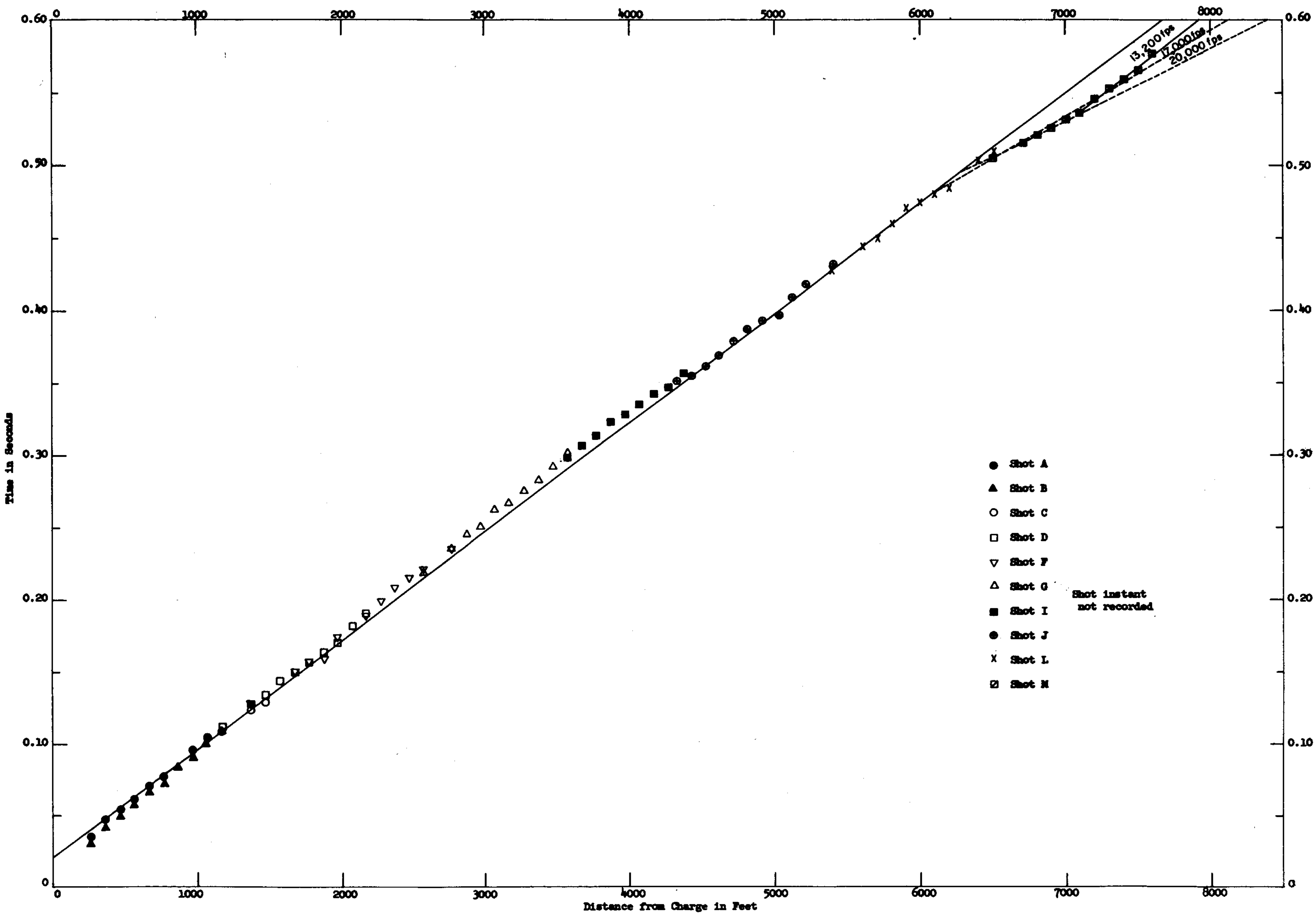

Figure 11. Travel-time curve, long seismic refraction spread, Ogotoruk Creek, Alaska

distance, and an increase in its thickness causes an apparent velocity decrease. The map (fig. 10) shows that the long profile passes very close to an outcrop of the Tiglukpuk at the place where the velocity changes occur. If the high velocity is caused by a deep refractor, the velocity decrease at the end of the profile could easily be explained by an increasing thickness of unconsolidated material beyond the outcrop. On the other hand, much of the velocity increase between 6,400 and 7,000 feet might be caused by a thinning of the overburden as the outcrop is approached, and no refractor would be indicated.

However, the high velocity seems a little more pronounced than might be expected from a bedrock outcrop, and the possibility of a deep refractor deserves consideration. Calculation of the depth of this refractor depends on the velocity of the refractor which cannot be accurately determined over such a short distance. The dashed lines in figure 11 show the range of velocities between 17,000 and 20,000 feet per second that might be indicated by the data. Calculations using these velocities indicate that the greatest depth for this possible deep refractor would be 1,750 feet, and that it might be even shallower than the bottom of Drill Hole Baker at 1,172 feet. A relatively small amount of well-planned, additional seismic work could eliminate many of the very serious uncertainties in these calculations.

Literature cited

Dix, C. H., 1952, Seismic prospecting for oil, Harper and Bros., New York.

