Test Wells, Umiat 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-B

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

Test Wells, Umiat Area Alaska

By FLORENCE RUCKER COLLINS

With Micropaleontologic Study of the Umiat Field, Northern Alaska
By HARLAN R. BERGQUIST

And sections on Temperature Measurement Studies
By MAX C. BREWER

And Core Analyses, Umiat Test Well 9
By GEORGE L. GATES, United States Bureau of Mines

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TEST WELLS, UMIAT AREA, ALASKA

By Florence Rucker Collins

ABSTRACT

The Umiat anticline, in the southeastern part of Naval Petroleum Reserve No. 4, northern Alaska, was first mapped in 1944, and has been tested by drilling 11 holes, 7 of which produced some oil. Umiat test well 1, a 6,000-foot hole west of the producing area, was the first exploratory test drilled. It was spudded by United States Navy personnel in 1945, as part of the petroleum exploration program in the Naval Petroleum Reserve. Like other wells on the anticline, it was drilled through rocks of the Colville and Nanushuk groups and the Topagoruk and Oumalik formations, all of Cretaceous age. Umiat test well 2, the deepest hole (6,212 feet), was located structurally high on the anticline but produced no oil. Umiat test well 3, the shallowest well (572 feet), produced only a small amount of oil, and drilling in the area was discontinued for nearly 2 years.

The introduction of cable-tool rigs in 1950 resulted in five oil wells, which produced primarily from sandstones of the Grandstand formation. The use of oil-base mud in the drilling of a sixth oil well corroborated the theory that water-base mud reduced permeability and prevented oil production in Umiat test well 2. Two holes which produced only water were located north and south of the productive area, in structurally low locations.

This report includes geologic and engineering data obtained in drilling 11 tests; much of the material is presented graphically.

INTRODUCTION

Between 1944 and 1953 the United States Navy conducted an extensive exploration program in Naval Petroleum Reserve No. 4, northern Alaska, in order to arrive at an estimate of the possible petroleum reserves of the region. The United States Geological Survey, as a cooperating agency, studied the geology of the area both in the field and laboratory; Arctic Contractors, under contract to the Navy, drilled test wells and core tests in many localities throughout the Reserve (fig. 7).

The Umiat area is located in the southeastern part of the Reserve on the north side of the Colville River, west of the bend where the river changes its easterly course and flows north into the Arctic Ocean. It is within the Northern foothills section of the Arctic foothills physiographic province. The area has a maximum relief of about 500 feet that consists of discontinuous erosion-resistant sandstone ridges alternating with valleys in less resistant rocks. The Colville River and its valley are the only large stream and extensive lowland in the area. The ground is permanently frozen below the tundra to a depth of about 900 feet, except under the Colville River flats where the permafrost is approximately 770 feet thick.

The Umiat anticline is about 10 miles long and 3 miles wide, trends east, and has more than 800 feet of closure. It is the highest part in a structural trend extending many miles beyond the limits of the closed anticline. Its limits were defined by field and photogeologic mapping. Two seismic profiles across the anticline, run by United Geophysical Co., Inc. in 1946 show a reversal of dip and suggest the presence of faults in the shallow reflecting horizons. Drilling has revealed evidence of reverse faulting in several holes, with duplication of as much as 775 feet of beds. Near the axis of the anticline, no reflections were recorded from beds below 1,500 feet. Magnetometer and gravity surveys of the Reserve show a magnetic anomaly of unusual intensity coinciding roughly with the Umiat anticline and with a small gravity low in the same area.

Eleven wells were drilled on Umiat anticline between 1945 and 1952 to determine the production possibilities. Umiat test wells [1] 1 and 7 [1] were too low structurally to produce oil; sandstones in Umiat test well 11, on the downthrown northern flank of the anticline, contained water. Umiat test well 2, although located near the crest of the anticline, was a dry hole, probably because it was drilled with fresh-water drilling mud which reacted with the argillaceous material (predominantly montmorillonite) in the sandstone, making it impermeable to oil. The other wells all produced some oil from the Grandstand formation, with a very minor amount

[1] Since some of the earlier Umiat wells were drilled, their names were changed for easier reference: Umiat test well 3 was originally Umiat core test 1, and Umiat test wells 4, 5, 6, and 7 were known as Umiat (Ruby) test wells 1, 2, 3, and 4, respectively.

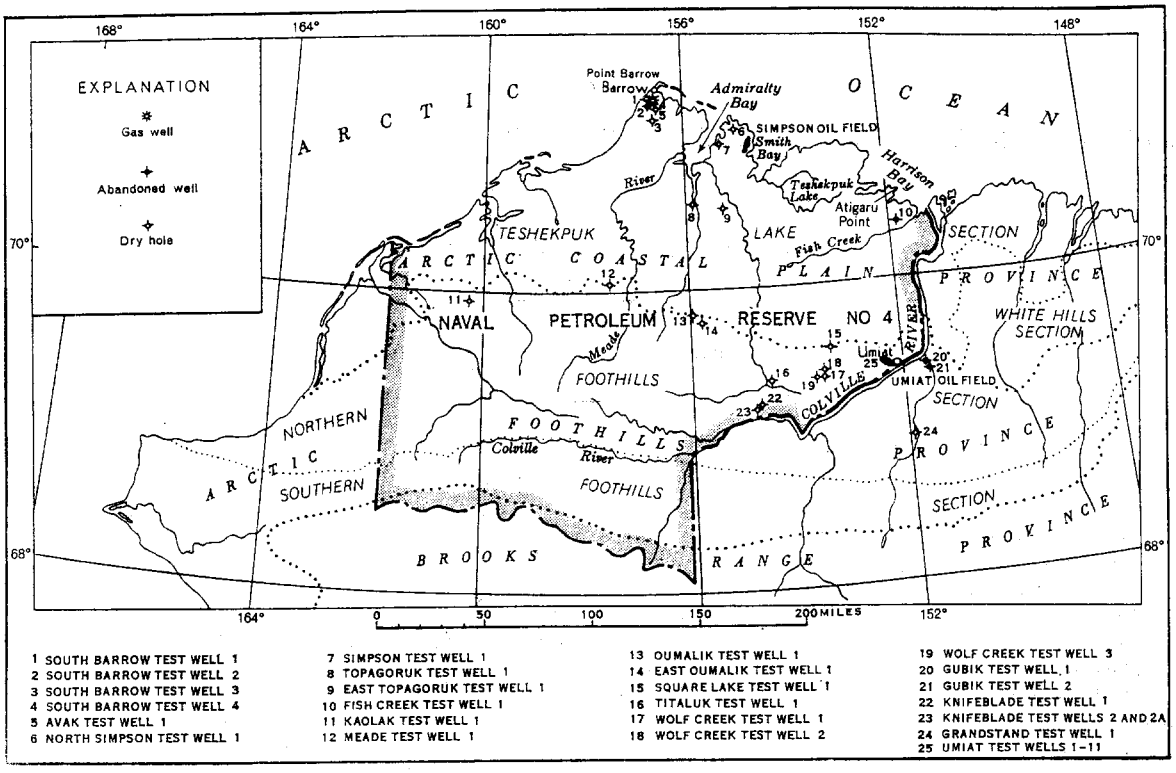


FIGURE 7.—Index map of northern Alaska showing locations of test wells and oil fields.

from sandstones in the overlying formations. The oil is green, has an API gravity of about 36°, and contains a high precentage of napthenes, gasoline with a pour point of −80°F., and diesel fuel. Umiat test well 8 produced a moderate amount of gas. All of the test wells have been shut in or abandoned.

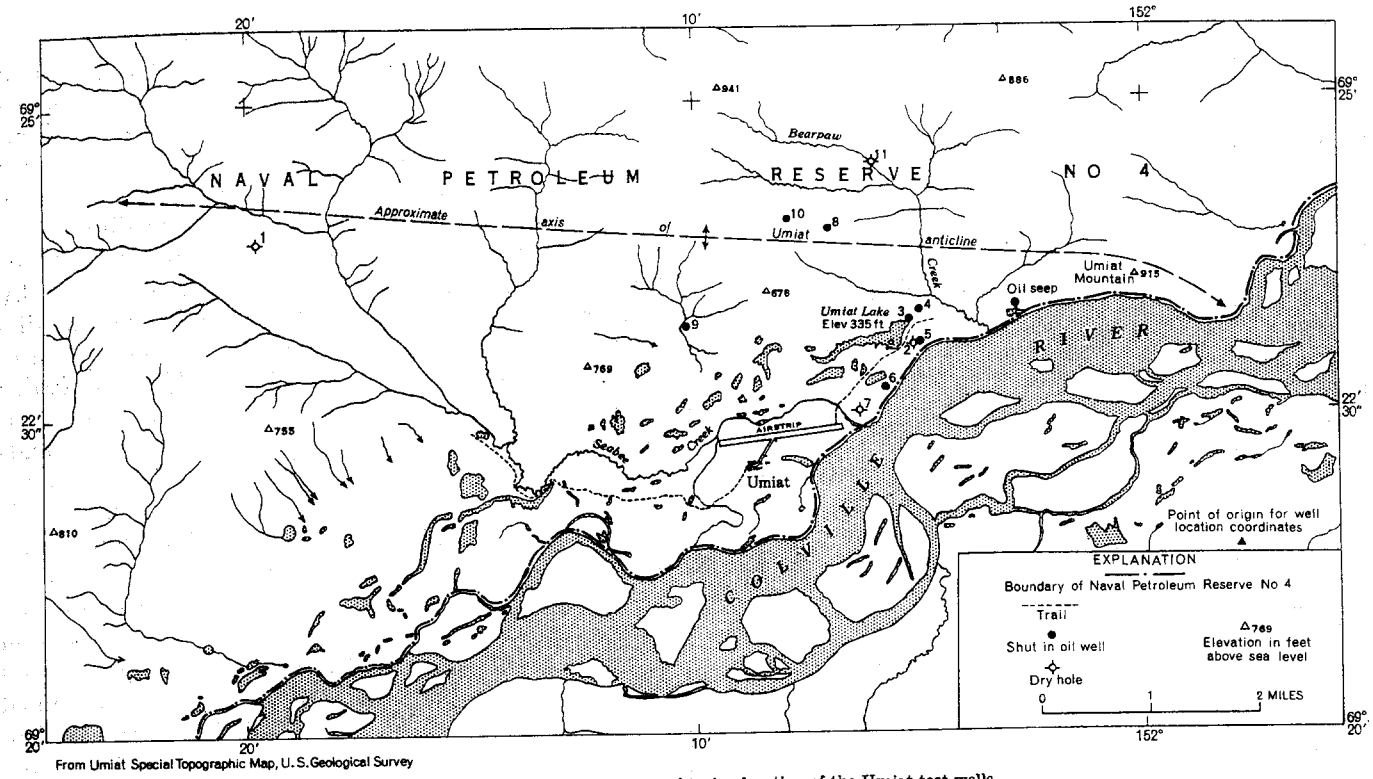
Because maps of the area lacked accurate horizontal and vertical control when the wells were drilled, the latitude and longitude used in this paper have been calculated from the position of Umiat test well 2 as plotted on the Umiat special topographic map published in 1948 by the U. S. Geological Survey. The well sites shown on figure 8 have been located, with the aid of aerial photographs and accurate measurements by Arctic Contractors, on the same base. The following table gives the distance in feet between an arbitrary point of origin (shown on fig. 8) about 4 miles east and a little south of Umiat and the well sites. This coordinate system was established by Arctic Contractors to locate the wells accurately in relation to each other. Elevations of the wells have been accurately determined with respect to each other, although they are only approximate in relation to sea level.

This report presents detailed geologic and engineering data obtained in drilling the 11 Umiat test wells. Technical data were compiled from reports made for the U. S. Navy by Arctic Contractors, United Geophysical Co., Inc., The Schlumberger Well Surveying Corp., and the U. S. Geological Survey. Results of special studies by the United States Bureau of Mines and the National Bureau of Standards are also included. The help of many engineers, geologists, and geophysicists connected with these organizations is gratefully acknowledged.

Distance of test wells from an arbitrary point (see fig. 8) measured along west and true north coordinates

Umiat test well	Distance west (feet)	Distance north (feet)
1	47, 999	14, 901
2	16, 317	10, 048
3	16, 783	11, 304
4	16, 037	11, 728
5	16, 143	10, 145
6	17, 714	7, 986
7	18, 936	6, 890
8	20, 433	15, 627
9	27, 432	11, 112
10	22, 422	16, 137
11	18, 364	18, 734

Cores and cuttings were examined by Thomas G. Roberts and the author, and unless otherwise noted porosity and permeability were also determined in the U. S. Geological Survey laboratory in Fairbanks, Alaska. Additional core analyses were made by Paul D. Krynine, and heavy-mineral studies were made by R. H. Morris. Microfossils were identified by Harlan R. Bergquist. The stratigraphic distribution of fossils in the test wells of northern Alaska will be presented



From Umiat Special Topographic Map, U.S. Geological Survey

FIGURE 8.—Map of the Umiat area showing location of the Umiat test wells.

by him in another chapter of this professional paper. Reports on thermal investigations were made by Max C. Brewer.

STRATIGRAPHY

Except for unconsolidated Quaternary sediments, the rocks drilled in the Umiat area are Cretaceous in age (see fig. 9); the Cretaceous nomenclature used in this report is discussed by Gryc, Patton, and Payne (1951) and by Gryc and others, (1956). The rocks consist almost entirely of clay shale and sandstone, with rare bentonite, clay ironstone, and coal in the upper part of the sequence; some of the formations contain diagnostic microfaunal assemblages. Formation boundaries are based on lithologic and paleontologic evidence and on correlation of beds between wells.

QUATERNARY DEPOSITS

Unconsolidated sand and gravel present in many test wells are probably alluvial deposits of the Colville River and Bearpaw Creek; they are Recent(?) in age. Both sand and gravel consist of subround to rounded grains of yellow, white, and black chert and clear quartz, in beds from a few feet to 80 feet thick. The sand and gravel are absent in Umiat test well 1 and others that are located away from stream valleys.

CRETACEOUS ROCKS

COLVILLE GROUP

TULUVAK TONGUE OF THE PRINCE CREEK FORMATION

The youngest Cretaceous rocks found in the subsurface of the Umiat area are a part of the Tuluvak tongue of the Prince Creek formation (Late Cretaceous) which was penetrated only by Umiat test well 11.

The formation is dominantly a nonmarine sequence, is about 500 feet thick (22–545 ft), and contains 5- to 40-foot beds of sandstone and siltstone, with interbedded shale, coal, and bentonite. The sandstone is light gray and consists of very fine angular grains of clear and white quartz with some silt and clay; many beds are slightly to very bentonitic. The siltstone is similar in composition to the sandstone. Most of the shale is medium light gray and bentonitic; claystone with conchoidal fracture is also present. White or yellowish-white bentonite beds a few inches thick are common; the largest beds, 7 feet and 5 feet thick, occur at 488 and 502 feet, respectively. The coal is black and shiny, and has blocky to shaly fracture; beds a few inches to 3 feet thick are common in the upper 100 feet and between 300 and 500 feet.

Marine deposits are rare, but some beds of shale (70–80, 146–156, and 420–430 ft) contain a sparse

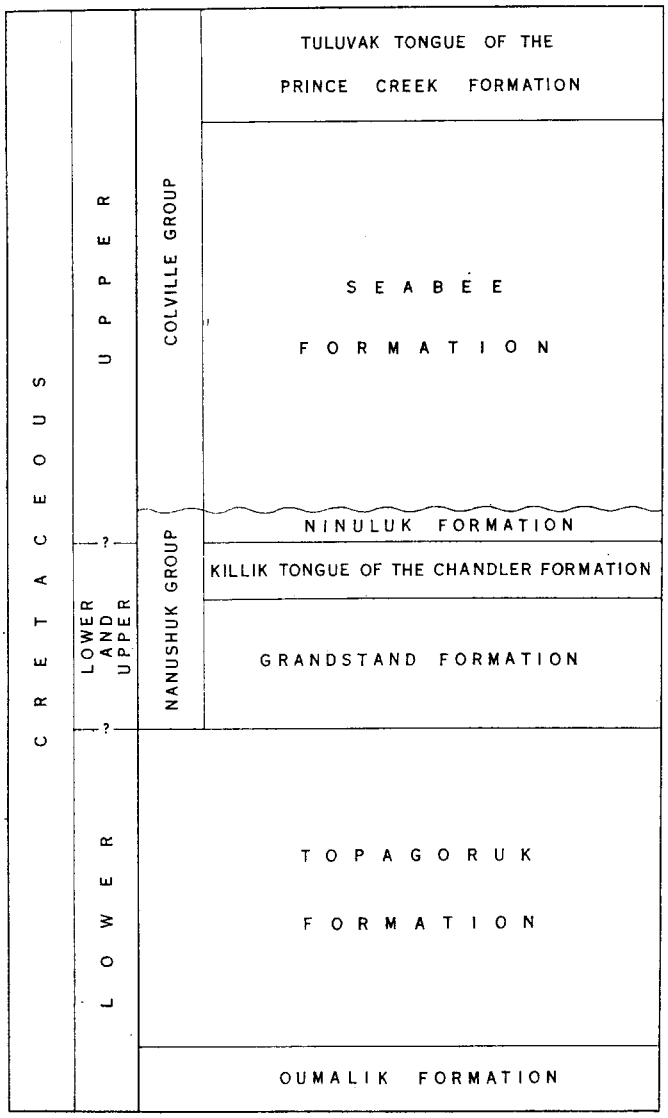


FIGURE 9.—Cretaceous rocks in the Umiat area, northern Alaska.

microfauna indicative of a shallow-water marine environment. In Umiat test well 11, these beds are the only representative of the Schrader Bluff formation, which is the marine equivalent of the nonmarine Tuluvak tongue.

SEABEE FORMATION

The marine Seabee formation (Late Cretaceous) is about 1,500 feet thick in Umiat test well 11, the only hole in which the formation is complete. The upper part consists of 190 feet of bentonitic medium-gray clay shale underlain by a 55-foot bed of fine-grained silty slightly bentonitic medium-light-gray sandstone. The shale contains Foraminifera and rare minute fragments of fishbones. These beds are probably equivalent to the sandy Ayiyak member, the uppermost part of the Seabee formation, of the outcrop. The 300 feet of shale immediately below the 55-foot sandstone unit is similar to that overlying the sandstone but is in turn underlain by shale which is darker, harder, and nonbentonitic. About 1,000 feet below the sandstone is a 200-foot unit consisting of a series of medium-light-gray very fine- to fine-grained sandstone beds 5–55 feet thick and separated by thin beds of clay shale. This in turn is underlain by 300 feet of medium-dark-gray clay shale, and at the base is another, 230-foot group of sandstone and siltstone beds separated by thinner beds of clay shale. Both sandstone and siltstone are characterized by scattered plates of biotite which may be common to abundant. The sand grains are subangular clear quartz with a small amount of white quartz and other rock fragments, and the sandstone is commonly "dirty," containing a large amount of silt, clay, and micaceous particles. Bentonite is more common than in the underlying Nanushuk group, though less abundant than in the Tuluvak tongue.

Specimens of an ammonite, *Borissiakoceras* sp., were found in the lower part of the Seabee formation in Umiat test wells 1 and 11; cores between 400 and 600 feet above the base of the formation contained *Inoceramus* cf. *I. labiatus* Schlötheim. Minute fishbone fragments are typical of the Seabee formation, and some Foraminifera are also present in the lower part of the formation.

NANUSHUK GROUP

NINULUK FORMATION

The shallow-water marine Ninuluk formation (Late Cretaceous) is represented by about 100 feet of medium-light-gray fine-grained sandstone, underlain by about 20 feet of siltstone and clay shale. One or two thin beds of clay shale divide the sandstone section in most of the Umiat test wells; in Umiat test well 1, however, this unit consists partly of siltstone. The clay shale beds are also somewhat thicker than they are in the more easterly wells. Clay ironstone is present in the sandstone in some wells; the lower shale and the uppermost part of the formation contain *Trochammina rutherfordi* Stelck and Wall in Umiat test wells 6 and 10.

KILLIK TONGUE OF THE CHANDLER FORMATION

The Killik tongue of the nonmarine Chandler formation (Early and Late Cretaceous) is 260–280 feet thick in the Umiat area. It consists of interbedded silty sandstone, siltstone, clay shale, and claystone in beds 5–25 feet thick, with thin beds of coal and rare bentonite in the upper part. The sandstone is medium light gray, very fine to fine grained, silty, argillaceous, sericitic, and rarely calcareous. It is composed of angular to subangular grains of white and clear quartz, with rare dark rock fragments, and common carbonaceous particles. The siltstone differs from the sand-

stone primarily in grain size, although some is slightly darker. Clay shale is medium dark gray, slightly to very silty, slightly micaceous, and noncalcareous, with a small amount of carbonaceous material. Claystone differs from the clay shale by having irregular or conchoidal fracture and being slightly less micaceous. The top of the formation is placed below the lowest occurrence of *Trochammina rutherfordi* Stelck and Wall of the Ninuluk formation and above the coal; the base is marked by a thin but persistent bed of sandstone.

GRANDSTAND FORMATION

Almost all of the oil produced in the Umiat field came from the 660- to 760-foot Grandstand formation (Early and Late Cretaceous?), a sequence of marine sandstone. The light- to medium-light-gray very fine- to fine-grained sandstone beds are 5–100 feet thick and composed of subangular to subrounded grains of clear and white quartz, with some gray chert and dark rock fragments, rare grains of muscovite, biotite, pyrite, and carbonaceous material. The rock is slightly silty and argillaceous, and very little of it is calcareous. The sandstone beds are commonly massive, but a few have laminae of siltstone and claystone. Porosity ranges from less than 1 to 20 percent, and permeability from less than 5 to almost 500 millidarcys. The uppermost sandstone is 50–75 feet thick and is found throughout the area. The lower sandstone, much greater in total thickness, is massive in some wells and contains clay shale beds in others. These two beds of sandstone contain most of the oil in Umiat field and are referred to in this report as the upper sandstone bed and the lower sandstone bed.

The upper and lower sandstone beds are separated by 300 feet or more of medium-dark-gray slightly to very silty slightly micaceous and noncalcareous clay shale, with some silty or carbonaceous partings and fair shaly cleavage. It contains some thin beds of sandstone. Siltstone is also present as laminae or thin beds in the sandstone and clay shale; it is medium gray and commonly argillaceous.

The top of the Grandstand formation is characterized by the abrupt appearance of the *Verneuilinoides borealis* fauna of Bergquist (see p. 199) in a 2- to 40-foot bed of clay shale. The same fauna is also present in most of the shale beds between the sandstones of the Grandstand formation and in the underlying Topagoruk formation; it is sparsely represented in the sandstone beds themselves. This foraminiferal assemblage is largely arenaceous and suggests a shallow-water marine environment. The base of the formation is picked arbitrarily at the base of the lowest thick sandstone.

TOPAGORUK FORMATION

The clay shale of the marine Topagoruk formation (Early Cretaceous) is medium dark gray, slightly to very silty, noncalcareous, and partly micaceous; it is indistinguishable from that of the Grandstand formation. A few thin beds of very fine-grained very silty argillaceous noncalcareous sandstone are present in the upper part, and both siltstone and sandstone form laminae and irregular lenses in the shale. The siltstone and sandstone of the Topagoruk formation are likewise similar to those of the Grandstand formation, but the sandstone is finer grained, siltier, and more argillaceous. The Topagoruk formation had no shows of oil or gas. It is about 2,800 feet thick, and particularly the upper part contains a large number of Foraminifera typical of the *Verneuilinoides borealis* fauna. An Albian ammonite, *Gastroplites* sp., and very rare crinoid ossicles have also been found in this formation.

OUMALIK FORMATION

Only about 400 feet of the Oumalik formation (Early Cretaceous) has been penetrated in the Umiat area (in test wells 1 and 2), and its total thickness is unknown. It is composed of marine clay shale with very rare thin beds of siltstone and sandstone. The clay shale is slightly darker and harder than that of the Topagoruk formation and contains fewer silty laminae; it is medium dark to dark gray, very slightly silty in part, and noncalcareous. The sandstone is light brownish gray and very fine grained, and it is composed of angular clear quartz, much of which has a brownish tinge; the small amount of silty argillaceous interstitial material is also brownish gray. Silt, clay, mica, chert, and other interstitial material are less common than in the sandstone of the overlying Topagoruk and Grandstand formations. The *Verneuilinoides borealis* faunal assemblage is absent; a very few microfossils are present that are not found in the overlying formations.

UMIAT TEST WELL 1

Location: Lat 69°23′52″ N., long 152°19′45″ W.
Elevation: Ground, 801 feet; kelly bushing, 810 feet.
Spudded: June 22, 1945; shut down September 19, 1945, and reopened June 2, 1946.
Completed: October 5, 1946, dry and abandoned.
Total depth: 6,005 feet.

The first deep test in Naval Petroleum Reserve No. 4 was originally scheduled to be located at Cape Simpson, but this plan was changed after the Umiat anticline was found to have several hundred feet of closure, in contrast to the area of unknown structure at Cape Simpson. The site for Umiat test well 1, on a ridge between two branches of Seabee Creek, was picked on the basis of geologic and topographic reconnaissance mapping by a Navy party under Lt. W. T. Foran in

1944. In August 1944 Navy Construction Battalion Detachment No. 1058 set up a base camp at Barrow, and during the winter of 1944–45 a National 50 drilling rig, with a 96-foot cantilever-type mast, and other rotary drilling equipment were hauled by sled train to the drill site. In December 1944 a small group of Seabees established a temporary tent camp at the east end of Lake Umiat to support drilling operations. The present Umiat camp, about a mile southwest of the lake, was used as a base of operations for field work and drilling in the southern part of the Reserve until the exploration program was suspended.

The well was spudded in June 22, 1945, and shut down for the winter on September 19, 1945, at a depth of 1,816 feet. On June 2, 1946, drilling was resumed by Arctic Contractors. The test was abandoned on October 5, 1946, at a total depth of 6,005 feet. In the summer of 1946 more detailed geologic mapping of the anticline by a U. S. Geological Survey field party showed that the well was several hundred feet south of the axis and about 5 miles west and several hundred feet below the apex of the anticline.

Approximately 900 feet (9–915 feet) of the marine Seabee formation was penetrated in drilling Umiat test well 1. Sandstone makes up more than half of the upper 250 feet of the formation; below that depth only a few thin sandstone beds, less than 15 feet thick, were found. Oil odor and stain were reported from a few sandstone beds, but a formation test recovered only a trace of oil. The clay shale and claystone above 341 feet are medium light to medium gray, with shaly, irregular, or conchoidal fracture; laminae of silt are common. The unit between 341 and 535 feet is also clay shale, but it is much darker (medium dark gray), and much of it is fissile. Bentonite partings are common, and 3 beds of bluish-white bentonite, about 1½, 3, and 5 feet thick, are present in the lower part of the shale; biotite flakes are common. *Inoceramus* cf. *I. labiatus* and *Borissiakoceras* sp., diagnostic of the Seabee formation, were in the cores from these beds.

A 15-foot fine-grained sandstone bed marks the top of the shallow-water marine Ninuluk formation, which is present between 915 and 1,010 feet. In this hole the formation is composed of nearly equal amounts of sandstone, siltstone, and shale in beds 3–20 feet thick. The siltstone has crossbedded clay shale laminae, and the clay shale has slightly crossbedded laminae of siltstone. A trace of oil was reported in the uppermost sandstone bed.

The Killik tongue of the Chandler formation occurs between 1,010 and 1,309 feet and between 2,010 and 2,085 feet. The repetition is caused by a reverse fault at 2,010 feet which duplicated not only a small part of the Killik tongue but almost all of the Grandstand formation as well; the vertical displacement is 775 feet. Oil saturation was reported in the thin sandstone at the base of the tongue.

The top of the Grandstand formation at 1,309 feet is marked by a 20-foot bed of clay shale containing the uppermost occurrence of the *Verneuilinoides borealis* fauna. Below the shale is 50 feet of sandstone, with interbedded sandstone and shale beneath. At 1,530–1,560 feet is a sandstone which cannot be identified in the other Umiat wells; it is represented in them by a shale sequence containing a few thin sandstone beds. The thickest sandstones, however, ranging from 10 to 80 feet in thickness, occur between 1,735 and 2,840 feet; they are separated by thin beds of shale. The section including the thick sandstone beds between 1,735 and 2,010 feet is repeated below 2,010 feet by the thrust fault mentioned above. Porosity of the sandstone ranges from 6.2 to 20 percent, and permeability, from less than 1 to 63 millidarcys. (See table on p. 91.) Oil shows were reported in several beds, and gas was detected once, but tests recovered fresh water with only a trace of oil.

Below 2,840 feet, however, the Topagoruk formation has only a few thin sandstone beds, although sandstone and siltstone laminae, crossbedded in many places, are common. The high dips recorded are partly caused by crossbedding, but some high dips are in beds that show no sign of crossbedding and consequently are presumed to be the true dip.

The contact between the Topagoruk formation and the underlying Oumalik formation is not easily recognized in this hole. The similarity between the shale of the two formations and contamination of the ditch samples from overlying beds obscure any break. The Topagoruk formation extends through the core at 4,200–4,204 feet. A few specimens of the pyritic *Lithocampe* sp., diagnostic of the Oumalik formation, were found in ditch samples between 5,780 and 5,830 feet, and a heavy-mineral sample from 5,995 feet contained some augite, typical of the Oumalik formation. The intervening 1,500 feet, however, was not cored and is represented by ditch samples which show only a gradual change in the characteristics of the shale and sandstone. The base of the Topagoruk formation is therefore tentatively placed at about 5,650 feet.

DESCRIPTION OF CORES AND CUTTINGS

A slowly increasing lag in return of the ditch samples to the surface in Umiat test well 1 caused a discrepancy in depths of lithologic changes as shown in the ditch samples and in the electric log. This difference in depth increases from about 5 feet at 1,200 feet to about 15 feet near the bottom.

In this and the following wells, the lithologic descriptions are based on an examination of ditch samples and cores. All depths are measured from the top of the kelly bushing or the derrick floor. The material was described dry, and colors were determined by comparison with the Rock Color Chart (Goddard, 1948). Clay ironstone is a yellowish-gray to grayish-yellow and grayish-orange dense hard argillaceous rock with conchoidal fracture; it is sideritic and usually reacts slowly with cold dilute hydrochloric acid.

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, and over 50 very abundant.

Lithologic description

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

Core	Depth (feet)	Remarks
-----	0–9	Kelly drive bushing to ground level.
-----	9–11	Clay, grayish-orange; with some angular to subangular very fine grains of orange, white, and clear quartz and rock fragments. Top of test well in Seabee formation. (Sample from ground at rig site.)
-----	11–22	Sandstone, light-olive-gray, fine- to medium-grained, silty to very silty, argillaceous, slightly to very calcareous, hard; composed of subangular to subrounded grains of clear quartz, white, light-gray and dark-gray chert, and some dark rock fragments, with rare grains of hematitic (?) and sideritic clay and subhedral biotite grains. Lower part of unit contains white silty, argillaceous calcareous bentonite which contains abundant grains of dark rock fragments. Some medium-gray noncalcareous shale present in lower part.
-----	22–26	Clay shale, medium-gray, very slightly silty, noncalcareous, with rare minute biotite flakes and a small amount of sandstone as above.
-----	26–31	Sandstone as above, with a small amount of clay shale.
1	31–41	Recovered 7 ft 8 in.: Microfossils absent. Claystone, medium-light-gray, noncalcareous, nonmicaceous to slightly micaceous, with subconchoidal fracture; abundant laminae and thin beds of argillaceous to slightly sandy siltstone, slightly lighter gray than the claystone, totaling a third of the rock. Laminae have sharp contacts and are commonly very regular. Dip 10°–13°.
2	41–55	Recovered 7 ft 6 in.: Microfossils absent. Claystone with siltstone as above; siltstone decreases to a fourth of the rock, with depth.
3	55–65	Recovered 8 ft: Microfossils absent. Claystone with some siltstone laminae as above that total less than 10 percent of core.
4	65–82	Recovered 8 ft 6 in.: Microfossils absent. 8 ft, claystone as above, with rare siltstone laminae. 2 in., sandstone, light-greenish-gray, very fine-grained, calcareous, with a ½-in. lamina of medium-light-gray clay shale in center; dip 25°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		3 in., sandstone, greenish-gray, very fine-grained, very silty and argillaceous, noncalcareous. 1 in., sandstone, light-gray, fine-grained, very silty and argillaceous, very calcareous, with abundant biotite; slightly bentonitic matrix; massive. Grains angular to subangular clear and white quartz, with some gray chert, dark rock fragments, calcite, and reddish (hematitic clay?) grains.
5	82–92	Recovered 5 ft: Microfossils absent. 4 ft 6 in., sandstone, light- to olive-gray, very fine- to fine-grained, very silty and argillaceous, moderately to very calcareous, very slightly bentonitic, massive; common carbonaceous particles, pyrite grains, and biotite flakes. Grains angular to subangular, with the same composition as in core 4 above. A rounded fragment of medium-light-gray noncalcareous conchoidally fracturing claystone, larger than diameter (2½ in.) of core, has lighter-colored laminae dipping approximately 90°. 6 in., claystone, medium-light-gray, noncalcareous, with conchoidal fracture; also a few fine laminae of light-gray clay.
6	92–96	Recovered 3 ft 10 in.: Microfossils absent. Clay shale, medium-light-gray, noncalcareous, with irregular fracture; faint laminae of light-gray clay and a few laminae of light-gray silty clay toward base. Dip approximately 5°.
-----	96–97	No sample.
7	97–102	Recovered 3 ft 6 in.: Microfossils absent. 11 in., clay shale with laminae as above; grades into unit below. 3 in., interlaminated clay shale, siltstone, and very fine very silty argillaceous light-gray calcareous sandstone. Laminae dip 5°–9°. Grades into unit below. 3 in., sandstone, light-gray, very fine-grained, very silty and argillaceous, calcareous. Thin streaks of clay shale dipping as much as 12° give a slightly crossbedded appearance. 2 ft 1 in., interbedded claystone, medium-light-gray, with conchoidal fracture; with silty laminae and sandstone as above.
-----	102–105	Siltstone, light-olive-gray, argillaceous, very slightly calcareous; with a small amount of light-olive-gray very fine-grained very silty and argillaceous very slightly calcareous slightly micaceous sandstone as in sandstone described in core 7 above.
-----	105–110	Clay shale, medium-gray, very slightly silty, noncalcareous; with a very small amount of siltstone. Sample contaminated with cement.
-----	110–115	No sample.
-----	115–117	Clay shale, with a small amount of siltstone, as in sample described above.
8	117–132	Recovered 11 ft 8 in.: Microfossils absent. 2 ft, claystone with irregular laminae of silt; dip 5°. 9 ft 8 in., sandstone, light-olive-gray, fine- to very fine-grained, very silty and argillaceous, noncalcareous to

Lithologic description—Continued

Core	Depth (feet)	Remarks
		moderately calcareous, slightly bentonitic; with common flakes of biotite. Grains angular to subangular white and clear quartz, with gray chert and dark rock fragments; pyrite and carbonaceous particles rare. Sandstone is massive. A ½-in. unit 4 ft below top of core contains abundant flakes of carbonized plant remains; bed of medium-light-gray claystone ¾–1 in. thick, with conchoidal fracture, is present 1 in. below carbonaceous unit.
9	132–142	Recovered 9 ft 6 in.: Microfossils absent. 3 ft 6 in., sandstone as above; grades into fine- to medium-grained at base; noncalcareous. 1 ft 2 in., sandstone as above, fine- to very fine-grained, with thin lenticular beds of medium-light-gray claystone totaling 20 percent of the rock. 4 in., sandstone as above, with abundant carbonaceous flakes 1 mm to 1 cm in diameter, giving appearance of very fine laminae. Dip 9°. 1 ft 6 in., sandstone as at top of core. 3 in., sandstone with carbonaceous flakes as in 4-in. unit above. Dip 6°. 2 ft 9 in., sandstone as above; grades from very fine grained and noncalcareous at top to fine to medium grained, slightly calcareous, at base.
-----	142–143	No sample.
10	143–163	Recovered 17 ft 6 in.: Microfossils very rare. 13 ft, claystone, medium-light- to medium-gray, noncalcareous, conchoidal fracture; rare laminae of light-gray clay and light-olive-gray siltstone, very thin to one-half in. thick, some lenticular. Dip approximately 6°. *Inoceramus* shell, one-fourth in. in diameter, 9 ft below top of core. 4 ft 6 in., sandstone, light-olive-gray, fine- to very fine-grained, very silty, argillaceous, very slightly bentonitic. Grains angular to subangular, same composition as those in core 9. Sandstone is massive.
11	163–183	Recovered 18 ft: Microfossils absent. Sandstone as above, fine-grained, slightly calcareous in part; basal 3 ft very calcareous.
12	183–203	Recovered 12 ft: Microfossils absent. 9 ft 6 in., sandstone as above. Irregular beds of medium-light-gray claystone, ½–1 in. thick, dipping 20° or less, present 4 ft below top of core, and between 5 and 6 ft below top of core. 1 ft, interlaminated sandstone as above, slightly calcareous to noncalcareous, and claystone as above. A ¼-in. bed of sandstone has abundant carbonaceous flakes on bedding planes. 1 ft 6 in., claystone, medium-gray, with rare light-gray claystone laminae; conchoidal fracture. Laminae dip 5°.
13	203–221	Recovered 13 ft: Microfossils absent. Sandstone as in core 12 above, very fine- to fine-grained, noncalcareous, massive, with rare beds and lenses (as much as 2 in. thick) of medium-gray claystone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
14	221–232	Recovered 7 ft 4 in.: Microfossils absent. Claystone, medium-gray, noncalcareous; with conchoidal fracture; with abundant laminae of light-gray clay and silt and thin beds (2 in. maximum) of very fine-grained noncalcareous sandstone, especially in bottom 2 ft. Beds commonly lenticular; dip 5°–15°.
15	232–252	Recovered 18 ft: Microfossils very rare. 2 ft, interlaminated claystone, siltstone, and sandstone as above. 9 ft, sandstone, light-olive-gray, very fine- to fine-grained; slightly calcareous in part; with very rare thin beds (1 in. maximum) and laminae of medium-gray clay shale. Sandstone is massive; laminae dip 9°–15°. 7 ft, interbedded sandstone and claystone as above. Beds 2–10 in. thick, approximately three-fourths claystone. Basal 2 ft have odor of gas or distillate when freshly broken and produce slight coloring in ether.
16	252–265	Recovered 11 ft: Microfossils very rare. Claystone, medium-gray, noncalcareous; has irregular fracture; with rare beds (½–6 in. thick) of light-olive-gray very silty and argillaceous noncalcareous slightly bentonitic sandstone with abundant biotite flakes.
17	265–285	Recovered 9 ft: Microfossils absent. Claystone, medium-gray, noncalcareous, fractures irregularly; with very rare laminae of light-gray silty clay. Cleavage conchoidal to irregular.
18	285–292	Recovered 6 ft 6 in.: Microfossils absent. 4 ft 4 in., bentonite, light-bluish-gray, very silty, noncalcareous; with abundant minute flakes of biotite; irregular to conchoidal fracture. Fishbone fragment present 1 ft below top of core. 2 ft 2 in., claystone, medium-gray, silty, noncalcareous, slightly bentonitic; with conchoidal to blocky fracture; biotite flakes very rare; rare streaks of light-gray bentonitic claystone.
19	292–302	Recovered 10 ft: Microfossils absent. Claystone as in core 18 above. A 2-in. streak of light-olive-gray siltstone containing rare patches of carbonized plant remains 3 ft below top of core. Minute light-brown shiny balls of clay were noted in a sample washed for microfossils.
20	302–312	Recovered 9 ft: Microfossils absent. Claystone, medium-gray, slightly silty, noncalcareous; blocky fracture. Becomes less silty, slightly darker, with depth. Clay balls noted, as in core 19.
21	312–316	Recovered 3 ft: Microfossils absent. Claystone, medium-gray; becomes slightly darker at base; irregular fracture; a 2-in. unit is very well indurated, slightly calcareous, 1 ft above base of core. Clay balls as in core 19.
22	316–326	Recovered 9 ft 6 in.: Microfossils very rare. Claystone, medium- to medium-dark-gray, noncalcareous; irregular to blocky fracture. Lower part has rare silty micaceous laminae and poor shaly cleavage.

Lithologic description—Continued

Core	Depth (feet)	Remarks
23	326–336	Recovered 8 ft 6 in.: Microfossils absent. 8 in., clay shale, medium- to medium-dark-gray, noncalcareous; irregular fracture. Clay balls as in core 19 were noted in a composite sample from this core. 1 ft, claystone, light-olive-gray, very silty, slighty calcareous, micaceous, with rare pyrite, blocky fracture. 3 ft, clay shale as at top of core. 2 ft 8 in., bentonite, light-greenish-gray, slightly silty, with scattered small flakes biotite. Rare cross-bedded laminae and small scattered irregular bodies of light- to medium-gray claystone are present. Laminae flat lying to 10° dip. 11 in., claystone, light-gray, very bentonitic, slightly silty. 3 in., claystone as at top of core.
24	336–346	Recovered 8 ft 6 in.: Microfossils absent. 2 ft 4 in., claystone, medium-gray, noncalcareous; conchoidal to irregular fracture; slightly darker, with very poor shaly cleavage, in part. Faint silty laminae toward base dip 8°–10°. 1 ft 4 in., interbedded sandstone, light-gray, very fine-grained, very silty and argillaceous, noncalcareous to slightly calcareous, very slightly bentonitic; with siltstone, similar to the sandstone, and claystone as above. 4 ft 10 in., claystone, medium-gray and medium-dark-gray, noncalcareous, with conchoidal to irregular fracture. Top of dark fissile shale.
25	346–356	No recovery, bit plugged.
26	356–366	No recovery, bit plugged.
27	366–370	No recovery, bit plugged.
28	370–374	No recovery, bit plugged. Note: Ditch samples described below were taken from the depths from which no cores were recovered. 346–350 ft: Siltstone, medium-gray; probably contamination from the hole above this sample; ditch samples immediately below consist of medium-dark-gray fissile shale. 350–374 ft: Clay shale, medium-dark-gray, fissile; fine partings of light-colored bentonite are abundant and seem to be responsible for the fissility.
29	374–377	Recovered 3 ft: Microfossils abundant. 2 in., sandstone, light-gray, very fine-grained, silty, very calcareous, nonbentonitic. 2 ft 10 in., clay shale, medium-dark-gray, fissile; dip 9°; cleavage caused by partings of white bentonite, with abundant flakes of biotite. Rare beds of light-bluish-gray bentonite, ⅛–1 in. thick. Contacts of nonbentonitic clay shale with bentonite are sharp. *Inoceramus* and fishbone fragments throughout. Note: 5 ft of additional core, identical lithologically with core 29, may represent part of cores 25 to 28. It is labeled "core 24, bottom 5 ft" but this is incorrect, because the full recovery of core 24 is present without this 5 feet of additional core.

Lithologic description—Continued

Core	Depth (feet)	Remarks
30	377–387	Recovered 10 ft: Microfossils common. Clay shale, as in core 29 above, with *Inoceramus* and fish-bone fragments. Shaly cleavage poor except on bentonite partings. Rare beds of bluish-white bentonite, ¼–1 in. thick, with abundant dark grains, and light-bluish-gray bentonite which lacks black grains, are present throughout the rock. Dip 7°. Several specimens of *Inoceramus* cf. *I. labiatus* Schlötheim and *Borissiakoceras* sp., and fishbone fragments between 379 and 387 ft.
31	387–397	Recovered 10 ft: Microfossils very rare. Clay shale as above, with rare bentonite beds; dip 6°. Numerous specimens of *Inoceramus* cf. *I. labiatus* Schlötheim, 4 specimens of a large fish scale (*Tissotia* sp.), fishbone fragments, and 1 specimen of *Borissiakoceras* sp. were found in this core.
32	397–407	Recovered 10 ft: Microfossils absent. Clay shale as in core 31 above, but with poor shaly to conchoidal cleavage, and lacking partings and beds of bentonite. *Inoceramus* cf. *I. labiatus* Schlötheim, *I.* cf. *I. pictus* Sowerby, *Borissiakoceras* sp., fishbone fragments and scales present.
33	407–417	Recovered 10 ft: Microfossils very rare. Clay shale, medium-dark-gray, noncalcareous, very slightly bentonitic, with abundant minute biotite flakes. Bentonite laminae very rare; one lamina contains abundant minute euhedral pyrite crystals. Very poor shaly to conchoidal cleavage. Fishbone fragments abundant, *Inoceramus* cf. *I. pictus* Sowerby present.
34	417–427	Recovered 10 ft: Microfossils very rare. Clay shale as in core 33 above, with very rare white bentonite laminae containing minute pyrite crystals and biotite flakes and very rare light-bluish-gray bentonite beds one-half in. thick. Dip approximately 5°. *Inoceramus* fragments present.
35	427–437	Recovered 10 ft: Microfossils absent. Clay shale with bentonite, as in core 34 above. *Inoceramus* cf. *I. labiatus* Schlötheim and fish scales present.
36	437–447	Recovered 10 ft: Microfossils very rare. Claystone, like clay shale in core 34 above but more bentonitic, and with blocky to subconchoidal fracture more common than shaly cleavage. Dip probably low. Fishbone fragments common; fish scales also present.
37	447–457	Recovered 10 in.: Microfossils common. Claystone as in core 36 above.
38	457–467	Recovered 10 ft: Microfossils rare. Claystone as above, but very slightly micaceous in lower part; bentonite present in faint partings and as a 1-in. bed 3 ft above base of core. Fishbone fragments and scales present. Dip probably low.
39	467–477	Recovered 10 ft: Microfossils absent. Claystone as above. Two 2-in. beds of

Lithologic description—Continued

Core	Depth (feet)	Remarks
		light-gray bentonite with abundant biotite flakes 3 and 6½ ft below top of core; fishbone fragments present.
40	477–487	Recovered 10 ft: Microfossils common. 1 ft 2 in., claystone as above, with common pyrite grains and abundant faint laminae of bentonite in bottom 2 in. Dip 9°. 2 ft 5 in., bentonite, bluish-white at top; grades to light gray at base; biotite flakes absent at top; increase from rare and minute in middle part of interval to abundant and larger (fine sand size) at base. Good conchoidal fracture at top grades to blocky and irregular at base. 6 ft 5 in., claystone as at top of core; fishbone fragments present.
41	487–490	Recovered 3 ft: Microfossils common. Claystone as in core 40 above.
42	490–499	Recovered 7 ft: Microfossils very abundant. 4 ft 2 in., claystone, as in cores above, with laminae and thin beds of bentonite in bottom 1 ft. 1 ft 4 in., bentonite, bluish-white, with biotite flakes increasing from rare to abundant with depth. Conchoidal fracture at top grades to fissile at base; dip 6°. 1 ft 6 in., claystone as at top of core.
43	499–509	Recovered 10 ft: Microfossils very abundant. 3 ft 8 in., clay shale, medium-dark-gray, noncalcareous, slightly bentonitic; resembles claystone above, except for shaly cleavage. Fish fragments rare. Dip 6°. A 1-in. bed of light-bluish-gray bentonite 3 inches below top of core. 4 ft 8 in., claystone as in cores above. A 1-in. bed of bluish-gray bentonite 6 in. above base of claystone. 1 ft 8 in., bentonite, light-bluish- to light - greenish - gray, with biotite flakes common to abundant. Friable, with conchoidal fracture.
44	509–519	Recovered 10 ft: Microfossils abundant. 3 ft 4 in., bentonite as in core 43 above. 2 in., siltstone, medium-gray, very argillaceous and sandy, noncalcareous, hard. 6 ft 6 in., claystone, medium-dark-gray, very slightly silty, micaceous, nonbentonitic, noncalcareous, slightly pyritic, irregular to poor conchoidal fracture.
45	519–529	Recovered 10 ft: Microfossils very abundant. Claystone as in core 44 above, with common pyrite grains.
46	529–539	Recovered 10 ft: Microfossils absent. 1 ft 8 in., claystone as in core 44 above; basal 8 in. slightly silty; very good conchoidal fracture. 1 ft 8 in., clay shale, medium-dark-gray, silty and micaceous, noncalcareous, with very poor shaly cleavage that suggests a dip of approximately 5°. 2 ft 6 in., claystone, like clay shale above, but with irregular fracture. Base of dark fissile shale. 4 ft 2 in., sandstone, medium-light-gray, very fine-grained, silty and argillaceous, micaceous, slightly calcareous in bottom 6 in., nonbentonitic, massive; grains angular, mostly clear quartz; some are white quartz and dark rock fragments. Pyrite rare; *Inoceramus* fragments rare. Strong oil odor and color in test with CCl_4; oil showed on ditch, but no gas detected.
47	539–549	Recovered 5 ft 6 in.: Microfossils absent. 5 ft, sandstone with oil stain as above. 6 in., claystone, medium-gray, nonsilty to slightly silty, noncalcareous, irregular fracture. Slickensides on 1 or 2 surfaces.
48	549–554	Recovered 5 ft: Microfossils absent. 3 in., claystone as at base of core 47 but somewhat siltier. 3 ft 6 in., sandstone with oil stain as in core 47 but calcareous. 1 ft 1 in., claystone, medium-gray, slightly silty, micaceous, noncalcareous, pyritic; irregular fracture. 2 in., sandstone as above, noncalcareous.
49	554–559	Recovered 5 ft: Microfossils absent. 2 ft 4 in., sandstone as at base of core 48; becomes slightly calcareous at base; slight oil odor. 2 ft 8 in., claystone, medium-gray, nonsilty to very silty, noncalcareous, pyritic, with sandy silt laminae and one 3-in. bed of very fine-grained sandstone 6 in. below top of claystone.
50	559–564	Recovered 5 ft: Microfossils rare. 4 ft 1 in., clay shale, medium- to medium-dark-gray, with laminae and thin beds of silt and very fine-grained sandstone; bentonitic partings contain abundant large biotite flakes. 6 in., interlaminated siltstone, sandstone, and clay shale, micaceous; dip 7°. 5 in., bentonite, grayish-white, slightly silty, partly calcareous, friable, with abundant flakes of light-brown to black biotite.
51	564–569	Recovered 5 ft: Microfossils absent. Claystone, medium- to medium-dark-gray, noncalcareous, nonsilty to slightly silty, with rare irregular laminae and thin beds (as much as 2 in.) of siltstone, slightly sandy, very micaceous, argillaceous, noncalcareous. A 3-in. bed of sandstone, very fine grained, noncalcareous, very silty and argillaceous, 8 in. above base; *Inoceramus* fragments at its base.
52	569–574	Recovered 5 ft: Microfossils very rare. 4 ft, claystone, medium-gray, slightly silty to nonsilty, noncalcareous, irregular to conchoidal fracture. 10 in., sandstone, medium-gray, very fine-grained, very silty and argillaceous, with faint slightly darker laminae. Dip 7°. 2 in., claystone as above.
53	574–579	Recovered 4 ft 6 in.: Microfossils common. 1 ft, claystone, medium-gray, noncalcareous, irregular to conchoidal fracture. 6 in., siltstone, medium-light-gray, sandy, argillaceous, noncalcareous, with faint micaceous laminae dipping 11°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		3 ft, claystone as above, slightly silty in part, with thin beds of micaceous siltstone totaling 20 percent of the rock. Flat lying to 2° dip.
54	579–584	Recovered 5 ft: Microfossils absent. Claystone, medium-gray, nonsilty to slightly silty, noncalcareous, conchoidal fracture.
55	584–591	Recovered 7 ft: Microfossils common. Claystone as above.
56	591–601	Recovered 8 ft: Microfossils abundant. Claystone as above.
-----	601–604	No sample.
57	604–614	Recovered 9 ft: Microfossils common. Claystone as above.
58	614–624	Recovered 10 ft: Microfossils abundant. Claystone as above.
-----	624–625	No sample.
-----	625–640	Clay shale, medium-dark-gray; slightly silty, calcareous, partly bentonitic; small amount of siltstone in lower 5 ft.
-----	640–644	Siltstone, medium-light-gray, very sandy, argillaceous, moderately calcareous, bentonitic; small biotite flakes common.
59	644–654	Recovered 10 ft: Microfossils very rare. 6 ft 10 in., claystone as above, with 1-in. bed of siltstone, slightly calcareous, micaceous, sandy and argillaceous, with slightly crossbedded laminae 1 ft below top of core. Laminae dip 5°–15°. 2 ft 5 in., claystone as above, with thin (½–2 in. thick) beds of siltstone totaling a quarter of the rock. 9 in., siltstone, medium-light-gray, very sandy and argillaceous, micaceous, noncalcareous. Pelecypod shell cast at 653½ ft.
60	654–664	Recovered 10 ft: Microfossils rare. Claystone as above, with rare laminae and thin (½–4 in.) beds of siltstone, medium-light-gray, noncalcareous to slightly calcareous, flat lying to 10° dip.
-----	664–665	No sample.
-----	665–675	Siltstone, medium-light-gray, very argillaceous, with some silty clay shale.
-----	675–682	Clay shale with some siltstone in upper part.
61	682–692	Recovered 8 ft: Microfossils absent. 3 ft 4 in., claystone, medium-gray, silty, micaceous, noncalcareous; irregular fracture, uniform. 2 ft 1 in., claystone as above, but calcareous, slightly more silty. 6 in., clay shale, medium-gray, nonsilty, very slightly micaceous. 2 ft 1 in., claystone, medium-gray, silty, micaceous, noncalcareous to slightly calcareous; irregular fracture.
62	692–693	Recovered 1 ft: Claystone, medium-dark-gray, slightly silty, noncalcareous, hard.
-----	693–695	Siltstone.
-----	695–715	Clay shale, medium-gray, slightly to very silty; slightly bentonitic in part.
-----	715–720	Siltstone, medium-light-gray, sandy, argillaceous, slightly micaceous, slightly pyritic; composed of angular grains of clear and white quartz.
-----	720–722	Siltstone, very argillaceous, calcareous, nonbentonitic, with a small amount of clay shale.
63	722–732	Recovered 9 ft 6 in.: Microfossils absent. 8 in., siltstone, medium-gray, very argillaceous, very calcareous, slightly micaceous; grades into unit below.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		8 in., claystone, medium-gray, very silty, calcareous; grades into unit below. 8 ft 2 in., clay shale, medium-gray, slightly silty to nonsilty, noncalcareous; irregular to poor shaly cleavage; beds approximately flat lying. A 2-in. section of medium-light-gray calcareous siltstone, with irregular dip (as much as 10°), 2 ft 9 in. above base of core.
64	732–740	Recovered 7 ft 6 in.: Microfossils very rare. Claystone, medium-gray, nonsilty to very slightly silty; irregular to subconchoidal fracture.
65	740–750	Recovered 9 ft 6 in.: Microfossils common. 8 ft 6 in., claystone as in core 64 above. Very rare particles of carbonized plant remains scattered throughout. A 2-in. bed of medium-gray very argillaceous calcareous siltstone 4 ft 6 in. below top of core. 4 in., siltstone, medium-gray, very argillaceous, noncalcareous, with scattered small fragments (maximum one-half in. in diameter) of carbonized plant remains. 8 in., sandstone, fine- to very fine-grained, silty, argillaceous, noncalcareous, with carbonaceous partings dipping 3°–5°. Slight oil odor, slight indication of gas.
66	750–760	Recovered 9 ft: Microfossils absent. 5 ft 6 in., sandstone, medium-light-gray, very fine-grained, slightly silty, argillaceous, noncalcareous to slightly calcareous; grains angular to subangular clear quartz with some white quartz, white and gray chert, and dark rock fragments. Biotite and muscovite flakes abundant; particles of limonite, coal, and carbonized plant remains common. Sandstone massive, uniform, except for a 6-in. unit of sandy siltstone 2 ft below top. Slight oil odor. 3 ft 6 in., siltstone, medium-gray, very argillaceous, noncalcareous, micaceous; irregular fracture. A few laminae of sandstone in top 3 in.; rounded mass of medium-light-gray sandstone 1 in. by 2 in. in diameter, is present 6 in. above base of core. No visible bedding in sandstone or siltstone. Sharp sand-silt contact; sandstone calcareous; siltstone noncalcareous.
67	760–765	Recovered 4 ft 6 in.: Microfossils absent. Claystone, medium-gray, slightly to very silty, micaceous, noncalcareous; irregular fracture. A few irregular patches and lenticles (maximum one-half in. thick) of calcareous very fine-grained light-gray sandstone 1 ft below top of core which suggest "swirly" bedding. Dip of patches changes abruptly from 0°–30°; claystone-sandstone contacts irregular but sharp.
68	765–770	Recovered 5 ft: Microfossils absent. 2 in., siltstone, medium-light-gray, very sandy, very slightly calcareous. 4 ft 10 in., clay shale, medium-gray, slightly silty, micaceous, noncalcare-

Lithologic description—Continued

Core	Depth (feet)	Remarks
		ous to slightly calcareous; irregular to poor shaly cleavage.
-----	770–780	Siltstone, with a small amount of clay shale; cement contamination in sample from 770 to 775 ft.
-----	780–785	Sandstone, medium-light-gray, very fine-grained, very calcareous, with some argillaceous silt.
-----	785–800	Clay shale, medium-gray; slightly silty in part.
-----	800–812	Clay shale, with siltstone, very small amount of sandstone.
69	812–817	Recovered 4 ft 6 in.: Microfossils absent. Clay shale, medium-gray, nonsilty to slightly silty, noncalcareous, with some micaceous partings. Shaly cleavage poor; rare silty laminae; dip 1°–5°, with faint crossbedding.
-----	817–845	Clay shale, medium-gray, silty, micaceous, nonbentonitic, with small amount of argillaceous micaceous nonbentonitic siltstone.
-----	845–865	Siltstone, medium-light-gray, slightly to very sandy, slightly micaceous, moderately calcareous.
70	865–870	Recovered 4 ft 6 in.: Microfossils common. 10 in., clay shale, medium- to medium-dark-gray, slightly micaceous, noncalcareous; shaly cleavage poor; beds approximately flat lying. 6 in., claystone, medium-gray, very silty, very micaceous, with lenticle of siltstone at base. 2 ft 1 in., clay shale as at top of core; shaly cleavage poor at top, fair at base; beds flat lying to 5° dip. 1 ft 1 in., siltstone, medium-light-gray, micaceous, noncalcareous, with abundant laminae of medium-gray clay shale that dip 6°.
-----	870–895	Siltstone, medium-light-gray, very argillaceous, with clay shale increasing to half of sample at base.
-----	895–920	Clay shale, medium- to medium-dark-gray, very silty in lower part. Small amount of siltstone between 905 and 920 feet. Clay ironstone at 900 feet; small chips of calcite, probably from a veinlet, are rare. The top of the Ninuluk formation is reflected by ditch samples at 920 feet, and at 915 feet by electric log; the latter is considered more accurate.
71	920–925	Recovered 4 ft 6 in.: Microfossils absent. Sandstone, light-gray, salt-and-pepper, fine-grained, very slightly silty, noncalcareous. Grains subangular to angular clear quartz, with minor amounts of black chert and coal, white quartz, and white and gray chert. Sandstone, uniform, with irregular fracture, no bedding. Trace of oil and gas odor. *Inoceramus* shell fragments at base.
-----	925–930	Sandstone, as in core 71 above.
-----	930–945	Sandstone as above, and medium-gray silty clay shale.
72	945–950	Recovered 4 ft 6 in.: Microfossils absent. Claystone, medium-gray, nonsilty, noncalcareous; very slightly micaceous in part; subconchoidal fracture. Basal 6 in. has abundant crossbedded (dip as much as 15°); laminae of medium-light-gray silt.

Lithologic description—Continued

Core	Depth (feet)	Remarks
73	950–955	Recovered 4 ft 8 in.: Microfossils absent. Siltstone, medium-light-gray, argillaceous, noncalcareous, slightly micaceous, with abundant crossbedded (dip as much as 10°) medium-gray clay shale laminae. Rare irregular laminae of very fine-grained sandstone toward base of core.
74	955–960	Recovered 1 ft 6 in.: Microfossils absent. Siltstone as above, with crossbedded laminae and lenticles of clay shale.
75	960–961	Recovered 6 in.: Microfossils absent. Claystone, medium-gray, noncalcareous, nonsilty; irregular fracture.
-----	961–965	Siltstone, medium-light-gray, very sandy, noncalcareous, very sericitic.
-----	965–970	Clay shale, medium-dark-gray, slightly silty, noncalcareous, slightly micaceous.
-----	970–980	Siltstone, with small amount of clay shale.
-----	980–990	Sandstone, light-gray, fine- to very fine-grained, silty, argillaceous, very slightly calcareous, very sericitic, nonbentonitic; composed of subangular grains of clear and white quartz with some gray chert and dark rock fragments. Small amount of clay shale at top of unit.
-----	990–1, 000	Clay shale and sandstone, as above.
-----	1, 000–1, 020	Clay shale, medium-dark-gray, slightly silty, finely micaceous, with a very small amount of siltstone. Top of Killik tongue of Chandler formation at 1,010 feet.
76	1, 020–1, 025	Recovered 2 ft: Microfossils absent. Claystone as above, but with rare silty laminae dipping approximately 5°.
77	1, 025–1, 027	Recovered 1 ft 6 in.: Microfossils absent. Claystone as in core 75 above.
-----	1, 027–1, 055	Clay shale, medium-gray; slightly silty except in lower part; with rare thin beds siltstone. Fragments of carbonized plant remains on some shale chips.
-----	1, 055–1, 060	No sample.
-----	1, 060–1, 075	Clay shale, medium- to medium-dark-gray, very silty; grades to very argillaceous siltstone, in upper part; some in lower part nonsilty.
-----	1, 075–1, 080	Siltstone, light-gray, very sericitic, moderately calcareous, and clay shale.
78	1, 080–1, 085	Recovered 5 ft: Microfossils absent. 6 in., siltstone, medium-light-gray, sandy, argillaceous, noncalcareous, with small fragments of carbonized plant remains scattered throughout. Irregular carbonaceous partings suggest 10°–12° dip. 4 ft 6 in., claystone, medium-gray, slightly to very silty, slightly micaceous, noncalcareous, with thin irregular beds (up to one-half in. thick) of siltstone, with small carbonized plant fragments common throughout. Subconchoidal fracture.
79	1, 085–1, 090	Recovered 5 ft: Microfossils absent. 1 ft 6 in., claystone, medium-gray, very silty; grades to siltstone, medium-gray, very argillaceous, noncalcareous, micaceous, with scattered small carbonized plant fragments; irregular to subconchoidal fracture. 1 ft 9 in., claystone, medium-gray, nonsilty, nonmicaceous, noncalcareous, conchoidal fracture. 5 in., clay shale, medium-dark-gray, with abundant fragments (maximum

Lithologic description—Continued

Core	Depth (feet)	Remarks
		length 1 in.) of coaly plant remains. Beds flat lying to 5° dip. 1 ft 4 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, very sericitic, with carbonaceous particles in streaks and patches dipping 5°–10°.
-----	1, 090–1, 100	Clay shale, medium-dark-gray, slightly silty, with medium-light-gray, slightly silty and argillaceous, noncalcareous, very sericitic sandstone, composed of subangular clear and white quartz, white and gray chert, and dark rock fragments.
-----	1, 100–1, 105	Siltstone, light-gray, sericitic.
-----	1, 105–1, 110	Siltstone and clay shale.
-----	1, 110–1, 115	Clay shale.
-----	1, 115–1, 120	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, moderately calcareous, very sericitic.
-----	1, 120–1, 150	Clay shale, medium-dark-gray, nonsilty to very silty, with very small amount of siltstone.
-----	1, 150–1, 155	Sandstone, very fine-grained, and clay shale.
-----	1, 155–1, 160	Siltstone, medium-light-gray, slightly argillaceous, noncalcareous to slightly calcareous.
-----	1, 160–1, 165	Clay shale, very silty.
-----	1, 165–1, 195	Interbedded sandstone, medium-light-gray, very fine-grained, slightly silty, argillaceous, moderately calcareous; medium-gray very argillaceous siltstone; and medium-dark-gray shale.
-----	1, 195–1, 213	Clay shale, medium-dark-gray, nonsilty to very silty, with small amount siltstone and sandstone in lower part.
80	1, 213–1, 223	Recovered 9 ft: Microfossils absent. 4 ft 6 in., clay shale, medium- to medium-dark-gray, slightly to moderately silty, with abundant siltstone laminae; medium light gray and calcareous in upper part. Irregular to poor shaly cleavage; dip of laminae 5°–7°; faintly crossbedded in part. Grades into unit below. 3 ft 6 in., claystone, medium-dark-gray, nonsilty, nonmicaceous, noncalcareous; conchoidal fracture. 1 ft, siltstone, medium-light-gray, very argillaceous, noncalcareous, massive; irregular fracture.
81	1, 223–1, 233	Recovered 10 ft: Microfossils absent. 1 ft 9 in., sandstone, medium-light-gray; fine grained at top grading to very fine grained with depth; silty, argillaceous, sericitic, noncalcareous, with clay laminae and carbonaceous partings in lower part. Laminae dip 3°–5°. 3 ft 3 in., siltstone, medium-gray, argillaceous, noncalcareous, micaceous, with irregular laminae of clay shale and very fine-grained sandstone. Clay shale increases with depth; grades into unit below. 5 ft, clay shale, medium-dark-gray, very slightly silty, with scattered micaceous siltstone laminae, with small carbonized plant fragments scattered throughout. Poor shaly to subconchoidal fracture.
82	1, 233–1, 243	Recovered 10 ft: Microfossils absent. 5 ft, claystone, medium- to medium-dark-gray, noncalcareous, nonsilty to slightly silty; subconchoidal fracture.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		1 ft 9 in., siltstone, medium-gray, argillaceous, noncalcareous, with irregular thin beds and laminae of clay shale. Laminae dip 3°–5°. Grades into unit below. 1 ft 3 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, micaceous, with streaks of carbonaceous material or clay dipping as much as 5°. 2 ft, siltstone, medium-gray, very argillaceous, noncalcareous, slightly micaceous, with streaks of light-medium-gray sandstone near top, and laminae and streaks of medium-dark-gray clay throughout; all dip as much as 10°. A few fine even laminae dip 5°–6°. Fracture irregular.
83	1, 243–1, 253	Recovered 9 ft: Microfossils absent. 7 ft 6 in., clay shale, medium-gray, very silty, with abundant laminae of siltstone in upper 2 ft; scattered irregular siltstone streaks in lower part. Clay shale and siltstone both micaceous, noncalcareous and have irregular to poor shaly fracture. 1 ft 6 in., siltstone, medium-light-gray, very slightly calcareous, with abundant clay shale laminae and partings dipping as much as 5°; slightly crossbedded.
84	1, 253–1, 258	Recovered 5 ft: Microfossils absent. Clay shale, medium-dark-gray, noncalcareous, nonsilty to slightly silty, micaceous; subconchoidal to poor shaly cleavage.
85	1, 258–1, 268	Recovered 10 ft: Microfossils absent. 7 ft 6 in., claystone, dark-gray, noncalcareous, with conchoidal fracture. A 6-in. bed of very fine-grained slightly calcareous sandstone, uniform except for rare small streaks of clay shale 3 in. below top of core. 1 ft, interbedded clay shale and very fine-grained sandstone; beds 2–3 in. thick. 1 ft 6 in., interbedded sandstone, very fine- to fine-grained, and argillaceous siltstone with abundant laminae and partings of clay shale and carbonaceous clay shale. Dip ranges from 4° to 21°.
86	1, 268–1, 278	Recovered 10 ft: Microfossils absent. 2 ft, interbedded clay shale, medium-dark-gray, silty, noncalcareous; and medium-light-gray noncalcareous siltstone. A nodule of light-olive-gray noncalcareous clay ironstone three-fourths in. thick 21 in. below top of core. Grades into unit below. 8 ft, clay shale, medium-dark-gray; slightly silty in part, noncalcareous, irregular to poor shaly cleavage. Light-olive-gray noncalcareous clay ironstone nodules 1½ in. thick at 2- to 3-ft intervals through core.
87	1, 278–1, 288	Recovered 6 in.: Microfossils absent. Core barrel plugged; recovery consists of small fragments of medium-dark-gray clay shale.
88	1, 288–1, 293	No recovery.
89	1, 293–1, 295	Recovered 1 ft 4 in.: Microfossils absent. 1 ft 1 in., clay shale, medium-dark-gray, slightly to very silty.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		3 in., clay ironstone, brownish-gray, hard, noncalcareous; conchoidal fracture.
90	1, 295–1, 305	Recovered 9 ft: Microfossils very rare. 5 ft, claystone, medium-dark-gray; slightly silty in part, noncalcareous, conchoidal fracture. 4 ft, sandstone, medium-light- to light-gray, very fine- to fine-grained, silty to very silty, argillaceous, noncalcareous; grain size decreases with depth; silt content increases. Clay shale streaks and partings increase from rare at top to abundant at base; dip as much as 5°.
91	1, 305–1, 315	Recovered 10 ft: Microfossils very abundant. 1 ft 3 in., clay shale, medium-dark-gray, with common siltstone laminae. 2 ft 9 in., sandstone, medium-light-gray, fine-grained, argillaceous, silty, noncalcareous, with streaks of very fine-grained sandstone increasing with depth. Common streaks and partings of clay shale and carbonaceous material become abundant with depth. A 2-in. bed of medium-dark-gray clay shale with faint medium-gray clay laminae dipping 4° 9 in. above base. Brownish-gray clay ironstone mass 1 in. thick, hard, with conchoidal fracture, above the shale. Sandstone saturated with light-gravity oil. 6 ft, clay shale, medium-dark-gray, slightly silty to nonsilty, noncalcareous, with poor shaly to conchoidal fracture. This clay shale is at top of Grandstand formation.
92	1, 315–1, 325	Recovered 10 ft: Microfossils very abundant. 2 ft 5 in., clay shale as in lower part of core 91 above. 11 in., sandstone, medium-light-gray, very fine-grained, with common very irregular thin streaks of clay shale throughout. 6 ft 8 in., clay shale, medium-dark-gray, noncalcareous; becomes very silty at top. Subconchoidal fracture grades to poor shaly cleavage.
93	1, 325–1, 335	Recovered 10 ft: Microfossils very abundant. 2 ft 6 in., clay shale as in core 92 above; becomes silty at base; poor shaly cleavage grades to subconchoidal fracture. 2 ft, interbedded silty clay shale, siltstone, and very fine-grained calcareous sandstone; beds ¼–2 in. thick, crossbedded, with dips as much as 15°. 5 ft 6 in., clay shale, medium-dark-gray, nonsilty to very slightly silty, noncalcareous; becomes fissile and dark gray with depth. Small coal fragments (up to one-half inch in diameter) at base. Olive-gray hard clay ironstone 1 in. thick, with conchoidal fracture, 2½ ft above base.
94	1, 335–1, 345	Recovered 5 ft: Microfossils absent. Sandstone, medium-light-gray, fine-grained, silty, argillaceous, noncalcareous, slightly sericitic. Sandstone of angular to subangular grains of clear and white quartz with minor gray chert and dark rock fragments. Pyrite and biotite absent; muscovite rare. Sandstone uniform, massive. Oil saturation, gas odor.
95	1, 345–1, 350	Recovered 4 ft 6 in.: Microfossils absent. Sandstone as in core 94 above, but with very rare streaks of carbonaceous particles. Bottom 7 in. has 1- to 2-in. layers of medium-gray nonsilty clay shale with subconchoidal fracture, interbedded with crossbedded sandstone dipping as much as 10°. Oil saturation, gas odor.
96	1, 350–1, 355	Recovered 1 ft 6 in.: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, very silty, argillaceous, micaceous, noncalcareous, uniform, massive; composition as in core 94 above. Oil and gas noted.
97	1, 355–1, 365	Recovered 10 ft: Microfossils absent. Sandstone as in core 96 above, but with 1 in. of medium-gray clay shale at top. Oil and gas noted.
98	1, 365–1, 375	Recovered 10 ft: Microfossils absent. Sandstone as in core 96 above. Oil and gas noted.
99	1, 375–1, 383	Recovered 1 ft 6 in.: Microfossils absent. Sandstone as above, but with rare streaks of clay and carbonaceous particles, and streaks of very calcareous sandstone. Oil and gas noted.
100	1, 383–1, 393	Recovered 7 ft 6 in.: Microfossils common. 3 ft, siltstone, medium-gray, with abundant irregular intercalations of clay and some very fine-grained sandstone. Grades into unit below. 4 ft 6 in., clay shale, medium-dark-gray, noncalcareous, slightly silty, with abundant siltstone intercalations and lenticles in upper part decreasing to rare at base. Rare small fragments of coal or carbonaceous material scattered throughout. A 1-in. bed of medium-light-gray very fine-grained sandstone 1 in. above base.
101	1, 393–1, 403	Recovered 8 ft: Microfossils absent. 1 ft 2 in., sandstone, light- to medium-light-gray; fine grained at top to very fine grained at base; noncalcareous, with abundant intercalations and slightly crossbedded laminae of silt and clay shale dipping 5°–10°. Grades into unit below. 5 ft 3 in., clay shale, medium-dark-gray, noncalcareous, slightly to very silty, with laminae and streaks of siltstone abundant at top, decreasing to rare at base. 5 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous; composed of angular and subangular clear and white quartz with very rare dark rock fragments, and scattered pyrite, muscovite, biotite, and coaly particles. 1 ft 2 in., siltstone, medium-gray, very argillaceous, noncalcareous, slightly micaceous. Streaks of medium-light-gray very fine-grained sandstone as much as 1 in. thick in lower part.
102	1, 403–1, 409	Recovered 6 ft: Microfossils absent. 10 in., siltstone as at base of core 101 above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		10 in., sandstone, medium-light-gray, very fine-grained, noncalcareous, with laminae of siltstone, clay, and rare carbonaceous particles dipping 5°–10°.
		2 ft 2 in., clay shale, medium-dark-gray, noncalcareous, silty, with medium-gray siltstone laminae decreasing from abundant to very rare with depth. Lenticles (one-eighth in. thick) of grayish-brown clay ironstone at top and 7 in. below top of section.
		2 ft 2 in., sandstone, light-gray, fine-grained, silty, argillaceous, noncalcareous; grades to very fine grained at base; fine clay intercalations increase from rare at top to about a third of core at base. Intercalations are flat lying to 10° dip.
		Note: Cores 100–102 have cyclic bedding, grading from shale to silt to sandstone from bottom to top. Top contact of each sandstone bed is sharp.
103	1, 409–1, 414	Recovered 5 ft: Microfossils rare.
		Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, sericitic; composed of angular to subangular grains of white quartz with some clear quartz; biotite and coaly or carbonaceous particles rare. Irregular intercalations of clay and patches of carbonaceous material rare to common throughout. A 1-in. bed of light-gray fine-grained sandstone 2 ft above base of core is underlain by 5 in. bed of silty clay shale.
104	1, 414–1, 424	Recovered 9 ft: Microfossils very abundant.
		Clay shale, medium-dark-gray, slightly silty, noncalcareous, with shaly cleavage grading from poor at top to fair at base. Rare streaks and small lenses of slightly crossbedded siltstone and silty clay shale in upper part. A 3-in. section of light-yellowish-gray clay ironstone 4 ft below top of core. Beds lie approximately flat.
105	1, 424–1, 434	Recovered 7 ft: Microfossils common.
		Clay shale as above, with very rare small streaks of siltstone in upper part.
106	1, 434–1, 444	Recovered 10 ft: Microfossils absent.
		2 ft 7 in., clay shale as in core 104.
		11 in., sandstone, medium-light-gray, very fine- to fine-grained, argillaceous, silty, slightly to moderately calcareous, very slightly micaceous. Rare small irregular patches of dark-gray clay shale.
		3 in., clay shale as above.
		1 ft 2 in., siltstone, medium-light-gray, very sandy, argillaceous, with abundant streaks and laminae clay shale, some of which are broken and slightly distorted.
		9 in., clay shale as above.
		1 ft 4 in., siltstone as above with laminae and ½-in. beds of clay shale.
		3 ft, clay shale as above, with irregular siltstone laminae dipping as much as 8°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
107	1, 444–1, 454	Recovered 10 ft: Microfossils absent.
		Clay shale, medium-dark-gray, very slightly micaceous, noncalcareous, with poor shaly cleavage or subconchoidal fracture. Beds approximately flat lying. Irregular silty laminae abundant in lower 6 in.
108	1, 454–1, 464	Recovered 10 ft: Microfossils rare.
		Clay shale as in core 104 with scattered laminae and beds (less than 1 in. thick) of medium-gray siltstone. Some laminae crossbedded. Poor shaly to irregular cleavage suggests beds lie approximately flat; siltstone laminae dip as much as 8°, average 5°.
109	1, 464–1, 474	Recovered 5 ft 4 in.: Microfossils very rare.
		Clay shale as above but lack silt laminae. Fissile in lower part. Dip as much as 5°.
-----	1, 474–1, 485	Siltstone, light-olive-gray, sandy, calcareous; grades to very fine-grained sandstone in lower part; a small amount of medium-gray shale.
-----	1, 485–1, 490	Clay shale, medium-dark-gray, slightly silty, micaceous.
-----	1, 490–1, 495	Sandstone, medium-light-gray, very fine-grained, slightly silty, very calcareous, slightly micaceous, with a small amount siltstone and clay shale.
-----	1, 495–1, 500	Clay shale, very to slightly silty, with siltstone, and a small amount of very fine-grained silty calcareous micaceous sandstone.
-----	1, 500, 1, 505	Sandstone as above, with siltstone and a small amount of clay shale.
-----	1, 505–1, 520	Clay shale, with a very small amount of siltstone and sandstone.
-----	1, 520–1, 530	Siltstone, light-olive-gray and very slightly calcareous to medium-light-gray and noncalcareous.
-----	1, 530–1, 580	Sandstone, medium-light-gray, very fine- to fine-grained, silty; slightly calcareous in part, slightly micaceous. A small amount of medium-dark-gray clay shale and medium-light-gray siltstone in lower 20 feet.
-----	1, 580–1, 605	Clay shale, dark- to medium-dark-gray, nonsilty to very silty, with small amount of siltstone.
-----	1, 605–1, 615	Sandstone, very fine-grained, with some siltstone.
110	1, 615–1, 625	Recovered 8 ft 6 in.: Microfossils common.
		Clay shale, medium-dark-gray, noncalcareous, nonsilty to slightly silty; fair shaly cleavage; beds approximately flat lying.
111	1, 625–1, 635	Recovered 10 ft: Microfossils abundant.
		Clay shale as above; poor shaly cleavage.
112	1, 635–1, 645	Recovered 10 ft: Microfossils very abundant.
		Clay shale as above.
113	1, 645–1, 651	Recovered 6 ft: Microfossils abundant.
		1 ft 4 in., sandstone, medium-light-gray, fine-grained, slightly silty, argillaceous, noncalcareous, slightly micaceous, composed of subangular to subround grains of clear and white quartz, white and gray chert, and dark rock fragments. Streaks and patches of carbonaceous material dip 2°–5°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		4 ft 8 in., clay shale as above with poor shaly cleavage. At 1,648 ft is a 1-in. by 2-in. mass of pale-yellowish-brown slightly calcareous clay ironstone; grades into surrounding clay shale. Lower 1 ft of clay shale silty; contains patches of sandy silt and sand.
-----	1, 651–1, 675	Sandstone, medium-light-gray, very fine-grained, very silty; grades into light-olive-gray argillaceous noncalcareous siltstone.
-----	1, 675–1, 680	No sample.
-----	1, 680–1, 693	Clay shale, medium-dark- to dark-gray, nonsilty to very silty, with a very small amount of siltstone.
114	1, 693–1, 703	Recovered 10 ft: Microfossils very abundant. Clay shale, medium-dark-gray, noncalcareous, nonsilty; poor shaly cleavage to subconchoidal fracture. A 6-in. section of medium-light-gray fine-grained sandstone with streaks of clay shale and rare patches of carbonaceous material at 1,696 ft; very slightly calcareous, silty, and argillaceous. A 3-in. bed of very sandy medium-gray noncalcareous siltstone at base of core. Pelecypod shell fragments and ⅛-in. nodule of pyrite in shale a few inches above sandstone. Beds approximately flat lying.
115	1, 703–1, 713	Recovered 10 ft: Microfossils absent. Clay shale as above, but micaceous and silty in lower 1 ft. Pelecypod shell fragments (*Corbula?* sp.) in lower half of core. Beds approximately flat lying.
116	1, 713–1, 723	Recovered 10 ft: Microfossils common. Clay shale, medium-dark-gray, noncalcareous, very silty, slightly micaceous. Pelecypod shells (*Corbula* sp.) in upper half of core.
117	1, 723–1, 733	Recovered 10 ft: Microfossils abundant. 5 ft, clay shale as above, with scattered streaks and grains of pyrite. A 7-in. bed of sandy siltstone with intercalations of clay shale at 1,725 ft. Lower part has abundant intercalations of siltstone and fine-grained sandstone, with some carbonaceous streaks. Grades into unit below. 2 ft 4 in., sandstone, medium-light-gray, fine-grained, with abundant intercalations of clay shale, siltstone, and carbonaceous material in upper part; intercalations become rare with depth. Carbonized plant fragments in lower part of sandstone. 2 ft 8 in., clay shale, medium-dark-gray, slightly to very silty, with abundant intercalations of sandstone and siltstone, some of which are slightly crossbedded.
118	1, 733–1, 743	Recovered 8 ft: Microfossils common. 3 ft 4 in., clay shale, medium-dark-gray, nonsilty to slightly silty, noncalcareous, with siltstone and sandstone intercalations in upper 6 in. 4 ft. 8 in., sandstone, medium-light-gray, fine- to medium-grained, argillaceous, noncalcareous, massive; composed of subangular to subrounded grains of clear and white quartz, with some gray chert and dark rock fragments. Carbonaceous particles common in upper 2 ft, usually in small patches. Good odor and fair saturation of oil were noted.
119	1, 743–1, 745	Recovered 1 ft 6 in.: Microfossils absent. Sandstone as above.
120	1, 745–1, 755	Recovered 9 ft: Microfossils absent. Sandstone as above, but bottom 4 ft has fair bedding-plane cleavage. Beds approximately flat lying.
121	1, 755–1, 765	Recovered 9 ft 6 in.: Microfossils absent. Sandstone as above, but massive.
122	1, 765–1, 772	Recovered 6 ft: Microfossils absent. Sandstone as above.
123	1, 772–1, 782	Recovered 7 ft 6 in.: Microfossils absent. Sandstone as above but with spotty oil odor.
124	1, 782–1, 792	Recovered 9 ft 6 in.: Microfossils absent. Sandstone as above; a 2-in. unit at 1,790 ft has abundant carbonaceous laminae dipping 5°; 1 in. below laminae is mass of light-brownish-gray hard noncalcareous clay ironstone approximately 1 in. thick.
125	1, 792–1, 800	Recovered 2 ft 6 in.: Microfossils absent. Sandstone as above.
126	1, 800–1, 810	Recovered 4 ft 6 in.: Microfossils very abundant. 1 ft 6 in., interbedded sandstone as above, and clay shale, medium-dark-gray, slightly silty, noncalcareous, with poor shaly cleavage, infiltrated with drilling mud. 3 ft, clay shale, medium-dark-gray, nonsilty to slightly silty, noncalcareous, friable, with poor shaly cleavage. Badly infiltrated with drilling mud. A 1-in. bed of sandstone with alternating crossbedded laminae of light-gray medium-grained and medium-light-gray fine-grained sandstone at 1,808 ft.
127	1, 810–1, 816	Recovered 2 ft 6 in.: Microfossils very abundant. Clay shale as above.
-----	1, 816–1, 818	No sample.
-----	1, 818–1, 825	Sandstone, light-gray, fine-grained, slightly silty, noncalcareous, soft; composed of subangular to subround grains of clear and white quartz, with some dark rock fragments and pyrite.
-----	1, 825–1, 830	Clay shale, dark-gray, slightly carbonaceous, slightly micaceous, with sandstone.
-----	1, 830–1, 875	Sandstone, as between 1,818 and 1,825 ft, with very small amount of clay shale between 1,830 and 1,840 ft and 1,845 and 1,850 ft.
-----	1, 875–1, 885	Clay shale, medium-dark-gray, with some sandstone.
-----	1, 885–1, 910	Sandstone, light-gray, fine-grained; becomes very fine grained, calcareous to noncalcareous downward; composed of white and clear quartz, small amount of gray chert, and dark rock fragments.
128	1, 910–1, 920	Recovered 4 ft: Microfossils very abundant. Drilling mud with fragments of friable medium-dark-gray clay shale as above. A 1-in. fragment of medium-light-gray medium-grained noncalcareous sandstone at base of core.
-----	1, 920–1, 970	Sandstone as in core 128 above, with small amount of medium-dark- to dark-gray very slightly silty slightly micaceous clay shale which is most common between 1,940 and 1,955 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	1, 970–2, 020	Clay shale, medium- to medium-dark-gray, nonsilty to very silty, very slightly micaceous. Some loose sand in ditch samples between 1,980 and 2,010 ft probably contamination from overlying sandstone. A reverse fault repeats beds of the Killik tongue between 2,010 and 2,085 feet.
-----	2, 020–2, 030	Sandstone, light-gray, very fine-grained, silty, slightly calcareous, with clay shale and very small amount of siltstone.
-----	2, 030–2, 055	Clay shale, medium-dark-gray, nonsilty to very silty; grades to very argillaceous siltstone in lower part.
-----	2, 055–2, 080	Clay shale, with increasing siltstone and a small amount of sandstone which increases somewhat with depth.
-----	2, 080–2, 100	Clay shale, medium-dark-gray. Top of Grandstand formation where it is repeated by faulting is at 2,085 ft.
-----	2, 100–2, 115	Clay shale with sandstone, light-gray, very fine-grained, very small amount of siltstone.
-----	2, 115–2, 125	Sandstone as above, with some clay shale.
-----	2, 125–2, 185	Interbedded sandstone, siltstone, and clay shale; some fissile carbonaceous clay shale at 2,145 ft.
-----	2, 185–2, 250	Clay shale, medium-dark-gray; silty in part, with a small amount of siltstone and sandstone.
-----	2, 250–2, 252	Siltstone, medium-light-gray, argillaceous to sandy, very calcareous, with a very small amount of clay shale and sandstone.
129	2, 252–2, 257	Recovered 4 ft: Microfossils absent. Clay shale, medium-dark-gray; slightly silty in part, noncalcareous, with scattered, faint, slightly crossbedded laminae of silty medium-gray clay shale. Fair shaly cleavage dips as much as 10°.
130	2, 257–2, 266	No recovery; bit plugged.
131	2, 266–2, 271	No recovery; bit plugged.
132	2, 271–2, 276	No recovery; bit plugged.
-----	2, 276–2, 277	No sample.
133	2, 277–2, 287	Recovered 10 ft: Microfossils rare. 1 in., clay shale and dark-brownish-gray clay ironstone. 8 in., sandstone, medium-gray, fine-grained, noncalcareous, with abundant intercalations of dark-gray micaceous clay shale. 10 in., clay shale, medium-dark-gray, very slightly silty, noncalcareous. 5 ft 6 in., sandstone, medium-gray, very fine-grained, very silty, argillaceous, noncalcareous, micaceous, with some intercalations of clay shale in upper 6 in. Common siltstone laminae and carbonaceous partings dip 3°–8°. A 6-in. unit at 2,281 ft contains abundant lenticles and intercalations of medium-dark-gray clay shale. 1 ft 9 in., sandstone as above, but with intercalations of medium-dark-gray clay shale increasing with depth from 2 to 20 percent of the rock. 1 ft 2 in., claystone, medium-dark-gray, slightly to very silty, noncalcareous, with irregular fracture. Slickensides on some surfaces.
134	2, 287–2, 292	Recovered 5 ft: Microfossils common. 3 ft, clay shale, medium-dark-gray, silty, noncalcareous, with common siltstone laminae and intercalations dipping 1°–15°. Slickensides on a few surfaces in upper 1 ft. 2 ft, interbedded clay shale as above and medium-light-gray noncalcareous argillaceous sandy siltstone, with crossbedded argillaceous laminae dipping 1°–10°. Individual beds 1–6 in. thick; siltstone totals more than half of unit.
135	2, 292–2, 297	Recovered 5 ft: Microfossils abundant. Interbedded clay shale and siltstone as above; clay shale totals three-fourths of upper half of core, and siltstone makes up two-thirds of lower half. Two ½-in. beds of brownish-gray clay ironstone in siltstone at 2,296 ft and a 1-in. bed at 2,296½ ft.
136	2, 297–2, 302	Recovered 5 ft: Microfossils common. Sandstone, medium-light-gray, very fine-grained, silty, and argillaceous, very slightly calcareous, micaceous, massive; composed of subangular grains of clear and white quartz, gray chert, and dark rock fragments, with some carbonaceous particles. Lower half of core has beds of medium-dark-gray silty clay shale ½–3 in. thick, totaling a third of the rock. Irregular laminae of silt in clay shale, and clay shale in sandstone dip 1°–6°. Strong odor of oil and gas; core bled oil.
137	2, 302–2, 307	Recovered 2 ft: Microfossils rare. 10 in., clay shale, medium-dark-gray, silty, noncalcareous, slightly micaceous, with intercalations of medium-gray siltstone. 1 ft 2 in., sandstone, medium-light-gray, fine-grained, very slightly silty, argillaceous, noncalcareous. Fair bedding-plane cleavage suggests flat-lying beds. Strong oil and gas odor; cores bled oil.
138	2, 307–2, 309	Recovered 2 ft: Microfossils absent. Sandstone as above.
139	2, 309–2, 314	Recovered 5 ft: Microfossils very rare. Sandstone as above, but very fine- to fine-grained. Beds approximately flat lying.
140	2, 314–2, 318	Recovered 3 ft 6 in.: Microfossils absent. Sandstone as above.
141	2, 318–2, 327	Recovered 9 ft: Microfossils absent. Sandstone as above. Beds approximately flat lying.
142	2, 327–2, 337	Recovered 6 ft 6 in.: Microfossils absent. Sandstone as above.
143	2, 337–2, 347	Recovered 9 ft: Microfossils very rare. 3 ft 6 in., sandstone as above, but more massive. Carbonaceous partings in 1-in. unit at 2,339 ft dip 13°. 5 ft 6 in., sandstone, medium-light-gray, very fine-grained, very silty, argillaceous, noncalcareous, micaceous, massive. Rounded 1-in. mass of fine-grained sandstone at 2,341 ft; argillaceous, micaceous laminae at 2,342 ft dip 15°–17°. Nearly vertical calcite veinlet in lower foot of core.
144	2, 347–2, 357	Recovered 10 ft: Microfossils abundant. 2 ft, sandstone as above, with vertical calcite veinlets. 7 in., claystone, medium-dark-gray, slightly to very silty, micaceous,

