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Core Test, Sentinel Hill Area, and Test Well Fish Creek Area, Alaska

EXPLORATION OF NAVAL PETROLEUM RESERVE NO. 4 AND ADJACENT AREAS, NORTHERN ALASKA, 1944–53

PART 5, SUBSURFACE GEOLOGY AND ENGINEERING DATA

GEOLOGICAL SURVEY PROFESSIONAL PAPER 305-I

Prepared and published at the request of and in cooperation with the U. S. Department of the Navy, Office of Naval Petroleum and Oil Shale Reserves

Core Test, Sentinel Hill Area and Test Well Fish Creek Area, Alaska

By FLORENCE M. ROBINSON *and* FLORENCE RUCKER COLLINS

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EXPLORATION OF NAVAL PETROLEUM RESERVE NO. 4 AND ADJACENT AREAS, NORTHERN ALASKA, 1944–53

CORE TEST, SENTINEL HILL AREA, AND TEST WELL, FISH CREEK AREA, ALASKA

By Florence M. Robinson and Florence R. Collins

ABSTRACT

Sentinel Hill core test 1 and Fish Creek test well 1 were drilled in 1947 and 1949, respectively, as part of the petroleum exploration of Naval Petroleum Reserve No. 4, northern Alaska, carried on by the U. S. Navy from 1944 to 1953. Fish Creek test well 1 is near an oil seep in the northeastern corner of the Reserve, which is in the Arctic coastal plain province; and Sentinel Hill is about 50 miles to the south. Both holes were drilled into the youngest Cretaceous (the uppermost divisions of the Late Cretaceous Colville group) formations found in northern Alaska, and Fish Creek test well 1 penetrated several older Cretaceous formations, as well. The strata are composed primarily of clay shale, with some sandstone and siltstone; most of the section is marine. Tuffaceous beds and bentonite are abundant in the upper part of the sequence. The 7,020-foot test well at Fish Creek recovered a small amount of heavy black oil, but the core test, a much shallower hole, had no oil or gas shows.

INTRODUCTION

A program of petroleum exploration was conducted in Naval Petroleum Reserve No. 4, northern Alaska, by the U. S. Navy, between 1944 and 1953. Among the holes drilled to help evaluate petroleum possibilities were Fish Creek test well 1 and Sentinel Hill core test 1, both of which penetrated Cretaceous rocks near the eastern edge of the Reserve. The test well, 7,020 feet deep, is on the Arctic coastal plain near the Arctic Ocean (see fig. 39), and the comparatively shallow core test is 50 miles to the south, near the southern boundary of the coastal plain. Fish Creek test well 1, near an oil seep, recovered a little heavy black oil; Sentinel Hill core test 1, on the flank of the Sentinel Hill anticline, was a dry hole.

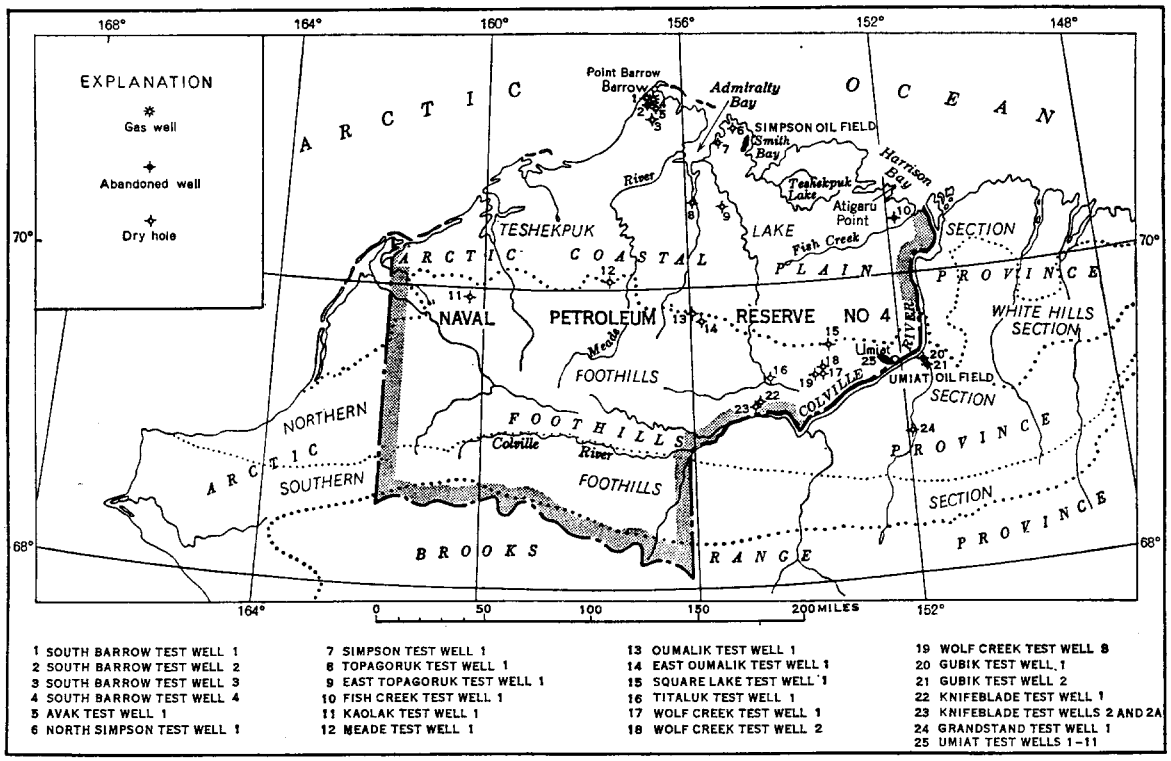


Figure 39.—Index map of northern Alaska showing location of test wells and oil fields.

Detailed geologic, engineering, and logistic data obtained from drilling these two tests are presented in this report, and much of it is summarized on graphic logs. The report has been compiled from information supplied, under contract, to the Navy by Arctic Contractors, United Geophysical Co., Inc., and the Schlumberger Well Surveying Corp., and by the U. S. Geological Survey, the U. S. Bureau of Mines, and the National Bureau of Standards as cooperating Government agencies. Geologists of the Geological Survey described the cores and ditch samples and determined porosity and permeability in the Survey's laboratory in Fairbanks, Alaska; Paul D. Krynine also made porosity and permeability studies. Invertebrate megafossils were identified by George Gryc and C. Wythe Cook, and plant fossils were studied by Roland Brown. Microfaunal studies were made by Harlan R. Bergquist. The stratigraphic distribution of fossils in the test wells of northern Alaska will be presented by him in another chapter of this series. The heavy-mineral data is part of a regional study of the heavy-mineral zones by Robert H. Morris. The help of many other engineers, geophysicists, and geologists connected with the above organizations is gratefully acknowledged.

SENTINEL HILL CORE TEST 1

By Florence M. Robinson

Location: Lat 69°36′57″ N., long 151°27′11″ W.
Elevation above sea level: Kelly bushing, 209 feet; ground, about 200 feet.
Spudded: January 26, 1947.
Completed: March 23, 1947; dry and abandoned.
Total Depth: 1,180 feet.

Sentinel Hill core test 1 was located on the west side of the Colville River 24 miles northeast of Umiat (see fig. 40); the core test is 12 miles due north of Gubik test well 1 which is shown on figure 39. The site chosen was on a mud and gravel bar a few feet above water level and at the base of 350-foot bluffs. This bar is probably covered with water during the breakup in late spring and early summer.

Sentinel Hill, a topographic feature 18 miles north of the core test and near the mouth of the Kogosukruk River, was named by F. C. Schrader and W. J. Peters, of the U. S. Geological Survey, on their traverse down the Colville River in 1901 (Schrader and Peters, 1904). The term "Sentinel Hill area" was first used in a report made in 1945 to the U. S. Navy (unpublished) by one of their reconnaissance geologic field parties led by Lts. J. A. Rogers and A. P. McConnel, Jr. The area covered by this party was mostly northwest of the site of the core test and along the Kogosukruk and Kikiakrorak Rivers. Toward the end of the season, however, they made a short study along about 10 miles of the Colville River. They recognized a broad, low anticlinal fold with several crests which they presumed extended from the Kogosukruk River to the Colville River. (See fig. 40.)

In 1945 and 1946 the U. S. Geological Survey in conjunction with the U. S. Navy made a survey of the Reserve with an airborne magnetometer. A magnetic high which was called West Sentinel Hill was discovered north-northwest of Umiat, but this was centered about 30 miles from the Sentinel Hill core test site. (See fig. 8, Payne and others, 1951, sheet 2.) A gravity maximum mapped by United Geophysical Co., Inc., coincides with the magnetic high. (See fig. 9, Payne and others, 1951, sheet 2.)

Sentinel Hill core test was drilled early in 1947 by Arctic Contractors. Later, in the summer of 1947, a U. S. Geological Survey field party under K. Stefansson studied the surface geology on the Colville River north of Umiat and on the Kogosukruk River. In 1950 a reflection seismograph tie-line run between the Fish Creek area and Umiat by United Geophysical Co., Inc., showed a reversal in this vicinity and helped to define the Sentinel Hill anticline. Some seismic detail work was done in the area in 1951. The contour lines on figure 40 show possible closure on the anticline 13 miles northwest of the core test.

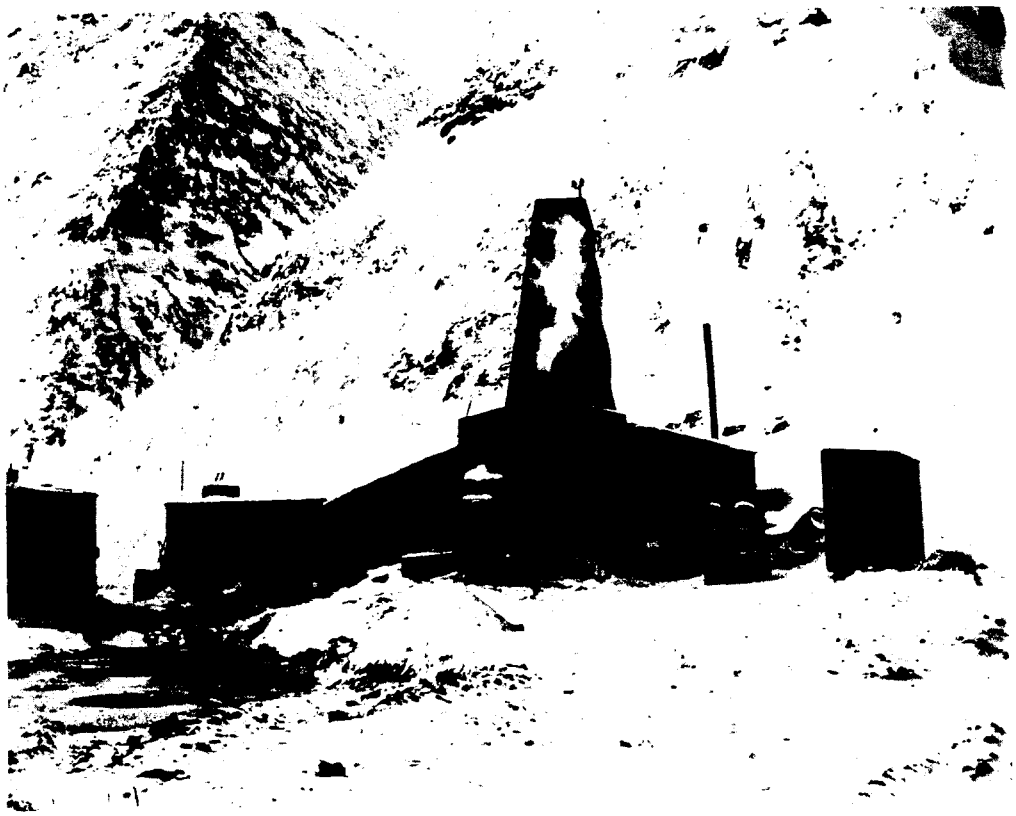
In 1954 W. P. Brosgé, of the U. S. Geological Survey compiled the field and photogeologic data and determined the position of the anticlinal and synclinal axes shown on figure 40. The Kogosukruk tongue of the Prince Creek formation (see section on stratigraphy) of Late Cretaceous age crops out in the area (W. P. Brosgé, written communication).

The purpose of the core test was "* * * to ascertain the nature of the shallow subsurface formations on the Sentinel Hill anticline and test shallow oil possibilities" (written communication, Arctic Contractors, March 1953). Stratigraphically, the test provided valuable information but the present structural data indicate that the core test is actually far out on the flank of the anticline and in a relatively low area between two of the axial flexures. No gas or oil was found.

STRATIGRAPHY

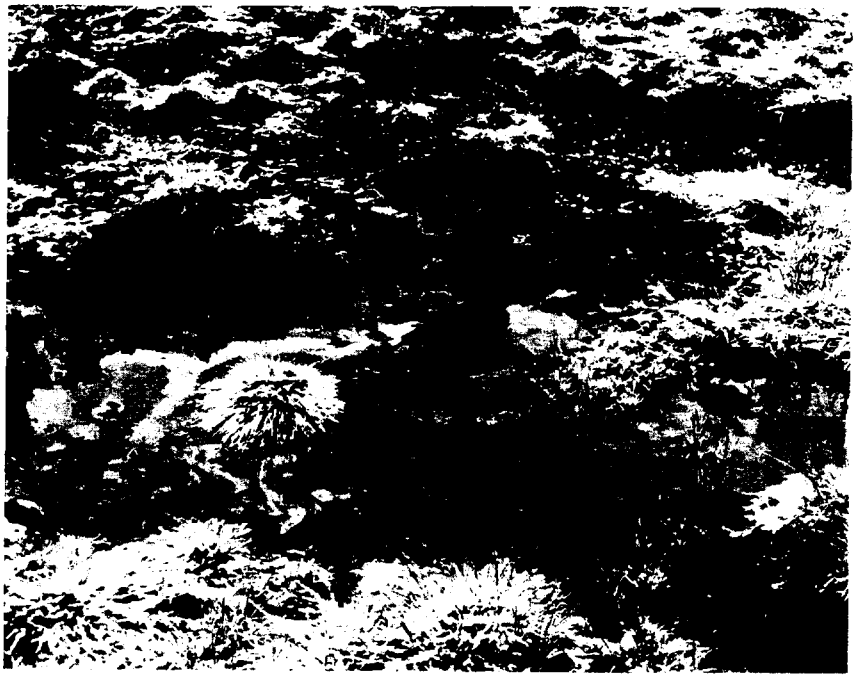
UPPER CRETACEOUS—COLVILLE GROUP

The rocks penetrated by Sentinel Hill core test 1 are interbeds of the nonmarine Kogosukruk tongue of the Prince Creek formation and of the marine Sentinel Hill member of the Schrader Bluff formation. (See pl. 31.) The tongue and the member are the age equivalents of the uppermost part of the Colville group of Late Cretaceous age. The type sections of the Schrader Bluff



SENTINEL HILL CORE TEST 1

Note the high bluffs to the rear. February 17, 1947.



A. OIL SEEP NEAR FISH CREEK TEST WELL 1

Dark oil-impregnated sand rims the depression, which is partly filled with water on which black viscous oil is floating. Snow-covered clumps of grass and moss surround the seep. September 17, 1947.

B. SECTION OF CORE FROM FISH CREEK TEST WELL 1

Distorted bedding in a core from 6,431 feet.

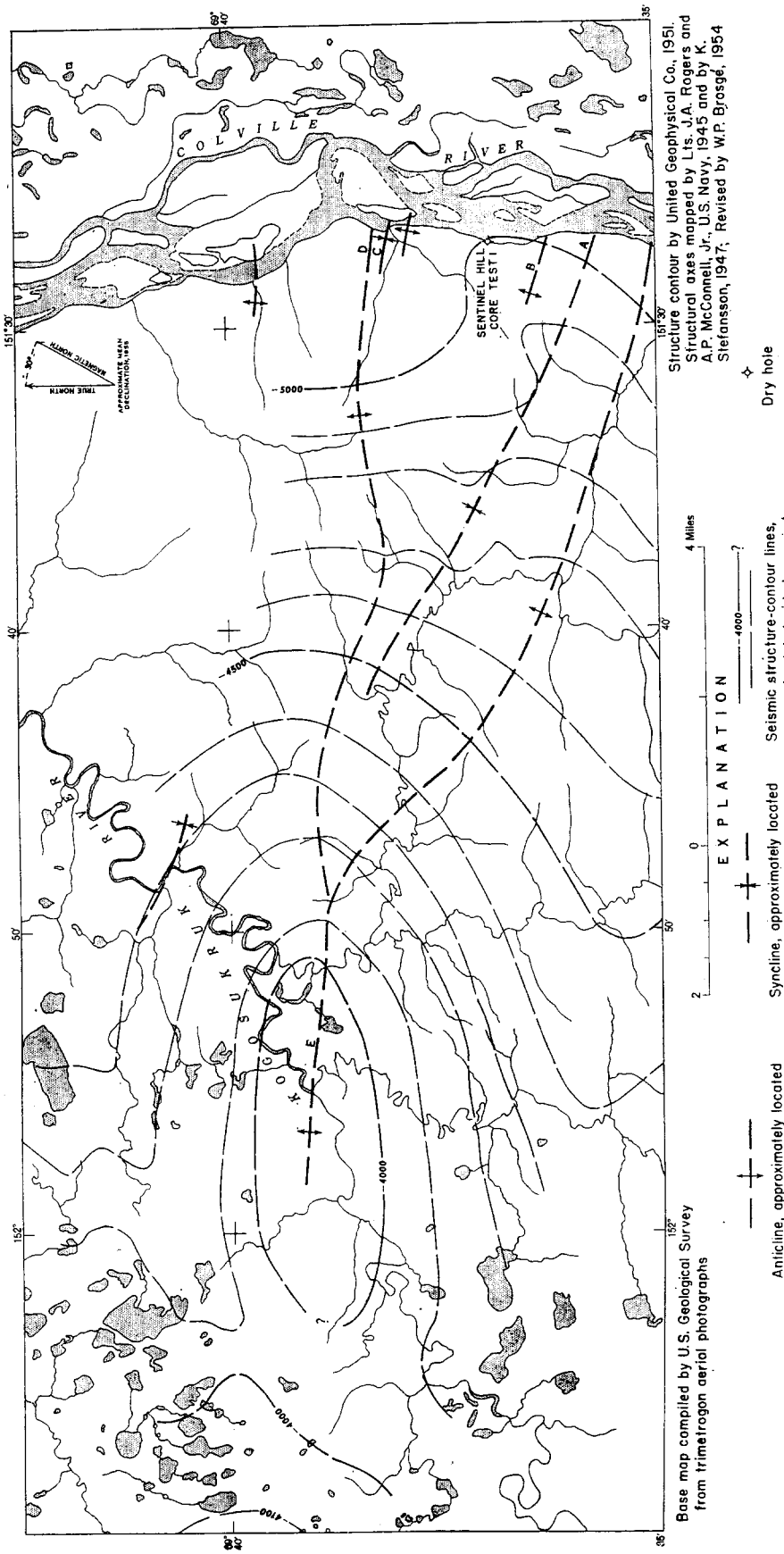


FIGURE 40.—Map showing location of Sentinel Hill core test 1 and structure-contour lines, in the surrounding area, drawn on phantom seismic horizon "A," equivalent to sandstones in the Cretaceous, Nanushuk group. Letters A through D indicate the flexures originally recognized by the Navy geologic field party in 1945.

and Prince Creek formations were described by Gryc, Patton, and Payne (1951). Originally, Sentinel Hill core test 1 was designated as the type section of the Sentinel Hill member, but C. L. Whittington (1956) redefined the member and described a new type locality on the Colville River about 10 miles south of the core test.

The thicknesses of these formations in Sentinel Hill core test 1 are indicated in figure 41. The

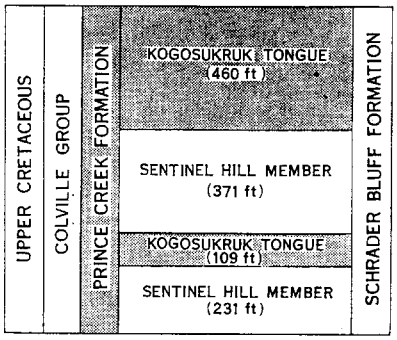


FIGURE 41.—Columnar section, Sentinel Hill core test 1.

interfingering of the beds is more complex than this simple chart indicates. However, the Kogosukruk tongue as described below is predominantly nonmarine and the Sentinel Hill member is predominantly marine. The formations are differentiated largely on a correlation by William P. Brosgé (written communication) with the outcrop and on the presence of macrofossils and microfossils as indicators of marine beds. Coal is an important factor in recognizing the nonmarine sections.

PRINCE CREEK FORMATION, KOGOSUKRUK TONGUE

The beds of the Kogosukruk tongue from 9 to 469 feet and from 840 to 949 feet make up approximately one-half of the total sequence drilled in the core test. The Kogosukruk tongue is mostly clay shale or claystone which ranges from light-gray and light-olive-gray to dark-gray. Claystone, medium-hard and with irregular fracture, is more common than the slightly softer bentonitic and carbonaceous clay shale which breaks easily parallel to the bedding. Some of the claystone is silty and some is moderately to very calcareous. In places the claystone grades to brownish clay ironstone.