Gilbert, E. W., 1949, Report of well velocity survey South Barrow Test Well No. 3, United Geophysical Co. Report; also U. S. Geol. Survey open-file release no. 49-20.

Literature cited--continued

Legge, J. A., 1948, Report of well velocity survey Simpson Test Well no. 1, United Geophysical Co. Report; also, U. S. Geol. Survey open-file release no. 48-1.

Payne, T. L., and others, 1951, Geology of Arctic slope of Alaska, U, S. Geol. Survey Map OM 126.

GROUND-WATER CONDITIONS IN THE VICINITY OF PROJECT CHARIOT, OGOTORUK CREEK, NORTHWESTERN ALASKA

By

R. M. Waller

Introduction

A ground-water investigation of the Ogotoruk Creek area, Alaska, was undertaken by the Geological Survey to determine the possibility of contamination of ground-water by fallout from the detonation of the nuclear devices in the construction of the proposed excavation at the Chariot site. Ground-water may occur in the Arctic region of Alaska in shallow aquifers immediately beneath, and adjacent to, surface-water sources and also in deep aquifers beneath and within the perennially-frozen ground. The shallow aquifers consist principally of unconsolidated material dependent upon water influent from adjacent surface sources during the summer. The deep aquifers are permeable layers of bedrock and may very likely receive recharge from distant surface-water sources at most times of the year.

Both of the above types of aquifers can be contaminated by any radioactive fallout from the proposed Project Chariot nuclear detonation. The shallow aquifers could receive contaminated surface water immediately, whereas it might take many years for the deep aquifers to receive water that came from a contaminated surface source. Both types of aquifers in the vicinity of Ogotoruk Creek and the assessment of possible contamination by radioactive fallout are discussed herein.

Ogotoruk Creek Valley

Shallow aquifers

The lower reach of Ogotoruk Creek flows across a broad valley underlain by a relatively thin layer of unconsolidated material resting on bedrock. Several shallow test pits were excavated in the flood plain (fig. 12) to determine the thickness and character of the flood plain deposits and the presence of permafrost and bedrock. The first 4 pits were aligned in a profile across the flood plain between rock outcrops near the stream-gage site and on the opposite side of the creek. A few feet of coarse, water-bearing gravel overlying a thin frozen clay layer which in turn lies upon highly fragmented bedrock, was penetrated in all the test pits except one. Pit 3 had a harder frozen-clay layer than the others, which could not be penetrated. In pit 2 a maximum depth of 5 feet was reached.

Pits 5 and 6 (fig. 12) were excavated half a mile and a quarter of a mile from the beach, respectively. Pit 5 was dug to about 8 feet in water-bearing gravel; the bulldozer was unable to dig deeper owing to the high water-table in the test pit. Although the thickness of gravel was not determined in this test pit, there seemed to be clay at the bottom of the pit. Pit 6 exposed similar coarse water-bearing gravel which