Lithologic description—Continued

Core	Depth (feet)	Remarks
		noncalcareous, with subconchoidal fracture. 3 ft 5 in., sandstone, medium-light-gray, very fine-grained, very silty, argillaceous, slightly calcareous, micaceous, with argillaceous laminae dipping 1°–17°. Rare 1-in. claystone beds in lower part. Grades to siltstone at base. 4 ft, claystone, medium-dark-gray, nonsilty to very silty, noncalcareous; irregular fracture. Rare laminae and thin beds (1 in. or less) of medium-gray siltstone; 3-in. bed of siltstone with argillaceous laminae in basal 1 ft of core.
145	2, 357–2, 365	Recovered 8 ft: Microfossils common. Claystone as above, with rare intercalations of siltstone.
146	2, 365–2, 370	Recovered 5 ft: Microfossils very abundant. Claystone as above.
-----	2, 370–2, 390	Interbedded clay shale, slightly to very silty, siltstone, and small amount of sandstone.
-----	2, 390–2, 425	Clay shale, medium-dark-gray, silty, very finely micaceous; rare fragments of dark-gray to grayish-black clay.
-----	2, 425–2 430	Clay shale as above with some very slightly calcareous siltstone and sandstone.
-----	2, 430–2, 435	No sample.
-----	2, 435–2, 440	Sandstone, medium-light-gray, very fine-grained, very silty, argillaceous, very slightly calcareous, with some clay shale and siltstone.
-----	2, 440–2, 445	Siltstone, sandy, similar to the sandstone above, with a small amount of clay shale.
-----	2, 445–2, 455	Siltstone, grading to very fine-grained sandstone, and clay shale.
-----	2, 445–2, 500	Siltstone, grading to sandstone, with some clay shale; siltstone decreases with depth as clay shale increases to make up all the rock.
-----	2, 500–2, 515	Clay shale, with some siltstone and light-gray very fine- to fine-grained silty argillaceous sandstone composed of subangular to subrounded grains of white and clear quartz with some gray chert and dark rock fragments. Mica very rare.
-----	2, 515–2, 537	Sandstone, as described between 2,500 and 2,515 ft above.
147	2, 537–2, 542	Recovered 5 ft: Microfossils very rare. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous to very slightly calcareous, very slightly micaceous, massive, uniform. Sandstone composed of subangular grains of clear and white quartz, white and gray chert, and rare dark rock fragments.
148	2, 542–2, 547	Recovered 5 ft: Microfossils absent. Sandstone as above.
149	2, 547–2, 557	Recovered 10 ft: Microfossils absent. 8 ft 6 in., sandstone as above, massive, uniform. 1 ft 3 in., clay shale, medium-dark-gray, silty, poor shaly cleavage, with rare siltstone laminae. 3 in., sandstone as above.
150	2, 557–2, 563	Recovered 5 ft: Microfossils very rare. Sansdtone as above; lower 1 ft 9 in. has common carbonaceous laminae dipping 10°–15°; irregular subangular mass of medium-dark-gray silty claystone 2 in. in diameter at top of laminated unit. A ½-in. bed of silty medium-gray claystone at 2,562 ft, and irregular mass of clay ironstone, approximately ½ in. thick, at base.
151	2, 563–2, 568	Recovered 5 ft: Microfossils common. 1 ft 2 in. sandstone, very fine-grained, and medium-dark-gray silty claystone intermingled in irregular masses and thin beds. Rare carbonaceous partings in sandstone dip as much as 15°. 3 ft 10 in., sandstone, very fine-grained, massive, uniform as in core 150.
152	2, 568–2, 573	Recovered 5 ft: Microfossils very rare. Sandstone, medium-light-gray, very fine-grained, as above, but with common laminae of micaceous clay shale and carbonaceous partings dipping 1°–10°, with some slight crossbedding. Most laminae even and subparallel, some irregular and undulating. A 1-in. bed of medium-dark-gray claystone at 2,570 ft and 2-in. bed at base of core.
153	2, 573–2, 578	Recovered 5 ft: Microfossils very abundant. Clay shale, medium-dark-gray, very slightly silty and micaceous, noncalcareous; very poor shaly cleavage dips less than 5°.
-----	2, 578–2, 585	Interbedded sandstone, very fine-grained, silty, argillaceous, noncalcareous, and medium-dark-gray clay shale.
-----	2, 585–2, 595	Clay shale, dark-gray, nonsilty to slightly silty, very finely micaceous, with small amount of very fine- to fine-grained sandstone.
-----	2, 595–2, 600	Sandstone, fine-grained, with very small amount of clay shale.
-----	2, 600–2, 625	Clay shale, medium-dark-gray, and very small amount of sandstone.
-----	2, 625–2, 635	Sandstone, light-gray, very fine- to fine-grained, slightly silty, very slightly calcareous, with common carbonaceous particles in lower part; with medium-dark-gray clay shale.
-----	2, 635–2, 660	Clay shale, medium-dark-gray, nonsilty to very silty.
154	2, 660–2, 670	Recovered 8 ft: Microfossils absent. Sandstone, medium-light-gray, very fine- to fine-grained, argillaceous, silty, very slightly micaceous, noncalcareous to slightly calcareous, massive, uniform. Sandstone of subangular grains of white and clear quartz with some chert and dark rock fragments. Rare scattered grains of limonite.
155	2, 670–2, 680	Recovered 1 ft 6 in. (bit plugged): Microfossils absent. Sandstone, as above.
156	2, 680–2, 682	No recovery; bit plugged.
157	2, 682–2, 688	Recovered 6 ft: Microfossils absent. Sandstone as above, but very fine grained, with common intercalations and laminae of medium-dark-gray clay shale between 2,684 and 2,685 ft.
158	2, 688–2, 695	Recovered 7 ft: Microfossils absent. Sandstone as above but with fair bedding-plane cleavage suggesting a dip of approximately 5°. Rare faintly crossbedded silty laminae in units 2–3 in. thick.

Lithologic description—Continued

Core	Depth (feet)	Remarks
159	2, 695–2, 705	Recovered 10 ft: Microfossils absent. Sandstone as above, but slightly coarser and more massive in upper 3 ft. Two ⅛-in. streaks of limonitic clay 1 ft below top of core dip approximately 5°.
160	2, 705–2, 715	Recovered 9 ft: Microfossils absent. Sandstone as above, but massive except for bottom 2 ft. Scattered intercalations of limonitic clay between 2,706 and 2,707 ft.
161	2, 715–2, 718	Recovered 3 ft: Microfossils absent. Sandstone as above, with a ⅛-in. bed containing abundant coarse subangular grains of coaly material and hematitic clay.
162	2, 718–2, 728	No recovery.
163	2, 728–2, 733	Recovered 5 ft: Microfossils absent. Sandstone as above but with common subparallel laminae of clay shale, dipping 10°–15° between 2,730 and 2,732 ft. A ⅛-in. lamina of light-brownish-gray clay ironstone at 2,731 ft.
164	2, 733–2, 743	Recovered 10 ft: Microfossils absent. Sandstone as above, massive, uniform. Medium-dark-gray claystone laminae and intercalations in lower 3 ft; laminae, commonly micaceous and carbonaceous, dip 3°–15°.
165	2, 743–2, 748	Recovered 5 ft: Microfossils absent. Siltstone, medium-gray, argillaceous, very micaceous, noncalcareous. Sandstone and silty clay shale laminae and intercalations in lower half of core; laminae dip 10°–15°.
166	2, 748–2, 758	Recovered 4 in.: Not sampled for microfossils. Claystone, medium-dark-gray, very silty, noncalcareous.
167	2, 758–2, 759	Recovered 2 in.: Not sampled for microfossils. Claystone as above, but less silty.
-----	2, 759–2, 765	Clay shale, with a small amount of siltstone and sandstone.
-----	2, 765–2, 775	Siltstone, medium-light-gray, with a small amount of sandstone and clay shale.
-----	2, 775–2, 795	Clay shale, with some siltstone in upper 5 ft, and a very small amount of sandstone and siltstone decreasing toward base of unit.
-----	2, 795–2, 800	No sample.
-----	2, 800–2, 810	Clay shale with a small amount of siltstone at top.
-----	2, 810–2, 820	Sandstone, very fine-grained, as in core 168.
168	2, 820–2, 825	Recovered 5 ft: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, very micaceous, very slightly calcareous, massive, uniform.
169	2, 825–2, 833	Recovered 8 ft: Microfossils absent. 5 ft, sandstone as above, but with faint argillaceous laminae in lower part dipping 3°–8°. A ¼-in. bed of clay ironstone at 2,528 ft. Grades into unit below. 7 in., siltstone, medium-gray, sandy, argillaceous, noncalcareous, with carbonaceous particles and intercalations of dark-gray clay shale; rare patches of pyrite. 2 ft 5 in., sandstone as above, but very calcareous, hard.

Lithologic description—Continued

Core	Depth (feet)	Remarks
170	2, 833–2, 843	Recovered 10 ft: Microfossils absent. 5 ft 8 in., sandstone as above, with common intercalations of medium-dark-gray clay shale, and carbonaceous micaceous laminae dipping 8°–10°. 4 ft 4 in., claystone, medium-dark-gray, slightly to very silty, with intercalations and beds (less than 2 in. thick) of medium-gray sandy siltstone. Top of Topagoruk formation at approximately 2,840 ft.
171	2, 843–2, 853	Recovered 10 ft: Microfossils absent. 8 ft 3 in., siltstone, medium-gray, very argillaceous, partly sandy, micaceous, noncalcareous, with intercalations of medium-dark-gray micaceous clay shale and medium-light-gray micaceous sandstone. Clay shale common in beds ¼–1 in. thick between 2,845 and 2,849 ft. Grades into unit below. 1 ft 9 in., sandstone, medium-light-gray, very fine-grained, very argillaceous, silty, micaceous, noncalcareous. Upper part has faint carbonaceous partings dipping approximately 10°.
172	2, 853–2, 858	Recovered 1 ft 6 in.: Microfossils rare. 1 ft, siltstone as above. 6 in., claystone, medium-dark-gray, very silty, micaceous, noncalcareous, with irregular fracture. Irregular silty intercalations in upper part.
173	2, 858–2, 865	Recovered 7 ft: Microfossils very rare. Claystone as above; very rare pyritized and carbonized plant fragments scattered throughout.
174	2, 865–2, 875	Recovered 10 ft: Microfossils common. 8 ft 11 in., claystone as above, slightly to very silty. 1 ft 1 in., sandstone, medium-light-gray, very fine-grained, very silty, argillaceous, slightly calcareous, micaceous, with faint carbonaceous, micaceous partings and clay shale laminae dipping 5°–12°. Fracture irregular.
175	2, 875–2, 885	Recovered 8 ft: Microfossils very rare. 4 ft 6 in., interbedded sandstone and claystone as above; beds ½–6 in. thick, about half sandstone and half claystone. 3 ft 6 in., claystone as above but only slightly silty and micaceous.
-----	2, 885–2, 890	Clay shale, sandstone, and siltstone.
-----	2, 890–2, 950	Clay shale, medium-dark- to dark-gray, nonsilty to very silty, with rare siltstone in upper 25 ft.
-----	2, 950–2, 955	Clay shale, with siltstone, medium-light-gray, sandy, argillaceous, noncalcareous.
-----	2, 955–2, 981	Clay shale, with rare siltstone.
176	2, 981–2, 986	Recovered 5 ft: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, very silty, argillaceous, very slightly calcareous, slightly micaceous, massive, uniform. Sandstone composed of subangular grains of clear and white quartz with gray chert and dark rock fragments and carbonaceous particles. Spotty oil saturation and odor.

Lithologic description—Continued

Core	Depth (feet)	Remarks
177	2, 986–2, 996	Recovered 10 ft: Microfossils absent. Sandstone as above, with vertical calcite veinlets.
178	2, 996–3, 001	Recovered 5 ft: Microfossils absent. Sandstone as above, with vertical calcite veinlets; bottom 1 ft lacks veinlets, but has carbonaceous partings dipping 10°–12°.
179	3, 001–3, 011	Recovered 10 ft: Microfossils absent. Sandstone as above, massive, uniform, lacks veinlets.
180	3, 011–3, 016	No recovery.
-----	3, 016–3, 020	Clay shale with some siltstone.
-----	3, 020–3, 085	Clay shale, medium-dark-gray; grades to dark-gray with depth. Small amount of siltstone from 3,030 to 3,040 ft and from 3,050 to 3,055 ft; elsewhere very rare.
-----	3, 085–3, 095	Sandstone, medium-light- to medium-gray, very fine-grained, slightly calcareous, with a large amount of clay shale in upper part.
-----	3, 095–3, 160	Clay shale, with rare brownish-gray siltstone.
-----	3, 160–3, 210	Clay shale, with siltstone, brownish-gray; very sandy in part, calcareous.
-----	3, 210–3, 225	Clay shale, slightly to very silty.
-----	3, 225–3, 250	Clay shale and medium-gray, very argillaceous siltstone.
-----	3, 250–3, 345	Clay shale, slightly to very silty, with rare siltstone.
-----	3, 345–3, 350	No sample.
-----	3, 350–3, 395	Clay shale with rare siltstone.
181	3, 395–3, 405	Recovered 10 ft: Microfossils abundant. 5 ft, claystone, medium-dark-gray, slightly to very silty and sandy, noncalcareous, micaceous, with scattered patches and streaks of pyrite and carbonaceous particles. Irregular fracture. 5 ft, siltstone, medium-gray, very sandy, argillaceous, noncalcareous, micaceous, with patches of medium-dark-gray clay.
182	3, 405–3, 415	Recovered 10 ft: Microfossils very abundant. 6 ft, claystone, medium-dark-gray, slightly to very silty, noncalcareous, micaceous. Irregular fracture. 4 ft, siltstone, medium-gray, very argillaceous, very slightly pyritic, noncalcareous, with intercalations of medium-dark-gray claystone. Irregular fracture.
183	3, 415–3, 425	Recovered 10 ft: Microfossils very abundant. Claystone, medium-dark-gray, very silty, micaceous, noncalcareous, mas sive, uniform. Irregular fracture. Small patches of carbonized plant remains scattered throughout.
184	3, 425–3, 430	Recovered 5 ft: Microfossils common. Claystone as above.
-----	3, 430–3, 465	Clay shale, with rare siltstone, medium-light-gray; slightly calcareous in part.
-----	3, 465–3, 497	Siltstone, very sandy; grades to sandstone in upper part; becomes darker, very argillaceous; not sandy in lower part. Amount of clay shale increases with depth.
185	3, 497–3, 507	Recovered 10 ft: Microfossils very rare. Claystone and siltstone, interbedded, medium-light-gray, slightly argillaceous, sandy, noncalcareous. Beds 1–6 in. thick and about half siltstone and half claystone. Rare faint slightly carbonaceous laminae dip 10°.
186	3, 507–3, 512	Recovered 5 ft: Microfossils common. Claystone as in core 183 above, with scattered thin siltstone intercalations.
187	3, 512–3, 522	Recovered 10 ft: Microfossils common. Claystone and siltstone, interbedded, as in core 185 above, with beds 1–12 in. thick.
188	3, 522–3, 532	Recovered 10 ft: Microfossils abundant. Clay shale, medium-dark-gray, noncalcareous, slightly to very silty, with scattered medium-gray siltstone intercalations. Very poor shaly cleavage suggests a dip of 1°–5°.
-----	3, 532–3, 640	Clay shale, medium-dark-gray, with very small amount of very argillaceous siltstone.
-----	3, 640–3, 650	No sample.
-----	3, 650–3, 725	Clay shale, with argillaceous medium-light- to olive-gray, slightly calcareous siltstone which makes up 5–40 percent of the rock. Siltstone at bottom of unit is brownish gray, noncalcareous.
-----	3, 725–3, 835	Clay shale, medium-dark-gray, slightly to very silty; abundant fine particles of pyrite in shale at 3,820 ft. Very rare siltstone.
-----	3, 835–3, 845	Sandstone, brownish-gray, very fine-grained, very argillaceous, silty, with siltstone that is similar but finer grained and medium-dark-gray clay shale.
-----	3, 845–3, 985	Clay shale, medium-dark-gray, partly silty, finely micaceous.
-----	3, 985–4, 070	Clay shale as above, but with rare siltstone at 3,985–3,995, 4,030–4,040, and 4,065–4,070 ft.
-----	4, 070–4, 075	Siltstone, medium-gray, sandy, very slightly calcareous, with small amount of clay shale.
-----	4, 075–4, 080	No sample.
-----	4, 080–4, 085	Clay shale with small amount siltstone.
189	4, 085–4, 090	Recovered 3 ft 6 in.: Microfossils common. Clay shale, medium-dark-gray, nonsilty to slightly silty, noncalcareous, very poor shaly cleavage, with rare intercalations and laminae of medium-gray siltstone. Laminae slightly crossbedded and dip 3°–10°.
190	4, 090–4, 095	Recovered 5 ft: Microfossils common. Clay shale as above.
191	4, 095–4, 104	Recovered 8 ft 6 in.: Microfossils abundant. Clay shale as above.
192	4, 104–4, 114	Recovered 10 ft: Microfossils abundant. Clay shale as above.
-----	4, 114–4, 155	Clay shale, medium-dark-gray, with very small amount of siltstone decreasing to rare with depth. Fragments of calcite veins in lower part; a few pieces of grayish-black shale found in botton 10 ft.
-----	4, 155–4, 176	Clay shale and sandstone, interbedded, medium-light-gray, very fine-grained, argillaceous, silty, slightly calcareous.
193	4, 176–4, 181	Recovered 3 ft 6 in.: Microfossils very abundant. Claystone, medium-dark-gray, noncalcareous, slightly micaceous; slightly silty in part, with irregular fracture. Laminae and intercalations of very argillaceous siltstone are rare.
194	4, 181–4, 190	Recovered 9 ft: Microfossils common. Clay shale, like claystone above; very poor shaly cleavage and silty laminae suggest a dip of 18°–20°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
195	4, 190–4, 200	Recovered 9 ft: Microfossils common. Clay shale as above; very poor shaly cleavage and laminae dip 10°–25°.
196	4, 200–4, 204	Recovered 4 ft: Microfossils abundant. Clay shale as above; cleavage and laminae dip 10°–20°.
-----	4, 204–4, 225	Clay shale, with a small amount of siltstone and rare sandstone.
-----	4, 225–4, 255	Clay shale with very small amount of siltstone; a few fragments of shale are black.
-----	4, 255–4, 260	Clay shale and argillaceous siltstone, interbedded, with some sandstone.
-----	4, 260–4, 280	Clay shale, with rare siltstone.
-----	4, 280–4, 285	Siltstone with some clay shale.
-----	4, 285–4, 355	Clay shale, partly very silty, with rare siltstone in upper part of unit.
-----	4, 355–4, 380	Clay shale and medium-light-gray, very fine-grained sandstone.
-----	4, 380–4, 395	Clay shale, with small amount of siltstone and silty sandstone.
-----	4, 395–4, 490	Clay shale, slightly harder, darker, and more fissile than that above.
-----	4, 490–4, 560	Clay shale as above, with a very small amount of medium-gray very argillaceous slightly calcareous siltstone, at 4,490 to 4,500 ft and 4,520–4,540 ft. Crinoid ossicles were found at 4,500 and 4,525 ft.
-----	4, 560–4, 710	Clay shale, hard; rare siltstone only at 4,595–4,615, 4,625–4,635, and 4,670–4,690 ft.
-----	4, 710–4, 815	Clay shale as above, with argillaceous siltstone, and a few fragments of very fine-grained sandstone at 4,715 ft and 4,770 ft. One or two fragments have bituminous (?) partings.
-----	4, 815–5, 005	Clay shale, with rare siltstone. Bottom 15 ft slightly darker than shale above.
-----	5, 005–5, 070	Clay shale as above, with some siltstone; some of shale is very silty.
-----	5, 070–5, 150	Clay shale, nonsilty to very silty, with rare siltstone and a very few pieces of medium-brownish-gray noncalcareous sandstone, with much dark-brown clear quartz, in dark silt matrix.
-----	5, 150–5, 365	Clay shale, partly silty, with different amounts of argillaceous siltstone, ranging from 1/10 to 1/2 of the rock. A crinoid ossicle was found at 5,150 ft.
-----	5, 365–5, 400	Clay shale, partly silty, with small amount of siltstone and very rare medium-light-gray very argillaceous silty sandstone.
-----	5, 400–5, 565	Clay shale and rare siltstone.
-----	5, 565–5, 580	Clay shale and slightly sandy siltstone.
-----	5, 580–5, 990	Clay shale, rarely very silty, with siltstone making up 10 percent or less of the rock. Few pieces of medium-gray very fine-grained sandstone make up 5–10 percent of the rock between 5,800 and 5,810 ft. Rare pieces of brownish-gray very fine-grained sandstone at 5,665–5,675 ft. Crinoid ossicles at 5,740–5,750 and 5,800–5,810 ft. Top of Oumalik formation at 5,650 ft.
197	5, 990–6, 005	Recovered 15 ft: Microfossils absent. Clay shale, medium-dark-gray, noncalcareous, slightly silty, with abundant very fine, very uniform partings of micaceous silt, 1/16–1 in. apart, which give varvelike appearance and very good bedding-plane cleavage. Laminae dip 5°.
	6, 005	Total depth.

CORE ANALYSES

The following table shows the porosity, permeability, and carbonate content of core samples from Umiat test well 1. Most of the effective porosity and air permeability data were determined in the U. S. Geological Survey laboratory in Fairbanks, Alaska, using the Washburn-Bunting porosimeter and the Hayward permeameter; some samples were also tested by Paul D. Krynine. Tests were also made by Dowell Incorporated of Tulsa, Okla. Carbonate-content tests and sieve analyses (see p. 92 for the latter) were made in the Fairbanks laboratory.

Analyses of core samples from Umiat test well 1

Depth (feet)	Effective porosity (percent)	Air permeability (mil lidarcys)	Content of carbonate minerals (percent by weight)
89	16.8	14.4	13.24
118	24.1	16.0	-----
120	17.2	6.25	16.97
124	9.8	5.0	-----
130	16.2	8.8	-----
135	17.2	7.5	-----
139	15.6	5.75	-----
166	4.8	<5	36.19
171	5.2	<5	-----
177	17.5	<5	-----
187	15.2	<5	17.23
537	16.4	9.9	-----
540	17.5	17.3	-----
543	9.5	<5	26.31
549	13.7	<5	21.78
554	10.7	<5	-----
748	12.1	<5	-----
751	10.8	<4	20.2
754	10.8	<4	-----
924	20.0	87.5	-----
1,224	8.6	<5	-----
1,336 [1]	17.7	1.2	4.0
1,339	9.3	<5	-----
1,346 [2]	-----	2.5	-----
1,346 [1]	20.0	5.2	3.7
1,348	12.2	<5	-----
1,352	9.4	<5	-----
1,355 [1]	12.7	<1	5.2
1,356	11.1	<5	-----
1,358 [1]	10.6	<1	8.1
1,360	10.8	<4	-----
1,363	11.4	<5	-----
1,363 [1]	13.9	<1	8.8
1,366 [1]	12.3	<1	6.3
1,368	11.6	27.8	-----
1,372 [2]	-----	.09	-----
1,372 [1]	9.5	<1	8.3
1,374	10.2	6.5	-----
1,379 [1]	14.4	<1	-----
1,380	12.6	<6	36.6
1,739 [2]	-----	62.6	-----
1,740 [1]	15.9	14.4	2.4
1,742	15.6	59.5	-----
1,746	17.8	50.0	-----
1,746 [1]	18.3	14.9	3.5
1,748	17.6	35.0	-----
1,752 [2]	-----	25.8	-----
1,753	21.9	13.4	3.5
1,757	-----	.41	-----
1,757 [1]	18.9	1.2	5.6
1,760	14.9	<5	-----
1,762	10.4	<6	-----
1,765	10.1	<5	-----
1,768	10.9	<5	-----
1,773	9.1	<5	-----
1,776	9.7	<5	-----
1,780	7.7	<5	-----
1,783	8.5	<5	-----
1,787	8.4	<4	-----
1,790	9.0	<4	-----
1,796	8.6	<4	-----
2,281	8.9	<5	-----
2,291	7.7	<6	-----
2,299	10.0	<5	-----
2,308 [1]	18.1	-----	9.5
2,310	15.2	-----	-----
2,311 [1]	15.7	3.8	3.63
2,314	16.3	-----	-----
2,321 [1]	-----	11.0	-----
2,322 [1]	19.6	25.2	5.61
2,330 [1]	14.3	<1	5.5

See footnotes at end of table.

Analyses of core samples from Umiat test well 1—Continued

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)	Content of carbonate minerals (percent by weight)
2,335	16.0	<4	
2,340 [1]	14.5	1.8	6.36
2,341	10.3	<6	
2,345	11.4	<5	
2,537	7.3	<5	
2,540	11.7	<5	
2,543	10.7	<5	
2,546	10.1	<5	
2,549	8.1	<4	
2,553	6.2	<5	
2,556	6.8	<5	
2,558	8.5	<4	
2,562	8.2	<6	
2,565	8.6	<5	
2,661	14.1	<7	
2,664	14.7		
2,668	7.2	<5	27.76
2,669			20.6
2,675	10.5	<4	
2,683	7.5	<4	13.48
2,690 [2]		12.3	
2,690 [1]	17.9	9.5	5.68
2,694	23.8	23.0	
2,698 [1]	14.7	4.0	5.31
2,699	15.2	<4	
2,702 [2]		2.4	
2,703 [1]	16.3	<1	5.75
2,706	13.1	<5	
2,710	14.0	<5	
2,715	15.6	<13	
2,718	12.1		
2,729	10.7	<6	
2,733	10.9		
2,738	9.2	<5	
2,821	9.1		13.45
2,825	10.5	<5	
2,829	10.0	<5	16.0
2,876	7.0		
2,981	12.7		9.47
2,981 [1]	12.5	2.78	
2,983 [2]		.05	
2,987	11.2		
2,991	10.8	<4	
2,995	10.0	<5	
3,000	9.0		
3,005	8.5	<6	
3,498	13.4		
3,500	9.8		

[1] Samples tested by Dowell Incorporated.
[2] Samples tested by P. D. Krynine.

Sieve analyses of samples from Umiat test well 1

Depth (feet)	Wentworth scale Sand grain size,[1] (percent)				
	60 mesh (medium)	120 mesh (fine)	230 mesh (very fine)	Less than 230 mesh (silt, clay)	Total
139	3.4	57.2	10.6	28.8	100.0
537	1.2	31.7	31.3	35.6	99.8
754	1.5	45.9	22.4	30.4	100.3
922		67.5	7.4	25.0	99.9
1,348		48.81	19.21	31.98	100.00
1,360		33.0	33.0	33.0	99.0
1,368	Trace	28.60	33.20	40.14	101.94
1,370	0.61	49.70	30.92	18.01	99.24
1,744	9.68	67.20	11.20	11.54	99.62
1,748	4.92	61.20	13.47	20.00	99.59
1,760	.2	32.8	30.8	36.0	99.8
1,773	11.0	26.4	28.5	33.8	99.7
1,796	9.6	29.4	38.8	22.3	100.1
2,310		49.0	28.0	23.0	100.0
2,540	1.7	33.6	32.6	32.0	99.9
2,558	4.3	26.6	33.7	35.0	99.6
2,664	12.30	40.19	26.59	20.18	99.26
2,694		56.3	23.7	20.2	100.2
2,987		10.8	50.8	38.5	100.1

[1] All material passed through the 35-mesh screen.

PETROGRAPHIC ANALYSES

A detailed petrographic study of 18 thin sections from sandstone and siltstone penetrated in drilling Umiat test well 1 was made by Paul D. Krynine (*in* Payne and others, 1951). His data are summarized below and in the following table.

All 18 samples consist of low-rank graywacke, characterized by quartz and chert grains with a large amount of metamorphic or volcanic rock fragments and micas, with very little feldspar. The grains are typically angular and poorly sorted. The Umiat samples have an unusually large amount of montmorillonite. Mineral grains present consist of about 35 percent of detrital quartz, 15 percent of chalcedony, and 20–30 percent slate, phyllite, and quartzitic or quartz-mica schist. Minute particles of mica (muscovite, sericite, and chlorite) and illite make up a large part of the rock fragments. Mica (muscovite, biotite, and chlorite) is also present as larger detrital flakes; much of the chlorite is altered biotite. The rare feldspar grains are mostly plagioclase; traces of andesitic volcanic rocks are present in most samples. Authigenic minerals, mostly produced by alteration of clay minerals and volcanic glass, include illite, chlorite, kaolinite, and montmorillonite. Illite is most abundant and lines most of the pore spaces and coats sand grains. Chlorite is less common but occurs in the same manner. Kaolinite is very rare and is possibly detrital in origin. Montmorillonite, probably the result of alteration of andesitic volcanic glass, occurs as nests of fibrous radiating crystals, or as isolated shreds intergrown with authigenic illite. It is abundant enough to cause a large amount of swelling as a result of hydration. Calcite and dolomite are present in small amounts, and collophane is rare in scattered samples.

Reservoir properties of the rock are affected by the quantity and type of pore space and by the interstitial material. Visible porosity, or pore spaces easily seen under the microscope, ranges from less than 1 percent to 10 percent; and residual porosity, consisting of planes of discontinuity between grains, is 5 percent or more. The effectiveness of the rock as a reservoir, however, is greatly affected by the amount of interstitial clays and micas, which did not exceed 7 percent of the rock and coated 60 percent or less of the sand grains in the reservoirs classed as fair or good. (See table on p. 94–95.) Hydration of clay minerals, especially montmorillonite, by fresh water is a major factor affecting permeability. Where these minerals are incorporated in rock fragments, swelling is negligible; where they are disseminated particles, swelling may partly or completely destroy the original permeability of the rock.

Samples from 1,379 and 1,746 feet were acidized by Dowell Incorporated. In these samples the carbonate content is very low; so the acidizing had very little effect on porosity. In the dried sample acidizing caused the montmorillonite to swell, plugging some pore space but opening a new capillary network by

shattering the rock along lines of weakness, with a slight net gain in porosity. However, the effect of acid on montmorillonite-bearing rock in place, confined by pressure and containing connate water, cannot be determined from the reaction of a dried sample at atmospheric pressure.

HEAVY-MINERAL ANALYSIS

Sandstone samples were disaggregated and treated with dilute hydrochloric acid to remove the carbonates. The disaggregate was sieved, and the material passing the 80-mesh and retained on the 235-mesh screens was separated in bromoform (sp gr 2.7) and methylene iodide (sp gr 3.0) into light, medium, and heavy fractions. Slides of the heavy fractions (sp gr >3.0) were prepared with canada balsam or aroclor.

The following information was supplied by Robert H. Morris, who studied the samples. The heavy-mineral zones in the Umiat area include the biotite zone, in beds of the Colville group in Umiat test well 11; the hornblende zone, in strata of the Nanushuk group; the zoned zircon zone, in the Grandstand and Topogoruk formations; and possibly the augite zone, in one sample from the Oumalik formation in Umiat test well 1. Abundance of heavy minerals noted in the samples is shown on plate 10.

OIL AND GAS

OIL AND GAS SHOWS

Several poor shows of oil were noted, but none indicated producing strata. The oil shows listed in the table below are those recorded by Don W. Jopling, geologist, and J. R. Coleman, petroleum engineer, of Arctic Contractors, while the well was being drilled.

Oil and gas shows from Umiat test well 1

Depth (feet)	*Remarks*
250–252	Odor of gas or distillate on freshly broken surface; faint cut in ether.
535–555	Strong oil odor; positive cut in CCl_4.
555–584	Slight oil odor.
749–766	Slight oil odor; gas detected by indicator.
919–934	Gas odor and trace of oil.
1,305–1,308	Core well saturated with light-gravity oil.
1,335–1,386	Good oil saturation and gas odor.
1,736–1,772	Good oil odor and fair saturation.
1,772–1,786	Spotty oil odor.
2,296–2,350	Strong odor of oil and gas and good saturation. Cores bled when removed from barrel.
2,650–2,746	Strong to weak oil odor and some saturation, in streaks.
2,980–3,011	Spotty oil odor and saturation.
3,497–3,499	Faint show of oil.
3,832–3,834	Trace of gas detected by indicator.

Twenty feet (about 120 gal) of oil was found in the hole on June 4, 1946, when operations were resumed after shutting down for the winter on September 19, 1954. During the winter, the drilling fluid had frozen and formed ice in the hole between 775 feet and 920 feet; the oil seeped into the hole on top of the ice.

FORMATION TESTS

Eight formation tests were made in Umiat test well 1; one was unsuccessful, but the others, except for the seventh, recovered drilling mud with a trace of oil. The packer and valve leaked in the seventh test (1,693–1,816 ft), and fresh water and fresh-water-cut mud were recovered by bailing. The detailed descriptions given below are based on data from the petroleum engineer's records.

Test 1, 530–584 feet.—The packer was set at 530 feet; 37 feet of drilling mud with a trace of oil was recovered from drill pipe above packer.

Test 2, 679–692 feet.—This test was made to test the water shut-off of casing cement. A 9⅝-inch outer diameter rubber open-hole packer was set with its base at 679 feet. It had 10 feet of perforated anchor below. The tester was open 20 minutes; 15 feet of drilling mud was recovered in the pipe above the retaining valve.

Test 3, 918–1,027 feet.—The packer was set at 918 feet, with 15 feet of perforated pipe below packer, and 90 feet of drill pipe below the perforated pipe. The pin in the packer failed to shear. The tool was pulled, and drilling mud was found in the drill pipe 150 feet below the top. The trip valve was reset, and the tester was rerun without the shear pin in the packer, which did not hold. When the tester was pulled out, the drill pipe was found to be full of mud. One joint of drill pipe was added below the packer, and the tool was rerun. The packer was set at 887 feet, and the valve was opened, but the test was not satisfactory as the packer was not long enough to seat in the open hole and did not hold. The tester was pulled out, and mud was found in the drill pipe; it filled 390 feet of pipe in 15 minutes through a 5/16-inch bottom-hole choke.

Test 4, 1,213–1,350 feet.—The packer was set at 1,213 feet, with perforated pipe from 1,340 to 1,344 feet. The trip valve was open 30 minutes, and 30 feet of drilling mud with a trace of oil was recovered from above the packer. There was no free oil.

Test 5, 1,325–1,383 feet.—A Johnston formation tester was run with 3 perforated joints and 30 feet of drill pipe below packer and a Johnston bottom-hole pressure gauge on the bottom. The rat-hole packer did not hold; the tester was pulled out and the packer built up from 8½ inches to 9⅝ inches at the top, taper-

Petrographic characteristics of sandstones from

	Dirty sandstone at 1,346 ft.	Dirty sandstone at 1,371 ft.	Dirty sandstone at 1,379 ft.	Clean sandstone at 1,739 ft.	Clean sandstone at 1,746 ft.	Dirty sandstone at 1,752 ft.
Texture						
Average diameter (millimeters)	0.07–0.14	0.08–0.15	0.06–0.20	0.12–0.25	0.08–0.15	0.08–0.15
Grains:matrix:cement	75:25:1	63:35:2	71:20:4	88:7:5	88:9:3	83:15:2
Grain composition (percent)						
Quartz	37	35	29	42	35	40
Chert	18	5	20	41	42	30
Feldspar	2	2	4	2	2	3
Mica flakes (large)	3	5	1–2	Trace	2	1
Slate, phyllite	20	15	24	2	9	8
Quartzite, schist	10	20	10	8	4	6
Volcanic rocks	Trace	Trace	Andesite	----------	Andesite	Andesite
Accessories	Trace	Zircon, garnet	Titanite	----------	----------	Zircon
Biotite	Present	----------	Present	Present	----------	----------
Chlorite	----------	Present	----------	----------	----------	----------
Muscovite	Present	Present	Present	Present	Present	Present
Pyrite	----------	----------	----------	----------	----------	----------
Collophane	Present	----------	Present	----------	Present	----------
Interstitial material (percent)						
Chlorite	3	1	2	1	Trace	1
Sericite	Trace	2	Trace	Trace	Trace	Trace
Illite	3	3	2	2	Trace	2
Montmorillonite	2–4	3–4	4	1	?	3–4
Kaolinite	1–2	3	Trace	Trace	Trace	2
Silica cement	0.05	1	Trace	1	Trace	Trace
Carbonates	----------	1	3	----------	3	2
Reservoir properties						
Type of reservoir	Poor	Very poor	Poor	Very good	Fair	Fair
Porosity (percent)	13.7	8.1	20.4	16.9	22.7	14.5
Permeability (millidarcys)	2.55	0.1	<1	62	9.7	25.8
Pore size (millimeters)	0.03	0.02	0.04	0.09	0.05	0.05
Visible porosity (percent)	3	<1	3.5	10	4.5	5
Residual porosity	Very low	Very low	Very low	Good	Fair	Fair
Bonding material	Chlorite, illite	Illite	Chlorite, illite	Silica, illite	Chlorite	Illite
Wall-space coating (percent)	65	85	75	35	50	50
Hydration (swelling)	Strong	Strong	Strong	Moderate	Low	Strong

ing to 6 inches at the base. The tester was rerun with the bottom-hole pressure gauge on the bottom, and 5 feet of perforated pipe, 30 feet of drill pipe, and 5 more feet of perforated pipe between the gauge and the packer, which was set at 1,325 feet. The valve was open 1 hour and 50 minutes; 75 feet of drilling mud with a trace of oil was recovered from above the packer.

Test 6, 1,325–1,414 feet.—The rat-hole packer was set at 1,325 feet, with 62 feet of drill pipe, 10 feet of perforated pipe, and a Johnston bottom-hole pressure gauge on the bottom. Opened trip valve, and swabbed once every 15 minutes for several hours with a Guiberson 2½-inch tubing swab run on sand line. Tubing above swab was loaded with water to get enough fluid to swab. Load water with some drilling mud and a trace of oil was recovered on each swab.

Test 7, 1,693–1,816 feet.—The rat-hole packer was set at 1,693 feet, with 5 feet of perforated pipe, 92 feet of drill pipe, and 10 feet more of perforated pipe between it and the Johnston bottom-hole pressure gauge at the bottom of the tool. The packer and valve leaked, and the mud level dropped when the valve was opened; the test was unsatisfactory. The drill pipe contained 2,160 feet of drilling mud. The hole was bailed from 500 to 1,100 feet in 6 hours and to 1,200 feet in an additional 4 hours. Drilling mud cut with fresh water was recovered; the fluid level could not be lowered below

Umiat test well 1, as determined by P. D. Krynine

Dirty sandstone at 1,757 ft.	Siltstone at 2,298 ft.	Dirty sandstone at 2,311 ft.	Dirty sandstone at 2,321 ft.	Dirty sandstone at 2,690 ft.	Clean sandstone at 2,702 ft.	Dirty sandstone at 2,881 ft.	Coarse siltstone at 2,983 ft.	Siltstone at 2,990 ft.	Siltstone at 3,002 ft.	Sandy siltstone at 3,497 ft.	Siltstone at 3,507 ft.
Texture											
0.06–0.15 70:25:5	0.02–0.08 86:10:4	0.07–0.15 78:20:2	0.09–0.15 70:25:5	0.09–0.12 78:20:2	0.10–0.16 80:16:4	0.06–0.14 67:30:3	0.03–0.07 61:35:4	0.02–0.08 60:35:5	0.03–0.08 60:30:5	0.04–0.09 75:20:5	0.02–0.08 60:35:5
Grain composition (percent)											
23	36	36	50	55	35	25	52	32	43	45	33
17	12	10	11	9	16	12	7	21	9	13	8
Trace	5	3	5	9	7	5	5	4	4	4	6
2	10	6	2	2	2	5	2	6	4	3	5
35	16	18	14	17	21	29	12	11	16	4	19
12	8	18	6	4	11	7	3	6	4	6	7
Andesite	----	----	2	Trace	Trace	Andesite, basalt	Trace	----	Trace	Trace	Trace
----	Titanite	----	----	----	Apatite, garnet	Garnet	Apatite, calcite	----	----	Garnet, zircon	Zircon
----	Present	Present	----	Present	----	Present	----	----	----	----	----
Present	Present	Present	Present	Present	----	Present	Present	Present	Present	Present	Present
Present	Present	Present	Present	Present	Present	Present	Present	Present	Present	----	Present
----	----	----	----	----	----	----	----	----	Present	----	----
----	Present	----	Present	Present	----	----	----	Present	----	----	----
Interstitial material (percent)											
2	1	2	1	1	1	1	2	1	2	1	2
Trace	1	1	Trace	Trace	----	Trace	1	2	1	Trace	Trace
2–3	5	6	2	4	4	10	8	10	6	10	9
1–2	1	Trace	Trace	1	1	2	3	4	2	----	Trace
Trace	1	Trace	Trace	Trace	Trace	Trace	1	1	Trace	----	----
2	1	Trace	1	Trace	2	1	2	1	2	2	Trace
2	3	----	3	2	2	4	3	4	7	9	11
Reservoir properties											
Very poor	Very poor	Poor	Good	Fair	Fair	Very poor	Very poor	Very poor	Very poor	Very poor	Very poor
12.8	Very low	14.3	15.8	14.2	13.3	Low	8.7	8.2	7.4	9	Low
0.4	None	18.6	11.0	12.3	2.4	Low	<0.05	<1	<1	<1	Low
0.04	0.05	0.04	0.045	0.04	0.06	0.03	0.02	0.03	0.03	0.04	0.03
2	<1	4	6	5	7	3	1	1	1	2	<1
Very low	Very low	Low	Fair	Fair	Fair	Very low	Very low	Very low	Very low	Very low	Very low
Silica	Illite	Illite	Illite	Silica, illite	Illite	Calcite, illite	Illite	Illite	Illite	Illite	Illite
55	85	65	50	60	65	80	85	85	90	85	95
Strong	Strong	Moderate	Moderate	Moderate	Moderate	Strong	Strong	Strong	Strong	Moderate	Moderate

1,200 feet. The hole yielded approximately 10 barrels of fresh water per hour. It was shut down 13 hours, at which time the fluid level was at 1,100 feet, and muddy water with a trace of oil was bailed.

Test 8, 2,252–2,370 feet.—The rat-hole packer was set at 2,252 feet, with 15 feet of perforated anchor spaced by 30.9 feet of drill pipe. A bottom-hole pressure gauge was on the bottom of the anchor. The hole was open 20 minutes, shut in 10 minutes; 150 feet of drilling mud with a trace of oil was recovered. Static pressure of the mud column at 2,300 feet was 1,200 pounds per square inch, and closed in pressure, 590 pounds per square inch.

OIL ANALYSES

The data presented here were prepared for the U. S. Navy by the U. S. Bureau of Mines Petroleum Experiment Station at Bartlesville, Okla.

Tests were made on a sample consisting of 1 pint of oil taken from that found on top of the ice in the hole in June 1946. (See p. 93.) The crude oil is similar to better grade oil from the midcontinent region, except that it is deficient in the more volatile constituents. It differs considerably from oils produced from the other Umiat wells, which contain more gasoline and are less paraffinic. Crude oil from Umiat test well 1 could be used to manufacture kerosene, jet propulsion fuel, diesel fuel, and some lubricating oils. Details are presented in the following tables.

Analysis of U. S. Bureau of Mines crude-petroleum sample 46064, from Umiat test well 1

[General characteristics of sample: Sp gr, 0.839; sulfur, 0.077 percent; Saybolt Universal viscosity at 100°F, 44 sec; gravity, 37.2° API; color, Natl. Petroleum Assoc. color no. 5]

Distillation by 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	130°F	210°F	Cloud test (°F)	Viscosity index	Index refraction [2]
Stage 1.—Distillation at atmospheric pressure, 742 mm Hg; first drop, 77°C (171°F)														
1	50	122												
2	75	167												
3	100	212	0.9	0.9										
4	125	257	2.1	3.0	0.725	63.7		65.4						1.40331
5	150	302	3.1	6.1	.745	58.4	17							1.41412
6	175	347	4.3	10.4	.760	54.7	17							1.42175
7	200	392	5.3	15.7	.772	51.8	16							1.42976
8	225	437	6.9	22.6	.792	47.2	20							1.43794
9	250	482	9.1	31.7	.806	44.1	22	76.6						1.44644
10	275	527	10.9	42.6	.818	41.5	23							1.45480
Stage 2.—Distillation continued at 40 mm Hg														
11	200	392	8.1	50.7	.842	36.6	30	76.6	42			20		
12	225	437	10.3	61.0	.851	34.8	30		47			35		
13	250	482	8.3	69.3	.865	32.1	34		74	47	36	45		
14	275	527	6.2	75.5	.877	29.9	36		91	61	40	55		
15	300	572	6.4	81.9	.890	27.5	39		160	90	46	60	131	
Residuum [3]			17.1	99.0	.919	22.5					125			

[1] Specific gravity at 60°F, compared with water at 60°F.
[2] Index of refraction based on sodium D line at 20°C.
[3] Carbon residue of residuum, 1.6 percent; carbon residue of crude, 0.3 percent.

Approximate summary

Constituent	Percent	Specific gravity	Gravity, °API	Saybolt Universal viscosity
Light gasoline	0.9			
Total gasoline and naphtha	15.7	0.754	56.2	
Kerosene distillate	26.9	.807	43.8	
Gas oil	14.3	.846	35.8	
Nonviscous lubricating distillate	16.3	0.853–0.879	34.4–29.5	50–100
Medium lubricating distillate	8.7	0.879–0.897	29.5–26.3	100–200
Viscous lubricating distillate				Above 200
Residuum	17.1	0.919	22.5	
Distillation loss	1.0			

Hydrocarbon analysis of gasoline and diesel-oil cuts from Umiat test well 1, using American Society for Testing Materials method ES–45a

[Analysis by U. S. Bur. Mines]

Composition and characteristics	Gasoline (Hempel fractions 1–7)	Diesel oil (Hempel fractions 8–12)
Blends		
Aromatics plus olefins	6.0	13.8
Naphthenes	38.2	66.3
Paraffins	55.8	19.9
Total	100.0	100.0
Data on raffinates (paraffins plus napthenes) from above blends		
Density (at 20°C compared with water at 4°C)	0.7500	0.8102
Index of refraction with mercury g line, at 20°C	1.42717	1.45755
Index of refraction with sodium D line, at 20°C	1.41797	1.44759
(Refraction g−refraction D)×10⁴	92.0	99.6
Specific dispersion: $\frac{(\text{Refraction g}-\text{Refraction D})\times10^4}{\text{Density}}$	122.7	122.9
Average boiling point °C	159	265
Molecular weight (estimated)	137	211
Molecular volume	183	260
Naphthene rings percent by weight	18.2	19.5
Paraffin and paraffin side chains do	81.8	80.5

Characteristics of possible products from Umiat test well 1

[Analysis by U. S. Bur. Mines]

Product	
Aviation gasoline base stock percent by volume	0
Motor gasoline do	15
F–2 octane number, clear	Very low
Jet propulsion fuel 100°–600°F percent by volume	53.9
Aromatics do	15.7
Sulfur do	0.03
Viscosity centistokes at −40°F	22.5
Viscosity centistokes at 100°F	2.0
Diesel fuel (400°–600°F boiling range) percent by volume	45
Cetane number, calculated	55
Lubricating oil, percent by volume:	
50–200 Saybolt Universal viscosity at 100°F	25
50–200+ Saybolt Universal viscosity at 100°F	25

LOGISTICS

A National 50 rig, with a 96-foot Ideco cantilever mast, casing, and other drilling equipment and supplies were freighted from Barrow in March and April 1945.

D8 Caterpillar tractors hauled Micheler No. 9 bobsleds and welded pipe sleds over the ocean ice and across Dease Inlet, up the Chipp and Ikpikpuk Rivers, and overland to Umiat, a distance of about 300 miles. Other supplies were flown from Fairbanks. A mud tank was made by welding four pontoons together. The water supply came from Seabee Creek through 1,775 feet of 2½-inch pipe; a Gardner-Denver 4- by 5-inch pump at the creek furnished about 3 barrels per minute. A 4-foot dam in the creek helped insure the water supply until the creek ran dry in September 1945, when the rig was shut down. In 1946 a new dam in the creek formed a pond 10 feet deep, with a capacity of 15,000 barrels; at the end of August, rains washed it out, and a smaller dam was put in 200 yards downstream.

Winterizing the rig was completed the first week in October 1945—a canvas-covered wood-frame house was erected over the water tanks, and Ric-Wil insulated pipe was installed. A welded frame was raised to support the canvas cover enclosing the jackknife derrick. Water pipes were kept open or thawed by steam lines from the boiler. Seabee Creek and the pond froze solid on September 28, 1946, and a Caterpillar tractor hauled water in a 30-barrel tank on a go-devil sled, for the last week of operations.

Drilling in 1945 was done by Navy employees; in 1946, some of the same men were employed by Arctic Contractors, whose staff at the well site included a tool pusher, a petroleum engineer, a geologist, and a technical assistant.

DRILLING OPERATIONS

DRILLING NOTES

The following drilling operations were reported by J. R. Coleman, petroleum engineer.

Notes from drilling records

Depth (feet)	*Remarks*
19	The 17½-inch Ideal rotary table was 9 ft above the ground, and 14 ft above the cellar floor. Base of 16 ft of 24-in. conductor pipe was set 19 ft below kelly bushing in a 30-in. hole. Cement made of 14 sacks of Victory portland cement mixed with 63 gal of water at 160°F (4½ gal per sack) was put outside pipe.
97	Set 16-in. inner-diameter Western slip-joint point-welded casing at 97 ft, and cemented it with 60 sacks of Victory Oil Well high-temperature cement mixed with an Aquagel and water mixture, and then 40 sacks of Victory Oil Well high-temperature cement with 10 sacks of Victory portland cement and water at 170°F. The mud was heated for 14 hr with steam injected through casing. Shaffer 18⅝-in. blowout preventer installed. Drilling suspended for 2 weeks waiting for orders.
692	Set 24 joints of 11¾-in. Youngstown 47-lb J-55 casing (with float shoe on bottom, and 2 bottom joints spot welded) at 685 ft. Cemented with 350 sacks of cement mixed with water at 120° to 130° F. First, 200 sacks of Victory high-temperature (Sloset) cement was mixed with 2 percent Aquagel; next, 125 sacks with 2 percent $CaCl_2$, and then 25 sacks of Victory portland cement was mixed with 2 percent $CaCl_2$. Steam was run intermittently through the drill pipe for 3 days to keep the mud warm.
780	Left two drill collars, reamer, and bit on bottom; recovered fish with Bowen 4½-in. Rotary Taper Tap.
865	Left bit and reamer in hole, recovered fish with Bowen 4½-in. Rotary Taper Tap.
1,080	Halliburton line broke, leaving Totco and 680 feet of wire line inside drill pipe; recovered fish with homemade tools.
1,816	Filled hole to 750 ft with drilling mud. Closed rams on Shaffer control gate. Left the well site Sept. 19, 1945; returned on June 2, 1946, and rigged up. Bailed 44 gal of oil and no water. Ran drill pipe to 685 ft with no mud, then stopped and filled hole with mud as a small amount of gas was coming through the drill pipe. Found top of ice at 775 ft and drilled ice to 920 ft.
1,920	Lost circulation when wire line core barrel was lowered for coring; pulled out core barrel, mixed mud, and put 10 bales of Fibrotex on bottom and regained circulation.
1,978	Lost circulation, regained it after using 20 sacks of Aquagel and 4 bales of Fibrotex in conditioning mud.
2,287	Tested blowout preventers by closing rams around drill pipe and building up pressure with mud pumps. Formation began to take fluid when pressure built up to 300 lb per sq in.
2,967	Lowered derrick substructure 1 in. on west side to level derrick.
3,021	Motor lowering Schlumberger instrument stopped for 45 min and left instrument stationary in hole for that time. When motor was started, instrument was stuck, with its top at 2,114 ft. Drill pipe with homemade fishing tool was run in hole, using Schlumberger line as a guide, and freed instrument, which was then pulled out of the hole. Globe basket was used to recover thermometer case knocked off of top of instrument.
3,963	Drilling line broke and was replaced by old line, which had been removed a short time earlier.
4,041	Additional timbers put beneath derrick substructure immediately below derrick legs to prevent further settling.
4,085	Replaced old drilling line with new line.
4,339	Drilling line broke near dead line sheave; 21-in. sheave replaced with 36-in. diameter sheave, and additional 30-in. sheave installed in crown block. New drilling line strung. Worn pistons and other difficulties with the two small (7¼ x 10 in.) mud pumps made it impossible to get enough mud pressure to drill; four new pistons were ordered from Barrow. Lack of racking capacity in derrick caused a change from 4½-in. drill pipe to 3½-in. pipe; this necessitated higher pressure from mud pumps, to afford proper mud circulation.

Notes from drilling records—Continued

Depth (feet)	*Remarks*
5,061	Schlumberger instrument stuck at 3,290 ft, loosened and pulled out with homemade fishing tool.
6,005	Drilling mud bailed to depth of 950 ft. All casing left in hole; 11¾-in. casing projects 1 ft above ground; it is topped by an 11¾-in. collar 8 in. long and an 11¾-in. nipple 7 in. long. Nipple covered by a ⅜-in. steel plate welded on, with 2-in. nipple, 6 in. long, in center of plate. A 2-in. 125-lb brass gate valve caps nipple.

DRILL AND CORE BITS

Only two types of core bits were used in Umiat test well 1. Cores 1–18 and core 197 were taken with a conventional Hughes type "J" core barrel, and a 6⅛-inch hard-formation core head. Cores 19–196 were taken with an A–1 No. 2 retractable wire line core barrel, with a 7⅝-inch hard-soft formation roller core bit. Of a total of 259 feet cored with the Hughes tools, 73.7 percent was recovered; 83.8 percent of the 1,375.5 feet cored with the A–1 barrel was recovered.

Several types of drill bits were used, ranging in size from the 22-inch Reed rock bit to the 9⅞-inch Hughes OSQ–3A. A total of 56 bits was used, the Hughes OWS and Hughes OSQ–2 being the ones most commonly employed. Crum Brainard rock bits and pilot bits and Zublin Simplex bits were also used. Depths through which each bit drilled, cored, or reamed are shown on the graphic log (pl. 9). Hughes OSQ–2 bit no. 47, which reamed at 4,898 feet without deepening the hole, is not shown.

DRILLING MUD

The test well was started with an Aquagel-water mud, and except for a small amount of Fibrotex and similar material to regain lost circulation, no other types of additives were necessary. The hole produced a large amount of mud from the bentonite and shale penetrated in the upper part of the section. Clay ironstone and other iron-bearing minerals caused the mud weight to increase gradually, making the use of Baroid unnecessary. The mud temperature ranged from 40° to 79°F., averaging about 55° to 60°. The mud characteristics and additives used are shown in the following table.

Drilling-mud characteristics and additives at Umiat test well 1

Depth (feet)	Viscosity API	Weight (Lb cu ft)	Water loss (cc/30 min)	Additives
25	39.0	66.0		9,200 lb Aquagel.
50	35.0	68.0		
97	44.0	70.0		2,000 lb Aquagel.
97	45.0	70.0		
102	35.0	65.0		
143	44.0	68.0		1,500 lb Aquagel, 50 lb Quadrafos.
143	35.0	65.0	5.0	
163	35.0	66.0	4.5	
183	41.0	68.5	5.8	
223	40.0	67.0	18.0	

Drilling-mud characteristics and additives at Umiat test well 1—Continued

Depth (feet)	Viscosity API	Weight (Lb cu ft)	Water loss (cc/30 min)	Additives
253	38.0	69.5	11.2	
285	42.0	72.0	4.8	
302	42.0	74.0	3.8	
346	45.0	74.5	2.9	
467	52.0	75.5	2.6	
490	44.0	76.0	2.4	
584	44.0	78.0	2.5	
584	42.0	78.5	2.2	
584	43.0	78.5	2.2	
584	43.0	79.0	2.1	
601	43.0	80.0	2.2	
603	45.0	80.0	2.2	
637	43.0	80.0	2.5	
659	40.0	79.5	2.7	
692	40.0	79.0	2.7	
692	43.0	79.0	2.7	
693	43.0	78.5	2.7	
718	43.0	78.5	4.0	
751	38.0	78.0	4.5	
775	42.0	78.0	4.2	
817	45.0	77.0	5.5	
870	38.0	79.0	5.0	
920	38.0	80.0	4.2	
961	39.0	82.0	4.5	
1,020	38.0	82.0	4.1	
1,035	38.0	83.0	3.6	
1,080	39.0	83.5	3.0	
1,113	40.0	85.0	3.0	
1,155	41.0	86.0	3.2	
1,204	40.0	85.0	3.3	
1,238	39.0	85.0	3.3	100 lb Quadrafos.
1,273	40.0	84.0	3.5	
1,310	41.0	85.0	3.3	
1,367	39.0	85.0	3.3	
1,383	41.0	85.0	3.9	
1,383	38.0	84.0	3.8	
1,414	39.0	85.0	3.7	
1,414	40.0	85.0	3.8	
1,414	39.0	84.0	5.5	
1,480	39.0	85.0	5.3	
1,555	41.0	87.0	5.4	2,000 lb Aquagel.
1,615	37.0	82.0	5.0	
1,615	39.0	83.0	4.5	
1,641	40.0	82.0	4.4	
1,653	40.0	82.0	4.5	
1,682	41.0	83.0	4.5	
1,703	38.0	84.0	4.4	
1,730	37.0	83.0	4.4	
1,743	38.0	83.0	4.5	
1,746	40.0	83.5	4.5	25 lb Quadrafos.
1,772	39.0	83.5	4.5	
1,810	36.0	80.5	4.8	
1,816	36.0	71.3	5.0	
1,826	36.0	71.3	5.0	
1,876	37.5	76.9	4.5	
1,888	35.5	76.0	5.0	
1,910	36.0	77.0	4.5	
1,920	36.0	77.0	5.0	10 bales Fibrotex.
1,946	36.0	78.0	5.0	
1,984	35.0	77.0	5.5	
2,023	36.0	77.0	5.0	
2,074	35.5	77.3	5.0	
2,138	36.5	78.7	4.5	
2,162	35.5	77.8	5.0	
2,223	35.5	78.8	5.0	
2,259	35.5	79.0	5.0	
2,289	35.8	78.8	4.5	
2,318	35.7	78.6	5.0	
2,359	35.3	77.5	5.0	
2,370	35.4	77.8	4.5	
2,401	35.2	77.8	5.0	
2,461	35.4	78.5	5.5	
2,473				1,200 lb Aquagel.
2,500	36.4	78.5	4.5	
2,550	37.2	78.0	4.0	
2,578	36.0	78.1	5.0	
2,629	36.9	78.0	5.0	
2,661	38.2	79.3	4.5	
2,698	38.8	78.7	4.0	
2,732	35.5	78.3	5.5	
2,759	35.8	77.8	5.5	
2,800	36.8	78.6	5.0	
2,834	37.5	79.5	5.0	
2,863	36.0	79.0	5.0	
2,885	36.0	79.0	5.0	
2,914	35.3	79.5	5.5	
2,967	36.7	81.1	5.0	
3,001	36.5	81.1	5.0	
3,021	36.0	80.0	4.5	1,700 lb Aquagel.
3,023	40.0	80.5	4.5	
3,063	39.0	80.0	5.0	
3,109	38.5	80.5	4.5	
3,148	38.8	81.0	4.5	
3,197	37.8	80.0	5.0	
3,257	38.2	80.8	5.0	
3,309	38.3	81.3	4.5	
3,375	40.0	83.3	4.5	
3,406	37.0	82.3	5.0	
3,430	37.0	81.0	5.0	

Drilling-mud characteristics and additives at Umiat test well 1—Continued

Depth (feet)	Viscosity API	Weight (Lb cu ft)	Water loss (cc/30 min)	Additives
3,490	36.4	81.2	5.0	
3,517	36.8	81.5	5.5	
3,532	36.0	81.0	5.0	3 sacks Micatex.
3,574	36.6	81.9	5.0	
3,618	37.8	82.0	6.0	
3,656	37.2	81.2	5.5	
3,693	37.7	81.7	6.0	
3,727	39.0	82.5	5.5	
3,757	40.0	83.8	5.0	
3,780	41.5	83.8	5.5	
3,825	39.0	83.2	5.5	
3,855	38.5	83.0	6.0	
3,896	39.0	83.5	7.0	
3,928	37.7	83.3	6.8	
3,961	37.3	83.0	6.7	
3,994	37.4	83.3	6.8	
4,041	37.5	83.2	6.5	
4,050	37.8	83.2	7.0	
4,085	37.0	83.0	6.5	
4,096	38.3	83.0	5.5	
4,114	37.8	83.2	6.0	
4,158	36.5	82.8	6.5	
4,181	36.0	82.7	6.0	
4,204	36.8	82.9	6.5	
4,242	36.0	83.0	7.0	
4,292	36.4	83.5	8.0	
4,339	36.3	83.0	6.5	
4,377	38.5	83.3	7.0	
4,410	37.5	83.3	7.0	
4,429	36.8	83.1	6.5	
4,483	37.5	82.8	7.5	
4,542	37.0	83.2	7.5	
4,581	38.0	83.0	7.0	
4,614	36.5	83.0	6.5	
4,656	36.8	83.0	6.5	
4,693	36.8	82.8	7.0	
4,737	37.0	82.9	7.0	
4,771	37.0	82.9	7.0	
4,818	36.8	82.8	7.0	
4,857	37.0	83.0	6.5	
4,888	36.8	83.0	6.5	
4,896	37.5	82.5	7.0	
4,898	37.5	82.5	7.0	
4,914	38.5	82.5	7.0	
4,962	37.4	82.0	7.0	
4,992	37.0	81.0	6.5	
5,043	36.2	80.5	7.0	
5,061	36.5	80.7	6.5	
5,089	38.5	81.0	6.5	
5,146	36.5	80.5	6.8	
5,184	36.8	81.5	6.5	
5,236	37.5	81.5	6.5	
5,304	38.0	82.0	7.0	
5,359	38.0	82.5	6.5	
5,429	37.5	82.0	6.5	
5,477	38.0	81.8	7.0	
5,552	37.5	82.0	7.0	
5,609	40.0	83.0	7.0	
5,760	39.5	83.0	7.0	
5,777	42.0	83.0	7.0	
5,842	42.0	83.0	6.5	
5,886	41.5	83.0	7.0	
5,981	39.5	82.8	6.5	
6,001	40.0	83.0	6.5	
6,005	39.0	82.5	6.5	

HOLE-DEVIATION RECORD

The deviation of the hole was measured with a Totco (Technical Oil Tool Co.) Recorder and with the Eastman Oil Well Survey Co. single-shot survey instrument. The deviation (as measured by Totco) increased gradually to 2° 45′ at 600 feet, owing to continuous coring; after a decrease to 1° 15′ at 825 feet, it again increased to a maximum of 5° at 1,685 feet, below which it again decreased to 2° at 2,080 feet. Below 3,000 feet deviation was under 2° except for a short interval between 5,550 and 5,700 feet where it rose to 2° 15′. The Eastman survey showed the direction of deviation to be northwest for the first 2,000 feet, below which it was southeast. The following table gives the results of the Eastman survey; the Totco readings are shown on the graphic log (pl. 9).