Only about 25 percent of the Kogosukruk tongue as found in this test is sandstone and siltstone. The sandstone is light gray and ranges from medium soft with an argillaceous matrix to hard with a calcareous matrix. The grain size ranges from fine to medium, and the grains are composed of about 50 percent of clear quartz, with some white quartz. The remainder of the grains are rock fragments, white mica, black carbonaceous particles, volcanic glass shards, and chert. They are cemented by argillaceous, bentonitic, or in places calcareous or sideritic material. A more detailed description of one sandstone sample from 345 feet by P. D. Krynine may be found on p. 498. At 882 feet the sandstone contains a layer of rounded gray and black chert granules and pebbles as large as one-half an inch in diameter.

The siltstone is similar to the sandstone. At some depths it is soft and has good shaly cleavage, and at others it is massive, hard, and calcareous. Both the siltstone and the sandstone contain plant fragments. The average effective porosity of the sandstone is 24 percent, and ranges from 9.2 to 31.1 percent; the air permeability ranges from 5.2 to 348 millidarcys. There were no shows of oil or gas in these sandstones or siltstones.

One 10-inch bed of limestone is present at 176 feet, and this is pale to dark yellowish brown, very hard, and dense, and has conchoidal fracture, and it may be very sideritic. Clay ironstone lenses and nodules are fairly common, particularly in the upper part of the tongue.

Ten percent of the formation is lignite, coal, or black carbonaceous shale. The lignite is rather soft, dull, and brownish and grayish black, and the coal is medium hard, dull to shiny, black, and brittle and has blocky fracture. Plant fragments and carbonaceous particles are present throughout the tongue.

Bentonite is finely disseminated in the clays and matrix of the siltstone and sandstone as well as in individual beds that are up to 2 feet thick. It is white, very light gray, light yellowish, and gray or brownish gray, and is hard when dry, fractures irregularly, and contains rare biotite plates, glass shards, or carbonaceous particles. The bentonite and the clay shale and sandstone containing it swell into an unctuous mass when moistened with water.

The diversified nature of the Kogosukruk tongue of the Prince Creek formation is characterized by thin beds with much variation from one type of rock to another, the abundance of coal and carbonaceous plant material, and the absence of marine fossils.

SCHRADER BLUFF FORMATION, SENTINEL HILL MEMBER

In this core test the Sentinel Hill member of the Schrader Bluff formation is found between 469 and 840 feet and from 949 to 1,180 feet, total depth. Unlike the Kogosukruk tongue of the Prince Creek formation, it is just slightly more than half clay shale and claystone.

In this member, clay shale is a little more common than claystone. This argillaceous rock is medium light

gray—or rarely light olive gray where sideritic or dark gray where carbonaceous. In general it is medium hard and has fair to good cleavage along bedding planes. Most of it is noncalcareous, but it is very calcareous or sideritic in a few places.

Sandstone and siltstone make up about 45 percent of the Sentinel Hill member drilled here. These clastic units together are massive, as much as 100 feet thick, and are light gray or very light gray. Except where calcareous and hard, the sandstone and siltstone are rather soft and friable. The grain size ranges from silt to medium sand. The grains, which are angular to subangular, are composed of 70–85 percent of white and clear quartz with carbonaceous particles, muscovite and biotite, rock fragments, sideritic particles, and pyrite in an argillaceous or bentonitic matrix.

The composition of the grains in the siltstone is the same as in the sandstone, but the siltstone tends to be a little harder and more calcareous than the sandstone in the upper part of the member. The siltstone near 1,060 feet is light colored and has a very bentonitic matrix.

The effective porosity of 28 sandstone samples tested ranges from 15.2 to 29 percent (see table on p. 498) and averages 22.6 percent. The air permeability in the same samples ranges from less than 10 to 290 millidarcys. The porosity and the permeability in the upper part of the formation are consistently higher than in the lower. These rocks would probably make poor reservoirs, however, because they contain so many clay minerals that the potential hydration is high.

Coal is not common in the Sentinel Hill member although beds of carbonaceous clay shale as much as 5 feet thick are found. Carbonaceous plant remains are found in both the clay shale and the sandstone but are particularly uncommon in the lowest part of the member.

Bentonite is about as abundant as in the Kogosukruk tongue. It is found in beds ranging in thickness from 1 inch to 5 feet; it is white, very light gray, or greenish gray and is rather hard, has subconchoidal fracture, and contains tiny biotite plates.

Plant fragments in the core from 822–826 feet are, according to Roland W. Brown, chiefly dicotyledons but not further identifiable. George Gryc identified *Mytilus* sp., a marine pelecypod, in a sample at 603 feet. One gastropod, the fresh-water genus *Lymnaea*? sp., at 524½ feet was identified by C. Wythe Cook. At several depths in the Sentinel Hill member there are numerous nacreous pelecypod shells which are too fragmentary to identify. The formation is primarily marine, however, as indicated by the presence of a marine microfauna typical of the Colville group of Late Cretaceous age. *Eoeponidella strombodes* Tappan is characteristic of the Sentinel Hill member (Tappan, 1951, p. 6).

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DESCRIPTION OF CORES AND CUTTINGS

The core recovery from Sentinel Hill core test was very good. The cores were originally described by William N. Lockwood, of the U. S. Geological Survey, in 1947 and were redescribed by the author in 1954 to conform in style with the other descriptions in this professional paper series. All samples were described dry; colors were determined with the aid of the National Research Council Rock Color Chart (Goddard and others, 1948). The term "trace" as used here is defined as less than 3 percent and usually represents less than 1 percent. Clay ironstone is a sideritic, dense, and rather hard mudstone that effervesces generally very slowly in cold dilute hydrochloric acid.

The latitude and longitude of the core test are based on preliminary topographic surveys and are subject to correction. All depths were measured from the kelly bushing. The height of the kelly bushing above sea level is estimated.

Lithologic description

[Where no core number is listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
-----	0– 9	Kelly bushing to ground level.
-----	9– 19	Clay shale, dark-gray, carbonaceous; trace medium-light-gray clay shale; trace coal.
-----	19– 29	Clay shale, 90 percent medium-dark-gray, 10 percent medium-light-gray; trace coal.
-----	29– 39	Clay shale, 80 percent medium-dark-gray, 20 percent medium-light-gray.
-----	39– 49	Clay shale, 90 percent medium-gray- to medium-dark-gray; 10 percent white bentonite.
-----	49– 59	Clay shale, 60 percent, medium-gray to medium-dark-gray; 40 percent pale-yellowish-brown slightly calcareous clay ironstone.
-----	59– 69	Clay shale, 50 percent medium-dark-gray, 20 percent medium-gray; 30 percent pale-yellowish-brown clay ironstone.
-----	69– 79	Clay shale, 80 percent medium-dark-gray, 10 percent medium-gray; 10 percent yellowish-brown clay ironstone.
-----	79– 89	Clay shale, 90 percent medium-light-gray, 10 percent dark-gray; trace clay ironstone.
-----	89– 99	Clay shale, 80 percent medium-gray and medium-dark-gray; 20 percent pale-yellowish-brown clay ironstone.
-----	99–109	Clay shale, 50 percent medium-dark-gray, 20 percent medium-gray; 30 percent clay ironstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
1	109–119	Recovered 8 ft. 2 ft 4 in., clay shale, medium-light-gray, medium-hard, noncalcareous, slightly micaceous; fair cleavage; very rare carbonaceous fragments; beds lie flat. 10 in., clay shale, medium-dark-gray; contains numerous very thin laminae (one-sixteenth inch) of brittle coal. 4 in., coal, black, dull to shiny; vertical fracture planes coated with brownish layer. 4 ft, claystone, medium-light-gray, slightly silty, noncalcareous, medium-hard; irregular fracture; rare carbonaceous fragments; contains light-gray bentonitic layers in top foot. 6 in., clay shale, carbonaceous; low-grade coal.
2	119–129	Recovered 10 ft. 1 ft 5 in., clay shale, light-gray, very soft, bentonitic; a few chips of coal. 2 in., clay shale, very carbonaceous; medium-hard brittle low-grade coal. 3 ft, claystone and clay shale, light-gray, slightly silty, noncalcareous; abundant medium-dark-gray carbonaceous partings; bedding irregular but beds lie approximately flat. 1 ft, clay shale, medium-dark-gray, carbonaceous; 1-in. coal bed. 2 ft 5 in., claystone and clay shale, light-gray, bentonitic, medium-soft; carbonaceous plant fragments. 2 ft, siltstone, light-gray, very argillaceous and micaceous, bentonitic, medium-hard; carbonaceous plant fragments present.
3	129–139	Recovered 8 ft. 7 in., clay shale, medium-light-gray, very soft; streaks of coal broken by drill. 3 ft 5 in., interbedded clay shale and siltstone, light- to medium-light-gray, medium-hard, noncalcareous, bentonitic, thin-bedded; fair cleavage; scattered carbonaceous plant fragments. 4 ft, clay shale, medium-gray, medium-hard; fair cleavage; a few silty partings and laminae; some crossbedding.
4	139–149	Recovered 6 ft. 1 ft 8 in., clay shale, soft; broken by drill. 1 ft 8 in., clay shale, light-gray, noncalcareous, bentonitic, medium-hard; fair cleavage. 5 in., low-grade coal, black, dull, brittle; blocky fracture.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		2 ft 3 in., clay shale as above in this core, quite silty, noncalcareous, bentonitic; grades in places to siltstone.
5	149–159	Recovered 10 ft. 4 ft 9 in., sandstone, light-gray, very fine-grained, medium-soft; grains subangular; 50 percent clear with a little white quartz; 40 percent white mica; remainder is mostly carbonaceous flecks and light-brown rock particles; argillaceous-bentonitic matrix. Contains about a foot of hard yellowish-gray very calcareous sandstone in middle. Calcareous rock contains numerous dark-brown and black plant fragments; no oil or gas shows. 5 ft 3 in., siltstone, light-gray, noncalcareous, very argillaceous, medium-hard; fair cleavage; grades in streaks to medium-light-gray clay shale; beds lie flat.
6	159–169	Recovered 10 ft. Siltstone as above; upper 5 ft of recovery moderately to very calcareous; lower half essentially noncalcareous.
7	169–179	Recovered 8 ft. 6 ft 7 in., siltstone, light-gray to light-olive-gray micaceous, very argillaceous; medium-soft to medium-hard; sandy partings; has brownish blotches (sideritic material ?). 10 in., limestone (and some clay ironstone), pale- to dark-yellowish brown, very hard, dense; conchoidal fracture. 7 in., siltstone as above; good cleavage.
8	179–189	Recovered 10 ft. Clay shale, light-gray, light-olive-gray, and yellowish-brown, very calcareous, medium-hard; good to excellent cleavage parallels bedding; numerous silty and sandy laminae; carbonaceous partings; dip 4°.
9	189–199	Recovered 7 ft. 4 ft 8 in., Interbedded light-gray siltstone 60 percent; sandstone 20 percent; and grayish-yellow clay shale 20 percent, medium soft, very calcareous. Sandstone is very fine to fine grained, contains clear quartz, a large amount of yellow calcite grains, carbonaceous particles, mica, and argillaceous material. Numerous dark-gray carbonaceous partings. Dip 4°. 2 ft 4 in., Sandstone, light-gray, hard; composition as above; very calcareous matrix; very "dirty."

Lithologic description—Continued

Core	Depth (feet)	Remarks
10	199–209	Recovered 8 ft. 2 ft 5 in., claystone, medium-light- to light-olive-gray, medium-hard grades down into unit below. 10 in., clay ironstone, pale-yellowish-brown, very hard, dense; effervesces slightly with dilute HCl. 4 ft 9 in., clay shale and claystone, medium-light-gray, medium-soft; bentonitic in upper foot; poor to fair cleavage; hard clay ironstone nodule 3 in. thick in middle of interval. Just below this is 4 in. of medium-dark-gray carbonaceous shale. Whole interval is noncalcareous.
11	209–219	Recovered 10 ft. 2 ft 5 in., bentonite, very light-gray, argillaceous, soft but brittle. 8 in., carbonaceous clay shale, medium-dark-gray; contains very thin layers of low-grade coal. 6 ft. 11 in., clay shale and claystone, medium-light-gray, medium-hard; poor to good cleavage; rare silty and carbonaceous streaks; noncalcareous; dip 3°.
12	219–229	Recovered 9 ft. 6 in., bentonite, white to very light-gray; hard when dry; conchoidal fracture. 5 in., lignite, grayish-black, hard, brittle, bedded; dip 2°. 6 ft 4 in., claystone, light- to medium-light-gray; slightly to moderately calcareous, medium-hard; irregular fracture; slightly silty in places; contains vary rare coaly fragments. 1 ft 9 in., clay shale, medium-dark-gray, carbonaceous; contains layers up to an inch thick of lignite and dull black coal having a blocky fracture.
13	229–239	Recovered 10 ft. 1 ft 7 in., clay shale as immediately above; carbonaceous but with no coal or lignite. 1 ft, claystone, very light-gray, very bentonitic, medium-soft; contains scattered black carbonaceous particles; grades into unit below. 4 ft 8 in., siltstone, light-gray, very micaceous, noncalcareous, slightly bentonitic, medium-hard; grades into unit below. 2 ft 9 in., sandstone, light-gray, very fine-grained, noncalcareous, medium-soft; grains angular to subangular; 75 percent white and clear quartz; remainder is mostly white mica and carbonaceous particles; argillaceous matrix.
14	239–249	Recovered 8 ft. 4 ft 6 in., sandstone as above, silty, noncalcareous, soft and friable; irregular fracture. 2 ft, clay shale and claystone, medium-olive-gray, medium-soft; fair to poor cleavage; contains brownish plant material and streaks of grayish black lignite; noncalcareous to moderately calcareous toward bottom. 1 ft 6 in., clay shale and claystone, light-olive-gray, moderately calcareous; lacks plant material; irregular fracture; dip 2°.
15	249–259	Recovered 10 ft. Claystone, light-olive and yellowish-gray to light-gray, medium-hard; irregular fracture; rare carbonaceous particles; about 4 in. of dark gray brittle lignitic clay at 243 ft. Calcareous in yellowish upper 3 ft; noncalcareous in lower part.
16	259–269	Recovered 10 ft. 3 ft 2 in., claystone, medium-light-gray, noncalcareous, medium-hard; irregular fracture; rare silty laminae. 1 ft 4 in., carbonaceous clay shale and lignite, medium-dark to dark-gray, medium-hard; rare shiny coal stringers, ½-in. layer of very light-gray bentonite in middle. Beds lie flat. 3 ft 6 in., claystone as in first part of core; very uniform of texture and color. 4 in., lignite and carbonaceous shale, grayish-black. 1 ft 8 in., claystone as above but contains 4 in. of soft friable noncalcareous fine-grained light-gray sandstone, coaly plant remains and carbonaceous partings.
17	269–279	Recovered 10 ft. Claystone, medium-light- to medium-gray, noncalcareous medium-hard; following are variations: At 272½ ft is 6 in. of dark-gray lignitic brittle clay shale, bentonitic at upper end; at 276 ft is about a foot of light-gray soft bentonitic streaks; at 277 ft is 2 in. of carbonaceous clay shale.
18	279–289	Recovered 7 ft 6 in. 3 ft, claystone as above, 4 in. of dull-black lignite at 280 ft. 4 ft 6 in., siltstone, light-gray, very argillaceous, finely micaceous, noncalcareous, slightly bentonitic, medium-soft to soft and friable; grades into claystone toward base. One-inch layer of carbonaceous shale 3 in. from base.

Lithologic description—Continued

Core	Depth (feet)	Remarks
19	289–299	Recovered 10 ft. 7 ft, claystone, light-gray, very silty, noncalcareous, medium-hard; grades to siltstone in places, dip 1°. 2 ft 6 in., lignite and carbonaceous clay shale, dark-gray to grayish-black, medium-soft, brittle. 6 in., claystone, light-olive-gray, slightly calcareous or sideritic, hard.
20	299–309	Recovered 10 ft. Interbedded clay shale (or claystone) and siltstone with all gradations, light, to medium-light-gray, medium-soft; rare thin streaks of calcareous (sideritic?) brownish clay shale; rare very fine-grained sandstone laminae; 4 in. of hard calcareous sandstone at 302½ ft.
21	309–319	Recovered 9 ft. 2 ft 10 in., claystone and clay shale, light-brownish-gray, noncalcareous, medium-soft; contains much macerated plant material. 8 in., carbonaceous shale and lignite, dark-brownish- to dark-gray. 5 ft 6 in., interbedded claystone and siltstone, noncalcareous; medium-soft, about equal proportions as in core above; rare black carbonaceous particles.
22	319–329	Recovered 8 ft 6 in. 2 ft, claystone, light- to medium-light-gray, noncalcareous, medium-soft. 1 ft 2 in., clay shale, medium-dark-gray, carbonaceous; streaks of lignite and coal. 2 ft 8 in., clay shale, medium-light-gray, bentonitic, soft; conchoidal fracture. 2 ft 8 in., clay shale, medium-light-gray, noncalcareous, medium-soft; rare carbonaceous plant fragments.
23	329–339	Recovered 10 ft. 2 ft 4 in., interbedded claystone and siltstone, light- to medium-light-gray; grades into unit below. 7 ft 8 in., sandstone, light-gray, very fine- to fine-grained noncalcareous, medium-soft; irregular fracture; grains angular to subangular and made up of clear quartz with some white quartz, also chert, white mica, black carbonaceous particles, volcanic glass shards, rock fragments, and rare minerals; essentially noncalcareous; matrix is bentonitic and argillaceous; no oil or gas shows.

Lithologic description—Continued

Core	Depth (feet)	Remarks
24	339–349	Recovered 10 ft. Sandstone,[1] as above, friable, fine- to medium-grained; rare calcareous grains; bentonitic matrix; rare black carbonaceous coaly plant fragments; no shows.
25	349–359	Recovered 10 ft. Sandstone, as immediately above.
26	359–369	Recovered 10 ft. 5 ft, sandstone, as above. 1 ft 2 in., clay shale, medium-dark-gray, carbonaceous; a few thin laminae of lignite. 4 in., clay ironstone, dark-yellowish-orange; effervesces slightly with dilute HCl; contains dark-brown plant fragments. 1 ft 4 in., claystone, light-gray, bentonitic. 6 in., clay shale, and lignite as above. 6 in., clay shale, light-gray, bentonitic. 1 ft 2 in., claystone, medium-light-gray, slightly silty, noncalcareous, hard; dip 3°.
27	369–379	Recovered 9 ft. 4 ft 6 in., claystone, as immediately above. 11 in., clay shale, medium-dark-gray, carbonaceous. 7 in., bentonite, white, hard; irregular fracture; contains volcanic glass shards, rare biotite plates. 3 ft, clay shale, medium-light- to medium-dark-gray; varying amounts of carbonaceous material; some lignite; 2 in. of brittle dull black coal at 377 ft, also thin streaks of bentonite.
28	379–389	Recovered 9 ft. Claystone and clay shale, light- to medium-dark-gray; some spots have yellowish cast. Four inches of dark-gray-lignite and carbonaceous shale at 382 ft. Lowest third quite carbonaceous, with a few very thin laminae of lignite. One inch of very light-gray bentonitic shale at 381 and 385 ft. Noncalcareous to slightly calcareous.
29	389–399	Recovered 10 ft. Claystone, medium-hard; about half is light olive gray and is slightly to moderately calcareous; other half is medium gray and noncalcareous but is carbonaceous with a little lignite at 393 and 398 ft. Irregular fracture. Light gray bentonite layer at 392½ ft.