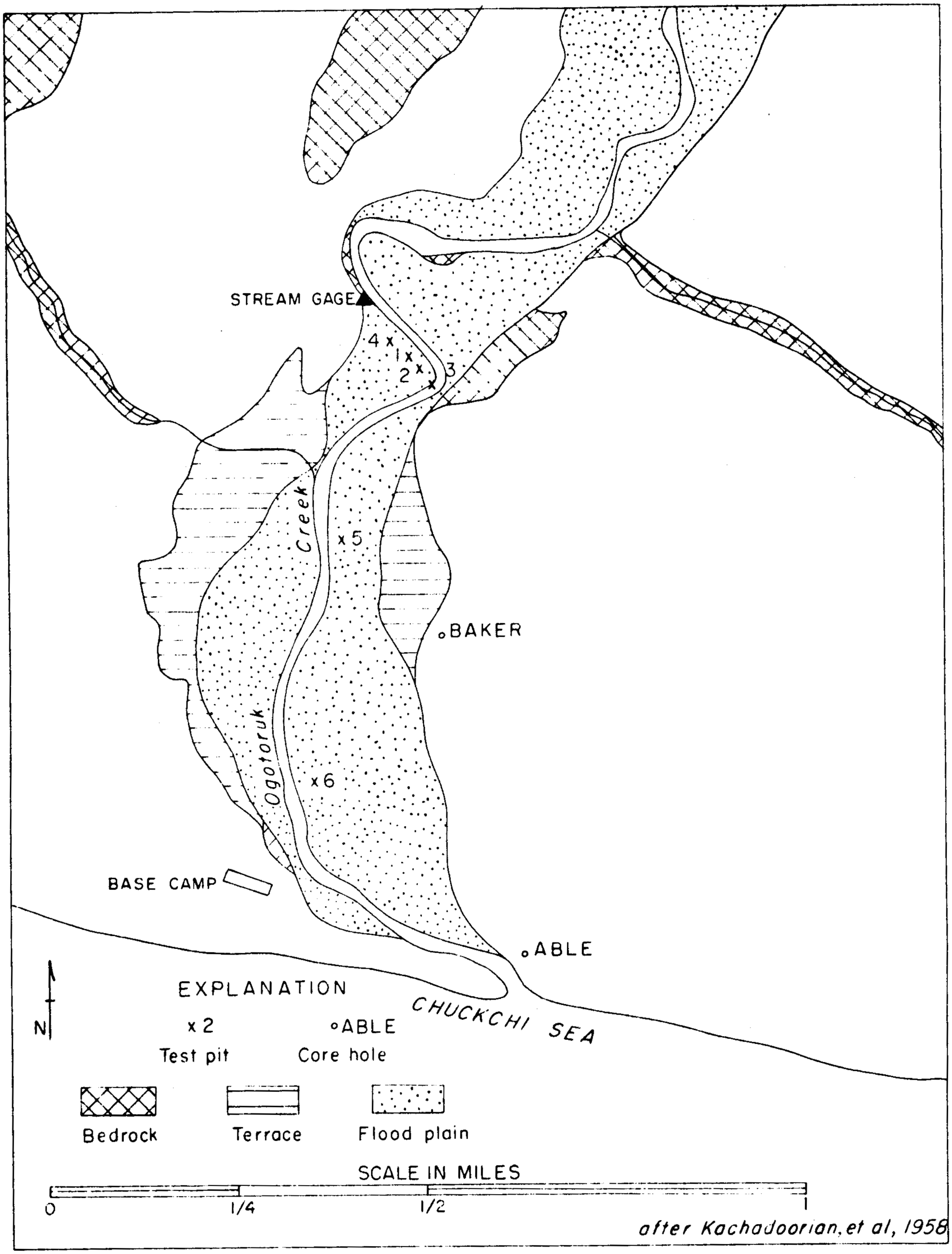

Figure 12.--Sketch map of lower Ogotoruk Valley, Alaska, showing general features and test-hole locations

could not be dug below a depth of 5 feet because of the presence of either frozen clay or bedrock. The nature of the bottom material in the test pit could not be determined because of the high water-table but the bulldozer operator stated that "it felt like bedrock."

The highly permeable deposits in the flood plain of Ogotoruk Creek readily permit infiltration of creek water which gradually thaws the seasonally frozen ground each year. If an unfrozen zone exists between the bottom of the seasonal frost and the top of permafrost it will remain unfrozen as long as recharge from the creek is adequate to maintain the creek underflow. The adequacy of recharge, the depth of seasonal frost, the thickness of the gravels, and presence or absence of a thawed zone during the winter are unknown. The occurrence of icings (ice formed by freezing of ground-water outflow) on the flood plain during the non-flow period of the creek would be an indication of a thawed zone. Late fall investigations are planned to note any flood plain icings.

Bedrock aquifers

The bedrock beneath the valley is primarily mudstone, as recorded in core hole Baker, to a depth of 1,172 feet. Hole Able also was cored in mudstone to a total depth of 598 feet. Limestone, chert, and sandstone have been mapped in the site area and occur principally west of Ogotoruk Creek. The rocks generally strike northeastward and dip to the northwest, and minor overturned folds to the east are common. Moreover, as stated earlier in this report and by Kachadoorian (1958), the beds have been ". . . . further disturbed by north-northeastward-trending high-angle reverse faults and imbricate thrust faults."

The mudstone in the core holes was reportedly frozen for the entire depth. Much sloughing occurred at places, especially from 136 to 150 feet in Hole Able and is believed to represent highly fractured zones. No water was reported in such zones. Although not noted in permafrost, ground-water may occur below the permafrost in fractured mudstone and if so would probably be mineralized.

Bedrock aquifers may be recharged where streams flow across the strike of the beds, such as along the east-trending course of the Kukpuk River about 10 miles to the north. It is likely that a deep aquifer could be contaminated only in such an area. Because of the normally slow rate of ground-water movement, it probably would take many years for such contamination to migrate to the vicinity of Ogotoruk Creek.

Adjacent areas

Shallow aquifers

Shallow ground-water bodies probably occur in the adjacent major stream valleys. The Kukpuk River to the north and Kisimulowk Creek to the east are the nearest streams. The Kukpuk River is much larger and hence probably sustains thawed zones beneath its course more readily than the creeks.

Deep aquifers

Deep aquifers in the area are indicated by springs. It is suspected that many of the major streams, as well as the smaller ones, derive part of their flow from ground-water outflow in the form of springs. Permafrost extends to great depths and the springs indicate that ground-water has sufficient pressure and temperature to maintain unfrozen passages through the permafrost. These unfrozen passages are thought to be principally along faults or highly fractured zones in the limestone and sandstone rocks throughout much of the area. Both types of rock are usually permeable and are likely to be the water-bearing formations beneath the permafrost. Water in the deep aquifers may be mineralized to some extent.

One set of springs was discovered by Survey personnel 27 miles southeast of Ogotoruk Creek, near Cape Seppings. The springs, which have five major zones of flow, emerge from unconsolidated gravel and sand near the base of Covreruk Mountain. Covreruk Mountain is reportedly sandstone (Moore, G. W., personal communication, 1959) with limestone thrust over it from the west. The springs had a measured discharge of more than 20 cubic feet per second (9,000 gallons per minute) on September 9, 1959 (Slaughter, M. J., personal communication, 1959) and had a temperature ranging from 37°F to 38°F. A chemical analysis of the spring water is given in table 11 (in pocket).