Degree and direction of hole deviation of Umiat test well 1

[Determined with Eastman single-shot directional survey instrument]

Depth (feet)	Deviation (degrees)	Direction	Depth (feet)	Deviation (degrees)	Direction
110	1	N. 5° E.	1,400	2	N. 40° W.
200	1	N. 16° E.	1,500	2½	N. 32° W.
300	¾	N. 12° W.	1,600	3	N. 35° W.
400	1	N. 54° W.	1,700	4½	N. 40° W.
500	3	N. 38° W.	1,800	4	N. 35° W.
600	2½	N. 42° W.	2,000	2½	N. 23° W.
680	1¼	N. 38° W.	2,200	¾	N. 35° E.
700	1½	N. 6° E.	2,400	1	N 45° E.
800	1¼	N. 67° W.	2,600	¾	N. 40° E.
900	1¼	N. 27° W.	2,800	1¾	S. 35° E.
1,000	1¾	N. 27° W.	3,000	1¼	S. 35° E.
1,100	2¼	N. 45° W.	3,200	1	N. 70° E.
1,200	1¾	N. 50° W.	3,400	¾	S. 28° E.
1,300	2	N. 25° W.			

The survey was stopped because batteries were too old to give satisfactory pictures. Directions are from magnetic north; true north is 29° 15′ west of magnetic north.

ELECTRIC LOGGING

Eight runs of Schlumberger electric logging equipment were made in the hole, and spontaneous potential and resistivity curves were obtained; run numbers and depths at which they were made are shown below. The electric log curves are shown on the graphic log (pl. 9), except for runs 1 and 3, which are overlapped by runs 2 and 4, respectively.

Run	*Depth (feet)*
1	97–584
2	97–684
3	685–1, 743
4	686–1, 815
5	1, 815–3, 106
6	3, 106–4, 041
7	4, 041–4, 875
8	4, 875–5, 981

TEMPERATURE SURVEY

A temperature survey was made in 1945, but it was later found that the temperature in the hole had not been in equilibrium with the surrounding rock, and the curve obtained was invalid. In cleaning out the hole in the spring of 1946, the base of the permafrost was found at 920 feet.

UMIAT TEST WELL 2

Location: Lat 69°23′04″ N., long 152°05′01″ W.
Elevation: Ground, 333 feet; kelly bushing, 342 feet.
Spudded: June 25, 1947.
Completed: December 12, 1947. Dry and abandoned.
Total depth: 6,212 feet.

Umiat test well 2 was actually the third test on the Umiat anticline; both Umiat test well 3 (originally named Umiat core test 1) and Umiat test well 1 were drilled earlier. The proposed location for Umiat test well 2, chosen to test the oil-producing possibilities of the Umiat anticline, was underlain by silt and muck which would have necessitated an expensive piling foundation. A site 79 feet downdip and 1,200 feet west along the strike of the anticline was found to have a bed

of gravel near the surface; so the proposed site was changed. The test well is about 5,000 feet south of the anticlinal axis as it is now mapped, and about 6,000 feet east of the probable apex of the anticline. The site is about halfway between Umiat Lake and the Colville River, on the gravel flats of the river valley, as pictured in plate 7*A*.

DESCRIPTION OF CORES AND CUTTINGS

Several sandstones had oil shows, but testing recovered only drilling mud with slight shows of oil. Because oil was obtained from Umiat test well 5, drilled with cable tools a few feet away, it is probable that the use of fresh-water drilling fluid caused the sandstone matrix to swell and become impermeable, thus preventing oil from entering the well.

The original plan was to drill a 3,000-foot hole with the rotary equipment used at Umiat test well 3, but a heavier derrick had to be used because the lighter one was damaged in dismantling. It was decided later to drill the hole to the safe capacity of the rig.

The top 70 feet sampled consisted of alluvial gravel and coarse sand deposited by the Colville River. The dominant constituent of the beds to this depth is gray, black, or grayish-brown chert, although some fine-grained siliceous sandstone pebbles are also present.

The uppermost Cretaceous rock drilled, the Killik tongue of the Chandler formation, is present from 80 to 365 feet. It consists of clay shale, sandstone, claystone, and a small amount of siltstone in beds 2–25 feet thick. Bentonite and coal seams are very rare. Thin beds and laminae of clay shale are present in much of the sandstone, and the siltstone and sandstone laminae in the shale are commonly responsible for its tendency to break parallel to the bedding planes Some of the sandstone is crossbedded. A show of oil or gas was reported in some of the sandstone beds; the permeability of one sandstone, at 320 to 328 feet, ranges from 20 to 72 millidarcys. (See table on p. 108.)

The Grandstand formation, consisting of thick beds of sandstone separated by thinner beds of clay shale containing the *Verneuilinoides borealis* faunal assemblage, is present between 365 and 1,060 feet in the hole. The sandstone beds range from 5 to 100 feet in thickness and are very fine to fine grained (rarely medium grained), slightly silty, argillaceous, and noncalcareous.

Permeability ranges from 3.5 to 270 millidarcys but is generally less than 50 millidarcys. Several shows of oil or gas were noted, but tests recovered only traces of oil. Clay shale and claystone are present in beds a few inches to 70 feet thick and contain some laminae of sandstone.

At 1,060 feet the drill penetrated the marine Topagoruk formation, which consists of medium-dark-gray silty clay shale with a few thin (less than 30 feet) sandstone beds in its upper part. The sandstone is medium light gray and very fine grained; it had no shows of oil or gas. Siltstone, somewhat more common than in the upper part of the hole, is medium gray, argillaceous, and noncalcareous.

Between 1,060 and 4,700 feet, the approximate base of the formation, the beds commonly dip 10° or less, except for rare crossbedding. The section between 1,850 and 2,400 feet is repeated between 2,400 and 2,950 feet by a reverse fault at 2,400 feet. Between 5,100 feet and the total depth at 6,212 feet, the Topagoruk formation is repeated by another reverse fault, which cuts the well at 5,100 feet. The presence of the Topagoruk formation below the older Oumalik formation is indicated by the reappearance of a distinctive microfauna and an abrupt change from the rather steep dips of the Oumalik formation to flat-lying beds in the Topagoruk formation.

The Oumalik formation is composed of marine clay shale with very rare thin beds of sandstone. The sandstone grains are commonly angular, and there are less silt, argillaceous material, mica, chert and rock fragments with the quartz sand than in the overlying Topagoruk and Grandstand formations. The Oumalik formation is present between 4,700 and 5,100 feet in Umiat test well 2; the contacts are not exact, but the presence of the formation is indicated by a few distinctive microfossils and differences in dip and lithologic characteristics from the Topagoruk formation above and below it.

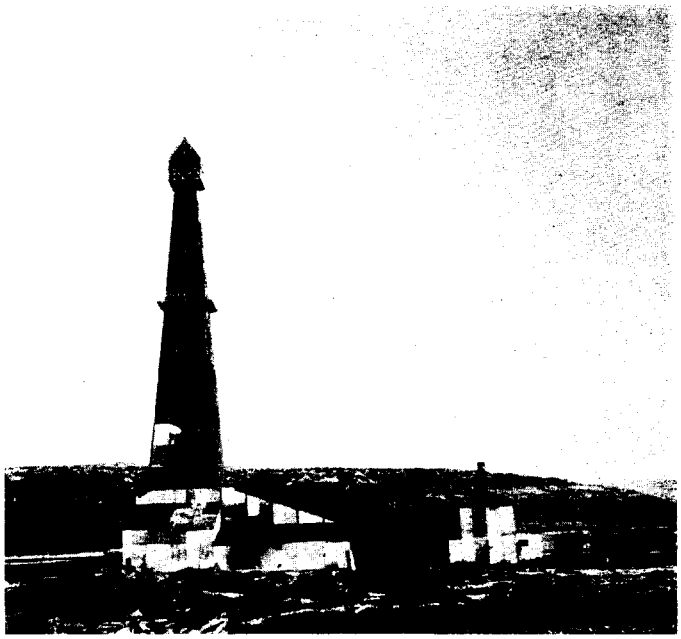
Lithologic description

[Where no cores are listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
-----	0–9	Kelly bushing to ground level.
-----	9–13	Ground level to bottom of cellar. Note: Samples above 130 feet were taken before surface casing was set and consist primarily of surface gravel and sand. Base of surface alluvial material placed at 80 ft, because the first fragments of rock similar to the underlying beds of Cretaceous age occur in samples at that depth; however, the surface gravels may be much thinner.
-----	13–20	Gravel, rounded and angular fragments half an inch or less in diameter, consisting of gray, black, light-grayish-brown, and rarely yellow chert, with a few fragments of medium- to fine-grained siliceous sandstone, composed of clear or dark quartz, with rare varicolored rock fragments. A small amount of coarse sand has the same composition as the gravel.
-----	20–30	Gravel and sand, as described above.
-----	30–60	Sandstone fragments similar to those in gravel above, with some chert pebbles.
-----	60–80	Sand similar to that in the sandstone, with some chert grains.

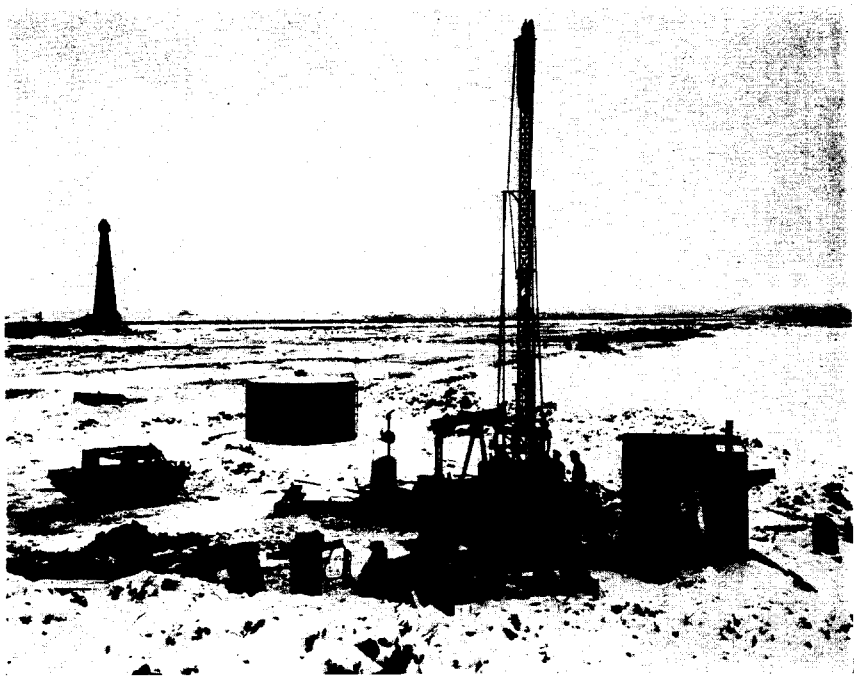
A. AERIAL PHOTOGRAPH OF UMIAT TEST WELL 2, SEPTEMBER 22, 1947

Enclosed derrick and rigsite camp, with Colville River in background to the southeast. A small amount of snow has collected on the frozen surface of Umiat Lake in the foreground and in ruts cut in the tundra by tractor and weasel treads.



B. ENCLOSED RIG AT UMIAT TEST WELL 2

The 122-foot derrick, the rest of the rig, and the boilerhouse enclosed for winter drilling. The view was taken looking north, September 23, 1947.

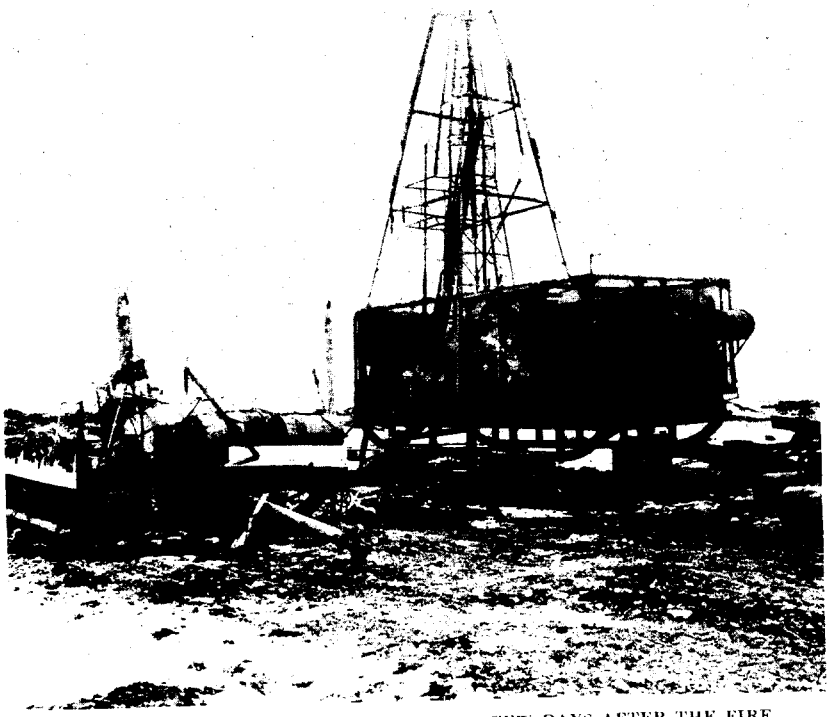


C. UMIAT TEST WELL 3 DURING PUMPING TEST, OCTOBER 10, 1947

Spudder and pumping unit are in the foreground, and Umiat test well 2 is in the background. White expanse to the right and behind Umiat test well 3 is snow-covered Umiat Lake, and Colville River flows from right to left in the distance.

A. DRILLING RIG AT SITE OF UMIAT TEST WELL 4, JUNE 2, 1950

Rig is surrounded by a canvas windbreaker, and the wanigan was the only other shelter necessary.



B. UMIAT TEST WELL 5 ON MAY 1, 1951, A FEW DAYS AFTER THE FIRE

Remains of Heat-Pak and generator wanigan are on the left, and Failing rig, on the right. Sleds on which both are mounted are made of pipe.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	80–130	The top of the Killik tongue of the Chandler Formation is at 80 feet. Chert and sandstone granules similar to gravel above, with rare fragments of medium-gray argillaceous micaceous siltstone and clay shale, and very rare fragments of medium-light-gray very fine-grained sandstone.
-----	130–140	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, slightly calcareous, with some flakes of muscovite. Angular to subangular white and clear quartz grains, with rare dark rock fragments. Small amount of clay ironstone present in upper half of unit.
-----	140–145	Sandstone as above, with siltstone and clay shale. Siltstone is similar in composition and color to the sandstone; the clay shale is medium gray, noncalcareous, very slightly silty to very silty.
-----	145–175	Clay shale, dark-gray; slightly carbonaceous at top; medium-gray in lower part. Between 150 and 160 ft it grades into medium-gray very argillaceous slightly to moderately calcareous siltstone. Between 165 and 170 feet is a small amount of light-gray fine-grained slightly silty noncalcareous sandstone composed of subangular clear and white quartz with rare dark rock fragments. Very fine-grained medium-light-gray sandstone rare.
-----	175–190	Shale, fine-grained and very fine-grained sandstone, small amount, contaminated by a large amount of cement.
-----	190–195	Sandstone, angular, very fine- to fine-grained; composed of clear and white quartz with some dark rock fragments.
-----	195–200	Clay shale, medium-gray to medium-dark-gray, slightly to very silty; a small amount of very argillaceous siltstone.
-----	200–215	Clay shale, medium-dark-gray, silty, micaceous; with very fine-grained silty argillaceous noncalcareous sandstone, grading to siltstone with depth.
-----	215–225	Clay shale, medium-gray, slightly to very silty, micaceous; cement contamination.
-----	225–230	Sandstone, very fine-grained, angular grains, with some black shiny coal having blocky to conchoidal fracture.
-----	230–260	Sandstone, fine-grained; composed of clear and white subangular to angular quartz grains, argillaceous, slightly calcareous cement and rare muscovite. Small amount of medium-gray very silty micaceous clay shale present in lower 10 feet.
-----	260–265	Siltstone, medium-light-gray, slightly to very argillaceous; very slightly calcareous in part; similar in composition to the sandstone above.
-----	265–290	Clay shale, medium-gray to medium-dark-gray; slightly to very silty in part, noncalcareous. Siltstone rare at 275–280 ft.
-----	290–297	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, slightly calcareous in part; composed of angular to subangular clear and white quartz, with dark rock fragments.

Lithologic description—Continued

Core	Depth (feet)	Remarks
1	297–302	Recovered 4 ft 4 in.: Microfossils absent. Clay shale, medium-dark-gray, noncalcareous, very slightly micaceous in part, with poor shaly to subconchoidal fracture; particles and small fragments of carbonized plants are rare. Dip 2° to 4°.
2	302–312	Recovered 9 ft: Microfossils absent. 8 ft, clay shale as above; fish scale found at 310 ft. Dip 3°–5°. 3 in., bentonite, grayish-white, with abundant minute euhedral biotite flakes. 9 in., clay shale as above.
3	312–322	Recovered 8 ft 11 in.: Microfossils absent. 4 ft 6 in., clay shale as above, dip 3°–5°. 4 ft 5 in., sandstone, medium-light-gray, very fine-grained, silty, slightly argillaceous, noncalcareous; composed of subangular grains of clear quartz, with some white quartz and rare dark rock fragments, carbonaceous particles, and biotite. Small irregular patches of medium-dark-gray clay shale scattered throughout.
4	322–332	Recovered 2 ft 5 in.: Microfossils absent. Sandstone as above.
5	332–342	Recovered 8 ft 9 in.: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, slightly micaceous, slightly crossbedded; grades to medium-light-gray sandy slightly crossbedded siltstone.
6	342–345	Recovered 2 ft 5½ in.: Microfossils absent. Siltstone and sandstone as in core 5 above, but with some intercalated medium-dark-gray very silty claystone.
7	345–355	Recovered 9 ft: Microfossils absent. Claystone, medium-dark-gray, slightly to very silty, with conchoidal fracture; thin beds and laminae of medium-gray silty clay shale in upper 1 ft. Small rare carbonized plant fragments. A 2-in. bed of very fine-grained medium-light-gray sandstone present at bottom of core.
8	355–365	Recovered 3 ft 6 in.: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, slightly to very sericitic, with rare small fragments of carbonized plants. Thin beds of crossbedded siltstone (¼–2 in. thick) and laminae and intercalations of medium-gray clay shale rare. Top of the Grandstand formation is at 365 feet.
9	365–370	Recovered 1 ft: Microfossils abundant. Claystone, medium-dark-gray, very slightly silty and micaceous, with irregular to subconchoidal fracture.
10	370–375	Recovered 4 ft 7 in.: Microfossils abundant. Claystone as above.
11	375–385	No recovery.
12	385–387	Recovered 1 ft 10 in.: Not sampled for microfossils. Fragments of claystone as above, with a few fragments of medium-gray siltstone in upper part, medium-gray very sandy claystone in lower part, and one fragment of light-olive-gray fine-grained sandstone at base.

Lithologic description—Continued

Core	Depth (feet)	Remarks
13	387–392	Recovered 2 in.: Not sampled for microfossils. Claystone, medium-dark-gray, in fragments, and one fragment of light-olive-gray fine-grained noncalcareous sandstone.
14	392–395	Recovered 2 ft 6 in.: Not sampled for microfossils. Sandstone, medium-light-gray, fine-grained, silty, argillaceous, noncalcareous, sericitic in part; composed of subangular to subround clear and white quartz, gray chert, and dark rock fragments, with rare carbonaceous particles and rare to common biotite. Poor shaly cleavage suggests beds dip 3°–5°.
15	395–400	Recovered 2 ft 9 in.: Not sampled for microfossils. Sandstone as in core 14.
16	400–408	Recovered 1 ft 8 in.: Not sampled for microfossils. Sandstone as in core 14.
17	408–413	Recovered 4 ft 9 in.: Not sampled for microfossils. Sandstone, medium-light-gray, silty, argillaceous, noncalcareous; sericitic in parts; very fine to fine grained, grading to very fine grained at base of core. Laminae with abundant carbonaceous particles present in lower part of core.
18	413–418	Recovered 4 ft 1 in.: Not sampled for microfossils. Sandstone as above, very fine- to fine-grained.
19	418–423	Recovered 4 ft 8 in.: Not sampled for microfossils. Sandstone as in core 18.
20	423–433	Recovered 9 ft 6 in.: Not sampled for microfossils. Sandstone as above, very fine-grained.
21	433–439	Recovered 5 ft 6 in.: Microfossils abundant Sandstone as in core 20, with a 1-in. bed of medium-dark-gray claystone 2½ ft above base and 3- to 4-in. beds of medium-dark-gray claystone, slightly silty and micaceous, noncalcareous, with subconchoidal fracture, in lower 1½ ft.
22	439–444	Recovered 4 ft 2 in.: Not sampled for microfossils. 9 in., claystone, medium-dark-gray, and medium-light-gray intercalated sandy siltstone. 3 in., clay ironstone, yellowish-gray, dense, hard, calcareous, with conchoidal fracture. 3 in., siltstone, medium-light-gray, very calcareous. 1 in., claystone, medium-dark-gray, noncalcareous. 2 ft 10 in., sandstone, medium-light-gray, very fine-grained, silty, very argillaceous; slightly calcareous in part; composed of subangular grains of clear and white quartz with dark rock fragments, biotite, and carbonaceous particles.
23	444–450	Recovered 4 ft 6 in.: Not sampled for microfossils. Sandstone as above, massive; small (less than 1 in. diameter) clay ironstone nodules very rare.

Lithologic description—Continued

Core	Depth (feet)	Remarks
24	450–455	Recovered 4 ft 11 in.: Not sampled for microfossils. Sandstone, as in core 23 above, with 1-in. claystone beds in basal 6 in.
25	455–465	Recovered 9 ft 9 in.: Microfossils rare. 4 ft 3 in., sandstone as above, very silty. 11 in., clay shale, medium-dark-gray, very silty, noncalcareous, micaceous, with sandstone intercalations in lower 2 in. Poor shaly partings dip 5° or less. 2 ft 3 in., sandstone as above, with intercalations of clay shale in basal 2 in. 2 ft 4 in., clay shale, medium-dark-gray, slightly to very silty, micaceous, noncalcareous; poor shaly parting dips 3°–4°. Two 1-in. beds of very fine-grained very silty sandstone in basal 6 in.
26	465–475	Recovered 10 ft 2 in.: Microfossils very abundant. Clay shale as above, with very rare ¼–2-in. beds and intercalations of siltstone and sandstone. Thin streaks of medium-dark-gray sandstone with clay matrix rare. A tube of *Ditrupa* sp. found at 468 ft and a shell of a *Pecten* sp. at 466 ft.
-----	475–482	Clay shale, medium-dark-gray, and medium-gray siltstone.
27	482–487	Recovered 4 ft 4 in.: Microfossils absent. 2 ft 4 in., claystone, medium-dark-gray, silty, and medium-light-gray very fine and fine-grained sandstone, intercalated; small amount of medium-gray siltstone; micaceous and carbonaceous particles common throughout. *Corbula?* at 482 ft. 2 ft., sandstone, light-gray, fine-grained and very fine-grained, noncalcareous; 2-in. of interlaminated sandstone and clay shale at 486 ft.
28	487–492	Recovered 5 ft: Microfossils absent. 1 ft 7 in., sandstone, very fine- and fine-grained; clay shale; and siltstone; intercalated. 1 ft 2 in., clay shale, medium-dark-gray, very silty, micaceous, noncalcareous; some patches of sandstone in upper 2 in. Poor shaly cleavage dips 5° or less. 2 ft 3 in., sandstone, medium-light-gray, very fine- to fine-grained, silty, noncalcareous, slightly micaceous, thin-bedded; dip 5° or less.
29	492–499	Recovered 7 ft: Microfossils absent. Sandstone as above; fine- to medium-grained at base.
30	499–509	Recovered 7 ft 4 in.: Microfossils rare. 6 in., sandstone, fine- to medium-grained, as at base of core 29. 6 ft 8 in., clay shale, medium-dark-gray, noncalcareous; slightly silty in part. Good shaly cleavage dips 1°–3°. Rare clay ironstone beds ¼-in. thick in upper part. Pelecypod shell fragment at 503 ft. 2 in., sandstone, medium-light-gray, fine-grained, silty, argillaceous, noncalcareous.
31	509–519	Recovered 9 ft 11 in.: Microfossils rare. 1 ft 2 in., siltstone, medium-gray, noncalcareous, with abundant intercala-

Lithologic description—Continued

Core	Depth (feet)	Remarks
		tions and partings of carbonaceous clay shale, grading to unit below. 10 in., clay shale, medium-dark-gray, silty, with abundant siltstone partings in upper part. 1 ft 3 in., siltstone, medium-gray, partly sandy, argillaceous; cross-bedded with faint partings and minute fragments of carbonaceous material. Dip as much as 10°. 4 ft 3 in., clay shale, medium-dark-gray, noncalcareous, slightly silty in part; very slightly micaceous; fissile in part. Dip 1°–3°. A 1-in. clay ironstone nodule at 515 ft. 2 ft 5 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, micaceous, with small flakes and partings of carbonaceous material.
32	519–529	Recovered 9 ft 10 in.: Microfossils rare. 4 in., sandstone as above. 2 ft 3 in., claystone, medium-dark-gray, slightly to very silty, with abundant laminae of siltstone dipping 3°–4° in upper 1 ft; irregular fracture. 5 ft., clay shale, medium-dark-gray, fissile. 2 ft 3 in., sandstone; medium gray in upper part; grades to medium light gray in lower part; very fine to fine grained, noncalcareous, micaceous; composed of clear and white quartz with gray chert, dark rock fragments, and carbonaceous particles. Lower part less silty and argillaceous, and carbonaceous particles are concentrated in partings instead of being disseminated.
33	529–539	No recovery.
34	539–544	No recovery.
35	544–554	Recovered 9 ft 4 in.: Microfossils absent. 6 in., sandstone, grading through siltstone to silty claystone, all with abundant fine laminae of dark-gray carbonaceous micaceous clay shale dipping 25°. 8 ft 10 in., claystone, medium-dark-gray, slightly to very silty, slightly to very micaceous, noncalcareous; has irregular fracture.
36	554–560	No recovery.
37	560–562	No recovery.
38	562–572	Recovered 10 ft 2 in.: Microfossils absent. Claystone as above, but very slightly silty; subconchoidal fracture.
39	572–582	Recovered 9 ft 1 in.: Microfossils common. Claystone as above, but with very rare silty laminae dipping as much as 8° (average dip 4°).
-----	582–602	Clay shale, medium-dark-gray, slightly silty, micaceous, with rare carbonaceous partings, and small amount of medium-gray very argillaceous slightly calcareous siltstone.
40	602–609	Recovered 5 ft 7 in.: Microfossils common. Claystone as in core 39, with scattered medium-gray very silty clay shale laminae that dip 5° or less.
-----	609–610	No sample.
-----	610–630	Clay shale, medium- to medium-dark-gray, with very small amount of medium-gray siltstone in upper part.

Lithologic description—Continued

Core	Depth (feet)	Remarks
41	630–640	Recovered 9 ft 4 in.: Microfossils common. Claystone, medium-dark-gray, very silty, noncalcareous, micaceous; irregular fracture; has intercalations, laminae, and thin beds (less than 2 in. thick) of medium-gray siltstone and medium-light-gray very fine-grained sandstone. Laminae dip 5° or less.
42	640–648	Recovered 8 ft 1 in.: Microfossils abundant. 5 ft, claystone as in core 41. 3 ft 1 in., claystone, medium-dark-gray; very slightly silty in part; very slightly micaceous; irregular to subconchoidal fracture.
-----	648–650	No sample.
-----	650–655	Clay shale, medium-dark-gray, with a very small amount of siltstone.
-----	655–665	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous; moderately calcareous in part; and medium-gray argillaceous siltstone.
-----	665–680	Clay shale, medium-dark-gray; slightly silty in part; slightly micaceous; siltstone in upper part.
43	680–690	Recovered 9 ft 2 in.: Microfossils very abundant. Claystone as in core 42, but slightly to moderately silty.
-----	690–750	Clay shale, medium-dark-gray; slightly silty in part; slightly micaceous. Small amounts of siltstone at 715–720, 725–735, and 745–750 ft. A thin bed of very fine-grained medium-light-gray sandstone composed of subangular grains of clear and white quartz at 735–740 ft. Note: Below base of the permafrost at 750 ft, cores absorbed water from drilling mud, and a mud sheath was formed on them.
44	750–760	Recovered 9 ft 8 in.: Microfossils very rare. 5 ft 6 in., claystone as in core 43. 4 ft 2 in., siltstone, medium-gray, slightly sandy, argillaceous, slightly micaceous, noncalcareous, massive, with scattered small fragments (¼ in. or less in diameter and 1/16 in. thick) of reddish-brown clay ironstone 2 ft above base of core.
45	760–770	Recovered 2 in. Core not received in laboratory.
46	770–780	Recovered 10 ft 2 in.: Microfossils abundant. 2 ft, sandstone, medium-light-gray, fine-grained, slightly silty and argillaceous, noncalcareous; composed of clear and white quartz with some gray chert and dark rock fragments. Mica common; carbonaceous particles rare. Sandstone thin bedded, approximately flat lying. 8 ft 2 in., clay shale, medium-dark-gray, very slightly silty, noncalcareous, fissile; beds approximately flat lying.
47	780–790	Recovered 10 ft 4 in.: Microfossils very abundant. 3 ft 10 in., claystone, medium-dark-gray, noncalcareous; very slightly silty in part; conchoidal fracture.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		9 in., intercalated clay shale, very fine-grained sandstone, and siltstone. 4 ft 6 in., claystone as above but very silty in upper 1 ft; reddish-brown clay ironstone in upper 6 in.; 1 ft 3 in., intercalated sandstone, fine-grained, light-gray, noncalcareous, and medium-dark-gray noncalcareous clay shale.
48	790–800	Recovered 9 ft 3 in: Not sampled for microfossils. Sandstone, medium-light-gray, fine- to medium-grained, slightly silty, noncalcareous; composed of subangular to subround grains of clear and white quartz, with dark rock fragments and rare gray chert. Sandstone is thin bedded and approximately flat lying.
49	800–810	Recovered 6 ft 6 in: Not sampled for microfossils. Sandstone as above.
50	810–820	Recovered 1 ft 6 in: Not sampled for microfossils. Sandstone as above, grading to fine-grained at base.
51	820–822	Recovered 1 ft: Not sampled for microfossils. Sandstone, fine-grained, and otherwise as in core 48.
-----	822–824	No sample.
52	824–834	Recovered 6 ft 4 in: Not sampled for microfossils. Sandstone as in core 51. Medium-bedded, uniform. A 1-in. bed of medium-dark-gray claystone 1½ ft below top of core.
53	834–843	Recovered 7 ft: Not sampled for microfossils. Sandstone as in core 51 above.
-----	843–845	No sample.
-----	845–875	Sandstone, light-gray; fine-grained in upper part; grading to very fine grained in lower part; slightly to very argillaceous; silty; slightly calcareous in part; very slightly micaceous. Grains subangular to subround clear and white quartz, gray chert, some dark rock fragments, and rare carbonaceous particles. Very small amount of dark-gray carbonaceous clay shale in upper part of unit.
-----	875–880	Sandstone as above, and medium-dark- to dark-gray clay shale; very silty in part.
-----	880–885	Sandstone, medium-light-gray, very fine-grained, grading to siltstone.
-----	885–900	Siltstone, medium-light-gray, argillaceous, noncalcareous; slightly sandy in part.
-----	900–910	Sandstone, very fine-grained, very silty and argillaceous, with some siltstone and a small amount of clay shale.
-----	910–938	Sandstone, medium-light-gray, fine- to very fine-grained, grading to very fine-grained, silty, argillaceous, very slightly micaceous, noncalcareous.
54	938–948	Recovered 10 ft 2 in: Not sampled for microfossils. Sandstone, medium-light-gray, fine-grained, slightly silty, noncalcareous; composed of subangular to subround grains of clear and white quartz, with rare dark rock fragments and gray chert. Carbonaceous partings rare between 944 and 945 ft. A 1-in. bed of light-brownish-gray clay ironstone 3 in. above base of core. Sandstone thin bedded and approximately flat lying.

Lithologic description—Continued

Core	Depth (feet)	Remarks
55	948–956	Recovered 9 ft 6 in.: Not sampled for microfossils. Sandstone as above, but massive; rare carbonaceous partings in lower foot of core dip 2°; carbonaceous particles abundant in ½-in. interval at 953 ft. A dip of 7° indicated in a 2-in. thickness of medium-gray sandstone by abundant carbonaceous particles in varying concentrations along bedding planes. Upper part of unit cut by sharp diagonal contact which is overlain by medium-light-gray massive sandstone; sharp contact dips 42°.
56	956–966	Recovered 9 ft 10 in.: Not sampled for microfossils. Sandstone as above, thin-bedded.
57	966–969	Recovered 2 ft. 6 in.: Not sampled for microfossils. Sandstone as above.
58	969–979	Recovered 9 ft: Not sampled for microfossils. Sandstone, light-yellowish-gray, fine-grained, slightly silty, very calcareous, dense; grades to noncalcareous at base. Scattered small nodules (less than one-half in. in diameter) of clay ironstone common at 974–975 ft; faint carbonaceous patches rare throughout.
59	979–986	Recovered 6 ft 9 in.: Microfossils abundant. Sandstone, medium-light-gray, very fine-grained, with rare to common carbonaceous partings dipping 1°–2°, rarely as much as 12°. One foot below top of core is a 1-in. thickness of sandstone containing intercalations of medium-dark-gray clay shale that have irregular, undulating, but sharp boundaries, and commonly pinch out to form minute lenses. Two 6-in. beds of medium-dark-gray slightly silty claystone 1 ft and 6 ft below top of core.
60	986–996	Recovered 9 ft 8 in.: Microfossils abundant. 2 ft 4 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, slightly micaceous, noncalcareous. One-inch bed of medium-dark-gray claystone 1 ft below top of core. Sandstone grades into unit below. 1 ft 8 in., sandstone, as above, but fine- to medium-grained. Two 1-in. beds of clay ironstone in basal foot. 2 ft 6 in., clay shale, medium-dark-gray, slightly silty, with rare siltstone laminae and carbonaceous micaceous partings in upper part that dip as much as 8°. 3 ft 2 in., sandstone, medium-light-gray, very fine-grained, noncalcareous, thin-bedded; dip 1°–4°. Very fine carbonaceous micaceous partings in lower 6 in. dip 4°–18°.
61	996–998	Recovered 2 ft: Not sampled for microfossils. Sandstone, light-gray, very fine-grained, slightly silty, moderately calcareous, massive.
62	998–1,000	Recovered 2 ft: Not sampled for microfossils.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		Sandstone, light-gray, fine-grained, very slightly silty, micaceous, very calcareous, hard, massive; composed of subangular to subround grains of clear and white quartz with rare carbonaceous particles and dark rock fragments.
63	1,000–1,005	Recovered 4 ft 2 in.: Not sampled for microfossils.
		Sandstone as above, with a few streaks of clay shale and clay ironstone, less than one-fourth inch thick, in the upper foot. Sandstone grades to medium light gray, very fine grained at base of core.
64	1,005–1,015	Recovered 9 ft 8 in.: Microfossils absent.
		Sandstone as at base of core 63; noncalcareous, silty, argillaceous in lower half of core.
65	1,015–1,025	Recovered 10 ft: Microfossils absent.
		Sandstone as in lower part of core 64.
66	1,025–1,034	Recovered 9 ft 1 in.: Microfossils absent.
		Sandstone as in lower part of core 64 but moderately calcareous in part.
67	1,034–1,044	Recovered 9 ft 7 in.: Microfossils absent.
		Sandstone as in lower part of core 64. Rare carbonaceous micaceous laminae dip 6°.
68	1,044–1,045	Recovered 7 in.: Microfossils absent.
		Sandstone as above.
69	1,045–1,055	Recovered 10 ft: Microfossils absent.
		Sandstone as above, but lacking laminae; grades to medium gray, very argillaceous, with irregular streaks of medium-dark-gray carbonaceous micaceous claystone at base.
70	1,055–1,065	Recovered 10 ft: Microfossils absent.
		5 ft, sandstone as at base of core 69, with abundant irregular laminae of medium-dark-gray claystone; grades into unit below.
		5 ft, claystone, medium-dark-gray, very silty and micaceous, noncalcareous, with rare small carbonaceous plant fragments, and irregular laminae of silty sandstone and siltstone. Top of Topagoruk formation at 1,060 ft.
71	1,065–1,066	Recovered 1 ft: Microfossils common.
		Claystone as at base of core 70.
-----	1,066–1,075	Clay shale, medium-dark-gray, noncalcareous, with a small amount of siltstone in lower part.
-----	1,075–1,085	Siltstone, grading to medium-gray very fine-grained very argillaceous and silty sandstone, with some clay shale.
-----	1,085–1,090	Clay shale, medium-dark-gray, silty.
-----	1,090–1,095	Siltstone, grading to sandstone, with a small amount of clay shale.
-----	1,095–1,100	Clay shale, with some siltstone and sandstone.
		Note: From 1,100 to 1,665 ft ditch samples from every second 5-ft unit were washed and examined. Below 1,665 ft a continuous series of 10-ft samples was recorded.
-----	1,100–1,209	Clay shale, medium-dark-gray, noncalcareous. Some shale at 1,200–1,205 ft is dark gray and carbonaceous.
72	1,209–1,211	Recovered 1 ft 6 in.: Microfossils rare.
		Claystone, medium-dark-gray, slightly silty, micaceous, noncalcareous, with irregular fracture.
-----	1,211–1,255	Clay shale, medium-dark-gray, slightly silty and micaceous, noncalcareous. At 1,210–1,225 ft clay shale is medium gray, nonsilty, and nonmicaceous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	1,255–1,265	Clay shale, with small amount of very argillaceous medium-gray siltstone.
-----	1,265–1,275	Siltstone, with small amount of clay shale.
-----	1,275–1,305	Clay shale, with siltstone decreasing from a half to a fifth of the sample, with depth.
-----	1,305–1,345	Clay shale, slightly to very silty, slightly micaceous.
-----	1,345–1,365	Clay shale with some very argillaceous medium-gray siltstone.
-----	1,365–1,415	Clay shale, medium-dark-gray, slightly silty, with some dark-gray very slightly carbonaceous clay shale at 1,380–1,385 ft.
-----	1,415–1,429	Clay shale, medium-dark-gray, with small amount of siltstone and very rare pyrite.
73	1,429–1,439	Recovered 10 ft: Microfossils abundant.
		Claystone, medium-dark-gray, slightly to very silty, micaceous, noncalcareous, with streaks of argillaceous siltstone increasing from rare to common with depth. Fracture irregular, except for some smooth, nearly vertical joint planes between 1,433 and 1,434 ft.
-----	1,439–1,440	No sample.
-----	1,440–1,465	Clay shale; slightly to very silty in part.
-----	1,465–1,495	Siltstone, medium-gray, very sandy, with small amount of very fine-grained sandstone and some clay shale.
-----	1,495–1,515	Clay shale, medium-dark-gray; very silty in part; some dark-gray slightly carbonaceous clay shale. Pyrite very rare.
-----	1,515–1,535	Clay shale, medium-dark-gray; very silty in part; very rare pyrite; siltstone increases from a very small amount to nearly half the rock and then decreases again, with depth.
-----	1,535–1,605	Clay shale, medium-dark-gray, partly silty, with very rare pyrite.
-----	1,605–1,615	Clay shale as above, with some siltstone; echinoid spine at 1,600 ft.
-----	1,615–1,618	No sample.
74	1,618–1,623	Recovered 5 ft: Microfossils rare.
		Claystone, medium-dark-gray, very silty, micaceous, noncalcareous; sandy in part, with abundant intercalations and patches of siltstone with some very fine-grained sandstone totaling about half the rock. Irregular fracture.
-----	1,623–1,655	Clay shale, medium-dark-gray, slightly to very silty, with some medium-gray very argillaceous noncalcareous siltstone; sandy in part; siltstone increases from very small amount to nearly half the rock at 1,630 ft and decreases below that depth.
-----	1,655–1,715	Clay shale, medium-dark-gray, silty.
-----	1,715–1,755	Clay shale, with very small amount of siltstone.
-----	1,755–1,850	Clay shale, medium-dark-gray, partly silty, with rare pyrite. Sample from 1,840–1,850 ft contaminated with surface gravel.
75	1,850–1,855	Recovered 5 ft: Microfossils very abundant.
		Clay shale, medium-dark-gray, slightly to moderately silty, micaceous, noncalcareous.
-----	1,855–1,870	Clay shale; samples contaminated with surface gravel.
-----	1,870–1,880	Clay shale, with small amount of siltstone and sandstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	1, 880–1, 910	Sandstone, medium-light-gray, slightly calcareous to noncalcareous, silty to very silty, argillaceous; composed of subangular grains of clear and white quartz with some dark rock fragments and rare muscovite. Some siltstone and claystone.
-----	1, 910–1, 920	Siltstone, similar in composition to the sandstone above, with some sandstone and clay shale.
-----	1, 920–1, 970	Clay shale, medium-dark-gray, slightly silty.
-----	1, 970–1, 990	Clay shale, with some medium-gray slightly calcareous siltstone in upper part.
-----	1, 990–2, 130	Clay shale, medium-dark-gray, slightly silty, micaceous, noncalcareous; pyrite very rare at 2,100–2,110 ft and rare at 2,120–2,130 ft.
-----	2, 130–2, 145	Clay shale with very small amount of siltstone in upper part. Ca cite very rare.
76	2, 145–2, 150	Recovered 5 ft: Microfossils abundant. Clay shale, medium-dark-gray, slightly micaceous, noncalcareous; slightly silty in part; poor shaly partings dip about 4°. *Gastroplites* sp. at 2,148 ft.
-----	2, 150–2, 190	Clay shale, medium-dark-gray, with some medium-gray slightly calcareous partly very sandy siltstone composing from 10 to 40 percent of the rock.
-----	2, 190–2, 230	Clay shale, medium-dark-gray; slightly silty in part; very rare pyrite.
-----	2, 230–2, 270	Clay shale as above, with small amount of very argillaceous siltstone.
-----	2, 270–2, 408	Clay shale, medium-dark-gray, micaceous, slightly silty in part. A reverse fault repeats beds of the Topagoruk formation between 2,400 and 2,950 ft.
77	2, 408–2, 413	Recovered 5 ft: Microfossils common. Claystone, medium-dark-gray, very silty, micaceous, noncalcareous, with rare intercalations of siltstone. Faint lines of pyrite ⅛–½ in. long scattered through the rock; echinoid spine in washed sample.
78	2, 413–2, 418	Recovered 5 ft: Microfossils common. Claystone as above.
-----	2, 418–2, 430	Claystone as above, with very small amount of siltstone in upper part and sandstone in lower part.
-----	2, 430–2, 450	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, noncalcareous; composed of angular grains of white and clear quartz, gray chert, and dark rock fragments, with very rare muscovite.
-----	2, 450–2, 460	Clay shale, with small amount of siltstone.
-----	2, 460–2, 490	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous; grades to medium-gray slightly to very sandy argillaceous noncalcareous siltstone with some clay shale.
-----	2, 490–2, 540	Clay shale, medium-dark-gray, and medium-gray argillaceous nonsandy siltstone, decreasing gradually from a half to a quarter of the rock with depth.
-----	2, 540–2, 590	Clay shale, medium-dark-gray, with some dark-gray clay shale and very small amount of siltstone in upper part.
-----	2, 590–2, 631	Clay shale, with small amount of medium- and medium-dark-gray siltstone; siltstone contains larger proportion of dark rock fragments and gray chert and is very argillaceous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
79	2, 631–2, 641	Recovered 9 ft: Microfossils rare. Clay shale, medium-dark-gray, slightly silty, noncalcareous, with common laminae and rare thin beds (less than 2 in. thick) of siltstone, crossbedded in part, totaling about 5 percent of the rock, and dipping as much as 10°. *Gastroplites* sp. at 2,634 ft.
-----	2, 641–2, 700	Clay shale, medium-dark-gray, with very small amount of medium-gray siltstone.
-----	2, 700–2, 730	Clay shale, with some siltstone.
-----	2, 730–2, 784	Clay shale, medium-dark-gray; slightly silty in part; pyrite very rare in lower 10 ft.
80	2, 784–2, 794	Recovered 7 ft 8 in.: Microfossils rare. Claystone, medium-dark-gray, slightly silty noncalcareous, with rare laminae of siltstone. Pelecypod shell fragment *Inoceramus* sp. juv. cf. *I. anglicus* Woods at 2,784 ft.
-----	2, 794–2, 870	Clay shale, medium-dark-gray, slightly silty and micaceous; rare medium- or medium-dark-gray siltstone.
-----	2, 870–2, 950	Clay shale, as above, with a slightly larger amount of either medium-gray slightly sandy or medium-dark-gray very argillaceous siltstone.
-----	2, 950–3, 000	Clay shale, medium-dark-gray, with very rare light-gray siltstone and very rare pyrite in lower 20 feet.
81	3, 000–3, 007	Recovered 6 ft 2 in.: Microfossils very abundant. Claystone, medium-dark-gray, slightly to very silty, micaceous, noncalcareous; has irregular fracture. *Ditrupa* sp. at 3,004 ft.
-----	3, 007–3, 070	Clay shale, medium-dark-gray, with some dark-gray clay shale in upper 10 ft.
-----	3, 070–3, 100	Clay shale as above, with some medium-gray siltstone and medium- and medium-light-gray sandstone that increases with depth.
-----	3, 100–3, 110	Clay shale, medium-dark-gray.
-----	3, 110–3, 150	Clay shale with very small amount of medium-gray siltstone and medium-light-gray sandstone.
-----	3, 150–3, 267	Clay shale, medium-dark-gray, slightly to very silty, with small amount of dark-gray fissile shale.
82	3, 267–3, 277	Recovered 8 ft 11 in.: Microfossils absent. Claystone, medium-dark-gray, slightly to very silty, micaceous, noncalcareous with irregular fracture.
-----	3, 277–3, 340	Clay shale with small amount of medium-gray very fine-grained sandstone composed of angular grains of white quartz, gray chert, and dark rock fragments in about equal proportions.
-----	3, 340–3, 441	Clay shale, medium-dark-gray; slightly to very silty in part.
83	3, 441–3, 450	Recovered 7 ft: Microfossils very rare. Claystone, medium-dark-gray, slightly to very silty, micaceous, noncalcareous, with scattered small lenses and intercalations of sandy medium- to medium-light-gray siltstone a quarter inch or less thick, totaling less than 5 percent of core and dipping 5°–10°.
-----	3, 450–3, 510	Clay shale, medium-dark-gray, slightly silty.
-----	3, 510–3, 520	Clay shale, with small amount of medium-gray very argillaceous siltstone.
-----	3, 520–3, 530	No sample.
-----	3, 530–3, 606	Clay shale, medium-dark-gray, with very small amount of siltstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
84	3, 606–3, 616	Recovered 9 ft 6 in.: Microfossils absent. Clay shale, medium-dark-gray, slightly silty and micaceous, with common laminae of siltstone and very silty clay shale, dip 9°.
85	3, 616–3, 621	No recovery.
86	3, 621–3, 626	Recovered 2 ft: Microfossils absent. Clay shale as in core 84.
-----	3, 626–3, 690	Clay shale, medium-dark-gray, with very small amount of dark-gray fissile shale.
-----	3, 690–3, 737	Clay shale; very silty in part; very small amount of very argillaceous siltstone.
87	3, 737–3, 747	Recovered 1 ft 11 in: Microfossils absent. Claystone, medium-dark-gray, silty, micaceous, noncalcareous; has irregular fracture.
88	3, 747–3, 750	Recovered 6 in: Microfossils rare. Claystone as in core 87, with very abundant intercalations of silty claystone.
-----	3, 750–3, 790	Clay shale; very silty in part; very small amount of very argillaceous siltstone.
-----	3, 790–3, 830	Clay shale, medium-dark-gray; very silty in part.
-----	3, 830–3, 870	Clay shale, with small amount of very argillaceous siltstone.
-----	3, 870–3, 877	Clay shale, medium-dark-gray, slightly silty.
89	3, 877–3, 887	Recovered 5 ft 6 in.: Microfossils very rare. Claystone, medium-dark-gray, slightly silty, micaceous, noncalcareous; has irregular fracture. Very rare laminae of medium-light-gray siltstone dip 11°.
-----	3, 887–4, 087	Clay shale, medium-dark-gray, slightly silty, with small amount of dark-gray fissile clay shale in lower part.
90	4, 087–4, 097	Recovered 7 ft 2 in.: Microfossils rare. Claystone, medium-dark-gray, very slightly micaceous, noncalcareous; very slightly silty in part; has irregular fracture. Laminae of slightly lighter-colored silty claystone dip 20°; rare slickensides also dip 20°.
-----	4, 097–4, 220	Clay shale, medium-dark-gray, slightly silty, with rare siltstone at 4,100–4,110, 4,140–4,150, and 4,190–4,200 ft.
91	4, 220–4, 232	Recovered 6 ft 6 in.: Microfossils very rare. Claystone, medium-dark-gray, very slightly micaceous, noncalcareous; very slightly silty in part; irregular fracture. Laminae of silty claystone are crossbedded, dip 12°–20°.
-----	4, 232–4, 320	Clay shale; silty to very silty in part; rare siltstone at 4,250–70 ft.
-----	4, 320–4, 350	Clay shale, with small amount of siltstone.
-----	4, 350–4, 370	Clay shale, with siltstone increasing to about half the rock between 4,360 and 4,370 ft.
-----	4, 370–4, 400	Clay shale, with very small amount of siltstone in upper part.
-----	4, 400–4, 420	Clay shale, medium-dark-gray, partly silty.
-----	4, 420–4, 433	Clay shale, with very argillaceous siltstone.
92	4, 433–4, 443	Recovered 7 ft 9 in.: Microfossils rare. Clay shale, medium-dark-gray, very slightly micaceous, noncalcareous; very slightly silty in part; abundant faint silty, very even laminae dipping 1°–3°.
-----	4, 443–4, 450	Clay shale, medium-dark-gray, partly silty, with a very small amount of siltstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	4, 450–4, 610	Clay shale; silty in part; rare pyrite in lower part.
93	4, 610–4, 620	Recovered 9 ft 2 in.: Microfossils very abundant. Clay shale, medium-dark-gray, very slightly micaceous, noncalcareous; very slightly silty in part; abundant silty laminae dipping 10°.
-----	4, 620–4, 787	Clay shale, medium-dark-gray, slightly silty in part; rarely very silty; pyrite rare. Some dark-gray fissile clay shale at 4,710–4,720 ft. Top of Oumalik formation at 4,700 ft.
94	4, 787–4, 797	Recovered 9 ft 6 in.: Microfossils very rare. Clay shale, medium-dark-gray, very slightly micaceous, noncalcareous, with abundant very faint laminae and thin beds (less than a half an inch thick) of slightly silty clay shale that are a little lighter in color. Laminae dip 4° at top of core; dip increases gradually to 9° at base.
-----	4, 797–4, 870	Clay shale, medium-dark-gray, partly silty.
-----	4, 870–4, 890	Clay shale, medium-dark-gray, silty, with very small amount of siltstone in upper part, and very small amount of brownish-gray very fine-grained sandstone composed of angular grains of clear quartz with a slightly brownish cast.
-----	4, 890–4, 985	Clay shale, slightly to very silty, with very rare fragments of brownish-gray very fine-grained sandstone at 4,910–4,920 ft.
95	4, 985–4, 995	Recovered 7 ft 9 in.: Microfossils very rare. Clay shale, medium-dark-gray, very slightly micaceous, noncalcareous, with abundant very faint laminae and thin beds (less than one-half inch thick) of slightly silty clay shale, dipping 23°. Rare bedding-plane slickensides also dip 23°.
-----	4, 995–5, 130	Clay shale, medium-dark-gray; slightly to very silty in part; some dark-gray fissile clay shale; rare fragments of brownish-gray very fine-grained sandstone at 5,090 ft. Base of Oumalik formation is at about 5,100 ft; it is in fault contact with repeated beds of the Topagoruk formation.
-----	5, 130–5, 140	Clay shale as above, with very small amount of medium-gray very argillaceous siltstone.
-----	5, 140–5, 185	Clay shale, as above.
96	5, 185–5, 195	Recovered 6 ft 6 in.: Microfossils very rare. Clay shale, medium-dark-gray, very slightly micaceous, noncalcareous, with abundant very faint flat-lying laminae and thin beds of slightly silty clay shale.
-----	5, 195–5, 230	Clay shale as above, with rare siltstone.
-----	5, 230–5, 310	Clay shale, medium-dark-gray; slightly silty in part.
-----	5, 310–5, 360	Clay shale as above, with very small amount of very argillaceous medium-gray siltstone.
-----	5, 360–5, 385	Clay shale as above.
97	5, 385–5, 395	Recovered 8 ft: Microfossils absent. Clay shale, medium-dark-gray, very slightly micaceous, with common flat-lying laminae of medium-gray argillaceous siltstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	5, 395–5, 585	Clay shale, medium-dark-gray, with very rare siltstone; echinoid spine at 5,410 ft.
98	5, 585–5, 595	Recovered 8 ft 9 in.: Microfossils very abundant. Clay shale, medium-dark-gray, very slightly micaceous, with common flat-lying or rarely crossbedded laminae of medium-gray argillaceous siltstone. Thin (1/16–1/4 in.) beds of olive-gray clay shale rare.
-----	5, 595–5, 630	Clay shale, medium-dark-gray; slightly silty in part.
-----	5, 630–5, 700	Clay shale, medium-dark-gray, slightly silty, with very small amount of argillaceous siltstone; very small amount of medium-light-gray very argillaceous sandstone at 5,630–5,650 ft.
-----	5, 700–5, 785	Clay shale, medium-dark-gray; slightly silty in part; crinoid ossicle at 5,730 ft.
99	5, 785–5, 795	Recovered 8 ft 9 in.: Microfossils common. Clay shale, medium-dark-gray, very slightly micaceous, with common medium-gray argillaceous siltstone laminae that dip 9°. Two ½-in. beds of olive-gray clay shale at 5,784 ft.
-----	5, 795–5, 883	Clay shale, medium-dark-gray; slightly silty in part; rarely very silty; crinoid ossicle at 5,800 ft.
100	5, 883–5, 903	Recovered 4 ft 2 in.: Microfossils very abundant. Clay shale, medium-dark-gray, very slightly micaceous, with common medium-gray argillaceous siltstone laminae that dip 10°. Crinoid ossicle in washed sample.
-----	5, 903–5, 940	Clay shale, slightly silty in part, with rare siltstone.
-----	5, 940–6, 052	Clay shale, medium-dark-gray; slightly silty in part; commonly fissile.
101	6, 052–6, 072	Recovered 17 ft 6 in.: Microfossils very rare. Clay shale, medium-dark-gray, very slightly micaceous, with common medium-gray argillaceous siltstone laminae that dip 3°.
-----	6, 072–6, 110	Clay shale, medium-dark-gray; slightly silty in part.
-----	6, 110–6, 185	Clay shale, medium-dark-gray, with rare very argillaceous siltstone beds at 6,110–6,120 ft and rare medium-light-gray very fine-grained, very argillaceous sandstone at 6,140–6,150 ft.
102	6, 185–6, 200	Recovered 14 ft 6 in.: Microfossils very rare. Clay shale, medium-dark-gray, very slightly micaceous, with common laminae of medium-gray argillaceous siltstone and silty clay shale, dipping 3°.
----	6, 200–6, 212	Clay shale, medium-dark-gray, with rare argillaceous siltstone.
	6, 212	Total depth.

CORE ANALYSES

The porosity and permeability of samples from Umiat test well 2 are shown in the following table. The effective porosity was determined with the Washburn-Bunting porosimeter; and the air permeability, with a Hayward permeameter.[2] Sieve analyses were made with two groups of samples, using different mesh sizes in part; results of these analyses and specific-gravity data are given in the following tables.

Analyses of core samples from Umiat test well 2

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
320	13. 3	20. 0
328	17. 0	72. 0
392	18. 4	78. 0
410	12. 8	<10
422	9. 2	<10
444	8. 2	<10
449	10. 5	<10
453	8. 7	<10
491	15. 7	42. 0
493	15. 8	36. 4
498	14. 3	270. 0
517	8. 6	5. 85
525	10. 0	<10
528	12. 6	9. 8
771	19. 1	----------
789.5	16. 7	----------
793	17. 1	----------
796	19. 3	164. 0
797	18. 0	65. 0
800	16. 8	----------
802	17. 7	187. 0
827	14. 8	10. 7
833	14. 7	14. 9
834	12. 7	9. 6
839	12. 0	17. 9
843	17. 2	71. 5
939	12. 8	<10
942	11. 3	<10
949	11. 5	<10
953	11. 8	<10
957	10. 5	<10
960	11. 6	4. 4
964	11. 6	<10
988	13. 3	----------
989	9. 1	<10
994	13. 4	----------
1,007	16. 9	----------
1,008	15. 4	<10
1,011 [1]	10. 9	3. 5
1,014	13. 1	4. 1
1,016	13. 8	4. 2
1,020	12. 2	<10
1,023	11. 7	<10
1,036	10. 2	<10

[1] Carbonate content 13.8 percent by weight.

Sieve analyses of samples from Umiat test well 2 using American Society for Testing Materials sieves that approximate the Wentworth grade scale

Depth (feet)	35 mesh (coarse)	60 mesh (medium)	120 mesh (fine)	230 mesh (very fine)	325 mesh (silt)	<325 mesh (clay)	Total
393	----------	0. 82	67. 60	13. 00	1. 39	16. 85	99. 66
395–400	----------	. 62	67. 00	12. 91	1. 98	16. 59	99. 10
408	0. 03	. 91	62. 00	17. 40	4. 50	15. 10	99. 94
428	----------	----------	44. 25	37. 50	2. 26	16. 15	100. 16
1,340	Trace	4. 25	65. 3	9. 35	3. 7	16. 25	99. 05

[2] Additional studies of permeability, made by P. D. Krynine, resulted in the following data for samples from 491, 802, and 839 feet, respectively: fresh-water permeability, 1.8 millidarcys, 0.25 millidarcys, and impermeable; brine permeability, 1.9, 97.5, and 0.4 millidarcys; Klinkenberg air permeability (i. e., permeability at infinite pressure) before liquid flow: 22.0, 131, and 7.4 millidarcys; Klinkenberg air permeability after liquid flow: 18.5, 100, and 1.84 millidarcys.

Sieve analyses of samples from Umiat test well 2 using American Society for Testing Materials sieves

Depth (feet)	Grain sizes (percent) [1]				
	60 mesh (medium)	120 mesh (fine)	230 mesh (very fine)	<230 mesh (silt and clay)	Total
320	----------	17.3	53.8	28.9	100.0
422	----------	22.0	38.1	40.0	100.1
491	0.3	46.4	27.1	26.2	100.0
528	.1	44.2	29.2	26.6	100.1
793	1.5	62.9	15.1	20.4	99.9
802	4.7	73.3	9.5	12.5	100.0
824	1.5	64.6	12.6	21.3	100.0
843	.6	67.0	16.0	16.5	100.1
953	----------	19.5	43.9	36.5	100.0
960	----------	38.3	26.5	35.3	100.1
1,011	----------	14.7	55.9	29.4	100.0
1,023	----------	9.1	51.8	39.1	100.0

[1] The 40-mesh (0.42 mm) screen was also used, but no grains were retained on it.

Specific gravity of samples from Umiat test well 2

Depth (feet)	Specific gravity	Rock type
310	2.3	Clay shale.
446	2.5	Very fine-grained sandstone.
578	2.5	Claystone.
751	2.5	Claystone.
1,040	2.49	Very fine-grained sandstone.
1,619	2.55	Silty sandstone.
2,147	2.5	Clay shale.
2,632	2.48	Siltstone.
3,612	2.5	Clay shale.
4,434	2.5	Clay shale.
5,391	2.5	Clay shale, with silty laminae.
6,060	2.5	Clay shale.

PETROGRAPHIC ANALYSES

A detailed petrographic study of thin sections of three graywacke sandstone samples from Umiat test well 2 was made by Paul D. Krynine (*in* Payne and others, 1951). The data are presented below and in the following table.

The sample from 491 feet is a very fine-grained graywacke sandstone composed of unoriented very poorly sorted mineral grains which are only slightly sorted in size. The matrix is very evenly distributed and consists of detrital and authigenic clay minerals and micas, besides a large volume of soft clay masses and slate fragments which are poorly consolidated and would disintegrate in a mechanical analysis or swell on hydration. The cement is relatively disseminated, as coatings of secondary quartz, and the rock is bonded by adhesion of the clay minerals.

Grains of quartz, the most common mineral, are angular and many are elongated. Most of the quartz is of igneous origin, and some is from pegmatites or veins, judging from the large number of bubbles, muscovite inclusions, and comb structure. A small amount shows undulatory extinction typical of metamorphic origin. Chert is rare and of several varieties ranging from cryptocrystalline to very fine grained and from colorless to deep yellow. Metamorphic rock fragments are the most abundant constituent and include metamorphosed siltstone; slate composed of sericite and illite; phyllite (wavy) made up of sericite, illite, and chlorite of different colors; and schists consisting primarily of sericite, muscovite-sericite, quartz, or chlorite. Grains are angular, elongated, and usually smaller than the quartz grains. Feldspar is primarily sodic plagioclase, and the grains are unweathered.

The matrix consists of kaolinite and montmorillonite, partly as aggregates and masses of many shapes and sizes that may exceed 0.1 millimeter in diameter. It is evenly distributed through the rocks. In some places authigenic illite and some chlorite surrounds and rarely replaces quartz grains. It forms very thin coatings on at least half of the wall spaces, as well as thin, elongated masses between grains. True cement, as secondary quartz overgrowths, is very rare. An X-ray diffraction pattern of fine material (<0.044 mm in diameter, which passed the 325-mesh sieve) shows it to be 49 percent quartz, 31 percent of illite, 8 percent of montmorillinote, small amounts of albite and kaolinite and rare chlorite.

Petrographic characteristics of sandstone from Umiat test well 2

[Determined by Paul D. Krynine]

Characteristic	Samples by depth		
	491 feet	802 feet	839 feet
Texture			
Average diameter range ____ mm	0.03–0.20	0.03–0.20	0.04–0.25
Principal mode ____ mm	0.12	0.14	0.12
Grains: matrix: cement ratio in percent.	85:14:trace	90:9:1	86:14:trace
Grain composition in percent			
Quartz	32	45	24
Chert	4	33	9
Feldspar	2	2.5	7
Mica flakes, large	1	----------	1
Slate, phyllite	42	11	42
Quartzite, schist	5	3	3
Volcanic rocks	1	Trace	Trace
Chlorite	Present	----------	----------
Muscovite	Present	----------	Present
Interstitial material in percent			
Chlorite	Trace	Trace	Trace
Sericite	1	Trace	1
Illite	5	2	2
Montmorillonite	1.5 }	6.5 }	10
Kaolinite	7 }		
Silica cement	Trace	Trace	Trace
Pore space and characteristics			
Pore size, principal mode microns	20	60	22
Visible porosity ____ percent	1	8	2
Residual porosity	Very poor	Fair	Very poor
Bonding material	Illite, kaolinite	Kaolinite, montmorillonite	Illite, kaolinite, montmorillonite
Clay-coated wall area ____ percent	85	70	85
Wall coating ____ type	Illite, kaolinite	Illite, kaolinite, montmorillonite	Illite, kaolinite, montmorillonite
Potential hydration	High	Very high	High

The visible pore space and the residual porosity are very small in size and in percentage of rock volume, and the wall spaces are coated with clay minerals, mostly illite. Montmorillonite is abundant and disseminated through the rock, further decreasing the pore space. As a result, the rock has very poor reservoir characteristics for storage or yield of oil.

The rock from 802 feet is another graywacke sandstone, composed of angular to subangular fine-sand grains, with about 10 percent matrix and a very small amount of secondary quartz cement. The dominant mineral is quartz, which occurs as nearly equant, rarely elongated grains. Most of it is igneous, with some from pegmatites or veins and some from metamorphic rocks. Chert is another important constituent, occurring in somewhat larger, better-rounded grains than the quartz. It ranges from cryptocrystalline to fine grained and from colorless to pale yellow. Rock fragments are much less abundant than in the sample at 491 feet but include the same rock types—metamorphosed siltstone, slate, phyllite, and schists. Igneous rock fragments are very rare, as are feldspars and biotite or chlorite flakes. Some green or brown tourmaline is present.

The matrix, which is evenly distributed through the rock, consists mostly of kaolinite and montmorillonite in aggregates and masses of different sizes, and grain-coatings of undifferentiated kaolinite or montmorillonite. Authigenic illite is also common surrounding and partly replacing some quartz grains, and acting as a bond between grains. It may be in thin coatings, or as elongate masses, the former covering nearly a quarter of the grain surfaces. An X-ray diffraction pattern shows the fine material (<0.044 millimeter in diameter, passing the 325-mesh sieve) to be 62 percent of quartz, 21 percent of illite, and small percentages of albite, montmorillonite, chlorite, and kaolinite.

The rock would be a fairly good oil reservoir, as it has large pore spaces and well-developed residual capillary porosity, although well over half of the grain surfaces are covered with coatings of clay minerals, mostly illite. Montmorillonite is common as disseminated particles and would lower the permeability greatly unless care were taken to prevent hydration.

The very fine graywacke sandstone from 839 feet is very poorly sorted, mineralogically, and the grains show no orientation. They are generally angular, with some subangular grains, and are bonded by adhesion to the clay matrix. Cement consists of scattered coatings of secondary quartz and tiny particles of carbonate minerals. Quartz that makes up about a quarter of the rock is igneous in origin; a small amount came from pegmatites, veins, and metamorphic rocks; chert is uncommon. About half of the rock consists of metamorphic rock fragments, including metamorphosed siltstone, slate, phyllite, and rare grains of schist. Igneous rock fragments and feldspars and mica flakes are very scarce. The matrix consists mostly of kaolinite with some montmorillonite, as aggregates, masses, and minute particles. Authigenic illite is present, surrounding and partly replacing some quartz grains as coatings or elongate masses. An X-ray diffraction pattern of the fine material (<0.044 mm in diameter, passing the 325-mesh sieve) shows it to be composed of quartz and illite, with small amounts of montmorillonite, albite, kaolinite, and chlorite.

The rock contains an unusually small number of pore spaces; and both residual capillary and pore spaces are lined with a thin coating of clay minerals, mostly illite. If hydrated the abundant and disseminated montmorillonite would greatly reduce the yield capacity of the rock. This, with the small number and size of pore spaces, makes the rock a very poor reservoir.

HEAVY-MINERAL ANALYSIS

A dozen heavy-mineral samples were examined by Robert H. Morris, who found them all to be within the hornblende zone; the zone as defined by these samples ranges from 400 to 1,044 feet. A chart of heavy-mineral occurrences is presented on plate 10.

OIL AND GAS

OIL AND GAS SHOWS

The oil and gas shows recorded at the well site by L. C. Riggins, Arctic Contractors geologist, and at the Fairbanks laboratory by W. N. Lockwood and R. M. Chapman, of the U. S. Geological Survey, in 1947, are shown in the following tables. When the cores were reexamined, in 1954, they had lost all but the strongest indications of petroleum. A small flow of gas came from the 11¾-inch casing when the blowout preventers were removed. (See section on Gas and water analyses.)

Oil and gas shows in Umiat test well 2 recorded by Arctic Contractors

[L. C. Riggins]

Depth (feet)	*Shows*
125–130	Good kerosenelike odor. No oil show on ditch or mud under ultraviolet light.
130–160	Gas odor, decreasing with depth; no oil show.
250–255	Thin beds have show of oil, good kerosene odor.
316–335	Bled light-gravity greenish-yellow oil, with some gas bubbles, and strong kerosenelike odor.
355–365	Kerosene odor.
387–392	Bled oil.
392–395	Good light-colored oil stain, strong kerosene odor; first show of oil in the ditch.

Oil and gas shows in Umiat test well 2 recorded by Arctic Contractors—Continued

Depth (feet)	Shows
395–418	Good light-colored oil stain.
386–444	All rock types have oil, depending upon the porosity and permeability.
444–459	Good kerosene odor.
482–487	Good oil odor.
489–492	Good oil odor.
492–499	Excellent oil odor, bled oil in part.
499–500	Good oil odor.
509–519	Good oil odor, good gas show.
525–529	Good to excellent oil odor; oil stained in part.
665–675	Slight oil odor.
770–773	Excellent odor.
789–822	Strong petroleum odor, some gas odor when core barrel was opened. Sandstone contains water in lower part.
824–834	Good oil odor but wet.
834–843	No oil odor at bottom of core.
986–990	Good petroliferous odor.
1,007–1,015	Fair to good oil odor.
1,017–1,019	Good oil odor.
1,019–1,028	Fair oil odor.
1,034–1,037	Slight oil odor.

Oil and gas shows in Umiat test well 2 recorded by U. S. Geological Survey

[W. N. Lockwood and R. M. Chapman]

Depth (feet)	Shows
317–332	Petroleum odor.
332–334	Slight petroleum odor.
334–335	Petroleum odor.
335–339	Slight petroleum odor.
339–342	Petroleum odor.
387–423	Petroleum odor.
423–438	Petroleum odor in part.
442–463	Petroleum odor.
484–485	Petroleum odor.
490–500	Petroleum odor.
517–519	Slight petroleum odor.
524–529	Strong petroleum odor in part.
770–780	Strong petroleum odor.
788–790	Petroleum odor.
790–810	Strong petroleum odor.
824–834	Strong petroleum odor and discoloration.
834–843	Petroleum odor in part.
938–948	Slight petroleum odor.
956–966	Strong petroleum odor in part.
991–996	Petroleum odor.
1,009–1,015	Slight petroleum odor.
1,015–1,025	Slight petroleum odor.

FORMATION TESTS

Production tests in Umiat test well 2 were all made by bailing. The tests recovered fresh or brackish water with a skim of oil and very little gas.

Test 1, 103–345 feet.—The hole was bailed dry and the water contained only a very slight show of oil and gas.

Test 2, 389–444 feet.—Sections of 2½-inch open-end tubing were run to 440 feet, with a packer set on a shoulder at 381 feet. The packer failed to hold on first two attempts to swab; the third attempt was successful, and the well was swabbed dry but showed no appreciable gas or oil. Some mud was removed from the wall of the hole by agitating the water, and the hole was allowed to stand for 8 hours. The packer was reset, and the well swabbed for 9 hours; a strong oil odor was noted, but no oil was recovered. The packer was removed, more perforations cut in the anchor pipe, and the packer reset. The hole was swabbed and washed at 30-minute intervals, producing a gas odor and slight oil stain on the wash water. Continued swabbing, recovered 30 gallons of wash water, with a stain of oil, with two runs of the bailer.

Test 3, 103–444 feet.—The hole from 381 to 418 feet was reamed to 15½ inches and bailed dry; only a slight show of oil and gas was noted.

Test 4, 103–544 feet.—Drilling mud was replaced with water for a bailing test. The hole was bailed down and allowed to stand for 15 minutes, then bailed again, with a recovery of 25 gallons of fresh water with a skim of oil. After 15 minutes the same quantity of water, with a skim of oil, was recovered. After 1 hour 25 gallons of water and 1 pint of oil were recovered on each of 5 trips. After 2 hours 25 gallons of fresh water and 1 pint of oil were bailed per trip.

Test 5, 755–822 feet.—The packer run on 2½-inch open-end tubing was set at 752 feet but did not hold. The hole was reamed to 753 feet, and the packer reset; it failed again, came loose, and was recovered. The hole was reamed to 755 feet, and the packer was set successfully. One barrel of drilling mud and brackish water with a skim of oil was swabbed at a rate of 1 barrel an hour for 6½ hours. Continuous swabbing then recovered about 2 barrels of brackish water with a slight show of oil and a small amount of gas. Swabbing was discontinued for 10 hours; the hole was then swabbed twice, and 30 barrels of brackish water (3,000 ppm chloride) with a film of oil was recovered.

GAS AND WATER ANALYSES

After the total depth of 6,212 feet was reached, the hole was bailed to 950 feet in preparation for a temperature survey; and when the blowout preventers were removed, a small flow of gas came out of the 11¾-inch casing. In preparing to test the volume and pressure of the gas, the hole was reentered to bail it down. The fluid level was found at 730 feet, and a water sample was taken at that depth. The hole was bailed to 1,075 feet, and the gas flow, as measured by a water manometer, was estimated at 15,520 cubic feet per day, probably from a sandstone bed at 1,030–1,060 feet. The casing

was closed in, and pressures were measured with a 200-pound steam-pressure gauge. The pressure was recorded at irregular times, 2–30 hours apart, for 12 days and every 24 hours for the next 11 days. For the first 5 days, the pressure ranged from 0 to 62 pounds per square inch; a casing weld leaked and was rewelded; four 1-gallon samples of gas were taken during that time. The pressure rose to 86 pounds in the next 2 days, remained at that figure for 2 days, and then declined, dropping at a slowly decreasing rate (6 lb per day at first, 1 lb per day at the end of the test) to 20 pounds, when the last record was made. The casing leaked throughout the last part of the test, but the decline in pressure was believed to be the result of a rise in fluid level in the hole, which shut off the producing sandstone.

One of the gas samples was analyzed by the National Bureau of Standards, using a mass spectrometer. (See following table.)

Analysis of gas from Umiat test well 2

[Analysis by Natl. Bur. Standards]

Component	*Mole percent*
Methane	82.0
Ethane	2.3
Propane	.6
Carbon dioxide	1.7
Toluene	.2
C_7 cycloparaffins	2.1
Heptanes	4.0
Xylenes	.1
C_8 cycloparaffins	1.7
Octanes	5.3

Two samples of water from the hole were analyzed by the U. S. Bureau of Mines. The first was taken during the first formation test, when the hole was 345 feet deep; the second was taken with the fluid level at 730 feet, after the hole was completed, as described above. Although the second sample contained more salts than the first (see following table), neither approached the salt content (35,000 ppm) of normal sea water.

Analyses of water from Umiat test well 2 in parts per million (milligrams per liter)

[Analysis by U. S. Bur. Mines]

Radical	Sample from 345 feet	Sample from 730 feet
Ca^{++}	243	64
Mg^{+}	1	13
Na^{+}	244	1,022
OH^{-}	223	0
CO_3^{--}	142	27
HCO_3^{-}	0	865
SO_4^{--}	5	21
Cl^{-}	173	1,176
Total solids	1,031	3,188

LOGISTICS

Information on logistics presented here for Umiat test well 2 was furnished by Arctic Contractors.

Permanent personnel.—The supervisory staff was composed of a drilling foreman, petroleum engineer, and geologist. The rig crew consisted of 2 drillers, 2 derrickmen, 6 floormen, 1 heavy-duty-equipment mechanic, and 1 welder-mechanic. A carpenter, 1 oiler, 1 timekeeper-clerk, 2 cooks, and 1 cook's helper were also employed.

Temporary personnel.—The following temporary workers were employed at the rig at different times: 4 rigbuilders, a cable-tool driller and helper, 5 carpenters, a Schlumberger engineer, the chief petroleum engineer, an extra laborer, an extra tractor operator, and 2 men who helped make the well-velocity survey.

Housing.—Besides the rig, the camp at the site was made up of 11 jamesway huts and 3 wanigans (small 1-room building generally mounted on runners or skids to facilitate moving.) Seven of the jamesway huts housed 4 men each; 3, set up end to end, made up the galley and mess, and 1 housed galley stores. One wanigan, serving as the store and hospital, was able to house the hospital corpsman and 1 or 2 patients; 1 was used as an office, which contained radio equipment as well; the third, made of celotex and wood and mounted on Micheler go-devil-type sled, was a combined laboratory and sleeping quarters for the geologist.

Vehicles and heavy equipment.—Men and materials were transported by a D8 Caterpillar tractor, a 1½-ton 4 by 4 truck, two weasels (military, fully tracked, amphibious vehicles), a jeep, and a T–9 crane (cherry-picker). Besides these, a Model 25 Northwest crane, a D8 Caterpillar tractor with carryall, and an Athey wagon were brought from Umiat when needed.

The drilling equipment used by Arctic Contractors is given below.