[1]For a detailed description of a sample from 345 ft by P. D. Krynine see p. 498

Lithologic description—Continued

Core	Depth (feet)	Remarks
30	399–409	Recovered 10 ft. Claystone, light- to medium-light-gray; silty beds; light-colored bentonitic laminae at 406 and 408 ft. Carbonaceous laminae and 1 in. of lignite at 404 and 407 ft. 1 in. Slightly to moderately calcareous in silty streaks; noncalcareous elsewhere.
31	409–419	Recovered 8 ft. 1 ft, claystone as above. 6 ft, claystone, light-olive-gray to moderate-yellowish-brown, silty, moderately to very calcareous, hard; irregular fracture; carbonaceous partings. 1 ft, claystone as in core 30, slightly carbonaceous.
32	419–429	Recovered 10 ft. 4 ft 6 in., claystone, light-olive-gray, moderately calcareous, medium-hard; irregular fracture; contains numerous black carbonaceous plant fragments and particles. 5 ft 6 in., claystone, light-gray; as above but with fewer plant fragments and noncalcareous.
33	429–439	Recovered 10 ft. Claystone, mostly of type in upper interval of above core, and about 20 percent medium-light-gray clay shale, one-half inch of carbonaceous shale at 434 ft; slightly to moderately calcareous; quite silty toward base.
34	439–449	Recovered 9 ft. 1 ft 10 in., sandstone, light-gray, fine-grained, soft and friable, very "dirty"; about 50 percent micaceous material, 40 percent quartz; remainder is carbonaceous material and yellowish calcareous grains, argillaceous and slightly bentonitic matrix, grains angular to subangular. 1 ft 1 in., claystone, light-olive-gray, moderately calcareous, medium-hard. 4 in., lignite, grayish-black; dip 4°. 5 ft 9 in., claystone, light-olive-gray, moderately calcareous, medium-hard.
35	449–459	Recovered 10 ft. 5 ft, siltstone, light-olive-gray, moderately calcareous, medium-hard, massive; sandy near base. 3 ft 9 in., sandstone, light-olive-gray, medium-grained, hard, massive; angular to subangular grains made up of 70 percent white and clear quartz, 10 percent calcite, 10 percent mica; remainder carbonaceous particles and other minerals. Lower 1½ ft is very hard, yellowish gray, and very calcareous. 1 ft, claystone, medium-gray, hard. 3 in., carbonaceous clay shale and lignite, dark-gray.
36	459–469	Recovered 7 ft 6 in. 1 ft 4 in., clay shale, medium-dark-gray, carbonaceous, and low-grade, dull to shiny black coal. 1 ft, clay shale, light-gray, bentonitic, soft. 5 ft 2 in., claystone, medium-gray, slightly silty, noncalcareous, medium-hard contains carbonaceous partings.
37	469–479	Recovered 8 ft. 4 ft 6 in., sandstone, medium-light-gray, very fine-grained, silty, noncalcareous soft and friable; contains numerous carbonaceous partings and particles; dip 4°, no gas or oil shows. 3 ft 6 in., claystone, medium-gray and light-olive-gray; 3 in. of very light-gray bentonite in middle and 3 in. at bottom.
38	479–489	Recovered 10 ft: Microfossils present. 8 ft 6 in., interbedded siltstone and clay shale, light-olive-gray, moderately calcareous, medium hard; poor cleavage; contains numerous carbonaceous plant fragments. 1 ft 6 in., clay shale, medium-light-gray, noncalcareous; fair cleavage, subconchoidal fracture; shell fragments.
39	489–499	Recovered 9 ft. 4 in., clay shale as above. 7 in., clay shale, medium-dark-gray, carbonaceous; 1 in. shiny black coal. 6 ft 9 in., claystone, light-olive-gray, silty, medium-hard, noncalcareous to moderately calcareous; bentonitic in top few inches. 1 ft 4 in., clay shale, medium-light- to medium-dark-gray, carbonaceous; fair cleavage; 1 in. of grayish-black lignite
40	499–509	Recovered 10 ft. Interbedded clay shale (and claystone) 60 percent and siltstone 40 percent, light- to medium-light-gray, medium-hard; fair to poor cleavage; rare thin laminae of very fine sandstone, also rare laminae (up to one-half inch thick) of moderate yellowish-brown clay ironstone; noncalcareous in clay shale to moderately calcareous in siltstone; dip 3°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
41	509–519	Recovered 8 ft: Microfossils present. 1 ft, claystone as above, with clay ironstone laminae. 5 ft 8 in., clay shale, medium-light- to medium-gray, noncalcareous medium-hard; fair cleavage; bentonitic and crumbly in places. 1 ft 4 in., clay shale, medium-gray to medium-dark-gray, carbonaceous; plant remains.
42	519–529	Recovered 10 ft. 2 ft, claystone, light-olive-gray, moderately calcareous; grades into unit below. 8 ft, siltstone, light-olive-gray, very argillaceous moderately calcareous, medium-soft. A gastropod, *Lymnaea*? sp., found at 524½ ft.
43	529–539	Recovered 9 ft. 1 ft, claystone (and clay ironstone (?)), light-olive-gray, very calcareous, hard. 8 ft, interbedded clay shale and claystone 70 percent, and siltstone 30 percent, light- to medium-light-gray, some with olive cast; hardness variable; siltstone generally softer than clay shale; fair to poor cleavage; 3 in. of medium-grained sandstone streaked with very thin coal beds at 534 ft. Sandstone also contains very small white gastropod and pelecypod fragments; scattered plant fragments in claystone. Siltstone moderately calcareous. Claystone noncalcareous.
44	539–549	Recovered 9 ft: Microfossils present. 3 ft, clay shale, medium-light-gray, slightly to moderately calcareous, medium-hard; fair cleavage; contains carbonaceous plant impressions and ostracodes. 5 ft, sandstone, light-gray, medium-soft and friable; lowest 1 ft very hard, fine to medium grained; grains angular to subangular and made up of about 60 percent white and clear quartz, 20 percent yellowish calcareous grains, 10 percent black carbonaceous particles, and remainder is white mica, other minerals, and rock fragments; argillaceous matrix except for lowest 1 ft which is very calcareous; no oil or gas shows. 1 ft, clay shale, light-gray, as in upper part of this core.
45	549–559	Recovered 10 ft. Claystone and clay shale, light-gray, slightly calcareous; very rare silty laminae.

Lithologic description—Continued

Core	Depth (feet)	Remarks
46	559–569	Recovered 10 ft: Microfossils present. Clay shale, light- to medium-light-gray, slightly to noncalcareous; some parts have olive cast; small white mollusk fragment at 559 ft; dip 0°–3°.
47	569–579	Recovered 10 ft: Microfossils present. Clay shale, as above; noncalcareous; fair to good cleavage; very rare pyrite nodules with brownish halo; 1 white pelecypod fragment at 569½ ft; brownish hard clay ironstone nodule at 576½ ft; 1 in. of white bentonite at bottom.
48	579–589	Recovered 9 ft: Microfossils present. Clay shale and claystone, light- to medium-light-gray, medium-soft; fair cleavage; 1 in. of light-olive-gray clay ironstone at top; noncalcareous except for ironstone and some silty streaks; bentonitic. White pelecypod shell fragment at 584 ft; carbonaceous partings and some silty beds in middle; beds lie essentially flat.
49	589–599	Recovered 8 ft: Microfossils present. 4 ft 7 in., clay shale and claystone, light- to medium-light-gray; olive cast in part; fair to poor cleavage; becomes silty toward base; dip 2°. 1 ft 6 in., interbedded sandstone and siltstone, light-gray, moderately calcareous, medium-soft; sandstone is fine to medium grained; numerous thin clay laminae. 1 ft 11 in., clay shale as in first part of core; bentonitic at top.
50	599–609	Recovered 10 ft: Microfossils present. 5 ft 6 in., clay shale, medium-light-gray, medium-hard; poor to excellent cleavage; silty in upper foot; contains rare tiny black plant fragments, small pyrite nodules with brownish halo, numerous white pelecypod remains, *Mytilus* sp.; 1 in. of white bentonite at about 608 ft; dip 1½°. 4 ft 6 in., bentonite, white and very light-gray, rather hard, interbedded with some light-gray clay shale; breaks parallel bedding; subconchoidal fracture; contains little biotite particles, carbonaceous partings.
51	609–619	Recovered 8 ft: Microfossils present. 11 in., bentonite, light-gray, interbedded with clay shale as above. 7 ft 1 in., clay shale, medium-light to medium-gray, noncalcareous, medium-hard; poor to excellent cleavage; 5 in. of lignite or low-grade grayish-black coal; blocky fracture at about 614 ft; becomes siltier toward base.

Lithologic description—Continued

Core	Depth (feet)	Remarks
52	619–629	Recovered 10 ft. 1 ft, bentonite (?), core infiltrated by drilling mud. 9 ft, sandstone, light-gray, fine- to medium-grained, noncalcareous or very slightly calcareous, rather soft and friable; grains angular to subangular, 85 percent white and clear quartz; remainder is carbonaceous particles, various micas, rock fragments, yellowish clayey particles, argillaceous matrix; porous; carbonaceous laminae and partings; no oil or gas shows.
53	629–639	Recovered 10 ft. Sandstone, as above, medium-grained, noncalcareous or very slightly calcareous; no shows.
54	639–649	Recovered 10 ft. Sandstone as above, medium-grained; no shows.
55	649–659	Recovered 10 ft. Sandstone as above; medium grained at top grading to very fine at bottom. A little harder (medium soft) than cores above; no shows.
56	659–669	Recovered 10 ft. Sandstone as above, very fine- to fine-grained, noncalcareous; bentonite in matrix, no shows.
57	669–679	Recovered 9 ft. Sandstone, as above, fine-grained, massive; carbonaceous partings absent except for one 5-in. interval with abundant partings at 674 ft; very calcareous and hard in the lower 4 ft; no shows.
58	679–689	Recovered 10 ft. Sandstone as above, fine- to medium-grained, calcareous and hard in first 9 in.; grades into siltstone in bottom 3 in.; 1 brownish sideritic lens at 683 ft; no shows.
59	689–699	Recovered 10 ft. Siltstone, light-gray, very argillaceous, noncalcareous, medium-soft; fair cleavage; interbedded clay laminae; irregular bedding.
60	699–709	Recovered 10 ft: Microfossils present. 3 ft, clay shale, medium-light-gray, silty, noncalcareous; poor cleavage. 7 ft, siltstone, light-gray, very argillaceous, noncalcareous, medium-hard.
61	709–719	Recovered 10 ft: Microfossils present. Siltstone, as above; hard rare medium-light-gray clay shale interbeds; also scattered thin very fine-grained sandstone beds; noncalcareous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
62	719–729	Recovered 7 ft 6 in.: Microfossils present. Siltstone, light-gray, very argillaceous, noncalcareous, medium-soft to medium-hard; contains numerous white pelecypod shell fragments.
63	729–739	Recovered 10 ft: Microfossils present. Interbedded siltstone and clay shale; about equal proprtions of each, light- to medium-light-gray, noncalcareous; bentonite streaks at 736 and 737 feet.
64	739–749	Recovered 9 ft 6 in.: Microfossils present. Interbedded siltstone 70 percent, claystone 20 percent, and very fine-grained sandstone 10 percent, light- to medium-light-gray, noncalcareous; white pelecypod remains at 741 ft and 746 ft.
65	749–759	Recovered 4 ft 6 in. 1 ft 8 in., siltstone, light-gray, hard, massive; streaks of very fine-grained sandstone. 2 ft 10 in., clay shale and claystone, medium-light-gray, hard; poor to fair cleavage; pyrite nodules with brownish halos; scattered pyritized plant remains; trace of siderite in two places in shale; noncalcareous; beds essentially lie flat.
66	759–769	Recovered 10 ft: Microfossils present. 5 ft, sandstone, light-gray, very fine- to fine-grained, medium-soft and slightly friable; grains are subangular to angular quartz, mica, carbonaceous particles, rare calcite grains, and rock fragments in white bentonitic matrix. Sandstone has numerous intercalations of clay, numerous carbonaceous partings; becomes silty toward base; rare pelecypod remains; no oil and gas shows. 5 ft, clay shale, medium-light-gray, medium-hard; fair cleavage; silty in upper foot; 4 in. of very light-gray bentonite at 764 ft, and 2 in. at 764½ ft; 2-in. light-olive-gray ironstone nodule at 768 ft; pyrite nodules and pyritic plant remains.
67	769–779	Recovered 8 ft. 6 in., clay shale, medium-dark-gray, carbonaceous. 7 ft, interbedded siltstone 60 percent, and claystone, light- and medium-light-gray, hard; slightly sandy streaks, siltstone is slightly calcareous. 6 in., bentonite, very light-gray.

Lithologic description—Continued

Core	Depth (feet)	Remarks
68	779–789	Recovered 10 ft. 9 ft, clay shale, medium-light- to medium-dark-gray, partly carbonaceous and bentonitic, medium-soft; abundant black carbonaceous and pyritic plant impressions; very rare white pelecypod remains; pyrite nodules with alteration halos. 1 ft, siltstone, light-gray, sandy; carbonaceous partings; very bentonitic matrix.
69	789–799	Recovered 10 ft: Microfossils present. 5 ft, siltstone and sandstone, light-gray, medium-soft; sandstone very fine-grained; numerous tiny pelecypod shells; bentonitic matrix; scattered black carbonaceous laminae; thin interbeds of clay shale; noncalcareous. 5 ft, carbonaceous clay shale, medium-gray to medium-dark-gray, medium-hard; black plant remains; 3 in. of very light-gray bentonite at 795 ft; very thin almost varvelike bentonite laminae in lowest foot; noncalcareous; beds lie approximately flat.
70	799–809	Recovered 10 ft: Microfossils present. 5 ft, clay shale, medium-dark- to dark-gray, carbonaceous, medium-hard; good cleavage; 1 in. of greenish-gray bentonite at 801½ ft; 2 in. of light-gray bentonite at 803 ft. 1 ft 6 in., clay shale, medium-gray; carbonaceous plant fragments. 3 ft 6 in., siltstone, medium-light-gray, irregularly bedded; clay intercalations; rare bands of coaly plant material.
71	809–819	Recovered 10 ft. 4 ft, interbedded clay shale 70 percent, and sandy siltstone 30 percent, light- to medium-light-gray, medium-soft; gradations of color, carbonaceous partings; siltstone is bentonitic. 6 ft, clay shale, medium-light-gray, medium-hard; fair cleavage; scattered black plant fragments; rare small pelecypod remains; 3-in. of very light-gray bentonite at base.
72	819–829	Recovered 10 ft: Microfossils abundant. Clay shale, medium-light- to medium-dark-gray; fair cleavage; carbonaceous shale at 822–825 ft; streaks of light-gray bentonite at 823 ft and 828 ft; abundant black plant impressions; beds lie approximately flat.
73	829–839	Recovered 10 ft: Microfossils abundant. Clay shale, as above, medium-gray, noncalcareous; plant fragments; one-half inch of light-gray bentonite at 837 ft. Last 6 in. of recovery has thin beds of dull to shiny black coal.
74	839–849	Recovered 4 ft. 1 in., clay shale, medium-light-gray, silty. 6 in., bentonite, white, medium-soft. 7 in., lignite and coal, black, dull, earthy to shiny, soft and brittle. 2 ft 6 in., bentonite, very light-gray to white, soft and friable to medium-soft; contains black carbonaceous plant fragments. 4 in., lignite, grayish-black.
75	849–859	Recovered 10 ft. 2 ft, clay shale, medium-light-gray, rather soft and slightly bentonitic. 8 ft, siltstone, medium-light-gray, noncalcareous, medium-hard; bentonitic matrix.
76	859–869	Recovered 7 ft. Siltstone 70 percent and claystone 30 percent; siltstone is light gray; claystone is medium light gray, hard and compact, slightly calcareous; dip 2°.
77	869–879	Recovered 10 ft. Siltstone, sandstone, and claystone, as above, in equal parts; sandstone is fine grained, made up of subangular grains of about 80 percent quartz, 10 percent yellowish calcite, also mica, carbonaceous particles, and some rock fragments in bentonitic matrix.
78	879–889	Recovered 10 ft. 1 ft, interbedded siltstone, sandstone, and clay shale as above. 1 ft 6 in., claystone and clay shale, light-gray, slightly bentonitic, medium-hard; excellent cleavage. 10 in., sandstone and conglomerate, light-gray, medium grained, hard; irregular fracture; grains subangular, 50 percent white and clear quartz, 20 percent carbonaceous particles; remainder is dark chert, rock fragments, and mica. Sandstone contains layer of rounded gray and black chert pebbles up to one-half of an inch in diameter. 6 ft 8 in., clay shale, medium-gray to medium-dark-gray; carbonaceous and bentonitic in spots, a few inches of grayish-black lignite at 884 ft and 888½ ft.
79	889–899	Recovered 8 ft 6 in. 6 ft, lignite and carbonaceous clay shale, medium-dark-gray to grayish-black; layers of light-brownish-gray bentonite at 891 and 893 ft; at 895 ft 8 in. of white bentonite which contains black carbonaceous fragments.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		2 ft 6 in., claystone, medium-light-gray, noncalcareous; irregular fracture; contains scattered coaly laminae; 1 in. of bentonite at 897 ft.
80	899–909	Recovered 4 ft: Microfossils very rare. 1 ft 8 in., lignite and low-grade coal 50 percent, carbonaceous shale 50 percent. Lignite and hard brittle dull to shiny black subbituminous coal. Carbonaceous shale is medium-dark gray. 1 ft, clay shale, medium-light-gray, medium-hard. 1 ft 4 in., carbonaceous clay shale, as above, topped by one-half inch of bentonite.
81	909–919	Recovered 1 ft 6 in. Siltstone, light-gray, noncalcareous, hard, massive; slightly bentonitic matrix.
82	919–929	Recovered 10 ft. 5 ft 6 in., siltstone as above, a few very fine grained sandstone beds, also a few medium-light-gray clay shale beds; dip about 5°. 2 ft 6 in., clay shale, medium-gray; fair cleavage; contains numerous black plant impressions. 2 ft, bentonite, very light-yellowish-gray, medium-hard.
83	929–939	Recovered 8 ft: Microfossils absent. 5 ft, clay shale, carbonaceous, and lignite, medium-dark- to dark-gray, soft; some is brittle; badly infiltrated by drilling mud; 1 in. of light-gray bentonite at about 931 and at 934 ft. 3 ft, clay shale, medium-dark- to dark-gray; as above but with less lignite; no drilling mud; medium-light-olive gray bentonite layers present.
84	939–949	Recovered 8 ft 6 in. Clay shale, as above, very carbonaceous; numerous layers of lignite and low-grade coal, lowest 1½ ft is almost all coal; medium-light-olive-gray bentonite at 944, 945, and 946½ ft.
85	949–959	Recovered 3 in. Sandstone as below; no oil or gas shows.
86	959–969	Recovered 6 ft. Sandstone, light-gray, fine-grained, essentially noncalcareous, medium-hard, slightly friable; subangular grains; made up of 70 percent white and clear quartz, 10 percent carbonaceous particles; remainder is mica, calcareous grains and rock fragments in bentonitic matrix; breaks parallel bedding; rare dark carbonaceous partings, dip 2°; no oil or gas shows.

Lithologic description—Continued

Core	Depth (feet)	Remarks
87	969–979	Recovered 7 ft. Sandstone as above, breaks readily parallel to bedding; no shows.
88	979–989	Recovered 10 ft. 3 ft 4 in., sandstone as above, very fine- to fine-grained; no shows. 6 ft 8 in., interbedded siltstone and claystone, light- to medium-light-gray, noncalcareous, hard; breaks parallel bedding.
89	989–999	Recovered 10 ft: Microfossils very rare. Interbedded siltstone 60 percent and clay shale 40 percent, as above, also 1 bed 6 in. thick of very fine-grained sandstone; bedding somewhat irregular and lenticular; rare carbonaceous plant fragments.
90	999–1,005	Recovered 5 ft: Microfossils present. Clay shale, medium-light-gray, noncalcareous, moderately hard; fair to good cleavage; numerous light-gray siltstone laminae.
91	1,005–1,015	Recovered 9 ft. Sandstone, light-gray, fine- to rarely medium grained, very rarely coarse grained, medium-hard but slightly friable; angular to subangular grains of white and clear quartz, carbonaceous particles, rock fragments, pyrite, white and biotite mica, calcareous particles in bentonitic matrix; black carbonaceous partings fairly common; mostly noncalcareous except 1 ft at 1,010–1,011 ft which has very calcareous matrix; dip 2°–4°; no oil or gas shows.
92	1,015–1,025	Recovered 10 ft. Sandstone, as above, fine-grained, noncalcareous; no shows; dip 4°.
93	1,025–1,035	Recovered 10 ft. Sandstone, as above, fine-grained, hard, massive; no carbonaceous partings, noncalcareous except for last 6 in. which is very calcareous; no shows.
94	1,035–1,045	Recovered 10 ft. 2 ft, sandstone as immediately above; no shows. 8 ft, interbedded siltstone 80 percent and clay shale 20 percent, light-gray, medium-light-gray, hard; fair cleavage; scattered sandstone laminae.
95	1,045–1,052	Recovered 6 ft 6 in.: Microfossils present. Interbedded clay shale and siltstone, about equal proportions, light- to medium-light-gray, noncalcareous; fair to good cleavage; dip 2°.
96	1,052–1,060	Recovered 8 ft. 6 ft, interbedded siltstone 80 percent and clay shale 20 percent, as above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		noncalcareous. 2 ft, sandstone, light-gray, very fine-grained, silty, noncalcareous, hard, massive.
97	1, 060–1, 070	Recovered 10 ft: Microfossils present. Siltstone, very light- to light-gray, argillaceous, noncalcareous, hard; bentonitic matrix; some clay shale interbeds; good cleavage; grades in places to very fine-grained sandstone; dip 2°.
98	1, 070–1, 080	Recovered 8 ft 6 in.: Microfossils present. Siltstone, as above, very light-gray, slightly softer; very bentonitic matrix; rare medium-gray clay shale laminae.
99	1, 080–1, 090	Recovered 10 ft: Microfossils present. Siltstone, as above, very light- to light-gray, about 5 percent medium-light-gray clay shale; rare very fine-grained sandstone laminae; noncalcareous.
100	1, 090–1, 100	Recovered 9 ft: Microfossils present. Siltstone as above; grades in places to claystone; noncalcareous, vermicular structures of clay in silt or silt in clay up to one-fourth of an inch long and one thirty-second to one-sixteenth inch wide abundant throughout.
101	1, 100–1, 110	Recovered 7 ft: Microfossils present. 3 ft 8 in., claystone and siltstone, light- to medium-light-gray intercalated, hard; poor cleavage. 1 ft 3 in., claystone, medium-light-gray, very calcareous, hard; thin fractures filled with white calcite. 2 ft 1 in., clay shale, medium-light-gray, silty, noncalcareous, hard; good cleavage.
102	1, 110–1, 120	Recovered 9 ft: Microfossils rare. Claystone and clay shale, medium-light-gray, very silty, hard; poor cleavage; rare fish scales; pyritic plant (?) impressions; noncalcareous except for 3 in. of limestone at 1,110½ ft. Limestone is medium light gray, very hard, argillaceous.
103	1, 120–1, 130	Recovered 4 ft: Microfossils common. Clay shale as above; lowest 3 ft badly infiltrated by drilling mud.
104	1, 130–1, 140	Recovered 10 ft: Microfossils present. Clay shale and claystone, medium-light-gray as above, silty, noncalcareous; fair cleavage; beds lie approximately flat.
105	1, 140–1, 150	Recovered 5 ft: Microfossils common. Clay shale and claystone, as above, noncalcareous.
106	1, 150–1, 160	Recovered 10 ft: Microfossils rare. Clay shale and claystone, as above, noncalcareous; beds lie flat.
107	1, 160–1, 170	Recovered 2 ft: Microfossils present. Clay shale and bentonite, medium-light-gray, soft; infiltrated by drilling mud. One inch of yellowish-gray soft bentonite.
108	1, 170–1, 180	Recovered 6 ft: Microfossils very rare. Siltstone. light-gray, very argillaceous, bentonitic, hard; some very fine sand, micaceous and carbonaceous grains.