Covreruk Springs, or similar ones, may be recharged from the Kukpuk River and other major rivers to the north, or from the Kivalina River to the northeast. Both rivers, and other lesser streams, flow across the regional strike of the rocks throughout the Chariot site area and may lose water to permeable, unfrozen portions of the rocks. Here is probably the chief area where contaminated water could have access to the deep aquifers. The springs, of course, may not show contamination for years because of the slow rate of ground-water movement and the possibility of a more remote source of recharge.

A water sample of Nusoaruk Creek, 3 miles west of Ogotoruk Creek, was analyzed (see table 11) because the locale indicated a possible source of ground-water outflow. The small creek flows along the strike of steeply dipping limestone. An analysis of Ogotoruk Creek water is given for comparison (table 7).

The writer believes that other springs are likely in this region. The presence of limestone and sandstone, the structure of the formations, and a source of recharge in the large rivers to the north, all contribute to the probability that ground-water is present in deep aquifers in the vicinity of the Project Chariot site.

Literature cited

Kachadoorian, Reuben, Campbell, R. H., Sainsbury, C. L., and Scholl, D. W., 1958, Geology of the Ogotoruk Creek area, northwestern Alaska: U. S. Geol. Survey TEM-976, open-file report.

QUALITY OF WATER OF THE CHARIOT TEST SITE AND VICINITY, NORTHWESTERN ALASKA

By

W. L. Lamar

Introduction

A quality-of-water investigation was made of the Chariot test site and vicinity, northwestern Alaska, to gather background data for the Chariot event and is concerned chiefly with the public safety aspects of the Chariot program. The Chariot test offers an opportunity to investigate the effects of underground nuclear detonations on the water supplies of the

Table 7.--Chemical composition of Ogotoruk Creek at Chariot site, northwestern Alaska

Analytical results in parts per million except as indicated

Date of Collection	Mean discharge (cfs)	Silica (SiO_2)	Iron (Fe)	Manganese (Mn)	Zinc (Zn)	Calcium (Ca)	Magnesium (Mg)	Sodium (Na)	Potassium (K)	Bicarbonate (HCO_3)	Sulfate (SO_4)	Chloride (Cl)	Fluoride (F)	Nitrite (NO_2)	Nitrate (NO_3)	Orthophosphate (PO_4)	Dissolved solids (residue on evaporation at 180°C)	Hardness as $CaCO_3$: Calcium, Magnesium	Hardness as $CaCO_3$: Non-carbonate	Specific conductance (micromhos at 25°C)	pH	Color
July 8, 10-11, 1959	363	2.6	0.02	0.00	0.0	4.0	1.9	3.2	0.5	16	7.0	3.5	0.0	0.0	0.3	0.00	31	18	5	52	6.8	20
July 13-20	77	2.9	.05	.00	.0	4.8	1.7	3.7	.5	16	9.0	4.0	.0	.0	.2	.00	35	19	6	61	6.8	10
July 22, 24-31, Aug. 1-2	42	3.2	.05	.00	.0	5.2	2.1	4.1	.6	18	10	4.0	.0	.0	.1	.00	38	22	6	69	7.0	10
Aug. 4-11	5	3.3	.05	.00	.0	6.0	2.4	4.5	.4	18	16	4.0	.0	.0	.1	.00	46	25	10	79	7.0	5
Aug. 15-24, 26-30	36	3.3	.03	.00	.0	7.1	3.1	5.0	.6	20	19	5.0	.0	.0	.2	.00	53	30	14	94	7.0	5

test area and on the recovery of the water supplies from radioactive contamination. Samples were collected at selected points within the area of predicted contamination and at control points outside of this area to provide information on pre-shot background levels of activity of the waters. Regular chemical analyses of the waters were made to provide background information and to provide data for the biological studies. Since under the original plan Ogotoruk Creek would discharge into the proposed harbor, the sediment discharge of this stream was measured.

Appreciation is expressed to the following members of the Geological Survey who assisted in this study: F. B. Barker and B. P. Robinson who provided the radiochemical examinations and evaluations, F. B. Walling who was in charge of the chemical quality and suspended sediment testing of Ogotoruk Creek, and George Porterfield who provided the suspended-sediment evaluations.

Collection of samples

Ogotoruk Creek was sampled daily at the Chariot site, just below the gaging station which is 1.2 miles upstream from the mouth. Samples were collected for chemical quality examination and suspended sediment measurement for the period July 8 to August 30, 1959. Chemical analyses were made on 5 composite samples for the months of July and August. The compositing of these samples was controlled through daily tests for specific conductance.

The samples for suspended sediment were collected with the US DH-48 hand sampler. These samples were depth integrated and collected by the equal transit rate method. The highest water discharge occurred during the initial part of the sampling. Since no rainstorm of any particular consequence occurred either during the last half of July or in August, only one sample was taken for size gradation.