1	Ideco 122-ft steel derrick with 7 ft 3-in. derrick substructure.
1	National 50 drawworks.
2	Caterpillar D13000 diesel engines.
1	Ideco 200-ton crown block.
1	Emsco 4-sheave traveling block, type NC–36.
1	Emsco swivel, type AB–6.
1	Ideal 17½-in. rotary table.
1	Byron-Jackson 125-ton hook.
1	Gardner-Denver 5- by 10-inch pump.
2	Gardner-Denver 7¼- by 10-in. pumps.
1	Gardner-Denver 4- by 5-in. pump.
1	Chrysler industrial engine.
1	Broderick 75 hp boiler.
1	Oilwell 6- by 4- by 6-in. boiler-feed pump.
1	Link-Belt 48- by 60-in. mud screen.
1	Baash-Ross 4½-in. by 45-ft hexagonal kelly.
1	Baash-Ross 3½-in. by 33-ft square kelly.
1	General Electric 25-kw-generating light plant.

1 O'Keefe-Merritt 15-kw-generating light plant (spare).
1 Schramm air compressor, 210 CFM, model 428.
1 Bolted steel 250-bbl water tank.
1 Welded steel 2,500-bbl water tank.
1 Shaffer 11¾-in. double cellar control gate blowout preventer.
2 Shaffer 18⅝-in. single type gate blowout preventers.
1 International cementing unit.

Fuel, lubricant, and water consumption.—Diesel fuel and 80-octane gasoline consumption were 87,713 and 5,768 gallons, respectively. Lubricating compounds used totaled 1,295 gallons of No. 20 lubricating oil, 413 gallons of No. 90 gear oil, and 419 pounds of No. 00 grease. Water was pumped from a nearby lake to the righouse through a 2-inch pipe supported by halves of steel oil drums. In November and December oil was burned in the drum halves to prevent icing in the pipe. The average water consumption was about 5,000 gallons per day.

DRILLING OPERATIONS

An area of tundra 200 feet long and 100 feet wide was covered with a 3-foot layer of river gravel for a campsite. This made a satisfactory, although rather small, surface for the camp which was connected with the camp at the Umiat airfield by a gravel road.

For the rig foundation, an area 60 by 120 feet was cleared of a 3-foot layer of frozen tundra and soil to the frozen gravel below, and a 3-foot-thick concrete foundation for the derrick corners was poured on the gravel. The concrete under the rotary table and the pipe rack was 2 feet thick. Gravel was then filled in around the foundation, and under the derrick floor and engine substructure was a 6-inch concrete apron. Marston landing mat was used as reinforcing material.

The derrick was covered with a single thickness of canvas, on a wood frame constructed of 2 by 4's. The covering was made at the camp, and sections were numbered for reuse. The rest of the rig, except for the cementing unit, welding machine, and Schlumberger truck, was enclosed with plywood or canvas as shown in plate 7*B*.

DRILLING NOTES

The drilling operations and other data included below were reported by William C. Fackler, petroleum engineer for Arctic Contractors.

Notes from drill records

Depth (feet)	*Remarks*
126	Cemented 103 ft of 16-in. Western Pipe and Steel welded slip-joint casing, with a Baker cement guide shoe at 103.25 ft, using 115 sacks of cement mixed with water at a temperature of 150°F. Wooden plug pumped to bottom, and pressure maintained 8 hr. Top of cement found at 98 ft, cleaned out to 126 ft.
217	Casing slipped 2 ft down hole; was pulled up into place and recemented with 50 sacks of Superior portland cement mixed with 100 lb of calcium chloride in water heated to 150°F. Drill pipe lowered in hole; no cement found in casing; plug placed below shoe, and casing recemented, using 50 sacks Superior portland cement mixed with water at 150°F, which had 100 lb of calcium chloride dissolved in it. Top of cement found at 70 ft. Steam circulated to set cement.
850	Packer and 50 ft of 2½-in. anchor pipe were knocked off tubing during bailing test; fish recovered without difficulty.
1,045	Set 11¾-in. casing at 1,005 ft and cemented it with 250 sacks of Superior portland cement. Top plug pumped down and 300 lb pressure maintained on it for 12 hr. Casing then steamed through open-end drill pipe for 13 hr. The 16-in. blowout preventers replaced by 11¾-in. preventers, and cement placed between 16- and 11¾-in. casings in cellar. Casing tested with 500 lb pressure; Top of plug at 996 ft; drilled out with fresh water.
2,791	Drill pipe washed out at tool joint; fish consisted of 1,607 ft of drill pipe and collars, with top of fish, a tool joint box, at 1,184 ft. Fish recovered with Bowen 300 series overshot.
3,443	Corrected depth 3,441 ft.
3,980.5	Changed from 4½-in. to 3½-in. Hydril drill pipe, because of excessive wear on tool joints; 4½-in. rams on blowout preventers replaced by 3½-in. rams. Installed new 1-in. drilling line, and replaced 3-sheave traveling block with 4-sheave block.
4,220	Mud circulated, and drill pipe rotated to enlarge tight spots in hole at 4,000–4,010 ft and 4,419 ft. Trouble apparently caused by mud pumps which were inadequate to remove cuttings at rate of penetration achieved.

Notes from drill records—Continued

Depth (feet)	*Remarks*
4,232	Replaced 7¾-in. drill collars with 5¾-in. drill collars, to decrease weight on bit and slow rotary table, so that pumps could remove cuttings at rate drilled. Ball-peen hammer dropped in hole, and hole deepened to 4,235.5 ft, during two unsuccessful attempts to recover hammer with Globe junk basket. Hammer left in hole, and caused no further difficulty.
4,421	About 300 cu ft of mud removed, and replaced with Aquagel and water, to reduce mud weight. Excessive weight caused by fine silt which would not settle out.
4,443	Tested blowout preventers with 500 lb of pressure and found satisfactory.
4,454	Leveled derrick by jacking up low corners of both derrick and rotary table support with a hydraulic jack, and inserting steel plate shims until all the corners were level with the highest one. Drill pipe in hole was supported by rotary table while derrick was leveled; it was hung in elevators, and hence supported by derrick when rotary table support was leveled. Lowest corner of derrick, which had settled 1⅜ in., was that nearest mud pits; circulation from pits possibly thawed some of frozen gravel on which concrete foundation was poured.
4,507	Crown block moved to compensate for leveling of derrick.
4,595	Removed more drilling mud and replaced with Aquagel and water, to reduce weight.
4,705	Schlumberger instrument run once, and long normal curve recorded, but it was impossible to get instrument past bridge at 1,936 ft to record other curves; they were recorded later on final run.
5,468	Operations discontinued for several hours waiting for good weather for parts for a washed-out swivel to be flown in from Barrow.
5,709	Drill-pipe joints so worn that they measured less than 4.4 in. in outer diameter were discarded as unsafe. Total of 47 joints, about 38 percent of those in use, were replaced. Fine abrasive silt that would not settle out of the drilling mud was judged to be source of wear.
6,014	Rice put in drilling mud to determine rate of circulation; noted in returning mud 10 hr after added. Lubricating oil added for same purpose took 5 hr and 20 min; third check, using cellophane scraps, got same result.

Notes from drill records—Continued

Depth (feet)	*Remarks*
6,212	Mud pumps were inadequate to clean hole, and it was necessary to ream from 6,035 to 6,200 ft; rotary swivel heated excessively, and drill pipe could be rotated only in low-low gear. After rereaming from 6,080 to 6,205 ft, mud circulated in hole but took 10½ hr of alternate reaming and circulating, and 15 hr of continuous mud circulation, to get hole in satisfactory condition for running logging equipment. Schlumberger electric log run to 6,203 ft and Schlumberger temperature survey to 6,198 ft. Seismic velocity survey also run. Geophone lowered in well on Schlumberger cable, and shots set off in shotholes 44, 47, and 41 ft deep, which were 820 ft southwest of test well and 100 ft apart. Hole bailed to 950 ft; small flow of gas noted, and its pressure and volume measured for several days. (See section Oil and gas.) Mud bailed to 996 ft, and coupling put on 11¾-in. casing. An 11¾-in. to 4-in. swage nipple was put on coupling, and capped by 4-in. Cameron FlexSeal valve. Top of valve 36 inches above ground.

DRILL AND CORE BITS

Two types of core bits were used in Umiat test well 2. The first 89 cores were taken with an A–1 Universal retractable wire line core barrel and a 7⅝-inch hard-formation core head; below 3,890 feet, following the change to 3½-inch drill pipe, a Hughes type "J" conventional core barrel with a 6⅛-inch hard-formation core head was used. Of the 658 feet cored with the A–1 Universal barrel, 77.5 percent was recovered; 156 feet of core was taken with the Hughes tools, and 74.5 percent was recovered.

Several types and sizes of drilling bits were used, from the 20-inch Reed Pilot Reamer to the 9⅞-inch Hughes OSQ–3A rock bit. The Hughes W7 10⅝-inch rock bit and the Reed T 9⅞-inch rock bit were the types most often employed; a total of 50 bits were used. The graphic log (pl. 11) gives the footages drilled by each bit. On the graphic log, some abrupt increases in the rate of penetration below 2,500 feet are close to, but not coincident with, the cored intervals. The offset is the probable result of slight differences in the depth measurements, and the slow drilling rate should actually be associated with the coring.

DRILLING MUD

The drilling mud was a mixture of Aquagel and water, only minor amounts of other material being added. Lost circulation in the surface gravels necessitated the addition of 17 sacks of Fibrotex and 14 sacks of Gel-flake; Smentox was added after casing was cemented to remove the cement contamination. The mud tended to increase in viscosity and weight with depth and was controlled by the addition of water and small amounts of Aquagel when necessary. The viscosity was kept as low as possible, to facilitate settling of fine abrasive particles. Mud characteristics and additives are shown in the table below.

Drilling-mud characteristics and additives, Umiat test well 2

Depth (feet)	Weight (lb cu ft)	Viscosity (Mfs [1])	Water loss (cc per (30 min)	Additives
0				25 sacks Aquagel, 13 sacks Gelflake, 12 sacks Fibrotex.
38				21 sacks Aquagel, 1 sack Gelflake, 3 sacks Fibrotex.
75				65 sacks Aquagel, 2 sacks Fibrotex.
225				23 sacks Aquagel.
392				5 sacks Aquagel.
444				7 sacks Aquagel, 3 sacks Smentox.
[2] 475	70.5	33.0		3 sacks Aquagel.
499	72.0	34.0		2 sacks Aquagel.
530	72.0	35.5		
541	62.0	40.0		
544	73.5	33.0		
560	70.0	38.0	17.0	
582	72.0	32.5		
602	73.5	34.0		
608	75.0	40.0		
630	75.5	37.5		
648	72.7	36.0		
677	75.2	35.6		
690	76.3	33.0		
710	76.5	36.0		
730	76.3	34.7		
750	77.0	34.7		
760	77.2	34.4		
785	78.3	34.7		
811	77.8	34.0		
822	79.0	36.0		
[3] 781	77.5	33.5		10 sacks Aquagel.
[3] 822	79.0	34.7		
840	79.0	34.3		
845	78.7	34.7		6 sacks Aquagel.
863	76.5	32.7		10 sacks Aquagel.
884	77.0	33.7		9 sacks Aquagel.
904	79.0	35.3		
934	78.0	35.5	7.0	
971	77.5	35.0	7.5	14 sacks Aquagel.
998	76.0	35.0	7.0	5 sacks Aquagel.
998	77.5	36.0	6.5	4 sacks Aquagel, 2 sacks Micatex, 3 sacks Smentox.
1,015	78.5	37.0	6.25	2 sacks Aquagel, 3 sacks Smentox.
1,045	78.5	38.5	6.5	
[4] 1,045	77.0	37.0	7.0	
1,066	69.0	38.0	[5] 40.0	45 sacks Baroid, 3 sacks Smentox.
1,219	73.0	38.0	16.0	1 sack Baroid, 2 sacks Smentox.
1,429	73.0	38.0	13.0	3 sacks Smentox.
1,547	76.0	37.0	9.5	
1,652	77.0	36.0	9.0	
1,796	77.0	38.0	9.0	
1,875	79.5	38.0	7.0	
1,981	79.0	38.0	7.0	
2,180	77.0	35.0	7.0	
2,273	77.0	35.0	7.0	
2,418	77.0	35.0	6.0	
2,511	77.0	35.0	6.0	
2,596	77.0	35.0	6.5	
2,791	78.0	35.0	8.0	
2,880	77.5	35.0	8.0	
2,982	75.0	34.0		4 sacks Aquagel.
3,007	75.0	34.0	8.0	5 sacks Aquagel.
3,149	75.0	34.0	8.0	
3,267	73.0	33.0	8.5	

Drilling-mud characteristics and additives, Umiat test well 2—Continued

Depth (feet)	Weight (lb cu ft)	Viscosity (Mfs [1])	Water loss (cc per (30 min)	Additives
3,319	76.0	34.0	8.5	9 sacks Aquagel, 2 sacks Smentox.
3,409	79.0	36.0	8.0	
3,529	78.0	35.0	7.5	
3,606	78.5	35.5	7.0	
3,626	78.5	36.0	7.0	
3,694	78.5	35.0	7.5	3 sacks Aquagel.
3,737	78.0	35.0	8.0	
3,750	79.0	35.0	7.0	
3,829	79.5	35.0	8.0	
3,902	80.0	35.0	8.0	
3,951	79.0	34.0	8.5	2 sacks Aquagel.
3,980	76.0	34.0	9.0	2 sacks Aquagel.
4,026	75.0	35.0	9.0	
4,058	76.0	36.0	9.0	
4,087	77.0	37.0	9.0	
4,143	77.0	36.0	10.0	
4,220	78.0	36.0	9.0	
4,232	79.0	38.0	6.0	
4,233	79.0	39.5	7.0	
4,235	79.0	37.0	8.0	2 sacks Aquagel.
4,265	79.5	39.0	8.0	
4,286	79.0	37.0	8.0	
4,324	79.0	38.0	8.0	
4,349	79.0	37.5	8.0	
4,380	80.0	37.5	8.0	
4,421	81.0	36.0	8.0	3 sacks Aquagel.
4,432	81.0	37.0	7.5	
4,443	80.0	37.5	8.0	
4,454	80.0	36.3	8.0	
4,475	80.0	35.5	8.0	
4,507	80.5	36.0	8.0	
4,545	80.8	37.0	8.0	
4,595	81.5	37.6	7.0	3 sacks Aquagel.
4,611	82.0	39.0	7.0	
4,635	82.0	38.7	8.0	
4,686	83.0	38.0	6.7	
4,729	83.0	37.5	7.3	
4,767	83.0	37.5	7.0	
4,787	83.6	37.3	7.0	
4,800	83.5	38.8	7.0	
4,849	83.0	37.0	7.0	
4,894	83.5	38.0	7.0	
4,915	83.5	37.5	7.0	
4,967	84.0	38.0	7.0	
4,985	83.5	39.0	6.0	3 sacks Aquagel.
5,012	83.25	37.8	8.2	
5,062	83.1	37.5	8.3	
5,100	83.25	37.5	7.9	
5,119	82.0	38.1	8.0	
5,168	83.4	37.3	8.4	2 sacks Aquagel.
5,189	83.5	37.3	8.5	
5,211	84.5	38.0	8.0	
5,248	84.5	37.6	7.9	
5,278	84.5	37.9	8.0	
5,322	84.0	37.8	7.8	
5,377	84.4	37.9	7.9	
5,393	83.8	38.4	8.0	3 sacks Aquagel.
5,431	84.0	37.6	7.5	
5,468	84.0	38.0	6.5	
5,482	85.0	39.7	7.0	
5,536	84.75	38.9	7.25	
5,595	85.5	39.0	8.25	
5,689	85.0	38.7	7.6	
5,709	84.7	38.0	7.5	
5,753	84.9	39.4	8.0	
5,785	84.7	38.8	7.7	
5,795	84.5	38.8	8.0	
5,841	84.3	38.5	7.5	
5,883	84.5	38.9	7.5	
5,894	84.5	39.1	7.5	
5,905	84.6	39.0	7.6	
5,947	84.6	38.8	6.8	
5,972	84.5	38.8	7.7	
6,017	84.5	38.8	7.3	
6,052	85.6	39.6	6.8	
6,072	85.5	40.8	6.5	
6,104	85.0	39.5	7.5	
6,153	85.0	39.9	7.0	
6,185	84.7	39.8	8.0	
6,200	85.0	41.0	6.6	
6,212	85.0	40.6	7.5	
[4] 6,212	85.0	39.1	8.0	

[1] Marsh funnel seconds.
[2] No data on mud characteristics were recorded above 440 feet.
[3] Reaming.
[4] After running Schlumberger.
[5] Probably caused by cement contamination.

HOLE-DEVIATION RECORD

Deviation measurements were taken with the Totco; no directional surveys were made, as the deviation of the hole never exceeded 2°45′. Between 100 and 500 feet the deviation was 1° or less; between 700 and 1,200 feet it averaged slightly more than 2°; below 1,200 feet it was generally under 1° and never exceeded 1°15′ (pl. 11).

ELECTRIC LOGGING

Electric well logs were made with the Schlumberger well-logging truck at the rig site. Seven runs were made, with no difficulties except on the sixth, when only one trip of the instrument was possible because of a bridge which blocked the hole after the run was made. The long normal curve, made on that run, showed no indications of oil or gas; so the other curves were logged on the seventh run. Runs 1–7 covered footages as follows: Run 1, 103–751 feet; run 2, 751–1,006 feet; run 3, 1,005–1,700 feet; run 4, 1,700–2,999 feet; run 5, 2,999–3,737 feet; run 6, 3,737–4,684 feet; run 7, 4,684–6,203 feet.

VELOCITY SURVEY

A velocity survey of Umiat test well 2 was made using three shot holes. They were 41, 44, and 47 feet deep and penetrated 25, 28, and 31 feet of gravel, respectively; the upper part of the gravel contains a few feet of silty clay and is underlain by shale of Cretaceous age. The holes were 820 feet S. 59°16′ W., S. 66°16′ W., and S. 73°16′ W., respectively, from the test well and 100 feet apart. None were cased. The records obtained were good and showed a slight decrease in velocity with depth, which is unusual. The velocity decreased rapidly from about 12,000 feet per second to a little more than 11,000 feet per second in the first thousand feet; below that depth it fluctuated somewhat but averaged slightly less than 11,000 feet per second in the lower part of the hole.

TEMPERATURE SURVEY

A Schlumberger temperature survey was run when the final electric log was made. The lowest temperature recorded was 40.5°F at 260 feet. Above that depth the temperature was about 42°F; it fluctuated slightly above and below 43°F between 310 and 525 feet; and then, except for a regression of 1° at 850 feet, it rose gradually to 104°F at 6,198 feet, the lowest depth reached by the instrument.

UMIAT TEST WELL 3

Location: Lat 69°23′16″ N., long 152°05′14″ W.
Elevation: Ground, 351 feet; kelly bushing, 360 feet.
Spudded: November 15, 1946.
Completed: December 26, 1946. Pumped 24 barrels of oil per day; abandoned.
Retested: October 1, 1947, to November 15, 1947.
Total depth: 572 feet.

Umiat test well 3, originally described as Umiat core test 1, was drilled to determine the stratigraphic position of a tentative location for Umiat test well 2 and to test some of the oil-bearing zones penetrated in drilling Umiat test well 1, if possible. The well is located on the Colville River flats at the northeast corner of Umiat Lake and is about one-fourth mile north toward the axis of the anticline, from Umiat test well 2. When the total depth of the well was reached, bailing tests produced oil at a rate of 50 barrels per day; but 9 months later, after being cleaned out and shot, only 24 barrels of oil per day was recovered.

DESCRIPTION OF CORES AND CUTTINGS

No samples were taken from the upper 60 feet of the hole; between 60 and 225 feet the Killik tongue of the Chandler formation is represented by alternating clay shale and sandstone, with common clay ironstone in the upper part. The electric log through this section suggests that a larger proportion of clay shale is present than the samples indicate. The log is probably more reliable, as the ditch samples may be contaminated with sand drilled higher in the hole. A small amount of the oil produced came from this formation.

Below 225 feet the drill penetrated 150 feet of sandstone with thin beds of shale, underlain by about 170 feet of clay shale with thin sandstone and siltstone beds, all in the Grandstand formation. The sandstone beds are believed to be the primary source of the oil recovered from the hole.

Lithologic description

[Where no cores are listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
-----	0–9	Kelly bushing to ground level.
-----	9–60	No sample.
-----	60–100	Clay shale, medium-dark-gray, very slightly silty and micaceous, noncalcareous; yellowish-gray clay ironstone, slightly calcareous in part, increases from rare at 60 ft to half of the rock at 100 ft.
-----	100–140	Sandstone, medium-light-gray, fine-grained, silty, sericitic, noncalcareous; composed of angular to subangular grains of clear and white quartz with dark rock fragments and carbonaceous particles, becoming very fine grained and sericitic in part at base. Clay shale rare throughout.
-----	140–150	Clay shale, medium-dark- to dark-gray, slightly to very silty with some sandstone and medium-gray argillaceous noncalcareous siltstone.
-----	150–160	Clay shale and siltstone, with rare sandstone.
-----	160–180	Clay shale, slightly to very silty, with rare sandstone and siltstone.
-----	180–210	Sandstone, medium-light-gray, very fine-grained, silty, noncalcareous, with small amount of siltstone in upper 10 ft; rare clay shale throughout.
-----	210–225	Sandstone, very fine-grained; sericitic in part; small amount clay shale.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	225–236	Clay shale and some sandstone. Top of Grandstand formation at 225 ft.
1	236–245	Recovered 1 ft 6 in.: Microfossils absent. Clay shale, medium-dark-gray, rarely slightly silty, noncalcareous; very slightly micaceous in part. Beds approximately flat lying.
2	245–249	Recovered 4 ft: Microfossils rare. 3 ft, clay shale, medium-dark-gray, partly silty, noncalcareous, with abundant irregular laminae of siltstone and sandstone in upper foot. Beds lie approximately flat. 2 in., coal, black, shiny to dull; blocky to shaly fracture. 10 in., sandstone, light-brownish-gray, fine-grained, very slightly silty, noncalcareous, moderately hard, massive; composed of subangular to subround grains of clear quartz with some white quartz, da k rock fragments, and abundant carbonaceous particles.
3	249–257	Recovered 4 ft: Not sampled for microfossils. Sandstone as above, friable.
4	257–262	Recovered 4 ft: Not sampled for microfossils. Sandstone, medium-light-gray, fine-grained, slightly silty, noncalcareous; composition as in core 2.
5	262–272	Recovered 1 ft: Not sampled for microfossils. Sandstone as above, very fine- to fine-grained; carbonaceous laminae in upper few inches dip 7°.
6	272–281	Recovered 7 ft 6 in.: Not sampled for microfossils. Sandstone, medium-light-gray, fine-grained, slightly silty, micaceous, noncalcareous; massive except for rare faint slightly carbonaceous laminae, dipping 7°, in upper 1 ft.
7	281–286	Recovered 5 ft: Not sampled for microfossils. Sandstone as above.
8	286–294	Recovered 3 ft 6 in.: Not sampled for microfossils. Sandstone as above.
9	294–303	Recovered 2 ft 6 in.: Not sampled for microfossils. 1 ft, drilling mud, with fragments of clay shale, medium-dark-gray, slightly silty and micaceous, noncalcareous. 1 ft, sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous. 6 in., drilling mud with fragments of clay shale and very fine-grained sandstone.
10	303–312	Recovered 1 ft: Not sampled for microfossils. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, massive.
11	312–320	Recovered 4 ft 6 in.: Not sampled for microfossils. 3 ft, drilling mud with fragments of medium-dark-gray slightly silty clay shale and very fine-grained sandstone. A 1-inch nodule of pyrite at top of core. 1 ft. 6 in., sandstone, as in core 10 above.
12	320–328	Recovered 2 ft: Microfossils common. Interbedded siltstone, medium-gray, very argillaceous, noncalcareous, and medium-dark-gray clay shale, slightly to very silty.
13	328–335	Recovered 5 ft: Microfossils rare. 1 ft 6 in., claystone, medium-dark-gray, slightly silty, noncalcareous, with rare nodules of brownish-gray clay ironstone. A few streaks of light-gray sandstone at base. 1 ft 6 in., sandstone, medium-gray, fine-grained, very argillaceous, noncalcareous, massive; composed of subrounded grains of clear quartz, gray chert, and dark rock fragments. Small slickensided surfaces are horizontal. 2 ft, interbedded and interlaminated medium-dark-gray slightly to very silty claystone and medium-gray slightly to very argillaceous, rarely sandy siltstone. Carbonaceous plant fragments rare.
14	335–344	Recovered 4 ft: Not sampled for microfossils. Drilling mud with fragments of medium-dark-gray claystone and very small fragments of fine-grained sandstone.
15	344–352	Recovered 8 ft: Not sampled for microfossils. 2 ft 3 in., irregularly interbedded and interlaminated fine-grained light-gray sandstone and medium-gray siltstone with silty clay shale, showing "swirly" bedding. Irregular carbonaceous and micaceous partings common. 2 ft, claystone, with rare minute irregular lenses of siltstone and sandstone dipping about 5°. Grades to clay shale, with good shaly cleavage dipping 7°. 3 ft 9 in., sandstone, medium-light-gray, medium-grained, very slightly silty, noncalcareous, massive; composed of subrounded grains of clear and white quartz, some gray chert, and common carbonaceous particles.
16	352–359	Recovered 6 ft 6 in: Not sampled for microfossils. Sandstone as at base of core 15, fine-grained; rare laminae of carbonaceous material in upper part dip as much as 15°.
17	359–368	Recovered 9 ft: Microfossils common. 3 ft, sandstone as in core 17. 1 ft 6 in., drilling mud with fragments dark-gray clay shale, and a 1-in. nodule of olive-gray clay ironstone. 4 ft 6 in., clay shale, medium-dark-gray, slightly micaceous, noncalcareous, with rare faint slightly silty laminae dipping 9°.
18	368–377	Recovered 6 ft: Not sampled for microfossils. Clay shale, medium-dark-gray, noncalcareous; slightly to very silty in part; small irregular laminae and lenses of siltstone and very fine-grained sandstone make up about half the rock in upper 2 ft, decreasing to very rare with depth. Siltstone and sandstone in lower part of core are in laminae instead of irregular lenses; laminae dip about 10°.
19	377–385	Recovered 3 ft: Not sampled for microfossils. 1 ft, sandstone, medium-light-gray, fine-grained. 2 ft, clay shale with common small irregular lenses of siltstone and sandstone as in top of core 18.
20	385–393	Recovered 4 ft: Not sampled for microfossils. 1 ft, fragments of sandstone, medium-light-gray, fine-grained, silty, argillaceous, noncalcareous. 1 ft, drilling mud with fragments of medium-dark-gray clay shale. 2 ft, interbedded clay shale, medium-dark-gray, noncalcareous; slightly silty in part; and medium-light-gray very fine-grained very silty and argillaceous, noncalcareous sandstone, with rare carbonaceous partings.

Lithologic description—Continued

Core	Depth (feet)	Remarks
21	393–402	Recovered 1 ft 6 in.: Not sampled for microfossils. Drilling mud with fragments of medium-dark-gray clay shale.
22	402–411	Recovered 4 ft 6 in.: Microfossils absent. 2 ft 3 in., sandstone, medium-light-gray, fine-grained, grading to very fine with depth, silty, sericitic, moderately calcareous; carbonaceous and argillaceous partings rare at top, common at base, and dip 5° to 10°. 2 ft 3 in., siltstone, medium-gray, very argillaceous, with abundant thin beds and laminae of medium-dark-gray clay shale; some sandstone laminae.
23	411–419	Recovered 6 ft: Not sampled for microfossils. 4 in., siltstone, medium-gray, very argillaceous, moderately calcareous, massive, grading to unit below. 2 ft, claystone, medium-dark-gray, very slightly calcareous, micaceous. 8 in., claystone as above and interbedded very fine-grained medium-light-gray moderately calcareous sandstone, with "swirly bedding." 3 ft, claystone, medium-dark-gray, partly silty, slightly calcareous, slightly micaceous, with blocky fracture.
24	419–429	Recovered 4 ft: Microfossils absent. Drilling mud, with fragments of medium-dark-gray claystone, micaceous, noncalcareous; slightly silty in part.
25	429–439	Recovered 4 ft: Microfossils common. 3 ft 6 in., drilling mud with claystone as above. 6 in., siltstone, medium-gray, argillaceous, moderately calcareous, with irregular lenses of clay shale in upper 2 in.
26	439–445	Recovered 6 ft: Microfossils absent. Clay shale, medium-dark-gray; slightly to very silty in part; laminae and thin beds (less than 2 in.,) of medium-gray very argillaceous slightly calcareous siltstone, commonly slightly crossbedded; poor shaly cleavage dips less than 7°.
27	445–454	Recovered 9 ft: Microfossils common. Clay shale, medium-dark-gray, noncalcareous, slightly micaceous; slightly silty in part; laminae of slightly calcareous medium-gray siltstone in upper half and common laminae and thin beds (as much as 3 in.) of medium-gray slightly calcareous, slightly sandy siltstone in lower part. Siltstone commonly crossbedded. Shaly cleavage dips less than 7°.
28	454–463	Recovered 6 in.: Microfossils absent. 2 in., sandstone, medium-light-gray, very fine-grained, very argillaceous and silty. 4 in., claystone, medium-dark-gray, noncalcareous, with moderately calcareous slightly silty laminae.

Lithologic description—Continued

Core	Depth (feet)	Remarks
29	463–472	Recovered 7 ft: Microfossils common. 6 ft 4 in., clay shale, like claystone in core 27 but with fair shaly cleavage dipping less than 5°. A 5-in. bed of very argillaceous medium-gray siltstone at 466 ft. 8 in., siltstone, medium-gray, argillaceous, slightly sandy, moderately calcareous, massive.
30	472–478	Recovered 4 ft 6 in.: Microfossils abundant. Fragments of medium-dark-gray claystone, very slightly silty in part, noncalcareous, with drilling mud.
-----	478–481	No sample.
31	481–490	Recovered 8 ft: Microfossils very rare. Claystone, with intermingled streaks, beds, and very irregular lenses of siltstone and very silty claystone. Minute fragments of clay shale (less than 1/16-in. thick and 1/4-in. long) with a coating of sand grains, and small nodules of brownish-gray clay ironstone rare. One nodule broken and crack filled with silt.
32	490–498	Recovered 4 ft 6 in.: Microfossils common. Claystone, medium-dark-gray; slightly silty in part; irregular laminae and small lenses of siltstone as above.
33	498–507	Recovered 6 in.: Not sampled for microfossils. Fragments of sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, with carbonaceous particles.
34	507–514	Recovered 1 ft 6 in.: Not sampled for microfossils. Siltstone, medium-gray, slightly sandy, very argillaceous, noncalcareous, with some carbonaceous particles.
35	514–520	Recovered 3 ft: Microfossils rare. Claystone, medium-dark-gray, noncalcareous; slightly silty in part. *Ditrupa* sp. at 515 ft.
36	520–529	Recovered 9 ft: Microfossils abundant. Claystone as above.
37	529–538	Recovered 9 ft: Microfossils abundant. Claystone as above.
38	538–547	Recovered 9 ft: Microfossils abundant. Claystone, medium-dark-gray, slightly to very silty, micaceous, noncalcareous, with rare small carbonaceous plant fragments.
39	547–555	No recovery.
40	555–563	Recovered 8 ft: Microfossils abundant. Clay shale, medium-dark-gray, noncalcareous, slightly to very silty; very poor shaly cleavage suggests a dip as much as 5°.
41	563–572	Recovered 8 ft: Microfossils abundant. Clay shale, medium-dark-gray, noncalcareous; slightly silty in part; slightly micaceous; poor shaly cleavage dipping less than 5°.

CORE ANALYSES

The data on porosity and permeability and on sieve analyses were determined by the Fairbanks laboratory of the U. S. Geological Survey.

Analyses of core samples from Umiat test well 3 made by the Fairbanks laboratory

Depth (feet)	Effective porosity (percent, Washburn-Bunting porosimeter)	Air permeability (millidarcys, Hayward permeameter)	Content of carbonate minerals (percent by weight)
257	16.5	165.0	0.4
259	13.6	47.0	4.9
261	12.4	57.0	5.4
273	8.5	<10	5.9
276	9.5	<10	7.6
278	8.1	<10	9.6
280	9.7	<10	7.1
282	7.1	<10	5.1
284	8.8	<10	15.9
286	8.8	<10	11.4
288	7.0	<10	13.2
291	8.0	<10	14.8
297	7.3	<10	13.9
299	7.3	<10	14.8
344	17.0	480.0	3.0
350	14.7	70.0	3.0
352	16.6	188.0	7.4
355	16.5	80.0	8.1
357	14.2	7.4	6.2
359	13.2	11.0	11.6
361	15.4	42.0	3.3

Additional porosity and permeability information is supplied by P. D. Krynine in the following table.

Analyses of core samples from Umiat test well 3

[Analysis by P. D. Krynine]

Depth (feet)	Porosity (percent)	Permeability (millidarcys)				
		Air	Klinkenberg [1]	Klinkenberg [2]	Brine	Fresh water
251	16.2	97.0	91.3	93.4	70.0	55.2
257		155.0				
259		48.5				
261		61.5				
265	4.0	64.0				
344	18.2	465.0	390	333	295	200
352	17.6		138	117	56.5	37.5
355		90.0				
359	13.9	13.0	10.0	10.9	5.2	4.02

[1] Before liquid flow. [2] After liquid flow.

Sieve analyses of sandstones from Umiat test well 3

Depth (feet)	Sand grain size, Wentworth scale (percent)						
	35 mesh (coarse)	60 mesh (medium)	120 mesh (fine)	230 mesh (very fine)	325 mesh (silt)	<325 mesh (clay)	Total
258	Trace	1.81	66.20	10.71	2.33	18.95	100.00
259		4.95	56.8	14.9	23.3		99.95
274		.02	46.00	18.05	3.00	33.08	100.15
278			29.0	29.5	41.3		99.8
282		Trace	49.0	20.8	3.91	26.8	100.51
288			32.2	29.7	38.3		100.2
290		0.01	38.60	24.00	7.30	29.94	99.85
357		2.0	29.0	35.3	34.5		100.8

PETROGRAPHIC ANALYSES

A detailed petrographic study of thin sections from three cores from Umiat test well 3 made by Paul D. Krynine (*in* Payne and others, 1951) is summarized below and in the following table.

The graywacke sandstone from 344 feet consists of poorly oriented grains of several rocks and minerals, with the matrix evenly distributed between them and with scattered thin overgrowths of secondary quartz coating and cementing some of the grains. Quartz, the main constituent (see table below on petrographic characteristics), is mostly of intrusive igneous origin, though much of it may have been through another sedimentary cycle before deposition in its present position. Between 10 and 20 percent of the quartz is derived directly from the aureole of a batholith, coming from pegmatites and veins, and from schists that were permeated with quartz-bearing magmatic liquids. Both metamorphic quartz and volcanic quartz are very rare, and very few quartz grains show strain shadows. The grains are generally subangular to angular and subequant to subelongated. They are 0.18–0.19 millimeters in diameter.

Petrographic characteristics of sandstones from Umiat test well 3

[Determined by P. D. Krynine]

Characteristics	Depth		
	344 feet	352 feet	359 feet
Texture			
Average diameter range ... mm	0.50–0.30	0.08–0.25	0.04–0.20
Principal mode ... mm	0.17	0.18	0.14
Grains:matrix:cement ratio in percent	97:2:1	95:3½:1½	84:15:1
Grain composition in percent			
Quartz	62	42	40
Chert	24	35	20
Feldspar	2	1	4
Mica flakes, large	Trace	1	2
Slate, phyllite	5.5	11.5	20
Quartzite, schist	2.5		1
Volcanic rocks	0.5	1.5	Trace
Biotite	Present	Present	
Chlorite		Present	Present
Muscovite		Present	
Garnet	Present	Present	
Pyrite			Present
Interstitial material in percent			
Chlorite	Trace	Trace	2
Sericite		Trace	Trace
Illite	Trace	2–3	6
Montmorillonite		Trace	1
Kaolinite	1.5	1	2
Silica cement	1.0	0.5	Trace
Carbonates	Trace	1	
Pore space and characteristics			
Pore size, principal mode ... microns	68	50	26
Visible porosity ... percent	15	12	3
Residual porosity	Very good	Good	Poor
Bonding material	SiO_2 Illite	Illite	Illite
Clay-coated wall area ... percent	10	20	60
Wall coating ... type	Illite	Illite	Illite, kaolinite
Potential hydration	Very low	Low	High

Several types of chert are present, ranging from a very fine cryptocrystalline variety with particles 1–2 microns across, through a coarser, commonly yellowish type with grains 2–3 microns in size, to chert with particles 30 microns in diameter. The grains are equidimensional, subangular to subround, and rarely contain abundant dolomite-ankerite rhombs.

Rock fragments are a minor constituent. The metamorphic rocks include metamorphosed siltstone, light and dark slate and phyllite composed of sericite and illite, and sericite schist with muscovite, quartz, or chlorite as auxiliary minerals. All these rocks contain 20–50 percent of quartz. The metamorphic rock fragments are smaller than the quartz and chert grains, being 0.08–0.12 millimeters across; they are elongated and commonly better rounded than the quartz. Feldspar, making up 2 percent of the rock, is dominantly microcline, with some orthoclase and plagioclase. Most feldspar fragments are fresh and unaltered. Volcanic rock fragments, andesitic or rhyolitic, are very rare. Garnet, also very rare, is colorless and in some cases abnormally anisotropic.

The matrix consists of small "nests and bunches" of clay minerals, mostly kaolinite though a little authigenic illite coats and partly replaces some quartz grains. An X-ray diffraction pattern of fine material (less than 0.044 millimeter diameter, which passed the 325-mesh sieve) shows it to be made of fine quartz particles (70 percent), with small amounts of kaolinite, illite, albite, and montmorillonite.

Elongate pores 40–200 microns in diameter (visible porosity), and flattish voids and planes of discontinuity between grains (residual porosity), combine with the small amount of clay-mineral wall coating to make this a rock with very good reservoir characteristics. Swelling from hydration should be negligible, because montmorillonite is absent.

The graywacke sandstone sample from 352 feet is finer grained and contains a slightly higher percentage of matrix and cement than the one from 344 feet. It contains considerably less quartz, but more chert and a slightly larger amount of rock fragments. The grain area with illite coating is twice as great as in the upper sample. The cement includes "nests" of siderite, as well as secondary quartz. The mineral and rock grains are similar in shape and composition to those from 344 feet. The matrix is composed of fine particles of quartz and micas from metamorphic rocks, and rare montmorillonite, as well as the kaolinite and illite found at 344 feet. Clays and hydromicas make up about 3.5 percent of the rock, while the quartz, chert, and rock particles less than 50 microns in diameter total about 6.5 percent. An X-ray-diffraction pattern of the material under 0.044 millimeter in size showed it to have the same amount of quartz, but less kaolinite and more illite than the matrix from 344 feet. The pore spaces are smaller (30–65 microns across) and the total porosity is slightly less than in the upper sandstone. The very minor amount of montmorillonite present is in aggregates, which reduces its tendency to fill all pore space by swelling from hydration; this, with the comparatively high porosity, makes this a good reservoir rock.

The sample from 359 feet was not described in detail; the available data is shown in the preceding table. It is considered a poor reservoir rock.

HEAVY-MINERAL ANALYSIS

The analyst, Robert H. Morris, reported (written communication) that "samples ranging from 250 to 370 feet are assigned to the hornblende zone. Glaucophane is present in three of them." The kinds and the abundance of heavy minerals are shown on plate 10.

OIL AND GAS

OIL SHOWS

Several good shows of oil were noted in the sandstones between 248 and 380 feet, and there were some shows below that. The following shows were reported by D. W. Jopling, Arctic Contractors well geologist.

Oil shows, Umiat test well 3

Depth (feet)	*Remarks*
238–245	Strong odor of oil in the ditch.
248–320	Sandstone well saturated with oil.
348–362	Sandstone saturated with oil.
362–370	Shale with spotty oil odor.
377–380	Sandstone with some oil saturation.
402–405	Sandstone with oil odor but no visible saturation.
507–514	Sandstone, well saturated.

FORMATION TESTS

Two bailing tests were made before the rig was removed in December 1946. The first one, made when the hole was 286 feet deep, was to test an oil-bearing sandstone between 248 and 286 feet. Oil was bailed from the well at a rate of 7 gallons per hour, giving an estimated rate of 5 barrels per day. The fluid rose to 232 feet in 24 hours, and after 40 hours it reached a stationary level of 212 feet. After the total depth of 572 feet was reached, mud was bailed from the hole to a depth of 400 feet, and the well then produced 17 barrels of oil in 7 hours, with an estimated capacity of 50 barrels per day. After standing for 17 hours the top of the fluid was at 163 feet. A 24-hour bailing test produced 49 barrels of oil with a trace of drilling mud; the well was bailed continuously from the bottom of the oil-bearing sandstone during the last 14 hours of the

test, and 26 barrels of oil were produced, giving an estimated rate of 44 barrels per day.

In September 1947 a Keystone spudder was installed over the hole (see pl. 7*C*), and the fluid level was found at 145 feet, and a bridge, possibly of ice, at 240 feet. The well was cleaned out to a depth of 457 feet, using a 6-inch bit. Pumping began on October 6, 1947; 14 barrels of oil and 0.2 percent of basic sediment and water were produced in the first 1½ hours, at twenty-six 12-inch strokes per minute. Fourteen strokes per minute for the next 4 hours, and 12 per minute for the 17 hours following, produced 14 more barrels of oil, with a trace of basic sediment and water. Intermittent pumping (1 hr at 12 strokes per min and 1 hr off, alternately) produced 17.2 barrels of oil and no water on October 7. The well was then pumped intermittently, at 16 strokes per minute, for a total of 8 hours on October 8 and 7 hours on October 9, recovering 16.6 and 15 barrels of oil and no water, respectively. For the next 5 days the well was pumped intermittently for 6 hours each day, and 14, 15, 14, 15, and 13 barrels of oil and no water were recovered during that time. On October 15 continuous pumping at 12 strokes per minute was resumed, with 13.8 barrels of oil recovered in the first 24 hours, and 13 barrels per day in the next 2 days. During the pumping tests the air temperature ranged from 32° to 2°F, averaging about 20°–25° for the first 4 days and 10°–15° for the last 8 days. The temperature of the oil decreased slightly with the colder air, averaging about 25° on the first 4 days and 22°–24° on the last 8 days, with a maximum of 26° and a minimum of 20°.

After the pumping test, the hole was shot several times with 60 percent seismograph dynamite, and the hole loaded to the surface with oil before each shot. Sixty pounds of dynamite was placed between 355 and 362 feet in four 15-pound charges. After the shot, the hole was bridged at 334 feet. A second shot of five 5-pound sticks was made at 315–324 feet, and the hole was then found bridged at 314 feet. The third shot, again with five 5-pound sticks, was between 305 feet and 314 feet, and the hole was bridged at 304 feet. Shot number four, with five 5-pound sticks of dynamite placed between 294 and 304 feet did not bridge the hole. Shots 5 and 6 each used ten 5-pound sticks placed at 274 to 294 feet and 254–274 feet, respectively. The hole was then cleaned out to 457 feet with a 6-inch bit, and another pumping test was made. After recovering the load oil, 15 barrels of oil with no water was pumped in 12 hours of continuous pumping. Continuous pumping for the next 2 days recovered 24 barrels of oil the first day and 24.1 barrels the second. Pumping was discontinued for 6 days because there was no storage room in the tanks. After a burn pit was prepared, about 400 feet from the well, testing was resumed at 14 strokes per minute, and 53 barrels of oil with no water was pumped the first 23 hours after the test was started. For the next 6 days, continuous pumping at 14 strokes per minute produced 25.5, 24.1, 24.8, 24.1, 23, and 22.8 barrels of oil, and no water, in the 6 days. Engine trouble caused by cold weather resulted in 22 hours of pumping per day for the next 2 days, with a recovery of 23 and 22 barrels of oil, respectively. The test was continued 4 days more, however, with recoveries of 23.5 barrels in 24 hours, 21 barrels in 21 hours, 18 barrels in 19 hours, and 29 barrels in 24 hours. An estimated 5 barrels of the last 29 probably collected in the well during the shutdown from engine trouble the day before. The indicated capacity of the well is 24 barrels per day. The air temperature ranged from 1° to 17°F for the first part of the test and from −23° to +14°F for the last part. The oil temperature dropped gradually from 24°F to 18°F, during the test.

OIL ANALYSES

Two samples of crude oil from Umiat test well 3 were analyzed by the Petroleum Chemistry and Refining Section of the U. S. Bureau of Mines Petroleum Experiment Station at Bartlesville, Okla. A quart of oil was submitted in 1946 (sample 46164), and a gallon in March 1947 (sample 47017). Routine analyses (see p. 122) and analyses of the gasoline and diesel oil fractions (see p. 123) were made for both samples. The second sample was large enough to permit additional studies of the gasoline and diesel fractions and the residuum (see p. 123,124). Characteristics of products for the two crude oils are compared in table on p. 124.

The oil is light colored and differs from most other crude oils by having a very high naphthene and aromatic content. The naphthene content is approximately constant in the gasoline fractions, then increases rapidly, maintaining a constant high value in the higher part of the diesel fuel and in all the lubricating-oil boiling range. Paraffin content is very low. Pour points of the 2 crude oil samples are −15°F and −25°F; the pour point of the combined gasoline fractions is less than −80°F, and that for the diesel fuel cut is about −10°F. The average API gravity of the 2 samples is 36.5°, the Saybolt Universal viscosity at 100°F is 36.5 seconds, and sulfur content is less than 0.1 percent.

Analyses of U. S. Bureau of Mines crude petroleum samples 46164 and 47017 from Umiat test well 3

[General characteristics of samples follow: Sample 46164: sp gr, 0.843; sulfur, <0.1 percent; Saybolt Universal viscosity at 100°F, 37 sec; gravity, 36.4°API; pour point −15°F; color, Natl. Petroleum Assoc. no. 6. Sample 47017: sp gr, 0.842; sulfur, 0.079 percent; Saybolt Universal viscosity at 100°F, 36 sec; gravity, 36.6°API; pour point, −25°F; color, Natl. Petroleum Assoc. no. 4½]

Distillation by Bureau of Mines routine method

Fraction	Cut at—		Percent		Sum percent		Specific gravity [1]		Gravity, °API at 60°F		Correlation index		Aniline point (°C)		Saybolt Universal viscosity at—						Cloud test (°F)		Viscosity index		Index of refraction (sodium D line at 20°C)		Diesel index		Pour point (°F)	
															100°F		130°F		210°F											
	°C	°F	46164	47017	46164	47017	46164	47017	46164	47017	46164	47017	46164	47017	46164	47017	46164	47017	46164	47017	46164	47017	46164	47017	46164	47017	46164	47017	46164	47017
Stage 1.—Distillation at atmospheric pressure of sample 46164, 757 mm Hg, sample 47017, 748 mm Hg. First drop, sample 46164: 52°C (126°F); sample 47017: 62°C (144°F)																														
1	50	122																												
2	75	167	1.1	0.7	1.1	0.7																								
3	100	212	5.3	4.5	6.4	5.2	0.723	0.739	64.2	60.0																				
4	125	257	8.3	9.0	14.7	14.2	.768	.769	52.7	52.5	35	36													1.4094	1.4131				
5	150	302	7.0	7.0	21.7	21.2	.785	.788	48.8	48.1	36	37	39.0	38.7											1.4265	1.4270				
6	175	347	7.2	6.9	28.9	28.1	.799	.800	45.6	45.4	35	36													1.4324	1.4390		51.3	Below −80	Below −70
7	200	392	5.3	5.7	34.2	33.8	.811	.811	43.0	43.0	35	35													1.4400	1.4454				
8	225	437	6.1	6.5	40.3	40.3	.823	.824	40.4	40.2	35	35													1.4450	1.4506				
9	250	482	7.4	7.5	47.7	47.8	.838	.839	37.4	37.2	37	37	62.3	62.4											1.4525	1.4582				
10	275	527	10.2	10.0	57.9	57.8	.855	.858	34.0	33.4	40	41													1.4622	1.4683		50.3	−5	−15
																									1.4763	1.4768				
Stage 2.—Distillation continued at 40 mm Hg																														
11	200	392	6.4	5.1	64.3	62.9	0.873	0.869	30.6	31.3	45	43	62.3	62.4	42	42					5	15						50.3	−5	−15
12	225	437	7.1	7.8	71.4	70.7	.878	.873	29.7	30.6	43	41			48	47					20	30								
13	250	482	6.0	6.5	77.4	77.2	.884	.883	28.6	28.8	43	42			61	60	48	48	36.3	36	45	45								
14	275	527	4.7	5.2	82.1	82.4	.893	.888	27.0	27.9	44	41			83	94	59.1	60	38.1	38	55	55	63	46						
15	300	572	5.3	6.4	87.4	88.8	.899	.897	25.9	26.3	44	43			165	190	87.8	97	44.5	45	65	70	99	85						
Residuum [2]			12.4	10.8	99.8	99.6	.913	.916	23.5	23.0									102.9	110										45

[1] Specific gravity of oil at 60°F compared with water at 60°F.
[2] Carbon residue of residuum for both samples 1.7 percent; carbon residue of crude, 0.2 percent.

Approximate summary

Constituent	Percent		Specific gravity		Gravity, °API		Saybolt Universal viscosity	
	46164	47017	46164	47017	46164	47017	46164	47017
Light gasoline	6.4	5.2	0.723	0.739	64.2	60.0		
Total gasoline and naphtha	34.2	33.8	.776	.782	50.9	49.5		
Kerosene distillate	6.1	6.5	.823	.824	40.4	40.2		
Gas oil	28.6	28.1	.858	.858	33.4	33.4		
Nonviscous lubricating distillate	11.9	11.7	0.879–.894	0.875–.889	29.5–26.8	30.2–27.7	50–100	50–100
Medium lubricating distillate	6.2	6.0	.894–.901	.889–.898	26.8–25.6	27.7–26.1	100–200	100–200
Viscous lubricating distillate	.4	2.7	.901–.902	.898–.902	25.6–25.4	26.1–25.4	Above 200	Above 200
Residuum	12.4	10.8	.913	.916	23.5	23.0		
Distillation loss	.2	.4						

Hydrocarbon analyses of gasoline and diesel-oil cuts from Umiat test well 3 samples 46164 and 47017, using American Society for Testing Materials method ES–45a

[Analysis by U. S. Bur. Mines]

Composition and characteristics	Gasoline (Hempel fractions 1–7)		Diesel oil (Hempel fractions 8–12)	
	46164	47017	46164	47017
Blends				
Aromatics plus olefins	23.4	22.7	26.1	22.9
Naphthenes	43.4	44.8	73.9±10	77.1
Paraffins	33.2	32.5	.0	.0
Total	100.0	100.0	100.0	100.0
Pour point °F	Below −80	Below −70	−5	−15
Bromine No.		1.33		4.33
Olefins percent		0.84		5.14
Data on raffinate (paraffin plus naphthenes)				
Density at 20°C compared with water at 4°C	0.7520	0.7546	0.8262	0.8268
Index of refraction with sodium D line at 20°C	1.4176	1.41910	1.4541	1.4539
Average boiling point °C	136	136	262	262
Molecular weight, estimated	121	121	207	207
Molecular volume	160	160	250	250
Naphthene rings percent by weight	34.5	36.9	[1] 43.1	[1] 44.2
Paraffin and paraffin side chains percent by weight	65.5	63.1	56.9	55.8

[1] A naphthenic compound such as octylcyclohexane ($C_{14}H_{28}$) would contain 57 percent of the carbon atoms in the paraffin chain; so the analyses showing 73.9 and 77.1 percent naphthenes and 0 percent paraffins are not in conflict with the ring-chain split.

Hydrocarbon analysis of gasoline fraction of sample 47017 distilled at 150°–273°F

[Analysis by U. S. Bur. Mines]

Hydrocarbons	*Percent of crude oil*
N-hexane	0.56
Methylcyclopentane	.45
2,2- and 2,4-dimethylpentane	.20
Benzene	.26
Cyclohexane	1.51
1,1-dimethylcyclopentane	.28
2,3-dimethylpentane and 2-methylhexane	.55
Trans-1,3-dimethylcyclopentane	.42
Trans-1,2-dimethylcyclopentane	.27
3-methylhexane	.34
N-heptane	.64
Methylcyclohexane	2.56
Ethyl cyclopentane	.55
2,2-dimethylhexane	.24
2,5- and 2,4-dimethylhexane	.19
Toluene	1.67
Trimethylcyclopentanes (?) 222°–235°F	.51
2,3-dimethylhexane	.15
A trimethylcyclopentane (?) 234°–243°F	.14
Trans 1,3- and trans 1,4-dimethylcyclohexanes and other naphthenes (243°–251°F)	1.30
2-,3-, and 4-methylheptanes	.56
Ethylbenzene	.26
Trans 1,2-dimethylcyclohexane	.72
N-octane	1.04
N-Propylcyclopentane, isopropylcyclopentane and ethylcyclohexane	.99
Total	16.44

Characteristics of diesel-oil fraction of sample 47017 from Umiat test well 3

[Analysis by U. S. Bur. Mines]

Fraction	Temperature 0°F	Percent by volume		Average boiling point (°F)	Density at 20°C	Viscosity (centistokes)		Index of refraction at 20°C.			Cetane no.	Aromatics (percent)
								Mercury		Sodium		
		Fraction	Sum			68°F	100°F	D line	e line	g line		
1 [1]	400	39.8	39.8									
2	420	3.3	43.1	410	0.8164	2.128	1.681	1.45375	1.45606	1.46549	[2] 43	19
3	450	3.1	46.2	450	.8490	2.720	1.952	1.47176	1.47430	1.48527	42	27
4	480	3.2	49.4		.8470	2.957	2.086	1.47135	1.47391	1.48481		
5	510	3.2	52.6	505	.8526	3.501	2.403	1.47614	1.47884	1.49030	46	26
6	520	3.3	55.9		.8563	4.158	2.745	1.47765	1.48033	1.49177		
7	530	3.2	59.1	535	.8604	4.998	3.206	1.47969	1.48234	1.49377	47	29
8	560	3.2	62.3		.8635	6.100	3.898	1.48113	1.48379	1.49526		
9	580	3.2	65.5	581	.8602	7.797	4.669	1.47859	1.48116	1.49229	53	25
10	605	3.2	68.7		.8636	10.011	5.761	1.47947	1.48213	1.49307		
11	625	3.3	72.0	615	.8708	13.324	7.291	1.48351	1.48578	1.49729	[2] 54	24
Residue [3]		27.9	99.9									

[1] See tables p. 122 and above. [2] Not as accurate as other data. [3] See table below for data.

Composition and characteristics of residuum for sample 47017 from Umiat test well 3

[Analysis by U. S. Bur. Mines]

	Percent by volume of crude	Oil percent	Wax percent	Specific gravity at 60°F	Viscosity at—			Viscosity index	Pour point (°F)	Melting point (°F)	Index refraction at 20°C (D line)
					100°F	130°F	210°F				
Residuum	27.9	0	0	0.900	311	149	51.6	85	50		1.4987
Dewaxed oil	19.9	100	0	.916	295	136	50.1	81	−10		1.5077
Wax	8.0	0	100	.865						73	[1] 1.4633

[1] Calculated from index measured at 100°F.

Test data for motor-gasoline and diesel-fuel fractions of sample 47017 from Umiat test well 3

[Analysis by U. S. Bureau of Mines]

Characteristics	Gasoline	Diesel fuel
Yield ... volume percent of crude oil	40.0	32.2
Distillation by ASTM method D-86:		
Initial boiling point ... °F	199	400
5 percent evaporated ... °F	218	----------
10 percent evaporated ... °F	225	----------
50 percent evaporated ... °F	283	----------
90 percent evaporated ... °F	356	600
End point ... °F	387	----------
Residue ... volume percent	1.0	----------
Loss ... volume percent	0.8	----------
Specific gravity at 60° F compared with water at 60°F	0.790	0.858
Gravity ... °API	47.6	33.4
Reid vapor pressure ... lb	1.2	----------
Aromatic content ... volume percent	----------	25.7
Cetane number	----------	48

Characteristics of products from Umiat test well 3

[Analysis by U. S. Bureau of Mines]

Product	Sample 47017 (1 gal distillation)	Routine analyses	
		Sample 47017	Sample 46164
Aviation gasoline base stock ... percent by volume	16	21	22
F-3 octane number with 4.0 ml tetraethyl lead per gallon (calculated)	84	----------	----------
Motor gasoline ... percent by volume	40	34	34
F-2 octane number, clear	57.2	----------	59
F-2 octane number, with 3 ml tetrethyl lead per gallon	77.2	----------	----------
Jet propulsion fuel percent by volume at 100°–600°F	65	67	69.8
Aromatics ... percent by volume	----------	31.2	27.6
Sulfur ... percent by weight	----------	0.03	0.03
Viscosity ... centistokes, −40°F	----------	8.6	9.2
Viscosity ... centistokes, 100°F	----------	1.3	1.3
Diesel fuel (400°–600°F boiling range) percent by volume	32	37	37
Cetane number determined	50	----------	50
Lubricating oil:			
50–200 Saybolt Universal viscosity at 100°F percent by volume	----------	17.7	18.1
50–200+ Saybolt Universal viscosity at 100°F percent by volume	----------	20.4	18.5

LOGISTICS

Personnel.—Men employed at the well site were the drilling foreman, 3 drillers, 6 semiskilled laborers (roughnecks), and 1 tractor driver. Additional employees, including carpenters, electricians, and mechanics, were sent to the rig site from Umiat camp as they were needed.

Drilling equipment.—A Star well-drilling machine (spudder), model 71–SK, powered by a Continental gasoline engine (model PF–162) was used by Arctic Contractors for spudding, instead of the Failing rig employed later, because there were no bits available for the latter capable of making the desired 9-inch hole. Below a depth of 72 feet the Failing model 1500 (314–C) core rig was used. It was mounted on skids and enclosed by a wanigan constructed on a sled with pipes for runners. Power was furnished by a Chrysler gasoline engine (model 108–506), and the rig was equipped with a Gardner-Denver 4- by 5-inch mud pump, model FF–F2F–F. The contractors also used the equipment given below:

- 1 ... O'Keefe-Merritt 15-kw a-c engine generator unit, model N–15.
- 1 ... Kohler 1.5 kw a-c generator unit.
- 1 ... Bettis 40 hp steamer, type 4992.
- 1 ... shop-made Prospect-type boiler.
- 1 ... Hughes 7-in. master gate.
- 2 ... mud pits, 5 by 7 by 2½ ft, made of pontoon sections cut in half.
- 1 ... water tank, 25 bbl, made of 5- by 5- by 7-ft pontoon section.
- 1 ... steel water tank, 300 gal.

From September through November 1947, one each of the following items of equipment was used in shooting and testing the wells:

- Keystone spudder, model 53, with tools and auxiliary equipment.
- Lufkin T7–3A pumping unit.
- Le Roi 4- by 4-in. 4-cylinder engine.
- Simplex stuffing box. No. A2192.
- Oilmaster 2½-in. by 2-in. by 8-ft, stationary barrel, top-anchor oil pump, No. A–528–8.

Fuel consumption.—The pump, drilling, and light-plant engines used 2 drums of gasoline (106 gal) daily. The shop-made Prospect-type boiler and 3 heating stoves used 1½ drums of diesel oil per day.

Water storage and use.—Water was stored in a 300-gallon tank mounted inside the Failing rig wanigan and in a 25-barrel tank. Both tanks could be heated, and it was possible to pump water from Umiat Lake, adjacent to the well, even at −52°F, if great care was taken to keep the hoses empty and in a warm place when they were not in use. Water consumption was kept as low as possible and averaged less than 300 gallons per day.

DRILLING OPERATIONS

The following drilling operations were recorded by J. R. Coleman, Arctic Contractors' petroleum engineer.

Notes from drill records

Depth (feet)	*Remarks*
9	After a 6- by 6- by 3-ft cellar was dug, hole was spudded with a Star spudder, using a 9-in bit.[1] (All depths are corrected to read from the top of the Failing rig kelly bushing, which was 9 ft above the ground, and 12 ft above the cellar floor).
72	Sixty-two ft of 23-lb 7-in. casing was set with top 1 ft below ground level and base 72 ft below kelly bushing. Casing cemented with 25 sacks of portland cement mixed with 100°F water. After settling, top of

[1] The available information on bits is included in this section on drilling operations.

Notes from drill records—Continued

Depth (feet)	Remarks
	cement was found 7 ft below cellar floor, and 5 sacks of portland cement were added by hand to cement pipe. After setting 7 hr, cement was warmed with steam to about 150°F for 4 days. Failing rig was moved over hole during this time. Top of cement found at 67.5 ft and drilled out with Failing equipment.
155	Deviation 0°45′.
236	Drilled 5⅞-in. hole from 72 to 236 ft with a 5⅞-in. Hughes roller bit. Mud used was natural, with the addition of Aquagel and water.
280	Deviation 15′.
390	Deviation 2°15′.
525	Deviation 2°30′.
572	Cored 236–572 ft with a 3-in. by 10-ft Oklahoma-type "N" double-tube core barrel with drag-type cutter heads, recovering 57.5 percent of rock cored. Hole reamed to 538 ft with 5⅞-in. Hughes roller bit, and Schlumberger electric log run from bottom of casing at 72 ft to 525 ft. Mud weight at time log was run was 74 lb per cu ft, and viscosity was 37 sec API.
	At end of bailing tests hole was frozen below 460 ft, and fluid level was at 147 ft. Just before pumping tests began, hole was found to be bridged or frozen at 240 ft, and fluid level was 145 ft below top of casing.
	Hole abandoned with 7-in. casing capped by flanged head having two 2-in. plugged ports. On top of casing head was a flanged tubing head capped by swages with plugged nipples on the side and 2- by 4-in. nipple with 2-in. gate valve on top. Top of installation is 5 ft above ground.

UMIAT TEST WELL 4

Location: Lat 69°23′20″ N, long 152°04′53″ W
Elevation: Ground, 482 feet; top of surface pipe, 483 feet.
Spudded: May 26, 1950.
Completed: July 29, 1950; pumped 100 barrels of oil per day; shut in.
Total depth: 840 feet.

Because the first 3 holes on the Umiat anticline produced only a small quantity of oil, drilling ceased for more than 2 years. In 1950, however, it was decided to drill a cable-tool hole to see if the low production of the earlier wells was caused by the fresh water from the drilling fluid. If the fresh water had lowered permeability of the sandstone by reacting with the matrix or freezing in the pore spaces, then a cable-tool hole, using just enough brine to lubricate the tools, might be a much better test of the possible yield of the anticline. The experiment was successful, as a pumping test produced oil at a rate of 100 barrels per day from Umiat test well 4. The hole (see pl. 8*A*) is about 1,000 feet northeast of Umiat test well 3; and although it is higher structurally than the older well, it started in younger beds, probably of the Ninuluk formation. because of its greater elevation. No samples from the Ninuluk formation were saved, but correlation with other wells would place its base at about 40 feet.

DESCRIPTION OF CORES AND CUTTINGS

The first sample, at 90 feet, is in the Killik tongue of the Chandler formation, which is present as alternating clay shale and sandstone to the base of a thin persistent sandstone at 320 feet. Clay ironstone and coal are both present between 180 and 260 feet; the clay ironstone is more common. At a total depth of 840 feet, the drilling had penetrated only about 80 feet of the lower sandstone bed of the Grandstand formation; a broken drilling line which left tools stuck in the hole prevented deepening the well. Oil was found in both the upper and the lower sandstone units of the Grandstand; the proportion produced from each is uncertain. The hole was shut in for over a year and a half and then pumped to obtain oil for oil-base mud.

Lithologic description

[Where no cores are listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
-----	0–1	Top of surface pipe to ground.
-----	1–90	No sample. "Hard sand" reported by driller from 2 to 75 ft, and "hard sandy shale" from 75 to 90 ft.
-----	90–100	Clay shale, medium- to medium-dark-gray, slightly silty, micaceous, slightly calcareous, with a very small amount of medium-light-gray very argillaceous siltstone and moderate-yellow-brown slightly calcareous clay ironstone with conchoidal fracture. Small amount of medium-light-gray very fine-grained silty argillaceous slightly calcareous sandstone, composed of subangular clear and white quartz with some dark rock fragments, yellow grains and coaly particles, and rare mica.
-----	100–110	Sandstone and shale, with rare clay ironstone. Ice reported by driller 100–108 ft.
-----	110–120	Clay shale, dark-gray, slightly carbonaceous, silty, noncalcareous, with some medium- to medium-dark-gray clay shale, and clay ironstone.
-----	120–130	Clay shale, medium-dark-gray, very silty, micaceous, noncalcareous, with very small amount of siltstone.
-----	130–140	Sandstone, very light-brown, fine-grained, noncalcareous, friable; composed of subangular clear and white quartz with some light-brown grains and dark rock fragments; small amount of clay shale is medium dark gray, very silty, micaceous, noncalcareous.
-----	140–150	Siltstone and clay shale with small amount of sandstone.
-----	150–160	Clay shale, medium-gray, very slightly silty, noncalcareous, with rare siltstone and clay ironstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	160–170	Sandstone, light-olive-gray, very fine-grained, very argillaceous and silty, slightly micaceous, noncalcareous, with scattered carbonized plant flakes. Some clay shale and siltstone present.
-----	170–195	Clay shale, medium- to medium-dark-gray, very slightly silty and micaceous, noncalcareous, with small amount of black dull to shiny coal with irregular to poor shaly fracture at 180–190 ft.
-----	195–235	Sandstone, very light-brown, fine-grained, slightly argillaceous, noncalcareous, friable; composed of subangular clear and white quartz with some light-brown grains and dark rock fragments. Siltstone, shale, and clay ironstone rare at base.
-----	235–240	Sandstone, medium-gray, very fine-grained, silty, argillaceous, slightly to very calcareous, with some medium-gray sandy argillaceous slightly to very calcareous siltstone.
-----	240–245	Clay shale, medium-gray, slightly silty, slightly calcareous, with very small amount of yellowish-brown slightly calcareous clay ironstone with conchoidal fracture.
-----	245–255	Siltstone, with very small amount of clay shale and sandstone.
-----	255–260	Clay shale, medium-dark-gray, very silty, noncalcareous, with rare bluish-white bentonite.
-----	260–265	Sandstone, light-olive-gray, fine-grained, silty, argillaceous, noncalcareous.
-----	265–280	Clay shale, medium- to medium-dark-gray, slightly to very silty; slightly calcareous in part; some siltstone and dark-gray fissile clay shale at 270–275 ft.
-----	280–298	Sandstone, medium-light-gray, fine-grained, very slightly silty, noncalcareous, friable; composed of subangular clear and white quartz, gray chert, and dark rock fragments.
1	298–299	Recovered 1 ft:[1] Not sampled for microfossils. Siltstone and very fine-grained sandstone, indurated, noncalcareous.
2	299–300	Recovered 1 ft: Not sampled for microfossils. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, slightly micaceous, noncalcareous, massive; composed of subangular clear and white quartz with some gray, yellow, and dark grains.
-----	300–305	Siltstone, medium-light-gray, slightly argillaceous, noncalcareous.
-----	305–310	Clay shale, medium-dark-gray, very silty, noncalcareous, with medium-gray very argillaceous noncalcareous siltstone.
-----	310–315	Sandstone, light-gray, fine-grained, silty, argillaceous, noncalcareous, with small amount of medium-dark-gray very silty clay shale.
-----	315–320	Sandstone and clay shale.
-----	320–325	Siltstone, with very small amount of clay shale. Top of Grandstand formation at 320 ft.
-----	325–335	Clay shale, medium-dark-gray, noncalcareous; slightly silty in part; rarely very silty.
-----	335–343	Siltstone, medium-gray, slightly to very argillaceous, noncalcareous, with small amount of clay shale.

See footnotes at end of table.

Lithologic description—Continued

Core	Depth (feet)	Remarks
3	343–345	Recovered 2 ft:[2] Not sampled for microfossils. Shale.
4	345–350	Recovered 5 ft:[2] Not sampled for microfossils. Shale.
5	350–353	Recovered 3 ft:[2] Not sampled for microfossils. Shale and coal, with 2 in. of sandstone.
-----	353–355	Sandstone, medium-light-gray, fine-grained, very slightly silty, friable, noncalcareous; composed of subangular clear and white quartz, gray chert, and dark rock fragments. Dark-gray slightly carbonaceous clay shale rare.
-----	355–357	No sample.
6	357–360	Recovered 3 ft:[2] Not sampled for microfossils. Sandstone.
-----	360–375	Sandstone as above, with rare medium-dark-gray clay shale, and rare black dull coal with shaly fracture. Dark-gray carbonaceous clay shale in lower part.
-----	375–385	Clay shale, medium-dark- to dark-gray, noncalcareous; rarely very slightly silty.
-----	385–395	No sample.
-----	395–427	Sandstone, medium-light-gray, very fine- and fine-grained, silty, argillaceous, with small amount of medium-gray silty noncalcareous clay shale in upper part and rare black carbonaceous shale at 410–420 ft.
-----	427–445	Clay shale, medium- to medium-dark-gray, slightly to very silty, noncalcareous, with some medium-gray very argillaceous siltstone in upper part.
-----	445–450	Clay shale, with medium-light-gray fine-grained sandstone and siltstone.
-----	450–475	Sandstone, medium-light-gray, fine-grained, noncalcareous, friable; composed of subangular clear and white quartz with some dark rock fragments.
-----	475–485	Clay shale, medium-dark-gray, noncalcareous, very silty in upper part; small amount of grayish- to greenish-white bentonite with conchoidal fracture, some of which contains yellow grains.
-----	485–490	Sandstone, medium-light-gray, fine- and very fine-grained, silty, argillaceous, noncalcareous, and medium-dark-gray very silty clay shale, with rare dark-gray carbonaceous shale and medium-gray very fine-grained sandstone.
-----	490–495	Sandstone and siltstone with small amount of clay shale.
-----	495–500	Bentonite, pale-yellowish-brown, conchoidal fracture, with medium-gray silty clay shale and rare black shale.
-----	500–505	Bentonite, white, argillaceous, shaly fracture, with medium- to medium-dark-gray silty shale.
-----	505–510	Clay shale, medium-dark-gray; slightly silty and slightly calcareous in part; very rare black shale.
-----	510–515	Bentonite, grayish-white, and medium-gray calcareous siltstone.
-----	515–520	Sandstone, siltstone, and clay shale.
-----	520–545	Clay shale, medium-dark-gray, slightly silty, noncalcareous, with rare medium-gray very argillaceous siltstone in upper part.
-----	545–550	Clay shale, medium-dark-gray, very silty, noncalcareous, with medium-gray very argillaceous very slightly calcareous siltstone.

See footnotes at end of table.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	550–560	Clay shale with small amount of siltstone.
-----	560–565	Siltstone with small amount of clay shale.
-----	565–570	Clay shale with some siltstone.
-----	570–590	Clay shale, medium-dark-gray, noncalcareous; very slightly silty in part; rare siltstone and medium-gray very fine-grained slightly calcareous very argillaceous sandstone.
-----	590–595	Clay shale with small amount of sandstone.
-----	595–600	Siltstone, medium-gray, very argillaceous, noncalcareous, with some slightly to very silty clay shale.
-----	600–610	Siltstone and clay shale with very small amount of sandstone in lower part.
-----	610–630	Clay shale, slightly to very silty, with small amount of siltstone at 620–630 ft.
-----	630–640	Siltstone, medium-light-gray, slightly to very sandy, argillaceous, noncalcareous, with very small amount of sandstone.
-----	640–715	Clay shale, medium-dark-gray, slightly to very silty, micaceous, noncalcareous, with rare siltstone in upper 10 feet.
-----	715–720	Sandstone, medium-light-gray, fine-grained, slightly silty, calcareous, pyritic, friable, with clay shale.
-----	720–725	Sandstone, with rare medium-dark-gray clay shale and dark-gray slightly carbonaceous clay shale.
-----	725–735	Siltstone, medium-gray, argillaceous, noncalcareous; slightly sandy in part; very small amount sandstone, and rare clay shale in lower part.
-----	735–745	Clay shale, with some sandstone.
-----	745–760	Sandstone, medium-light-gray, fine-grained, noncalcareous, friable.
-----	760–764	No sample.
7	764–767	No recovery.
8	767–768	Recovered 1 ft: Not sampled for microfossils. Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous slightly micaceous, noncalcareous, massive. Lower part medium gray, calcareous; composed of clear quartz with some white quartz and unidentified yellow, gray, and dark grains.
-----	768–775	Sandstone as above.
-----	775–820	Sandstone, with very small amount of medium-dark-gray very silty shale in upper 20 ft.
-----	820–821	No sample.
9	821–826	Recovered 1 ft 6 in.: Not sampled for microfossils. Sandstone, medium-light-gray, very fine- to fine-grained, silty, argillaceous, noncalcareous, with rare small carbonized plant fragments. Sand composed of subangular clear and white quartz with some unidentified gray, yellow, and dark grains.
10	826–826.5	Recovered 6 in.: Not sampled for microfossils. Sandstone as above.
-----	826.5–831	Sandstone as above.
-----	831–840	No sample.

[1] Core not received in Fairbanks; description made by well geologists.
[2] Core not received by Fairbanks laboratory; description made by driller.

CORE ANALYSES

The table below shows the porosity and permeability of four core samples from Umiat test well 4. Effective porosity was determined by the Barnes method; air permeability was determined on a permeameter, the general requirements for which are detailed in American Petroleum Institute Code No. 27, second edition, April 1942.

Analyses of core samples from Umiat test well 4

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
299	10.3	0
767	.8	0
821	10.3	0
826	5.49	0

OIL AND GAS

OIL AND GAS SHOWS

Shows of oil noted during the drilling of Umiat test well 4 are given below.

Depth (feet)	
283–298	Strong odor of oil.
298–300	Good show of light-green oil.
353–360	Oil sand.
395–430	Thin beds of oily sand.
748–826	Slight odor of oil and gas.

FORMATION TESTS

Two bailing tests and four pumping tests, the latter ranging from several hours' to 18 days' duration, were made before the well was shut in. The following discussion of the tests is based primarily on observations by Gordon Oosting, petroleum engineer.

Test 1, 33–353.5 feet.—After drilling 6 inches into an oil-bearing sandstone at 353 feet, a 15-minute bailing test was made. Slightly gas-cut oil was produced at a rate of at least 200 barrels per day, taking into consideration the drop of fluid level during the test.

Test 2, 33–427 feet.—A 5-hour bailing test produced 6.75 barrels of oil. During the test, ice was noted on the bottom of the bailer and in the oil, suggesting that water from the formation was freezing in the sandstone and limiting production. The temperature of the oil bailed from the hole was 27.5°F.

Test 3, 33–427 feet.—Brine made with 610 pounds of salt in 8 barrels of water was used to fill the hole to 350 feet (just above the oil bearing sandstone) in order to thaw any ice in the sandstone. Fluid levels checked after 12 hours showed top of fluid at 315 feet, top of salt water at 360 feet. A barrel of brine (made with 80 pounds of salt) was added to bring the salt water to 350 feet. In order not to remove the brine during the test, the pumping equipment was placed at 348 feet, just above the top of the brine; the oil, being lighter than the brine, would presumably flow from the sandstone through the brine and be picked up by the pump. Eleven joints of 2½-inch inner-diameter ex-

ternal-upset tubing were run with the shoe at 348 feet and two 20-pound sacks of salt suspended by rope from it at 351 feet and 355 feet. Using a 12-inch stroke at 24 strokes per minute, the fluid rose to the surface in 31 minutes. After pumping one-fourth of a barrel of brine, 5 barrels of water-free oil was pumped in 1 hour and 24 minutes. In the next 10 hours and 10 minutes, 6 barrels of oil was pumped, indicating a rate of 14.4 barrels per day. During the pumping for oil, salt water was pumped up with the oil only during 2 hours in the middle of the test.

Test 4, 33–840 feet.—After drilling to 840 feet the drilling line broke, and this and subsequent tests were made with the cable-tool fish between 802 and 840 feet. Tubing, sucker rods, and pump were installed with the bottom of the mud anchor at 800 feet and the bottom of the pump at 791 feet. There were thirteen ⅛- by 1-inch slots spirally placed from 783 to 787 feet. Oil reached the surface after 10 minutes of pumping with 24-inch strokes. After being shut down 25 minutes, the well pumped 4–5 barrels of oil; brine reached the surface in 35 minutes. Eleven barrels of brine was pumped in the next hour and 10 minutes, when oil again was produced and was pumped at 12 strokes per minute for 5 hours and 25 minutes. The rate was then increased to 22 strokes, which was continued for 24 hours. The well averaged 3.6 barrels per hour during this time. In one 24-hour period 88.5 barrels of water-free oil was pumped. Only a trace of gas was noted.

Test 5, 33–840 feet.—With the bottom of the pump at 776 feet, the fluid reached the surface in 14 minutes. After pumping for about 2½ hours, the pump stopped because of mechanical trouble; it had pumped 10.8 barrels of oil in the time. After 1¼ hours for repairs, the well was pumped continuously with a 24-inch stroke at 23 strokes per minute and produced 104.6 barrels in approximately 20 hours, including a 34-barrel fluid column in the hole. In the next 24 hours 88.6 barrels was pumped.