CORE ANALYSES

Porosity and permeability determinations were made by P. D. Krynine (written communication) in 1947 and 1948 on some samples. The results are given in the following table. In addition, Krynine made the following comments about the sample from 345 feet:

Texture: Average diameter range—.06 to .20 millimeter; principal mode—.14 millimeter; ratio of grains to matrix to cement—80 percent to 10 percent to 10 percent. The grains are composed of the following materials: Quartz 22 percent, chert 13 percent, feldspar 4 percent, mica flakes (large) trace, rock fragments—slates and phyllites 36 percent, quartzite and schist 3 percent, volcanics 1½ percent, and pyrite trace. The interstitial matter is composed of chlorite 1 percent, sericite 3 percent, illite 3 percent, montmorillonite and kaolinite 2 percent, SiO_2 cement trace, and carbonate 9 percent. Carbonaceous material and illite binds the grains together. The pore wall area covered by kaolinite, montmorillonite and illite is 50 percent and the potential hydration of the rock is very high.

Krynine analyses this rock as a poor reservoir type with 8 percent visible porosity and fair residual porosity.

Porosity and permeability determinations, Sentinel Hill core test 1

[Analyses by P. D. Krynine]

Depth (feet)	Air permeability (in millidarcys)	Effective porosity (percent)	Depth (feet)	Air permeability (in millidarcys)	Effective porosity (percent)
199	<10	9.2	682	120	25.9
210	148	25.6	686	28	23.4
241	47.5	29.3	761	----------	23.2
243	29.6	24.9	793	108	25.0
333	----------	29.3	812	----------	16.2
338	----------	25.0	879	108	20.6
342	346	31.1	883	51	16.9
345	348	29.7	960	233	25.6
350	224	30.6	973	.20	15.2
354	98	20.4	981	<10	----------
359	5.2	10.6	1,005	<10	----------
364	160	27.3	1,007	<10	----------
453	145	29.4	1,009	<10	----------
545	35.5	24.0	1,011	<10	----------
624	163.0	25.0	1,013	<10	----------
629	290	26.2	1,017	<10	18.1
638	195	27.7	1,019	<10	18.2
643	----------	25.6	1,021	<10	17.5
646	----------	29.0	1,023	----------	21.0
652	52	24.1	1,025	<10	24.0
657	44	24.0	1,030	----------	16.2
661	----------	25.1	1,033	----------	23.6
666	22.5	23.0	1,036	<10	21.4
672	41	24.8	1,071	10	18.1
677	750	23.8	1,100	----------	20.4

Other permeability tests on a few samples were as follows:

Depth (feet)	Permeability (Klinkenberg) (in millidarcys)		Brine permeability (in millidracys)	Fresh-water permeability (in millidracys)
	Before liquid flow	After liquid flow		
354	78.6	123	Trace	0
686	13.6	15.2	0.1	----------
879	26.5	43.0	0	----------

The Fairbanks laboratory of the U. S. Geological Survey made the specific gravity measurements shown in the following table.

Specific gravity of rocks from Sentinel Hill core test 1

Depth (feet)	Specific gravity	Description
119	1.86	Carbonaceous clay shale.
219	1.93	Claystone.
319	2.28	Siltstone.
419	2.17	Claystone.
519	2.07	Clay shale.
609	1.91	Bentonite.
669	2.02	Sandstone, bentonitic.
790	2.04	Sandstone, bentonitic.
899	2.09	Clay shale and coal.
919	2.04	Siltstone.
1,020	2.29	Sandstone, bentonitic.
1,100	2.11	Siltstone.

Robert H. Morris (written communication, 1954) in his study of the heavy minerals of northern Alaska identified the "fractured garnet zone" in Sentinel Hill core test 1 from 140 to 1,023 feet. Nine rock samples from within that interval were examined. (See fig. 42.)

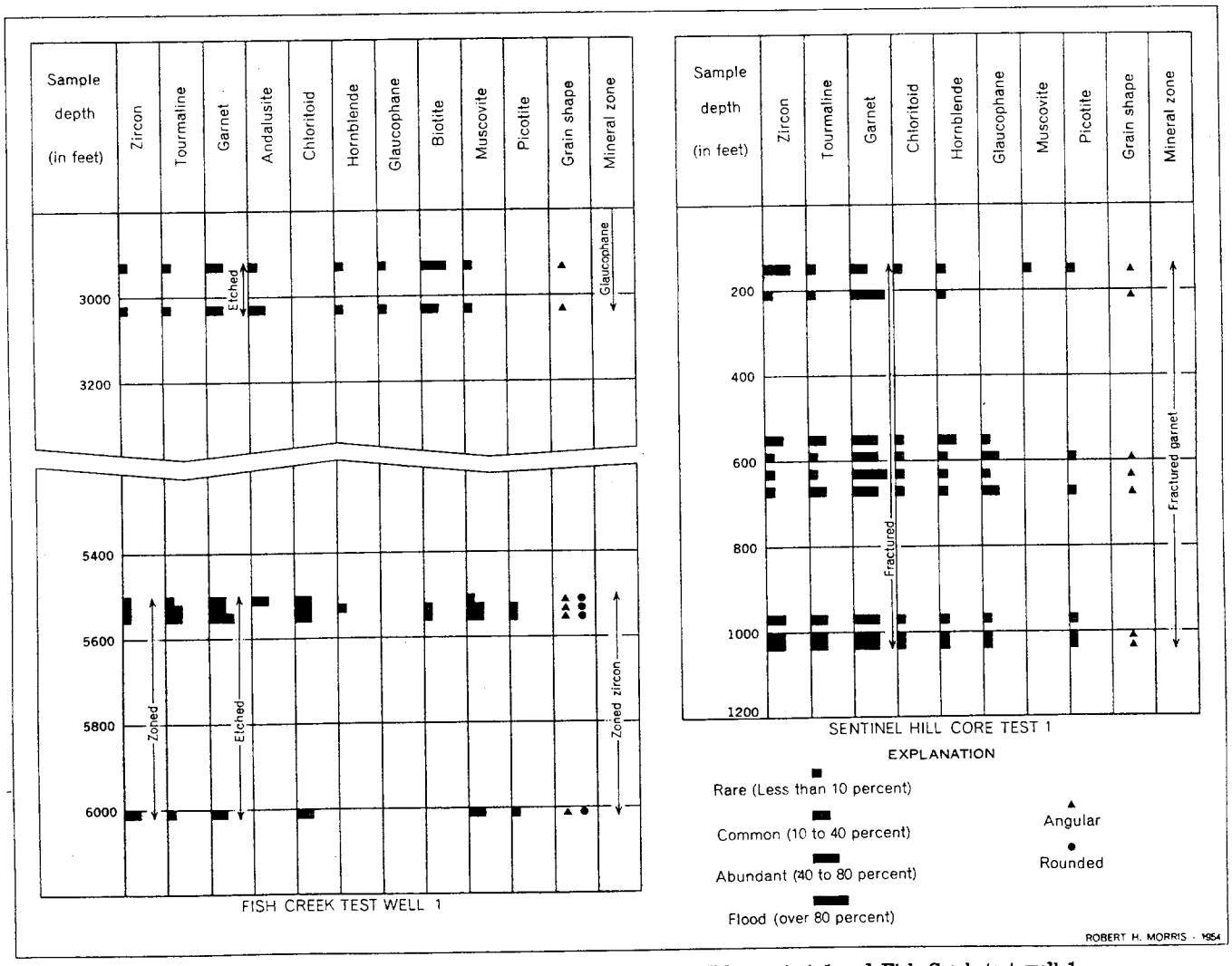

FIGURE 42.—Relative abundance of heavy minerals in Sentinel Hill core test 1 and Fish Creek test well 1.

OIL AND GAS

Sentinel Hill core test 1 is one of the few tests in Naval Petroleum Reserve No. 4 which had no shows of oil or gas.

LOGISTICS

Transportation.—From December 30, 1946, to January 20, 1947, preparatory work of assembling complete drilling and auxiliary equipment for Sentinel Hill core test 1 was carried on at Umiat. This equipment, amounting to about 700 tons, was moved by Caterpillar tractor train to the drilling site from January 16 to January 19, and a camp was established. Drilling began January 26, 1947. Two small-plane landing strips were maintained on the river adjacent to the test site to serve in emergencies.

Housing.—Seven wanigans were used to house the personnel and equipment—a generator wanigan, a mud-pit wanigan, a water wanigan, a boiler wanigan, a sleeping wanigan, a galley wanigan, and a radio wanigan. The generator and mud-pit wanigans were double-canvas-covered buildings mounted on Michler go-devil sleds placed adjacent to the rig and connected to it by a light wooden frame covered with canvas. Sufficient heat was given off by the engines of the complete unit to maintain efficient operation even at minus 40°F. The water wanigan was a wooden roofed structure that was insulated inside and sheathed outside with plywood. It was mounted on a go-devil sled and contained a steel pontoon and a heating element. The boiler wanigan consisted of a frame structure with double plywood walls and roof mounted on a go-devil sled; it housed a prospect-type boiler, a space heater, and a water container. Plate 33 is a photograph of the Sentinel Hill core test rig.

Personnel.—The personnel at the rig consisted of a drilling foreman, 2 regular drillers, 4 roughnecks, 1 mechanic and tractor operater, 1 cook, and 1 bull cook. The basic work week was seven 12-hour days.

Vehicles and drilling equipment.—One D8 Caterpillar tractor with a winch, blade, and A frame and one weasel were kept in camp for automotive and construction use. The drilling equipment used by Arctic Contractors consisted of one of each of the following:

- Failing core drill, Model 1500.
- Portable mud pump unit, Gardner-Denver pump, Model FF–FXF–F, 4-in. by 5-in., powered by Model 108–506 Chrysler gasoline engine.
- Portable generator unit, O'Keefe and Merrill 15-kw capacity.
- Dravo heating unit, skid mounted.

Fuel, water, and lubricant consumption.—Water was obtained from the river. Two steam points at 90 pounds per square inch pressure were used for thawing holes in the ice. The following were used in drilling the core test: 150 barrels of 35 cetane fuel, 144 barrels of 80 octane fuel, 1 barrel of white gasoline, 10 gallons of alcohol, 2 gallons of starting fluid, 2 barrels of No. 10 lube oil, 1 barrel of No. 20 lube oil, 25 gallons of all-purpose grease, and 10 gallons of kerosene.

DRILLING OPERATIONS

The test site was chosen on a small mud bank approximately 3 feet above the surrounding gravel bar to facilitate drainage and heating. The cellar was dug on the 22d of January (with the aid of the steam points), and the skid-mounted drilling unit was set up over it. Drilling began on the 26th of January. A 6⅛-inch hole was drilled to a depth of 42 feet and reamed to 9⅞-inch diameter. (See pl. 31.) Thirty feet of 7-inch diameter surface pipe was set and cemented with 15 sacks of cement. The mud in the surface pipe was heated by steam to approximately 150°F and held at that temperature for 3 days while the cement set. The plug was drilled out, and a 6⅛-inch diameter hole was drilled to 109 feet. The hole was then reamed from 9 to 51 feet with a 9⅞-inch bit and from 51 to 109 feet with a 6⅛-inch bit. Coring started at 109 feet, and the hole was cored continuously using a 5⅞-inch Reed Kor-King core barrel. At 539 feet, while running the core barrel, control was lost at the cat head and the core barrel, and the hoisting plug with the cat line dropped into the hole. The fish was recovered, and the hole reconditioned with a total lost time of 41 hours. Coring continued to a depth of 1,180 feet, where drilling was stopped and the hole abandoned because the stratigraphic information desired had been obtained.

A total of 1,071 feet (109–1,180 ft) was cored with a 5⅞-inch core head and a total recovery of about 940 feet or 87 percent. Five sacks of Aquagel were mixed with the water during drilling, and no further treatment was necessary. The mud weight and viscosity is given in the following table.

Mud weight and viscosity, Sentinel Hill core test 1

Depth (ft)	Weight (lbs per cu ft)	Viscosity (sec. API)	Depth (ft)	Weight (lbs per cu ft)	Viscosity (sec. API)
75	9. 6	41	715	9. 8	37
125	9. 8	42	745	9. 8	37
150	9. 7	38	775	9. 8	39
185	9. 6	38	800	9. 8	38
220	9. 8	38	825	9. 8	37
245	9. 9	40	855	9. 7	38
265	9. 7	38	880	9. 7	38
290	9. 9	41	895	9. 8	39
310	9. 7	39	915	9. 8	38
335	9. 7	39	935	9. 7	38
380	9. 9	39	960	9. 7	39
400	9. 9	40	975	9. 7	40
425	9. 8	39	995	9. 8	39
450	9. 8	38	1, 005	9. 8	37
475	9. 9	40	1, 025	9. 7	38
500	9. 7	39	1, 045	9. 8	40
525	9. 8	38	1, 055	9. 7	40
540	9. 7	38	1, 075	9. 7	40
560	9. 8	39	1, 095	9. 8	41
585	9. 8	39	1, 110	9. 7	41
600	9. 8	39	1, 125	9. 7	39
610	9. 8	39	1, 135	9. 7	41
625	9. 8	38	1, 155	9. 7	41
675	9. 8	39	1, 175	9. 8	38
700	9. 7	36			

Nine deviation surveys were made. The hole was off vertical by a steadily increasing amount from 1° at 100 feet to 4° at 975 ft. (See pl. 31.)

No electric log was run.

In anticipation of future temperature surveys, 1,172 feet of 2½-inch diameter tubing was run in the hole and filled with approximately 8¼ barrels of diesel oil. The tubing was plugged at the top and bottom and welded to the top of the 7-inch casing. The cellar was filled with gravel, and the equipment moved out. On August 31, 1948, a geologist checked the site of the test from an airplane. A pole was still to be found on the top of the cliff above the location, but heavy mud slides had completely buried the casing and the pipe marking the site. No thermistor cables were installed.

FISH CREEK TEST WELL 1

By Florence R. Collins

Location: Lat 70°19′15″ N., long 151°58′08″ W.[1]
Elevation above sea level: Ground, 16.5 feet; kelly bushing, 31.5 feet.
Spudded: May 17, 1949.
Completed: September 4, 1949; pumped 10 barrels of oil per day; abandoned.
Total depth 7,020 feet.

Fish Creek test well 1 is on the Arctic Coastal Plain, about 20 miles west of the mouth of the Colville River (fig. 39). It is in a flat region of marshy tundra and numerous lakes connected by small, meandering streams. The ground is permanently frozen beneath the few inches of sediment thawed by the summer sun; the anomalous character of the electric log in the upper part of the hole (pl. 32) suggests that the permafrost is present to a depth of some 600 feet.

An oil seep about 1½ miles southwest of the well was visited in 1943 by representatives of the U. S. Bureau of Mines and the Alaska Territorial Department of Mines (N. Ebbley and H. R. Joesting, written communication, 1944). They described the seep as being about 6 feet wide and 20 feet long; the oil was solid and tarry, with no apparent thin oil on the surface. It was gummy enough to trap birds and small rodents. The petroleum laboratory of the Bureau of Mines at Bartlesville, Okla., analyzed a sample, and extracted 51.2 percent hydrocarbon. The specific gravity of the sample at 60°F (compared to that of water at 60°F) was 0.986; its API gravity was 12.0°. The hydrocarbon was black, viscous, and asphaltic, and its low gravity suggested that it was "weathered" and that the more volatile constituents had evaporated.

[1] The latitude and longitude have been determined with reference to the Harrison Bay quadrangle map (1:250,000 scale, 1951 ed.) in the Alaska reconnaissance topographic series published by the U. S. Geol. Survey.

In September 1947, the Arctic Contractors personnel visited the seep and described it as a small exposure of consolidated sand, impregnated with black asphaltic residue. (See pl. 34*A*.) Depressions in the sand were filled with water, on which floated a small amount of black highly viscous, pitchlike material with the appearance and odor of heavy fractions of petroleum. A few small birds were trapped in it.

The test well was drilled by Arctic Contractors to disclose the stratigraphy of the northeastern part of the Reserve; the seep, and a large gravity anomaly (located by United Geophysical Co., Inc.) underlying the area, suggested the possible presence of petroleum-bearing rocks and of some structural anomaly which might be a trap for oil. The drilling penetrated a little more than 7,000 feet of Cretaceous marine shales and a small amount of siltstone and very fine-grained sandstone. Volcanic shards are abundant in the uppermost 600 feet, and bentonite is present in the underlying 1,000 feet. About 10 barrels per day of heavy black oil was produced, by pumping, from very fine-grained sandstone and siltstone between 2,920 and 3,060 feet. Shows of lighter oil were noticed in thin sandy siltstones below 5,400 feet, but tests of these were unsuccessful.

STRUCTURE

A seismic survey of the Fish Creek area made by United Geophysical Co., Inc., in 1948 indicates that the shallow Cretaceous beds (above 3,500 ft, at the well site) have a regional dip of about 50 feet to the mile, in an easterly direction. Beds of earliest Cretaceous or Jurassic age, at about 10,000 feet below the surface, dip somewhat more steeply to the south and are complicated by minor faulting. No anticline or closure was detected at any depth. The records did suggest the possibility of a small normal fault (downthrown 200 ft or less to the east) intersecting the well near the upper oil-bearing zone (United Geophysical Co., Inc., written communication, 1953). Projected to the surface, it would crop out close to the oil seep southwest of the well. Possibly such a fault could not only form a trap for the oil 3,000 feet below the surface, but the fault plane could also be the path of the oil to the surface to form the seep. There is no evidence from the well to corroborate or disprove the existence of such a fault.

Results of a gravity survey of the Reserve by the United Geophysical Co., Inc., completed in 1947, show a large area of unusually high gravity in the Fish Creek area (fig. 43); the well is near its apex. This reconnaissance survey was made on an approximate 5-mile grid. A magnetic survey, made jointly by the U. S. Navy and the U. S. Geological Survey in 1945 and 1946 shows the well to be in an area of comparatively uniform magnetic intensity. A short distance to the west,

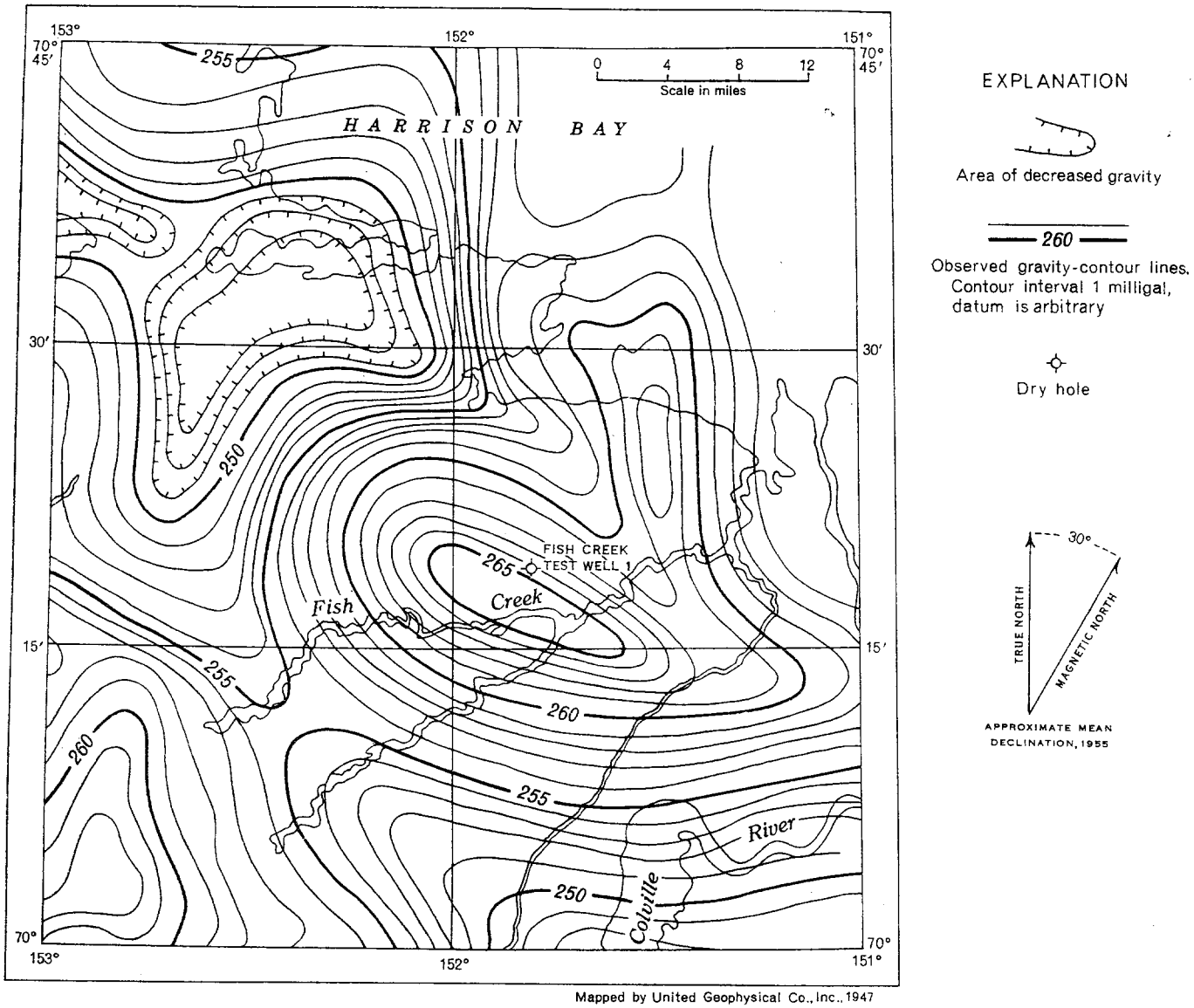

FIGURE 43.—Observed gravity in the vicinity of Fish Creek test well 1, as mapped by United Geophysical Co., Inc.

the intensity decreases rapidly southwestward. To the east the intensity changes much less rapidly, but the decrease is still to the southwest.