Spot water samples were collected in northwestern Alaska during the period August 4 to September 9, 1959 as follows: Surface water samples were collected at four points in the Kukpuk River basin eastward from near the mouth of the Kukpuk River to about longitude 165°W. One sample was collected from the Wulik River near its mouth and one sample from the Noatak River at the junction with the Kelly River. This latter sample was collected on the same side as the inflow of the Kelly River and probably represents principally the water from that stream. Samples were also collected from a stretch of the coastal region extending from 5 miles northwest of Cape Thompson to 9 miles southeast of Cape Seppings. These collections were from small streams, ponds, a lagoon, and Covreruk Springs. One of these small streams, Nusoaruk Creek, appears to be spring fed from a deep source. Two samples were taken from the Chukchi Sea: one, two miles south of Point Hope, and another half a mile offshore from the mouth of Ogotoruk Creek. At 15 of the above points samples were also collected for comprehensive radiochemical examination. In addition, 4 composites of daily samples from Ogotoruk Creek were selected for examination for alpha and beta activity. Acetic acid was added to the samples collected for comprehensive radiochemical analysis at the time of collection to keep the radiochemical constituents in solution. Each sample for radiochemical examination included a sample for regular chemical analysis.

The water temperature was measured at the time the samples were collected. The chemical and physical measurements including the radiochemical analyses are reported in tables 7 to 13. The location of the sampling points is shown in figure 13.

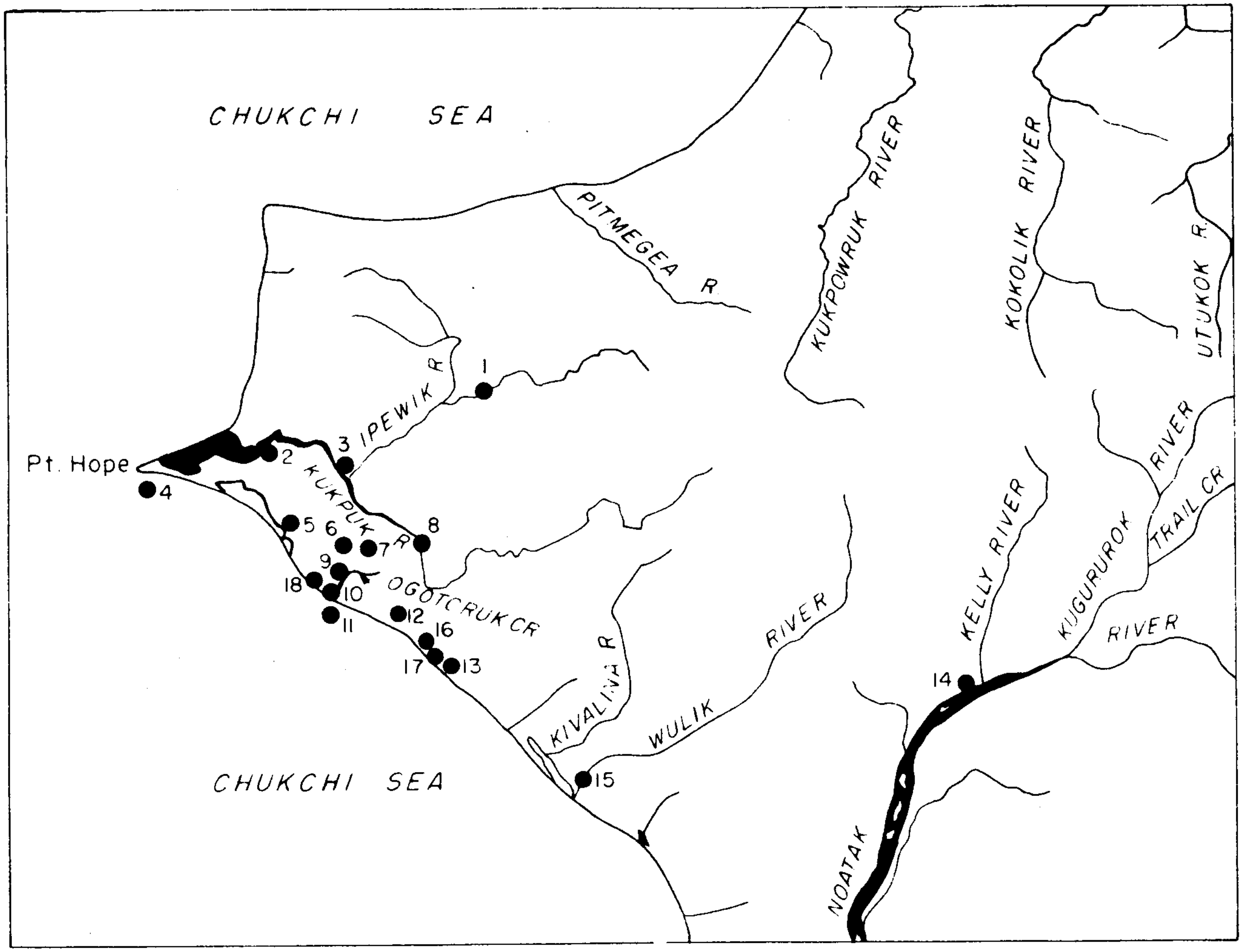

Figure 1?.--Index map showing locations of water sample collection sites, orthwestern Alaska