Test 6, 33–840 feet.—After an unsuccessful fishing operation, the pump was again installed, with the bottom of the pump at 787 feet, the bottom of the mud anchor at 800 feet, and 13 spirally placed 1- by ⅛-inch slots between 787 and 791 feet. The well was pumped continuously with a 24-inch stroke for 18 days, except for a few shut-downs of a few hours' duration. The daily production for this period is shown in the table below. The variable production rate may have been caused by mud plugging the pump and then being washed out by the head of oil built up in the hole; the indicated rate of production was 90–100 barrels per day, with no decline.

Daily[1] *production in 18-day pumping test, Umiat test well 4*

Date	Hours pumped	Strokes per minute	Barrels oil
1950			
Jul 29	16	23	54.0
30	18	23	78.3
31	18	23	73.6
Aug 1	5½	23	27.7
2	22	23	102.0
3	15½	23	75.0
4	24	14	80.0
5	20	23	90.0
6	19	23	83.0
7	24	23	101.5
8	24	20	90.5
9	24	23	90.5
11	16	20	92.0
12	24	20	100.5
13	16	20	64.0
14	21	23	114.0
15	8	23	36.0
Total			1,269.6

[1] Shut down on August 10 for repairs to rig engine.

OIL AND GASOLINE ANALYSES

In June 1950 two 5-gallon samples of oil from Umiat test well 4 were sent to the U. S. Bureau of Mines Petroleum Experiment Station, Petroleum Chemistry and Refining Section, Bartlesville, Okla., for analysis. One sample was from a bailing test, and one from a pumping test (tests 2 and 3, respectively; see pages 127–128), the oil coming from between 353 and 427 feet. The analyses made by the U. S. Bureau of Mines are shown in the table on p. 119. The bailing test is represented by U. S. Bureau of Mines sample 50103, the pumping test, by U. S. Bureau of Mines sample 50104.

In order to obtain oil for use in oil-emulsion mud, a boiler was constructed at Umiat to remove some of the lighter fractions of crude oil. As an experiment lighter fractions of oil from Umiat test well 4 were separated at temperatures as high as 330°F, and the cuts were analyzed by the U. S. Bureau of Mines at Bartlesville, Okla. The gasoline, as shown in table (p. 130) has a high natural octane number which can be raised appreciably by the addition of tetraethyl lead.

Analyses of Bureau of Mines crude-petroleum samples 50103 and 50104 from Umiat test well 4

[General characteristics of samples follow: Sample 50103: Sp gr, 0.841; sulfur, <0.1 percent; Saybolt Universal viscosity at 100°F, 37 sec; gravity, 36.8°API; pour point, −5°F color, Natl. Petroleum Assoc. no. 4½. Sample 50104: Sp gr, 0.842; sulfur, <0.1 percent; Saybolt Universal viscosity at 100° F,37 sec; gravity, 36.6°API; pour point, −5°F color, Natl. Petroleum Assoc. no. 4]

Distillation by Bureau of Mines routine method

Fraction	Cut at—		Percent		Sum percent		Specific gravity [1]		Gravity °API at 60°F		Correlation index		Aniline point (°C)		Saybolt Universal viscosity at 100°F		Cloud test (°F)	
	°C	°F	50103	50104	50103	50104	50103	50104	50103	50104	50103	50104	50103	50104	50103	50104	50103	50104
Stage 1.—Distillation at atmospheric pressure, sample 50103: 749 mm Hg; sample 50104: 749 mm Hg First drop, sample 50103: 48°C (118°F); sample 50104: 54°C (129°F)																		
1	50	122	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------	------
2	75	167	1.1	1.3	1.1	1.3	0.695	0.691	72.1	73.3	------	------	------	------	------	------	------	------
3	100	212	5.1	4.9	6.2	6.2	.738	.742	60.2	59.2	30	32	40.5	41.0	------	------	------	------
4	125	257	9.0	9.5	15.2	15.7	.767	.769	53.0	52.5	35	36	35.0	36.3	------	------	------	------
5	150	302	6.8	6.6	22.0	22.3	.785	.787	48.8	48.3	36	36	34.2	34.5	------	------	------	------
6	175	347	6.7	6.8	28.7	29.1	.798	.799	45.8	45.6	35	35	38.9	39.3	------	------	------	------
7	200	392	5.7	5.4	34.4	34.5	.808	.809	43.6	43.4	33	34	46.6	46.9	------	------	------	------
8	225	437	6.2	7.0	40.6	41.5	.822	.825	40.6	40.0	34	36	53.7	54.0	------	------	------	------
9	250	482	7.8	7.0	48.4	48.5	.840	.842	37.0	36.6	38	39	57.7	57.6	------	------	------	------
10	275	527	8.9	9.8	57.3	58.3	.855	.856	34.0	33.3	40	41	60.5	60.0	------	------	------	------
Stage 2.—Distillation continued at 40 millimeters Hg																		
11	200	392	6.6	4.6	63.9	62.9	0.866	0.868	31.9	31.5	41	42	65.6	65.4	40	41	Below 5	Below 5
12	225	437	7.9	8.6	71.8	71.5	.872	.870	30.8	31.1	40	39	71.6	72.2	46	46	20	20
13	250	482	6.1	6.1	77.9	77.6	.881	.881	29.1	29.1	41	41	------	------	60	60	35	35
14	275	527	5.3	4.6	83.2	82.2	.889	.887	27.7	28.0	42	41	------	------	85	88	50	50
15	300	572	4.7	5.1	87.9	87.3	.897	.895	26.3	26.6	43	42	------	------	175	155	55	55
Residuum [2]	------	------	12.0	12.1	99.9	99.4	.915	.915	23.1	23.1	------	------	------	------	------	------	------	------

[1] Specific gravity at 60°F compared with water at 60°F.
[2] Carbon residue of residuum, sample 50103: 1.6 percent; sample 50104: 1.5 percent. Carbon residue of both samples of crude: 0.2 percent.

Approximate summary

Constituent	Percent		Specific gravity		Gravity, °API		Saybolt Universal viscosity	
	50103	50104	50103	50104	50103	50104	50103	50104
Light gasoline	6.2	6.2	0.730	0.731	62.3	62.1	------	------
Total gasoline and naphtha	34.4	34.5	.777	.778	50.6	50.4	------	------
Kerosene distillate	6.2	7.0	.822	.825	40.6	40.0	------	------
Gas oil	29.3	27.8	.857	.858	33.6	33.4	------	------
Nonviscous lubricating distillate	11.5	11.5	0.875–.890	0.873–.888	30.2–27.5	30.6–27.9	50–100	50–100
Medium lubricating distillate	5.6	6.5	.890–.899	.888–.899	27.5–25.9	27.9–25.9	100–200	100–200
Viscous lubricating distillate	.9	------	.899–.901	------	25.9–25.6	------	Above 200	Above 200
Residuum	12.0	12.1	.915	.915	23.1	23.1	------	------
Distillation loss	.1	.6	------	------	------	------	------	------

Analyses of gasoline samples distilled from crude oil from Umiat test well 4

[Analysis by U. S. Bur. Mines]

	Sample				
	1	2	3	4	5
General characteristics					
Distilled at ° F	260	280	295–305	320–325	325–330
Specific gravity	0.757	0.775	0.792	0.799	0.805
Gravity ° API	55.4	51.1	47.2	45.6	44.3
Reid vapor pressure lbs	2.9	1.7	0.9	0.6	0.5
Distillation by American Society for Testing Materials method D 86					
Initial boiling point °F	156	186	210	216	236
5 percent evaporated °F	178	206	220	248	256
8 percent evaporated °F	184	208	228	252	264
10 percent evaporated °F	185	210	238	256	270
20 percent evaporated °F	192	218	250	268	284
30 percent evaporated °F	199	224	263	281	296
40 percent evaporated °F	206	231	275	295	308
50 percent evaporated °F	214	243	293	311	328
60 percent evaporated °F	224	255	313	331	349
70 percent evaporated °F	236	275	337	355	377
80 percent evaporated °F	258	300	368	387	407
90 percent evaporated °F	300	340	420	434	454
95 percent evaporated °F	340	376	463	468	484
End point °F	420	462	510	514	526
Sulfur percent by weight	0.0027	0.0042	0.0066	0.0072	0.0091
Motor octane nos.:					
Clear	66.7	61.8	53.4	50.0	48.0
1.5 ml tetraethyl lead per gal	80.8	76.1	69.7	66.9	65.2
3.0 ml tetraethyl lead per gal	84.9	81.2	75.2	72.6	71.1

LOGISTICS

Personnel and housing.—The supervisory personnel consisted of a petroleum engineer-geologist and a drilling foreman. Drilling crews included 1 driller, 2 tool dressers, and 1 pumper and gauger, making a permanent personnel of 6. Other employees coming from the Umiat camp as they were needed included a welder to dress drill bits, a mechanic, a bulldozer operator, and laborers. Shelter at the rig site consisted of a shed and canvas windbreaker around the drill rig; the crew lived at Umiat camp.

Vehicles and heavy equipment.—Vehicles were borrowed from Umiat camp when they were needed. These included 1 D8 Caterpillar bulldozer, 1 small crane (cherrypicker), and 3 weasels. One each of the following major items of drilling equipment was listed by the Arctic Contractors as having been used.

Bucyrus-Armstrong water-well drill, model 29–W, with 45-ft all-steel mast.
Buda 6-cylinder gasoline engine, model HP–298.
Kohler 1.5-kw light plant.
Wisconsin engine model VF–4, for water pump.
Water tank of bolted steel, 100-bbl capacity.
Oil tank of bolted steel, 250-bbl capacity.
Compressor unit for mosquito control.
Lufkin TC–3A pumping unit.
Le Roi 4-cylinder gasoline engine (power supply for Lufkin pump).
Oilmaster 2½-in. by 2-in. by 8-ft. stationary barrel top-anchor oil pump, model A–528–8.

Fuel, water, and lubricant consumption.—The materials recorded below were used in drilling the hole to 170 feet and from 299 to 840 feet, the total depth. Diesel fuel and 72-octane gasoline consumption was 415 and 1,110 gallons, respectively. Lubricating compounds totaled 34 gallons of No. 2170 lubricating oil and 112 pounds of grease; 5,805 gallons of water were used.

DRILLING OPERATIONS

DRILLING NOTES

The Bucyrus-Armstrong cable-tool rig was mounted on skids and pulled to the well site with a D8 Caterpillar tractor.

Data on drilling operations presented below was recorded by Gordon H. Oosting, petroleum engineer.

Notes from drill records

Depth (feet)	*Remarks*
33	Drilled 15-in. hole to 33 ft, and cemented 1 joint of 11¾-in. casing with 12 sacks of Cal-Seal.
130	Added rock salt to 10–25 gal of fresh water being used to lubricate bit. Hole froze up whenever bit was out for several hours; 2–3 lbs of rock salt with 25 gal of water found sufficient to keep hole from freezing.
298	Ran Wideo electric log from 33 to 285 feet, in fresh water. Bailed hole dry; drilled and reamed ice out of hole.
427	Ice in oil during bailing test suggested ice in the sand; brine added to prevent ice formation. (See section on Formation tests.)
565	Reamed out ice from 427 to 565 ft.
585	Added 8 bbl of brine made with 400 lb of salt, bringing brine level to 427 ft.
630	Added 2 bbl of brine made with 200 lb of salt.
693	Fluid level was at 316 ft, with oil-water interface near 670 ft. Temperature of bottom-hole sludge 30°F,[1] and its salinity (at 675 ft) was 1,906 grains per gal, compared with 6,432 grains per gal of brine added. Decrease in salinity was caused by addition of small amounts of fresh water as hole deepened, and possibly by some thawing of permafrost.
760	Temperature of bottom-hole sludge was 33°F; fluid level at 307 ft.
826	Temperature of bottom-hole sludge was 36°F; fluid level at 307 ft.

[1] Sludge-temperature measurements were made at the surface in fluid brought up by the bailer. The bit had not been in use for 1–3 hr previously, and the bailer remained on the bottom at least 10 min. It was brought to the surface, and the temperature of the fluid in the bottom of it was measured as rapidly as possible.

Notes from drill records—Continued

Depth (feet)	*Remarks*
840	Drilling line broke off just above socket, leaving tools, including 6-in. bit, stem, jars, and socket, in hole with top of fish at 802 ft. Several unsuccessful attempts made to recover fish. On second attempt fish was lifted 10 ft off bottom, but tools stuck, and fish and four 3¼-in. slips lost. Fishing with wall hooks also unsuccessful. Pumping equipment installed, and well tested. (See Test 4, p. 128.) Pumping equipment then removed, after half a barrel of hot salt water was poured into tubing and allowed to remain for 2 hr to free pump from tubing. Pump cleaned and reinstalled, but when the oil stopped flowing after 15 min of pumping, pump was again removed and found full of mud. When pump was put back, a 15-ft joint of tubing was removed and mud-anchor based at 785 ft, 15 ft above its earlier position. After pumping about 2 days, pump again removed and hole cleaned, including removal of 7 ft of cavings. A 2-lb charge of dynamite set off just above fish, but fishing operations that followed were unsuccessful. Pump put down hole again, and 18-day pumping test begun. (See Test 6.) Rig moved off well location at that time. After pumping test, Lufkin pumping unit removed.

In April 1952 Umiat test well 4 was cleaned out and oil pumped from it in order to supply oil for oil-base mud. A Bucyrus rig was installed over the hole, and a 6-inch cable-tool bit used to clean out the hole. Only a slight amount of bridging was found, and this was at depths greater than 400 feet. The top of the fluid was at 306 feet. It was bailed down to 616 feet, and after standing an hour, the fluid level rose 157 feet. A pump was installed, and the well pumped 145 barrels of oil in 12 hours; a shorter pump stroke later recovered 111 barrels in 9 hours, and 110 barrels in 11½ hours. A total of 500 barrels of oil was produced. The casing was capped, and the pipe-line valve at the well closed.

DRILL AND CORE BITS

Thirteen drill bits were used in making the hole; as each became dull it was redressed by hard-surface welding at Umiat camp. The Baker cable-tool core barrel No. 6 was used with two 5¾-inch core bits for the 24.5 feet of coring done. About 17.5 feet of cored rock was recovered, all badly broken. On the graphic log (pl. 12) bits used to ream through cored intervals are shown as having drilled these intervals to avoid confusion from short intervals of alternate drilling and reaming by one bit. Bit no. 8, not shown on the log, was used only for reaming ice from the hole.

ELECTRIC LOGGING

After the hole was filled with fresh water, an electric log was run with the Widco (Well Instrument Developing Company) Logger, from 33 to 285 feet.

TEMPERATURE MEASUREMENT STUDIES

By Max C. Brewer

Umiat test well 4 had been abandoned for 20 months and should have very nearly reached thermal equilibrium when a thermistor cable was lowered on April 1, 1952, to a depth of 291 feet where an obstruction, thought to be a thin plug of ice, was reached. Readings were taken in this upper air-filled part of the hole the following day when the thermistors had had sufficient time to come to thermal equilibrium with their surroundings.

Permafrost is here used in Muller's sense (Muller, 1945) of a thickness of soil or other surficial deposit or of bedrock at a variable depth beneath the surface of the earth in which a temperature below freezing has existed continuously for a long time. Although not explicitly stated in this definition, Muller has consistently used the term "permafrost" to apply to material whose temperature is perennially below 0°C, and it was his intention to do so (oral communication).

The thermal profile in this hole (temperature vs. depth) showed that the minimum permafrost temperature is approximately −6.20°C at a depth of 100 feet. The temperatures above 100 feet are slightly warmer than those at similar depths in Umiat test well 6, but temperatures at depths below 100 feet are considerably colder (1.1°C at 250 feet). Because both wells are subject to about the same climatic effects and are in rather similar lithologic surroundings, any differences in temperature in these two holes should be the effect of either topography, the Colville River, differences in well-filling material (Aquagel or air), surface cover, or a combination of these factors. Temperature and other data are not sufficient for a complete interpretation of the role of these factors in the temperature differences in the wells, especially at Umiat test well 4, but they indicate that the temperature differences above 100 feet in depth (the approximate depth of seasonal change) may well be caused by topography. The hole is very close to the south-facing slope of the ridge and thus, to depths on the order of 100 feet, may be exposed to certain warming side effects not found in holes in flat areas. The differences below 100 feet may be caused by topography and (or) the nearness of the Colville River to Umiat test well 6.

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It is doubtful if drilling penetrated through the bottom of permafrost as the total depth of the well is 840 feet, while the indicated depth of permafrost is 890 feet according to an extrapolation of the geothermal profile curve. This extrapolation, for a distance of 600 feet, is subject to error, but there are several lines of evidence favoring this conclusion. First, the inverse geothermal gradient of the bottom eight measurements and the extrapolated part of the curve is 115 feet per degree centigrade, whereas the inverse geothermal gradient at nearby Umiat test well 6 is 117 feet per degree centigrade from 250 to 700 feet in depth. Secondly, the depth of permafrost at Umiat test well 6 is approximately 770 feet, and the difference of −1.1°C at 250 feet, if carried on to greater depths in accordance with the observed gradient, would indicate a depth of permafrost of 897 feet at Umiat test well 4.

UMIAT TEST WELL 5

Location: Lat 69°23′05″ N., long 152°04′56″ W.
Elevation: Ground level 334 feet; rig floor, 335 feet.
Spudded: July 5, 1950.
Suspended: September 22, 1950.
Resumed: April 22, 1951.
Completed: October 4, 1951; pumped 400 barrels of oil per day; shut in.
Total depth: 1,077 feet.

To demonstrate further the value of drilling with cable tools and using brine, Umiat test well 5 was drilled close (174 feet east and 97 feet north) to Umiat test well 2, which had several oil shows but produced only a trace of oil when tested. Umiat test well 5 produced 400 barrels of oil per day and expanded the known producing area of the field in addition to testing the lower sandstone bed of the Grandstand formation.

DESCRIPTION OF CORES AND CUTTINGS

The hole probably spudded in the Ninuluk formation, but the first sample, at 65 feet, was taken 5 feet below the top of the Killik tongue of the Chandler formation as determined by correlation with nearby wells. Thin coal beds are common between 85 and 105 feet, and clay ironstone is present throughout the formation, which consists primarily of interbedded sandstone and clay shale. A slight show of gas was noted just below 200 feet, with oil in a lower sandstone. The base of the formation, at 335 feet, is marked by sandy siltstone instead of sandstone as in other wells.

All the sandstone beds in the Grandstand formation (335–1,060 feet) had shows of oil and are the source of the oil produced from the well. When the well was drilled below 800 feet, however, salt water also entered the hole. Pressure in the lower sandstone held the fluid level 195 feet higher in the hole than pressure in the upper sandstone; this probably caused movement of oil from the lower to the upper sandstone while the hole was idle. The open hole produced oil at the capacity of the pump, with very little water; no decline was apparent in a 93-day test. (See table on p. 135.) The bottom of the hole is 17 feet below the top of the Topagoruk formation (1,060–1,077 ft).

Several rigs were employed in drilling Umiat test well 5; they are described on page 136. Depths in the well are measured from the derrick floor used with the cable-tool rigs, 1 foot above ground level.

Lithologic description

[Where no cores are listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
-----	0–65	No sample.
-----	65–70	Sandstone, siltstone, clay shale. Sandstone, medium-light-gray, fine-grained, silty, micaceous, noncalcareous; composed of subangular clear and white quartz and gray and dark rock fragments. Siltstone, medium-light-gray, argillaceous, sandy, micaceous, noncalcareous. Clay shale, medium-dark-gray, very micaceous, noncalcareous.
-----	70–75	Clay shale and siltstone as above, with rare clay ironstone and carbonaceous shale.
-----	75–85	Sandstone as above, with small amount of siltstone and clay shale, and rare clay ironstone.
-----	85–90	Siltstone, with small amount of light-olive-gray very fine-grained micaceous sandstone and clay shale, with very small amount of clay ironstone and black shaly coal.
-----	90–100	Siltstone, medium-light-gray, argillaceous, slightly calcareous, with very small amount of clay shale, carbonaceous shale, and coal.
-----	100–110	Clay shale, medium-dark-gray, very silty, noncalcareous, and small amount of very argillaceous siltstone; rare coal in upper part; some light-grayish-brown noncalcareous clay ironstone with conchoidal fracture in lower part.
-----	110–115	No sample.
-----	115–120	Sandstone, medium-light-gray, fine-grained, silty, noncalcareous.
-----	120–125	Sandstone and siltstone, medium-light-gray, very sandy, argillaceous, with rare black carbonaceous clay shale.
-----	125–130	Sandstone, siltstone, and clay shale.
-----	130–135	Sandstone, medium-light-gray, fine- to medium-grained, noncalcareous, friable; composed of subangular clear and white quartz, gray chert, and dark rock fragments.
-----	135–140	Clay shale, very silty, with small amount of siltstone and sandstone.
-----	140–150	Sandstone, with small amount of siltstone.
-----	150–155	Sandstone and very silty clay shale.
-----	155–170	Sandstone, with very small amount of clay shale and siltstone.
-----	170–180	Clay shale, medium-dark-gray, slightly silty, slightly micaceous, noncalcareous, slightly carbonaceous.
-----	180–185	Sandstone, with some siltstone and very silty clay shale.
-----	185–195	Clay shale, with siltstone, medium-gray, slightly to very argillaceous, and clay ironstone in lower part.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	195–200	Clay ironstone, light-brownish-gray, conchoidal fracture.
-----	200–215	Sandstone, light-gray, fine-grained, friable; composed of subangular clear and white quartz with rare dark rock fragments.
-----	215–230	Sandstone, light-gray, fine- to very fine-grained, silty, argillaceous, noncalcareous, with some medium- to medium-dark-gray silty clay shale which increases with depth from a fourth to a half of the rock.
-----	230–235	Sandstone, light-gray, fine- to very fine-grained, silty, argillaceous, noncalcareous.
-----	235–290	Clay shale, medium-dark-gray, slightly to very silty, with very small amount of siltstone at 240–245 and 255–275 ft, and very argillaceous light-gray bentonite at 280 ft.
-----	290–300	Sandstone, medium-light-gray, very fine-grained (rarely fine-grained), friable; composed of subangular clear and white quartz with rare dark rock fragments.
-----	300–304	No sample.
1	304–306	Recovered 2 ft: Microfossils absent. 1 ft 8 in., sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, noncalcareous, massive; composed of subangular clear and white quartz, gray chert and dark rock fragments. Brown oil stain on lower 1 ft. 4 in., drilling mud.
2	306–308	Recovered 2 ft: Microfossils absent. Sandstone, dark-olive-gray, very fine-grained, very silty and argillaceous, noncalcareous; friable in part; brown oil stain. Beds of slightly calcareous sandy siltstone, 2–4 in. thick rare.
3	308–310	Recovered 2 ft: Microfossils absent. Sandstone as above.
4	310–312	Recovered 2 ft: Microfossils absent. Sandstone as above.
-----	312–320	Sandstone as in cores above; light brownish gray in upper part, medium light gray in lower part.
-----	320–330	Clay shale, medium-dark-gray, slightly silty, micaceous, noncalcareous.
-----	330–335	Siltstone, light-olive-gray, sandy, argillaceous, noncalcareous, with very small amount of sandstone and clay shale.
-----	335–360	Clay shale, medium-dark-gray, slightly silty, with clay ironstone at 345 ft. Top of Grandstand formation at 335 ft.
-----	360–365	Clay shale, dark-gray, with small amount of sandstone.
-----	365–375	Sandstone, light-gray, fine- to very fine-grained, friable, with very small amount of medium-dark- to dark-gray clay shale.
5	375–376	Recovered 6 in.: Microfossils absent. Sandstone, dark-olive-gray, very fine-grained, silty, noncalcareous, with brown oil stain.
6	376–377	Recovered 6 in.: Microfossils absent. Sandstone as above.
7	377–378	Recovered 4 in.: Microfossils absent. Sandstone as above.
8	378–379.5	Recovered 1 ft. Core not received in laboratory.
-----	379.5–390	Sandstone, medium-light-gray, slightly silty, noncalcareous, friable, with rare clay shale and very argillaceous light-gray bentonite in lower 5 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	390–400	Sandstone with small amount of bentonite, siltstone, and clay shale.
9	400–403	Recovered 4 in.: Microfossils absent. Sandstone, light-olive-gray, very fine-grained, silty, argillaceous, micaceous, noncalcareous, massive.
10	403–404	Recovered 7 in.: Microfossils absent. Sandstone as above.
-----	404–410	Sandstone, medium-light-gray, fine- to very fine-grained, slightly silty, noncalcareous.
-----	410–415	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous.
-----	415–420	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, with very small amount of clay shale and siltstone.
-----	420–425	Clay shale, slightly to very silty.
-----	425–430	Sandstone, with small amount of clay shale.
-----	430–455	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous, with very small amount of sandstone and siltstone in upper part and rare reddish-brown sideritic argillaceous limestone at 440 ft.
-----	455–460	Sandstone, medium-light-gray, fine-grained, slightly silty, noncalcareous, friable; composed of subangular clear and white quartz with some gray chert and dark rock fragments.
-----	460–465	Sandstone as above and clay shale, slightly silty in part.
-----	465–475	Sandstone as above.
-----	475–480	Clay shale, slightly to very silty, with small amount of sandstone.
-----	480–485	Clay shale, very silty; and fine-grained sandstone.
-----	485–490	Clay shale, slightly to very silty, with some sandstone.
-----	490–495	Sandstone, light-olive-gray, fine-grained, slightly silty, friable, noncalcareous, with small amount of clay shale and light-yellowish-brown clay ironstone.
-----	495–500	Clay shale, very slightly silty, with small amount of sandstone and rare light-greenish-gray bentonite.
-----	500–505	Sandstone, light-olive-gray, fine-grained, slightly silty, friable.
-----	505–610	Clay shale, medium-dark-gray, slightly to very silty, micaceous, noncalcareous.
-----	610–615	Clay shale and siltstone, medium-gray, very argillaceous, micaceous, noncalcareous.
-----	615–630	Clay shale, slightly to very silty.
-----	630–640	Siltstone, medium-gray, sandy, argillaceous, with some clay shale.
-----	640–730	Clay shale, slightly to very silty in upper part, slightly silty in lower part.
-----	730–735	Siltstone, medium-gray, sandy, argillaceous, noncalcareous, pyritic, with small amount of clay shale.
-----	735–740	Sandstone, medium-light-gray, fine-grained, silty, argillaceous, noncalcareous, with some dark fine to medium grains; some siltstone and clay shale also present.
-----	740–750	Sandstone, medium-light-gray, fine-grained, silty, argillaceous, calcareous, friable; composed of subangular clear and white quartz with gray chert, dark rock fragments, and pyrite.
-----	750–765	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous; some silty clay shale is pyritic.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	765–770	Clay shale as above, with some sandstone and rare siltstone.
-----	770–786	Sandstone, light-gray, fine-grained, very slightly silty, noncalcareous, friable; composed of subangular clear and white quartz with some dark rock fragments and rare pyrite.
11	786–789	Recovered 9 in.: Not sampled for microfossils. Sandstone, medium-light-gray, fine-grained, silty, argillaceous, noncalcareous; composed of subangular grains of clear and white quartz with some dark rock fragments.
-----	789–835	Sandstone as above.
12	835–837	Recovered 1 ft 6 in.: Not sampled for microfossils. Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, slightly calcareous; composed of subangular grains of clear and white quartz with some dark rock fragments.
-----	837–863	Sandstone as above, with rare clay shale in lower 10 ft.
-----	863–865	No sample.
-----	865–870	Siltstone, medium-gray, argillaceous, micaceous, noncalcareous, with clay shale.
-----	870–880	Clay shale, slightly to very silty, with small amount of sandstone and very small amount of siltstone.
-----	880–885	Sandstone, light-gray, fine-grained, as above.
-----	885–890	Sandstone and white bentonite.
-----	890–910	Sandstone as above.
-----	910–920	Sandstone with clay shale, medium-dark-gray, slightly to very silty.
-----	920–960	Sandstone, medium-light-gray, grading from fine to very fine grained with depth. Small amount of sandstone at base is medium gray and calcareous, with abundant dark rock fragments and mica.
-----	960–965	Sandstone, very fine-grained, and clay shale.
-----	965–970	Sandstone, fine-grained, very pyritic, with very small amount of clay shale.
-----	970–1, 005	Sandstone, fine-grained, grading to very fine grained with depth.
-----	1, 005–1, 010	Clay shale and sandstone.
-----	1, 010–1, 025	Sandstone, very fine-grained, with rare clay shale in lower part; sandstone at 1,025 ft is medium gray, very fine grained, argillaceous, and silty, with abundant gray chert and dark rock fragments.
-----	1, 025–1, 030	Sandstone, with clay shale and siltstone.
-----	1, 030–1, 035	Sandstone with very small amount of bentonite.
-----	1, 035–1, 045	Sandstone with very small amount of very silty clay shale, increasing to one-third of the rock with depth.
-----	1, 045–1, 050	Clay shale, very silty, with very small amount of sandstone.
-----	1, 050–1, 060	Sandstone, very fine-grained, with small amount of clay shale in lower half.
-----	1, 060–1, 075	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous. Top Topagoruk formation at 1,060 ft.
-----	1, 075–1, 077	No sample.

CORE ANALYSES

The table below shows the porosity and permeability of core samples from Umiat test well 5. The effective porosity was determined by the Barnes method; air permeability was determined with a permeameter described on page 127.

Analyses of core samples from Umiat test well 5

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
305	16. 60	95. 0
307	15. 50	26. 0
309	13. 42	16. 0
311	9. 25	2. 0
375	12. 21	13. 0
376	12. 41	44. 0
787	17. 64	118. 0

OIL AND GAS

OIL AND GAS SHOWS

The following shows were noted by the Arctic Contractors petroleum geologist and petroleum engineer. The only gas show was a slight odor in sandstone at 204–245 feet. Oil shows were good at 304–320 feet, in one of the main producing sandstones at 370–425 feet, in short intervals at 635–643 and 738–748 feet, and in the lower thick oil-bearing sandstone at 770–960 feet. Light oil stains were also noticed at 460–480 feet, 490–506 feet, and below the good show in the lower sandstone from 960–1,061 feet.

FORMATION TESTS

Several bailing, swabbing, and pumping tests were made on the well, one pumping test lasted 93 days.

Test 1, 32–510 feet.—The hole was bailed dry every 2 hours for 12 hours, producing 4.3 barrels of oil at a steady rate of 30 gallons every 2 hours, or an estimated rate of 8.6 barrels per day. Temperature of the oil from 510 feet, taken after bringing the bailer rapidly to the surface after 2 hours on the bottom (510 ft), was 31°F. In the next 12 hours 38 gallons was bailed. The fluid level was at 460 feet after 12 hours, and the temperature of the oil from 460 to 510 feet was 28.5°F. The 36-hour test indicated a rate of 7 barrels per day.

Test 2, 32–615 feet.—Bailed to bottom (615 ft) every 2 hours for 6 hours, producing 4.3 barrels each 2 hours for the first 2 periods, and 6.5 barrels in the third. Fluid level after 12 hours was 316 feet.

Test 3, 32–615 feet.—A pump was installed with the bottom of the mud anchor at 605 feet, bottom of the pump at 595 feet, and nine ¾-inch perforations, covered by 3 layers of wire screen, from 597 to 598 feet. The

pumping test began 4 days later, with a 24-inch stroke. Fluid reached the surface in 7 minutes, and then the well pumped about 9 barrels per hour for 3 hours, thereafter dropping to about 3 barrels per hour. The well produced 27 barrels of oil. The fluid level before pumping began is estimated at 150 feet. Results of the 15-day pumping test, which averaged about 70 barrels per day, pumping by heads, are given in the following table.

Oil produced between 32 and 615 feet during 15-day pumping test of Umiat test well 5

Date	Hours pumped	Oil (bbl)	Date	Hours pumped	Oil (bbl)
1950			*1950*—Con.		
Aug. 18	21	81	Aug. 26	24	82
19	24	66	27	24	79
20	24	66	28	24	70
21	24	70	29	24	73
22	24	72	30	24	70
23	24	76	31	24	72
24	15	60	Sept. 1	24	67
25	18	63			

Test 4, 32–837 feet.—Water was found at 800 feet; 2–3 barrels was bailed from 800 feet every 1½ hours for 6 hours. At 1½ hours salinity was 3,616 grains per gallon, but it dropped to 1,133 grains per gallon after 4½ hours. A sandstone at 825 feet showed a light cut in CCl_4.

Test 5, 771–1,077 feet.—Tubing was run with a packer at 771 feet and 30 feet of perforated pipe below it. The hole was swabbed dry, with no shows of oil or gas. The next day swabbing recovered 31 barrels of water and drilling fluid and half a barrel of oil. The fluid level above the packer dropped 30 feet. The following 24 hours of swabbing recovered 23 barrels of muddy water with 5,500 parts per million of chlorides and 2 barrels of Simpson crude oil, which was used as drilling fluid. Fluid above the packer dropped 7 inches per hour. Continued swabbing at a rate of 3 barrels per hour recovered 14 barrels of water (with 5,800 parts per million of chlorides) and 36 barrels of Simpson crude oil, with a fluid-level drop of 2 inches every 12 hours. The last day of the test recovered 10 barrels of water with 5,940 parts per million chlorides.

Test 6, 32–1,077 feet. Seventy barrels of oil was bailed in 14 hours, with the fluid level remaining at 375 feet.

Test 7, 32–1,077 feet.—Thirty-three joints of 2½-inch tubing, with one perforated joint on the bottom, were landed at 1,018 feet. The swab stuck in the tubing, possibly frozen in, and the sandline broke. After recovering the line, 309 barrels of oil was swabbed in 15½ hours. Continuous swabbing for 19 hours then recovered 275 barrels of oil, and the fluid level rose from 250 to 100 feet during that time. The well headed twice and flowed about 1 barrel each time. The oil averaged about 4.7 percent water and 0.1 percent sediment by volume, though the quantity of water varied considerably. Continued swabbing for 24 hours recovered 407 barrels of oil.

Test 8, 32–1,077 feet.—Beginning on June 20, 1951, a 93-day pumping test was made with the bottom of the pump at 1,075 feet for the first 3 days, then at 1,055 feet. For the first 1½ weeks the well produced 300–400 barrels of oil per day, with water content decreasing from 1.35 percent to 0.4 percent, with about 3,500 parts per million chlorides. The temperature of the flow line, in spite of the heater at the bottom of the tubing, was only 27°–28°F. The pump stuck twice, and one shutdown, at least, was caused by ice on the pump or rods. The following table gives the results of the 93-day test. For the first 49 days the pump stroke was 46 inches; after that it was reduced to 36 inches. Strokes per minute were 16–18 for the first 6 days, 24 per minute for the next 12 days, 18 through the 50th day, and 14 thereafter (except for 1 day, the 51st, of 17 strokes per minute). Temperatures ranged from 28°–32°F throughout; no wax or hydrogen sulfide was noticed. During the entire test the pump was too small to handle the full producing capacity of the well.

Results of 93-day pumping test during 1951, Umiat test well 5

Date	Hours pumped	Oil (bbl)	Date	Hours pumped	Oil (bbl)
June 20	9.0	137.0	Aug. 6	24.0	368.0
21	21.0	306.0	7	24.0	367.0
22	17.0	347.5	8	24.0	283.0
23	15.0	217.0	9	23.5	268.0
24	8.5	115.5	10	23.0	182.0
25	19.0	288.5	11	24.0	185.0
26	18.5	320.0	12	24.0	180.0
27	19.0	359.0	13	15.25	121.5
28	18.0	363.5	14	23.0	196.0
29	18.0	323.0	15	24.0	183.0
30	24.0	440.0	16	24.0	189.5
July 1	23.0	448.0	17	24.0	169.5
2	22.0	402.5	18	24.0	191.5
3	24.0	437.0	19	24.0	200.0
4	20.0	355.5	20	24.0	195.0
5	22.5	351.0	21	24.0	191.0
6	15.0	271.0	22	24.0	193.5
7	13.5	226.0	23	24.0	161.0
8	13.5	251.0	24	24.0	193.5
9	24.0	383.0	25	24.0	192.5
10	24.0	379.0	26	24.0	175.5
11	23.0	346.0	27	24.0	189.0
12	23.5	360.0	28	24.0	194.5
13	24.0	367.0	29	24.0	185.0
14	24.0	374.5	30	24.0	197.0
15	24.0	357.5	31	24.0	197.0
16	24.0	368.0	Sept. 1	24.0	195.0
17	24.0	373.5	2	24.0	183.0
18	24.0	401.5	3	24.0	188.5
19	24.0	367.5	4	24.0	189.0
20	24.0	365.0	5	24.0	186.5
21	24.0	344.5	6	17.0	145.0
22	24.0	354.0	7	17.5	148.0
23	24.0	357.5	8	24.0	191.5
24	24.0	364.5	9	24.0	194.0
25	24.0	373.5	10	24.0	197.0
26	24.0	359.0	11	22.0	180.5
27	24.0	374.5	12	20.5	167.0
28	24.0	364.0	13	24.0	183.0
29	24.0	366.5	14	17.0	139.5
30	24.0	344.0	15	20.0	145.0
31	24.0	373.0	16	24.0	191.5
Aug. 1	24.0	373.0	17	24.0	186.0
2	24.0	361.5	18	15.5	120.5
3	24.0	358.0	19	21.0	170.0
4	24.0	313.5	20	21.0	214.0
5	24.0	341.5	Total	2,059.25	24,987.0

LOGISTICS

Personnel and housing.—A drilling foreman and a petroleum engineer or geologist acted as supervisors. The drilling crew for the cable-tool rig included 2 drillers and 2 tool dressers; the rotary drilling was done by 2 drillers and 4 helpers. Temporary workers came from Umiat camp when necessary. An extra floorman, a welder for dressing bits, mechanic, bulldozer operator, cementer, and laborers were all used for short periods. The housing at the rig site besides the rig included the power and Heat-Pak boiler wanigan, and the cement-pump wanigan, which was also used at other Umiat wells.

Vehicles and heavy equipment.—All vehicles were supplied from Umiat camp as they were needed. Caterpillar tractors, cranes, weasels, and trucks were used. Several rigs were used in drilling this well—2 cable-tool rigs (1 spudder and 1 capable of drilling deeper) and 2 rotary rigs. The first rotary rig, and some of its associated equipment, was destroyed by fire. Equipment used by Arctic Contractors included that destroyed as well as items used as replacements:

1 Keystone spudder, model 53.
1 Bucyrus-Erie cable-tool rig, model 29W.
1 Bucyrus-Armstrong cable tool rig.
2 Failing 1500 rotary rigs.[1]
2 Buda gasoline engines,[1] model HP–326.
2 Heat-Pak boilers,[1] model 624–S.
1 Westco boiler-feed pump.
1 Gardner-Denver 4½- by 6-in. pump.
3 Mud tanks,[1] 3½- by 5- by 4-ft (half of a pontoon), mounted on go-devil.
1 Gardner-Denver 5- by 8-in. pump (with mud tanks), powered by Caterpillar D8800 diesel engine.
1 Gardner-Denver 4½- by 10-in. pump, powered by Caterpillar D8800 diesel engine.
1 Kato generator[1] with Wisconsin gasoline engine, model VE–4.
1 generator, 4 kw, powered with Waukesha gasoline engine, model FCL–70.
1 Gardner-Denver 5½- by 10-in. pump powered by Caterpillar D8800 diesel engine (in cement wanigan).

[1] One destroyed by fire.

Fuel, water, and lubricant consumption.—The consumption of gasoline (72-octane) and diesel fuel was 3,439 gallons and 1,784 gallons, respectively. Slightly more than 42,873 gallons of water was used; as no record of it was kept for the first week of drilling, the figure given here does not represent the total consumption. Lubricating oil no. 9170 consumed was 62¼ gallons, and thread-lubricating grease, 150½ pounds.

DRILLING OPERATIONS

DRILLING NOTES

All the rigs used in drilling Umiat test well 5 were mounted on sleds made of pipe set on 12- by 12-inch timbers on a pad of gravel. The well was spudded with a Keystone cable-tool rig, which was replaced by Bucyrus-Erie cable-tool rig because the Keystone rig was too light to reach the depth desired. This rig was replaced by a Bucyrus-Armstrong cable-tool rig which drilled to the total depth. About 7 months later a Failing rotary rig was moved over the well, and the hole was reamed to the bottom. Fire destroyed the rig, and a second Failing rig was installed to complete scraping the walls and testing the well. The following drilling operations were reported by Gordon Oosting, petroleum engineer.

Notes from drill records

Depth (feet)	*Remarks*
15	Drive belt broke and rig shut down 22 hr waiting for replacement.
23½	Set 8⅝-in. casing with welded shoe on bottom at 23½ ft, and cemented with 12 sacks of Cal-Seal. Well stood cemented for 24 hr.
52	Drilled out shoe and continued drilling to 52 ft. Water-bearing sand and caving sediments encountered just below casing shoe. Casing was broken free of Cal-Seal, a 9-ft joint was added and casing driven to 32 ft. Water-bearing, caving interval thus sealed off.
120	Two hours spent relacing drive belt. Bit points were too sharp, which caused them to stick in ice or hard rock. Attempts to ream from 110 to 120 ft were unsuccessful until points were flattened.
152	Shut down about 2 days waiting for drive-belt lacing.
200	In drilling first 200 feet of hole, 15–25 gal of fresh water was put into hole each time it was bailed out. Small amounts of salt were added occasionally but without effect on drilling. Little or no ice formed in hole.
230	Shut down almost 2 days because drive-belt lacing wore out; day spent putting wire lacing on belt. Hole reamed from 30 to 210 ft; this was necessary probably because of ice formation on sides of hole during shutdown. Ice may have been caused by freezing of melt water from near surface. Fifteen gal brine added at surface drained down to bottom leaving a salt coating on hole walls.
255	Used 75 lb salt with 53 gal (1 bbl) of water.
270	Spudding shaft broke while drilling. Tools and cable lost in hole but recovered with little difficulty. Rig taken down and moved off well site; hole filled with 12.5 bbl of crude oil from Umiat test well 4. A week later a Bucyrus-Erie cable-tool rig was moved into position, oil bailed out of hole, and drilling resumed.

Notes from drill records—Continued

Depth (feet)	Remarks
293	Five hours to repair engine.
304	Hole bailed dry and drilled and cored from 304 to 316 ft with only oil seeping into hole as drilling fluid. Drilling slow and difficult without water in hole because oil would not hold sand in suspension; so 50 lb salt and 50 gal water added at 316 ft.
370	Reached top of an oil-bearing sandstone and bailed out salt water and mud in order to core. No fluid used except oil seeping into hole; and although cores were recovered, drilling was very slow. Salt water (50 lb of salt per barrel of water) again used for reaming from 375 to 379.5 ft and to drill ahead. Each time hole was bailed, every 5 feet or less, 1 bailer of mud was replaced by 1 bailer (17 gal) of salt water.
510	Hole filled with 8 bbl of brine to a point above oil-bearing sandstone. Sides of hole scraped, all fluid bailed from hole, and bailing test made (Test 1, p. 134).
585	Fourteen hours spent repairing reel sheave.
615	In drilling from 425 to 615 feet, 1 bailer of brine consisting of 35 lb of salt per barrel of water was added whenever hole was bailed. Three or four bailers of mud often had to be removed from hole at the same time, because shale being penetrated formed mud naturally.
	After a bailing test, operations shut down for a day while waiting for pumping equipment; and after it was installed, Bucyrus-Erie rig removed. After 15-day pumping test, Bucyrus-Armstrong cable-tool rig moved to well site.
960	Brine of 35 lb of salt per barrel of water used between 615 and 960 ft. Total salt used to 960 ft was 2,000 lb.
980	Hemp-center drilling line broke while coming out of hole, leaving cable tools and 75 ft of line in hole. Fish recovered with center spear. Hemp center of drilling line seemed to be rotten, although it had been in use only 2 weeks—replaced with steel-center line.
1,061	After being shutdown a day, two 1,000-ft, ½-in. sand lines were put on and spliced with a 40-ft splice. A 12-hr delay caused by working on Umiat test well 6.
1,075	From 620 to 630 ft reamed to a diameter of 8 in., cleaned hole with salt water and scratchers on bailer. Total of 525 lb of salt used between 960 and 1,075 ft. Swabbing test made before well was shut in and rig removed. Seven months later, in April 1951, Failing rig moved over hole; its floor was 7 ft higher than cable-tool floor to which depths have been adjusted. Two days spent waiting for a flange from base camp at Barrow. After finding fluid level at 121 ft, 77 bbl of crude oil pumped in to get circulation. Attempt was unsuccessful and 40 bbl of fluid containing water and tundra moss and 25 bbl of brine was pumped in before gaining circulation. Ice and tundra bridges reamed between surface and 51 ft. After losing circulation and regaining it with brine, ice was reamed between 51 and 155 ft, with brine and oil as returns. Brine replaced with 7 bbl of weathered crude. Hole reamed to 233 ft, and returns were fresh oil. After tools were pulled out of hole to repair clutch, generator wanigan caught fire from Heat-Pak; flames spread to oil-tank wanigan where crude oil caught fire. Flames then destroyed rig. (See pl. 8*B*.) Control gate was closed, and well itself was not damaged.
	A second Failing rig moved over hole with rig floor set 3 ft lower than that of first rotary rig, and 2½ weeks later hole was again reamed, ice being removed to 312 ft. About 22 hr spent waiting for heat-pack unit. After installation, reaming continued to 539 ft. Circulation lost at 386 ft and regained by pumping in 28 bbl of oil and 8 sacks of tundra moss; circulation lost again at 396 ft but regained after adding 10 bbl of Umiat crude oil.
1,077	While reaming from 396 to 1,075 ft and drilling to 1,077 ft, 22 bbl more of Umiat crude oil, 8 bbl of crude oil from Simpson Seeps core tests, and 3 bbl of diesel fuel were added. Hole reamed with 7⅞-in. bit from surface to 772 ft and again with 5⅞-in. bit from 772 ft to total depth, finding bridges at 825 and 956 ft. Twelve barrels of Simpson crude and 3 bbl of diesel fuel added during reaming. A 7⅝-in. packer on tubing stuck at 30 ft, and hole was again reamed with 7⅞-in. bit to that depth before making swabbing test. After test, hole reamed with 7⅞-in. bit to 772 ft, and 26 bbl of crude oil and half sack of peat moss added. The 5⅞-in. hole was reamed from 772 to 873 ft, and from 686 to 1,056 ft, with 7⅞-in. bits; during the reaming 38 bbl of crude oil was put into hole. A 9½-in. wall scraper reamed from 366 to 516 ft and from 726 to 746 ft, and 18 bbl of crude and 5 bbl of diesel fuel added. A 10¼-in. scraper reamed from 456 to 509 ft, and 7⅞-in. bit reamed from 886 to 1,057 ft; 3 bbl of crude oil added during reaming. A 9½-in. wall scraper reamed from 726 to 896 ft, with addition of 8 bbl of crude oil. Tools twisted off while reaming at 900 ft, but fish was recovered, and reaming with the 9½-in. scraper continued to 906 ft, where tools twisted off again.
	After recovering fish again, reaming continued to 913 ft. Hole cleaned out with 7⅞-in. bit from 913 to 1,056 ft. After bailing, tubing run for swabbing test, pump installed, and a 93-day pumping test made. Well cleaned out again, from 721 to 1,076 ft, using 192 bbl of Umiat crude oil to maintain circulation. Tight spots from 688 to 1,076 ft then

Notes from drill records—Continued

Depth (feet)	Remarks
	rereamed with same bit, using 154 bbl of Umiat crude oil to retain circulation.
	After waiting 4 days for cement, 49 joints of 5½-in. 15-lb National seamless line pipe were run to 1,068 ft and cemented with 150 sacks of cement. Annulus between 8¾- and 5½-in. casings cemented at surface with 20 sacks of Cal-Seal. Top of plug at 1,065 ft; hole filled to surface with Umiat crude oil and shut in. On top of 8⅝-in. surface casing is 8⅝-in. coupling with 8⅝- by 10-in. nipple with a flange welded to it. The 5½-in. casing head is cemented to flange and projects above it, with screwed flange on top. A 2½-in. flanged tubing head is capped by swage nipple, coupling, and bushing. Casing head and fixtures extend about 3 ft above ground.

DRILL AND CORE BITS

A total of 24 cable-tool drilling bits were used in drilling the hole—one 10¾-inch bit, 13 bits 8 inches in diameter, and the rest 6 inches across. To improve the condition of the hole, bits 5, 6, 10, 23, and 24 were used entirely for reaming. Bits 8 and 11 also did some reaming as well as drilling. One core bit 5¾ inches in diameter was used with a Baker No. 6 cable-tool core barrel to take 20 feet of core.

Except for 2 feet of drilling, the rotary rig was used entirely for reaming and cleaning out the hole. Four Reed rock bits (2 SE–HM, and 2 SE–2HM) were used, and one Hughes OSC–2 bit; all were 7⅞ inches in diameter, except one of the SE–2HM bits, which was 5⅞ inches across. A 9½-inch Baker wall scraper and a 10¼-inch Grant wall scraper were also used. At some depths one bit was used for short alternate intervals of drilling and reaming; to avoid confusion on the graphic log (pl. 12), these bits are shown as having drilled only.

DRILLING FLUID

The first 200 feet of hole was drilled with a small amount of fresh water in the hole, to which only a little salt was added. Between 200 and 1,075 feet, brine was used, consuming 3,875 pounds of salt in a mixture that ranged from 35 to 50 pounds of salt for each 53-gallon barrel of water. Below 1,075 feet crude oil from Umiat or Simpson Seeps wells was used as a drilling fluid, as well as a little (11 bbl) of diesel fuel. A total of 107 barrels of Simpson crude oil and 550 barrels of Umiat crude oil was used.

UMIAT TEST WELL 6

Location: Lat 69°22′44″ N., long 152°05′40″ W.
Elevation: Ground level, 334 feet; rig floor, 337 feet.
Spudded: August 14, 1950.
Completed: December 12, 1950; pumped estimated 80 barrels of oil per day; junked and abandoned.
Total depth: 825 feet.

This well, the third drilled with cable tools, is about 3,500 feet southwest of, and structurally lower than Umiat test well 2. Its purpose was to extend or define the limits of production on the south flank of the anticline. Below alluvium, the Seabee (about 31 to 220 feet), Ninuluk (220–350 ft), Chandler (Killik tongue) (350–630 ft), and Grandstand (630–825 ft) formations were penetrated; oil shows were noted in several sandstone beds below 245 feet. They were inadequately tested, because water appeared at a depth of 825 feet and could not be completely shut off, causing ice to form in the tubing during production tests; however, a possible recovery of about 80 barrels of oil was indicated. An unsuccessful fishing attempt and a badly caving hole prevented further testing and drilling; so the hole was filled with mud and capped. The condition of the hole precluded deepening it to test the lower sandstone bed of the Grandstand formation, although plans originally called for possible deepening if it was warranted by production from that sandstone in Umiat test well 5.

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

[Where no cores are listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
-----	0–3	Surface pipe to ground.
-----	3–100	No sample; Marvin A. Heany, well geologist, states the hole penetrated gravel for the first 31 ft, and clay, silt and shale between 31 and 100 ft. Top of Seabee formation is at 31 ft.
-----	100–120	Clay shale, medium-dark-gray; very silty and slightly calcareous in part.
-----	120–140	Clay shale, with a small amount of bluish-white bentonite with abundant minute biotite flakes, and very small amount of medium-gray argillaceous noncalcareous siltstone.
-----	140–160	Clay shale, medium-dark-gray, slightly to very silty, with very small amount of siltstone.
-----	160–170	Clay shale, slightly to very silty.
-----	170–175	Clay shale with some medium-gray, very argillaceous siltstone.
-----	175–210	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous.
-----	210–220	Clay shale; calcareous in part; very calcareous medium-gray siltstone.
-----	220–240	Clay shale, with rare siltstone and bentonite. Top of Ninuluk formation at 220 ft.
-----	240–260	Sandstone, medium-light-gray, very fine-grained, slightly silty and argillaceous, friable, slightly calcareous in part; composed of subangular clear and white quartz with dark rock fragments and rare carbonized plant flakes.
-----	260–270	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous, with very small amount of sandstone and siltstone in upper part and rare black carbonaceous shale in lower part.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	270–280	Sandstone, medium-light-gray, fine-grained, slightly silty and argillaceous, noncalcareous; some medium-grained sandstone contains abundant carbonaceous particles and very small amount of clay shale.
-----	280–285	Sandstone, medium-light-gray, very fine-grained, noncalcareous; and medium-dark-gray clay shale.
-----	285–290	Siltstone, medium-gray, sandy, argillaceous, noncalcareous; medium-light-gray very fine-grained sandstone; and medium-dark-gray noncalcareous clay shale.
-----	290–295	Clay shale, medium-dark-gray, very silty, noncalcareous.
-----	295–325	Sandstone, medium-light-gray, fine-grained, noncalcareous, friable; composed of subangular clear and white quartz, gray chert and dark rock fragments; medium-grained sandstone increases from very rare at 310 ft to 20 percent at 325 ft.
-----	325–335	Clay shale, very silty, with small amount of very argillaceous siltstone and rare sandstone.
-----	335–350	Clay shale, slightly to very silty. Very rare clay ironstone at 350 ft contains structureless oolitelike pellets of calcite, similar to those at 515 ft in Umiat test well 7.
-----	350–380	Clay shale, with small amount of medium-gray very argillaceous siltstone and very small amount of black dull to shiny coal in lower part. Top of Killik tongue of Chandler formation at 350 ft.
-----	380–385	Siltstone, medium-gray, argillaceous to sandy, and medium-dark-gray clay shale with some black carbonaceous clay shale.
-----	385–390	Clay shale.
-----	390–410	Sandstone, medium-light-gray, fine- to very fine-grained, argillaceous, silty, slightly micaceous, calcareous, with a very small amount of clay shale and rare siltstone in lower part.
-----	410–415	Siltstone, medium-gray, slightly sandy, argillaceous, slightly calcareous.
-----	415–420	Clay shale, slightly to very silty, with very small amount of medium-light-gray noncalcareous siltstone.
-----	420–440	Clay shale, slightly to very silty, with very rare carbonaceous black shale at 435 ft.
-----	440–450	Sandstone, medium-light-gray, fine-grained, slightly argillaceous and silty, noncalcareous, friable; composed of subangular clear and white quartz and dark rock fragments.
-----	450–465	Clay shale, with small amount of siltstone in upper 5 ft.
-----	465–475	Clay shale, with some siltstone.
-----	475–495	Clay shale, medium-dark-gray, noncalcareous.
-----	495–505	Sandstone, light-gray, fine-grained, noncalcareous, friable; composed of subangular clear and white quartz with rare gray and dark rock fragments.
-----	505–508. 5	No sample.
1	508. 5–515	Recovered 6 ft 6 in.: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, very argillaceous and silty, slightly micaceous, very slightly calcareous, massive.
-----	515–525	Sandstone as above.
-----	525–529	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, slightly calcareous, and very silty clay shale.
2	529–531. 5	Recovered 2 ft 6 in.: Miscrofossils absent. Sandstone, medium-light-gray, very fine-grained, very argillaceous and silty, slightly micaceous, very slightly calcareous, massive.
-----	531. 5–535	Sandstone as above.
-----	535–560	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous.
-----	560–570	Clay shale, with some siltstone.
-----	570–580	Clay shale, slightly to very silty in part.
-----	580–585	Sandstone, medium-gray, very fine-grained, carbonaceous, with black carbonaceous clay shale and medium-dark-gray clay shale.
-----	585–590	Clay shale, slightly to very silty.
-----	590–595	Clay shale and sandstone, light-gray, fine- to very fine-grained, slightly silty and argillaceous, noncalcareous; composed of subangular clear and white quartz with rare dark rock fragments.
-----	595–600	Sandstone as above.
-----	600–605	Siltstone, light-gray, with some sandstone.
-----	605–610	Sandstone, very fine-grained, very silty, with some siltstone.
-----	610–615	Clay shale, medium-dark-gray, slightly to very silty, with very small amount of sandy siltstone.
-----	615–620	Clay shale, slightly to very silty.
-----	620–625	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, sericitic, noncalcareous, with some clay shale.
-----	625–630	Clay shale and siltstone, medium-light-gray, very argillaceous.
-----	630–655	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous. Top of Grandstand formation at 630 ft.
-----	655–680	Sandstone, medium-light-gray, fine-grained, slightly silty and argillaceous, noncalcareous, friable; composed of subangular clear and white quartz with abundant dark rock fragments. Very small amount of clay shale in top 5 ft.
3	680–683	Recovered 1 ft: Not sampled for microfossils. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, very sericitic, noncalcareous, with common carbonaceous partings.
4	683–687	Recovered 2 in.: Not sampled for microfossils. Sandstone as above.
-----	687–695	Sandstone as above.
-----	695–720	Sandstone as above, with very small amount of clay shale.
-----	720–730	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous.
-----	730–735	Clay shale and siltstone, medium-gray, very argillaceous, noncalcareous.
-----	735–740	Clay shale, very silty.
-----	740–745	Siltstone, very argillaceous, with small amount of clay shale.
-----	745–755	Clay shale, slightly to very silty, with very small amount of siltstone.
-----	755–770	Sandstone, medium-light-gray, fine-grained, slightly silty, noncalcareous, friable.
-----	770–775	Clay shale and sandstone.
-----	775–785	Clay shale, medium-dark-gray; slightly silty in part.
-----	785–795	Clay shale, dark-gray, very silty; and very fine-grained sandstone.
-----	795–800	Sandstone, medium-light-gray, fine- to very fine-grained, friable, with abundant dark rock fragments.
-----	800–825	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous, with very small amount siltstone.

CORE ANALYSES

Analyses given in the table below were made witb the equipment described on page 127.

Analyses of core samples from Umiat test well 6

Depth (feet)	Effective porosity (percent)	Air permeability millidarcys
508–515	14.0	0
529–531	3.35	0
680	9.45	0
681–683	8.5	0

OIL AND GAS

OIL AND GAS SHOWS

In drilling this well oil-bearing sandstone beds were penetrated at 445–455, 498–543, 625–635 feet, and 655–710 feet; the deepest, the upper sandstone bed of the Grandstand formation, was the most productive. A gaseous odor and slight cut in CCl_4 were obtained from sandstones between 240 and 340 feet.

FORMATION TESTS

Tests described below were recorded by the petroleum engineer Gordon Oosting. At a total depth of 528 feet, the well was shut down for 6 hours; during that time 25 gallons of oil was bailed every 2 hours. The fluid level was at 427 feet. At 825 feet water was noted in the hole, and continuous bailing for 8 hours did not lower the fluid level from 583 feet. The well was first pumped when it had reached a depth of 825 feet. To shut off water, the hole was plugged back with cement to 800 feet, and tubing, pump, and rods were installed with the bottom of the tubing at 799 feet and the bottom of the pump at 786 feet. Thirteen 1-foot by ⅛-inch slots were spirally placed from 787 to 790 feet in tubing wrapped with 4 layers of wire screen. The pumping test began 2 days later; fluid reached the surface in 12 minutes; 28.5 barrels of oil and 11 barrels of fresh water were pumped in 13 hours. In the 12 hours following, 5.7 barrels of oil and 3.5 barrels of water were pumped, using 19 strokes per minute. The temperature of the oil and water at the well head was 32°F, and the salinity of the water was 168 grains per gallon. Some gas came from the well head during the test. When the tubing was removed after the test, it was filled with mushy ice.

The only other test of the well was made after the well was shut down for more than 6 weeks. A bailing test to verify the water shut-off was made of the interval between the bottom of the surface casing at 37 feet and the top of a plug at 783 feet. Before bailing began, the top of the oil was at 277 feet, and the top of the water in the hole was at 500 feet. After 10 hours of bailing, fluid from the bottom consisted of half water and half oil; an hour later, more water had drained into the hole. After the following hour of bailing, the fluid level was at 430 feet, and 14.5 barrels of water had been recovered in the 12-hour period. In the next 12 hours, 15 barrels of water was bailed. After standing 1 hour the top of the oil was at 295 feet, and the water level was at 600 feet. Ten barrels of water was bailed in the next 2 hours, after which the top of the oil was at 345 feet and the water at 680 feet. After standing 8 hours the top of the oil was still at 345 feet, and the water was at 660 feet. During a 12-hour bailing test, the hole was bailed dry with the removal of 22 barrels of water in 4½ hours and kept dry by bailing 1½ barrels of water every 1½ hours thereafter. In the 24-hour period following, the hole was bailed about every 3 hours, and the entry of water declined from 2 barrels to 10 gallons per hour. The oil level, after 5 hours, was at 474 feet, and the water level, at 760 feet. After a standing period of 4 hours, 1¼ barrels of water was bailed; after a 2-hour wait, 1¼ barrels was bailed. After 6 hours the top of the oil was at 445 feet, and the water level was at 748 feet; 13 hours later the oil was at 445 feet, and the water, at 725 feet. Gas continued to flow from the well head occasionally.

WATER ANALYSIS

The National Bureau of Standards analyzed a sample of water from the tank taken after the well had reached its maximum depth and while it was being pumped. The water contained the following radicals, in parts per million: sodium, 2,450; calcium, 15; magnesium, 20; sulfate, 685; chloride, 1,400; bicarbonate, 3,350; iodide, 2.6; and silica, 5.2; the total is 7,927.8.

LOGISTICS

Personnel and housing.—A drilling foreman and a petroleum engineer-geologist were the 2 supervisors at the well site; the drilling crews consisted of a driller, 2 tool dressers, and 2 pumpers and gaugers. All other workers were temporary and came from Umiat camp when needed. They included a welder to dress the drill bits, a mechanic, a bulldozer operator, and laborers.

The personnel was fed and housed at Umiat camp; the buildings at the well consisted only of the enclosed rig house, a boiler wanigan, a power wanigan, and a tool shed.

Vehicles and heavy equipment.—Three weasels were kept at the well site for transportation, and a D8 Caterpillar bulldozer and small crane (cherry picker) were brought from Umiat camp when needed.

One each of the following major items of drilling equipment was listed by the Arctic Contractors as having been used.

Bucyrus-Armstrong water-well drill rig, model 29–W, with a 45 ft all-steel mast which had a 6-ft extension.

Keystone cable-tool rig.
Buda 6-cylinder gasoline engine, model HP–298.
Lufkin TC–3A, pumping unit, powered by a Buda gasoline engine.
Kohler 4-kw light plant.
Barnes 7M water pump.
Water tank, capacity 250 gal.
Oil tank, 100-bbl, bolted steel.
Oil tank, 64-bbl, bolted steel.
Oilmaster 2½-in. by 2-in. by 8-ft stationary-barrel top-anchor pump, model A–528–8.

Fuel, water, and lubricant consumption.—In drilling Umiat test well 6, 1,234 gallons of 72-octane gasoline, 42 pounds of lubricating grease, 31 gallons of No. 9170 lubricating oil, and 29,350 gallons of water were used. After the drill rig was winterized, a boiler was added which used 1,197 gallons of diesel fuel.

DRILLING OPERATIONS

The Bucyrus-Armstrong cable-tool rig was mounted on skids and towed to the well site by a D 8 Caterpillar tractor. It was later removed for winterization, and a Keystone cable-tool rig was used to plug the hole back. When the Bucyrus-Armstrong rig was reinstalled after winterization, it was mounted on a welded-steel sled.

DRILLING NOTES

Drilling operations described below were recorded by the petroleum engineer Gordon Oosting.

Notes from drill records

Depth (feet)	*Remarks*
0–35	Hole drilled and casing driven, about 3 ft at a time. Small amounts of Aquagel used to drill through gravel for first 31 ft. Casing driven to 35 ft, 4 ft into shale below gravel.
108	Thawing formed a large cavity around pipe at surface. Cavity was filled with gravel, and a ring of 5 sacks of Cal-Seal was set around pipe at ground level, above gravel. Cal-Seal ring prevented surface material from falling into hole; ring would also support casing by collar should it tend to slip down hole.
529	Attempt to core with basket on tubing was unsuccessful, as tubing was only lowered 6 in.; no recovery.
825	Ten sacks of Cal-Seal dumped at bottom of hole with bailer, filling hole to 815 ft, but it did not shut off water entering hole from the formation. Six more sacks, raising plug to 805 ft, were also ineffective, as were six additional sacks, which brought plug to 800 ft. Tubing, pump, and rods installed, and rig moved off of well site.
	After pumping test a Keystone rig was moved over hole. Attempt to pull tubing from hole failed; removing top joint of tubing and top rod showed tubing to be full of mushy ice. Hot brine in tubing and a steam line in hole outside tubing necessary to thaw ice in tubing. It was necessary to saw 6 rods into 2 pieces in order to remove the rods and tubing from the hole.
	Bridge found at 564 ft, before hole was cleaned out with 7-in. horn socket on 3½-in. tools. Cal-Seal plug found at 810 ft. Well plugged to 780 ft with 10 sacks of Hi-Early cement mixed with 8 percent by weight of calcium chloride. Water heated before being mixed with cement. After standing cemented for 24 hrs, plug found at 783 ft. Bailer lowered to 70 ft stuck, and cable pulled off of it. Attempt to retrieve it with latch jack and jars resulted in leaving one prong of latch jack in hole. Hole shut down 4 days waiting for tools: next attempt to recover bailer was successful.
	Reaming from base of casing to 500 ft was easy, but was difficult from 500 to 551 ft (the maximum depth to which the Keystone rig drilling line could go), owing to the presence of an apparently solid bridge. Operations suspended with 100 lbs of salt and 2 bbls of water in hole and casing capped.
	About 6 weeks later winterized Bucyrus-Armstrong rig brought to well site, and well cleaned out to 783 ft. Elevation of rig floor was 3 ft higher than that of previous rig; all depths have been corrected to original rig floor. Fluid level was at 133 ft, and bridge was drilled from 479 to 510 ft.
	After a bailing test for water, 800 gals of brine (with 1.36 lbs of salt per gal of water) put into hole, after which top of oil was at 247 ft. Cavings cleaned out to 769 ft, and while going into hole with bit, drilling line broke, leaving tools in hole. Top of fish was at 347 ft and could not be recovered; well shut down 3½ days waiting for additional fishing tools from Barrow. Fish slid down hole to 758 ft during further fishing operations, and caving hole below 209 ft made recovery impossible. Hole was filled with mud made from 50 sacks of Aquagel to protect oil-bearing sandstones, and Widco electric log was made. Bridges to 700 ft drilled out, and thermistor cables installed before hole was abandoned. The 8⅝-in. casing topped with an open coupling covered only with wooden block to which thermistor cables are attached. Top of coupling 20 inches above ground.

DRILL AND CORE BITS

One 5¾-inch core bit in a No. 6 Baker cable-tool core barrel cored 16 feet of rock, of which 5 feet 7 inches was recovered. The cored rock was badly broken. Eight drilling bits were used to reach the total depth of the well, and a ninth was used for reaming. When bits wore dull they were sharpened by hard-surface welding at Umiat camp. An unsuccessful attempt was made to

core with a basket on tubing; it probably failed because there was no way of cleaning out cuttings.

DRILLING FLUID

A small amount of Aquagel was used to help drill through the surface gravel. Below that, brine made of 35 pounds of rock salt to 53 gallons (1 bbl) of water made the drilling fluid. One barrel of brine filled 3 bailers, and 1 bailerful was used with every 2–3 feet of hole drilled, so a 100-pound sack of salt was used with every 2–25 feet of hole drilled. Enough brine was kept in the hole to cover the cable tools. A total of 3,000 pounds of salt was used in the well.

ELECTRIC LOGGING

A Widco electric log was made after drilling had been abandoned, and the hole filled with Aquagel. Only 307 feet was logged (from 35 to 342 ft) because the sonde would go no deeper; it was probably blocked by cavings. It had been impossible to make an electric log before, because of the salt water put into the hole.

TEMPERATURE MEASUREMENT STUDIES

By Max C. Brewer

Two thermistor cables, the longest reaching to 700 feet, were installed in Umiat test well 6 on December 11, 1950. Two months later two short thermistor cables were installed in the upper air-filled (46 ft) part of the hole (now sealed at 7.2 ft) to give more detailed near-surface temperature measurements.

The thermal profile at Umiat test well 6 is characterized by two different gradients within the permafrost zone. The slope of the profile between 100 and 225 feet in depth is approximately 93 feet per degree centigrade, and the slope between 250 and 700 feet is approximately 117 feet per degree centigrade.

A short extrapolation of the thermal profile obtained at this site indicates that the bottom of permafrost is at a depth of approximately 770 feet. This is believed to be very close to the true depth of permafrost in this part of the Colville River valley as the temperatures at the greater depths should be very close to their normal equilibrium temperatures. It is probable that the depth of permafrost at this site has been affected by the nearness and consequent warming effect of the Colville River. Data from installations farther from the river lend considerable support for such a hypothesis and indicate that approximately 900 feet is a more normal depth of permafrost in this area when the effect of the river is removed.

The cooling curves (time vs. temperature at a given depth) for this cable-tool hole have very little in common with the cooling curves obtained at any of the rotary drill holes that penetrated to or through the bottom of permafrost. The temperatures at all depths within this hole have returned to within a few tenths of a degree centigrade of equilibrium temperatures within 3 weeks after abandonment of the hole and the installation of the first thermistor cables. This is in contrast to the several months required for temperatures in rotary-drilled holes of similar depth to return to within the same few tenths of a degree centigrade of equilibrium. These observed differences in the time of cooling in cable-tool and rotary-drilled holes is explained by the circulation of "warm" drilling fluid in rotary holes, whereas there is no similar degree of circulation of warm fluid in the cable-tool holes. The circulating warm fluid can, and does, lose a much greater amount of heat to the area surrounding the rotary holes than does the near stationary fluid in the cable-tool holes.

The trends in the cooling curves at depths of 500–700 feet were smooth until May 12, 1951, when the temperatures observed at 575, 650, 675, and 700 feet indicated a very marked departure from previous trends. On May 24 the temperatures at the same depths had returned almost to normal while the temperature at 600 feet showed an abnormal decrease. On June 7 the temperatures at all depths were continuing their previously established trends.

The above depths outline two sand units that are present at both Umiat test well 6 and Umiat test well 5, where considerable fluid was being added the last week in April 1951. As test well 5 is close to test well 6 and the sands dip from 5 toward 6, preliminary interpretation makes it seem reasonable that the fluid that was added to Umiat test well 5 caused some displacement of fluid near, and in, Umiat test well 6. From the results to date it seems that the displacement was upward at 575 and 650 feet and downward at 600, 675, and 700 feet in Umiat test well 6. Although the temperature variations were on the order of 0.10°C, it is not believed possible for heat conduction alone to be active over this vertical distance in so short a time without leaving any lingering evidence. Other temperature fluctuations were noted between depths of 600 and 650 feet from July through October 1951. It is thought that these fluctuations can also be traced to activity at Umiat test well 5.

Should the above interpretation be correct, it would indicate that at least two unfrozen units having temperatures below 0°C lie well within the so-called permafrost zone at Umiat test well 6.

UMIAT TEST WELL 7

Location: Lat 69°22′33″ W., long 152°06′17″ W.
Elevation: Ground, 326 feet; derrick floor, 330 feet.
Spudded: December 14, 1950.
Completed: April 12, 1951; dry and abandoned.
Total depth: 1,384 feet.

Umiat test well 7, about 1,300 feet southwest of Umiat test well 6, is the southernmost well on the Umiat anticline and is low enough structurally to have water in those sandstone beds of the Grandstand formation which contain oil where structurally higher. It was spudded in alluvium of the Colville River, and the drill penetrated the Seabee formation of Late Cretaceous age at about 50 feet. The top of the Ninuluk formation is at 390 feet; and the lower part of the sandstone contained a slight show of oil. The base of the formation is at 515 feet. Below the Killik tongue of the Chandler formation, present between 515 and 795 feet, the Grandstand formation was drilled to the bottom of the hole, but neither the upper nor the lower sandstone beds contained any oil. After attempting to shut the water off, an unsuccessful fishing operation (necessitated in part by tools catching in an ice and gravel bridge) resulted in the abandonment of the hole. The purpose of the test had been attained, however, as it determined the southern extent of the producing area of the field.