STRATIGRAPHY

The following is a brief summation of the stratigraphy:

Formation	*Feet*
Gubik formation	15–65
Schrader Bluff formation	65–1,632
Sentinel Hill member of the Schrader Bluff formation	65–680
Tuluvak tongue of the Prince Creek formation	1,632–1,655
Seabee formation	1,655–2,890
Topagoruk formation	2,890–7,020

GUBIK FORMATION

The well was spudded in unconsolidated sand of the Gubik formation. The sand grains are commonly well rounded and composed largely of clear quartz; a few are white or yellow. Small rounded black and yellow chert pebbles are also present. The marine origin and Pleistocene age of the surface deposit are shown by rare Foraminifera (H. R. Bergquist, personal communication); pelecypod shell fragments are also present.

SCHRADER BLUFF FORMATION

The Sentinel Hill member of the Schrader Bluff formation, underlying the Gubik formation, is the uppermost unit of the Colville group of Late Creta-

ceous age in this test. It is marine clay shale, with some interbedded siltstone. The rock is light gray, noncalcareous, and characterized by abundant clear, glassy volcanic shards. Rare sandstone beds are also light gray and are composed of subangular to angular grains of clear and white quartz with abundant shards, some gray chert, and minor amounts of pyrite and mica. The siltstone differs from the sandstone only in grain size. Green glauconite pellets are abundant between 570 and 600 feet; pyrite is abundant at 120–270 and 370–400 feet. Organic remains include scattered carbonized plant particles and rare minute fishbone fragments. Foraminifera are rare. Radiolaria are rare to abundant below 590 feet, and *Inoceramus* prisms first occur at 605 feet (H. R. Bergquist, personal communication).

The rest of the Schrader Bluff formation is made up primarily of marine clay shale, but it is medium as well as light gray, and interbedded siltstone is more common than in the Sentinel Hill member. Some light-gray slightly argillaceous and calcareous sandstone is near the base. Thin beds of light-yellowish-gray bentonite are below 825 feet, and some of the shale is bentonitic. There is a bed of dark-brown limestone at 765 feet. Biotite flakes are increasingly common below 1,300 feet.

PRINCE CREEK FORMATION, TULUVAK TONGUE

At 1,632 feet a 10-inch bed of dark-gray carbonaceous clay shale marks the top of the Tuluvak tongue of the nonmarine Prince Creek formation (Colville group of Late Cretaceous age). The 25-foot section of sandstone, lignite, and bentonite contrasts sharply with the marine sediments above and below. The sandstone is light gray, fine to medium grained, slightly argillaceous, and very friable; it contains carbonaceous partings, grains of carbonaceous material, and angular grains of gypsum. Its porosity is high—32.55 percent—and it was too friable to test for permeability. The lignite is brownish black and friable and is interbedded with ½-inch layers of coal. The bentonite is yellowish gray and argillaceous and contains partly carbonized plant fragments.

SEABEE FORMATION

The underlying Seabee formation (Colville group) is another marine shale; it contains a small amount of interbedded siltstone and rare sandstone beds. It is similar lithologically to the overlying Schrader Bluff formation, but it has less bentonite, and practically no volcanic shards, and carbonaceous material is very rare. The clay shale is light gray, micaceous, and noncalcareous and contains rare siltstone laminae; some has carbonaceous particles scattered through it. Biotite is common, especially in the lower part of the formation. The rare sandstone beds are light gray, very fine grained, and micaceous. The sand grains are angular white quartz with some gray chert; the mica is light green, clear, or light brown. Two thin limestone beds are at 2,175 and 2,290 feet; both are blue-gray, argillaceous, and massive. The formation contains a distinctive microfauna, and *Inoceramus* prisms, ammonite shell fragments, and fishbone fragments are common.

TOPAGORUK FORMATION

The beds between 2,890 and 3,060 feet in Fish Creek test well 1 consist of thin-bedded siltstone with some interbedded very fine-grained sandstone and clay shale. In much of northern Alaska, the Colville group is separated from the Topagoruk formation of Early Cretaceous age in the subsurface by the Ninuluk formation, the Killik tongue of the nonmarine Chandler formation, and marine sandstone of the Grandstand formation. In this test, however, no definitely nonmarine beds or massive sandstone layers can be identified; and as the lithology of this interval resembles that of the marine Topagoruk formation more closely than any other unit, these strata are tentatively assigned to the Topagoruk formation. Between 2,890 and 3,030 feet microfossils are absent except for a few specimens of doubtful identity, but below 3,030 feet the beds contain an assemblage of Foraminifera described by H. R. Borgquist as the *Verneuilinoides borealis* fauna. *Ditrupa* sp. and *Inoceramus* sp. shell fragments, commonly associated with the microfauna, are also present.

Between 2,920 and 3,060 feet, the beds of sandy argillaceous siltstone and clay shale, with rare argillaceous silty sandstone, contain black, asphaltic heavy oil which was pumped at a rate of about 10 barrels a day. The rock was too thin bedded and friable to permit adequate permeability tests, but the high proportion of silt and clay suggests that permeability is low. The porosity of 1 sample was 25.2 percent; the rest of the rock was too friable to be tested. The oil-stained beds are light yellowish brown to grayish brown; the unstained siltstone is light gray; the clay shale, medium gray. Below the oil-bearing rocks the proportion of shale increases, but sandy siltstone beds continue in decreasing abundance to 3,720 feet. The shale is light to medium gray and slightly silty and has some laminae and thin lenses of light-gray micaceous siltstone. The thicker beds of siltstone are also light gray and slightly micaceous, and carbonaceous particles are present in some. Light-bluish-gray argillaceous limestone beds are present near 3,170 feet.

The rest of the Topagoruk formation is composed almost entirely of marine clay shale, containing the

same microfauna as the upper beds. The shale darkens and hardens with increasing depth, however; and below 5,000 feet it is medium dark gray and cleaves easily into chips with their flat surfaces parallel to the bedding planes. The clay shale is commonly silty, and much of it contains thin laminae and beds of siltstone. In some places, deformation shortly after deposition (presumably by slumping of the unconsolidated sediment) has distorted the beds, mixing light-gray siltstone and darker clay shale, which gives the appearance of marble. (See pl. 34*B*.) Above and below such intervals, the bedding is relatively undisturbed. In contrast with the flat-lying strata of the upper beds, however, strata in this part of the Topagoruk formation have measured dips of 5° to 25° (the deviation of the hole was 4° where the measured dip was steepest).

Between 5,400 and 5,600 feet, the Topagoruk formation includes beds of siltstone (and 1 or 2 of very fine-grained sandstone), which are commonly less than 1 foot thick, are very argillaceous and are interbedded with clay shale. Many of them are slightly oil stained, but no successful tests of the section were made. Porosity and permeability are very low: 6–8 percent and less than 5 millidarcys, respectively. Below 5,600 feet, only 1 or 2 thin beds of siltstone interrupt the long sequence of clay shale.

DESCRIPTION OF CORES AND CUTTINGS

The detailed lithologic description is based primarily on an examination of cores and cuttings made in the Fairbanks laboratory and on the electric log. The material was described dry, and colors were determined by comparison with the Rock Color Chart (Goddarol and others, 1948). Some of the cores of clay shale break very uniformly along bedding planes, forming disk-shaped pieces about a quarter of an inch thick. This characteristic manner of breaking is described as poker-chip cleavage. All depths were measured from the kelly bushing. The abundance of microfossil specimens mentioned at the beginning of each core description is defined as follows: 1–4, very rare; 5–11, rare; 12–25, common; 26–50, abundant; more than 50 very abundant.

Lithologic description

[Where no core number is listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
-----	0–15	Kelly bushing to ground level.
-----	15–46	No samples. Driller reported soft sand to 22 ft, hard sandstone from 22 to 32 ft, and soft sand from 32 to 46 ft. Top of the Gubik formation at 15 feet.
-----	46–65	Sand, light yellowish gray, coarse to fine; pebbles as much as half an inch in diameter in lower part. Most grains rounded to subrounded, with frosted to polished surfaces. Sand is dominantly quartz (mostly clear, with some white or yellow). Small percentage of clear quartz grains are angular, with subconchoidal, unweathered surfaces. Pebbles commonly under one fourth of an inch in diameter, rounded to subrounded, and consist largely of black chert, with smaller quantity of yellow chert. Black pebbles commonly have bluish-gray or yellow cores.
-----	65–120	Clay, bluish-gray to gray, soft, sticky; rare sand. Top of Sentinel Hill member of Schrader Bluff formation at at 65 ft.
-----	120–225	Clay shale, light-gray; abundant colorless (rarely light-grayish-brown) transparent volcanic shards; some light-gray siltstone. Pyrite and carbonized plant material common below 160 ft.
1	225–234	Recovered 3 ft: Microfossils absent. 2 ft, siltstone, light-gray, noncalcareous, moderately indurated; shaly cleavage; abundant volcanic shards and pyrite grains, concretions, and pyrite-replaced organic matter; a few streaks of very fine sand. 1 ft, siltstone, light-olive-gray, noncalcareous, moderately indurated; scattered carbonized plant fragments. Abundant volcanic shards and pyrite as above. Beds lie approximately flat.
-----	234–425	As core 1, except pyrite is rare between 270 and 370 ft and from 400 to 610 ft.
2	425–435	Recovered 7 ft: Microfossils very rare. 4 in., sandstone, light-gray, medium- to fine-grained, slightly silty, friable, unstratified; very abundant volcanic shards. Sand grains are subangular to angular, have low sphericity, and are composed principally of clear or white quartz, with some gray chert and minor amounts of granular pyrite, and white, brown, or light-green micas. 6 ft 8 in., siltstone, light-gray, friable; shaly cleavage; abundant volcanic shards; some laminae of medium-gray noncalcareous friable clay shale and of light-gray very fine grained silty noncalcareous friable sandstone containing abundant volcanic shards. Beds lie approximately flat.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	435–627	Lithology is similar to siltstone in core 2. From 570 to 600 ft, rounded green clay pellets (glauconite?) are abundant, rare elsewhere. Between 605 and 627 ft are several small fragments of *Inoceramus* shells. At 610 ft, pyrite becomes common.
3	627–635	Recovered 5 ft 6 in.: Microfossils common. 1 ft 2 in., clay shale, light-gray, noncalcareous, moderately indurated; a few small streaks of pyrite, probably replacing macerated plant remains. Beds lie approximately flat. 4 ft 4 in., siltstone, medium- to light-gray, noncalcareous, moderately indurated; shaly cleavage at bottom; medium-gray moderately indurated noncalcareous clay shale streaks. Pyrite grains and small pyritized and carbonized plant fragments scattered throughout; also shell fragments and volcanic shards (abundant in top 1 ft). Microscopic fishbone fragments also present.
-----	635–825	Clay shale and siltstone as in core 3. Microscopic fishbone fragments present, though rare, from 700 to 4,230 ft. Dark-brown to light-gray limestone occurs at 755–760 ft. Base of Sentinel Hill member at 680 ft.
4	825–835	Recovered 10 ft: Microfossils common. Claystone, medium-gray, noncalcareous, poorly indurated, slightly waxy; conchoidal fracture; pyrite streaks and pyritized organic remains rare. At 827½ ft is a 1-in. layer of light-yellowish-gray, noncalcareous poorly indurated waxy bentonite that grades into and contains streaks of medium-gray claystone. At 831 ft is a 4-in. layer of light-yellowish-gray bentonite like that at 827½ ft.
-----	835–1, 025	Claystone as in core 4, with rare siltstone; bentonite common at 985 ft.
5	1, 025–1, 035	Recovered 10 ft: Microfossils abundant. 8 in., clay shale, light- to medium-gray, noncalcareous, moderately indurated. 2 in., bentonite, yellowish-gray, noncalcareous, friable; conchoidal fracture; slightly waxy luster. 9 ft 2 in., clay shale, brownish to medium-gray, moderately indurated; some flaky films of black carbonaceous material; no oil cut in CCl_4. Layers of yellowish-gray bentonite, as described above, occur as follows: ¼-in. layer at 1,028 ft, 4-in. layer at 1,031 ft, 1-in. layer at 1,032 ft, six 1-in. layers at 1,033–1,035 ft. Fishbone fragments and pyrite present throughout the core. Beds lie approximately flat.
-----	1, 035–1, 225	Clay shale as in core 5, with rare siltstone. Abundant bentonite at 1,075 ft and 1,105 ft; pyrite abundant from 1,190 to 1,225 ft. Microscopic ammonite shell fragment at 1,105 ft.
6	1, 225–1, 235	Recovered 10 ft: Microfossils very rare. Clay shale, light-gray, very silty, micaceous, slightly calcareous, well-indurated, with carbonized plant remains and interlaminated very fine-grained light-gray silty sandstone containing angular grains of gypsum (?) and dark-gray carbonaceous clay shale. Laminae are crossbedded with dips as much as 10°. Slight oil cut in CCl_4.
-----	1, 235–1, 422	Clay shale, as in core 6; some sandstone from 1,320 to 1,420 ft, especially in upper 30 ft; bed of fine- to medium-grained medium-light-gray sandstone at 1,317–1,320 ft. Biotite flakes rare to 1,300 ft; grade to common at 2,400 ft. *Inoceramus* prisms 1,290–1,422 ft.
7	1, 422–1, 432	Recovered 6 ft: Microfossils absent. 3 ft 6 in., clay shale as in core 6; at 1,424 ft is ½-in. layer of light-yellowish-gray noncalcareous slightly micaceous clay shale with a few carbonized plant particles. 2 ft 6 in., clay shale, light-gray, slightly micaceous, noncalcareous, moderately indurated; with carbonaceous laminae and intercalations of light- to medium-gray or yellowish-gray noncalcareous moderately indurated siltstone, containing carbonaceous laminae and flakes of carbonized plant material. Beds lie approximately flat.
-----	1, 432–1, 625	Clay shale as in core 7 above, with some siltstone; dark-brown siltstone in sample from 1,555 to 1,560 ft; some very fine- to medium-grained gray moderately calcareous carbonaceous micaceous sandstone interbedded with siltstone between 1,560 and 1,600 ft. Bentonite rare.
8	1, 625–1, 635	Recovered 10 ft: Microfossils very rare. 7 ft, interbedded clay shale and siltstone, light- to medium-gray, slightly micaceous, noncalcareous, moderately indurated; shaly cleavage; carbonaceous films common; flakes of carbonized macerated plant remains. Some crossbedding dips as much as 10°; single beds are 0.2–100 mm

Lithologic description—Continued

Core	Depth (feet)	Remarks
		thick. At 1,631 ft is a ½-in. lens of very light-gray fine-grained argillaceous well-indurated noncalcareous sandstone. Top of Tuluvak tongue of Prince Creek formation at 1,632 ft.
		10 in., clay shale, dark-gray, silty, carbonaceous, somewhat micaceous noncalcareous; scattered flakes of carbonized macerated plant remains.
		2 ft 2 in., sandstone, light-gray, medium-grained, argillaceous, noncalcareous, friable; no bedding visible. Contains angular grains of gypsum (?). Porosity 27.6 percent.
9	1, 635–1, 645	Recovered 10 ft: Microfossils absent.
		8 in., interlaminated clay shale, medium-gray, and sandstone, light-gray, very fine-grained, argillaceous, micaceous, noncalcareous, moderately indurated. No crossbedding; beds lie approximately flat.
		4 ft 4 in., sandstone, light-gray, fine- to medium-grained, slightly argillaceous, noncalcareous, very friable (largely unconsolidated); carbonaceous films and grains in upper 3 in., decreasing with depth. Contains angular grains of gypsum. Very faint oil stain in CCl_4; porosity 32.55 percent.
		2 ft 6 in., sandstone, light-gray, fine-grained, argillaceous, noncalcareous, moderately indurated. Streaks of macerated plant material, carbonized plant remains, and carbonaceous material throughout, increasing with depth.
		2 ft 6 in., lignite, brownish-black, friable; ½-in. coal seams; 2-in. layer of impure yellow-brown waxy homogeneous bentonite at 1,644½ ft.
10	1, 645–1, 655	Recovered 4 ft: Microfossils very rare.
		3 ft 2 in., lignite as in core 9, with intercalations of brown to black fissile carbonaceous clay shale in bottom 1 ft; 2-in. bed of bentonite, as at 1,644½ ft, 1 ft from top.
		9 in., bentonite, yellowish-gray, argillaceous, noncalcareous, moderately indurated; partly carbonized plant fragments scattered throughout.
		1 in., lignite.
-----	1, 655–1, 851	Clay shale, light-gray; some interbedded siltstone; light- to medium-gray fine- to very fine-grained calcareous micaceous slightly carbonaceous sandstone at 1,735 ft, and 1,835 ft. Sand grains are angular white quartz with some gray chert and light-green, clear or light-brown mica. Top of Seabee formation at 1,655 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
11	1, 851–1, 861	Recovered 10 ft: Microfossils absent.
		Clay shale, light-gray, very silty and micaceous, noncalcareous, moderately indurated; shaly cleavage; a few ¼-in. layers of light-grayish-yellow highly calcareous well-indurated claystone; carbonized flakes of plant remains very rare. At 1,856 ft is 1-in. bed of light-gray fine-grained argillaceous noncalcareous, well-indurated sandstone. Beds lie approximately flat.
-----	1, 861–2, 051	Clay shale as in core 11 above, some siltstone; very fine-grained light-greenish-gray calcareous sandstone at 1,970–1,975 ft and 1,990–1,995 ft.
12	2, 051–2, 061	No recovery.
13	2, 061–2, 071	Recovered 10 ft: Microfossils common.
		Clay shale, medium- to light-gray, very silty, slightly carbonaceous, highly micaceous, noncalcareous, moderately indurated; flakes and films of carbonized plant remains. Rare laminae of medium-gray clay shale. Beds lie approximately flat.
-----	2, 071–2, 270	Clay shale as in core 13 above, with some siltstone; white to yellow limestone at 2,100 ft. A fish vertebra found in sample from 2,140 ft; a bed of brown to blue-gray limestone at 2,170 ft.
14	2, 270–2, 280	Recovered 2 ft: Microfossils abundant.
		Clay shale, gray, micaceous, noncalcareous, moderately indurated; a few laminae of siltstone; flakes and films of black carbonized macerated plant material scattered throughout. Beds lie approximately flat.
15	2, 280–2, 283	No recovery.
16	2, 283–2, 293	Recovered 1 ft: Microfossils very rare.
		4 in., clay shale, light-gray, micaceous, noncalcareous, moderately indurated; rare siltstone laminae.
		8 in., limestone, bluish-gray, argillaceous, massive, well-indurated. Laminae with yellowish gray impurities show a miniature thrust fault with throw of one-fourth of an inch.
-----	2, 293–2, 493	Clay shale as in core 13 above, with some siltstone. Euhedral biotite flakes common to abundant from 2,400 to 4,000 ft. One to three *Inoceramus* prisms are present in most ditch samples from 2,350–2,490 ft; six were found in the 2,490–2,495 ft sample. Microscopic fragments of ammonite shells occur at 2,380 and 2,400 ft.
17	2, 493–2, 503	Recovered 3 ft 8 in.: Microfossils rare.
		Clay shale, light-gray, very silty and micaceous, noncalcareous, moderately indurated; flakes and films of