Water quality of Ogotoruk Creek

Ogotoruk Creek drains an area underlain chiefly by sandstone, siltstone, and mudstone with a little limestone and chert. The surficial deposits consist of gravel and windblown sand and silt covered and/or mixed with an organic mat in places. The unconsolidated material is generally permanently frozen 1 to 2 feet below the surface, whereas permafrost may be as much as 10 feet below the surface in bedrock. The geology and frozen condition of the ground is reflected in the quality of water of Ogotoruk Creek. Rain and surface water does not penetrate far into the ground and the ground water, which is discharged into Ogotoruk Creek, percolates through materials of relatively low solubility. Thus, the maximum dissolved solids observed in waters of Ogotoruk Creek was 40 parts per million (ppm) during the summer of 1958, and 55 ppm during the summer of 1959. The chemical analyses for Ogotoruk Creek for the summer of 1959 are shown in table 7 and the results of water temperature and specific conductance measurements are shown in table 8.

The sediment discharge of Ogotoruk Creek was lower in the 1959 water year (October 1, 1958 to September 30, 1959) than in the 1958 water year. This is due, in part, to greater shower activity and more flow from storm runoff in the 1958 water year. In 1958, the maximum instantaneous concentration of suspended sediment was 1,530 ppm, observed on August 11, while in 1959 the maximum instantaneous concentration was 161 ppm, observed on July 9. The highest monthly water discharge occurred in June prior to the arrival of the field party and the collection of sediment

Table 8.--Water temperature and specific conductance of Ogotoruk Creek at Chariot site, northwestern Alaska

Day	July 1959			August 1959		
	Mean discharge (cfs)	Water temperature (°F)	Specific conductance (micromhos at 25°C)	Mean discharge (cfs)	Water temperature (°F)	Specific conductance (micromhos at 25°C)
1				14	49	69
2				11	46	70
3				7	--	--
4				6	51	73
5				5	51	76
6				5	47	76
7				4	48	79
8	210	43	52	4	48	79
9	700	--	--	6	46	78
10	500	44	49	6	45	81
11	380	46	53	5	48	83
12	270	--	--	4	--	--
13	200	43	59	3	--	--
14	140	48	60	2	--	--
15	100	45	60	2	52	88
16	70	47	62	2	49	88
17	51	55	59	2	53	88
18	21	49	59	2	53	90
19	18	60	61	2	54	100
20	16	54	60	2	50	90
21	16	--	--	2	45	92
22	17	50	63	7	46	93
23	18	--	--	16	42	94
24	95	49	72	21	44	100
25	75	50	65	18	--	--
26	69	49	--	29	--	99
27	59	46	67	92	47	100
28	45	--	67	144	--	92
29	33	44	69	134	42	93
30	25	45	70	125	42	93
31	18	53	71	116	--	--

samples. It is likely that the highest monthly sediment discharge occurred during this period. A more complete picture of the sediment discharge of Ogotoruk Creek can be obtained through sediment sampling beginning at the time of breakup. On the basis of the data available, the sediment discharge from Ogotoruk Creek is considered minor in relation to the size of the proposed excavation. The results for suspended sediment concentration and loads are given in table 9.

One determination of the particle size of the suspended material transported by Ogotoruk Creek was made in 1959. These results are given in table 10. In addition, three particle-size analyses were made on samples collected in 1958 (Kachadoorian, Campbell, Sainsbury, and Scholl, 1958, p. 40).

Chemical composition of waters of northwestern Alaska

The waters examined in northwestern Alaska fall in several categories. The waters of Ogotoruk and Kisimulowk Creeks are soft and low in mineral content. Kisimulowk Creek drains an area roughly of the same kind of terrain as that drained by Ogotoruk Creek. Only 2 ppm of calcium was present in the sample from Kisimulowk Creek, and this low concentration could be expected in view of the virtual absence of limestone outcrops in the drainage basin.

For Ogotoruk Creek the cationic concentration consisted of 28 percent and more of alkali metal ions, and the anionic concentration consisted of 48 percent and more of strong acid ions as based on equivalents. In Kisimulowk Creek the cationic concentration of alkali metal ions and the anionic concentration of strong acid ions were both 57 percent. The above results are based on seven analyses for Ogotoruk Creek and only one

Table 9.--Concentration and discharge of suspended sediment for Ogotoruk Creek at Chariot site, northwestern Alaska

Day	JULY 1959			AUGUST 1959		
	Mean discharge (cfs)	Suspended sediment		Mean discharge (cfs)	Suspended sediment	
		Mean concentration (ppm)	Tons per day		Mean concentration (ppm)	Tons per day
1				14	1	(+)
2				11	70	2.1
3				7	120	a 2.3
4				6	65	1.0
5				5	12	.2
6				5	4	(+)
7				4	4	a (+)
8	210	70	40	4	1	(+)
9	700	142	268	6	--	(+)
10	500	30	40	6	1	(+)
11	380	17	17	5	1	(+)
12	270	17	a 12	4	--	a (+)
13	200	10	5.4	3	--	a (+)
14	140	12	4.5	2	--	a (+)
15	100	8	2.2	2	--	(+)
16	70	5	.9	2	--	(+)
17	51	5	.7	2	--	(+)
18	21	3	.2	2	--	(+)
19	18	2	.1	2	--	(+)
20	16	2	.1	2	1	(+)
21	16	1	a (+)	2	3	(+)
22	17	1	(+)	7	1	(+)
23	18	2	.1	16	1	(+)
24	95	15	3.8	21	--	(+)
25	75	4	.8	18	--	a (+)
26	69	3	.6	29	--	(+)
27	59	2	.3	92	1	.2
28	45	1	.1	144	4	1.6
29	33	1	.1	134	4	1.4
30	25	3	.2	125	4	1.4
31	18	2	.1	116	2	a .6
Total	3,146		397.3	798		11.2
Total discharge for period (cfs-days)						3,944
Total load for period (tons)						408.5

+ Less than 0.05 ton. a Computed from estimated concentration graph.