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

[Where no cores are listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
-----	0–4	Derrick floor to ground.
-----	4–35	Pebbles, rounded, ⅛- to ½-in. in diameter; composed of black chert, pale-yellowish-brown sandstone, and medium-gray quartzite of very fine- and fine-grained chert and clear quartz sand.
-----	35–39	No sample. This unit described by the drillers as "river gravel."
-----	39–52	No sample. This unit described as "gravel and sandstone."
-----	52–65	No sample. This unit described as "silty shale." Top of Seabee formation is placed at 50 ft.
-----	65–70	Siltstone, medium-gray, noncalcareous; and dark-gray silty slightly micaceous fissile clay shale.
-----	70–90	Clay shale, medium-dark-gray, slightly to very silty, micaceous, noncalcareous.
-----	90–95	Sandstone, medium-gray, very fine-grained, silty, friable; composed of angular grains of clear and white quartz and dark rock fragments with abundant pyrite.
-----	95–100	Clay shale, medium-dark-gray, slightly silty.
-----	100–105	Siltstone, medium-gray, very argillaceous, noncalcareous.
-----	105–110	Sandstone, very fine-grained, with common muscovite and abundant pyrite.
-----	110–115	Clay shale, slightly to very silty.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	115–145	Sandstone, medium-gray, very fine-grained, slightly silty, very calcareous, hard; composed of subangular clear and white quartz with some dark rock fragments. Grades through slightly calcareous, very silty sandstone to noncalcareous siltstone at base.
-----	145–155	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous.
-----	155–160	Sandstone, medium-gray, very fine-grained, silty, friable, with abundant pyrite.
-----	160–165	Clay shale, with some sandstone.
-----	165–170	Clay shale with siltstone.
-----	170–175	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous; slightly calcareous in part; composed of clear and white quartz with dark rock fragments and rare pyrite.
-----	175–180	Clay shale, very silty; and medium-gray very argillaceous noncalcareous siltstone.
-----	180–185	Siltstone, medium-gray, slightly sandy, very argillaceous, noncalcareous.
-----	185–190	Siltstone, with small amount clay shale.
-----	190–250	Siltstone, slightly to very argillaceous; calcareous at 205 ft. Pyrite common at base; very small amount of clay shale and rare sandstone at 205 ft.
-----	250–255	Sandstone, medium-light-gray, very fine-grained, argillaceous, silty, micaceous, noncalcareous; composed of subangular clear and white quartz, gray and dark rock fragments.
-----	255–260	Siltstone, with very fine-grained sandstone and shale.
-----	260–270	Sandstone, with some clay shale in lower part.
-----	270–275	Clay shale with some siltstone and rare sandstone.
-----	275–280	Sandstone, with rare clay shale.
-----	280–315	Sandstone, with some shale and siltstone. Greenish-white and bluish-white bentonite with minute scattered biotite flakes rare at 295 and 310 ft.
-----	315–320	Siltstone, medium-gray, very argillaceous, with small amount of clay shale and rare bentonite.
-----	320–325	Siltstone and clay shale.
-----	325–330	Siltstone, with very small amount of shale and rare bentonite.
-----	330–340	Clay shale, slightly to very silty, with very small amount of siltstone in lower part and rare bentonite and clay ironstone.
-----	340–345	Siltstone, slightly to very argillaceous; calcareous in part.
-----	345–355	Clay shale, slightly to very silty, with rare siltstone.
-----	355–360	Clay shale with yellowish-brown noncalcareous clay ironstone.
-----	360–365	Clay shale with small amount of light-blue-gray bentonite.
-----	365–370	Clay ironstone, brownish-gray, noncalcareous, with conchoidal fracture; small amount of clay shale present.
-----	370–375	Clay shale with small amount of clay ironstone.
-----	375–380	Clay shale with siltstone and very small amount of bluish-white bentonite.
-----	380–385	Siltstone, medium-gray, sandy, slightly argillaceous, noncalcareous.
-----	385–390	Clay shale, medium-dark-gray, with small amount of siltstone and rare sandstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	390–400	Sandstone, medium-light-gray, fine- to very fine-grained, slightly micaceous, noncalcareous, friable; composed of subangular clear and white quartz with dark rock fragments, and rare pyrite. Top of Ninuluk formation at 390 ft.
-----	400–405	Sandstone, fine- to very fine-grained, slightly silty, noncalcareous, with siltstone and shale.
-----	405–415	Clay shale; slightly to very silty in part; rare black carbonaceous shale with coaly partings.
-----	415–435	Sandstone, medium-light-gray, fine- to very fine-grained, slightly argillaceous, slightly micaceous, noncalcareous, friable; composed of subangular clear and white quartz and gray and dark rock fragments, with rare pyrite.
-----	435–440	No sample.
-----	440–445	Siltstone, medium-light-gray, with common carbonaceous and micaceous partings: sandstone and clay shale rare.
-----	445–490	Sandstone, medium-light-gray, very fine-grained, slightly silty, noncalcareous, friable; clay ironstone rare.
-----	490–515	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous, with rare clay ironstone at base. Clay ironstone contains structureless oolite-shaped pellets of calcite, similar to those at 350 ft in Umiat test well 6.
-----	515–545	Clay shale, with small amount of siltstone and very small amount of black shiny to dull coal with shaly to blocky fracture at base. Top of Killik tongue of Chandler formation at 515 ft.
-----	545–550	Sandstone, medium-light-gray, fine-grained, silty, argillaceous, calcareous; composed of subangular clear and white quartz, gray chert, dark rock fragments, and pyrite.
-----	550–555	Clay shale, slightly silty.
-----	555–560	Clay shale and sandstone, very fine-grained, silty, argillaceous, slightly to moderately calcareous.
-----	560–570	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, slightly calcareous.
-----	570–575	Clay shale, slightly silty in part.
-----	575–580	Clay shale, slightly to very silty, with small amount of medium-light-gray fine-grained sandstone.
-----	580–585	Clay shale.
-----	585–595	Clay shale with very small amount of very argillaceous siltstone.
-----	595–600	Siltstone, medium-gray, very argillaceous, noncalcareous.
-----	600–605	Clay shale, medium-dark-gray, fissile.
-----	605–610	Sandstone, medium-light-gray, fine-grained, slightly silty, very slightly calcareous, friable.
-----	610–635	Clay shale, slightly to very silty.
-----	635–640	Siltstone, medium-gray, very argillaceous, noncalcareous.
-----	640–645	Clay shale, very silty.
-----	645–650	Siltstone and clay shale.
-----	650–660	Clay shale, with very small amount of clay ironstone in upper part and very small amount of siltstone and rare coal in lower part.
-----	660–695	Sandstone, medium-light-gray, fine-grained; grades to fine to very fine grained at 670 ft; noncalcareous; friable; composed of subangular clear and white quartz with some gray and dark rock fragments. Black carbonaceous shale rare at 665 ft, and medium-dark-gray clay shale at 675 ft.
-----	695–720	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous.
-----	720–725	Clay shale, with small amount of siltstone.
-----	725–730	Sandstone, medium-light-gray, fine- to very fine-grained, silty, argillaceous, slightly calcareous, with carbonaceous partings.
-----	730–755	Clay shale, medium-dark-gray, noncalcareous; some is dark gray and fissile at base of unit.
-----	755–760	Sandstone, with small amount of medium-dark-gray clay shale and dark-gray fissile clay shale with carbonaceous partings.
-----	760–775	Sandstone, light-olive-gray, very fine-grained, silty, argillaceous, noncalcareous, with rare clay shale.
-----	775–780	Clay shale, with some siltstone.
-----	780–790	Clay shale, slightly to very silty.
-----	790–795	Sandstone, medium-gray, very fine-grained, very silty; and medium-light-gray sandy argillaceous siltstone.
-----	795–820	Clay shale, medium-dark-gray, with rare siltstone at 815 ft. Top of Grandstand formation at 795 ft.
-----	820–825	Sandstone, light-olive-gray, fine-grained, very silty and argillaceous, with small amount of clay shale, part of which is black, carbonaceous.
-----	825–830	Sandstone and clay shale with rare light-bluish-gray bentonite.
-----	830–834	Sandstone as above.
1	834–838	Recovered 4 ft: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, sericitic, noncalcareous, massive; composed of subangular grains of clear and white quartz, with gray chert, dark rock fragments and rare carbonaceous particles.
-----	838–845	Sandstone with some clay shale and rare light-yellowish-gray argillaceous dense limestone.
-----	845–862	Sandstone as above.
2	862–867	Recovered 4 ft: Microfossils absent. Sandstone as in core 1.
-----	867–870	No sample.
-----	870–879	Clay shale with rare bentonite.
3	879–880	Recovered 1 ft: Microfossils absent. Sandstone as in core 1; thin-bedded.
-----	880–890	Clay shale, slightly to very silty, with rare bentonite.
-----	890–895	Clay shale with sandstone and rare bentonite.
-----	895–910	Siltstone, medium-gray, sandy, argillaceous: slightly calcareous in part; some clay shale and very small amount of bentonite.
-----	910–915	Clay shale, medium-dark-gray.
-----	915–930	Sandstone, medium-light-gray, fine- to medium-grained at top; grades to fine- to very fine-grained at base; slightly silty and argillaceous; composed of clear and white quartz and gray and dark rock fragments and small amount of brownish quartz. Clay shale increases from rare at top to half of the rock at base.
-----	930–935	Clay shale.
-----	935–945	Clay shale with some siltstone and rare sandstone at base.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	945–950	Sandstone, with rare clay shale.
-----	950–995	Clay shale, slightly to very silty, with rare siltstone in upper third.
-----	995–1, 025	Siltstone, argillaceous, very slightly calcareous, with rare clay shale at top grading to silty clay shale with small amount of argillaceous siltstone at base.
-----	1, 025–1, 057	Clay shale, medium-dark-gray, very silty; makes up a tenth to four-fifths of every sample; and medium-gray very argillaceous siltstone. Each averages about half of the rock.
4	1, 057–1, 060	Recovered 1 ft: Microfossils rare. Clay shale, medium-dark-gray, very silty, sandy, micaceous, noncalcareous, with scattered particles of coal.
-----	1, 060–1, 070	Clay shale with some siltstone.
-----	1, 070–1, 120	Clay shale, with very small amount of sandstone; siltstone and bluish-white bentonite in upper part.
-----	1, 120–1, 125	Siltstone, with small amount of clay shale and very small amount of bluish-white bentonite.
-----	1, 125–1, 160	Clay shale, slightly to very silty, with small amount of argillaceous siltstone at 1,135 and 1,160 ft and microscopic light-brown shiny clay ball at 1,160 ft.
-----	1, 160–1, 165	Siltstone, with small amount of clay shale.
-----	1, 165–1, 170	Sandstone, medium-light-gray, very fine-grained, silty and argillaceous, slightly calcareous, with some siltstone and silty clay shale.
-----	1, 170–1, 175	Clay shale, very silty, with some very argillaceous siltstone.
-----	1, 175–1, 180	Clay shale, with small amount of sandstone.
-----	1, 180–1, 195	Clay shale with small amount of siltstone in upper part and small amount of sandstone at base.
-----	1, 195–1, 200	Clay shale, dark-gray, carbonaceous.
-----	1, 200–1, 211	Sandstone, medium-light-gray, fine-grained, slightly silty, noncalcareous; composed of subangular clear and white quartz with gray and dark rock fragments.
5	1, 211–1, 215	Recovered 2 ft: Microfossils absent. Sandstone, medium-light-gray, fine-grained, silty, argillaceous, noncalcareous, with rare carbonaceous partings; composed of subangular clear and white quartz with some dark rock fragments.
-----	1, 215–1, 295	Sandstone as above.
-----	1, 295–1, 300	Clay shale, with small amount of siltstone.
-----	1, 300–1, 310	Siltstone, medium-gray, very argillaceous, noncalcareous, with some medium-dark-gray clay shale.
-----	1, 310–1, 315	Sandstone, medium-light-gray, very fine-grained, noncalcareous, friable, pyritic.
-----	1, 315–1, 325	No sample.
6	1, 325–1, 327	Recovered 4 in.: Not sampled for microfossils. Sandstone, medium-light-gray, very fine-grained, very argillaceous and silty; composition as in core 5 above.
-----	1, 327–1, 349	Sandstone as above.
7	1, 349–1, 352	Recovered 2 ft 6 in.: Not sampled for microfossils. Sandstone, medium-light-gray, fine- to very fine-grained, argillaceous, massive.
-----	1, 352–1, 370	Sandstone as above.
8	1, 370–1, 372	Recovered 1 ft 8 in.: Not sampled for microfossils. Sandstone as above, fine-grained.
-----	1, 372–1, 384	Sandstone as above.

CORE ANALYSES

Analyses given in the table below were made with the equipment described on page 127.

Analyses of core samples from Umiat test well 7

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
838	13. 8	<1
1,215	9. 7	0
1,327	10. 4	<1
1,349	11. 2	19. 2
1,372	10. 1	0

OIL AND GAS

OIL AND GAS SHOWS

Several shows of oil and gas were noted in this well, but none were of commercial value. The same sandstone beds that are oil bearing higher on the Umiat anticline are water bearing at Umiat test well 7. When the total depth was 1,384 feet and the hole was being bailed from 275 to 750 feet, gas was noted in the bailer at 260 feet; there was enough in the bailer to burn for a minute. There were also slight shows of oil at 949–955, 1,000–1,008, and 1,072–1,089 feet, with an odor of oil at 1,165 to 1,168 feet, and oil shows in the sandstone reached at 1,200 feet. Below 825 feet, however, a large amount of water entered the hole, with no oil except for a very small amount in the first bailing test at 833 feet.

FORMATION TESTS

The many bailing tests made in this hole were for measuring and removing water in the hole. They are discussed in detail in connection with drilling operations. Only three tests recovered oil: a very little oil in a 20-minute bailing test at 530 feet, 20 gallons recovered at 650 feet, and 70 gallons of oil and water entered the hole in 1¾ hours at 833 feet.

LOGISTICS

Personnel and housing.—Supervisors of the personnel consisted of a drilling foreman and a geologist. The drilling crews were composed of 2 drillers, 2 tool dressers, and 2 firemen. Other workers, such as a welder to dress the drill bits, a mechanic, a bulldozer operator, cementer, and laborers, were supplied by Umiat camp when they were needed. The drilling personnel was housed and fed at Umiat camp. At the well site, wanigans were used to house the cement pump, boiler, and water tank.

Vehicles and heavy equipment.—Vehicles such as Caterpillar tractors, LVT's (landing vehicle, tracked), cranes, weasels, and trucks were brought from Umiat camp as they were needed. One each of the following

major items of drilling equipment was listed by the Arctic Contractors as having been used.

Bucyrus-Erie cable-tool rig, model 29–W.
Caterpillar diesel engine (power supply for rig).
Generator, 15 kw.
Caterpillar D3400 diesel engine (power supply for generator).
Heat-Pak boiler, model 624–S.
Westco boiler feed pump (with Heat-Pak boiler).
Gardner-Denver, 5½- by 10-inch pump, for cementing.
Caterpillar D8800 diesel engine (power supply for Gardner-Denver pump).

Fuel, water, and lubricant consumption.—Figures given here combine estimated consumption of material for the first 4 weeks with recorded consumption for the time thereafter. Diesel fuel consumed was 15,054 gallons; gasoline, 3,559 gallons; and water, 146,000 gallons. Ninety pounds of grease and 184 gallons of No. 9170 lubricating oil were also consumed.

DRILLING OPERATIONS

The Bucyrus-Erie cable-tool drilling rig was mounted on a sled and pulled to the well site by a D8 Caterpillar tractor. The sled was then mounted on 12- by 12-inch timbers resting on a layer of gravel. While drilling the hole many bailing tests and measurements of fluid level were made to test fluid entry into the hole and to lower the water level.

DRILLING NOTES

Information presented in this section was recorded by John C. Bollenbacher, of Arctic Contractors.

Notes from drill records

Depth (feet)	*Remarks*
39.5	Hole drilled to 15 ft; set conductor pipe made of oil drums to prevent caving of surface gravel. At 16 ft 1 joint of 11¾-in. 47-lb casing with drive shoe on bottom was put in hole. Hole drilled to 39.5 ft with 10¾-in. bit; casing driven down to that depth.
52	Casing driven to 52 ft and cemented around shoe with 10 sacks and around top with 2 sacks of Cal-Seal.
67	Ten-inch gate valve and swage nipple installed on top of casing.
135	Three hours spent repairing engine.
440	Fluid bailed out of hole, and none entered in 3 hr.
453	Steam lines thawed and repaired in 6 hr.
485	Seven sacks of salt used to make brine for drilling below 485 ft; above that depth drilling was done with fresh water.
530	Bailed 20 min; found very little oil.
650	Bailed fluid down and recovered 20 gal of oil; after standing 2 hr, bailed 8 gal of water.
780	No water recovered in 3-hr bailing test.
827	In 5 bailing tests for water, 70 gal recovered after 1 hr; 55 gal, after 1½ hr; 40 gal, after 1 hr; 40 gal in another hour; and 30 gal after 1½ hr.

Notes from drill records—Continued

Depth (feet)	*Remarks*
833	Bailed hole dry after finding fluid level at 768 ft. In 1¾ hr, 70 gal of oil and water entered hole and was bailed out. Bailing and checking fluid levels for 10 hr showed a 30-ft rise in 2 hr.
838	Fluid level at 765 ft lowered by bailing 392 gal of water, but 3½ hr later level was up to 768 ft, and 170 more gal of water were bailed. Although hole was bailed dry, an hour later 40 gal of water were bailed out. Clutch shaft and gear sent to Barrow for repairs, and shut rig down 3 days waiting for it. Fluid level then at 508 ft, and bailed out 1,260 gal of water. Twenty feet of cavings cleaned out before resumption of drilling.
850	Fluid rose 25 ft in 1½ hr; bailed out 50 gal of water.
867	In attempt to shut off the water, wooden plug driven to top of rathole at 827 ft, with 10 sacks of cement on top. Fluid level at 592 ft, after the hole stood cemented 12 hr, and after bailing 72 gal of oil and 1,224 gal of water, hole was dry. Oil temperature 30°F; and water 32°F. Two hours later, fluid level at 742 ft, and bailed 190 gal of water, showing plug to be unsuccessful. Only 2 ft of hard cement found in hole, and while setting second plug, dump stick lost in hole. Seven sacks of cement put in and allowed to set before dump stick was drilled up. Another wooden plug then placed at 827 ft. Twelve sacks of construction cement with 4 percent by weight of calcium chloride put in hole, but it went beyond the plug on down the hole. Plug and cement drilled out of hole to 867 ft.
910	Water with temperature of 30°F stood at 557 ft.
927	Drilling line changed, as one in use badly worn after drilling 242 ft of hole. Water level at this depth was 564 ft.
979	Water level, at 525 ft, was high enough to slow down drilling somewhat; drilling made even slower by bentonitic beds which made thick mud in hole.
1,039	Water level at 551 ft.
1,057	Water level at 554 ft.
1,072	Water level at 534 ft.
1,105	Water level at 494 ft.
1,147	Water level high (492 ft), partly because less bailing of heavy mud was necessary. Water brackish.
1,170	Water level at 525 ft.
1,190	Water level at 502 ft.
1,204	Oil level at 494 ft; water level at 514 ft.
1,215	Oil level at 411 ft; water level at 449 ft. Fluid from top of column had a temperature of 30.5°F, while that from the bottom of the hole was 40°F.

Notes from drill records—Continued

Depth (feet)	Remarks
1,235	Ice reamed from casing shoe to 838 ft. Drilling line broke, leaving 500 ft of line and tools in hole, but fish recovered. Thick heavy mud bailed from 350 to 700 ft. Drilling line broke again while reaming hole at 840 ft, leaving 100 ft of line and tools in hole. After unsuccessful fishing attempt, shut down well for 40 hr waiting for drive-down socket from base camp at Barrow. After shutdown, ice found at 350 ft and drilled from there to 798 ft. Fish recovered, and hole cleaned out to 840 ft, with heavy mud and ice being removed.
	New drilling line put on, and hole reamed with 10-in. bits to 325 ft. Ice reamed from 100 to 225 ft, and hole reamed on down, straightening key seat at 430–470 ft. Bit stuck at 660 ft, and drilling line broke. Fish recovered, but while reaming at 890 ft, line broke again, dropping tools down hole. Tools lost and recovered twice more, at 960 ft and 990 ft; new drilling line installed at 990 ft. Two makes of line were spliced together, but splice failed three times, leaving tools in hole the third time. After they were recovered, line broke and was replaced by still another line, which broke at 1,080 ft, and tools again fished from hole.
	While reaming at 1,095 ft, thick mud bailed from hole, after which ice had to be reamed from 100 to 150 ft. At 1,099 ft tools stuck and splice parted; line in hole was damaged in removing fish. While cleaning hole, bailer stuck at 100 ft and sand line parted, but recovered bailer. After waiting 12 hr for it, installed a new drilling line, and reamed hole to a 10-in. diameter to 1,200 ft, and cleaned with 6-in. bit to 1,235 ft.
	Steamed out ice around 11¾-in. casing; removed gate valve, and after waiting a day for a cementer, set 61 joints of 6⅝-in., 24-lb casing at 1,196 ft, with Baker Cement Washdown Whirler float shoe on bottom. Made brine with 13°F freezing point with 5,000 lb of salt in 90 bbl of water; 50 bbl of brine used to displace mud in hole. Some difficulty was experienced in making the brine, because the pumps froze in a cold wind, the first day it was attempted. A hundred sacks of portland cement, mixed with water treated with 2½ percent of calcium chloride, put in hole, followed by remaining 40 bbl of brine.
	Installed 6-in. gate valve and bailed brine down to top of cement. Casing dry, but when plug was drilled from top at 1,195–1,197 ft, water rose to 1,001 ft in 2 hr and continued to enter hole during bailing at a rate as high as 5¼ bbl per hr. Fluid rose to 812 ft in 6 hr and to 710 ft in 8½ hr, with casing bailed dry each time. Salinity of water 3,300 ppm sodium chloride, about the same as that of water sampled when hole was 867 ft deep.
	Pumped 4 bbl of oil into annulus between 6⅝-in. casing and surface pipe, but none returned. Meanwhile, water level rose to 390 ft. Attempted to break circulation of water with 1,000 psi of pressure, but only result was destruction of plug, leaving hole open below shoe.
	After reaming ice from 400 to 800 ft, hole was filled with half a barrel of gravel to 1,205 ft, with 2 sacks of Cal-Seal on top capping bridge at 1,202 ft. Water and sand bailed out, but after standing over night, water level rose to 327 ft. Water bailed for 15 hr, and another unsuccessful attempt made to stop circulation with pressure of 1,000 psi.
	Water containing 4½ percent of calcium chloride by weight was mixed with portland cement and put in hole. Only about half a barrel of fluid (equivalent to 2 sacks of cement) was forced down, with a pressure of 1,000 psi. After cement set, hole was bailed dry, and remained so for 10 hr. However, when cement bridge at 1,207–1,210 ft was drilled, tools dropped through to 1,213 ft, and water entered hole immediately; bailing 300 gal in 45 min did not lower water level. After 2½ hr water rose to 991 ft, and to 932 ft 1 hr later. Estimated rate of water entry 125 gal per hr, and its salinity was 4,125 ppm of sodium chloride.
	Water continued to enter hole for 2 days at a rate that gradually declined to 90 gal per hr. Ice reamed from 350 ft of casing, and gravel bridge from 1,215 to 1,235 ft drilled out. Water rose to 400 ft in 21 hr after hole was bailed dry.
	Tools stuck in ice at 400 ft and were thawed loose with warm brine.
1,258	Rate of water entry into well increased noticeably below 1,250 ft.
1,277	Ice forming in casing made it necessary to drill only short intervals; two bits were battered before ice was reamed down to 140 ft. Water level rose to 283 ft, and when bailed down to 500 ft, 129 gal entered hole first hour, and 100 gal the second.
1,278	With water bailed down to 500 ft again, water entered at rate of 143 gal per hr for 1½ hr.
1,327	Water level rose from 400 to 280 ft in 2 hr.
1,335	Water level rose from 500 to 418 ft in 3 hr, and to 300 ft in 5½ hr more.
1,380	Fluid level at 310 ft.
1,384	Fluid level at 285 ft. After bailing to 500 ft fluid rose to 420 ft in 2 hr and to 355 ft in 4 hr more, reaching 271 ft the next day. After running an electric log, 300 ft of ice was reamed from casing.
	Sidewall packer on tubing was run to 1,318 ft with 66 ft of tailpipe, including 15 ft of perforated tubing on bottom. Annulus between 6⅝-in. casing and tubing filled with

Notes from drill records—Continued

Depth (feet)	*Remarks*
	brine having a freezing point of 18°F, and fluid rose in tubing. After swabbing 1 hr, recovered fluid with 7,344 grains sodium chloride per gal. Packer did not hold, so pulled tubing out of hole. It was rerun with sidewall packer at 1,325 ft, and 59 ft of tailpipe, including 15 ft of perforated tubing, on bottom. When annulus between casing and tubing was filled with brine, fluid rose to same level inside tubing and tubing was again pulled out.
	Fluid bailed from 275 to 750 ft, and bailing 22 hr more brought level to 1,030 ft, but could not be lowered farther. Salinity dropped to 232 grains of sodium chloride per gallon.
	Tubing was rerun to 1,380 ft. With fluid level at 485 ft, very viscous mud (240 gal of water with 225 lb of Aquagel) was pumped to bottom of hole; fluid level rose to 88 ft. Pulling tubing up to 1,200 ft and swabbing removed excess mud and lowered fluid level to about 1,203 ft. Cement was mixed with 37.5 gal of water at 100°F that contained 4 percent of calcium chloride, mixture placed at 1,203 ft, and tubing pulled out. Fluid level then at 256 ft. After 27 hr, bailer was lowered, but cement was not encountered; bailer stopped at 1,348 ft.
	Hole was being filled with gravel to 1,200 ft, when tools caught in an ice and gravel bridge at 340 ft and could not be pulled free in spite of hot brine poured into hole. Drilling line cut and top of bridge and fish steamed through tubing for 22 hr; but fish, although ice-free at top, was covered with gravel and could not be pulled out. After 7 hr more of steaming and 5 hr of circulating with viscous mud, hole was bailed to top of fish, filled with brine having a 1°F freezing point, and abandoned. Ice was steamed from sled runners under rig, and rig moved away from hole. A 6⅝-in. coupling put on top of casing, and 6⅝- by 18-in. nipple on coupling. A 1- by 6-in. nipple was welded in a plate on larger nipple, and capped with 1-in. gate valve. Whole assembly extends 30 in. above ground.

DRILL AND CORE BITS

Of the drill bits used in Umiat test well 7, 13 were used in reaming the hole, either to enlarge it to drill cement or to remove ice from the sides. Bits 7–33 [3] were California type, except for nos. 14 and 15, which were reamers. The first 6 were not listed by type. When worn the bits were redressed at Umiat camp. At some depths one bit was used for short alternate intervals of drilling and reaming; to avoid confusion on the graphic log (pl. 12), these bits are shown as having drilled only. Bits 8, 20, and 29 are omitted from the log because they were used only to clean out the hole.

The cores were made with a Baker cable-tool core barrel, using two 5¾-in. core bits; 65 percent of the rock cored was recovered.

DRILLING FLUID

Above 485 feet the hole contained a small amount of fresh water. From 485 to 825 feet enough brine was kept in the hole to cover the tools; at that depth water entered the hole from the formation in quantities large enough to keep fluid in the hole to within a few hundred feet of the top. The water was probably brackish, although determinations were not very dependable because of the brine put into the hole.

ELECTRIC LOGGING

Two Widco electric-log runs were made in the well, the first between 370 and 1,235 feet and the second between the bottom of the casing, at 1,196 feet, and 1,378 feet. The top of the first run was no higher than 370 feet because that was the top of the fluid in the hole.

UMIAT TEST WELL 8

Location: Lat 69°23′59″ N., long 152°06′56″ W.
Elevation: Ground level, 735 feet; derrick floor, 740 feet.
Spudded: May 2, 1951.
Completed: August 28, 1951. Pumped 60 to 100 barrels of oil per day; gas estimated more than 6 million cubic feet per day; shut-in pressure 275 pounds per square inch. Shut in.
Total depth: 1,327 feet.

Umiat test well 8 was drilled to determine the quantity and quality of oil and gas in the sandstone of the Grandstand formation near the crest of the anticline and to learn more about the structure of the anticline. The well was drilled with cable tools on a hill about 400 feet above the Colville River flats and a little more than a mile northwest of Umiat test well 2.

DESCRIPTION OF CORES AND CUTTINGS

The well was spudded in Quaternary alluvium, beneath which a 40-foot thickness of Seabee(?) formation (20 to 60 feet) was found. Below this are a 90-foot bed of sandstone and about 20 feet of shale which are considered to be part of the Ninuluk formation (60–170 ft); the sandstone is composed of subangular clear and white quartz, gray chert, dark rock fragments, and a few yellow quartz grains typical of the Nanushuk group. Coaly shaly beds from 170 to about 390 feet resemble the Killik tongue of the Chandler formation.

[3] A discrepancy is present in the record; bit 27 is listed as a 6-in. bit used to clean out the hole from 1,200–1,265 ft and to drill cement from 1,207–1,210 ft. The next reference to the bit, however, describes it as a 5⅝-in. bit, with which the hole was cleaned out and deepened to 1,241 ft. Below 1,241 ft, bits are numbered consecutively until the hole was abandoned. It has been assumed that no. 27 was a 5⅝-in. bit.

Shale beds beneath them contain microfossils in a core which are diagnostic of the Colville group. The lithology of this sequence of rocks suggests the presence of a thrust fault above 400 feet, with the Seabee formation (Colville group) overlain by rocks of the Nanushuk group; contacts shown on the graphic log (pl. 12) are based on this assumption. Some of the paleontologic data is at variance with this interpretation (see p. 202); Foraminifera from a core at 195–200 feet are diagnostic of the Colville group. Nevertheless, a foot of coal just below the siltstone of the same core is atypical of the Seabee formation but is characteristic of the Killik tongue. Unfortunately, no electric log was made of the well for additional information on the stratigraphy, and the thrust fault is arbitrarily placed at 350 feet.

Beneath 390 feet a normal sequence of beds was found; the Seabee formation is present from 350 (?) to 445 feet and is underlain by the Ninuluk (445–555 ft), the Killik tongue of the Chandler formation (555–840 ft), and the Grandstand formation (840 ft to the total depth).

Sandstone of the Ninuluk formation contained slight shows of oil both above and below the fault. Oil from the upper sandstone bed of the Grandstand formation averaged about 60 barrels per day on a pumping test; the lower sandstone bed yielded a flow of gas measured at about 5,858,700 cubic feet per day through a 1½-inch orifice. These amounts of gas and oil may be less than the actual producing capacity of the well, because icing and other difficulties reduced the fluid flow during testing. After casing was set at 1,231 feet, no oil or water was produced with the gas. When the well was shut in, the gas pressure rose gradually to 275 pounds per square inch.

Lithologic description

[Where no cores are listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
-----	0–5	Rig floor to ground level.
-----	5–20	Black chert pebbles, and rounded to subangular clear and white quartz sand grains. Pebbles may have come from a mat of gravel spread on ground to support drilling rig.
-----	20–30	Clay shale, medium-gray, slightly to very silty, noncalcareous, and light-olive-gray, very silty, calcareous. In the upper part, a very small amount of light-yellowish-brown very slightly calcareous clay ironstone, with conchoidal fracture; small amount of siltstone in lower part medium gray, slightly argillaceous, noncalcareous. Seabee formation found at 20 ft.
-----	30–35	Most of this sample consists of surface gravel—well-rounded pebbles of light-colored and black chert ⅛–¼ in. in diameter—which is not indicative of the formation penetrated; rest is clay shale, similar to that at 20–30 ft.
-----	35–45	Sandstone, medium-light-gray, fine- to very fine-grained, noncalcareous, friable; composed of subangular to angular clear and white quartz with dark rock fragments, chert, and rare pyrite. There is a small amount of medium-light-gray very argillaceous and sericitic siltstone.
-----	45–50	No sample.
-----	50–60	Clay shale, medium-gray, very silty, noncalcareous; medium dark gray in lower part. Very small amount of medium-light-gray very fine-grained argillaceous silty noncalcareous sandstone near base.
-----	60–65	Sandstone, medium-light-gray, noncalcareous, friable; composed of subangular clear and white quartz, gray chert, and dark rock fragments. Top of Ninuluk formation at 60 ft.
-----	65–75	Sandstone, light-olive-gray, fine-grained, noncalcareous, friable, with some light-brown and yellow quartz.
-----	75–80	Sandstone, light-yellowish-gray, very fine-grained, silty, argillaceous, very slightly calcareous, with abundant yellow and black grains.
-----	80–105	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous; very micaceous in part; very calcareous in upper part; friable in lower part.
-----	105–110	Sandstone and clay ironstone.
-----	110–120	Sandstone, medium-light-gray, fine-grained, slightly silty, noncalcareous, friable.
-----	120–125	No sample.
-----	125–150	Sandstone as above.
-----	150–160	Clay shale, medium-gray, very silty and micaceous.
-----	160–165	Clay shale, with some medium-gray sandy noncalcareous siltstone.
-----	165–170	Siltstone with some clay shale.
-----	170–180	Clay shale, medium-dark-gray, slightly to very silty. Top of Killik tongue of Chandler formation at 170 ft.
-----	180–185	Clay shale and grayish-black carbonaceous clay shale, with small amount of sandstone and very small amount of black shiny coal.
-----	185–190	Clay shale with some siltstone.
-----	190–195	Clay shale, medium-dark-gray.
1	195–200	Recovered 5 ft: Microfossils rare. 1 ft 5 in., clay shale, medium-dark-gray, very slightly silty, noncalcareous, with poor shaly cleavage to poor conchoidal fracture. 2 ft 7 in., siltstone, medium-light-gray, very sandy, argillaceous, with laminae of clay shale and very fine-grained sandstone. 1 ft, coal, black, shiny; conchoidal fracture.
-----	200–210	Clay shale, medium-dark-gray.
-----	210–215	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, calcareous, with small amount of black shiny blocky-fracturing coal.
-----	215–220	Clay shale, medium-dark-gray, with small amount of sandstone, siltstone, and clay ironstone.
-----	220–225	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, calcareous.
-----	225–230	Clay shale, medium-dark-gray.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	230–235	Siltstone, medium-light-gray, sandy, very slightly calcareous.
-----	235–240	Clay shale.
-----	240–250	Sandstone, light-gray, fine-grained (rarely medium-grained), noncalcareous, friable; composed of subangular clear quartz with some white quartz and dark rock fragments.
-----	250–290	Clay shale, medium-dark-gray and dark-gray, slightly to very silty and micaceous, noncalcareous, with small amount of siltstone at 255–260, and at 270–275 ft, and very small amount of sandstone at 275–280 ft.
-----	290–300	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, very micaceous, noncalcareous.
-----	300–320	Clay shale, medium-dark-gray, with small amount of siltstone, decreasing to rare with depth; very small amount of clay ironstone at 310–315 ft.
-----	320–325	No sample.
-----	325–330	Siltstone, medium-gray, argillaceous, sandy, noncalcareous.
-----	330–375	Clay shale, medium-dark-gray; slightly silty in part; noncalcareous; very small amount of sandstone at base. Top of Seabee formation at 350 ft.
-----	375–380	Sandstone, medium-light-gray, fine- to medium-grained, noncalcareous, friable; composed of subangular clear quartz with some white quartz and very rare dark rock fragments.
-----	380–400	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous.
2	400–405	Recovered 5 ft: Microfossils common. Claystone, medium-dark-gray; very slightly silty in part; noncalcareous; irregular to conchoidal fracture.
-----	405–445	Clay shale, with some medium-gray siltstone; calcareous at 420–430 ft.
-----	445–455	Sandstone, medium-light-gray, fine grained, silty, argillaceous, slightly calcareous; composed of subangular clear and white quartz and gray and dark rock fragments, with very small amount of clay shale. Top of Ninuluk formation at 445 ft.
-----	455–457	No sample.
3	457–462	Recovered 5 ft: Not sampled for microfossils. Sandstone, medium-light-gray, fine- to very fine-grained, silty, argillaceous, noncalcareous; massive in upper part; grades in lower part to very fine grained and thin-bedded.
-----	462–482	Sandstone as above, becoming very fine grained at base.
4	482–487	Recovered 5 ft: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, micaceous; massive to thin bedded; composed of subangular grains of clear and white quartz and gray and dark rock fragments.
-----	487–505	Sandstone as above, with small amount of clay shale in upper part.
-----	505–507	No sample.
5	507–512	Recovered 5 ft: Microfossils absent. Sandstone as in core 4.
-----	512–525	Sandstone as above, with very small amount of clay shale and clay ironstone; rare coal in upper part.
-----	525–532	Sandstone, medium- to fine-grained; composed of white and clear quartz with rare gray and dark rock fragments.

Lithologic description—Continued

Core	Depth (feet)	Remarks
6	532–537	Recovered 3 ft: Microfossils absent. Sandstone, medium-light-gray, fine-grained, slightly silty and argillaceous, noncalcareous, micaceous, massive, friable; composed of subangular clear and white quartz with some gray chert and dark rock fragments. Lower part of core badly infiltrated with drilling mud.
-----	537–547	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous.
-----	547–555	Clay shale, with some medium-gray noncalcareous siltstone.
-----	555–595	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous. Top of Killik tongue of Chandler formation at 555 ft.
-----	595–605	Clay shale with some siltstone.
-----	605–620	Sandstone, medium-light-gray, very fine-grained, very silty, argillaceous, calcareous, with clay shale in the upper 5 ft.
-----	620–635	Clay shale, medium-dark-gray, with small amount of sandstone.
-----	635–640	Sandstone, medium-light-gray, fine-grained; composed of subangular clear and white quartz with some dark rock fragments.
7	640–645	Recovered 5 ft: Microfossils very rare. Claystone, medium-dark-gray; very slightly silty in part, conchoidal fracture; faint silty laminae dip 13°.
-----	645–650	No sample.
-----	650–711	Clay shale, with very small amount of siltstone in upper part and some sandstone at 685–690 ft.
8	711–716	Recovered 5 ft: Microfossils very rare. Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, slightly micaceous, noncalcareous, thin bedded, with scattered flakes of coaly material; grades to fine grained at base.
-----	716–722	Sandstone, medium-light-gray, fine-grained.
-----	722–730	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous.
-----	730–745	Clay shale, medium-dark-gray, slightly to very silty, with some sandstone and small amount of siltstone in lower part.
-----	745–805	Clay shale, medium-dark-gray; slightly silty in part; rare siltstone at 770–775 and 800–805 ft and small amount of sandstone at 800–805 ft.
-----	805–810	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous.
9	810–815	Recovered 5 ft: Microfossils absent. Clay shale, medium-dark-gray, slightly silty; and very silty claystone and siltstone; all in ¼–1 in. fragments; rare light-gray bentonite fragments in lower part; fragments from base of core embedded in drilling mud.
-----	815–818	No sample.
-----	818–820	Clay shale and sandstone.
-----	820–830	Clay shale with very small amount of siltstone.
-----	830–840	Clay shale with medium-light-gray very calcareous sandstone.
-----	840–855	Clay shale, medium-dark-gray; slightly silty in part. Top of Grandstand formation at 840 ft.
-----	855–865	Clay shale, with small amount of siltstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	865–885	Sandstone, medium-light-gray, fine-grained, slightly silty and argillaceous, noncalcareous, friable, with rare clay shale in upper part.
-----	885–890	Sandstone, clay shale, and medium-gray argillaceous noncalcareous siltstone.
-----	890–895	Sandstone, very fine-grained, with some very silty clay shale.
-----	895–900	Clay shale, with some fine-grained sandstone.
-----	900–910	Sandstone, with some clay shale.
-----	910–920	Clay shale, slightly silty.
-----	920–930	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, noncalcareous.
-----	930–1,005	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous, with very rare siltstone and rare sandstone at 955–970 ft.
-----	1,005–1,010	Siltstone, medium-gray, argillaceous; calcareous in part.
-----	1,010–1,015	Clay shale, medium-dark-gray, slightly to very silty.
10	1,015–1,018	Recovered 3 ft: Microfossils absent. 2 ft 6 in., clay shale, medium-dark-gray, noncalcareous; slightly silty in part; in small fragments. 6 in., claystone, medium-dark-gray, noncalcareous, with conchoidal fracture; small carbonized plant fragments rare.
-----	1,018–1,038	Clay shale, slightly silty in part, with white bentonite at 1,030 ft.
11	1,038–1,041	Recovered 3 ft: Microfossils common. 2 ft 2 in., drilling mud with small fragments of medium-dark-gray clay shale as in core 10. 10 in., claystone as at base of core 10.
-----	1,041–1,061	Clay shale, slightly silty in part.
12	1,061–1,063	Recovered 1 ft: Microfossils abundant. Clay shale, medium-dark-gray; in fragments ½–2 in. in diameter; rare fragments of medium-light-gray very fine-grained sandstone and light-gray argillaceous bentonite.
-----	1,063–1,078	Clay shale, slightly to very silty.
13	1,078–1,080	Recovered 10 in.: Microfossils rare. Claystone, medium-dark-gray, noncalcareous, with subconchoidal fracture. A 1-in. nodule of brownish-gray noncalcareous clay ironstone at top of core.
-----	1,080–1,090	Clay shale, slightly to very silty.
-----	1,090–1,100	Siltstone, medium-gray, argillaceous, sandy, calcareous.
-----	1,100–1,120	Clay shale, slightly to very silty, with small amount of siltstone.
-----	1,120–1,125	Clay shale, slightly to very silty, with very small amount of light-brownish-gray slightly silty, very slightly calcareous clay ironstone.
-----	1,125–1,130	Siltstone, medium-gray, sandy, noncalcareous.
14	1,130–1,133	Recovered 1 ft 6 in.: Microfossils rare. Siltstone, medium- to medium-light-gray, argillaceous, noncalcareous.
-----	1,133–1,145	Clay shale, with small amount of siltstone.
-----	1,145–1,180	Clay shale, medium-dark-gray, slightly silty; brown crystalline limestone rare at 1,150 ft; some white bentonite at 1,170 ft.
-----	1,180–1,183	No sample.

Lithologic description—Continued

Core	Depth (feet)	Remarks
15	1,183–1,188	Recovered 3 ft: Microfossils very abundant. 10 in., drilling mud with small fragments clay shale. 2 ft 2 in., claystone, medium-dark-gray, noncalcareous, very slightly micaceous, with poor conchoidal fracture. Pelecypod shell fragment present.
-----	1,188–1,209	Clay shale, medium-dark-gray, with rare bentonite at 1,190 ft.
-----	1,209–1,215	Clay shale.
-----	1,215–1,216	No sample.
-----	1,216–1,230	Clay shale with very small amount of siltstone and small amount of clay ironstone at top.
-----	1,230–1,240	Clay shale and siltstone, medium-gray, very argillaceous, calcareous.
16	1,240–1,243	Recovered 3 ft: Microfossils common. Fragments of claystone, medium-dark-gray, noncalcareous, with rare fragments of light-gray argillaceous bentonite and medium-light-gray fine- to medium-grained slightly silty slightly calcareous sandstone; composed of clear and white quartz and dark rock fragments, with common grains of pyrite.
17	1,243–1,246	Recovered 2 ft.: Sandstone, medium-light-gray, fine- to medium-grained, slightly silty and argillaceous, noncalcareous. A 2-in. interval of medium-grained sandstone 1 ft below top of core contains rounded fragments (¼–¾-in. in diameter) of medium-dark-gray clay shale and carbonized plant fragments. Oil stain in lower 6 in.
-----	1,246–1,250	Sandstone, medium-light-gray, fine-grained, noncalcareous, friable; composed of subangular to subround clear and white quartz with some dark rock fragments and gray chert.
-----	1,250–1,260	Clay shale, with small amount of siltstone and sandstone.
-----	1,260–1,265	Clay shale.
-----	1,265–1,295	Sandstone, medium-light-gray, fine- to very fine-grained, argillaceous, silty, slightly micaceous, noncalcareous, friable. Some medium-gray very argillaceous sandy noncalcareous siltstone between 1,285 and 1,290 ft.
-----	1,295–1,296	No sample.
18	1,296–1,300	Recovered 4 ft: Microfossils very rare. 10 in., drilling mud with fragments of sandstone and medium-dark-gray clay shale. 3 ft 2 in., sandstone, light-gray, fine-grained, argillaceous, silty, micaceous, noncalcareous, massive; composed of subangular clear and white quartz with rare dark rock fragments.
-----	1,300–1,325	Sandstone, medium-light-gray, fine-grained, slightly silty, noncalcareous, friable, with very small amount of clay shale.
-----	1,325–1,327	No sample.

CORE ANALYSES

Analyses given in the table below were made with equipment described on page 127.

Analysis of core samples from Umiat test well 8

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
458	19.7	116
486	9.74	0
509	14.3	45
534	18.85	435

OIL AND GAS

OIL AND GAS SHOWS

Several shows of oil and gas were noted in this well by Arctic Contractors geologists, and the following notes were recorded during drilling operations.

Oil and gas shows, Umiat test well 8

Depth (feet)	Remarks
56–57	Sandstone has a faint odor of oil.
75–153	Faint odor of weathered Umiat crude oil in bailer samples.
172–487	Bailer samples and cores from this interval had an odor of oil, but no shows of oil or gas.
487–537	Good odor, fair fluorescence, and pale ether cut noted in sandstone.
810–815	Oil level rose to 630 ft on penetrating fractured shale at 810 ft.
1,015	Oil level rose to 615 ft; oil slightly gas cut.
1,243–1,253	Sandstone with good odor and light stain and cut of oil. As drilling progressed, oil flowed from sandstone into hole, and gas increased from light to fair blow, having closed-in pressure of 53 psi.
1,327	Strong blow of gas came from below casing at 1,231 ft.

FORMATION TESTS

The details of several bailing, pumping, and gas-volume tests made on the well are presented below. The information was recorded by John Bollenbacher and Marvin Heany, of Arctic Contractors. Results of bailing tests in the upper part of the hole are shown in the following table.

Bailing tests in the upper part of Umiat test well 8

Depth (feet)	Remarks
640	Recovered one-half a barrel of oil in an 8-hr test, and 2 bbl of oil in 10-hr test.
820	An 11-hr test showed oil entering hole at rate of 5–6 bbl an hr.
838	A 2-hr test recovered 11 bbl of oil.
875	Five bbl of oil bailed in 1 hr.
895	Bailing test recovered 5, 4½, and 3½ bbl of oil in first, second, and third hours, respectively.
905	A 1-hr test recovered 3 bbl of oil.
915	A 1-hr test recovered 3 bbl of oil.
967	A 1-hr test recovered 3½ bbl of oil.

After coring from 1,012 to 1,015 feet, the fluid level was at 615 feet. Eleven barrels of water-free slightly gas-cut oil was bailed; 33 barrels of mud was then bailed from the bottom of the hole. Four hours later 3 barrels of mud was bailed from the bottom of the hole, and 1 hour later one-half a barrel of mud was bailed, also from the bottom. The fluid level remained at 615 feet.

At 1,034 feet bailing 66 barrels of oil lowered the fluid level from 615 to 688 feet. There was no water in the bottom of the hole.

When the total depth was 1,080 feet, upset tubing (2½-in. diameter) was put in the hole with the shoe at 1,053 feet; the well produced 60 barrels of oil in 19 hours of swabbing. Pumping then produced 36 barrels of oil in 3 hours. The pumping test continued several days, but the results (see table following) are inconclusive because of the inadequate capacity of the pump and its tendency to collect wax. The oil contained 0.1 percent of water and 0.1 percent of silt and sand, by volume. It contained wax, and there was no odor of hydrogen sulfide.

Pumping test at 1,080 feet in Umiat test well 8

Hours pumped	Strokes per minute	Barrels of oil	Remarks
2	24	12	
5	32	59	
15	24	54	
24	----------	67	Two days was spent pulling tools and tubing from hole, bailing water, and overhauling pump. Fluid level was at 147 ft, and water, presumed to be drilling fluid, was bailed with six runs of bailer. Pump contained some mud and wax. Test was then continued.
8	----------	65	
24	----------	62	
24	----------	60	No water.
24	16	55½	
23	16	61½	A 36-in. stroke was used. Flow-line temperature was 24°–26°F.
24	----------	67	
24	16	62	
24	----------	55	No water; flow temperature 26°F.
24	----------	53	Flow temperature 22°–25°F.
7	----------	18	No water.

At 1,327 feet bailing began with the fluid level at 620 feet; and 40 barrels of oil and 3 barrels of mud were bailed from the bottom of the hole in 3 hours, and 67 barrels of oil was bailed from the top in 3 more hours. The fluid level dropped 180 feet, and the water was almost entirely removed during the 6-hour test.

The fluid level then rose to 660 feet in 2 hours and to 505 feet in 6 hours. After 3 hours of bailing the fluid level dropped to 645 feet, but continued bailing for an hour from the top of the fluid column did not lower the fluid level. The 4-hour test recovered 43 barrels of oil.

After running 2½-inch tubing to 1,250 feet, the well was swabbed for 15 hours, and 100 barrels of oil and

mud was recovered. The well then began to flow at a rate of 2.5 barrels per hour, with a fair blow of gas for 9 hours. The rate of flow and gas volume declined gradually, with recovery of 49 barrels of oil in 24 hours and 20 barrels in the following 15 hours. The pump could not be lowered below 480 feet, and when it was pulled out, it was coated with ice, which apparently caused the decline in production. The oil and gas flow through the tubing stopped, with only a weak blow still coming through the casing. When the tubing was lifted one joint, a strong blow came through the casing. The tubing then could not be lowered past 1,235 feet. The well was shut in 1 hour, and the gas pressure built up to 80 pounds per square inch (psi). Gas volume was checked with a 2-inch critical flow prover. The static closed-in pressure was 79 psi. With a ¼-inch orifice, pressure measured 72 psi, volume was 353,000 cubic feet, and temperature was 35°F. A second test with a ½-inch orifice recorded 61.5 psi and 441,500 cubic feet with the temperature at 35°F.

After setting 8⅝-inch casing at 1,231 feet and cleaning out the hole, a measure of the gas volume was made with the 2-inch critical flow prover. The static closed-in pressure was 245 psi. With a 1½-inch orifice, pressure was 18.1 psi, the volume was 1,893,300 cubic feet, and temperature, 33°F. Production with a 1-inch orifice was 1,788,500 cubic feet with 61.5 psi at 35°F, and with the ¾-inch orifice it was 1,559,400 cubic feet at a pressure of 106 psi and a temperature of 36°F.

After cleaning out the well another production test was made. With tubing at 1,312 feet the well was swabbed 3 hours and then flowed brine. Two hours later it was producing gas with only a small amount of brine. The 2-inch critical flow prover measured the following volumes and pressures: With a ½-inch orifice, pressure was 175 psi, volume 1,198,000 cubic feet, and temperature 31°F; with a 1-inch orifice pressure was 101 psi, volume 2,736,000 cubic feet, and temperature 30° F; witn a 1½-inch orifice pressure was 49 psi, volume 3,715,000 cubic feet and temperature 27°F. Casing pressure ranged from 45 psi flowing pressure to 205 psi when closed in.

Immediately after the test the well produced gas and a trace of oil and a very small amount of brine, but the following day no brine was produced with the gas and trace of oil. Minimum pressure with an open 3-inch valve on the tubing was 140 psi, with 215 psi maximum closed-in pressure.

The well flowed gas from the casing or tubing for 4 days, after which it was shut in, except for gas allowed to blow through the tubing every 4 hours to keep the tubing free from ice. Shut-in pressures were 200 psi in the tubing and 250 psi in the casing. A week later shut-in casing pressure at the well head rose to 270 psi.

A fourth test with the 2-inch critical flow prover, using the ½-inch orifice, resulted in a pressure of 237 psi, volume of 1,496,600 cubic feet, and a temperature of 25°F; the 1-inch orifice gave 170 psi, 4,385,500 cubic feet and 25°F; and the 1½-inch orifice gave 85 psi, 5,858,700 cubic feet, and 24°F.

OIL AND GAS ANALYSES

A gas sample taken after reaching the total depth was analyzed by the U. S. Bureau of Mines. In percent by volume it contained 0.1 of noncondensables, 97.3 of methane, 1.7 of ethane, 0.5 of propane, and slightly less than 0.5 of butane and higher fractions. An oil sample taken during the pumping test at 1,080 feet was also analyzed by the U. S. Bureau of Mines; the results are given in the following table.

Crude-petroleum analysis of U. S. Bureau of Mines sample 51050 from Umiat test well 8, taken during pumping test at 1,080 feet

[General characteristics of sample follow: Sp gr, 0.842; sulfur, 0.10 percent; Saybolt Universal viscosity at 100°F, 36 sec; gravity, 36.6°A PI; pour point, 5°F; color, Natl. Petroleum Assoc. no. 4]

Distillation by Bureau of Mines routine method

Fraction	Cut at— °C	Cut at— °F	Percent	Sum percent	Specific gravity [1]	Gravity, °A PI at 60°F	Correlation index	Aniline point (°C)	Saybolt Universal viscosity at 100°F	Cloud test (°F)
Stage 1.—Distillation at atmospheric pressure, 746 mm Hg. First drop, 48°C (118°F)										
1	50	122								
2	75	167								
3	100	212	7.0	7.0	0.731	62.1		42.1		
4	125	257	9.0	16.0	.770	52.3	36	34.0		
5	150	302	7.1	23.1	.789	47.8	37	32.2		
6	175	347	7.1	30.2	.802	44.9	37	38.1		
7	200	392	5.4	35.6	.813	42.6	36	46.8		
8	225	437	6.4	42.0	.827	39.6	37	52.9		
9	250	482	8.1	50.1	.846	35.8	41	56.8		
10	275	527	8.7	58.8	.859	33.2	42	59.5		
Stage 2.—Distillation continued at 40 mm Hg										
11	200	392	4.8	63.6	0.871	31.0	44	64.0	42	Below 5
12	225	437	8.1	71.7	.873	30.6	41	70.0	46	20
13	250	482	5.9	77.6	.881	29.1	41		60	40
14	275	527	5.0	82.6	.888	27.9	41		91	65
15	300	572	4.8	87.4	.895	26.6	42		160	70
Residuum [2]			12.4	99.8	.914	23.3				

[1] Specific gravity at 60°F compared with water at 60°F.
[2] Carbon residue of crude, 0.1 percent; carbon residue of residuum, 1.1 percent.

Approximate summary

Constituent	Percent	Specific gravity	Gravity, °API	Saybolt Universal viscosity
Light gasoline	7.0	0.731	62.1	
Total gasoline and naphtha	35.6	.779	50.1	
Kerosene distillate				
Gas oil	34.2	.854	34.2	
Nonviscous lubricating distillate	11.0	0.876–.889	30.0–27.7	50–100
Medium lubricating distillate	6.6	.889–.898	27.7–26.1	100–200
Viscous lubricating distillate				Above 200
Residuum	12.4	.914	23.3	
Distillation loss	.2			

LOGISTICS

Personnel and housing.—Eight men were employed at the rig site—a drilling foreman and geologist supervised the work, and the drill crews consisted of 2 drillers, 2 tool dressers, and 2 firemen. Temporary workers were brought from Umiat camp when their services were needed; they included a welder for dressing the drill bits, a mechanic, a bulldozer operator, an LVT operator, a cementer, and laborers. Both temporary and permanent employees were housed and fed at Umiat camp; so the only buildings at the rig site were a power and boiler wanigan, a cement-pump wanigan, and a water wanigan.

Vehicles and heavy equipment.—All vehicles used were supplied by the Umiat camp as they were needed; Caterpillar tractors, LVT's, cranes, and weasels were among the items employed. One each of the following major items of drilling equipment was listed by the Arctic Contractors as having been used.

Cardwell unitized spudder, model K.
Caterpillar, D8800 diesel engine.
Generator, 15 kw, powered by Caterpillar D3400 diesel engine.
Kohler 4-kw light plant.
Heat-Pak boiler.
Lufkin TC–3A pumping unit.
Buda gasoline engine.
Bolted steel 100-bbl oil test tank.
Bolted steel 64-bbl oil test tank.

Fuel, water, and lubricant consumption.—Fuel used consisted of 378 gallons of 72-octane gasoline and 6,877 gallons of diesel fuel. Lubricants consumed were 302 gallons of No. 9170 lubricating oil and 61 pounds of grease. Water consumption was 46,030 gallons.

DRILLING OPERATIONS

DRILLING NOTES

The Cardwell unitized spudder was mounted on a sled, and towed to the well site with a D8 Caterpillar tractor. The drilling operations which followed are described below; they were recorded by John Bollenbacher and Marvin Heany, of Arctic Contractors.

Notes from drill records

Depth (feet)	Remarks
44	Small amount of fluid in hole was freezing; so brine was mixed and put in as drilling fluid.
50	Two joints of 11¾-in. 47-lb casing with plain shoe were set at 50 ft. Four sacks of Cal-Seal was dumped in it and allowed to set; annulus then was filled with 16 sacks of Cal-Seal. After Cal-Seal set, top of cement found at 40 ft in casing.
80	Bit stuck in tight hole for 3½ hr but was worked loose. After being shut down 18 hr waiting for drilling jars to be flown in, hole was filled with gravel from 76 to 80 ft and redrilled with jars in order to straighten it.
124	Drilling line pulled out of rope socket, but tools recovered from hole.
657	Line broke at socket; tools fished out of hole in 3 hr.
758	Bailer line broke, fished out in 3 hr.
810	Bailer dump chain hauled out of hole after 3 hr of fishing.
850	Drilling line broke, leaving tools in hole, but they were recovered in 3 hr. Fluid level at 665 ft.
875	Fluid level at 695 ft.
1,015	After coring 3 ft, fluid level at 615 ft.
1,034–1,080	Fluid level remained at 615 ft.
1,080	Three 10-in. wall scratchers on bailer were used to scratch walls of hole for 8 hr, from 50 to 1,080 ft. After swabbing, rig was moved off of well, pump installed, and pumping test made. (See table on p. 152.) After test, pump found to contain large amount of wax. Bailer found bottom at 1,062 ft; no water in bottom of hole.
1,088	Caving sides made drilling difficult.
1,107	Shale caved into hole.
1,270	Drilling line broke, leaving tools and 445 ft of line in hole. Fish recovered in 5½ hr, which included a 3-hr wait for fishing tools.
1,300	Water found in bottom of hole; 40 bbl bailed out, lowering fluid level from 583 to 625 ft. Ice reamed from 50–100 ft and hole enlarged from 7½ in. to 10¾ in. to a depth of 1,260 ft. Bailer and 585 ft of line lost in hole but recovered in 3 hr, and reaming continued to 1,300 ft. Fluid level at 585 ft.
1,317	Fluid level at 610–628 ft.
1,327	Bailer and 200 ft of line stuck at 1,122 ft but were recovered in 1½ hr.
	After swabbing and gas-volume tests, a pick on a swab sinker-bar was run down hole; but although it cleaned out 30 ft of ice from tubing, it was not able to clean hole completely. Several gallons of glycol were poured down tubing, but pick still could not get through; so well was killed with brine (consisting of 80 bbl of water and 25 sacks of salt) and tubing removed.

Notes from drill records—Continued

Depth (feet)	Remarks
	Fluid level at 590 ft. Cavings filled hole to 1,215 ft; after cleaning them out to 1,260 ft, fluid level down to 595 ft.
	Casing set with shoe at 1,231 ft, using 59 joints of 8⅝-in. National seamless 32-lb API round-thread casing, and 140 sacks portland cement. Plug set with 78 bbl of brine and 500 psi of pressure. Twelve sacks of Cal-Seal also used to cement between 11¾-in. and 8⅝-in. casing.
	Ice was drilled out of casing from 50 to 550 ft, and hole then cleaned to 1,250 ft, drilling out plug at 1,213 ft. Though there was no sign of oil or water, gas came out of hole with sufficient volume to flow fluid out, and volume test was made.
	To kill the well, 111 bbl of brine (made of 35 lb of salt per barrel of water) mixed by cement pumps, were put in hole, but fluid level could not be raised above 600 ft. Hole cleaned out from 1,253 to 1,327 ft, and after 400 lb of salt were put down, tools were pulled out. Nineteen barrels of brine and 500 lb of additional salt were put in to maintain fluid level at 600 ft, and tubing was run to 1,312 ft.
	After testing gas flow, well was closed in with tubing to 1,312 ft; no fluid in hole. Top of surface installation [1] is 5 ft above ground level.

[1] Above ground level an 8⅝-in. coupling has an 8⅝-in. nipple flanged at top with a 2- by 6-in. nipple, and a 2-in. Merco-Nordstrom stopcock. Above that is an 8⅝-in. flanged spool with two 2-in. side ports closed by 2-in. standard gate valves. A 2½-in. external-upset tubing head is on top, and above the tubing head is a 2½- by 8-in. nipple capped by a 2½-in. tee which has a 2-in. gate valve attached to the side. On the top is a 3- by 2½-in. swage capped by a 3-in., 500-lb gate valve. The top was 5 ft above ground level.

DRILL AND CORE BITS

A total of 16 bits was used for drilling, and one other was used for cleaning out the hole. When the bits wore dull, they were redressed by hard-surface welding at Umiat camp. At some depths one bit was used for short alternate intervals of drilling and reaming; to avoid confusion on the graphic log (pl. 12), these bits are shown as having drilled only.

The Baker cable-tool core barrel no. 6, with eight 5¾-inch bits was used for all 69 feet of coring in the hole. Core bits are numbered 1 through 9, but there is no bit no. 4, and the total used is 8.

DRILLING FLUID

Brine was used in the drilling, usually a mixture of 35 pounds of salt to 1 barrel of water. Enough brine was put in the hole to cover the cable tools—1½–2 bailers full. Brine was also used to kill the well, and for placing the plug when cementing casing. A total of 21,695 pounds of salt was used.

UMIAT TEST WELL 9

Location: Lat 69°23′14″ W., long 152°10′11″ W.
Elevation: Ground level 418 feet; kelly bushing, 424 feet.
Spudded: June 25, 1951.
Completed: January 15, 1952; pumped an average 217 barrels oil per day before plugging back. Abandoned.
Total depth: 1,257 feet.

The purpose of drilling Umiat test well 9 was to determine the western extent of the producing area of Umiat field, to determine the feasibility of using oil-base drilling mud with rotary drilling in the Umiat area, to test the productive capacity of individual sandstone beds found, and to obtain complete, uncontaminated cores from them to determine characteristics affecting the oil reserves of the field. The well averaged 217 barrels of oil per day on a lengthy pumping test, extending the field and proving the advantage of using oil-base mud in drilling. It was impossible, however, to test each sandstone separately, as the mud evidently prevented oil from flowing immediately after the rocks were drilled; so swabbing tests were unsuccessful. When the total depth of the well was reached, oil began entering the hole, and plugging back by stages with cement did not serve to define the producing horizons closely, although some oil was shown to be coming from fractured shale between the sandstone beds. When the cement was drilled out and casing set and perforated opposite permeable sandstones, no oil entered the hole; either permeability was adversely affected by the casing cement or the perforations were not adequate. Except for Umiat test well 1, this hole, about 2 miles west of Umiat test well 2, is the westermost one on the anticline. It is just north of the Colville River flats on a small stream that has cut a notch in the southern slope of the long east-west ridge bordering the wide river valley.

DESCRIPTION OF CORES AND CUTTINGS

The drilling first penetrated 150 (?) feet of sandstone of the Ninuluk formation. If the upper 50 feet, represented by a single sample, is properly described, then the sandstone unit is 50 feet thicker than it is elsewhere in the field and may be duplicated by a reverse fault at 50 feet. On the other hand, if the upper 50 feet is incorrectly represented as a result of poor sampling and was partly clay shale or other rock, then the upper part of the well was drilled through a normal sequence and penetrated about 50 feet of the Seabee formation.

Below 155 feet the Killik tongue of the Chandler formation is present as clay shale with some interbedded sandstone to a depth of 425 feet; clay ironstone and coal, present in other wells, were rare in samples from this well. Most of the Grandstand formation (425–1,090 feet), and the upper part of the Topagoruk formation (1,090 feet to the total depth) were cored; they consist of medium-light-gray sandstone and medium-dark-gray clay shale typical of these two formations. The upper sandstone bed of the Grandstand formation is 60 feet thick; the lower sandstone beds total 180 feet and are divided into 3 units by 35 feet of clay shale and 25 feet of siltstone and clay shale.

Lithologic description

[Where no cores are listed, description is based on cutting samples]

Core	Depth (feet)	Remarks
-----	0–6	Kelly bushing to ground level.
-----	6–60	One sample, containing sandstone as below. Top of the Ninuluk formation is at 6 feet (?).
-----	60–80	Sandstone, light-olive-gray, very fine-grained, very silty and argillaceous, micaeous, noncalcareous; composed of subangular grains of clear and white quartz with some brownish quartz and dark rock fragments.
-----	80–90	Clay shale, medium-dark-gray, slightly to very silty, micaceous, noncalcareous.
-----	90–100	Sandstone with some siltstone and clay shale.
-----	100–140	Sandstone, medium - light - gray, fine - grained, silty, argillaceous, noncalcareous, with rare bentonite in upper 5 ft.
-----	140–170	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous. Top of the Killik tongue of the Chandler formation is at 155 ft.
-----	170–190	Clay shale, with a small amount of sandstone.
-----	190–200	Clay shale with some very argillaceous siltstone, and very small amount of sandstone.
-----	200–210	Clay shale, slightly to very silty.
-----	210–230	No sample.
-----	230–270	Clay shale, slightly silty, with very small amount of bentonite at 260 ft.
-----	270–280	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, noncalcareous.
-----	280–290	Siltstone, medium-gray, very sandy, argillaceous, micaceous, noncalcareous.
-----	290–300	Clay shale, medium-dark-gray, slightly to very silty, with some siltstone.
-----	300–310	Clay shale as above, with rare bentonite.
-----	310–320	Sandstone, light-olive-gray, very fine-grained, very silty and argillaceous; slightly calcareous in part.
-----	320–330	Clay shale, with some siltstone and very small amount sandstone.
-----	330–340	No sample.
-----	340–350	Sandstone, light-olive-gray, very fine-grained, very silty and argillaceous, noncalcareous.
-----	350–360	Clay shale.
-----	360–370	Clay shale and siltstone.
-----	370–380	Clay shale.
-----	380–385	No sample.
1	385–394	Recovered 9 ft 1 in.: Microfossils absent. Claystone, medium-dark-gray, noncalcareous, uniform, with subconchoidal fracture. A 1-in. bed of brownish-gray noncalcareous clay ironstone 4 ft below top of core; 6½ ft below top is 4-in. bed of grayish-white bentonite with abundant euhedral biotite crystals, increasing from very fine-sand size in upper part to fine-sand size at base. Beds dip 1°–3°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
2	394–403	Recovered 10 ft: Microfossils absent. Claystone as above.
3	403–413	Recovered 10 ft: Microfossils absent. 4 ft, claystone as above. 2 ft 9 in., sandstone, light-gray, very fine-grained, silty, argillaceous, sericitic; slightly calcareous in part; irregular fracture; scattered patches and faint partings of medium-dark-gray micaceous clay; intergrades with sandy siltstone in lower part and to underlying claystone at base. 3 ft 3 in., claystone, medium-dark-gray, very silty, noncalcareous, irregular fracture, with patches and thin irregular lenses of sandy siltstone which are abundant in upper part but rare in lower part. Patches of carbonaceous material common in upper part. Beds dip 1°–3°.
4	413–423	Recovered 10 ft: Microfossils absent. 7 ft 6 in., claystone, medium-dark-gray, very slightly silty and micaceous, noncalcareous: fracture irregular to conchoidal; contains small fragments and flakes of carbonized plants in upper 1 ft. 2 ft 6 in., sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, sericitic, noncalcareous, massive, with scattered small patches of carbonaceous material in upper inch. Grades to fine-grained, very sericitic, and micaceous rock at base. Beds dip 1°–3°.
5	423–433	Recovered 10 ft: Microfossils rare. 2 ft, sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, very sericitic; very slightly calcareous in part; abundant irregular patches of medium-gray siltstone and medium-dark-gray clay shale dipping 2°–8°. Grades to unit below. 8 ft, claystone, medium-dark-gray, very silty and sericitic at top, noncalcareous; grades to slightly micaceous and silty at base; irregular to conchoidal fracture. Top of Grandstand formation at 425 ft.
6	433–443	Recovered 10 ft: Microfossils very abundant. Claystone, medium-dark-gray, noncalcareous; conchoidal fracture; a few imperfect specimens of *Corbula* sp. at 435 ft.
7	443–454	Recovered 10 ft: Microfossils abundant. Claystone as above; silty in part; plant fragments at 445 ft. Very small slickensides at 451 ft, and 7-in. unit of light-brownish-gray slightly calcareous clay ironstone at 452 ft; bottom 2 in. of core silty, micaceous, and carbonaceous.
8	454–464	Recovered 10 ft: Microfossils very rare. Claystone as above, with small slickensides.
9	464–474	Recovered 10 ft: Microfossils absent. 2 ft 4 in., interbedded medium-dark-gray clay shale and medium-light-gray very fine-grained sandstone; beds are ¼–1 in. thick with irregular, sharp contacts and are approximately half shale and half sandstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		7 ft 8 in., sandstone, medium-light-gray, fine-grained, also fine- to medium-grained, slightly to very silty and argillaceous, noncalcareous, massive; irregular fracture; contains rare scattered streaks of coaly material. Sand composed of subangular clear and white quartz with some coaly particles and dark rock fragments. Dip approximately 3°.
10	474–484	Recovered 10 ft: Microfossils absent. Sandstone as above, but very fine- to fine-grained; grades to very fine grained; micaceous; carbonaceous streaks lacking. A 1-in. unit 7 ft below top of core has abundant carbonaceous partings.
	Note	Amount of rock recovered for cores 11 through 16 does not agree with footage cored, because the lower part of the core remained as a stub in the hole, and was covered with the next core.
11	484–494	Recovered 3 ft: Microfossils absent. Sandstone as above.
12	494–499	Recovered 6 in.: Microfossils absent. Sandstone as above.
13	499–500	Recovered 8 in.: Microfossils absent. Sandstone as above.
14	500–502	Recovered 10 ft 6 in.: Microfossils absent. Sandstone as above.
15	502–512	Recovered 1 ft 7 in.: Microfossils absent. Sandstone as above.
16	512–514	Recovered 10 ft 6 in.: Microfossils absent. Sandstone as above, slightly calcareous in lower half.
17	514–525	Recovered 9 ft 6 in.: Microfossils rare. Sandstone as above, but noncalcareous. A 6-in. unit of light-brownish-gray calcareous clay ironstone with conchoidal fracture 1½ ft below top of core; it is interbedded with very silty light-olive-gray to medium-gray claystone; beds ¼–½ in. thick and lenticular, with sharp or gradational contacts. Near top of uppermost clay ironstone bed is horizon of abundant stellate, yellowish-white multirayed calcareous finely granular (finely crystalline?) masses 1/16–⅛ in. diameter. Slickensides present at base of clay ironstone. Basal 2 ft of sandstone contains a few ½- to 1-in. beds of medium-dark-gray slightly to very silty noncalcareous clay shale, with common silt laminae dipping about 3°. Slickensides present in some clay shale beds.
18	525–533	Recovered 8 ft 7 in.: Microfossils abundant. 1 ft 7 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, sericitic, noncalcareous, with abundant faint carbonaceous partings commonly marked by carbonized plant fragments. Rock breaks along partings, which dip 4°. Thin irregular beds and laminae of medium-dark-gray clay shale in lower part, increasing from rare to abundant with depth. Grades into unit below. 7 ft, claystone, medium-dark-gray, slightly to very silty, noncalcareous, with irregular fracture. Lower part of core contains irregular beds and minute lenses of very fine-grained

Lithologic description—Continued

Core	Depth (feet)	Remarks
		medium-light-gray sandstone and medium-gray siltstone ⅛–1 in. thick that dip about 5°.
19	533–543	Recovered 9 ft: Microfossils absent. 4 ft 2 in., claystone, medium-dark-gray, very silty, noncalcareous, micaceous, pyritic, with scattered carbonized plant fragments throughout; irregular fracture. 4 ft 10 in., sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, micaceous, noncalcareous, with slickensides in upper 6 in. Patches and partings of carbonaceous material and medium-dark-gray clay common in upper part, rare in lower part. Laminae and thin beds of claystone common in basal 1 ft; dip 1°–4°.
20	543–553	Recovered 10 ft: Microfossils absent. Claystone, medium-dark-gray, slightly to very silty, noncalcareous; subconchoidal fracture with faint partings; irregular lenticular beds (less than half an inch thick) of medium-gray siltstone and very fine-grained sandstone, totaling 10–50 percent of the rock, and dipping 2°–5°. Carbonaceous partings also present. Sandstone absent in lower part of core, and siltstone present in faint even very argillaceous laminae and partings that dip 3°.
21	553–563	Recovered 9 ft 7 in.: Microfossils abundant. Clay shale, medium-dark-gray; slightly silty in part, noncalcareous; scattered carbonized plant fragments. Faint silty laminae rare; poor shaly cleavage suggests 2°–3° dip. Bottom 2 in. of carbonaceous very micaceous silty clay shale. A 14-in. bed of medium-light-gray fine- to very fine-grained sandstone 3 ft below top of core. Pelecypod shell fragments present at top of core, and specimen of *Arctica?* sp. at 562 ft.
22	563–573	Recovered 10 ft: Microfossils common. Clay shale as in core 21, with pelecypod shell (*Modiolus* sp.) at 566 ft.
23	573–583	Recovered 10 ft: Microfossils very rare. 5 ft 6 in., clay shale as in core 21. 4 ft 6 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, massive. Carbonaceous patches rare throughout. Two 3-in. units 1 and 1½ ft below top contain abundant irregular streaks and patches of clay shale and rare slickensides. Beds approximately flat lying.
24	583–593	Recovered 10 ft: Microfossils very rare. 8 ft, sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, micaceous, slightly to moderately calcareous, with faint laminae and thin beds of sandy siltstone and micaceous carbonaceous partings that dip 3°–5°. With depth sandstone becomes very silty, medium gray, and very calcareous. Grades into unit below. 2 ft, claystone, medium-dark-gray, very silty, micaceous, calcareous, uniform, with conchoidal fracture.

Lithologic description—Continued

Core	Depth (feet)	Remarks
25	593–603	Recovered 8 ft: Microfossils absent. Claystone, medium-dark-gray, slightly to very silty, micaceous, slightly calcareous, uniform, with conchoidal fracture.
26	603–611	Recovered 8 ft: Microfossils rare. Clay shale, similar to claystone in core 25, but with silty micaceous partings that give the rock poor shaly cleavage dipping 2°–3°.
-----	611–640	Clay shale, medium-dark-gray; very slightly silty in part; very slightly calcareous.
-----	640–649	Siltstone, medium-gray, argillaceous, sandy, calcareous.
27	649–659	Recovered 10 ft: Microfossils abundant. Clay shale, medium-dark-gray; very slightly silty in part; noncalcareous; rare silty laminae are slightly calcareous; dip 2°–3°.
28	659–669	Recovered 10 ft: Microfossils common. Clay shale as above; dip 1°–3°.
29	669–678	Recovered 7 ft 6 in.: Microfossils abundant. 5 ft, claystone, medium-dark-gray, noncalcareous, grades from very slightly silty at top to very silty at base; conchoidal fracture. 2 ft 6 in., sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, slightly calcareous, with laminae and thin beds medium-gray slightly calcareous siltstone and medium-dark-gray clay shale that are commonly crossbedded or wavy; dip 3°–12°.
30	678–687	Recovered 4 ft 2 in.: not sampled for microfossils. Claystone, medium-dark-gray, slightly to very silty, micaceous, noncalcareous; irregular fracture, with streaks and irregular lenses of medium-gray very argillaceous siltstone.
31	687–697	Recovered 10 ft: Microfossils rare. 5 ft, claystone as above but very silty; grades into unit below. 5 ft, sandstone, medium- to medium-light-gray, very fine-grained, very silty and argillaceous, micaceous, noncalcareous, with rare to common thin beds, streaks, and irregular patches of medium-gray siltstone and patches of claystone in upper 4 ft. Basal foot uniform, massive. Sandstone composed of subangular grains of clear and white quartz, with some dark rock fragments, carbonaceous particles, and abundant sericite. Pelecypod, *Protocardia* sp., was identified from 696 ft.
32	697–707	Recovered 10 ft: Microfossils very rare. 10 in., sandstone, as at base of core 31. 1 ft 3 in., sandstone as above but with small irregular patches and streaks of siltstone and clay shale ¼–1 in. long and less than 1/16 in. wide, dipping 2°–12. 1 ft 4 in., sandstone as at top of core but slightly calcareous. 2 in., claystone, medium-dark-gray, very slightly silty, with conchoidal fracture. 3 ft, siltstone, medium-gray, very argillaceous; very sandy in part; streaks of yellowish-gray slightly calcareous silty clay ironstone; grades to silty claystone at base.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		3 ft 5 in., sandstone as at top of core but slightly silty. A few faint argillaceous laminae rare to common; they are crossbedded in part and dip 1°–5°.
-----	707–710	No sample.
-----	710–720	Siltstone, medium-gray, argillaceous, sandy.
-----	720–809	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous.
33	809–819	Recovered 10 ft: Not sampled for microfossils.
		2 in., claystone, medium-dark-gray, very silty, irregular fracture.
		9 ft 10 in., sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, massive. Laminae, streaks and patches of medium-gray siltstone and medium-dark-gray claystone scattered throughout. Abundant minute (about one-sixteenth of an inch thick, and less than one-fourth of an inch long) lenses of yellowish-gray clay ironstone color the sandstone yellowish between 815 and 818 ft. Beds dip about 1°.
34	819–829	Recovered 8 ft 10 in.: Microfossils common.
		Sandstone, as above, with abundant small irregular patches and faint, even laminae of siltstone and clay shale; laminae dip 6°. Streaks of brownish-gray clay ironstone rare to common in bottom 4 ft.
35	829–838	Recovered 6 ft 8 in.: Microfossils abundant.
		3 ft 8 in., sandstone as above, with patches of claystone becoming abundant with depth and grading into—
		3 ft, claystone, medium-dark-gray, slightly silty, noncalcareous; poor conchoidal fracture; 4-in. bed of siltstone at base.
36	838–848	Recovered 8 ft 10 in.: Microfossils abundant.
		5 ft 10 in., clay shale, like claystone above but with poor shaly cleavage dipping less than 3°. Several specimens of *Corbula* sp. at 843 ft.
		1 ft 2 in., siltstone, medium-gray, argil laceous, noncalcareous, massive.
		1 ft 10 in., claystone, medium-dark-gray, slightly to very silty, noncalcareous, irregular to conchoidal fracture, with rare thin beds of siltstone in central part; specimens of *Corbula* sp. at base.
37	848–858	Recovered 10 ft: Microfossils abundant.
		9 ft 3 in., clay shale as at top of core 36; dip about 3°; very silty at base; grades into unit below.
		9 in., siltstone, medium-gray, argillaceous, noncalcareous, with abundant irregular patches and streaks of medium-dark-gray claystone.
38	858–868	Recovered 10 ft: Microfossils common.
		1 ft 6 in., siltstone, medium-gray, very argillaceous, noncalcareous, massive, with abundant irregular patches of clay shale; grades into unit below.
		3 ft 6 in., claystone, medium-dark-gray, very silty, slightly carbonaceous and carbonaceous and pyritic, massive; irregular fracture. Claystone contains coaly plant fragments in lower 1 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		4 ft, intermingled irregular laminae, lenses, streaks, and patches of medium-light-gray, very fine-grained sandstone, medium-gray siltstone, and medium-dark-gray clay shale, in about equal quantities.
		1 ft, sandstone, medium-light-gray, fine-grained, silty, noncalcareous, massive, with rare carbonized plant fragments.
39	868–878	Recovered 9 ft 6 in.: Not sampled for microfossils.
		Sandstone, light-olive-gray, fine- to medium-grained, silty, argillaceous, noncalcareous, massive, uniform; composed of subangular to subrounded clear and white quartz with some gray and dark rock fragments. Olive-gray color caused by faint oil stain.
40	878–888	Recovered 6 ft: Not sampled for microfossils.
		Sandstone as above but medium light gray.
41	888–898	Recovered 10 ft: Microfossils absent.
		Sandstone as in core 40; grades to fine-grained, with faint silt laminae and partings that dip 4°–9°.
42	898–901	Recovered 2 ft 6 in.: Microfossils absent.
		Sandstone, medium-light-gray, fine- to very fine-grained, silty, argillaceous, noncalcareous, massive, with very rare ½-in. beds of medium-dark-gray claystone. Composition similar to that of core 39.
43	901–911	Recovered 8 ft 6 in.: Not sampled for microfossils.
		Sandstone as above, very uniform, lacks clay shale beds.
44	911–919	Recovered 8 ft.: Not sampled for microfossils.
		Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, massive, with faint laminae containing abundant carbonaceous particles in lower half.
45	919–929	Recovered 10 ft: Microfossils absent.
		5 ft, sandstone as in core 43; slightly calcareous in lower part.
		5 ft, siltstone, medium-gray, slightly to very sandy, with rare faint slightly carbonaceous, argillaceous, and micaceous laminae; dips 4°.
46	929–939	Recovered 8 ft 7 in.: Microfossils common.
		Siltstone as at base of core 45. Beds of medium-dark-gray claystone 2 in. thick rare in lower part; slickensides near base of core.
47	939–949	Recovered 10 ft: Microfossils common.
		Claystone, medium-dark-gray, very silty, with patches and streaks of argillaceous medium-gray siltstone and an 8-in. bed of argillaceous sandy medium-gray siltstone with faint carbonaceous partings in basal foot of core. Partings dip 10°–12°. Slickensides rare in claystone.
48	949–959	Recovered 8 ft: Microfossils very abundant.
		2 ft 5 in., sandstone, medium-light-gray, fine- to very fine-grained, silty, argillaceous, slightly micaceous, noncalcareous, massive; composed of subangular clear and white quartz with rare dark rock fragments.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		5 ft 7 in., claystone, medium-dark to dark-gray, slightly to very silty, partly carbonaceous, noncalcareous, with streaks of siltstone; irregular fracture.
49	959–969	Recovered 10 ft: Microfossils very abundant. Sandstone as at top of core 48 but fine grained, grading to fine to medium grained at base of core. A 1-ft bed of silty claystone at 962–963 ft and 1 ft of dark-gray carbonaceous clay shale with very poor shaly cleavage at 964–965 ft, with coaly layer at base.
50	969–979	Recovered 10 ft: Not sampled for microfossils. Sandstone, medium-light-gray, fine- to very fine-grained, noncalcareous, massive, uniform.
51	979–989	Recovered 10 ft: Not sampled for microfossils. Sandstone as in core 50, with rare irregular carbonaceous streaks.
52	989–1,000	Recovered 8 ft 6 in.: Microfossils absent. Sandstone as above.
53	1,000–1,010	Recovered 8 ft: Not sampled for microfossils. Sandstone as above.
54	1,010–1,017	Recovered 8 ft: Microfossils absent. Sandstone as above, grades to very fine grained at base; common carbonaceous and argillaceous laminae, some of which are crossbedded dip 1°–22°.
55	1,017–1,027	Recovered 9 ft 7 in.: Microfossils common. Sandstone as at base of core 54; 2-ft bed of fine-grained sandstone 4 ft above base of core, with 1-ft bed of claystone below the bed.
56	1,027–1,037	Recovered 6 ft 7 in.: Microfossils common. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, noncalcareous, carbonaceous, massive; micaceous laminae rare.
57	1,037–1,047	Recovered 10 ft: Not sampled for microfossils. Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, slightly micaceous, noncalcareous, massive, uniform; composed of subangular grains of clear and white quartz, with rare dark rock fragments.
58	1,047–1,057	Recovered 10 ft: Not sampled for microfossils. Sandstone as above.
59	1,057–1,067	Recovered 3 ft 11 in.: Microfossils absent. Sandstone as above, with rare faint argillaceous or slightly carbonaceous laminae dipping about 4°.
60	1,067–1,076	Recovered 7 ft 11 in.: Not sampled for microfossils. Sandstone as in core 59 above; laminae dip 1°–11°. Basal 1 ft of core has rare thin (¼–1 in.) beds of medium-dark-gray silty clay shale.
61	1,076–1,086	Recovered 9 ft 11 in.: Not sampled for microfossils. Sandstone as in core 57, very micaceous, with common carbonaceous particles throughout.