Lithologic description—Continued

Core	Depth (feet)	Remarks
		carbonized macerated plant material scattered throughout. Rare *Inoceramus* and ammonite shell fragments. Beds lie approximately flat.
-----	2, 503–2, 700	Clay shale as in core 14 above; some siltstone; pyrite increases gradually from very rare at 2,503 ft to common at 2,700 ft. Carbonized plant material abundant at 2,680–2,695 ft. One microscopic fragment of an ammonite shell was noted at 2,545 ft.
18	2, 700–2, 710	Recovered 10 ft: Microfossils abundant. Clay shale, medium-gray, carbonaceous, very micaceous, noncalcareous, moderately indurated; dark-gray laminae (0.2–1.0 mm thick) of black carbonaceous material alternate with light-gray laminae 0.2 mm thick. From 2,706 ft to 2,707 ft are scattered laminae of light-gray very fine-grained argillaceous very micaceous noncalcareous sandstone containing angular gypsum grains. Beds approximately lie flat.
-----	2, 710–2, 915	Clay shale as in core 18 with rare sandstone and siltstone; one ammonite fragment at 2,750 ft. Top of Topagoruk formation at 2,890 ft.
19	2, 915–2, 925	Recovered 10 ft: Microfossils rare. 1 ft, clay shale, light-gray, micaceous, noncalcareous; light-gray micaceous noncalcareous siltstone laminae. 2 ft 8 in., as above, with moderate to strong petroliferous odor. 1 ft 4 in., as above, with faint petroliferous odor. 4 in., sandstone, very fine-grained, silty, noncalcareous; dark-gray clay laminae; crossbedding dips as much as 15°; well oil stained. 4 ft 5 in., interbedded clay shale, siltstone, and very fine-grained silty sandstone; 3 parts clay to 1 of sand and silt. Clay shale is light gray, noncalcareous, micaceous. Siltstone and sandstone beds are light gray, noncalcareous, 0.2–3.0 cm thick, have laminae of dark-gray clay, and show good stain of dark oil in most layers. Porosity at 2,923 ft is 25.25 percent. 3 in., siltstone, slightly sandy, micaceous, noncalcareous; yellowish brown owing to fair oil stain.
20	2, 925–2, 935	Recovered 1 ft 8 in.: Microfossils absent. 3 in., interlaminated sandstone, yellowish-brown, very fine-grained, silty, micaceous, noncalcareous, with fair oil stain; and silty light-gray micaceous noncalcareous clay shale. Beds lie approximately flat. 1 ft 5 in., sandstone, dark-brown, very fine-grained, silty, thin-bedded; well stained with dark oil.
21	2, 935–2, 945	Recovered 1 ft 5 in.: Microfossils very rare. Clay shale, light-gray, micaceous, noncalcareous; silt streaks.
22	2, 945–2, 950	Recovered 5 ft: Microfossils rare. 4 ft 4 in., clay shale, light-gray, slightly micaceous, noncalcareous. 8 in., clay shale, with lenses of sandstone, brownish-yellow, very fine-grained, silty; fair oil stain.
23	2, 950–2, 960	Recovered 10 ft: Microfossils absent. Clay shale, light-gray, slightly micaceous, noncalcareous; lenses and lenticles 0.2–100 mm (usually under 10 mm) thick of light-gray to yellow-brown noncalcareous micaceous siltstone with a poor to good stain of dark oil. Beds lie approximately flat.
24	2, 960–2, 970	Recovered 10 ft: Microfossils absent. 1 ft 7 in., clay shale, light-gray, micaceous, noncalcareous; a few layers of siltstone. Beds lie approximately flat. 5 ft 11 in., as above, with lenses of medium- to very fine-grained silty sandstone as much as 2 cm thick, with good stain of dark oil. 2 ft 6 in., siltstone, brown and yellowish-brown, slightly sandy, noncalcareous, friable, with good stain of dark oil.
25	2, 970–2, 980	Recovered 10 ft: Microfossils absent. Siltstone, grayish-brown to dark-brown, slightly sandy, micaceous, noncalcareous; fair to good stain of dark oil, with dark-gray clay shale laminae showing crossbedding dipping as much as 10°.
26	2, 980–2, 990	Recovered 10 ft: Microfossils absent. 11 in., siltstone, light-yellowish-gray, micaceous, noncalcareous; slightly oil stained. 3 ft 2 in., siltstone, light-yellowish-brown, slightly micaceous, noncalcareous; dark-brown clay laminae. A ½-in. coal bed at bottom of section. Beds lie approximately flat. 7 in., clay shale, light-gray, micaceous, noncalcareous; silt streaks, and scattered minute flakes of carbonized plants. 6 in., siltstone, yellow-brown, micaceous, noncalcareous; good stain of dark oil.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		2 ft 5 in., clay shale, light-gray, slightly micaceous, slightly calcareous; very faint petroliferous odor toward bottom of section; lenticles of light-gray siltstone throughout.
		8 in., siltstone, brown, noncalcareous; good stain of dark oil.
		7 in., clay shale, light-yellowish-gray, silty, very micaceous, noncalcareous: faint odor of oil.
		1 ft 2 in., siltstone, yellow-brown, micaceous, noncalcareous; good stain of dark oil.
27	2, 990–3, 000	Recovered 4 ft: Microfossils absent.
		Siltstone, light-gray (where not oil stained), friable, micaceous, noncalcareous; some flat-lying laminae and beds as much as 1 in. thick of light- to medium-gray noncalcareous micaceous clay shale; most of the siltstone is well stained yellowish-brown to dark-brown with dark oil.
28	3, 000–3, 010	Recovered 10 ft: Microfossils absent.
		1 ft, interbedded siltstone, micaceous, noncalcareous; fair to good stain of dark oil; and light-gray noncalcareous micaceous clay shale.
		1 ft 3 in., siltstone, medium- to dark-brown, noncalcareous, micaceous, friable; well stained with dark oil; laminae of dark-brown clay.
		1 ft 8 in., clay shale, light-gray, silty, micaceous, noncalcareous; faint oil stain in top 8 in.; intercalations of light-gray noncalcareous micaceous siltstone.
		7 in., siltstone, light-gray, slightly calcareous.
		1 ft 3 in., limestone, light-gray, well-indurated; very argillaceous in top.
		8 in., siltstone, light-gray, slightly micaceous, noncalcareous.
		3 ft 7 in., siltstone, yellow- to dark-brown; well stained with dark oil.
29	3, 010–3, 020	Recovered 10 ft: Microfossils absent.
		3 ft, siltstone, light-gray to light-yellowish-brown, micaceous; poor to good stain of dark oil.
		4 ft 5 in., siltstone, light-gray, micaceous, noncalcareous; a few intercalations of light-gray clay. Beds lie approximately flat.
		1 ft 3 in., siltstone, light-yellowish- to medium-brown, micaceous; fair to good stain of dark oil.
		1 in., clay shale, light-gray, micaceous, noncalcareous.
		1 ft 3 in., siltstone; light gray where unstained; yellowish gray to brown where oil stained; micaceous, noncalcareous; (1 in. poorly oil stained, 2 in. well stained, 3 in. poorly stained, 9 in. well stained).
30	3, 020–3, 030	Recovered 10 ft: Microfossils absent.
		1 ft 1 in., clay shale, light-gray, micaceous, very calcareous.
		5 in., siltstone, light-gray, micaceous, very calcareous; one-half an inch of dark-brown siltstone well stained with dark oil; friable at base.
		7 in., clay shale, light-gray, slightly micaceous, very calcareous.
		2 ft 11 in., interbedded clay shale, light-gray; and light-gray to dark-brown siltstone; good oil stain in part; small flakes of carbonaceous material on some partings.
		1 ft 9 in., siltstone, light-brownish-gray, micaceous, noncalcareous; fair oil stain.
		1 ft 5 in., siltstone as above, light-gray, with yellowish tinge; poor to no oil stain.
		1 ft 10 in., siltstone as above, yellow- to dark-brown, friable; well stained with dark oil.
31	3, 030–3, 040	Recovered 10 ft: Microfossils rare.
		4 in., sandstone, dark-brown, very fine-grained, silty; well stained with dark oil.
		1 ft, clay shale, light-gray, micaceous, slightly calcareous; laminae of light-gray calcareous micaceous silt; fair odor oil. Beds lie approximately flat.
		4 in., interlaminated clay shale and calcareous micaceous siltstone, yellowish-gray to yellowish-brown; poor to good stain dark oil.
		2 in., siltstone, dark-brown; well stained with dark oil.
		2 in., clay shale, light-gray, slightly calcareous; laminae of light-gray, calcareous siltstone.
		1 ft 5 in., siltstone, brown, micaceous; well stained with dark oil.
		2 in., clay shale, light-gray, with yellowish tinge, calcareous.
		6 in., siltstone, light- to yellow-gray, noncalcareous; poor to fair stain of dark oil.
		1 ft 1 in., siltstone as above, dark-brown; well stained with dark oil.
		9 in., interbedded siltstone and clay shale, light-gray to light-yellowish-brown, calcareous, micaceous; siltstone has fair oil stain in part.
		2 ft 7 in., clay shale, light-gray, slightly micaceous, slightly calcareous; laminae and thin (as much as 2 cm) beds

Lithologic description—Continued

Core	Depth (feet)	Remarks
		of light-gray to light-yellowish-brown siltstone; no stain to fair oil stain. Carbonaceous flakes on partings in upper 3 in. 1 ft 6 in., clay shale, light-gray, calcareous; a few laminae of light-gray micaceous slightly calcareous siltstone.
32	3, 040–3, 050	Recovered 10 ft: Microfossils rare. 4 ft, interbedded thin-bedded clay shale and siltstone, light- to medium-gray, micaceous, partly calcareous; slight oil stain in silt laminae in top 1 ft. Beds lie approximately flat. 6 in., siltstone, yellow-brown, micaceous, calcareous; good stain of dark oil. 5 ft 6 in., same as first 4 ft of core.
33	3, 050–3, 060	Recovered 10 ft: Microfossils abundant. Clay shale and siltstone as above.
-----	3, 060–3, 162	Similar to core 32. Tubes of the worm *Ditrupa* sp. (identified by R. W. Imlay) first appear at 3,060 ft, and are in a few samples from that point to 4,200 ft.
34	3, 162–3, 171	Recovered 7 ft 2 in.: Microfossils rare. 5 ft, siltstone, light-gray, slightly micaceous, noncalcareous, moderately indurated; shaly cleavage; rare clay laminae and carbonaceous films. Shell fragments at 3,165 ft. Beds lie approximately flat. 6 in., siltstone, light-gray, very calcareous, moderately indurated; grades into unit below. 1 ft 8 in., limestone, light-bluish-gray, very to moderately argillaceous, well-indurated.
35	3, 171–3, 181	Recovered 10 ft: Microfossils abundant. 3 in., limestone, medium-blue-gray, slightly argillaceous, well-indurated. 9 ft 9 in., siltstone, light-gray, slightly micaceous, slightly calcareous, moderately indurated. Pelecypod shell fragments, small carbonaceous flakes are scattered throughout.
-----	3, 181–3, 356	Siltstone as in core 35, with clay shale. Sandy strata from 3,240 to 3,250 ft. Bentonite at 3,285 ft; *Inoceramus* prisms common in 1 ditch sample at 3,325 ft. From core 35 upward, beds lie flat, except for small amount of crossbedding which dips as much as 10°. Variable and gradually increasing dips have been recorded in lower cores.
36	3, 356–3, 366	Recovered 10 ft: Microfossils very abundant. Clay shale, medium- to light-gray, noncalcareous; a few laminae and lenses of light-gray slightly calcareous micaceous siltstone; very rare carbonaceous flakes and partings. Beds dip 5°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
37	3, 366–3, 376	Recovered 10 ft: Microfossils common. 5 ft, same as above except dips range from 0° to 5°. 3 ft 6 in., clay shale, medium- to light-gray, slightly micaceous, noncalcareous. 1 ft 1 in., same as above, slightly carbonaceous; nodules, lenses and streaks of light-grayish-yellow noncalcareous claystone; streaks of light-gray sandy siltstone; with scattered carbonaceous flakes. 5 in., siltstone, light-gray, noncalcareous.
38	3, 376–3, 386	Recovered 10 ft: Microfossils common. 6 ft 3 in., siltstone, light-gray, noncalcareous; a few laminae of medium-gray crossbedded clay shale with dips to 10°; layer of clay shale at 3,379 ft is 1½ in. thick. Fragments of pelecypod shells and carbonized fragments in bottom 2½ ft. Coquina, one-half inch thick, of *Ditrupa* sp. fragments in clay shale matrix. 3 ft 9 in., interbedded clay shale, medium- to dark-gray, carbonaceous, noncalcareous; and light-gray noncalcareous siltstone. Scattered shell fragments. Single beds are 0.2 to 40 mm thick. Clay increases with depth.
-----	3, 386–3, 576	Lithology as in core 37 above, but with larger amount of siltstone; sandstone is in thin beds between 3,400–3,450 ft; rare limestone.
39	3, 576–3, 586	Recovered 10 ft: Microfossils very abundant. Clay shale, light- to medium-gray, slightly silty, noncalcareous; scattered silty partings, flakes and films of carbonaceous material, and micaceous streaks. Beds lie approximately flat.
-----	3, 586–3, 776	Clay shale as in core 39; rare silstone.
40	3, 776–3, 786	Recovered 9 ft: Microfossils very abundant. Clay shale as in core 39; a few laminae and thin beds of light-gray siltstone; slight increase of carbonaceous material. Beds lie approximately flat.
-----	3, 786–3, 976	Clay shale as in core 40, with siltstone in lower part. Minute ammonite shell fragment found at 3,810 ft.
41	3, 976–3, 986	Recovered 8 ft 4 in: Microfossils very abundant. Clay shale, light- to medium-gray, very slightly micaceous, noncalcareous; a few laminae of light-gray siltstone; pyrite nodule 1 in. diameter at 3,978 ft. Beds lie approximately flat.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	3, 986–4, 140	Clay shale as in core 41; sandy and silty streaks rare.
42	4, 140–4, 150	Recovered 7 ft 6 in.: Microfossils common. 2 ft 6 in., clay shale, light- to medium-gray, slightly silty, slightly micaceous, noncalcareous; rare laminae of light-gray siltstone. 5 ft, clay shale, medium-gray, noncalcareous; some carbonized plant flakes on partings; a few laminae of light-gray noncalcareous siltstone. Beds lie approximately flat.
-----	4, 150–4, 340	Clay shale as in core; siltstone very rare. *Ditrupa* sp. fragments at and above 4,200 ft; lowest fishbone fragments at and above 4,230 ft; fragment of delicate outer shell of *Inoceramus* sp. at 4,240 ft.
43	4, 340–4, 350	Recovered 8 ft 6 in.: Microfossils abundant. Clay shale, medium- to light-gray, partly silty, micaceous, noncalcareous, partly fissile; thin (under one-fourth inch) beds and laminae of light-gray, micaceous siltstone from 4,344 ft to bottom. Dip approximately 5°.
-----	4, 350–4, 534	Clay shale as in core 43. Biotite decreases gradually from common at 4,400 ft to rare base.
44	4, 534–4, 544	No recovery.
45	4, 544–4, 554	Recovered 8 ft 3 in., Microfossils rare. Clay shale, medium-gray, partly silty, micaceous, noncalcareous; poker chip cleavage; dips 5° for 1 ft, increasing to 10° in rest of core.
-----	4, 554–4, 698	Clay shale as in core 45.
46	4, 698–4, 708	Recovered 10 ft: Microfossils abundant. Clay shale as above; usually with poker chip cleavage, but rarely subconchoidal fracture; beds dip 10°. Fish scale (?) noted at 4,699 ft.
-----	4, 708–4, 900	Clay shale as in core 46.
47	4, 900–4, 910	Recovered 9 ft: Microfossils very rare. Clay shale as in core 46.
-----	4, 910–5, 078	Clay shale as in core 47; pyrite decreases gradually and is rare below 4,910 ft. Increase in sandstone noted from 4,990 to 5,030 ft.
48	5, 078–5, 088	Recovered 7 ft 8 in.: Microfossils absent. Clay shale, medium-dark-gray, slightly micaceous, noncalcareous; good poker chip cleavage; dip variable, increasing from 10° to 15°.
-----	5, 088–5, 280	Clay shale as in core 48.
49	5, 280–5, 290	Recovered 7 ft 9 in.: Microfossils absent. Clay shale as above; dip variable, from flat lying to 15°.
-----	5, 290–5, 480	Clay shale as in core 49 above; rare siltstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
50	5, 480–5, 490	Recovered 10 ft: Microfossils very rare. 8 in., clay shale, medium-dark gray, micaceous, noncalcareous, well-indurated; poker chip cleavage. 1 ft, siltstone, light-gray, argillaceous, noncalcareous, well-indurated; streaks of very fine sand; small amount of carbonaceous material and carbonized macerated plant remains on partings; fair odor of oil with pale-yellow cut and brownish-yellow residue in CCl_4 at 5,482 ft. 3 ft, clay shale as above, with partings, laminae, and thin beds (as much as 1 in. thick) of argillaceous siltstone. 1 ft 2 in., siltstone as above, with yellow cut and residue in CCl_4 at 5,485 ft. 3 in., clay shale as above. 6 in., siltstone as above. 3 ft 4 in., clay shale, medium-dark-gray, micaceous, noncalcareous, well-indurated; poker chip cleavage; a few laminae, partings, and rare beds (less than 1 in. thick) of argillaceous light-gray noncalcareous micaceous siltstone with shaly cleavage and macerated carbonized plant remains on parting. Beds dip 3° or less; some lie flat. 1 in., siltstone as above.
51	5, 490–5, 500	Recovered 9 ft: Microfossils absent. 1 1 ft 3 in., clay shale as above. 3 in., siltstone as above; straw-colored cut and pale-yellow residue in CCl_4 at 5,492 ft. 7 ft, clay shale as above, with carbonized macerated plant remains on some partings; yellow cut, yellow residue in CCl_4 from a test of silty laminae at 5,495 ft. 6 in., siltstone as above.
52	5, 500–5, 510	Recovered 10 ft: Microfossils absent. 1 in., siltstone as above. 8 ft 1 in., clay shale as above; pale-yellow cut and residue in CCl_4 at 5,501 ft. 10 in., siltstone as above; yellow cut and residue in CCl_4 at 5,508 ft; porosity 16.1 percent at 5,509 ft. 5 in., clay shale as above. 3 in., siltstone as above. 4 in., clay shale as above.
53	5, 510–5, 520	Recovered 9 ft 6 in.: Microfossils absent. 5 in., clay shale as above. 5 in., siltstone as above. 2 ft 3 in., clay shale as above 8 in., siltstone as above. 2 ft 2 in., clay shale as above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		5 in., siltstone as above; yellow cut and residue in CCl_4 at 5,517 ft.
		3 ft 2 in., clay shale as above.
54	5, 520–5, 530	Recovered 9 ft: Microfossils very rare.
		2 ft, clay shale as above.
		3 in., siltstone as above.
		3 ft 1 in., clay shale as above.
		3 in., siltstone as above.
		1 ft 6 in., clay shale as above.
		2 in., siltstone as above.
		8 in., clay shale as above.
		8 in., siltstone as above; slightly calcareous; no cut; faint straw-colored residue in CCl_4 at 5,529 ft.
		2 in., clay shale as above.
		3 in., siltstone as above; very calcareous, well-indurated.
55	5, 530–5, 540	Recovered 7 ft 10 in.: Microfossils very rare.
		11 in., sandstone, light-gray, very fine-grained, very argillaceous, calcareous, well-indurated; abundant black and brown carbonized macerated plant remains on partings; grains composed of angular white and clear quartz with some flakes of muscovite and a few angular yellow grains; no cut; pale-straw-colored residue in CCl_4 from sample taken after core was dried; permeability less than 5 millidarcys, and porosity 6.07 percent at 5,530 ft.
		6 ft 11 in., clay shale as above; at 5,537 ft and 5,539 ft are 1½-in. beds of light-gray argillaceous siltstone, streaks of very fine noncalcareous micaceous sand, and well-indurated rare carbonaceous laminae; straw-colored cut; very pale-yellow residue in CCl_4 at 5,534 ft.
56	5, 540–5, 550	Recovered 8 ft: Microfossils absent.
		1 ft 6 in., siltstone with shaly cleavage, light-gray, argillaceous; a few streaks of very fine noncalcareous micaceous sand. Contains laminae and thin beds (as much as 1 in. thick) of clay shale, as above.
		6 ft 6 in., clay shale as above, commonly silty, with 1 bed of friable argillaceous very fine-grained sandstone, 1½ in. thick, at 5,548 ft.
57	5, 550–5, 560	Recovered 6 ft 3 in.: Microfossils absent.
		1 ft 7 in., clay shale, medium-dark-gray, silty, micaceous, noncalcareous, well-indurated; good to poor poker chip cleavage; rare carbonized macerated plant remains on partings; laminae and rare beds (as much as 1 in. thick) of light- to medium-gray very micaceous noncalcareous siltstone. Beds lie flat or dip as much as 3°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		6 in., siltstone with shaly cleavage, light-gray, argillaceous, very micaceous, partly calcareous; some partings marked by carbonized macerated plant remains.
		2 ft, clay shale as at top of core.
		1 ft 2 in., sandstone, light-gray, very fine-grained, very silty, argillaceous, very micaceous, calcareous; flakes of carbonaceous matter on partings; very faint straw-colored residue at 5,557 ft; porosity 7.6 percent at 5,558 ft.
		1 ft, clay shale as at top of core.
59	5, 560–5, 565	Recovered 10 in.: Microfossils absent.
		7 in., clay shale as in core 57.
		3 in., siltstone as in core 57.
59	5, 565–5, 575	Recovered 10 ft: Microfossils absent.
		2 ft 2 in., clay shale as in core 57.
		5 in., siltstone as in core 57, with slight amount very fine sand.
		1 ft 1 in., clay shale as in core 57, grades into unit below.
		1 ft 4 in., siltstone as in core 57, grades into very fine silty sandstone near bottom and then into unit below.
		5 ft, clay shale as in core 57.
60	5, 575–5, 585	Recovered 10 ft: Microfossils very rare.
		10 in., clay shale as in core 57.
		8 in., siltstone with shaly cleavage with streaks very fine sand as at base of core 59.
		1 ft 2 in., clay shale as in core 57.
		4 in., siltstone as above.
		4 ft 2 in., clay shale as in core 57; 1½-in. bed of siltstone at 5,581 ft.
		7 in., siltstone as above, with streaks of very fine-grained sandstone.
		2 ft 3 in., clay shale as in core 57, interbedded with siltstone as above; 1 part silt to 2 of clay.
-----	5, 585–5, 588	Clay shale.
61	5, 588–5, 598	Recovered 7 ft 6 in.: Microfossils absent.
		1 ft 10 in., clay shale, medium-dark-gray, micaceous, noncalcareous.
		3 in., siltstone as in core 60.
		5 in., clay shale as above, with laminae and beds (as much as one-half inch thick) of siltstone with a small amount of very fine-grained light- to medium-gray very micaceous sandstone; beds dip 5° or less.
		5 in., siltstone as in core 60, with abundant macerated carbonized plant remains on partings.
		4 ft 7 in., clay shale, medium- to dark-gray, micaceous, noncalcareous; rarely slightly silty; dip 15°, increasing gradually to 20° and then decreasing to approximately 10°; fair poker chip cleavage.