Table 10.--Particle-size analysis of suspended sediment,

Ogotoruk Creek at Chariot site, northwestern Alaska

(Method of analysis: Bottom withdrawal tube; sieve; in distilled water; chemically dispersed; mechanically dispersed)

Date and time of collection: July 8, 1959 at 11:20 a.m.

Discharge, cubic feet per second ------------- 210

Concentration of sample, ppm ----------------- 48

Concentration of suspended analyzed, ppm ----- 150

Particle size (in millimeters)	Percent finer than size indicated
0.002	30
.004	38
.008	50
.016	60
.031	79
.062	87
.125	96
.250	100

analysis for Kisimulowk Creek.

The waters from the other streams, except for Nusoaruk Creek which appears to have ground-water contribution from a deep source, were moderately hard to hard. The dissolved solids of the waters of these streams ranged from 184 ppm for the creek flowing into the southeast end of Tusikpok Lagoon to 212 ppm for both the East Fork of the Ipewik River and Ahgahyoukuk Creek. The waters from these streams contain less than 15 percent alkali metal cations and less than 36 percent strong acid anions.

Nusoaruk Creek, 3 miles northwest of the Chariot site, had a dissolved solids content of 1,530 ppm at the time of observation. The quality of water indicates that this stream is spring fed from a deep source. Two samples of water were collected from Covreruk Springs which are southeast of the Chariot site. These samples showed a dissolved mineral content of 1,330 ppm on August 15 and 1,650 ppm on September 9. Both of these waters are high in sodium chloride and for both the cationic concentration consisted of about 70 percent alkali metals ions and the anionic concentration consisted of about 90 percent strong acid ions.

The two biological control ponds (analyses 6 and 7, tables 11 and 12) north of the Chariot site show a striking difference in chemical composition. The smaller pond to the west is low in mineral content (dissolved solids 36 ppm) as may be expected for a thaw pond in that area. The larger pond to the east was considerably higher in mineral content (dissolved solids 94 ppm). The composition of the water from this pond is unusual for a surface source in the area. On the basis of usual chemical combinations this water contained principally magnesium sulfate and sodium sulfate. It is also noted that the magnesium is more abundant than the calcium. Except for the sea water, this relationship is true in only one other place, Nusoaruk Creek which is considered spring fed. The cationic concentration of both ponds consisted of more than 74 percent alkali metal ions. The smaller pond to the west contained 60 percent strong acid anions consisting primarily of chloride, whereas the larger pond to the east contained 79 percent strong acid anions consisting primarily of sulfate.

Radiochemical analyses

The concentrations of alpha activity, beta activity, uranium, radium, radiostrontium and radiocesium were determined on 17 samples from streams, ponds, a lagoon, Covreruk Springs, and the Chukchi Sea. In addition, concentrations of alpha activity and beta activity were determined on four selected composite samples from Ogotoruk Creek. These results are shown in tables 12 and 13.

The concentrations of alpha and beta activity were, in general, of the same magnitude as normally found in similar water from other parts of the United States. The two biological control ponds, located north of the Chariot site, contain relatively high concentrations of beta activity as compared with other water in the vicinity. However, it seems unlikely that the beta activity can be due entirely to a build-up of natural radioelements. At least part of this beta activity might be ascribed to fall-out which has accumulated from previous nuclear tests and which has not been entirely flushed from the basin by natural drainage. The sea water samples contained considerable beta activity; most, if not practically all of this activity can be ascribed to the potassium-40 content of the water. The concentrations of radiocesium were below the detection limit

Table 13.--Radiochemical data for composite water samples from Ogotoruk Creek at Chariot site, northwestern Alaska

(Analytical results in micromicrocuries per liter)

Number on map (fig. 13)	Date of collection	Alpha activity	Beta activity
9	July 13-20, 1959	< 0.2 as of November 3, 1959	5.1 ± 2.6 as of November 2, 1959
9	July 22, July 24-Aug. 2, 1959	< 0.2 as of November 3, 1959	6.0 ± 2.6 as of November 3, 1959
9	August 15-24, 26-27, 1959	< 0.3 as of November 3, 1959	4.0 ± 2.6 as of November 2, 1959
9	August 4-11, 1959	< 0.2 as of November 3, 1959	5.6 ± 2.6 as of November 3, 1959

in some samples (table 12), and the concentrations of radiostrontium were equal to or less than detection limit in all samples.

The natural radioelements, uranium and radium, were found in very low concentrations in all fresh-water samples. The samples collected in the immediate vicinity of Ogotoruk Creek, however, have notably low uranium concentrations, even for this area.