Lithologic description—Continued

Core	Depth (feet)	Remarks
62	1,086–1,096	Recovered 10 ft: Microfossils absent. 4 ft 6 in., sandstone as above, with thin beds siltstone and clay shale at base. 5 ft 6 in., claystone, medium-dark-gray, very silty and micaceous, noncalcareous; irregular fracture; carbonized plant fragments. Top of Topagoruk formation at 1,090 ft.
63	1,096–1,106	Recovered 10 ft: Microfossils abundant. Claystone as above.
64	1,106–1,117	Recovered 2 ft 6 in.: Microfossils very rare. Claystone as above.
65	1,117–1,127	Recovered 3 ft 7 in.: Microfossils very rare. Siltstone, medium-gray, argillaceous, sandy, noncalcareous, with common thin beds of medium-dark-gray clay shale and carbonaceous laminae dipping 4°.
66	1,127–1,137	Recovered 3 ft: Not sampled for microfossils. Siltstone, medium-gray, argillaceous, sandy, noncalcareous, very micaceous, with rare thin beds of claystone and very fine-grained very silty argillaceous micaceous noncalcareous sandstone totaling 10 percent of core. Rare carbonaceous partings dip 4°. Light-yellowish-gray clay ironstone nodules as much as 1 in. across are rare.
67	1,137–1,147	Recovered 9 ft: Not sampled for microfossils. Siltstone as above, with a dip of 4°.
68	1,147–1,157	Recovered 10 ft: Microfossils common. 2 ft 6 in., siltstone as above, grades into unit below. 7 ft 6 in., claystone, medium-dark-gray, very silty, noncalcareous, irregular fracture, with carbonaceous patches and carbonized plant fragments.
69	1,157–1,167	Recovered 5 ft: Not sampled for microfossils. Claystone as above; pelecypod shell fragments rare 2 ft below top of core. A 10-in. bed of medium-gray argillaceous noncalcareous siltstone 1 ft above base of core.
70	1,167–1,177	Recovered 9 ft 6 in.: Microfossils abundant. Claystone as above; uniform.
71	1,177–1,187	Recovered 8 ft: Microfossils common. Claystone as above; slightly to very silty.
72	1,187–1,197	Recovered 10 ft: Microfossils abundant. Claystone as above, very silty and micaceous. A 2-in. bed of light-gray very fine-grained very silty and argillaceous calcareous sandstone at 1,194 ft. Pelecypod shell fragment at 1,196 ft.
73	1,197–1,206	Recovered 8 ft 6 in.: Microfossils common. Claystone, medium-dark-gray, very silty and micaceous, noncalcareous; irregular fracture.
74	1,206–1,208	Recovered 1 ft 6 in.: Microfossils common. Claystone as above.
75	1,208–1,218	Recovered 5 ft 6 in.: Microfossils common. Claystone as above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
76	1, 218–1, 228	Recovered 8 ft: Not sampled for microfossils. Small amount of core 76 recovered with core 77. Siltstone, medium-light-gray, very sandy and argillaceous, noncalcareous to slightly calcareous, with faint carbonaceous or argillaceous laminae dipping 1°–14°.
77	1, 228–1, 236	Recovered 9 ft 6 in.: Not sampled for microfossils. Includes small amount of core 76. Siltstone as above; slickensides 6 in. above base of core.
78	1, 236–1, 247	Recovered 10 ft: Microfossils common. Interbedded siltstone and claystone as above; beds are ½–8 in. thick, with sharp or gradational contacts; rock about half siltstone. Carbonaceous laminae dip 1°–5°.
79	1, 247–1, 257	Recovered 10 ft: Microfossils common. Claystone, medium-dark-gray, slightly to very silty, noncalcareous, with irregular fracture.

CORE ANALYSES

By George L. Gates, U. S. Bureau of Mines

CORING PROCEDURE

Umiat test well 9 was cored using the rotary method with oil-base drilling mud containing a dissolved chemical tracer which provided a means of determining the extent of invasion of oil filtrate from the drilling fluid into the core during the coring operation. Thus, the volume of oil and water in the reservoir sandstones was determined as accurately as possible. Because the filtrate from an oil-base mud is oil, not water, the water content of the cores cannot be contaminated by the filtrate from the drilling mud. When each core was removed from the core barrel, samples were selected from the recovered sandstone. The samples of core were wiped free of drilling mud, wrapped in aluminum foil, placed in a tin can, and the annular space was filled with paraffin. The can was then sealed for subsequent analysis of the cores in the Bureau of Mines laboratory in San Francisco. The oil-base drilling mud was sampled during the cutting of each core so that the quantity of chemical tracer present in a unit volume of drilling mud filtrate could be measured. (See table p. 162.)

CORE-ANALYSIS METHOD

In general the method of analyzing these cores has been described in detail by Gates, Morris, and Carraway (1950). Briefly, the method consists of selecting a center section of the core sample and determining the following properties of the sample: Total porosity, oil content, water content, drilling-mud filtrate content, chloride concentration in the interstitial water, air permeability, and density of the sand grains.

The permeability to water of a few samples of reservoir rocks was measured; this step was followed by determination of the permeability to oil of the water-contaminated samples. The permeability of horizontally adjacent core samples also was measured, using kerosene as the flowing liquid.

RESULTS

Data obtained in the analysis of these cores are tabulated in tables on p. 161–164. The sandstone sections having the most favorable porosity and permeability are found between 466 and 478 feet, 866 and 908 feet, and 964 and 972 feet. (See following table.)

Average properties of sandstone cores

Depth (feet)	Porosity (percent of bulk volume)	Water content (percent of pore space)	Oil (bbl per acre-ft)	Air permeability (millidarcys)
466–479	16.4	40.8	747	64
866–908	15.7	52.9	582	124
964–972	14.7	44.9	640	61

The oil content expressed in barrels per acre-foot was calculated from the core-analysis data by assuming that all the core volume not occupied by water is filled with oil.

Although the foregoing sandstone cores were found to be the most permeable to oil and air, it is significant that a total of 173 feet of sandstone cores bled Umiat crude oil after they were removed from the core barrel. Therefore, it may be concluded that the sandstone is capable of yielding crude oil, even though the flow of oil entering the well may be at a low rate.

The water content of the sandstone at 866–877 feet is unusually high. This is particularly surprising because this oil-bearing sandstone has the highest air permeability found in the cores from this well. However, it is believed that the reported water contents of these cores are accurate. The well produced dry oil, indicating that the water in the sandstone is immobile when oil flows through the sandstone. Accordingly, it is reasoned that the water in the sandstone also was immobile when the filtrate from the oil-base drilling fluid entered the sandstone and that the water found in the core is interstitial water present in the formation when the cores were cut. The production of dry oil from the sandstone having an unusually high water content may be the result of immobile water in the permafrost.

To determine whether or not filtrate from the oil-base drilling fluid entered the cores, the oil in each core sample was analyzed for its chemical tracer content. By this means the volume of drilling fluid filtrate in the core samples was measured. The results of the core analysis indicate that very little oil filtered into the cores.

To determine whether drilling-mud filtrate entered the cores from the sides of the cylindrical core towards the center, 6 core samples were cut along a diameter. The part of core cut along a diameter was divided into 3 parts—2 from outside sections and 1 from the center section of the core. Data from all 3 sections are given in the table on p. 162. The subscripts $_a$ and $_c$ indicate opposite outside sections of the core and subscript $_b$ indicates the center section. As shown in the table, the large volume of filtrate in the outside sections of the core when compared with smaller volume in the center sections indicates that radial filtration into the cores took place. However, it is believed that the entry of oil-filtrate from the mud did not move water from the cores, because dry crude oil moved through the pores in the production of oil from this well. Therefore, if crude oil can move through the sandstone without moving the interstitial water, it is reasonable to believe that oil-filtrate from the oil-base drilling mud may enter the pore space without moving interstitial water.

In an effort to learn the effect of water on the permeability of this sandstone to oil, a series of tests were made in which the following procedure was followed. A fresh core sample from the can sealed at the well was mounted in a low-temperature-setting plastic that is claimed to be inert to water and kerosene. The permeability to the flow of kerosene was measured with the interstitial oil and water present in the core. Next, the permeability of the core sample to water was measured and in making this test water was added to the sandstone to simulate the invasion of water into a sandstone where a well is drilled with water in the hole. The permeability of the sample containing the increased volume of water was measured by flowing kerosene through the core.

The results of these tests on four core samples having a wide range of permeabilities are shown in the table on p. 164. In all four tests the permeability to oil was greatly reduced by the addition of water to the sandstone.

It has been observed in the study of cores from many fields that generally the permeability of sandstones to the flow of air is greater than their permeability to oil, particularly if the tests using oil are made on core samples which contain interstitial water. Because the flow of crude oil into the well must be through the reservoir sandstone containing interstitial water, a series of tests was made measuring the flow of kerosene through fresh core samples mounted in plastic.

The properties reported in the table on p. 164 under the boxhead Adjacent permeability sample were measured on a core sample that was horizontally adjacent to the sample selected for core analysis. This adjacent sample was submerged in oil immediately after it was cut from the core and before it was cast in a low-temperature-setting plastic. As a result neither the interstitial water nor the swelling of the clay was altered as it inevitably would be if the sample was dried.

Core analyses, Umiat test well 9

[Analysis by U. S. Bur. Mines]

Depth of samples [1] in feet	Liquid content: Percent pore space: Total oil	Liquid content: Percent pore space: Water	Liquid content: Percent pore space: Drilling fluid filtrate	Liquid content: Oil (bbl per acre-ft [2])	Porosity (percent of bulk volume) [3 4]	Horizontal permeability (millidarcys) / Dry air	Sodium chloride concentration in interstitial water, (parts per million)	Core description
422.5	41.2	8.79	0.99	1,010	14.3	0.70	19,100	Fine-grained hard sandstone.
466.5	10.1	47.9	2.12	770	19.1	150	2,770	Fine-grained hard sandstone, wet.
467.5	12.1	54.3	.45	680	19.3	120	3,410	Do.
468.5	12.5	50.4	.92	790	20.4	81	3,180	Do.
469.5	23.8	36.8	.46	930	18.9	41	5,430	Do.
470.5$_a$	29.4	29.1	9.36	1,000	18.2	43	3,920	Do.
470.5$_b$	26.0	38.5	.44	870	18.2	50	3,710	Do.
470.5$_c$	27.9	31.5	4.32	990	18.6	89	5,290	Do.
471.5	34.1	39.4	3.79	780	16.6	120	3,680	Fine-grained hard sandstone, bleeds oil.
472.5	15.1	35.0	2.60	680	13.4	27	6,200	Do.
473.5	27.1	34.7	2.69	920	18.1	56	4,640	Do.
474.5	28.3	25.5	.62	850	14.7	20	9,660	Do.
475.5$_a$	35.6	38.2	12.0	640	13.3	40	4,080	Do.
475.5$_b$	33.1	39.7	1.55	640	13.5	45	4,620	Do.
475.5$_c$	36.9	30.4	13.9	750	13.9	29	5,260	Do.
476.5	15.8	45.8	.54	660	15.6	21	3,000	Do.
477.5	31.3	37.1	.33	610	12.4	5.1	4,690	Do.
478.5	22.4	45.2	.70	530	12.5	3.7	4,000	Do.
479.5	10.8	43.5	.53	610	13.8	5.0	10,100	Do.

See footnotes at end of table.

Core analyses, Umiat test well 9—Continued

Depth of samples [1] in feet	Liquid content: Percent pore space: Total oil	Liquid content: Percent pore space: Water	Liquid content: Percent pore space: Drilling fluid filtrate	Liquid content: Oil (bbl per acre-ft [2])	Porosity (percent of bulk volume)	Horizontal permeability (millidarcys) / Dry air	Sodium chloride concentration in interstitial water, (parts per million) [3 4]	Core description
480.5	30.2	32.0	0.30	630	11.9	0.25	9,020	Fine-grained hard sandstone, bleeds oil.
481.5	32.6	40.2	.31	480	10.4	.41	7,370	Do.
482.5	22.2	33.7	.37	720	13.9	1.0	6,720	Do.
483.5	29.7	37.8	.30	560	11.5	.93	6,240	Do.
484.5	51.5	38.2	.70	360	7.54	.08	11,600	Do.
485.5	41.6	48.2	.68	310	7.76	.20	10,500	Do.
486.5	34.2	47.7	.70	380	9.24	1.4	8,950	Do.
492.5	38.2	60.3	.69	230	7.57	.20	7,550	Do.
493.5	20.1	61.0	.62	280	9.12	.37	5,360	Do.
494.5	18.3	64.0	.52	250	9.06	.44	5,840	Do.
495.5$_a$	21.5	59.6	6.84	300	9.47	.28	5,030	Do.
495.5$_b$	15.7	65.7	.40	230	8.68	.25	4,970	Do.
495.5$_c$	26.1	63.0	8.92	240	8.41	.26	6,220	Do.
496.5	14.0	64.8	.31	250	9.19	.16	4,270	Do.
497.5	11.3	58.5	.34	330	10.1	.50	5,240	Do.
498.5	14.7	61.3	.62	280	9.30	.12	7,520	Do.
499.5	17.3	65.0	.47	230	8.64	.12	6,240	Do.
500.5	18.0	51.9	.24	380	10.1	.13	3,570	Do.
501.5	18.5	61.4	.18	250	8.29	.13	3,340	Do.
504.5	21.6	84.2	.66	90	6.91	.13	3,650	Do.
507.5	24.1	100	.31	----------	5.04	.06	3,650	Do.
510.5	Trace	100	.74	----------	2.61	.0	5,820	Do.
582.5	20.1	63.1	.22	260	9.23	.23	3,850	Very fine-grained hard sandstone, bleeds oil.
866.5	17.1	59.7	3.66	420	13.3	25	2,370	Fine-grained hard sandstone, bleeds water.
867.5	8.26	72.1	1:21	330	15.4	56	1,840	Do.
871.5$_a$	17.9	42.5	11.48	790	17.8	220	1,500	Fine-grained sandstone, bleeds water.
871.5$_b$	10.1	62.3	1.44	510	17.6	280	1,780	Do.
871.5$_c$	14.6	43.4	8.59	760	17.2	260	1,890	Do.
873.5	Trace	83.1	1.29	230	17.3	320	1,200	Do.
875.5	16.4	53.6	2.86	670	18.5	170	1,530	Do.
876.5	15.7	61.8	2.43	510	17.3	150	1,740	Do.
880.5	29.6	33.6	8.49	930	18.1	190	1,150	Do.
894.5	28.6	42.0	5.89	650	14.5	61	1,190	Fine-grained sandstone, bleeds water, oil and gas.
896.5	21.9	45.1	5.54	630	14.8	90	1,880	Do.
897.5	18.4	43.3	6.43	730	16.5	90	958	Do.
900.5$_a$	19.5	35.7	8.36	810	16.2	140	1,720	Do.
900.5$_b$	17.9	45.4	.49	660	15.5	62	1,270	Do.
900.5$_c$	20.1	32.0	10.68	830	15.8	53	6,410	Do.
906	24.1	33.2	.32	750	14.4	80	3,480	Fine-grained sandstone, bleeds oil and gas.
907.5	16.0	53.0	.47	550	15.1	42	2,350	Do.
909	13.6	52.9	.74	510	13.9	8.1	1,350	Do.
950.5	12.2	39.1	1.45	890	18.8	29	7,310	Fine-grained silty sandstone, bleeds water.
964.5	24.8	40.8	1.03	650	14.1	20	7,270	Fine-grained hard sandstone, bleeds oil and gas.
965.5	17.6	57.9	2.08	510	15.5	97	3,660	Do.
968.5	27.2	36.0	1.33	760	15.3	65	4,950	Do.
975	10.4	62.7	.62	340	11.9	5.5	5,540	Do.
977	9.10	67.3	.23	320	12.6	12	5,570	Do.
978$_a$	9.38	55.3	2.30	430	12.5	9.1	5,810	Do.
978$_b$	6.99	56.5	.20	420	12.3	5.2	5,920	Do.
978$_c$	15.6	51.5	7.27	440	11.8	6.4	6,540	Do.
995	9.09	59.0	.32	290	9.21	1.4	7,180	Do.
1,003	7.27	57.7	.41	391	11.9	1.4	7,960	Very fine-grained hard sandstone, bleeds oil and gas.
1,013	4.29	81.9	.39	107	7.59	.13	7,200	Very fine-grained hard silty sandstone, bleeds oil and gas.
1,040.5	16.7	61.0	.21	300	9.85	.39	7,400	Very fine-grained hard sandstone, bleeds oil and gas.
1,043.5	7.37	64.4	.27	290	10.5	.22	6,610	Do.
1,045.5	8.53	66.7	.26	270	10.3	.60	3,800	Do.

[1] $_a$ and $_c$ indicate opposite outside sections of core, and $_b$ indicates a center section.
[2] The barrel per acre-ft of oil was obtained by assuming that all of the pore volume not occupied by water is filled with oil.
[3] The average permeability of 52 samples with permeabilities equal to or greater than 1 millidarcy is 69.1 millidarcys.
[4] The average permeability of 38 samples with permeabilities equal to or greater than 10 millidarcys is 93.2 millidarcys.

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Study of the data in the table indicates that the effective permeability to oil was approximately the same as the air permeability and that the water content of the adjacent core sample had decreased during the test procedure, probably going into the low-temperature-setting plastic used in these tests. Owing to these difficulties, the test results are of little value except to show that no oil flow was obtained from sandstone beds (462–582 ft and 1,013–1,046 ft), under the above conditions. With this information in mind and judging from the core description, the sandstone beds from 1,046 to 1,257 would also be virtually impermeable to the flow of oil.

Permeabilities of cores from Umiat test well 9

[Analysis by U. S. Bur. Mines]

Depth [1] of sample in feet	Liquid content sample	Adjacent permeability sample			
	Dry Air permeability (millidarcys)	Water content (percent of pore volume)	Effective permeability to oil (millidarcys)	Dry air permeability (millidarcys)	Dry oil permeability (millidarcys)
422.5	0.70	26	No flow	1.5	No flow
466.5	150	30	68	86	84
467.5	120	16	110	110	120
468.5	81	11	82	74	47
469.5	41	16	53	68	58
470.5 a	43				
470.5 b	50	16	135	120	110
470.5 c	89				
471.5	120	14	110	150	90
472.5	27	27	25	23	23
473.5	56	12	40	43	39
474.5	20	28	2.6	15	12
475.5 a	40				
475.5 b	45	24		33	39
475.5 c	29				
476.5	21	23	40	34	33
477.5	5.1	21	55	28	10
478.5	3.7	43		3.2	3.0
479.5	5.0	6.5	No flow	2.9	No flow
480.5	.25	24	No flow	.23	No flow
481.5	.41		No flow	.22	No flow
482.5	1.0	25	No flow	.49	No flow
483.5	.93	10	No flow	1.5	No flow
484.5	.08	23	No flow	.04	No flow
485.5	.20	27	No flow	.13	No flow
486.5	1.4	13	No flow	.39	No flow
492.5	.20	8.3	No flow	.10	No flow
493.5	.37	48	No flow	.65	No flow
494.5	.44	39	No flow	.40	No flow
495.5 a	.28				
495.5 b	.25	3.6	No flow	.07	No flow
495.5 c	.26				
496.5	.16	12	No flow	.38	No flow
497.5	.50	9.8	No flow	.38	No flow
498.5	.12	89	No flow	.11	No flow
499.5	.12	11	No flow	.21	No flow
500.5	.13	1.5	No flow	.19	No flow
501.5	.13	7.2	No flow	.09	No flow
504.5	.13	15	No flow	.24	No flow
507.5	.06	49.0	No flow	.11	No flow
510.5	.0	17	No flow	.07	No flow
582.5	.23	39	No flow	.93	No flow
866.5	25	54		22	18
867.5	56			31	34
871.5 a	220				
871.5 b	280		210	Broken sample	Broken sample
871.5 c	260				
873.5	320			270	260
875.5	170	50	130	150	160
876.5	150		56	120	120
880.5	190	9.7	140	140	150
894.5	61		41	Broken sample	Broken sample
896.5	90	1.1	74	31	41
897.5	90	5.6	57	66	68
900.5 a	140				
900.5 b	62	.90	37	110	110
900.5 c	53				
906	80	2.9	31	30	29
907.5	42	26	50	54	54
909	8.1	18	31	4.8	4.2
950.5	29	9.2	30	15	14
964.5	20	3.4	30	25	14
965.5	97	13	49	78	53
968.5	65	9.6	81	43	48
975	5.5	24	7.4	5.5	3.9
977	12		24	13	12
978 a	9.1				
978 b	5.2	26	No flow	6.1	4.4
978 c	6.4				
995	1.4		2.1	5.8	1.9
1,003	1.4	9.2	8.3	1.6	1.3
1,013	.13	13	No flow	.13	No flow
1,040.5	.39	14	No flow	.35	No flow
1,043.5	.22	15	No flow	.17	No flow
1,045.5	.60	24	No flow	.87	No flow

[1] a and c indicate opposite outside sections of core, and b indicates a center section.

To determine the relative effect of air, oil, salt water, and fresh water on the permeability of some of the samples of this sandstone, six samples were selected for a series of tests. The samples were cleaned of water and oil, and then the permeability to dry air was measured. They were filled with kerosene, and the permeability to ½-normal sodium chloride solution was found to be somewhat less than before. Finally, the permeability to distilled water was measured and was found to be considerably less than the previous permeabilities.

The results of this series of tests (table below) indicate that water, particularly fresh water, lowers the permeability of these samples to values less than those

Air, oil, salt water, and fresh-water permeabilities of selected cores, Umiat test well 9

[Analysis by U. S. Bur. Mines]

Depth (feet)	Permeability in millidarcys to—			
	Dry air	Oil	0.5 normal sodium chloride solution [1]	Distilled water
866–867	22	18	15	13
867–868	31	34	32	30
873–874	270	260	250	200
875–876	150	160	140	120
880–881	140	150	130	100
907–908	54	54	35	26

[1] Samples were extracted and dried before determining permeability to salt water.

Liquid permeability (in millidarcys) of selected cores from Umiat test well 9 before and after soaking in water overnight. A 1-pound pressure drop was maintained across the sample

[Analysis by U. S. Bur. Mines]

	Sample from—			
	871.5 ft.	876.5 ft.	977 ft.	995 ft.
Permeability before soaking				
Oil (water phase remained immobile)	206.0	56.5	24.0	2.1
Water (oil phase remained immobile)	78.1	.0	.0	.0
Oil permeability after soaking				
Immediately after removal	31.4			
30 minutes after beginning test	37.9		10.8	
1 hr after beginning test		8.9		
2 hr after beginning test				0.3
2¼ hr after beginning test		13.4		
3 hr after beginning test			13.4	
4½ hr after beginning test	56.6			
6 hr after beginning test				0.6

obtained when dry air or oil is flowing through the sand.

The results of the analysis of these cores indicate that the most permeable sandstone units lie at depths from 466 to 478 feet, from 866 to 908 feet, and from 964 to 972 feet. They indicate that these beds average approximately 16 percent porosity, 88 millidarcys dry-air permeability, 47 percent of the pore space filled with water, and 660 barrels of oil per acre-foot. The 660 barrels of oil per acre-foot is total oil in place, only part of which is recoverable oil.

The results indicate that addition of water to these sandstones greatly reduces the permeability to oil. Therefore, water should be kept away from these sandstones to keep the permeability to oil at its maximum value and assure the maximum flow of oil into the well.

Properties of oil-base drilling fluid used in core-contamination test at Umiat test well 9

[Analysis by U. S. Bur. Mines]

Core	Depth (feet)	Drilling fluid								Drilling fluid filtrate	
		Filtrate volume (ml in 30 min) at—		Weight in—		Water content		API funnel viscosity (1 qt out)		Water content (percent by weight)	Tracer concentration (mg/ml)
		45°F	75°F	lb/gal	lb/cu ft	Percent by weight	Percent by volume	Time (sec)	Temperature (°F)		
----------	374–384	0.0	--------	8.6	64.5	10.95	11.34	95	61	--------	--------
4	413–423	.0	9	8.8	66.0	8.85	9.38	79	50	--------	14.2
9	464–474	1.3	12	9.0	67.0	9.08	9.77	83	48	1.05	14.7
10	474–484	1.1	10	9.1	68.0	9.07	9.90	85	45	1.07	14.3
11	484–494	1.1	10	9.2	69.0	8.76	9.70	95	46	.33	14.3
15	502–512	1.1	12	9.4	70.0	8.59	9.65	90	44	.82	14.1
23	573–583	5.2	16	9.8	73.0	6.92	8.11	72	45	.16	10.4
38	858–868	20.0	29	10.2	76.0	3.65	4.45	76	48	.0	4.5
39	868–878	20.0	30	10.3	77.0	3.57	4.41	69	47	(1)	18.5
40	878–888	20.0	27	10.3	77.0	3.64	4.50	69	47	(1)	17.7
41	888–898	20.0	34	10.4	78.0	3.71	4.64	69	46	--------	21.7
42	898–901	20.0	33	10.4	78.0	3.72	4.65	69	46	(1)	17.5
43	901–911	21.0	36	10.3	77.0	4.03	4.98	59	45	(1)	15.6
48	949–959	21.0	38	10.4	77.5	4.02	5.00	60	46	(1)	15.3
49	959–969	21.0	42	10.4	77.5	4.29	5.37	60	46	(1)	14.6
50	969–979	6.4	12	10.4	78.0	4.33	5.42	59.5	46	--------	13.8
52	1,895–1,000	7.9	14	10.5	78.5	4.54	5.72	57.0	46	--------	13.4
53	1,000–1,010	7.9	10	10.5	78.5	4.67	5.88	57.0	46	--------	12.8
54	1,010–1,017	--------	13	10.4	78.0	4.41	5.52	57.0	46	0.0	13.2
57	1,037–1,047	3.4	7	10.2	76.5	5.01	6.15	53.0	41	--------	10.6
58	1,047–1,057	2.2	--------	--------	72.0	--------	--------	52.0	42	--------	--------
59 [2]	1,057–1,067	3.0	--------	--------	72.0	--------	--------	46.0	42	--------	--------
61	1,077–1,086	1.9	--------	--------	59.5	--------	--------	42.0	45	--------	--------
62	1,086–1,096	4.1	--------	--------	59.5	--------	--------	44.0	42	--------	--------
67	1,137–1,147	2.0	--------	--------	60.5	--------	--------	48.0	40	--------	--------

[1] The drilling-fluid filtrates from drilling fluid samples 39, 40, 42, 43, 48, and 49 were combined, and the water content of the combined samples was negligible.
[2] Cuttings dropping from suspension.

PETROGRAPHIC ANALYSES

In 1952 Paul D. Krynine, of the U. S. Geological Survey, and John C. Ferm, of Pennsylvania State College, made a detailed study of 13 sandstone samples from Umiat test well 9. The material presented here is taken from their work.

The rocks are low-rank graywackes, composed primarily of quartz and chert grains, with a large amount of micaceous material (including micaceous rock fragments as well as a micaceous matrix), and a small amount of feldspar and kaolin. Two samples contain less than 20 percent of micaceous grains or clay-size particles, 5 have 20–30 percent of micaceous material, and 6 contain more than 30 percent of it. The quartz grains range from silt to fine sand in size and are poorly sorted. They were originally derived from intrusive igneous rocks but have been reworked several times. Inclusions such as bubbles, and bubble trains and microlites of apatite, biotite, tourmaline, and zircon are rare. Two types of chert are present—a colorless kind of relatively coarse microcrystalline quartz and a lesser quantity of yellow chert, fine textured enough to be almost isotropic, except for a small amount that is somewhat fibrous like chalcedony. Inclusions are very rare in both kinds. The origin of the chert is doubtful as only rare grains contain carbonate material suggestive of replacement, and nothing in the rest suggests its source. Feldspar makes up about 4 percent of the rock. Orthoclase, microcline, perthite, albite, and oligoclase are represented, the first two in some specimens as graphic intergrowths with quartz. Some of the feldspar

is unaltered, but part is sericitized or altered to muscovite, and about a third (including some sericitized grains) is kaolinized. This alteration suggests a pegmatitic origin followed by a long period of subaerial weathering before deposition in its present environment.

Less durable grains of similar size are composed of micaceous rock fragments, most of which are dark slate and nongraphitic phyllites, with some carbonized, pyritized, or limonitic plant remains. Fragments of siltstone, badly weathered volcanic rock, and mica are very rare. Many of these rock or mineral fragments are in somewhat flexible tabular particles which may block some of the pore spaces between the more rigid quartz and chert grains.

About two-thirds of the matrix, consisting of detrital constituents less than 0.032 millimeter in diameter, is made up of slate or phyllite particles. Clay particles are subordinate; montmorillonite, formed from volcanic ash, makes up less than 10 percent of the matrix, and other clay minerals are very rare. Minute illite crystals coat the surface of some quartz grains.

Chemically deposited cement is a very minor constituent of the rock. It includes secondary quartz overgrowths, some collophane, and dolomite, part of which is iron bearing. The mineral composition of the samples is shown in the table following.

A study of the relation between composition and reservoir properties of the rocks reveals that the greater the proportion of rock fragments and matrix to quartz and chert, the greater the porosity. Comparisons of grain size and sorting show them to have comparatively little effect on porosity; the shape of the rock fragments and consequently their packing is the controlling factor in these rocks. The sandstone samples from this well are better reservoir rock than those in many of the others from the Reserve because they have less montmorillonite and a lower percentage of micaceous rock fragments and micaceous matrix.

Porosity, permeability, and mineral composition of 13 sandstone samples from Umiat test well 9

[Analysis by P. D. Krynine and John C. Ferm]

Depth (feet)	Porosity (percent)	Permeability (millidarcys)	Quartz (percent)	Chert (percent)	Feldspar (percent)	Rock fragments (percent)	Matrix (percent)	Carbonates (percent)
422.5	14.3	0.7	42.0	12.0	1.0	30.5	9.0	5.5
466.5	19.1	150.0	61.5	17.0	1.5	17.0	3.0	.0
498.5	9.3	.12	35.5	2.5	1.5	47.0	13.5	.0
875.5	18.5	170.0	58.0	14.5	6.0	17.0	4.5	.0
900.5	15.8	53.0	57.0	14.0	3.5	22.0	3.5	.0
906.0	14.4	80.0	59.5	12.5	5.0	16.0	6.0	1.0
964.5	14.1	20.0	49.0	19.5	4.5	21.0	5.5	.5
965.5	15.5	97.0	40.0	30.5	6.5	21.0	1.5	.5
968.5	15.3	65.0	44.0	21.5	6.0	20.0	7.0	1.5
995.0	9.21	1.4	44.0	15.0	4.0	17.5	7.0	12.5
1,003.0	11.9	1.4	41.5	13.5	1.5	29.5	10.0	4.0
1,040.5	9.85	.39	48.5	9.5	4.5	27.5	8.0	2.0
1,043.5	10.5	.22	47.5	11.0	5.5	28.0	7.5	.5

OIL AND GAS

OIL AND GAS SHOWS

Several oil and gas shows, given below, were noted in this well. The well produced some oil (see p. 167), but the depth from which it came is uncertain.

Depth (feet)	*Remarks*
60	Oil odor in sandstone.
533–561	Faint show of oil in siltstone and thin sandstone beds.
649–707	Do.
829–838	Show of oil.
866–888	Water in sandstone.
888–901	Odor of oil in sandstone.
901–929	Odor of oil in sandstone; upper 10 ft bled oil.
929–939	Siltstone with show of oil.
969–1,010	Sandstone bled oil.
1,027–1,037	Sandstone with faint odor of oil.
1,037–1,071	Sandstone bled oil and gas.
1,127–1,146	Slight oil stain in siltstone.

FORMATION AND PRODUCTION TESTS

Several swabbing tests and a 6½-week pumping test produced an average of 217 barrels of oil per day with no water, but the source of the oil was not determined, in spite of plugging back by stages and later perforating casing opposite possible producing sands. These operations, most of which were recorded by George L. Gates, of the U. S. Bureau of Mines, and production during the test are given in the following two tables.

Depth (feet)	*Remarks*
533	Tubing run into hole with cone packer at 47 ft. Hole swabbed dry in 10 min, with recovery of 2 bbl of oil-base mud. An hour later it was swabbed again; no fluid recovered, although swab had faint odor of Umiat crude oil.
866–901	Packer set at 866 ft, and 3 hr of swabbing recovered 3 bbl of mud with no oil or water.

Depth (feet)	*Remarks*
959–1,017	Packer set at 959 ft with 43 ft of open-end tubing below it; 4 hr of swabbing recovered 5 bbl of mud with no oil, gas, or water.
1,257	Two-inch, open-end tubing with perforated bottom joint run in hole to 1,224 ft, and 75 bbl of oil-base mud was swabbed. Then 25 bbl of crude oil was swabbed, with fluid level at 1,000 ft. In next 7 hr, 90 bbl of crude swabbed and fluid rose to 800 ft.
	In 8 hr 110 bbl of oil swabbed. Fluid level remained at 800 ft but rose to 50 ft when swabbing stopped for lack of storage space. Tubing pulled out and rerun to 1,208 ft, with insulated wire welded to bottom joint and coming to surface, completing electrical circuit for heating. Pump shoe at 1,197 ft. After installing 39 joints of 30-ft sucker rod and pump, rig was moved away and pumping test begun. A 24-in. stroke used, except for last 3 days, when 36-in. stroke was used. Strokes per minute ranged from 20 to 25, although 22 was most common rate. Generator supplying power for heating tubing was set at 175 amperes, which maintained the flow-line temperature at 30°–32°F for the first 3 days. Then it was turned off to test icing conditions, and temperature dropped to 26°F, where it remained until last week of test, when it dropped to 24°F. Oil is gas-cut, and flows by heads, in small amounts.

Daily production during a 6½-week pumping test, Umiat test well 9

Date	Hours pumped	Oil (bbl)	Date	Hours pumped	Oil (bbl)
Aug. 15	24.0	249.5	Sept. 7	21.5	180.0
16	23.5	222.5	8	22.75	226.0
17	23.5	225.0	9	22.5	219.0
18	23.5	242.5	10	23.5	212.0
19	23.5	229.0	11	22.75	218.0
20	23.5	221.0	12	20.5	201.0
21	23.5	226.0	13	22.75	213.0
22	23.5	240.0	14	22.75	201.0
23	19.75	251.0	15	22.75	222.0
24		(1)	16	22.75	290.0
25	22.5	242.0	17	22.75	241.0
26	22.75	248.0	18	22.75	237.0
27	20.75	177.0	19	21.00	234.0
28	22.25	206.0	20	16.00	162.0
29	22.75	231.0	21	24.00	237.0
30	19.25	243.0	22	24.00	255.0
31	13.25	135.0	23	24.00	220.0
Sept. 1	23.75	265.0	24	6.00	52.0
2	22.5	245.0	25	6.00	89.0
3	7.0	83.0	26	24.00	317.0
4	6.0	72.0	27	24.00	309.0
5	22.5	234.0	28	18.00	223.0
6	22.25	224.0	Total	912.75	9,469.5

[1] Shut down repairing motor.

After the test the well was cleaned out to the total depth, using oil from the well as a drilling fluid, and the bottom of the hole was cemented with 45 sacks of Cal-Seal. The top of the plug, which was at 1,017 feet, was drilled out to 1,100 feet before running in 36 joints of 2½-inch tubing at 1,000 feet. Swabbing showed the tubing to be plugged at 408 feet, and the bottom 24 joints were found filled with ice and Cal-Seal. The ice was thawed, and tubing was lowered to 1,087 feet, and after circulating for 8½ hours, 5 hours of swabbing lowered the fluid level from the surface to 890 feet, recovering 35, 21, 15, 2, and 8 barrels of oil in hourly intervals. The fluid rose to 550 feet during a 2-hour shutdown to work on the rig. It was lowered to 890 feet again with 17, 11, and 11 barrels of oil pumped in 3 consecutive hours. The next 6½ hours produced 62 barrels of oil.

A plug of 45 sacks of Cal-Seal filled the hole up to 946 feet, was drilled out to 948 feet, and drilling fluid circulated for 2 hours. Tubing was run to 937 feet and swabbing produced 22.8, 11.4, and 4.7 barrels of oil in 3 hours, lowering the fluid level to 790 feet. The fluid rose to 560 feet when the hole was shut down 2½ hours, and further swabbing recovered 25.7, 19, 10, and 11.4 barrels of oil in 4 hours and 6 barrels in the next ½ hour. Twelve hours of intermittent swabbing was followed by continuous swabbing; 22 barrels was recovered in the first hour and 12 barrels in the second, lowering the fluid level from 342 to 515 feet.

The hole was plugged with cement up to 819 feet, and the plug cleaned out to 850 feet. Tubing was run to 846 feet, and fluid was circulated through it for 3 hours. Swabbing recovered 57 barrels of oil in the first 7 hours, and 54 in the next 10 at a steady rate of about 5½ barrels per hour.

The hole was then plugged to 742 feet with cement, cleaned out to 748 feet, and with tubing set at 723.5 feet, drilling fluid was circulated through the tubing for 3 hours. Swabbing recovered 20.0, 14.0, 11.4, 8.5, and 5.7 barrels of oil in 5 hours. The well was shut down for an hour; and 2 hours of swabbing thereafter recovered oil at 11 barrels per hour, lowering the fluid level from the surface to 600 feet. More swabbing recovered 17 barrels in 1 hour and 5 barrels of oil in an additional hour, lowering the fluid to 650 feet.

After cementing and standing for 21 hours, ice was drilled from 454 feet to the top of the plug, at 531 feet. Cement was drilled to 555 feet, and drilling fluid circulated 3½ hours before tubing was run in to 547 feet. After 2 hours of circulating through the tubing, the tubing was pulled up to 540 feet and swabbing began. The hole was swabbed dry in 2 hours; then warm oil was circulated through the tubing for 5 hours before swabbing again. After recovering 30 barrels of oil in 3½ hours, the hole was dry. Only 5 barrels of oil was recovered in the next 10 hours of swabbing.

Eleven days after drilling out the hole and setting 5½-inch casing at 1,257 feet (see p. 168), four attempts were made to perforate between 1,247 and 1,257 feet, but the gun did not fire on the first three attempts, and on the fourth, only 4 of the 24 shots were discharged.

Three weeks later, the hole was filled with Umiat oil from the storage tank, and 41 shots perforated the casing from 1,245 to 1,255 feet. Tubing was run to 1,253 feet, and about 28 barrels of oil was swabbed from the casing. Swabbing recovered no fluid for 8 hours thereafter, and then recovered 1½ barrels of oil after which the hole was again dry for 19 hours. The hole, filled again with Umiat crude oil from storage, was then perforated from 1,234 to 1,218 feet with 60 shots. After swabbing the hole out it remained dry, and the casing was again perforated, from 1,135 to 1,145 feet with 41 shaped charges. Swabbing showed no fluid entering the hole. The casing from 1,017 to 1,073 feet was perforated with 210 shots, and swabbing still produced no fluid. The same result was obtained after perforating from 960 to 1,017 feet with 210 shots, 900 to 938 feet with 150 shots, and 866 to 900 feet with 137 shots, although the hole was alternately swabbed and allowed to stand idle for several hours after each set of shots. Operations were shut down 2 days because of a storm, but 8 days more of swabbing once an hour for 12 hours a day failed to recover any oil.

LOGISTICS

Personnel and housing.—Supervisory personnel comprised drilling foreman and George L. Gates, U. S. Bureau of Mines petroleum engineer, who was making a study of the reservoir properties of the rock penetrated by the drill. Drilling crews consisted of 2 drillers, 2 derrickmen, and 2 floormen. Temporary workers such as a geologist, welder, cementer, electrician, carpenter, or plumber came from Umiat camp as their services were required. The crew was housed at Umiat camp; so the only buildings at the well site were the pump, cementing, and boiler and generator wanigans.

Vehicles and heavy equipment.—Vehicles such as vessels, Caterpillar tractors, and LVT's were brought from Umiat camp when necessary. One each of the following major items of drilling equipment was listed by the Arctic Contractors as having been used.

- Failing 1500 rotary rig.
- Buda 6-cylinder gasoline engine, model HP–326, mounted on a pipe sled; power supply for rig.
- Gardner-Denver 4½- by 6-in. pump, model FG–FXG.
- Gardner-Denver 4½- by 10-in. mud pump.
- Caterpillar D8800 diesel engine, power supply for mud pump.
- Heat-Pak boiler, model 624–S.
- Westco boiler feed pmp.
- Kohler 4 kw generator.
- Waukesha 4-cylinder gas engine, model FCL–70; Heat-Pak, boiler feed pump, generator, and engine are all mounted in a wanigan on a pipe sled.
- Oilmaster 2½- by 2-in. by 8-ft stationary-barrel top-anchor pump.
- Lufkin T7–3A pumping unit, with crank strokes of 12, 16, and 24 in.
- Gardner-Denver 5½- by 10-in. cementing pump.
- Caterpillar D8800 diesel engine, power supply for cementing pump.

Fuel, lubricant, and water consumption.—In drilling and testing Umiat test well 9, a total of 7,176 gallons of diesel fuel and 3,591 gallons of 72-octane gasoline were burned, and 130¼ gallons of no. 9170 lubricating oil, 111 pounds of thread-lubricating grease, and 54½ pounds of no. 00 grease were used for lubrication. Water requirements totaled 11,739 gallons.

DRILLING OPERATIONS

The Failing rotary rig was mounted on a welded steel sled and towed to the well site with a D8 Caterpillar tractor. It was set up on 12- by 12-inch timbers lying on the ground. After an extended production test the well was gradually plugged back and then drilled out, cased, and perforated in stages in an attempt to locate the source of the oil.

When the hole was 63 feet deep, surface casing of 8⅝-inch 24-pound, seamless line pipe was set at 61 feet with 40 sacks of Cal-Seal. The top of the annulus was cemented with 3 sacks of Cal-Seal and 1 sack of construction cement.

At the total depth of 1,257 feet, the drilling rig was removed for a 6½-week pumping test and then replaced over the hole. Plugging the hole back in stages to locate the source of the oil produced (see p. 167) was unsuccessful; so the hole was cleaned out to 876 feet. The oil used as a drilling fluid could not lift the cement out of the hole until reverse circulation was used, with the tubing at 700 feet. The tubing was lowered to 854 feet and more cement circulated out. Ice and frozen cement were cleaned out from 60 to 875 feet before drilling out the plug to 1,077 feet. The cement again failed to come out of the hole, and the rock began to take oil from the drilling fluid. Three sacks of Jelflake and two of Fibertex were circulated for an hour, but reversing circulation again forced oil into the rock when the tubing became plugged with cement.

The hole was cleaned out to 1,077 feet, and with brine made of 40 pounds of salt per barrel of water replacing oil as the drilling fluid, the cement plug was drilled out to the total depth. The cement did not settle out of the drilling fluid at first, but when it was displaced with 92 barrels of Umiat crude oil, the hole was finally cleaned out.

Casing (57 joints of 5½-in. 22.54-lb. pipe) was run to the total depth at 1,257 feet where it was cemented with 140 sacks of construction cement treated with 600 pounds of calcium chloride. The plug was emplaced with a pressure of 600 pounds per square inch.

The top of the hardened cement was found at 1,255 feet. The hole was filled with oil, and the top of the annulus between the 5½-inch and the 8⅝-inch casings was cemented with 3 sacks of Cal-Seal and 1 sack of construction cement.

In cleaning out the hole after perforating the casing, an ice bridge was drilled from 430 to 520 feet; thin ice stringers were present to the total depth. About 26 barrels of dead oil was swabbed through 2½-inch tubing, and the hole was left empty to 1,200 feet. Below that depth, it was filled with oil. A 3-inch gate valve was installed on the casing head, its top about 3 feet above the ground.

DRILL AND CORE BITS

The hole was cored for most of its depth, using 24 Reed hard-formation core bits, all 5⅞-inch in diamter except the last 2, which were 6 inches in diameter. Most of the drill bits used were Reed 2H, 7⅞-inch rock bits, and they did more reaming than drilling of new hole. Fifteen bits were used to reach the total depth; several of the 15 were reused to clean out the hole after casing had been set. One bit, a 4⅝-inch Reed, was used to clean ice out of the hole.

DRILLING MUD

The mud used when the hole was drilled to 209 feet was water-base mud to which 11 sacks of Jelflake were added; below that depth oil-base mud was used to avoid contaminating cores with fresh water, which would have made accurate fluid-content studies impossible.

The mud was composed of oil from Fish Creek test well 1, Ken-Oil concentrate, and diesel fuel; Aroclor was added as a tracer to provide a means of determining the extent of drilling-fluid penetration into the cores. Addition of Ken-Oil and Fish Creek crude oil increased the viscosity of the mud, and diesel oil was used to decrease it. Gel properties were increased by adding Ken-Oil and unslaked lime, which also decreased the filter loss. The mud weight was kept as low as possible to avoid losing drilling fluid in the rock. The following table shows the quantity of oil-base mud components used and the mud characteristics during drilling.

Constituents and characteristics of oil-base mud in Umiat test well 9

Depth (ft)	Diesel fuel (bbl)	Fish Creek oil (bbl)	Ken-Oil (bbl)	Unslaked lime (lb)	Weight (lb/cu ft)	Viscosity API (sec)	Filtration loss (cc/30 min)	Temperature (°F)
65								40
100								40
165								38
205								38
209	16.0	6	3.0	150				
265	2.0	7	1.0	60	59	75	0	48
312	1.0	1						
320	2.0	3	.5	30	64	95	0	
375 [1]	3.0							50
385	1.0							
395					66	92	0	50
412	1.5							
440					67	82	0	48
462	0.5							
482	1.0		.5	30				
495					69	95	1.2	42
500	0.5							
520	.5							
522					69	95	1.2	42
522	5.0				71	90	2.0	40
543	1.0							
583	2.0	1	.5	30				
603	1.0							
610					71	72	6.5	46.5
613	2.0							
630	1.0							
655					74	69	5	46
659	2.0		.5	30				
679	1.0							
695						71	8	47
707	2.0							
715					74	75	8	47
740	1.0		1.0					52
765	5.0				75	80		50
789	1.0							
808					77	75	8	50
822	3.0							
838					77	100	20	48
839	3.0							

See footnote at end of table

Constituents and characteristics of oil-base mud in Umiat test well 9—Continued

Depth (ft)	Diesel fuel (bbl)	Fish Creek oil (bbl)	Ken-Oil (bbl)	Unslaked lime (lb)	Weight (lb/cu ft)	Viscosity API (sec)	Filtration loss (cc/30 min)	Temperature (°F)
848	2.0							
865					77	75	20	52
868 [1]	4.0							
888	2.0							
895					76	73	16	52
900	3.0							
922	1.0							
925					76	63	2	42
950	2.0	1						
965					78	63	6.5	45
975	2.0	1						
988	1.0	1			78	58		42
1,015					76	60	7	48
1,018	5.0	2						
1,040		3						
1,050	4.0							
1,056					76	52	4	42
1,068	2.0	2						
1,075	8.0	3	.1	30	72	42		42
1,085	10.0	4	2	60	60	42	2	46
1,105		1		30				
1,117	1.0	4	.5					
1,125							2	42
1,136					60	45		
1,136		1		30				
1,156	4.0	1						
1,175					61	52		
1,190						50		
1,215					61	50		
1,245	1.0							
1,255	1.0	1						
1,257					62	50	5	41

[1] Five hundred pounds of Aroclor added.

Viscosity and gel strength were kept as low as possible, because cuttings did not drop from suspension when viscosity was above 50 Marsh funnel seconds at about 45°F. To remove cuttings from the cement plug, before setting casing, the oil-base mud was replaced with brine made of 2,500 pounds of salt, mixed with water at the ratio of 40 pounds per barrel. The cement did not circulate out with the oil-base mud, but cleaning out with brine was successful. After the casing had been set, the hole was then filled with 92 barrels of oil. Before abandoning the hole, diesel fuel was added to the oil in the hole to clean out ice bridges.

TEMPERATURE MEASUREMENT STUDIES

By Max C. Brewer

Umiat test well 9 was drilled with rotary drilling equipment; consequently, the thermal regime of the hole was considerably disturbed. Passage of fluid when the well was producing also affected the temperature.

Two thermistor cables, the longest reaching to a depth of 665 feet, were installed on November 23, 1952, approximately 10 months after the completion and abandonment of the hole. A third thermistor cable, reaching to a depth of 870 feet, was installed on October 12, 1953. These cables were operated until August 1954 when the hole filled with air down to 270 feet. Crude oil filled the hole below this depth.

The thermal profile for Umiat test well 9 is characterized by a gradient of about 135 feet per degree centigrade from approximately 100–870 feet. This is the largest inverse geothermal gradient found in the Umiat area. The inverse geothermal gradient at Umiat test wells 4 and 6 is approximately 115 feet per degree centigrade for similar depths.

A short extrapolation of the thermal profile in Umiat test well 9 on October 13, 1953, indicates a depth of permafrost of 1,055 feet. This thickness of permafrost is approximately 150 feet greater than that found at any of the other Umiat wells where temperature measurements have been made. Except for a well 8 miles south of Barrow, this is also the greatest indicated thickness of permafrost found in Naval Petroleum Reserve No. 4 to date. Although temperatures had not yet reached equilibrium at Umiat test well 9 on this date, they were close enough so that the shape of the thermal profile and the indicated thickness of permafrost will not be significantly different.

The minimum permafrost temperature in this well, below the depth of seasonal change, is approximately −7.2°C near the 70-foot depth. This temperature is approximately 1°C colder than those found at a similar

depth in Umiat test wells 4 and 6. The colder minimum temperature and the greater thickness of permafrost are, at least in part, the result of topography and the increased distance of the well from the Colville River. Sufficient data are not yet available to allow a study of the relative importance of these factors.

UMIAT TEST WELL 10

Location: Lat 69°24′04″ N., long 152°07′57″ W.
Elevation: Ground level 741 feet; derrick floor, 746 feet.
Spudded: September 9, 1951.
Completed: January 10, 1952; bailed 222 barrels of oil in 24 hours; plugged and abandoned.
Total depth: 1,573 feet.

This well was drilled to test the Umiat anticline northwest of Umiat test well 8, which was located less than half a mile away and on the same ridge.

DESCRIPTION OF CORES AND CUTTINGS

The first samples recovered from the hole were from the Ninuluk formation, and contain specimens of *Trochammina rutherfordi* Stelck and Wall (see p. 203). The presence of this foraminifer above the younger Seabee formation demonstrates the presence of a reverse fault at 210 feet. Below the fault a normal sequence of Seabee formation (210–645 ft), Ninuluk formation (645–765 ft), and Killik tongue (765–1,025 ft) of the Chandler formation was drilled. Below 1,025 feet the well was drilled through the Grandstand formation, and the upper sandstone bed of the formation was tested. The lower sandstone bed would normally be expected at 1,430 feet on the basis of correlation with Umiat test well 8 and other holes. Instead, the well continued in clay shale to 1,530 feet. From 1,530 feet to total depth, the formation consisted of a little sandstone and siltstone interbedded with clay shale. Although the amount of sandstone in the samples is small, these and oil recovered after the casing was set at 1,339 feet suggest that the lower sandstone bed was penetrated below 1,530 feet. The absence of sandstone in samples from 1,430 to 1,530 feet, however, implies the presence of a reverse fault near 1,430 feet which increases the thickness of the shale section by repetition. Because no electric log was run in this hole and the sides caved considerably during drilling, the above described lithology may be misleading.

The rocks penetrated contained oil at three different horizons: sandstone of the Ninuluk formation had an initial production of 96 barrels per day; an estimated maximum of 153 barrels per day was recovered by bailing from the upper sandstone bed of the Grandstand formation, and the lower (?) sandstone bed of the Grandstand formation produced a good show of oil but was not tested because caving forced abandonment of the hole.

Lithologic description

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

Core	Depth (feet)	Remarks
-----	0–4.5	Kelly bushing to ground level.
-----	4.5–70	No sample.
-----	70–160	Sandstone, medium-light-gray, fine-grained, slightly silty and argillaceous, slightly micaceous, noncalcareous, friable; composed of subangular clear and white quartz with some dark rock fragments. At 75–80 ft abundant yellow (quartz?) grains impart a light-olive-gray color to the rock. Between 80 and 90 ft sandstone is brownish gray, hard, and very calcareous, becoming slightly calcareous at 95 ft. Below 120 ft sandstone is very fine to fine grained, siltier, and more argillaceous. Very small amount of clay shale at base of sandstone.
-----	160–180	Clay shale, medium-dark- to dark-gray, noncalcareous, slightly to very silty and micaceous.
-----	180–200	Clay shale as above, and medium-gray argillaceous noncalcareous siltstone; sandy, pyritic, and carbonaceous in part. Very small amount of clay shale is bentonitic.
-----	200–220	Clay shale, medium-dark-gray, slightly to very silty. Top of Seabee formation at 210 ft.
-----	220–230	Siltstone, medium-gray, sandy, argillaceous, noncalcareous.
-----	230–250	Siltstone and clay shale as above, with rare clay ironstone in lower part. Minute light-brown shiny clay balls at 240–250 ft.
-----	250–280	Clay shale, medium-dark-gray, slightly to very silty, micaceous, noncalcareous. Some siltstone in bottom 5 ft. Minute light-brown shiny clay balls at 260–270 ft.
-----	280–290	Siltstone, medium-gray, argillaceous; very slightly calcareous in part; small amount of very silty medium-dark-gray clay shale. Minute light-brown shiny clay balls at 280–285 ft.
-----	290–300	Clay shale and siltstone.
-----	300–330	Siltstone, rarely slightly calcareous, with small amount of clay shale. Minute light-brown shiny clay balls at 300–305 ft.
-----	330–370	Clay shale, medium-dark-gray, slightly to very silty, with very small amount of siltstone in upper part.
-----	370–380	Siltstone, medium-gray, slightly to very sandy and argillaceous, very micaceous, noncalcareous, with small amount of clay shale.
-----	380–385	Siltstone and clay shale.
-----	385–395	Clay shale, medium-dark-gray, slightly to very silty and micaceous, with dark-gray slightly carbonaceous silty micaceous clay shale in lower half.
-----	395–400	Siltstone, with small amount of clay shale and very small amount of medium-light gray very fine-grained silty argillaceous partly calcareous sandstone.
-----	400–410	Clay shale, medium-dark-gray, slightly to very silty in part.
-----	410–420	Sandstone, light-olive-gray, fine-grained, silty, argillaceous, noncalcareous, slightly carbonaceous, friable, with rare yellow grains and mica. Very small amount of medium-dark- and dark-gray carbonaceous clay shale, rare pyritic carbonaceous siltstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
1	420–425	Recovered 4 ft: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, micaceous; slightly calcareous in part; massive except for rare carbonaceous or argillaceous laminae that dip 2°–12°. Sand composed of subangular clear and white quartz with some dark rock fragments, carbonaceous particles, and light and dark mica.
-----	425–445	Sandstone as in core 1, but darker, calcareous, hard.
-----	445–450	Sandstone, medium-light-gray, very fine-grained, very micaceous, noncalcareous, with some grayish-brown calcareous clay ironstone.
-----	450–465	Sandstone with small amount of siltstone and clay shale at top, increasing to half the rock at base.
-----	465–468	Sandstone, medium-light-gray, fine-grained (with rare medium grains), silty, argillaceous, micaceous, noncalcareous; composed of subangular clear and white quartz with some dark rock fragments.
2	468–473	Recovered 4 ft: Microfossils absent. Sandstone, medium-light-gray, fine-grained (with some medium-grained streaks in upper part), silty, argillaceous, noncalcareous, slightly micaceous, with carbonaceous partings in lower part dipping about 5°.
-----	473–485	Sandstone as in core 2, fine- to medium-grained at base.
3	485–490	Recovered 4 ft: Microfossils absent. Sandstone, fine- to medium-grained, as in core 2.
-----	490–495	Sandstone as in core 3.
-----	495–505	Siltstone, medium-gray, sandy, slightly argillaceous, noncalcareous, with small amount of sandstone in upper part and clay shale in lower part.
-----	505–540	Clay shale, medium-dark-gray, silty to very silty.
-----	540–550	Siltstone, medium-gray, sandy, argillaceous, noncalcareous, with very small amount of medium-light-gray very fine-grained very silty sandstone in upper part and small amount of light-blue-gray bentonite in lower part. Bentonite has slippery feel and conchoidal fracture.
-----	550–555	Siltstone, with clay shale and bentonite.
-----	555–570	Clay shale, slightly to very silty, with small amount of siltstone in upper part.
-----	570–575	Siltstone, with clay shale.
-----	575–605	Clay shale, slightly to very silty, with small amount of siltstone in upper part and yellowish-gray noncalcareous clay ironstone in lower part.
-----	605–610	Siltstone, with small amount of clay shale.
-----	610–615	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous.
-----	615–625	Siltstone and clay shale.
4	625–628	Recovered 2 ft 6 in.: Microfossils absent. Clay shale, medium- to medium-dark-gray, slightly silty, noncalcareous, with rare faint medium-light-gray silty laminae dipping less than 5°. Shaly cleavage poor.
-----	628–635	Siltstone and clay shale, with medium-gray very fine-grained sandstone in lower 5 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	635–650	Clay shale, with some siltstone and very small amount of sandstone. Top of Ninuluk formation at 645 ft.
-----	650–655	Sandstone, light-olive-gray, fine- to very fine-grained, silty, argillaceous, slightly calcareous; composed of subangular clear and white quartz with some dark rock fragments and rare carbonaceous particles and mica.
5	655–659	Recovered 4 ft 6 in.: Microfossils absent. Sandstone, light-olive-gray, very fine-grained, silty, argillaceous, slightly micaceous, noncalcareous, massive. Carbonaceous partings rare. Upper part of core consists of unconsolidated sand.
-----	659–670	Sandstone as above.
6	670–675	Recovered 5 ft: Microfossils absent. Sandstone as in lower part of core 5.
-----	675–685	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, sericitic, noncalcareous, friable.
7	685–690	Recovered 5 ft: Microfossils very rare. Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, micaceous, noncalcareous, massive.
-----	690–700	Sandstone, with some siltstone and clay shale.
8	700–705	Recovered 4 ft 9 in.: Microfossils absent. Sandstone, medium-gray, fine-grained, silty, argillaceous, micaceous, noncalcareous, massive; composed of subangular grains of clear and white quartz, gray chert and dark rock fragments.
-----	705–715	Sandstone as in core 8, with some medium-grained friable sandstone.
9	715–720	Recovered 3 ft: Microfossils absent. Sandstone, medium-gray, fine- to medium-grained, slightly silty and argillaceous, noncalcareous, with carbonaceous partings in the upper part; poorly indurated and massive; composition similar to core 8.
-----	720–730	Sandstone, fine-grained; composed of clear and white quartz with rare dark rock fragments.
10	730–735	Recovered 4 ft: Microfossils absent. Sandstone as in core 8.
-----	735–740	Sandstone as in core 8.
-----	740–745	Clay shale, medium-dark-gray, slightly silty.
11	745–750	Recovered 3 ft: Microfossils very abundant. Claystone, medium-dark-gray; slightly silty and micaceous in part; noncalcareous; irregular to conchoidal fracture.
-----	750–753	No sample.
-----	753–760	Clay shale with small amount of sandstone.
-----	760–770	Clay shale, dark-gray, carbonaceous, with very small amount of siltstone. Top of Killik tongue, Chandler formation, at 765 ft.
-----	770–775	Sandstone, light-gray, very fine-grained, silty, argillaceous, calcareous, with rare clay ironstone.
-----	775–785	Clay shale, medium-dark-gray, calcareous, with rare clay ironstone in upper part and silty clay shale with some coal particles and laminae in lower part.
-----	785–790	Siltstone, medium-gray, sandy, argillaceous, micaceous, slightly calcareous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	790–800	Siltstone and clay shale; siltstone decreases from over half of rock in upper part to third in lower part.
-----	800–805	Clay shale, siltstone, and sandstone, medium-light-gray, very fine-grained, calcareous.
-----	805–810	Clay shale, medium-dark-gray, slightly to very silty.
-----	810–815	Sandstone, siltstone, and shale.
-----	815–830	Sandstone, medium-light-gray, very fine-grained, silty, argillaceous, slightly micaceous, slightly calcareous; rare clay ironstone in lower part.
12	830–832	Recovered 1 ft: Microfossils absent. Sandstone, medium-light-gray, fine- to very fine-grained, very silty and argillaceous, micaceous, slightly to moderately calcareous; carbonaceous patches very rare; ¼-in. bed of medium-gray siltstone at bottom of core.
-----	832–835	Sandstone, fine- to very fine-grained, with some clay shale and rare clay ironstone.
-----	835–840	Clay shale, medium-dark-gray and dark-gray, slightly to very silty.
-----	840–850	Clay shale, with small amount of siltstone.
-----	850–855	No sample.
-----	855–885	Clay shale, very silty, and siltstone, very argillaceous.
-----	885–900	Clay shale with rare argillaceous siltstone; very small amount of white bentonite in lower part.
-----	900–905	Clay shale, medium-dark-gray, with some black coaly shale.
-----	905–915	Sandstone, medium-light-gray, very fine-grained, argillaceous, silty, noncalcareous, friable, with very small amount of clay shale in upper part.
-----	915–920	Clay shale with some very fine-grained sandstone.
-----	920–924	Sandstone, very fine-grained, with small amount of siltstone and clay shale.
13	924–930	Recovered 4 ft 5 in.: Microfossils absent. Siltstone, medium-gray, argillaceous, slightly sandy, micaceous, noncalcareous, with faint irregular partings and patches of carbonaceous material dipping 2°–8°.
-----	930–935	Clay shale, medium-dark-gray, with very small amount of sandstone.
-----	935–940	Sandstone, very fine-grained, and siltstone.
14	940–944	Recovered 3 ft 4 in.: Microfossils absent. Siltstone as in core 13, becoming slightly darker and very argillaceous toward base of core.
-----	944–970	Clay shale, medium-dark-gray, slightly to very silty; dark gray and slightly carbonaceous in upper 5 ft. Rare white bentonite just below top.
-----	970–975	Siltstone, medium-gray, slightly calcareous, with small amount of clay shale.
-----	975–995	Clay shale, medium-dark-gray, slightly to very silty.
-----	995–1,000	Clay shale and sandstone, medium-light-gray, fine- to very fine-grained, silty, argillaceous, noncalcareous, friable.
-----	1,000–1,010	Sandstone as above.
15	1,010–1,015	Recovered 5 ft: Microfossils absent. Siltstone, medium- to medium-light-gray, very sandy, argillaceous, micaceous, noncalcareous, with abundant faint slightly carbonaceous and argillaceous laminae in lower part. Dip 3°–10°.
-----	1,015–1,020	Clay shale, with rare siltstone.
-----	1,020–1,025	Sandstone, medium-light-gray, very fine-grained, argillaceous, silty, with small amount of clay shale.
-----	1,025–1,050	Clay shale, medium-gray, with rare siltstone, very small amount of clay ironstone at 1,035–1,040 ft, and very rare coal at 1,045–1,050 ft. Top of Grandstand formation at 1,025 ft.
-----	1,050–1,055	Siltstone, medium-light-gray, sandy, argillaceous, noncalcareous.
-----	1,055–1,065	Sandstone, medium-light-gray, very fine-grained, argillaceous, noncalcareous; composed of subangular clear and white quartz with rare dark rock fragments and carbonaceous particles.
16	1,065–1,070	Recovered 3 ft 6 in.: Microfossils absent. 6 in., claystone, medium-dark-gray, noncalcareous, conchoidal fracture. 3 ft, sandstone, light-olive-gray, fine-grained, slightly silty, argillaceous, noncalcareous; poorly indurated in lower part.
17	1,070–1,075	Recovered 3 ft 9 in.: Microfossils absent. Sandstone as above.
18	1,075–1,080	Recovered 5 ft: Microfossils absent. Sandstone as above.
-----	1,080–1,090	Sandstone and clay shale.
19	1,090–1,095	Recovered 2 ft 8 in.: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, argillaceous, silty, micaceous, noncalcareous; composed of subangular grains of clear and white quartz with dark rock fragments and rare carbonaceous particles.
-----	1,095–1,100	Sandstone, medium-gray, very fine-grained, calcareous, with common dark rock particles.
-----	1,100–1,108	No sample.
20	1,108–1,111	Recovered 2 ft 6 in.: Microfossils absent. 2 ft 2 in., sandstone as in core 19. 4 in., claystone, medium-dark-gray, slightly silty, noncalcareous; irregular fracture.
-----	1,111–1,120	Sandstone, as in core 19, friable.
21	1,120–1,124	Recovered 3 ft: Microfossils absent. 6 in., sandstone as in core 19 above, grades into unit below. 1 ft 8 in., siltstone, medium-gray, sandy, argillaceous, noncalcareous. 10 in., clay shale fragments, medium-dark-gray, noncalcareous; very slightly silty in part; slickensides present on some fragments.
-----	1,124–1,131	Sandstone, as in core 19.
22	1,131–1,134	Recovered 2 ft 6 in.: Microfossils absent. 1 ft 6 in., claystone, medium-dark-gray, slightly to very silty, noncalcareous, irregular fracture, with streaks of yellowish-gray clay ironstone in lower part. 1 ft, sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, slightly calcareous, massive.
-----	1,134–1,150	Siltstone, with slightly to very silty clay shale increasing from half to about 90 percent of rock with depth.
-----	1,150–1,155	Interbedded siltstone, clay shale, and sandstone.
-----	1,155–1,195	Clay shale, medium-dark-gray, slightly to very silty, with very small amount of siltstone.
-----	1,195–1,210	Clay shale, medium-dark-gray, with some dark-gray clay shale at 1,200 ft.
-----	1,210–1,215	Clay shale and sandstone, light-olive-gray, very fine-grained, calcareous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	1,215–1,235	Clay shale with small amount of siltstone, decreasing with depth.
-----	1,235–1,250	Clay shale, medium-dark-gray, slightly silty, noncalcareous.
-----	1,250–1,255	No sample.
-----	1,255–1,275	Clay shale with small amount of siltstone.
-----	1,275–1,330	Clay shale, medium-dark-gray, slightly to very silty, noncalcareous.
-----	1,330–1,340	Clay shale with very small amount of very fine-grained sandstone.
-----	1,340–1,350	Clay shale with very rare siltstone.
-----	1,350–1,530	Clay shale, medium-dark-gray, slightly silty, irregular to shaly fracture.
-----	1,530–1,540	Clay shale, with small amount of medium-light-gray very fine-grained very argillaceous and silty noncalcareous sandstone; and medium-gray sandy very argillaceous noncalcareous siltstone.
23	1,540–1,542	Recovered 1 ft: Microfossils absent. Siltstone, medium-gray, very sandy, argillaceous, micaceous, noncalcareous, massive.
-----	1,542–1,545	Clay shale with rare sandstone.
-----	1,545–1,570	Clay shale as above, with rare sandstone between 1,555 and 1,565 ft.
-----	1,570–1,573	No sample.

CORE ANALYSES

A sandstone bed at 486 feet has an effective porosity of 18.9 percent and an air permeability parallel to the bedding of 640 millidarcys; the tests were made with the equipment described on page 127.

OIL AND GAS

OIL AND GAS SHOWS

Several shows of oil, and a few of gas, were noted by the Arctic Contractors' workers at the well and are given in the following tabulation.

Oil and gas shows, Umiat test well 10

Depth (feet)	*Remarks*
410–498	Slight shows of oil and gas in the cuttings and ditch.
653–655	Good show of oil in sandstone.
655–748	Oil entered hole at approximate rate of 4.5 bbl per hr.
998–1,015	Slight show of oil and gas in sandstone.
1,060–1,116	An oil-bearing sandstone increased oil production in well from 4.5 to more than 10 bbl per hr.
1,339–1,470	Slight odor of oil in bailer samples, but samples showed no fluorescence.
1,518	Bailer had show of oil while cleaning out hole at 1,458 ft.
1,573	Drilling mud was gas cut.

FORMATION TESTS

Bailing and swabbing tests were made while drilling Umiat test well 10; the results in the following table were recorded by Marvin Heany and Kenneth R. Freed, Arctic Contractors' petroleum engineers.

Oil and gas shows, Umiat test well 10

Depth (feet)	*Remarks*
532	Bailed hole dry; still dry after standing 10½ hr.
753	Hole bailed dry in 2 hr, with recovery of 2½ bbl of mud and 20 bbl of oil. After scratching walls with scratchers on bailer for an hour, hole was again bailed dry, and 8 bbl of oil and mud was recovered. Walls washed with brine, and hole bailed dry. Fluid rose to 615 ft in 6 hr, and 2 hr of bailing recovered 20 bbl of oil. In bailing the hole dry hourly for 22 hr, 88 bbl of oil was recovered.
785	Fluid level at 615 ft.
832	Fluid level at 680 ft.
875	Fluid level at 660 ft.
980	With fluid level at 640 ft, hole bailed dry in 9 hr, recovering 120 bbl of oil. Bailing hole dry hourly thereafter for 34 hr, 183 bbl of oil was recovered.
1,095	The fluid level was 650 ft. Oil was bailed for 36 hr, recovering 332 bbl (222 bbl in the first 24 hr) and lowering the fluid level to 935 ft.
1,116	Fluid level at 650 ft.
1,124	Twenty barrels of mud and oil bailed from bottom of hole, and 92 bbl of oil then bailed from top of fluid in hole, lowering fluid level to 759 ft. Six hours more of bailing recovered 72 bbl of oil but could not bail hole dry.
1,129	Fluid level at 650 ft.
1,233	Fluid level at 650 ft.
1,295	Fluid level at 635 ft.
1,339	Fluid level at 630 ft.
1,518	When hole filled with cavings to 1,468 ft, it was bailed dry, and 1 hr later recovered about 8.5 bbl of fluid composed half of mud and half of oil.

Later, when the well reached the total depth of 1,573 feet, the fluid level was at 990 feet, and the drilling mud was gas cut. A swabbing test was made, with tubing run to 1,573 feet with a 9-foot slotted section at the base. Plugged slots caused intermittent entry of fluid at first, but fluid soon began to enter the hole steadily, and it could not be swabbed dry at first. The hole was swabbed dry after 41½ hours.

Tools were run for further drilling, and clean oil was found at 1,170 feet. After cleaning the hole, tubing with the lower 40 feet perforated was run to 1,552 feet.

The swab went through the first 31-foot perforated joint to the top of the 9-foot bottom joint. The mud level, at 1,000 feet, was lowered to 1,500 feet in 12 hours with the recovery of 30–40 barrels of slightly

oily and gas-cut mud. From 5 gallons of fluid composed half of oil and half of mud, the recovery declined to nothing after several hours of continued swabbing. When no more fluid entered the tubing, it was raised 42 feet. No fluid entered the hole for 4 hours, because of caving shale, but later about 400 feet of oil was found in the hole, and approximately 20 barrels of oil was recovered by swabbing. Hourly swabbing recovered about one-half a barrel per hour of oil with some oil-cut mud emulsion. After standing 12 hours fluid rose to 1,073 feet, and the hole produced three-fourths of a barrel per hour before being swabbed dry.

A 46-hour shutdown was caused by a storm, after which 300 feet of clean oil was found in the hole.

OIL ANALYSES

The Petroleum and Natural Gas Branch of the U. S. Bureau of Mines made three analyses (see following tables) of crude oil from Umiat test well 10. Samples taken with the total depth of the hole at 753, 1,518, and 1,573 feet were numbered 52011, 52001, and 52010, respectively. The first came from a bailing test in which an average of 4.5 barrels per hour of water-free oil was recovered. The second, taken after casing was set at 1,339 feet, was taken from a 1¼-hour bailing test which recovered 8 barrels of fluid composed half of oil and half of mud. The third came from the swabbing test made with tubing at 1,510 feet.

Analysis of U. S. Bureau of Mines crude-petroleum sample 52011 from Umiat test well 10, from a bailing test at 753 feet

[General characteristics of sample: Sp gr, 0.839; sulfur, <0.1 percent; Saybolt Universal viscosity at 100°F, 36 sec; gravity, 37.2°API; pour point, below 5°F; color, Natl. Petroleum Assoc. no. 4]

Distillation by 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	Cloud test (°F)
Stage 1.—Distillation at atmospheric pressure, 739 mm Hg. First drop, 54°C (129°F)										
1	50	122								
2	75	167								
3	100	212	6.9	6.9	0.728	62.9		43.0		
4	125	257	9.1	16.0	.767	53.0	35	34.8		
5	150	302	7.2	23.2	.786	48.5	36	33.6		
6	175	347	6.7	29.9	.799	45.6	35	39.2		
7	200	392	5.7	35.6	.807	43.8	33	48.7		
8	225	437	6.4	42.0	.824	40.2	35	55.6		
9	250	482	7.8	49.8	.839	37.2	37	58.6		
10	275	527	9.3	59.1	.855	34.0	40	61.6		
Stage 2.—Distillation continued at 40 mm Hg										
11	200	392	5.0	64.1	0.869	31.3	43	66.6	41	10
12	225	437	7.9	72.0	.870	31.1	39	72.2	46	25
13	250	482	6.3	78.3	.878	29.7	40		58	45
14	275	527	5.3	83.6	.885	28.4	40		86	55
15	300	572	4.5	88.1	.893	27.0	41		155	65
Residuum [2]			11.7	99.8	.916	23.0				

[1] Specific gravity at 60°F compared with water at 60°F.
[2] Carbon residue of crude, less than 0.1 percent.