Lithologic description—Continued

Core	Depth (feet)	Remarks
62	5, 598–5, 608	Recovered 10 ft: Microfossils absent. Clay shale, dark-gray, slightly micaceous, noncalcareous, well-indurated; poker chip cleavage; dips variable, commonly nearly flat, with an increase to 7° at approximately 5,601 ft.
-----	5, 608–5, 800	Clay shale with some siltstone as in cores 61 and 62, except for a slight increase in sand at 5,770 ft. Ditch lithology does not vary except where noted from this depth to the bottom of the hole.
63	5, 800–5, 810	Recovered 7 ft 6 in.: Microfossils absent. Clay shale, medium-dark-gray, partly silty, micaceous, very slightly calcareous, well-indurated; poker chip cleavage; beds dip 15°; laminae of very micaceous siltstone; rare partings commonly marked by small flakes of carbonized macerated plant remains.
-----	5, 810–6, 000	Clay shale as in core 63.
64	6, 000–6, 010	Recovered 10 ft: Microfossils absent. 5 ft, clay shale as above; beds dip 20°–25°. 1 ft 11 in., siltstone, argillaceous; shaly cleavage; streaks of very fine-grained medium-dark-gray micaceous slightly calcareous well-indurated sandstone with scattered flakes of carbonaceous material; oil odor noted; pale-yellow cut and brown-yellow residue in CCl_4. Light-olive-gray noncalcareous clay ironstone nodule three-fourths of an inch in diameter, at 6,006 ft. Porosity at 6,006 ft 10.35 percent. Permeability less than 5 millidarcys. 1 in., claystone, dark-gray, noncalcareous, well-indurated. 3 ft, siltstone, medium-gray, very finely sandy, noncalcareous, micaceous, well-indurated; scattered small flakes of carbonized macerated plant remains. Slight oil odor noted. At 6,009 ft porosity parallel to bedding 6.9 percent; normal to bedding 8.75 percent. Permeability less than 5 millidarcys in both directions.
65	6, 010–6, 020	Recovered 3 ft: Microfossils absent. 5 in., clay shale as in core 63. 4 in., siltstone as above, with small (one-half inch or less) chips of clay shale. No cut of oil but a faint yellow residue was obtained in CCl_4. 2 ft 3 in., clay shale as above; dip 10°–20°.
66	6, 020–6, 030	Recovered 10 ft: Microfossils absent. 5 ft 8 in., clay shale as in core 63; dip approximately 15°. 4 in., siltstone as above. 4 ft, clay shale as above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
67	6, 030–6, 040	Recovered 8 ft 6 in.: Microfossils absent. Clay shale, dark-gray; many thin laminae of medium- to light-gray silty clay, lenticular in part, but not crossbedded. Noncalcareous, micaceous; poker chip cleavage; dips approximately 15°. Oil odor; straw-colored cut, brownish-yellow residue in CCl_4. Thin (one-half inch thick or less) beds of medium-light-gray crossbedded slightly calcareous siltstone with shaly cleavage are rare. Three beds of siltstone, each 1½ in. thick, between 6,037 and 6,038 ft.
68	6, 040–6, 050	Recovered 10 ft: Microfossils absent. Clay shale as above, with thinner and fewer laminae and beds of siltstone. One 2½-in. siltstone bed at 6,047 ft; one 2-in. bed at 6,048 ft.
-----	6, 050–6, 235	Clay shale as in core 68.
69	6, 235–6, 245	Recovered 8 ft 8 in.: Microfossils common. Clay shale, medium-dark-gray, slightly micaceous, slightly calcareous, well-indurated; poker chip cleavage; dip 15°. Contains laminae and rare thin (one-fourth inch thick) partly lenticular beds of medium- to light-gray slightly sandy calcareous siltstone.
-----	6, 245–6, 395	Clay shale with sandy streaks occur at 6,250 ft and 6,390 ft.
70	6, 395–6, 408	No recovery.
-----	6, 408–6, 420	Clay shale.
71	6, 420–6, 432	Recovered 5 ft 6 in.: Microfossils very rare. 4 ft 7 in., clay shale, medium-dark-gray, slightly micaceous, noncalcareous, well-indurated; laminae (commonly lenticular) of light-gray siltstone, totaling about 5 percent of rock. Dips 16°. 11 in., clay shale as above, with laminae badly distorted, possibly owing to contemporaneous deformation by slumping. (See pl. 34*B*). Laminae pinched off and folded and resemble streaky appearance of marble. Deformation greatest in bottom half; where clay to silt ratio is about 9 to 1. Upper 5 in., which contains a few nearly undisturbed layers with contorted layers between them, is about 90 percent silt.
-----	6, 432–6, 590	Clay shale as above. Sand streak at 6,560 ft.
72	6, 590–6, 605	Recovered 1 ft 6 in.: Microfossils absent. Clay shale, medium-dark-gray, slightly micaceous, noncalcareous; laminae and thin lenses of medium-light-gray partly crossbedded siltstone. Clay-

Lithologic description—Continued

Core	Depth (feet)	Remarks
		silt ratio is 10:1. Clay shale has poker chip cleavage which dips 15°–20° (deviation of hole is 4°).
-----	6, 605–6, 740	Clay shale with small amount of very fine-grained argillaceous micaceous slightly calcareous light-gray sandstone at 6,690 ft; rare siltstone.
73	6, 740–6, 750	Recovered 8 ft 6 in.: Microfossils absent. Clay shale with siltstone as in core 72.
-----	6, 750–6, 915	Clay shale; siltstone increases slightly with depth.
74	6, 915–6, 925	Recovered 8 ft 10 in.: Microfossils absent. Clay shale, medium-dark-gray, slightly micaceous, noncalcareous; poker chip cleavage; beds dip 15°. Laminae, thin lenses, and rare beds (as much as 2 in. thick) of slightly calcareous slightly sandy commonly crossbedded light-gray siltstone make up about 10 percent of core.
-----	6, 925–7, 010	Clay shale as above, with some siltstone.
75	7, 010–7, 020	Recovered 8 ft: Microfossils very rare. Clay shale, with siltstone laminae, as in core 74.

CORE ANALYSES

Sandstone from the oil-bearing beds between 2,900 and 3,050 feet was too thin bedded and friable to permit many porosity and permeability tests. Thin sandstone beds below 5,400 feet were less friable but had low porosity and permeability. Their reservoir properties were studied by Paul D. Krynine and S. T. Yuster. The following table shows both the results of their investigations and the porosity and permeability determined in the Fairbanks laboratory. The Fairbanks determinations were made by the Barnes method and with a permeameter made in accordance with API Code No. 27, second edition, April 1942, respectively.

Reservoir properties of rocks from Fish Creek test well 1

Fairbanks laboratory				S. T. Yuster				P. D. Krynine [1]					
Depth (feet)[2]	Effective porosity (percent)	Air permeability (millidarcys)	Carbonate content (percent by weight)	Porosity (percent)	Permeability (millidarcys)	Oil saturation (percent)	Water saturation (percent)	Mode of sand grains (microns)	Matrix (percent)	Calcite and dolomite cement (percent)	Mode of visible pores (microns)	Amount of visible pores (percent)	Coatings on sand grains (percent)
1,634	27.6												
1,639	32.55												
2,923	25.25												
2,970 [3]				31.1	4110	34.2	48.7						
5,481				16.9	3.4	16.7	38.5						
5,508				13.4	8.9	15.1	47.2						
5,509 P	16.05												
5,509 P	16.15							80	15	5	20–30	3	65
5,530 P	6.07	<5	26.6	9.8	5.65	19.1	54.8	70	10–15	25	20	1–2	60
5,558 P	7.67		19.35					70	30	20	<20	Trace	80
6,006 P	10.35	<5											
6,006.5				11.5	1.4	7.4	30.6						
6,008.5				12.0	0.83	10.2	32.2						
6,009 P	6.90	<5											
6,009 N	8.75	<5											

[1] Possible error of figures ±25 percent.
[2] P, plug cut parallel to bedding; N, plug cut normal to bedding.
[3] Poorly consolidated sand.

Mr. Krynine concluded that the rock studied by him was not a suitable reservoir rock because of its fine grain size and the amount of interstitial material and carbonate cement. A sample from 2,970 feet that was studied by Mr. Yuster was of poorly consolidated sand having abnormally high porosity and permeability. Other samples from beds below 5,400 feet had low porosity, permeability, and oil saturation.

Sieve analyses of sandstone sampled between 2,925 and 3,035 feet (see table following) show that the rock is very fine grained and contains a large amount of silt and clay. Because heavy oil caused the grains to stick together, in spite of attempts to clean and separate them, percentages of the coarser grain sizes (very fine grained or larger) include some aggregates of finer material. Thus, the rock actually contains somewhat more silt, and less sand, than the figures indicate.

Sieve analyses of sandstone and sandy siltstone from Fish Creek test well 1

Depth (feet)	American Society for Testing Materials sieve number						Total
	+35 coarse sand (percent)	+60 medium sand (percent)	+120 fine sand (percent)	+230 very fine sand (percent)	+325 silt and clay (percent)	−325 clay (percent)	
2,925–2,935		0.02	3.56	32.62	48.60	15.23	100.03
2,970–2,980	0.04	.07	1.36	56.88	23.75	17.15	99.25
2,990–3,000			Trace	65.2	11.0	23.8	100.00
3,007		Trace	.05	45.7	26.21	27.61	99.57
3,029		Trace	.52	52.00	18.08	28.41	99.01
3,035		.02	Trace	63.5	15.44	20.6	99.56

Specific gravity of the clay shale penetrated by the well increases gradually, although rather irregularly, with increasing depth. The few siltstone and sandstone samples are generally lighter than clay shale from a comparable depth. (See table following.)

Specific gravity of rocks from Fish Creek test well 1

Depth (feet)	Specific gravity	Rock type
2,700–2,710	2.17	Silty clay shale.
2,915–2,925	2.19	Clay shale.
2,925–2,935	2.07	Silty clay shale.
2,935–2,945	1.95	Silty clay shale.
2,945–2,950	2.09	Clay shale.
2,950–2,960	2.39	Silty clay shale.
2,960–2,970	2.08	Clay shale.
2,970–2,980	1.90	Oil-bearing sandstone.
2,980–2,990	1.99	Oil-bearing siltstone.
2,990–3,000	2.01	Oil-bearing siltstone and clay shale.
3,000–3,010	2.27	Argillaceous siltstone.
3,010–3,020	1.92	Oil-bearing siltstone.
3,020–3,030	2.25	Clay shale.
3,030–3,040	1.95	Oil-bearing argillaceous siltstone.
3,040–3,050	2.07	Oil-bearing siltstone and clay shale.
3,050–3,060	2.20	Clay shale.
3,162–3,171	2.35	Clay shale.
3,171–3,181	2.12	Silty clay shale.
3,356–3,366	2.28	Clay shale.
3,360–3,376	2.30	Clay shale.
3,376–3,386	2.11	Argillaceous siltstone.
3,576–3,586	2.28	Clay shale.
3,776–3,786	2.25	Clay shale.
3,976–3,986	2.33	Clay shale.
4,140–4,150	2.44	Clay shale.
4,340–4,350	2.34	Clay shale.
4,544–4,554	2.39	Clay shale.
4,698–4,708	2.39	Clay shale.

A study of heavy minerals by Robert H. Morris has shown that the glaucophane zone is between 2,920 and 3,030 feet and the zoned zircon zone is from 5,500 to 6,010 feet. Figure 42, compiled by him, shows the composition and abundance of heavy minerals.

OIL AND GAS

OIL AND GAS SHOWS

Oil and a small amount of gas were found in thin sandstone and siltstone beds in this test well. Dark, heavy oil is in sands from 2,920 to 3,050 feet, and lighter oil from 5,480 to 5,585 and 6,005 to 6,027 feet. At all depths, however, the oil-bearing sands are thin and separated by beds of clay shale. Formation tests of the rocks at lower intervals were unsuccessful for mechanical reasons, and the recovered fluid showed no sign of oil or gas. The upper beds, between 2,920 and 3,060 feet, yielded an average of 12 barrels of oil per day when pumped (see p. 519). The following tables give details of shows noted by Arctic Contractors' well geologist John Bollenbacher and those recorded in the Fairbanks laboratory.

Oil and gas shows from Fish Creek test well 1

Recorded in the Fairbanks laboratory		Noted by Arctic Contractors' well geologist, John Bollenbacher	
Depth (feet)	Remarks	Depth (feet)	Remarks
1,025–1,035	No cut in CCl_4.	1,023–1,035	Core bled gas.
1,635–1,645	Very faint cut in CCl_4.	1,225–1,235	Core bled gas.
2,916–2,920	Faint to strong petroliferous odor.	2,920–3,046.5	Oil zone—oil along fracture and bedding planes and in streaks and beds of siltstone and very fine-grained sandstone totaling 1 ft 8 in. of oil sand, 51 ft 10 in. oil siltstone.
2,920–3,060	Good stain of dark oil in sandstone and siltstone beds, interbedded with unstained clay shale.	5,480–5,585	Petroliferous zone of light-gravity oil in thin (2 in. to 1 ft 8 in. thick), very fine-grained silty sandstone beds separated by dark-gray hard shale. Sandstone beds total 15 percent of rock, and have fair to good fluorescence, light to very light ether cut (green by reflected light, straw colored by transmitted light); oil odor in some beds.
5,482	Fair odor, pale-yellow cut; brownish yellow-residue in CCl_4.	6,005–6,007	Strong odor, good to moderate fluorescence, light-straw colored ether cut.
5,492	Straw-colored cut; pale-yellow residue in CCl_4.	6,007–6,008	No odor, cut, or fluoresence.
5,495	Yellow cut; yellow residue in CCl_4.	6,008–6,010	Good odor; light cut; slight to moderate fluorescence.
5,501	Pale-yellow cut; pale-yellow residue in CCl_4.	6,010–6,020	Slight to moderate fluorescence.
5,508	Yellow cut; yellow residue in CCl_4.	6,026–6,027	Good odor; no cut; slight fluorescence.
5,517	Yellow cut; yellow residue in CCl_4.		
5,529	No cut, faint straw-colored residue in CCl_4.		
5,530	No cut, pale-straw-colored residue in CCl_4.		
5,534	Straw-colored cut; very pale-yellow residue in CCl_4.		
5,557	Very faint straw-colored residue in CCl_4.		
6,006	Odor of oil; pale-yellow cut; brownish-yellow residue in CCl_4.		
6,007–6,010	Slight odor of oil.		
6,010–6,020	No cut; faint-yellow residue in CCl_4.		
6,030–6,040	Oil odor; straw-colored cut; brownish-yellow residue in CCl_4.		

FORMATION TESTS

Of the five attempted tests with the Johnston formation tester, only the first was successful; on the others, the packer failed to hold or mechanical difficulties prevented the test from being completed.

Test 1, 2,925–3,060 feet.—The tester was run and the packer set at 2,925 feet, with perforated tailpipe to 2,963 feet and with the hole open to 3,060 feet. The tool was open 1 hour, during which there was a steady blow of gas for 50 minutes and a blow by heads for 10 minutes. Gas reached the surface in 15 minutes. Of 560 feet of fluid recovered, 180 feet was of heavy black slightly gas cut oil, and 380 feet was of gassy oily mud.

Test 2, 5,481–5,585 feet.—This test was unsuccessful because the tester became partly plugged and the retaining valve was held open by shale chips.

Tests 3 and 4, 5,480–5,585 feet.—These two tests were in essentially the same interval as test 2; both were unsuccessful, as the packer failed to hold each time. No indications of oil or gas were noted on either attempt.

Test 5, 6,000–6,050 feet.—The test was unsuccessful when the trip valve opened before the packer was seated.

OIL, GAS, AND WATER ANALYSES

Analyses of oil from the Fish Creek well were made by the Petroleum Chemistry and Refining Section of the U. S. Bureau of Mines, Bartlesville, Okla., and of gas and water by the National Bureau of Standards. The oil is dark, heavy, and asphaltic; road oil, lubricating oil, and diesel fuel could be obtained from it. The following table gives the results of a routine analysis of a 5-gallon sample of crude oil recovered in formation test 1 (2,925–3,060 feet). The second routine analysis was made on a 1-gallon sample recovered shortly after the well was put on the pump. Other tables give data on diesel-fuel, lubricating-distillate, and road-oil fractions of the sample from formation test 1, and of a 15-gallon sample (which contained only about 6 gallons of oil with 9 gallons of water) from the pumping test.

Analysis by U. S. Bureau of Mines of crude-oil sample from formation test 1, (2,925–3,060 ft) in Fish Creek test well 1

[General characteristics of sample: Sp gr, 0.973; sulfur, 1.92 percent; Saybolt Universal viscosity at 100°F, 2,080 sec, at 130°F, 800 sec; gravity 13.9 ° API; pour point, 25°F; color, brownish black]

Distillation, Bureau of Mines routine method

Fraction	Cut at— °C	Cut at— °F	Percent	Sum (percent)	Specific gravity [1]	Gravity ° API at 60°F	Correlation index	Aniline point (°C)	Saybolt Universal viscosity at 100°F
Stage 1.—Distillation at atmospheric pressure, 745 mm Hg. First drop, 163°C (325°F)									
1	50	122							
2	75	167							
3	100	212							
4	125	257							
5	150	302							
6	175	347	0.9	0.9					
7	200	392	1.0	1.9	0.820	41.1		50.3	
8	225	437	1.7	3.6	.845	36.0	45	50.8	
9	250	482	3.6	7.2	.861	32.8	48	52.4	
10 [2]	275	527	6.8	14.0	.874	30.4		52.3	
Stage 2.—Distillation continued at 40 mm Hg									
11	200	392	3.8	17.0	0.898	26.1	56	54.9	45
12	225	437	7.3	24.3	.909	24.2	58	56.1	54
13	250	482	6.3	30.6	.924	21.6	62	58.4	80
14	275	527	7.1	37.7	.933	20.2	63	62.0	145
15	300	572	8.4	46.1	.940	19.0	63	67.1	350
Residuum [3]			53.8	99.9	1.019	7.4		Too dark	

[1] Specific gravity at 60°F compared with water at 60°F.
[2] Distillation discontinued at 270°C (518°F).
[3] Carbon residue of residuum; 18.5 percent; carbon residue of crude, 10.4 percent.