Conclusions

On the basis of the data available the suspended sediment discharge of Ogotoruk Creek can be considered minor in relation to the size of the proposed excavation. A more complete evaluation of the sediment discharge of Ogotoruk Creek can be obtained through measurements beginning at the time of breakup.

The chemical composition of the waters of northwestern Alaska fall into several categories. The analyses of samples from two sources, Covreruk Springs and Nusoaruk Creek, indicate ground-water contribution from a deep source, which is in accord with reports that these sources flow throughout the year.

The radiochemical levels of the fresh waters were low and of the same magnitude as would normally be found in similar waters from other parts of the United States. The highest activity of the fresh waters was found in the two biological control ponds located north of the Chariot site. Part of this higher beta activity might be ascribed to fallout which has accumulated from previous blasts and which has not been flushed out because of some lack of natural drainage. However, it should be noted that the chemical composition of the water of the larger control pond to the east is unusual for the area.

The evidence of deep ground-water aquifers in the area imposes a possibility of ground-water contamination particularly if the intake areas are in the zone of fallout. The analysis of Nusoaruk Creek is indicative that this stream is spring fed from a deep source. It is likely that other streams in the area derive some part of their flow from springs. The slow rate of ground water movement provides the possibility of late contamination which could appear in the discharge as much as several years after the detonation, in the event such activity is not removed by ion exchange and/or adsorption.

Literature cited

Kachadoorian, Reuben, Campbell, R. H., Sainsbury, C. L., and Scholl, D. W., 1958, Geology of the Ogotoruk Creek area, northwestern Alaska, U. S. Geol. Survey TEM-976; also, U. S. Geol. Survey open-file report.

SURFACE WATER DISCHARGE OF OGOTORUK CREEK NEAR POINT HOPE, ALASKA

By

M. J. Slaughter

Introduction

Ogotoruk Creek empties into the Chukchi Sea approximately $6\frac{1}{2}$ miles southeast of Cape Thompson and about 24 miles southeast of Point Hope, Alaska. The creek is approximately 10 miles long and is braided throughout most of its length. It flows westward for the first 6 miles and southward for the remaining 4 miles; it drains approximately 40 square miles.

The stream bed consists of clean gravel and mudstone, graywacke, and sandstone. The flood plain is about 1,000 feet wide and consists of gravel, sandstone, and mudstone.

Hydrology

The stream-gaging station on Ogotoruk Creek, 1.2 miles above the mouth, was reactivated on May 27, 1959. A tabulation of daily mean discharge through September 30, monthly flows June through September, and peak flows that exceeded 400 cubic feet per second is shown in table 14.

Table 14.--Daily discharge of Ogotoruk Creek near Point Hope, Alaska from May 27, 1959 to September 30, 1959, in cubic feet per second

Day	May	June	July	August	September
1		b 240	80	14	87
2		b 222	51	11	59
3		b 204	48	7	35
4		b 266	37	* 6	29
5		312	a 38	5	21
6		316	a 60	5	16
7		240	a 110	4	14
8		183	210	4	* 12
9		195	a 700	6	10
10		180	a 500	6	7
11		171	a 380	5	6
12		256	a 270	4	5
13		377	a 200	3	3
14		276	a 140	2	2
15		319	a 100	2	2
16		370	a 70	2	2
17		266	* 51	2	1
18		216	21	2	1
19		198	18	2	1
20		256	16	2	1
21		180	16	2	1
22		* 148	17	7	b 1
23		148	18	16	a 1
24		126	95	21	a 1
25		118	75	18	a 1
26		124	69	29	a 2
27	*b 41	153	59	92	a 3
28	b 63	137	45	144	a 4
29	b 83	102	33	134	16
30	b113	86	25	125	53
31	b156		18	116	
Total		6,385	3,570	798	397
Mean		213	115	25.7	13.2
Ac-ft		12,660	7,080	1,580	787

Peak discharge (base, 400 cfs).--June 13 (2 p.m.) 436 cfs (4.39 ft); June 15 (9 p.m.) 504 cfs (4.56 ft); July 9 (time unknown) 1,260 cfs (4.3 ft).

* Discharge measurement made on this day.

a No gage-height record; discharge estimated.

b Stage-discharge relation affected by ice.

For all practical purposes no flow occurred in Ogotoruk Creek from October 1, 1958 until late in May 1959. Some flow may have occurred on certain scattered days but amounts were too small to be of importance in the overall surface-water study.

The peak discharges recorded on June 13, 1959, June 15, 1959, and July 9, 1959 were 436 cfs, 504 cfs, and 1,260 cfs, respectively. The flood plain indicates that peaks much higher than these can be expected. The total discharge for June was 12,660 acre-feet; for July, 7,080 acre-feet; for August, 1,580 acre-feet; and for September, 787 acre-feet.

Conclusions

No conclusions can be drawn from the limited streamflow records obtained thus far, except that any flow between mid-October and mid-May is likely to be small. Between mid-May and mid-October unusually warm temperatures or heavy precipitation may markedly increase the flow. At times during this period, the rate of increase in flow may be rapid as on July 9, 1959.

End