Approximate Summary

Constituent	Percent	Specific gravity	Gravity ° API	Saybolt Universal viscosity
Light gasoline				
Total gasoline and naphtha	1.9	0.820	41.1	
Kerosene distillate				
Gas oil	16.6	.875	30.2	
Nonviscous lubricating distillate	7.8	0.904– .921	25.0–22.1	50–100
Medium lubricating distillate	10.0	.921– .935	22.1–19.8	100–200
Viscous lubricating distillate	9.8	.935– .944	19.8–18.4	Above 200
Residuum	53.8	1.019	7.4	
Distillation loss	.1			

Analysis by U. S. Bureau of Mines of crude-oil sample from 2,920–3,060 feet, recovered during pumping test of Fish Creek test well 1

[General characteristics of sample: sp gr, 0.974; sulfur, 1.15 percent; Saybolt Universal viscosity at 100°F, 3,650 sec, at 130°F, 1,150 sec; gravity, 13.8°API; pour point, 15°F; color, brownish black]

Distillation, Bureau of Mines Routine Method

Fraction	Cut at— °C	Cut at— °F	Percent	Sum (percent)	Specific gravity [1]	Gravity ° API at 60°F	Correlation index	Aniline point (°C)	Saybolt Universal viscosity at 100°F
Stage. 1—Distillation at atmospheric pressure, 743 mm Hg. First drop, 171°C (340°F)									
1	50	122							
2	75	167							
3	100	212							
4	125	257							
5	150	302							
6	175	347							
7	200	392	1.1	1.1					
8	225	437	1.9	3.0	0.839	37.2		50.0	
9	250	482	3.0	6.0	.863	32.5	49	57.6	
10	275	527	7.1	13.1	.877	29.9	50	50.6	
Stage. 2—Distillation continued at 40 mm Hg									
11	200	392	2.6	15.7	0.896	26.4	55		45
12	225	437	10.2	25.9	.913	23.5	60	50.6	60
13	250	482	6.1	32.0	.928	21.0	64		105
14	275	527	5.6	37.6	.937	19.5	65		180
15 [2]	300	572	9.8	47.4	.941	18.9			Over 400
Residuum [3]			49.8	97.2	1.015	7.9			

[1] Specific gravity at 60°F compared with water at 60°F.
[2] Distillation discontinued at 298°C (568°F).
[3] Carbon residue of residuum, 18.9 percent; carbon residue of crude, 9.8 percent.

Approximate summary

Constituent	Percent	Specific gravity	Gravity °API	Saybolt Universal viscosity
Light gasoline				
Total gasoline and naphtha				
Kerosene distillate				
Gas oil				
Nonviscous lubricating distillate	16.6	0.872	30.8	
Medium lubricating distillate	11.5	0.901–.926	25.6–21.3	50–100
Viscous lubricating distillate	7.4	.926–.938	21.3–19.4	100–200
Residuum	11.9	.938–.943	19.4–18.6	Above 200
Distillation loss	49.8	1.015	7.9	
	2.8			

Data on diesel fuel from Fish Creek crude oil

[Analysis by the U. S. Bur. Mines]

Characteristics	Sample from formation test	Sample from pumping test
Yield of crude oil ... percent by volume	40.0	36.7
Distillation, by ASTM method D-158:		
Initial boiling point ... °F	400	411
10 percent evaporated ... °F	501	484
50 percent evaporated ... °F	611	582
90 percent evaporated ... °F	704	679
end point ... °F		718
Specific gravity (at 60°F, compared with water at 60°F)	0.902	0.900
Gravity ... °API	25.4	25.7
Sulfur ... percent by weight	1.17	1.00
Saybolt Universal viscosity at 100°F	67.1	48.5
Saybolt Universal viscosity at 130°F	52.5	40.6
Cetane No	38	38
Aniline point ... °C	59.1	54.5
Aniline point ... °F	138.4	130.1
Pensky-Martin flash point ... °F	215	194
Corrosion test, ASTM method D-138 (copper strip, 3 hr at 212°F)	negative	negative
Cloud point ... °F	below −76	below −80
Pour point ... °F	−50	below −80
Bromine No	8.8	6.9
Olefins ... percent by volume [1]	14.6	10.8
Aromatics ... percent by volume	26.6	26.3

[1] Based on bromine number and probably not a true representation of olefins, because of the high sulfur and aromatic content, both of which react with bromine under certain conditions.

Data on lubricating distillate from Fish Creek crude oil

[Analysis by the U. S. Bur. Mines]

Characteristics	Distillate cuts [1] Cut 1	Cut 2	Cut 3
Yield of crude oil ... percent by volume	9.0	9.0	9.0
Specific gravity (at 60°F, compared with water at 60°F)	.9352	.9489	.9550
Gravity ... °API	19.8	17.6	16.7
Sulfur ... percent by weight	1.57	1.72	2.02
Saybolt Universal viscosity at 100°F	787	2074	3670
Saybolt Universal viscosity at 130°F	298	664	1093

[1] Prepared by distilling (topping) 40.0 percent of the crude oil prior to obtaining cut 1. Cuts 2 and 3 were then made successively.

Data on road-oil residue from Fish Creek crude oil

[Analysis by U. S. Bur. Mines]

Characteristics	Designation of sample from formation test, in percent of residium [1]				Designation of sample from pumping test, in percent of residium [2]			
	100	85	70	55	100	85	70	55
Yield of crude oil ... percent by volume	60. 0	51. 0	42. 0	33. 0	63. 3	53. 8	44. 3	34. 8
Specific gravity [3]	1. 007	1. 018	1. 036	1. 056	. 999	1. 009	1. 019	1. 033
Gravity ... °API	9. 0	7. 5	5. 1	2. 5	10. 1	8. 7	7. 4	5. 5
Sulfur ... percent by weight	2. 47	2. 61	2. 81	3. 05	--------	--------	--------	--------
Viscosity, Furol seconds:								
at 180°F	468	880	4, 584	--------	434	1, 186	4, 194	--------
at 210°F	157	248	1, 100	13, 860	171	410	1, 380	2, 720
Carbon residue, Conradson ... percent by weight	15. 8	20. 5	25. 9	31. 1	--------	--------	--------	--------

[1] Oil designated as 100 percent of residuum was the total residuum after distilling 40 percent of the crude oil off to prepare a diesel fuel. The figures 85 percent, 70 percent and 55 percent refer to the percentage of the residuum and correspond to removal by distillation of equal successive increments of 9.0 percent of the crude oil.
[2] Oil designated as 100 percent of residuum was the total residuum after distilling 33.7 percent of the crude oil to prepare a diesel fuel. The figures 85 percent, 70 percent, and 55 percent refer to the percentage of the residuum and correspond to removal by distillation of equal successive increments of 9.5 percent of the crude oil.
[3] Specific gravity at 60°F compared with water at 60°F

The gas is almost entirely methane; the percentage of butane isomers was not determined individually because there seemed to be some acetone in the sample (presumably contamination from the glass container), and this interfered with identification of the butanes. The gas analysis is shown in the following table.

Analysis of gas [1] from Fish Creek test well 1

[Analysis be Natl. Bur. Standards]

Component	*Mol percent*
Methane	99. 0
Nitrogen	. 49
Ethane	. 16
Butanes	. 08
Ethylene	. 06
Oxygen	. 05
Pentane	. 05
Propane	. 04
Argon	. 03

[1] Heating value, calculated, 997 Btu per cu ft; sp gr, 0.560.

The water, described as a turbid, dirty gray liquid, was filtered after determining the pH and before making the rest of the analysis. Sodium and chlorine radicals were predominant impurities in the water. The analysis is shown in the following table.

Analysis of water [1] from Fish Creek test well 1

[Analysis by Natl. Bur. Standards]

Radicals	*Parts per million*
Sodium	4, 286
Calcium	49. 3
Magnesium	18. 8
Sulfate	26. 7
Chloride	6, 596
Carbonate	-------
Bicarbonate	208
Iodide	25
Silica	21
Boron	(2)
Total	11, 231

See footnotes at end of table.

Analysis of water [1] from Fish Creek test well 1—Continued

Components	*Percent*
Alkalies	38. 21
Earths	. 61
Strong acids	59. 34
Weak acids	1. 84
Calcium earths	. 72
Chloride salinity	97. 14
Sulfate	. 34
Chemical character	*Percent*
Primary salinity	97. 35
Secondary salinity	. 28
Primary alkalinity	------
Secondary alkalinity	2. 37

[1] Specific gravity of sample at 25°C compared with water at 25°C, 1.0073; pH, 7.3; carbonate to chloride ratio, 0.0315.
[2] Very small amount.

LOGISTICS

Transportation.—Freighting of supplies and equipment to the site of Fish Creek test well 1 began on January 31, 1949. It was started earlier than usual for overice freighting because of an early freezeup and exceptionally good ice conditions. About 80 percent of the route from Barrow camp to Fish Creek was on ocean ice; it followed the coast, crossing bays and turning inland from Harrison Bay south of Atigaru Point. A crew was sent in early February to help unload the tractor trains. Careful stacking of material and accurate inventory speeded construction and prevented mislaying needed supplies. A carefully prepared 15-mile trail from the ocean to the well site was used uninterruptedly until April 4, 1949; during this time 14 tractor trains had brought 2,468 tons of material to the site.

Housing.—Camp construction was begun on March 15, 1949, by pile-driver and carpenter crews. The camp was built first, and by April 15, 2 quonset huts for galley and warehouse, 10 jamesway huts for sleeping quarters, a utility wanigan, and a lavatory wanigan

were in use. A jamesway hut for recreation and a galley storage wanigan connected to the galley were added later. The galley quonset had complete plumbing facilities, including hot water from a Heat-Pak boiler and a pressure system which also supplied steam for heating the galley and utility buildings. Drainage from the buildings was piped away from the area through heated insulated lines.

The camp buildings were set on short pilings, and walkways of scrap lumber connected them to a camp street and thence to the rig. Using the walkways and reducing the use of vehicles in the camp area as far as possible kept the site from becoming a morass when the ice and snow melted and the tundra thawed.

Rig construction began on April 1. A 50-horsepower Kewanee boiler with a thaw-point manifold capable of operating 6 steam points had been mounted in a wanigan at Barrow. With this to thaw the ground, the pile-driver crew drove about 1,110 pilings, 5–20 feet long, in 6 days. Rig foundations were completed by May 1, and rigging up (including installation of a power wanigan, a geologic and engineering office wanigan, and a garage of canvas-covered frame construction) was completed on May 18.

Personnel.—A drilling foreman, a petroleum engineer, and a geologist supervised drilling. In addition to the rig crews (2 drillers, 2 derrickmen, 6 floormen, 2 heavy-duty-equipment mechanics, and 2 firemen), an electrician, a carpenter, 2 tractor operators, a janitor-oiler, a warehouseman, a timekeeper, 2 cooks and 2 cooks' helpers worked at the well site. A cementer and a Schlumberger operator visited the well when their services were needed.

Vehicles and heavy equipment.—Seven vehicles were kept at the well site: a D8 Caterpillar tractor with bulldozer blade, 2 weasels, a D6 Caterpillar tractor with bulldozer blade, a T–9 crane (cherry picker), a Northwest crane, and an LVT. The D8 Caterpillar tractor was used to haul water, and the LVT was used for trips to the coast. Important items of drilling equipment used at the well were listed by Arctic Contractors as follows:

1---------- National 50 drilling rig powered by 2 D13000 Caterpillar engines.
1---------- Gardner Denver 7½- by 10-in. pump powered by a D13000 Caterpillar engine.
1---------- National C–250 slush pump powered by a GMC quad diesel engine.
1---------- Emsco 200-ton crown block.
1---------- Byron-Jackson 125-ton hook.
1---------- Ideal type D swivel.
1---------- Ideal 17½-in. rotary table.
1---------- Baash-Ross square kelly.
1---------- Shaffer double-gate blowout preventer.
1---------- Kewanee 25 hp boiler.
1---------- Link-Belt 48- by 60-in. shale shaker.
2---------- 140-bbl steel suction tanks.
3---------- 2500-gal water tanks.

Fuel, lubricant, and water consumption.—Fuel was supplied to the camp and rig by gravity flow from a centrally located fuel tank. Water was brought to the site in a 2,500-gallon water wanigan hauled by a D8 tractor. The first water source was a lake about a mile from the rig, but after thawing started, a small creek about 500 yards west of the camp furnished an adequate supply. Consumption of water and petroleum products was as follows: 955,000 gallons of water, 52,541 of diesel fuel, 2,815 of gasoline, 1,573 of lubricating oil, 663 pounds of grease, and 230 pounds of thread lubricant, which was used during the last half of the operation.

DRILLING OPERATIONS

The drilling rig was set on a foundation of pilings; the cellar was of concrete, reinforced with steel matting. The derrick was enclosed, and the righouse was constructed with canvas panels prefabricated in Barrow camp. The righouse roof was of 2- by 12-inch T-beams covered with tarpaulins.

DRILLING NOTES

The following drilling operations were recorded by C. S. Roberts, Arctic Contractors petroleum engineer.

Notes from drilling records

Depth (feet)	*Remarks*
46	Fifteen sacks of Oil Well cement mixed with 15 sacks of sand were used to cement 20-in. Naylor spiral-weld 48-lb casing at 46 feet.
194	Weather turned cold, and mud lines froze. Operations suspended for 5 days to complete righouse roof and thaw pipes. While reaming hole, circulation broke around 20-in. casing, which slipped down hole. Conductor pipe was recovered and recemented, and circulation regained. Sixteen-inch outer diameter Western Pipe and Steel 42-lb 5/16-in. welded-plate slip-joint casing was cemented at 193 feet with 90 sacks of Hi-Early cement.
1,046	After reaming hole, 11¾-in. J–55 47-lb A. O. Smith 8 round thread casing was set at 1,046 ft and cemented with 125 sacks of Hi-Early construction cement mixed with water heated to 90°F and treated with 2 percent calcium chloride.
3,060	Following first formation test, rubber packers were lost in hole. When packers were drilled up, rubber caught in flow pipe and was removed through window cut in flow line.
5,585	After unsuccessful second formation test, hole was cleaned out and prepared for third test.

Notes from drilling records—Continued

Depth (feet)	*Remarks*
7,020	When total depth was reached, hole was plugged back, and a sidetracked hole was drilled from 2,552 to 3,018 ft to test sandstone beds near 2,900 ft. Seven-inch casing (23-lb J–55 Youngstown 8 round thread API seamless) was set at 2,915 ft and cemented with 173 sacks of Portland construction cement, 12 sacks of Hi-early, and 60 sacks of Oil Well cement, mixed with 2 percent calcium chloride and enough water, heated to 60°F, to make 114-lb slurry. When cement was set, hole was drilled and underreamed to 3,018 ft, and gravel-packed liner was installed. Liner consisted of 126 ft of 4½-in. 11-lb 1,200-lb test API seamless line pipe with a Brown liner shoe on bottom. Liner was hung at 2,891 ft, with a 6-in. outer-diameter Brown pack-off hanger, and perforated from 2,918 to 3,017 ft with 8 rows of ½-in. drilled holes on 2⅞-in. centers, staggered, and covered with 4½- by 6-in. outer-diameter Nelson gravel prepack sleeves. Ran 2½-in. tubing (6.5-lb external upset H–40 range 2 seamless) with pump shoe and swab stop on bottom to 3,015 ft. After changing mud to water, tubing was pulled back to 2,860 ft and swabbed. Hourly swabbing caused a gradual fluid rise to about 2,400 ft.
	After swabbing for 2 days, pumping equipment was brought from the LCM on the beach and a pump and 285 10-ft rods were installed. Well was pumped from 10th to 20th of September; production decreased from 27 to 10½ bbl of oil per day, averaging about 12 bbl. Water accompanied oil on first day; no water produced thereafter, and pump was removed. Fluid level, estimated at 2,800 ft during pumping, rose to 2,400 ft in about 26 hr, and a hundred feet higher after 8 hr more. Bailer run to bottom of liner was two-thirds full of muddy water after first trip, and full of oil, with no water, sand, or silt, after second. Tubing and pump reinstalled on September 22, at 11:40 a. m. Fluid reached surface at 1:05 p. m. and was mostly clear water with stain of oil until 5:10 p. m., when it became clean oil. Small amount of gas came through 7-in. casing. On 23d and 24th of September 18 bbl of oil with 15 of water, and 12 bbl of oil with no water was pumped, respectively; well averaged 9–12 bbl daily through October 15. Tubing and pump again removed, and well bailed intermittently until October 25. Final well-head installations, from bottom up, are a Shaffer 11¾-in. plate landing base, a Shaffer 11¾-in. full-opening landing spool with 2-in. line-pipe side connections; Shaffer tubing head; swage; 3-in. Hughes 3,000-lb threaded flow-line valve.

DRILL AND CORE BITS

Most of the cores were taken by wire line, using the A-1 7⅝-inch core barrel and ten 7⅝-inch Universal rock bits. A few cores below 6,300 feet were taken with 3 Hughes conventional bits, because the wire line equipment could not be used inside the 3-inch drill pipe employed below that depth. The conventional bits had very poor recovery, however; so the lowest cores were taken with the wire line core barrel installed before running the drill pipe in the hole.

Thirty-eight bits in 8 sizes were used to drill the test, including the sidetracked hole. Most were Security or Reed rock bits, but two Globe bits were used in reaming the upper part of the hole. Used bits showed little wear on the teeth, but the bearings were badly worn. Core and drill bits used are listed on the graphic log (pl. 32).

DRILLING MUD

The rock drilled included some bentonite and a large amount of shale, which made very good mud. Silty beds furnished large amounts of abrasive silt which increased mud weight, but adding water reduced the weight and lowered the viscosity, and the silt settled out in the tanks. The C–250 mud pump furnished enough velocity to flush the hole and maintain it in good condition with low-viscosity mud.

After the hole was plugged back, the mud was diluted with water to counteract cement contamination. This also resulted in the light-weight mud desired for subsequent operations. Driscose and Aquagel were added after setting 7-inch casing to provide low-weight, low-viscosity, low-water-loss mud for drilling through the producing sands. The total additives used in the well were 220 sacks of Aquagel, 50 sacks of Baroid, 6 sacks of pyrophosphate, 2 sacks of quebracho, and five 50-pound sacks of Driscose. The following table is a week-by-week summary of the mud characteristics and the additives used.

Summary, by weeks, of drilling-mud characteristics and additives in Fish Creek test well 1

Depth (feet)	Weight (lb per cu ft)	Viscosity (secs)	Water loss (cc per 30 min)	Temperature (°F)	Additives
0– 184	--------	--------	--------	--------	18 sacks Aquagel.
194– 355	76–78	--------	--------	--------	12 sacks Aquagel.[1]
355–1,268	--------	--------	--------	--------	No record.
1,268–2,950	74–76	38–44	3–6	--------	75 lb pyrophosphate.
2,950–3,786	76–82	35–40	3–4	--------	75 lb pyrophosphate.
3,786–4,554	76	34	7	77–82	10 sacks Aquagel.
4,554–5,175	83–78	35–40	--------	--------	10 sacks Aquagel, 75 lb pyrophosphate.
5,175–5,585	83	38–42	5	86	40 lb pyrophosphate.
5,585–5,810	--------	--------	--------	--------	16 sacks Aquagel, 15 sacks Baroid, 30 lb pyrophosphate.
5,810–6,168	84–86	--------	--------	--------	Only water added.
6,168–6,431	--------	--------	--------	--------	Only water added.
6,431–6,729	82	40	8	86	Only water added.
[2] 6,729–7,020	80–82	--------	--------	--------	10 sacks Aquagel.

[1] Changed mud after setting casing.
[2] After 7,020 ft was reached, the hole was plugged back to 2,552 ft, and a sidetracked hole was drilled and casing set at 3,018 ft. Cement used in these operations contaminated the mud. Additives used to correct it are not shown on this chart.

HOLE DEVIATION

Above 6,000 feet, measurements with the Totco (Technical Oil Tool Co.) Recorder indicated very little deviation from vertical. Most of the readings were less than 1°, and only 3 were above 1°. Below 6,000 feet the hole was too small for the Totco instrument, and an Eastman directional survey was made. Deviation and direction measured with the Eastman tools are shown in the following table; the increase in deviation, which is 3°–4° below 6,000 feet, was seemingly caused by more steeply dipping beds. The sidetracked hole, begun at 2,552 feet in a vertical hole, increased from 3° off vertical at 2,572 feet to 8°45′ at 2,855 feet.

Direction of deviation, lower part of Fish Creek test well 1

Depth (feet)	Deviation	Direction
6, 000	0°55′	N. 20° E.
6, 200	3°00′	N. 02° E.
6, 400	3°30′	N. 15° E.
6, 580	3°55′	N. 25° E.
6, 600	4°00′	N. 25° E.
7, 000	3°40′	N. 37° E.

ELECTRIC-LOG AND VELOCITY SURVEYS

Sled-mounted hand-recording Schlumberger equipment was used to make the 8 electric-log runs needed to log the well from 187 to 7,013 feet. The unusually high resistivity shown by the upper part of the resistivity curve (which decreases irregularly from 130 ohms at 195 feet to 5 ohms at 600 feet) is caused by permafrost, which increases the resistivity of the rock. The spontaneous potential curve is also slightly affected by the frozen ground. Two runs were made in the side-tracked hole, and an additional run was made in the original hole through the oil-producing beds at 2,900–3,060 feet. The second run showed very little penetration of the rock by mud in the 19 days since the rock in that interval was first logged. The runs are listed in the following table, and runs 1–8 are shown on the graphic log (pl. 32).

Electric-log runs in Fish Creek test well 1

Run	Depth (in feet)
1	187–1, 031
2	1, 047–2, 291
3	2, 291–3, 060
4	3, 060–4, 147
5	4, 147–5, 079
Rerun	2, 900–3, 060
6	5, 079–5, 581
7	5, 581–6, 046
8	6, 046–7, 013
9	2, 500–2, 910
10	2, 915–3, 002

United Geophysical Co., Inc., used a shot hole 1,320 feet from the well to make a velocity survey. The average velocity recorded in the well was about 8,000 feet per second at 1,000 feet, increasing to 9,000 feet per second near 7,000 feet. Beds above 600 feet had a velocity of 9,476 to 9,833 feet, reflecting the presence of permafrost near the surface.

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