Approximate summary

Constituent	Percent	Specific gravity	Gravity, °API	Saybolt Universal viscosity
Light gasoline	6.9	0.728	62.9	
Total gasoline and naphtha	35.6	.776	50.9	
Kerosene distillate	6.4	.824	40.2	
Gas oil	28.6	.857	33.6	
Nonviscous lubricating distillate	11.4	0.873–.887	30.6–28.0	50–100
Medium lubricating distillate	6.1	.887–.897	28.0–26.3	100–200
Viscous lubricating distillate				Above 200
Residuum	11.7	.916	23.0	
Distillation loss	.2			

Analysis of U. S. Bureau of Mines crude-petroleum sample 52001 from Umiat test well 10, from a bailing test at 1,518 feet

[General characteristics of sample: Sp gr, 0.843; sulfur, <0.1 percent; Saybolt Universal viscosity 39 sec at 77°F; 37 sec at 100°F; gravity, 36.4°API; pour point, below 5°F; color, Natl. Petroleum Assoc. no.4]

Distillation by Bureau of Mines routine method

Fraction	Cut at—		Percent	Sum (percent)	Specific gravity [1]	Gravity, °API at 60°F	Correlation index	Aniline point (°C)	Saybolt Universal viscosity at 100°F	Cloud test (°F)
	°C	°F								
Stage 1.—Distillation at atmospheric pressure, 753 mm Hg. First drop, 47°C (117°F)										
1	50	122								
2	75	167	1.5	1.5	0.679	76.9				
3	100	212	5.3	6.8	.733	61.5	27	43.6		
4	125	257	9.0	15.8	.765	53.5	34	36.9		
5	150	302	6.9	22.7	.786	48.5	36	34.3		
6	175	347	6.7	29.4	.801	45.2	36	37.8		
7	200	392	5.8	35.2	.813	42.6	36	45.3		
8	225	437	6.4	41.6	.828	39.4	37	53.0		
9	250	482	7.2	48.8	.844	36.2	40	56.5		
10	275	527	9.9	58.7	.859	33.2	42	58.8		
Stage 2.—Distillation continued at 40 mm Hg										
11	200	392	5.2	63.9	0.878	29.7	47	64.7	41	Below 5
12	225	437	6.8	70.7	.879	29.5	44	71.0	48	20
13	250	482	6.3	77.0	.888	27.9	45		62	40
14	275	527	4.9	81.9	.893	27.0	44		93	55
15	300	572	5.2	87.1	.900	25.7	44		170	65
Residuum [2]			11.8	98.9	.923	21.8				

[1] Specific gravity at 60°F compared with water at 60°F.
[2] Carbon residue of crude, less than 0.1 percent.

Approximate summary

Constituent	Percent	Specific gravity	Gravity, °API	Saybolt Universal viscosity
Light gasoline	6.8	0.721	64.8	
Total gasoline and naphtha	35.2	.775	51.1	
Kerosene distillate				
Gas oil	33.3	.856	33.8	
Nonviscous lubricating distillate	11.5	0.880–.896	29.3–26.4	50–100
Medium lubricating distillate	6.6	.896–.903	26.4–25.2	100–200
Viscous lubricating distillate	.5	.903–.904	25.2–25.0	Above 200
Residuum	11.8	.923	21.8	
Distillation loss	1.1			

Analysis of U. S. Bureau of Mines crude-petroleum sample 52010 from Umiat test well No. 10, from a swabbing test at 1,573 feet

[General characteristics of sample: Sp gr, 0.845; sulfur, <0.1 percent; Saybolt Universal viscosity at 100°F, 38 sec; gravity, 36.0°API; pour point, below 5°F; color, Natl. Petroleum Assoc. no. 4½]

Distillation by Bureau of Mines routine method

Fraction	Cut at—		Percent	Sum (percent)	Specific gravity [1]	Gravity, °API at 60°F	Correlation index	Aniline point (°C)	Saybolt Universal viscosity at 100°F	Cloud test (°F)
	°C	°F								
Stage 1.—Distillation at atmospheric pressure, 739 mm Hg. First drop, 63°C (145° F)										
1	50	122								
2	75	167								
3	100	212	5.8	5.8	0.728	62.9		44.9		
4	125	257	8.8	14.6	.767	53.0	35	36.2		
5	150	302	6.9	21.5	.788	48.1	37	32.4		
6	175	347	6.7	28.2	.802	44.9	37	36.5		
7	200	392	5.5	33.7	.812	42.8	35	45.3		
8	225	437	6.3	40.0	.826	39.8	36	52.5		
9	250	482	8.3	48.3	.845	36.0	40	55.8		
10	275	527	9.3	57.6	.861	32.8	43	58.0		
Stage 2.—Distillation continued at 40 mm Hg										
11	200	392	5.7	63.6	0.875	30.2	46	64.1	41	Below 5
12	225	437	7.8	71.1	.877	29.9	43	70.2	47	20
13	250	482	5.8	76.9	.884	28.6	43		62	35
14	275	527	5.3	82.2	.892	27.1	43		94	45
15	300	572	4.8	87.0	.898	26.1	43		180	55
Residuum [2]			12.8	99.8	.917	22.8				

[1] Specific gravity at 60°F compared with water at 60°F.
[2] Carbon residue of crude, 0.1 percent.

Approximate summary

Constituent	Percent	Specific gravity[1]	Gravity, °API	Saybolt Universal viscosity
Light gasoline	5.8	0.728	62.9	
Total gasoline and naphtha	33.7	.779	50.1	
Kerosene distillate				
Gas oil	35.1	.856	33.8	
Nonviscous lubricating distillate	11.2	0.879–.893	29.5–27.0	50–100
Medium lubricating distillate	5.8	.893–.899	27.0–25.9	100–200
Viscous lubricating distillate	1.2	.899–.901	25.9–25.6	Above 200
Residuum	12.8	.917	22.8	
Distillation loss	.2			

[1] Specific gravity at 60°F compared with water at 60°F.

LOGISTICS

Personnel and housing.—A geologist and a drilling foreman were in charge of operations at the well; 2 drillers, 2 tool dressers, and 2 firemen made up the crew. Other workers, such as a welder to redress the drill bits, a mechanic, a bulldozer operator, a cementer, and laborers, came from Umiat camp when necessary; the personnel was housed and fed there. Three wanigans at the rig site housed the cement pump, the water, and power supply and boiler.

Vehicles and heavy equipment.—Caterpillar tractors, LVT's, cranes, and weasels were kept at Umiat camp except when they were needed. The drilling equipment used by Arctic Contractors included a Cardwell spudder, with a model H double-drum drawworks and spudding attachment and a 55-foot Cardwell mast. Power was furnished by a Caterpillar D8800 diesel engine, and electric power by a 15-kilowatt generator with a Caterpillar D3400 diesel engine.

Fuel, water, and lubricant consumption.—Petroleum products and water required to drill the well were 10,537 gallons of diesel fuel, 637 gallons of 72-octane gasoline, 90 gallons of 65-octane gasoline, 150 gallons of kerosene, 182 gallons of no. 9170 lubricating oil, 25 pounds of grease, and 77,355 gallons of water.

DRILLING OPERATIONS

DRILLING NOTES

The Cardwell cable-tool rig was mounted on a sled and towed to the well site by a D8 Caterpillar tractor and set on a foundation of 12- by 12-inch timbers on a thin mat of gravel. The following drilling operations were recorded by Marvin Heany and Kenneth R. Freed, of Arctic Contractors.

Notes from drill records

Depth (feet)	Remarks
27	Some gravel from mat underneath rig fell into hole and was cleaned out down to an ice lens; a barrel was set in hole, but did not prevent gravel from falling into hole.
60	Sack of Cal-Seal was used to cement around base of barrel to stop caving. Operations stopped 1 hr for engine repair.
70	Cemented 11¾-in., 47-lb J55 National seamless casing to 70 ft with 35 sacks of Cal-Seal.
532	Hole bailed dry and shut down 10½ hr to repair rig and spool new drilling line.
753	Lost bailer and 90 ft of line in the hole and recovered in 4½ hr.
1,095	The hole was filled back 23 ft with cavings.
1,125	Drilling line broke while reaming at 1,095 ft, leaving tools and 900 ft of drilling line in hole, but they were recovered in 15 hr with pronged grab. Cavings filled hole to 1,059 ft but were cleaned out before drilling deeper.

Notes from drill records—Continued

Depth (feet)	Remarks
1,149	Hole caved somewhat while drilling.
1,174	Lost bailer in hole but recovered in 2 hr.
1,192	Lost bailer in hole again but recovered in 3 hr.
1,229	Rig repairs and line splicing took 13 hr.
1,233	Lost bailer in hole but recovered in 9 hr.
1,249	Hole caved considerably. Stopped operations 5 hr to splice drilling line; afterwards, hole found to be filled with cavings to 1,210 ft.
1,253	Drilling line broke, leaving tools in hole; recovered tools in two fishing operations.
1,282	Hole still caving considerably.
1,339	Hole caved badly from 1,295 to 1,339 ft, and tools stuck in hole at 1,316 ft but were freed after 3½ hr of jarring; cavings cleaned out, although the tools caught often. Bailer lost in hole when line broke at 1,322 ft, but it was fished out in 5 hr. Continual bailing of cavings was necessary while last few feet to 1,339 ft were drilled.
	Casing set at 1,339 ft using 13 joints of 24-lb 8 V-thread casing with Baker float shoe on bottom and 51 joints of 32-lb 8-V thread casing on top. Top of casing 3 ft 9 in. below derrick floor. Top of casing cemented with 200 sacks of type-C construction cement treated with 500 lb of calcium chloride. Plug placed with 600 lb of pressure, and hole closed in at same pressure. After standing cemented 56 hr, top of annulus was cemented with 10 sacks of Cal-Seal. Cement was drilled out from 1,330 to 1,339 ft, and hole drilled ahead without bailing brine out of hole.
1,360	Tools stuck 4 ft above bottom of hole; jarring tools caused spudder-arm pin to shear, but it was repaired in 3 hr; more jarring did not loosen tools. Fishing operations were successful.
1,518	Owing to extensive caving spent 80 hr cleaning out hole between 1,470 and 1,518 ft, compared with 34½ hr in drilling. Caving also caused tools to stick in hole several times, and soon after drilling to 1,518 ft, the hole gradually filled up to 1,445 ft before an Aquagel-brine mud, held at level of 990–1,000 ft, allowed hole to be cleaned out. During cleaning, crown block froze but was thawed out without any damage.
1,573	Mud very viscous, especially at bottom while drilling hole from 1,518 to 1,573 ft. Mud later thinned with water before tubing was run for swabbing test.
	After test, hole partly cleaned out again; cleaning very slow because of large amount of caving. Bailer stuck at 1,453 ft, and line broke, leaving bailer and 600 ft of line in hole. These were retrieved but stuck again at 1,450 ft and were recovered. Before another test was made, hole was slowly cleaned out to total depth in spite of caving, with mud level kept at 1,000 ft.

Notes from drill records—Continued

Remarks

At end of swabbing test, a wind of 90–100 mph forced operations to shut down for 15 hours, during which time the rig filled with snow. Cleaning out and thawing rig required over a day, and 46 hr were lost because of storm. Before resuming drilling, spent additional time steaming ice and snow out of cellar.

Hole was filled with mud to 600 ft, but caving shale prevented hole from being cleaned out easily and often caught bailer, necessitating fishing jobs. Freezing crown sheaves also added to difficulties.

Hole was cleaned out to 1,520 ft and filled to 700 ft with drilling mud before abandoning. An 8⅝- by 12-in. nipple was put on top of casing, with flange welded to it. Nipple had a 2-in. side port closed by a 2- by 8-in. nipple and a 2-in., 500-lb gate valve. Top of assembly is 3 ft above ground.

DRILL AND CORE BITS

Of the 21 redressed cable-tool bits used in the hole, 17 were used for drilling, and 4 (no. 16 and the last 3) were used for cleaning out. At some depths one bit was used for short alternate intervals of drilling and reaming; to avoid confusion on the graphic log (pl. 12), these bits are shown as having drilled only. Six Baker 5¾-inch core bits cut 101 feet of core and recovered about 78 percent of the unit cored.

DRILLING FLUID

Above 650 feet mud made of brine and Aquagel (25 lb or more of salt per barrel of water) was used to keep the bit lubricated and to remove cuttings. Between 650 and 1,339 feet oil-bearing sandstone beds furnished oil for the drilling fluid, which stayed at a level of about 640 feet. After the casing was set, a viscous Aquagel-brine mud was kept at a level of 1,000 feet to keep the hole from caving so that drilling could proceed.

UMIAT TEST WELL 11

Location: Lat 69°24′29″ N., long 152°05′58″ W.
Elevation: Ground level, 464 feet; kelly bushing, 481 feet.
Spudded: June 3, 1952
Completed: August 29, 1952; dry and abandoned.
Total depth: 3,303 feet.

The last and most northerly hole on the Umiat anticline, Umiat test well 11, was drilled to test the production possibilities of the sandstone beds of the Grandstand formation on the northern, downthrown side of a fault that parallels the axis of the anticline and to determine whether oil could be produced from any younger sandstone units. Several sandstones, most of which are between 2,050 and 2,850 feet, had slight shows of oil or gas; but formation tests recovered only brackish water or drilling mud.

DESCRIPTION OF CORES AND CUTTINGS

The test well, on Bearpaw Creek, was spudded in a thin mantle of alluvium. Beneath the alluvium the drilling penetrated the nonmarine Tuluvak tongue (Prince Creek formation) between 22 and 545 feet where sandstone and siltstone are interbedded with shale, coal, and bentonite. A few thin marine beds contain a sparse microfauna. The Seabee formation was found between 545 and 2,040 feet. The upper part of this formation consists of 190 feet of medium-gray clay shale, a 55-foot bed of sandstone, and 300 more feet of medium-gray clay shale. Below 1,090 feet the clay shale is darker, harder, and nonbentonitic. A 55-foot very fine- to fine-grained medium-light-gray sandstone composed of angular grains of clear and white quartz and abundant flakes of biotite is present between 1,315 and 1,370 feet; sandstone and shale are interbedded below it to a depth of 1,500 feet. Another very fine-grained sandstone with abundant biotite occurs between 1,810 and 1,845 feet. Between this and the base of the formation is medium-light-gray siltstone also containing biotite flakes, with a few thin beds of shale and sandstone.

Borissiakoceras sp., the ammonite typical of the Seabee formation, was found at approximately 1,230 and 1,427 feet; *Inoceramus* prisms and minute fishbone fragments are also present, although rare. The lower part of the formation also contains some Foraminifera.

The shallow-water marine Ninuluk formation (2,040–2,160 feet) is represented in Umiat test well 11 by a massive sandstone, with a 10-foot shale bed in the middle. The upper 50 feet is calcareous and impermeable; the lower part is noncalcareous, and permeability ranges from 14 to 56 millidarcys. The formation was oil stained but when tested produced only water. The massive sandstone is underlain by about 20 feet of siltstone. Samples of cores from the basal 25 feet of the formation contain abundant specimens of *Trochammina rutherfordi* Stelck and Wall, a foraminifer commonly found in the Ninuluk formation.

Beneath the Ninuluk formation is the Killik tongue of the Chandler formation, a nonmarine sequence of interbedded silty sandstone and shale 260 feet thick (from 2,160 to 2,420 feet). A few thin beds of coal are present in the upper 50 feet of the formation, and a 1-inch bed of bluish-gray bentonite was noted at 2,235 feet. A thin sandstone bed at 2,420 feet marks the base of the Killik tongue. Underlying the Chandler and between 2,420 and 3,075 feet is the Grandstand formation. The upper 20 feet, of medium-dark-gray clay shale, contains the uppermost occurrence of the *Verneuilinoides borealis* fauna. The shale is underlain by approximately 100 feet of very fine- to fine-grained sandstone, with a few 10-foot interbeds of medium-

dark-gray clay shale. Below the sandstone is 260 feet of silty clay shale with rare thin beds of siltstone and a 10-foot and a 15-foot bed of very fine-grained sandstone. The 275 feet at the base of the formation includes a massive, fine-grained sandstone between 2,805 and 2,905 feet, and two massive, very fine-grained sandstone beds at 2,970–3,020 feet and 3,030–3,075 feet, separated by beds of siltstone and clay shale. The upper sandstone has a permeability of 100–400 millidarcys, and there were some shows of oil, but it yielded water when it was tested.

The Topagoruk formation was drilled between 3,075 feet and the total depth at 3,303 feet. An apparent recurrence at 3,210 feet of a microfauna first found at 2,700 feet suggests the presence of a reverse fault with about 500 feet of throw at 3,210 feet. The formation is all shale with no distinctive characteristics that would either corroborate or disprove a fault.

Lithologic description

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

Core	Depth (feet)	Remarks
-----	0–17	Kelly bushing to ground level.
-----	17–20	No sample.
-----	20–22	Surface gravel composed of rounded pebbles and grains of yellow and white chert and clear quartz; coal, limonite, and medium-gray argillaceous siltstone are probably of Colville (Late Cretaceous) age.
-----	22–30	Siltstone, medium-gray, argillaceous, and medium-dark-gray clay shale, with rare coal. A few pieces of very fine-grained hard sandstone with common green grains and fine-grained greenish-gray sandstone also present. Top of Tuluvak tongue of Prince Creek formation at or just above 22 ft.
-----	30–50	Coal, black, shiny to dull, blocky fracture to shaly cleavage, with some clay ironstone.
-----	50–60	Coal, with some light-gray, hard, noncalcareous siltstone.
-----	60–70	Sandstone, light-gray, fine- to medium-grained, salt-and-pepper, slightly calcareous, argillaceous, slightly micaceous, composed of angular to subangular grains of white and clear quartz, gray chert, and dark rock fragements.
-----	70–80	Clay shale, medium- to medium-light-gray, noncalcareous, nonbentonitic; minor amount of clay ironstone.
-----	80–90	Sandstone, with minor amount of clay ironstone.
-----	90–100	Clay shale, very silty, with some fine- to medium-grained sandstone.
-----	100–112	Sand, with minor amount of coal.
-----	112–115	Sample contains surface contamination and cement.
1	115–136	Recovered 20 ft 6 in.: Microfossils absent. 3 ft 6 in., sandstone, light-gray, fine-grained, salt-and-pepper, massive, somewhat friable, noncalcareous, micaceous, with bentonite cement, with common carbonaceous particles; composed of angular to subrounded clear and white quartz with dark rock fragments, carbonaceous particles, biotite, and rare yellow grains. Frosted grains are rare. Base of interval marked by thin (less than one-fourth of an inch) beds of sandstone that dip 20° and contain abundant grains of light-brown gypsum (?), with flakes of carbonaceous material and biotite. 1 ft 6 in., sandstone as above, but slightly coarser, calcareous, and with abundant laminae of slightly darker, slightly carbonaceous sandstone that dip 20°. 10 ft 6 in., sandstone as in top of core, but noncalcareous to slightly calcareous except for very calcareous basal 1 ft. Near base of interval are a few laminae and thin beds of very calcareous sandstone that have abundant grains of light-brown gypsum, with rare particles of biotite and carbonaceous material. 1 ft 4 in., sandstone as above, with increasing number of poorly defined, slightly darker laminae and thin beds (one-half an inch thick or less) that contain carbonaceous material. 3 ft 8 in., sandstone as in top of core, but grading to very fine grained at base.
2	136–156	Recovered 20 ft: Microfossils rare. 9 ft 3 in., sandstone as at base of core 1, becoming more bentonitic and slightly darker with depth. Dark, slightly carbonaceous laminae common in basal 1 ft dip 16°. 9 ft 3 in., claystone, medium-light-gray, friable, very bentonitic, noncalcareous, subconchoidal fracture, with some carbonaceous particles and silty laminae. Becomes silty toward base. Two 1-in. beds of light-brownish-gray slightly calcareous very slightly bentonitic clay ironstone at 147 and 151 ft. A 1-in. bed of light-gray argillaceous bentonitic siltstone with carbonaceous laminae at 146 ft. Grades into unit below. 1 ft 6 in., siltstone, light-gray, very argillaceous and bentonitic, noncalcareous, with interbedded 1-in. beds of claystone as above.
-----	156–161	Clay shale, medium- to medium-light-gray, bentonitic, with rare carbonaceous partings and silt laminae.
-----	161–165	Sandstone, very fine-grained, medium-light-gray, very bentonitic, very argillaceous and silty; minor clay shale.
-----	165–171	Clay shale.
-----	171–176	Clay shale; medium-light-gray calcareous bentonitic siltstone; and fine- to medium-grained sandstone.
-----	176–205	Clay shale, medium- to medium-light-gray, bentonitic, noncalcareous; minor amount of siltstone and sandstone in lower part.
-----	205–210	Clay shale and sandstone.
-----	210–215	Clay shale, with minor amount sand.
-----	215–222	Sandstone, very fine-grained; composed of white and clear quartz.
3	222–242	Recovered 20 ft: Microfossils absent. 2 ft 2 in., claystone, medium-gray, bentonitic, micaceous, slightly silty, noncalcareous, with blocky fracture. Light-brownish-gray clay ironstone 1 in. thick at base.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		5 ft 10 in., sandstone, light-gray, very fine-grained, bentonitic, very silty, moderately friable, massive.
		1 in., clay ironstone, light-yellowish brown, silty, very slightly calcareous.
		11 in., sandstone, light-gray, fine-grained, salt-and-pepper, very bentonitic, noncalcareous, with yellowish laminae containing sideritic (?) cement. Dip 9°.
		8 ft 8 in., sandstone, light-gray, fine-grained, salt-and-pepper, bentonitic, massive, noncalcareous, with nodules of light-grayish-brown clay ironstone ½–1 in. across at 231 ft; composed of subangular to subround grains of clear and white quartz, with some white, yellow, and dark rock fragments which include chert and possibly weathered feldspar. Very few frosted grains. Scattered patches of carbonized plant fragments in lower fourth of interval. Basal foot contains common carbonaceous partings, which become abundant in bottom inch. Dip 10°.
		2 ft 4 in., sandstone as above, but slightly lighter in color and slightly finer grained; calcareous, massive, with no carbonaceous partings or laminae. Becomes very fine grained and noncalcareous at base.
4	242–262	Recovered 20 ft: Microfossils absent.
		8 ft 7 in., sandstone as at base of core 3.
		4 ft 8 in., clay shale, medium-light-gray, poor shaly cleavage; slightly silty in part; slightly micaceous; bentonitic.
		5 in., clay shale, medium-dark-gray, with streaks of carbonized plant fragments. Base marked by slickensided surface below which are several very well rounded black chert pebbles 1/16–½ in. in diameter.
		10 in., claystone, medium-gray, with subconchoidal fracture, grades into unit below.
		10 in., claystone, medium-gray, hard, slightly silty; irregular fracture.
		2 ft 6 in., sandstone as in top of core, but slightly calcareous in part. A few clay laminae near base; dip 10°.
		1 ft, interlaminated sandstone and clay shale as above, with sandstone dominant in upper part and clay shale dominant in lower part.
		4 in., sandstone as above, with clay laminae.
		3 in., clay shale as above, with ¼-in. streak of light-brownish-gray clay ironstone.
		7 in., sandstone as above.
-----	262–268	Clay shale, as in cores 3 and 4 above.
-----	268–278	Sandstone, fine-grained, friable; composed of subangular grains of clear and white quartz and colored rock fragments.
5	278–298	Recovered 19 ft 4 in.: Microfossils absent.
		4 ft 6 in., clay shale, medium-gray; slightly silty in parts; bentonitic; subconchoidal to poor shaly cleavage.
		6 in., clay shale, medium-dark-gray, slightly silty, carbonaceous, poor shaly cleavage.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		2 ft 6 in., siltstone, light-gray, very bentonitic, slightly calcareous, micaceous, with light-yellowish-gray clay ironstone lenses at 284 and 285 ft.
		2 ft 1 in., clay shale as above, with streaks of silt.
		7 in., siltstone as above, with scattered clay laminae.
		2 ft 2 in., clay shale as above, with streaks siltstone.
		2 in., clay shale, black, carbonaceous.
		1 in., bentonite, white.
		5 in., coal, black, dull to shiny; shaly cleavage to blocky fracture.
		6 ft 4 in., clay shale as above with coaly laminae and rare pockets (1/8–¼ in. in diameter) of light-yellow amber in upper 6 in. Rare nodules of light-yellowish-gray clay ironstone; very rare grains of amber also present through rest of interval. Carbonized deciduous leaf fragments at 294 ft.
-----	298–303	Sandstone, medium-light-gray, very fine-grained; grading to siltstone; calcareous; nonbentonitic; argillaceous; some clay shale also present.
-----	303–308	Clay shale.
-----	308–313	Clay shale, black and medium-gray, with minor amount coal and white bentonite.
-----	313–318	Clay shale, black to medium-dark-gray.
-----	318–323	Clay shale, medium-gray, with some white bentonite.
-----	323–328	Sandstone, fine-grained, angular, composed of clear and white quartz with gray-colored rock fragments.
-----	328	Circulation sample.
		Sandstone, slightly bentonitic, calcareous, as in core 6 below.
6	328–348	Recovered 20 ft: Microfossil absent.
		11 ft 3 in., sandstone, light-gray, very fine- to fine-grained, very bentonitic, very calcareous from 328–330 ft and from 333–334 ft, slightly calcareous to noncalcareous elsewhere. Rare medium-gray carbonaceous patches and laminae dip 20°.
		6 in., claystone, light-olive-gray, friable, very bentonitic; conchoidal fracture; 1 in. of medium-dark-gray clay shale at top.
		4 ft 3 in., clay shale, medium-gray, bentonitic, noncalcareous, with many partings, laminae, and thin beds (up to 1½ in. thick) of medium-light-gray noncalcareous bentonitic silty clay shale and siltstone that dip approximately 10° and make up about a third of the rock. Basal 1 ft of interval medium dark gray.
		1 ft 7 in., bentonite, very light-yellowish-gray when dry, olive-gray when wet. Contains rare scattered specks of carbonaceous material.
		2 ft 5 in., coal, black, shiny; poor shaly cleavage to blocky fracture. A 1-in. bed of bentonite as above is 1 ft above base of core.
-----	348–358	Clay shale, medium-gray, bentonitic with small amount of siltstone in lower part.
-----	358–363	Clay shale and bentonite, light-yellowish-gray, slightly argillaceous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	363–368	Sandstone, very fine-grained, with minor siltstone and clay shale.
-----	368–373	Siltstone, sandy, with minor clay shale.
-----	373–375	No sample.
7	375–395	Recovered 20 ft: Microfossils absent. 2 ft, siltstone, medium-light-gray, argillaceous, very bentonitic, slightly to noncalcareous, partly sandy. Nodules (approximately 1 in. in diameter) of light-yellowish-gray clay ironstone 18 in. below top. Grades into unit below. 6 ft, interbedded siltstone and claystone. Medium- to medium-light-gray slightly silty to very silty bentonitic claystone with rare nodules of clay ironstone and streaks of siltstone. Grades into medium-light-gray bentonitic noncalcareous argillaceous siltstone. 3 in., clay shale, medium-dark-gray, slightly bentonitic. 10 in., coal, black, shiny, with blocky fracture. 1 ft 3 in., coal, black, shiny, shaly cleavage. 8 in., coal, black, shiny, blocky fracture. 5 in., bentonite as in core 6. 3 in., coal as above. 2 in., bentonite as above. 9 in., coal as above. 8 in., coal, black, shiny to dull, shaly cleavage. 1 ft 10 in., bentonite as above. 1 ft 4 in., coal as above; grades into unit below. 6 in., claystone, medium-dark-gray, bentonitic; conchoidal fracture; grades into unit below. 5 in., clay shale, black, carbonaceous, with abundant coaly laminae. 1 ft 4 in., bentonite, argillaceous, with a few specks of amber; grades into unit below. 1 ft 4 in., claystone, medium-gray; grades with depth from very to slightly bentonitic, and friable to hard.
-----	395–400	Siltstone, with some bentonite and medium-gray clay shale; trace of black shale.
-----	400–415	Siltstone, medium-light-gray, very slightly bentonitic to nonbentonitic, noncalcareous; minor amount clay shale at base.
-----	415–420	Coal, with some black shale.
-----	420–425	Clay shale, medium-gray, with some coal and black shale.
-----	425–430	Coal.
-----	430–435	Coal, gray clay shale, black clay shale, and sandstone.
-----	435–445	Siltstone, with clay shale in lower half.
-----	445–450	Coal and black clay shale.
-----	450–456	Clay shale, medium-gray, with coal and minor amount of clay ironstone.
8	456–476	Recovered 20 ft: Microfossils absent. 4 ft 9 in., claystone, medium-gray, very silty, micaceous, calcareous, very slightly bentonitic. Intercalated medium-dark-gray clay and streaks of medium-light-gray siltstone dip approximately 13°; irregular lenses of clay ironstone common; ¼-in. coal bed at base of interval. Grades into unit below. 5 ft 3 in., claystone, medium-dark-gray, noncalcareous, bentonitic to very bentonitic, nonsilty; conchoidal to subconchoidal fracture. Coaly laminae at base; 3-in. nodule of clay ironstone at 465 ft. 4 ft 5 in., clay shale, medium-gray, noncalcareous, with laminae of slightly crossbedded siltstone and carbonaceous partings. A 6-in. section beginning 6 in. below top of interval is dominantly sandy, slightly calcareous siltstone. Streaks of yellowish-gray clay ironstone are rare in upper half, common in lower half. Dip ranges from less than 1° to 5°. 9 in., coal, black, shiny; blocky fracture; shaly at top and bottom. 2 in., bentonite, medium-light-gray, argillaceous; conchoidal fracture. 1 ft, coal, black, shiny; blocky fracture; lens (one-half inch thick) of carbonaceous, sandy, silty bentonite 2 in. below top of section. 1 ft 4 in., bentonite, light-olive-gray, slightly argillaceous, with rare flakes carbonaceous material. Grades to olive gray at base. 1 ft 9 in., coal as above, becoming shaly at base; suggests dip of 5°–10°. 7 in., claystone, medium-dark-gray, bentonitic, conchoidal fracture with rare carbonaceous particles.
9	476–496	Recovered 20 ft: Microfossils absent. 6 in., claystone as above, grades into unit below. 10 in., clay shale, black, carbonaceous, fissile, with coaly laminae, grades into unit below. 4 in., coal, black, shiny, blocky fracture. 3 in., bentonite; very light yellowish gray when dry; olive gray when wet. 2 in., coal as above. 1 in., bentonite as above. 10 in., coal as above. 3 in., bentonite as above. 4 in., siltstone, medium-gray, very argillaceous and bentonitic, noncalcareous. 5 in., clay shale, medium-gray, bentonitic. 1 ft, siltstone as above. 2 ft, sandstone, medium-light-gray, very fine-grained, very silty, argillaceous, bentonitic, noncalcareous, with common medium-gray clay shale laminae in lower part that dip 5°–12°. 4 ft 9 in., sandstone, medium-light-gray, very fine- to fine-grained, bentonitic, noncalcareous, with abundant euhedral biotite flakes. No odor or cut of oil; greasy stain in CCl_4 from 483 ft. 3 in., coal as above. 6 ft 9 in., bentonite as above. 6 in., clay shale, medium-dark-gray, slightly coaly, fissile. 9 in., claystone, medium-gray, slightly to very silty, hard, slightly bentonitic, noncalcareous; irregular fracture.
10	496–516	Recovered 20 ft: Microfossils absent. 8 ft 2 in., claystone and bentonite; section grades from claystone as in core 9 above, through light-olive-

Lithologic description—Continued

Core	Depth (feet)	Remarks
		gray very bentonitic claystone with conchoidal fracture to very argillaceous olive-gray bentonite. Rare slickensided surfaces. Three beds of medium-dark-gray clay shale 1, 2, and 3 in. thick at 502, 503, and 504 ft, respectively.
		3 in., bentonite, grayish-white, with scattered flakes of carbonaceous material.
		5 ft 2 in., bentonite, light-olive-gray, very argillaceous; conchoidal fracture; grades into medium-gray slightly silty very bentonitic claystone.
		6 ft 5 in., sandstone, medium-light-gray, fine-grained, salt-and-pepper, calcareous to noncalcareous. Top 2 in. very fine grained. Grains subangular, clear and white quartz and gray chert. Biotite abundant; rock fragments rare. Bedding planes, marked by abundant large (medium sand size) euhedral biotite plates dip 16°. A ½-in. bed of medium-gray claystone at 505 ft.
11	516–536	Recovered 19 ft 6 in.: Microfossils absent.
		6 in., sandstone as above, grades to medium grained at base.
		2 ft 11 in., sandstone as above, but medium grained. Sharp contact with very fine-grained sandstone below dips 18°. Effective porosity at 519 ft 16.75 percent.
		4 in., sandstone as above, but very fine grained, calcareous.
		1 ft 3 in., sandstone as above, but fine grained; an 8-in. section between 520 and 521 ft is light brownish gray and contains sideritic (?) cement. Grades into unit below.
		1 ft 4 in., sandstone, medium-grained, slightly calcareous.
		2 ft 5 in., sandstone, very fine-grained, very calcareous; 55.7 percent carbonate content by weight at 524 ft; slightly lighter color than overlying sandstone; sharp contact with overlying sandstone dips 18°.
		1 ft 3 in., sandstone as above, but fine grained.
		3 ft 5 in., sandstone, very fine-grained, very calcareous, slightly lighter color than overlying sandstone. Faint oil odor; no cut; yellowish stain in CCl_4 from 535 ft.
		5 ft 3 in., sandstone as above, but medium grained, calcareous; abundant carbonaceous flakes and carbonized plant fragments in lower 3 in.
		10 in., sandstone, light-yellowish-brown, fine-grained, bentonitic, noncalcareous, with abundant streaks of carbonaceous material. Color is due to light-brown gypsum (?) cement.
12	536–549	Recovered 13 ft 3½ in.: Microfossils common.
		6 ft., sandstone as in 5 ft 3 in. interval above, but fine grained, coarsening slightly with depth. Upper inch has common patches of carbonaceous material. Good odor oil in lower part, faint odor in upper part; no cut, yellowish stain in CCl_4 at 545 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
12	536–549	2 ft 3 in., sandstone as above, but medium grained, with rounded pebbles of medium-gray bentonitic shale up to 2 in. in diameter, scattered through lower foot.
		1 ft 5 in., clay shale, medium-gray, bentonitic, poor shaly cleavage. Top of Seabee formation at approximately 545 ft.
		3 in., sandstone as above, but fine to medium grained, noncalcareous.
		2 in., clay shale as above.
		4 in., sandstone as above.
		7 in., clay shale as above.
		½ in., sandstone as above.
		2 in., clay shale as above.
		1 ft 7 in., sandstone as above.
		6 in., clay shale as above.
	549–551	No sample.
13	551–571	Recovered 15 ft: Microfossils very abundant.
		8 ft, claystone, medium-gray, slightly bentonitic, noncalcareous, with rare flakes of biotite, light-colored mica, and carbonaceous material. Three 5-in. beds of medium-light-gray bentonitic noncalcareous siltstone at 552, 553, and 557 ft. Siltstone-claystone contacts usually sharp; beds dip from less than 1° to 15°.
		2 ft, siltstone, medium-light-gray, bentonitic, noncalcareous.
		5 ft, claystone as above, with irregular thin (¼–1 in.) siltstone lenses as in claystone above, totaling 25 percent of lower 4 ft of core.
	571–580	Siltstone, light-gray, very micaceous (biotite), very bentonitic.
-----	580–590	Sandstone, fine-grained, subangular, clear and white quartz with gray, dark, and colored rock fragments.
-----	590–610	Clay shale, medium-gray, silty, bentonitic, with minor amount of clay ironstone in lower half.
-----	610–620	Clay shale, medium-gray, silty, bentonitic; and medium-light-gray slightly bentonitic calcareous siltstone.
-----	620–630	Clay shale.
-----	630–650	Clay shale with siltstone.
-----	650–709	Clay shale, medium-gray, silty, bentonitic to slightly bentonitic, with minor clay ironstone at 670–680 ft.
14	709–729	Recovered 18 ft 6 in.: Microfossils abundant.
		Clay shale, medium-gray, very slightly bentonitic, noncalcareous, nonmicaceous, with poor shaly to subconchoidal cleavage. Rare discontinuous medium-light-gray silty laminae dip 6°–10°.
-----	729–735	Siltstone, sandy, bentonitic, noncalcareous, friable.
-----	735–742	Sandstone, fine-grained, friable; composed of angular to subangular white and clear quartz and dark rock fragments.
15	742–762	Recovered 19 ft: Microfossils absent.
		1 ft 3 in., sandstone, medium-light-gray, fine-grained, silty, argillaceous, massive, very calcareous, with abundant biotite flakes. Sand composed of angular to subangular clear and white quartz and dark rock fragments, with grains of gypsum and coal.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		15 ft 3 in., sandstone as above but noncalcareous; slightly coarser between 745 and 747 ft; 2 partings, 2 in. apart, of carbonaceous (not coaly) material that contains a few small fragments (up to one-fourth inch in diameter) of light-yellow amber. A 1-in. interval at 750 ft also contains very fine discontinuous carbonaceous partings that dip 7°.
		2 ft 6 in., sandstone as above, but very fine grained, very calcareous.
16	762–782	Recovered 20 ft: Microfossils absent.
		8 ft 2 in., sandstone, medium-light-gray, fine- to very fine-grained (grading to fine grained at base), silty argillaceous, massive, calcareous, very slightly bentonitic, with abundant biotite. Poor shaly cleavage in lower 1 ft dips 15°. Six inches above base is 2-in. bed of medium-light-gray very sandy shale. At 763 ft effective porosity 12.7 percent; rock is impermeable; carbonate content percent by weight 7.82. Sandstone grades into unit below.
		1 ft 7 in., sandstone as above, but medium grained, salt-and-pepper, and more bentonitic. A 1-in. pebble of light-gray clay shale with one slickensided surface and a 1-in. patch of carbonaceous material 10 in. below top; coaly particles as much as one-sixteenth of an inch in diameter common throughout. Sharp contact with sandstone below.
		3 ft 7 in., sandstone, as in top of core, but very fine grained, with rare laminae of medium-gray clay shale in bottom 2 in.
		7 in., claystone, medium-gray, slightly to very silty, nonbentonitic, micaceous, very slightly calcareous; grades into unit below.
		1 ft 6 in., siltstone, medium-light-gray, very to slightly argillaceous.
		1 ft, claystone, medium-gray, slightly bentonitic, with conchoidal fracture.
		1 ft 3 in., sandstone, as above, but very fine grained.
		2 ft 4 in., intergraded and interlaminated medium-light- to medium-gray very argillaceous siltstone and medium-gray claystone. A 2-in. bed of very fine-grained sandstone 4 in. above base of core dips about 5°. Some very fine-grained claystone and siltstone laminae slightly crossbedded.
-----	782–790	Sandstone, very fine-grained, calcareous, slightly bentonitic.
-----	790–800	Clay shale, silty, with some very fine-grained sandstone and trace of fine-grained sandstone. *Inoceramus* fragments present.
-----	800–805	Sandstone, very fine-grained, calcareous, slightly bentonitic; driller reported oil on ditch while drilling at 804 ft; formation test recovered mud.
17	805–825	Recovered 20 ft: Microfossils rare.
		Siltstone, medium-light-gray, argillaceous, noncalcareous, very sandy in upper 1 ft; streaks of medium-gray claystone ⅛–2 in. thick throughout total approximately 10 percent of rock.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	825–845	Sandstone, very fine-grained, calcareous, slightly bentonitic; grades to very calcareous siltstone.
-----	845–855	Clay shale, medium-gray, slightly bentonitic; slightly silty in part, some siltstone.
-----	855–965	Clay shale, medium-gray, slightly silty and bentonitic in lower part; minor amount of very fine-grained silty sandstone in bottom 10 ft.
-----	965–975	Clay shale with siltstone, grading to very fine-grained sandstone.
-----	975–1, 005	Clay shale, with small amount of siltstone in upper 20 ft.
18	1, 005–1, 025	Recovered 20 ft: Microfossils absent.
		5 in., sandstone, light-gray, very fine-grained, very slightly calcareous, crossbedded, with faint laminae of clay shale at top and bottom.
		2 in., claystone, medium-gray, very slightly silty; conchoidal fracture.
		10 in., sandstone as above, but with one claystone streak at top; grades into siltstone with two ½-in.-thick lenses of clay ironstone and medium-gray claystone laminae in lower half.
		2 in., claystone with laminae of siltstone.
		9 in., siltstone and clay shale, interlaminated, slightly carbonaceous, with small amount of clay ironstone in upper half.
		4 ft 8 in., clay shale, medium-gray, slightly silty, noncalcareous, with common laminae of medium-light-gray argillaceous siltstone and partings of carbonized plant fragments. Dip 13°. A 3-in. interval of crossbedded very sandy siltstone at 1,011 ft.
		4 in., siltstone, very sandy, crossbedded, as at 1,011 ft.
		3 in., clay shale as above.
		11 in., sandstone as at top of core.
		11 ft 6 in., clay shale, medium-gray, silty, noncalcareous, good to poor shaly cleavage, with siltstone laminae and medium-dark-gray clay laminae. Siltstone beds 2–4 in. thick at 1,015, 1,016, and 1,021 ft. Streaks of slightly yellowish-gray clay ironstone rare. Dip 13°. Immature specimen of *Inoceramus labiatus* Schlotheim at 1,015 ft.
-----	1, 025–1, 030	Sandstone, medium-light-gray, very fine-grained, calcareous, very slightly bentonitic.
19	1, 030–1, 050	Recovered 10 ft: Microfossils abundant.
		11 in., clay shale as in base of core 18; dip 14°.
		8 in., siltstone, light-gray, sandy, as in core 18, slightly crossbedded, with carbonaceous and clay shale laminae. Clay ironstone one-half an inch thick 2 in. below top of interval.
		5 in., clay shale, medium-gray, silty, noncalcareous, with fair shaly cleavage dipping 15°.
		1 ft 2 in., sandstone, light-gray, very fine-grained, very silty and argillaceous, noncalcareous, massive; 1- by 2-in. pyrite nodule 7 in. below top of interval is underlain by 1-in. fragment of coal.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		3 in., claystone, medium-gray, very silty, with streaks of siltstone. 2 ft 4 in., sandstone as above, but with streaks (one-half an inch thick) of claystone, dipping 22°–27°, near top, and scattered fragments of clay shale up to 1½ in. long, which are inclined 20°–30°. 4 ft 3 in., clay shale as above, with a few carbonaceous partings and thin (as much as 2 in.) beds and laminae of siltstone totaling 10 percent of core. One 1-in. bed of very fine-grained sandstone 7 in. below top of interval dips 10°.
-----	1, 050–1, 060	Sandstone, medium-light-gray, very fine-grained, nonbentonitic, argillaceous, noncalcareous; trace of white bentonite.
-----	1, 060–1, 090	Clay shale, medium- to medium-dark-gray, silty, bentonitic; and medium-gray noncalcareous siltstone; slightly bentonitic in lower half.
-----	1, 090–1, 100	Clay shale, medium-dark-gray, less bentonitic and harder than that above; some siltstone.
-----	1, 100–1, 150	Clay shale, medium-dark-gray, with minor siltstone at base.
-----	1, 150–1, 160	Clay shale with some siltstone.
-----	1, 160–1, 170	Clay shale.
-----	1, 170–1, 180	Clay shale and light-gray slightly argillaceous bentonite.
-----	1, 180–1, 220	Clay shale, medium- and medium-dark-gray, with some siltstone; small amount of very fine-grained medium-light-gray bentonitic sandstone in bottom 10 ft.
-----	1, 220–1, 230	Clay shale, medium-gray, slightly bentonitic, and medium-dark-gray very slightly bentonitic, slightly harder clay shale.
20	1, 230–1, 245	Recovered 15 ft: Microfossils very rare. Claystone, medium-gray, noncalcareous; conchoidal fracture; with some laminae of medium-dark-gray claystone and medium-light-gray silty claystone. Dip of laminae approximately 10°; *Borissiakoceras* sp. at 1,230 ft. Fish scales and fishbone fragments throughout core.
-----	1, 245–1, 295	Clay shale as in core 20 above, with clay ironstone at 1,275–1,285 ft, and minor siltstone at 1,265–1,275 ft.
-----	1, 295–1, 305	Claystone as above, and light-bluish-gray slightly argillaceous bentonite.
-----	1, 305–1, 310	Clay shale as above, but slightly silty in part.
-----	1, 310–1, 315	No sample.
-----	1, 315–1, 322	Sandstone, light-gray, very fine-grained, calcareous, very micaceous; composed of clear and white quartz and dark rock fragments.
21	1, 322–1, 330	Recovered 7 ft 8 in.: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, noncalcareous, massive, composed of angular to subangular clear and white quartz and gray rock fragments, with abundant biotite flakes. Lower 18 in. of core slightly coarser, grading to fine grained at base; bottom 1 ft calcareous. Beds (5 in. thick) of claystone, as in core 20 above, at 1,323 and 1,324 ft; dip 10°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
22	1, 330–1, 341	Recovered 6 ft 6 in.: Microfossils absent. 3 ft 9 in., sandstone, medium-light-gray, fine-grained, very calcareous, hard, massive, with abundant biotite plates and a few nearly vertical calcite veinlets (under one-sixteenth of an inch thick). Sand grains angular to subangular clear quartz with white quartz and gray rock fragments; rare grains of carbonaceous material and gypsum (?) also present. 2 ft 9 in., sandstone as above, but slightly darker, noncalcareous, moderately hard.
23	1, 341–1, 354	Recovered 5 ft 4 in.: Microfossils absent. 6 in., sandstone as in core above, slightly to very calcareous. 4 ft 10 in., sandstone, medium-gray, fine- to very fine-grained, silty, noncalcareous, very slightly bentonitic, massive, with abundant biotite plates. A 2-in. bed of medium-gray noncalcareous siltstone with carbonaceous partings and rare grains of amber at base 1 ft. above base of core.
24	1, 354–1, 356	Recovered 1 ft 6 in.: Microfossils absent. Sandstone, olive-gray, very fine-grained, slightly silty, very calcareous (carbonate content 47.7 percent by weight), hard; composed of angular to subangular grains of clear and white quartz with abundant green (chert?) grains, gray and dark rock fragments, and biotite.
-----	1, 356–1, 357	Sandstone as in core 24 above.
25	1, 357–1, 377	Recovered 18 ft 4 in.: Microfossils absent. 11 ft 8 in., sandstone, medium-light- to light-gray, fine-grained, silty, argillaceous, slightly calcareous to noncalcareous, massive; slightly coarser grained at base. Flat pebble of medium-gray clay shale 3 in. in diameter and one-half an inch thick 4 in. below top of core; a few chips of medium- or medium-dark-gray shale occur in a ¼-in. streak of slightly coarser sand; dip approximately 15°. A 7-in. interval of medium- to fine-grained sandstone 2 ft below top of core contains flat or oval well-rounded pebbles of medium-gray clay shale; pebbles concentrated in central third of interval but are present throughout. They range from ½ in. to 2½ in. in long diameter and lie nearly flat. Two ½-in. beds of medium-gray clay shale at 1,359 ft. 6 in., clay shale, medium-gray, noncalcareous, slightly silty in lower part, with silty laminae dipping 20°–23°. Sharp basal contact with underlying sandstone dips 15°, in same direction as laminae. 7 in., sandstone as above; contact with underlying shale is sharp and dips 45° in opposite direction from that at top of sandstone. 1 ft 8 in., fragment (?) of clay shale as above, with many fine laminae dipping parallel to contact of shale and sandstone described immediately above. Slickensides on surface of one lamina. Base of clay shale has sharp, irregular contact that dips from 60°

Lithologic description—Continued

Core	Depth (feet)	Remarks
		to vertical. Laminae in lowest part of shale body sharply curved. Clay shale may be large fragment that was detached from underlying clay shale, and surrounded by sand that settled around it. Laminae probably curved by contemporaneous deformation which presumably slightly preceded shift from its original position. Sandstone surrounding shale also contains some pebbles as large as 2 in. in diameter, of the same type of clay shale.
		3 ft 11 in., clay shale, medium-gray, noncalcareous, with faint slightly silty laminae dipping 16°. Good shaly cleavage along laminae; conchoidal fracture in other directions. Fishbone fragments scattered throughout.
-----	1, 377–1, 393	Claystone, medium-dark-gray, noncalcareous, nonbentonitic; conchoidal fracture; and medium-gray very slightly bentonitic claystone in lower half.
-----	1, 393–1, 400	Sandstone, light-gray, fine-grained, very argillaceous and silty, calcareous.
-----	1, 400–1, 410	Clay shale, medium-gray and slightly bentonitic to medium-dark-gray and nonbentonitic; and light-gray argillaceous bentonite.
-----	1, 410–1, 417	Clay shale, medium-dark-gray, with small amount of clay ironstone.
26	1, 417–1, 429	Recovered 11 ft 4 in.: Microfossils absent.
		7 ft 4 in., interbedded sandstone, medium-light-gray, noncalcareous, very fine- or fine-grained; siltstone; and a few thin beds of medium-gray clay shale; all noncalcareous. Contacts are sharp, as grain size changes abruptly, and individual beds are ¼ in. to 6 in. thick, with the exception of 2 sandstone beds, both of which are approximately 12 in. thick and grade from very fine grained at top to fine grained at base. On top of lower bed of sandstone, at 1,422 ft, is a 4 in. unit of very fine-grained sandstone containing abundant carbonaceous flakes that dip from less than 1° to 20°. Beds lie essentially flat.
		4 ft, clay shale as at base of core 25 above. Silt laminae, common near top and bottom, dip 10°. A 6-in. section of very silty, sandy claystone 3 in. above base of interval contains a few rounded pebbles (as much as 1 in. in diameter) of sandstone, and irregular areas (½–2 in. across) of nonsilty, slightly darker clay. *Borissiakoceras* sp. and a fragment of an *Inoceramus* shell occurred at 1,427 ft.
-----	1, 429–1, 452	Sandstone, medium-light-gray, very fine- to fine-grained, noncalcareous to very slightly calcareous, with small amount of clay shale.
27	1, 452–1, 469	Recovered 13 ft 2 in.: Microfossils absent.
		2 ft, sandstone, medium-light-gray, very fine- to fine-grained, silty, slightly calcareous to noncalcareous, massive.
		7 ft 9 in., interbedded clay shale, fine-grained sandstone, and siltstone, as is core 26 above; some sandstone is calcareous, and a few steeply dipping white calcite veinlets are present in the sandstone. Carbonaceous partings at 1,455 ft contain ¼-in. fragments of amber and fishbone fragments.
		3 ft 5 in., sandstone, medium-light-gray, intergrading very fine- to fine-grained, silty, calcareous at top; top 3 in. contains abundant carbonaceous flakes. Steeply dipping calcite veinlets present. A 2-in. bed of medium-gray clay shale with 1 in. of siltstone above and below is present 1 ft. above base of core.
-----	1, 469–1, 476	Clay shale as in core 27 but with very small amount of light-gray very fine- to fine-grained very argillaceous and silty noncalcareous sandstone, with carbonaceous flakes.
-----	1, 476–1, 485	Clay shale, with some siltstone similar to sandstone above, but finer grained.
-----	1, 485–1, 495	Sandstone, medium-light-gray, very fine-grained, slightly calcareous.
-----	1, 495–1, 670	Clay shale, medium-dark-gray, fissile in lower part; small amount of siltstone at 1,495–1,505 ft and minor amount at 1,565–1, 575 ft; a minor amount of sandstone at 1,515–1,525 ft, and small amount at 1,555–1,565 ft; small amount bentonite at 1,535–1,545 ft. Trace of bluish-white bentonite at 1,626–1,635 ft had abundant, minute, euhedral cubic and dodecahedral pyrite crystals. Fishbone fragments at 1,625–1,635 ft and *Inoceramus* shell fragment at 1,595 ft.
28	1, 670–1, 690	Recovered 20 ft: Microfossils very abundant.
		Clay shale, medium-gray (with medium-light- or medium-dark-gray streaks) noncalcareous; silty and slightly bentonitic in part; a few silty slightly calcareous laminae and lenticles that dip from less than 1° to 5°; poor to good shaly cleavage. Top 2 ft contains 2–3-in. beds of argillaceous medium-light-gray bentonite; uppermost bentonite bed distorted though shale immediately above and below is flat lying. Pyrite, minute clay balls, and white bentonite with minute biotite flakes present.
-----	1, 690–1, 715	Clay shale as in core 28 above.
-----	1, 715–1, 720	Clay shale, with bentonite containing abundant small euhedral biotite plates.
-----	1, 720–1, 730	Clay shale and siltstone.
-----	1, 730–1, 780	Clay shale with minor siltstone.
-----	1, 780–1, 790	Siltstone, medium-gray, slightly calcareous, argillaceous.
-----	1, 790–1, 800	Clay shale, with some siltstone.
-----	1, 800–1, 809	Siltstone and clay shale with small amount of coal.
-----	1, 809–1, 823	Sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, nonbentonitic, slightly to very slightly calcareous, very slightly pyritic, hard to friable.
29	1, 823–1, 843	Recovered 19 ft 7 in.: Microfossils absent.
		6 ft, sandstone, medium-light-gray, very fine-grained, very slightly argillaceous, slightly calcareous, with abundant biotite; massive. Sand grains are angular clear and white quartz with some gray and dark rock fragments. A few rounded pebbles of medium-gray clay shale ¼–1 in. in diameter at 1,825 and 1,828 ft. At 1,824 ft effective porosity 9.66 percent; rock is impermeable; carbonate content percent by weight 10.3.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		8 in., claystone, medium-gray, noncalcareous, slightly micaceous; irregular fracture; sharp contact with overlying sandstone dips 10°. 1 ft 2 in., sandstone, medium- to medium-light-gray, very fine-grained, very silty, very slightly calcareous, with faint slightly carbonaceous streaks that suggest "swirly" bedding, in lower half of unit. 2 ft 6 in., sandstone, medium-light-gray, very fine- to fine-grained, slightly calcareous to calcareous, with 6 in. of medium-gray claystone between 1,841 and 1,842 ft, and 2 in. of clay shale pebbles with minor amount of sandstone matrix 8 in. above base of interval. 5 ft 8 in., sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, with 6 in. of medium-gray claystone at 1,836 ft; 2-in. interval of poorly rounded claystone pebbles and 4-in. bed of medium-gray claystone at 1,836 ft. 2 ft 3 in., claystone as above, with thin beds (up to one-half an inch thick) and laminae of medium-light-gray siltstone. 1 ft 4 in., sandstone as above, with 1½ in. at top containing varvelike laminae of medium-gray clay shale. Bottom 3 in. is also claystone as above.
30	1, 843–1, 863	Recovered 2 ft 10 in.: Microfossils absent. 1 ft 7 in., claystone as above, with abundant laminae of siltstone. *Inoceramus* fragment at top. 1 ft 3 in., sandstone as above, with two 1-in. beds of claystone 6 in. above base, and at base of interval.
31	1, 863–1, 864	Recovered 1 ft 3 in.: Microfossils absent. Sandstone as above, with laminae and thin beds of claystone as above, totaling 40 percent of core.
-----	1, 864–1, 910	Siltstone, medium-light-gray, argillaceous, noncalcareous, nonbentonitic, very micaceous (biotite), with silty shale at 1,864–1,870 and 1,900–1,910 ft, and traces of siltstone at 1,870–1,880, 1,890, and 1,900 ft.
-----	1, 910–1, 930	Clay shale, with argillaceous siltstone.
-----	1, 930–1, 940	Claystone, with trace of gray argillaceous limestone, dense, with very thin light-gray laminae.
-----	1, 940–1, 950	Siltstone, with small amount sandstone and claystone.
-----	1, 950–1, 955	Siltstone.
32–34	1, 955–1, 983	Recovered 18 ft 8 in.: Intervals described below are in proper sequence, but their exact depth is unknown. Microfossils very rare. 6 ft 8 in., siltstone, medium-light-gray, very slightly calcareous to noncalcareous, argillaceous; sandy in lower part, with very rare very faint carbonaceous streaks. 1 ft 5 in., bentonite, grading from medium light gray, very argillaceous, and slightly micaceous to very light gray, slightly argillaceous, with very abundant euhedral plates of biotite. Aragonite veins, 1/16–⅛ in. across, are very common in central part of interval.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		6 in., claystone, medium-dark-gray, silty, noncalcareous, micaceous. 9 in., sandstone, medium- to medium-light-gray, very fine-grained, argillaceous, very calcareous. 1 ft 7 in., siltstone as above, medium-gray, with rare particles of carbonaceous material. 7 ft 9 in., claystone as above, with thin (as much as 1 in. thick) beds of medium-gray very argillaceous siltstone dipping 5°–20°; siltstone averages less than 10 percent of section except for a 1 ft 5 in. interval 1 ft above base of core, which is approximately two-thirds siltstone with interbedded clay shale. Pelecypod (*Mytilus?*) shells at 5 ft above base of core.
-----	1, 983–1, 990	Siltstone, with minor shale and abundant pyrite grains.
-----	1, 990–2, 015	Clay shale, with minor siltstone.
-----	2, 015–2, 025	Clay shale with some siltstone.
-----	2, 025–2, 035	Siltstone with some very slightly bentonitic claystone.
-----	2, 035–2, 040	Clay shale, medium-dark-gray, and very silty medium-light-gray clay shale.
-----	2, 040–2, 047	Sandstone, medium-light-gray, very fine-grained, slightly calcareous, argillaceous. Top of Ninuluk formation at 2,040 ft.
35	2, 047–2, 068	Recovered 20 ft: Microfossils absent. Sandstone, medium-light-gray, very fine- to fine-grained at top, grading to only fine-grained at base, very argillaceous, calcareous; massive, except for 8 in. at 2,065 ft that contains common carbonaceous partings dipping 15°. Fair odor of oil in core. Light-yellow cut, yellow residue in CCl_4 at 2,060 ft; composed of angular to subangular grains of clear and white quartz and dark rock fragments, with some yellow quartz and gypsum (?); many grains frosted. Mica present but not common.
36	2, 068–2, 069	Recovered 1 ft: Microfossils absent. Sandstone as above.
37	2, 069–2, 077. 5	Recovered 8 ft 5 in.: Microfossils absent. 7 ft 9 in., sandstone as above, fine-grained, coarsening slightly with depth. Fair to good oil odor. Light-yellow cut, yellow residue in CCl_4 at 2,075 ft. 8 in., sandstone as above but very fine grained.
38	2, 077. 5–2, 097	Recovered 19 ft 7 in.: Microfossils absent. 9 ft 6 in., sandstone as above, but very calcareous and with poor shaly cleavage below 2,079 ft. Good odor oil, pale-yellow cut, yellow residue in CCl_4 at 2,085 ft. 4 ft, sandstone, medium-light-gray, fine- to medium-grained, with a few streaks of medium- to coarse-grained sandstone, argillaceous, calcareous, with common streaks of carbonaceous and coaly material as much as one-fourth of an inch thick, dipping as much as 30°. Faint oil odor. 3 ft 10 in., sandstone, medium-gray, very fine-grained, very silty and argillaceous, slightly calcareous to noncalcareous, with common carbonaceous particles.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		9 in., claystone, medium-dark- to medium-gray, noncalcareous, with conchoidal fracture.
		11 in., siltstone, medium-light-gray, argillaceous, with faint laminae medium-dark-gray clay shale.
		7 in., claystone, medium-dark-gray, slightly silty, noncalcareous, with thin beds of medium-gray, noncalcareous siltstone.
-----	2, 097–2, 105	Siltstone, with sandstone and clay shale.
-----	2, 105–2, 109	Sandstone, fine- to medium-grained, with small amount of fine-grained friable noncalcareous sandstone.
39	2, 109–2, 128	Recovered 18 ft 5 in.: Microfossils absent.
		1 ft 6 in., sandstone, medium-light-gray, fine-grained, slightly to noncalcareous, with good oil odor. Light-yellow cut and brownish-yellow residue in CCl_4 at 2,110 ft.
		3 ft 6 in., sandstone as above but very fine-grained, faint oil odor. Grades into rock below.
		1 ft 8 in., sandstone as at top of core, with good oil odor. Light-yellow cut, brownish-yellow residue at 2,117 ft.
		3 ft, sandstone as in 3½-ft interval above.
		8 ft 9 in., sandstone as at top of core; yellow cut, brownish-yellow residue in CCl_4 at 2,120 ft, light-yellow cut, yellow residue at 2,128 ft.
40	2, 128–2, 145	Recovered 16 ft 4 in.: Microfossils abundant.
		14 ft 3 in., sandstone, medium-light-gray, fine-grained, silty, very slightly calcareous to noncalcareous, massive; composed of angular grains of clear quartz with small amount of white quartz and dark rock fragments; frosted grains rare. Streaks of carbonaceous material dipping 5°–15° common in lower 1 ft, rare elsewhere; streaks of clay ironstone rare throughout.
		2 ft 1 in., claystone, medium-dark-gray, very slightly micaceous, noncalcareous; subconchoidal fracture.
-----	2, 145–2, 150	Sandstone as in sandstone of core 40.
-----	2, 150–2, 151	Clay shale, very silty, with small amount of siltstone and minor amount of bentonite.
-----	2, 151–2, 152	Siltstone, with small amount of clay shale.
-----	2, 152–2, 153	No sample.
41	2, 153–2, 173	Recovered 19 ft 2 in.: Microfossils abundant.
		2 ft 4 in., interbedded claystone, medium-dark-gray; and medium-gray siltstone, with proportion of siltstone decreasing from ⅔ to ⅓ of rock with depth. Individual laminae irregularly lenticular, all less than one-half an inch thick.
		12 ft. 6 in., claystone as in core 40 above, with 2-in. sandy interval at 2,164 ft, and silty claystone between 2,164 and 2,165 ft. Coaly laminae in basal 8 in. of claystone. Approximate top of Killik tongue of Chandler formation at 2,160 ft.
		2 in., claystone, medium-gray, silty, noncalcareous.
		3 in., siltstone, medium-light-gray, noncalcareous, argillaceous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		7 in., sandstone, medium-light-gray, very fine-grained, calcareous, with scattered irregular carbonaceous streaks. Contact with underlying claystone resembles wide shallow ripple mark.
		2 ft 7 in., claystone, medium-dark-gray, with irregular to subconchoidal fracture; rare patches of coaly material. A 2-in. section of medium-gray slightly silty claystone at 2,170 ft. Between 2,171 and 2,172 ft is an irregular mass, 2–8 in. in diameter, of very fine-grained sandstone, in distorted claystone, suggesting contemporaneous deformation.
		9 in., sandstone, medium-light-gray, very fine-grained, argillaceous, noncalcareous to calcareous, with irregular laminae of medium-dark-gray clay shale with carbonaceous material.
42	2, 173–2, 192	Recovered 13 ft 6 in.: Microfossils common.
		7 in., sandstone as in base of core 41 above.
		1 ft 9 in., claystone, medium-dark-gray, noncalcareous, with common laminae of medium-gray silty calcareous claystone dipping 8°–10°.
		1 ft 11 in., claystone, medium-dark-gray, slightly bentonitic, noncalcareous; conchoidal to irregular fracture. Pelecypod shells (*Meretrix?*, *Venilla?*, *Legumen?*) common.
		11 in., sandstone, medium-light-gray, very fine-grained, calcareous, with small discontinuous streaks and patches of silty sandstone.
		3 ft 11 in., interlaminated siltstone, medium-gray, calcareous, micaceous; and medium-dark-gray slightly calcareous claystone. Siltstone decreases with depth from 50 to less than 10 percent of the rock. Laminae slightly crossbedded, dip 8°–10°.
		3 ft 7 in., claystone, medium-dark-gray, noncalcareous, very slightly micaceous to nonmicaceous; conchoidal fracture.
		4 in., coal, dull to shiny, black; blocky to irregular fracture.
		6 in., clay shale, black, with abundant coaly laminae.
43	2, 192–2, 203	Recovered 10 ft: Microfossils absent.
		3 ft 2 in., claystone, medium-gray, with conchoidal fracture, and rare to abundant very thin laminae and partings of medium-light-gray calcareous siltstone. A 6-in. interval 1 ft below top of core contains abundant laminae and thin beds of very fine-grained, light-gray, very calcareous sandstone.
		1 ft 2 in., interlaminated claystone and siltstone. Laminae crossbedded with dips as high as 30°. Laminae become sandy with depth.
		5 ft 8 in., sandstone, light-gray, very fine-grained, argillaceous, silty, very calcareous; common carbonaceous partings in upper half dip 5°–20°; a few streaks of fine-grained sandstone present.

Lithologic description—Continued

Core	Depth (feet)	Remarks
44	2, 203–2, 221	Recovered 12 ft 6 in.: Microfossils absent. 6 in., sandstone as at base of core 43 above. 1 ft 5 in., claystone, medium-gray, noncalcareous, conchoidal fracture, with rare silty partings in lower part. A 1-in. bed of sandstone as at top of core 6 in. above base of claystone. 3 ft 6 in., sandstone, light-gray, very fine-grained, silty, very calcareous; faint slightly crossbedded streaks and laminae of carbonaceous material in upper 3 in. and in lower 15 in. 2 ft 2 in., claystone, medium-dark- to medium-gray, with abundant medium-light-gray laminae of siltstone. Two clay-ironstone nodules, 2 in. in diameter, at top of claystone. 2 ft 6 in., sandstone, light-gray, very fine-grained, silty, argillaceous, with abundant faint laminae, slightly darker than matrix because of increase in carbonaceous particles. Dip of laminae 18°. Slickensides at base of 1-in. bed of medium-gray claystone 2 in. below top of sandstone. Small (⅛–¾ in. in diameter) rounded pebbles of medium-gray clay at base of sandstone; 1 pebble, 2 in. by ½ in., just above base. 2 ft 5 in., sandstone as above, but slightly coarser, with common to abundant carbonaceous laminae and partings dipping 18°.
45	2, 221–2, 239	Recovered 18 ft: Microfossils very rare. 4 ft, claystone, medium-dark-gray, noncalcareous, nonsilty, nonmicaceous; conchoidal fracture. 2 ft 11 in., claystone as above, but silty, with streaks and thin beds silt and sandy silt. Poor shaly cleavage. 6 ft 6 in., claystone as at top of core, with 1-in. bed of light-bluish-gray bentonite 6 in. below top. Claystone becomes silty in lower half of interval. 10 in., sandstone, medium-light-gray, fine-grained, very slightly argillaceous, friable; composed of angular to subangular clear quartz with some light- to dark-gray rock fragments. 3 ft 9 in., interbedded sandstone, light- to medium-light-gray, fine- to very fine-grained, noncalcareous to calcareous; and medium-light-gray noncalcareous to slightly calcareous siltstone. Many sandstone beds are lenticular, usually under 3 in. thick; with depth they decrease from ⅔ to ⅓ of the rock. Clay ironstone streaks rare.
46	2, 239–2, 259	Recovered 18 ft: Microfossils absent. 3 ft, interbedded siltstone and sandstone as at base of core 45. Argillaceous partings common in upper part, carbonaceous partings common in lower part. Sandstone increases from ⅓ to ⅔ of rock with depth. 6 ft 1 in., claystone, medium-dark-gray, partly silty; conchoidal to irregular fracture. Slickensides at 2,244 ft. 4 ft 9 in., sandstone, fine- to very fine-grained, partly silty and argillaceous, noncalcareous to very calcareous, with scattered streaks and intercalations of olive-gray clay. Rare streaks of clay ironstone. 1 ft 8 in., claystone, medium- to medium-light-gray, silty, slightly to noncalcareous, with streaks clay ironstone. 10 in., sandstone as above. 1 ft 8 in., fragments of claystone as above, infiltrated with drilling mud.
-----	2, 259–2, 270	Clay shale, with small amount of siltstone; minor amount of bentonite has small biotite plates and rare small dark glassy (obsidianlike) fragments.
-----	2, 270–2, 277	Siltstone, noncalcareous, with small amount of claystone and trace of bentonite.
-----	2, 277–2, 285	Siltstone, very calcareous, and clay shale, with small amount of very calcareous very fine-grained sandstone.
-----	2, 285–2, 295	Sandstone, fine- and very fine-grained, with small amount of claystone and siltstone.
47	2, 295–2, 315	Recovered 19 ft: Microfossils absent. 15 ft, sandstone, light-gray, fine-grained, slightly silty, nonmicaceous, noncalcareous, massive; composed of subangular to angular clear quartz grains with minor amounts of white, gray, and black rock fragments; some grains have frosted surfaces. Sandstone becomes very fine grained, very silty and argillaceous, and very slightly calcareous at base. Faint odor of oil was noted, and a light-yellow cut, and yellow residue were obtained in CCl_4 at 2,298 ft and 2,305 ft. Patches of carbonaceous material common in basal 1 ft. Grades into rock below. 2 ft 8 in., siltstone, medium-light-gray, argillaceous, noncalcareous, with rare slightly irregular partings and laminae of medium-dark-gray clay shale increasing to abundant at base of siltstone. Dip approximately 13°. 11 in., claystone, medium-dark-gray, silty, with rare fishbone fragments and patches carbonaceous material. 5 in., sandstone as above, fine- to very fine-grained, with intercalations of medium-dark-gray clay shale.
48	2, 315–2, 335	Recovered 18 ft 6 in.: Microfossils common. 1 ft 1 in., claystone, medium-dark-gray, nonmicaceous; subconchoidal fracture. 2 ft 5 in., claystone, medium-gray, with scattered fragments of coaly plant material. Becomes silty with depth. Irregular 1- to 2-in. bed of clay ironstone at base. 3 ft 4 in., sandstone, light-gray, fine-grained, silty, argillaceous, noncalcareous, with much interstitial (authigenic?) mica. Clay and carbonaceous partings, common in upper 1 ft and rare in rest of section, dip 13°. 1 ft 8 in., sandstone, medium-light-gray, very fine-grained, very silty and argillaceous, with abundant laminae of medium-dark-gray clay shale. Laminae curve under and over nodule of clay ironstone 1 in. in diameter. 2 ft 6 in., siltstone with clay shale partings as in sandstone above. Grades into rock below.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		1 ft 7 in., claystone, medium-gray, with common streaks of clay ironstone. Slickensides, some with calcite coatings, 6 in. above base. Basal 2 in. is shaly, crumpled, and folded.
		2 ft 11 in., claystone, medium-dark-gray, nonmicaceous, noncalcareous, nonsilty; conchoidal fracture. Fish scales and fishbone fragments present.
		3 ft, claystone, medium-dark-gray, very silty; irregular fracture.
-----	2, 335–2, 344	Clay shale, dark-gray, with minor siltstone.
-----	2, 344–2, 350	Sandstone, very fine-grained, noncalcareous.
-----	2, 350–2, 373	Clay shale, medium-dark-gray, with very rare bentonite.
-----	2, 373–2, 374	Sandstone, very fine-grained, noncalcareous.
49	2, 374–2, 394	Recovered 19 ft: Microfossils absent.
		1 ft, sandstone, light-gray, very fine-grained, silty, argillaceous, nonmicaceous, slightly calcareous in part, massive; composed of angular to subangular grains of clear and white quartz and gray to black rock fragments; grades into rock below.
		4 ft, sandstone as above, but fine-grained, salt-and-pepper.
		14 ft, sandstone as at top of core. Faint slightly carbonaceous laminae abundant in basal 2 ft.
50	2, 394–2, 405	Recovered 11 ft 4 in.: Microfossils absent.
		5 ft, siltstone, medium-light-gray, very calcareous to noncalcareous, with common fine clay laminae dipping 18°. A 1-in. section at 2,398 ft has abundant carbonaceous flakes.
		1 ft 4 in., claystone, medium-dark-gray, silty, irregular fracture, with abundant laminae of medium-light gray siltstone.
		2 ft 3 in, sandstone, light-gray, very fine-grained, very silty and argillaceous, noncalcareous, very slightly bentonitic, with scattered carbonaceous partings; clay laminae concentrated in 2-in. sections 1 ft and 1 ft 9 in. below top of interval.
		9 in., siltstone with clay laminae as above. Some laminae show minute vertical displacement of approximately one-eighth of an inch.
		2 ft, claystone, medium-dark-gray, silty, noncalcareous, with irregular fracture.
51	2, 405–2, 411	Recovered 2 in.
		Claystone, as base of core above.
	2, 411–2, 417	Siltstone and clay shale with some sandstone, fine- and very fine-grained, noncalcareous, partly very micaceous; minor amount of limestone.
	2, 417–2, 435	Clay shale, medium-dark- and dark-gray and some sandstone; trace of bentonite with abundant biotite. Top of Grandstand formation at 2,420 ft.
	2, 435–2, 444	Sandstone, medium-light-gray, fine- and very fine-grained, noncalcareous, with black shale in upper half and dark-gray shale in lower half.
52	2, 444–2, 448	Recovered 2 ft 6 in.: Microfossils absent.
		Sandstone, medium-light gray, fine-grained, argillaceous, silty, noncalcareous, massive; composed of angular to subangular grains of clear quartz with some white quartz and dark rock fragments. Good oil odor, fair fluorescence.
53	2, 448–2, 461	Recovered 13 ft: Microfossils absent.
		Sandstone as above, but with faint oil odor in top 1 ft and no odor below. Carbonaceous partings dipping 13° common in 2- to 3-in. intervals spaced 1–2 ft apart.
-----	2, 461–2, 485	Sandstone, fine-grained and very fine-grained, noncalcareous, friable, with medium-dark-gray clay shale in upper half; minor clay ironstone in lower part.
-----	2, 485–2, 495	Clay shale, siltstone and sandstone, noncalcareous.
-----	2, 495–2, 505	Clay shale, with small amount of siltstone.
-----	2, 505–2, 510	Sandstone, very fine-grained, noncalcareous, with minor amount of clay shale.
-----	2, 510–2, 520	Clay shale.
-----	2, 520–2, 529	Sandstone, fine-grained, friable.
54	2, 529–2, 545	Recovered 16 ft: Microfossils rare.
		5 ft, sandstone, medium-light-gray, fine-grained, slightly silty; slightly calcareous in part; scattered intercalations of medium-dark-gray clay shale resulting in poor shaly cleavage. No oil odor present, but straw-colored cut and pale-yellow residue obtained in CCl_4 from 2, 532 ft. Sand grains subround to subangular clear quartz and gray and dark rock fragments. Mica very rare. Two 3-in. beds of medium-dark-gray claystone occur 1 ft and 1½ ft below top of core; they contain intercalations of sand and silt. Grades into rock below.
		1 ft 5 in, interlaminated sandstone as above, medium-dark-gray clay shale, and medium-gray siltstone, with coarser sediments predominating. Laminae irregular, "wavy," and lower part shows "swirly" bedding. Grades into rock below.
		4 ft 3 in, interlaminated sandstone, siltstone, and claystone as above, but with claystone predominating, except for a 6-in. sandy unit 2 ft above base of interval.
		1 ft 9 in, claystone, medium-dark-gray, nonsilty, noncalcareous; subconchoidal fracture.
		1 ft 3 in, claystone, medium-dark- to medium-gray, slightly to very silty, noncalcareous; irregular fracture.
		2 ft 4 in., sandstone as at top of core with some irregular streaks of claystone scattered throughout. A 4-in. bed of medium-dark-gray claystone 10 in. below top of sandstone.
-----	2, 545–2, 595	Clay shale, medium-dark-gray, nonsilty, with minor amount of calcareous siltstone at 2,565–2,575 ft and small amount of very fine-grained noncalcareous sandstone at 2,575–2,585 ft.
-----	2, 595–2, 605	Siltstone, slightly calcareous, grades to very fine-grained sandstone; small amount of clay shale.
-----	2, 605–2, 615	Claystone and slightly to noncalcareous siltstone.
-----	2, 615–2, 625	Sandstone, very fine-grained, calcareous.
-----	2, 625–2, 635	No sample.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	2, 635–2, 665	Clay shale, medium-dark-gray, silty, noncalcareous, with minor amount of very fine-grained calcareous sandstone, in upper part; and calcareous siltstone in lower part.
-----	2, 665–2, 670	No sample.
-----	2, 670–2, 675	Clay shale, with small amount of medium-gray calcareous siltstone.
-----	2, 675–2, 680	No sample.
-----	2, 680–2, 700	Clay shale, medium-dark-gray, silty, noncalcareous, with minor medium-gray calcareous siltstone.
-----	2, 700–2, 701	No sample.
55	2, 701–2, 721	Recovered 20 ft: Microfossils very abundant. Claystone, medium-dark-gray, noncalcareous, silty, slightly micaceous, with rare intercalated medium-gray argillaceous siltstone. Rare streaks and patches of pyrite, and specks of coaly material scattered throughout. Cleavage irregular; *Ditrupa* sp. and *Inoceramus* prisms present.
-----	2, 721–2, 750	Clay shale, medium-dark-gray, silty, noncalcareous, with trace of siltstone.
-----	2, 750–2, 805	Clay shale, as above, but less silty in upper part; trace of argillaceous bentonite 2,760–2,770 ft.
-----	2, 805–2, 810	Sandstone, light-gray, fine-grained, slightly calcareous to noncalcareous; small amount of claystone.
56	2, 810–2, 830	Recovered 16 ft: Microfossils very abundant. 15 ft 2 in., sandstone, medium-light-gray, fine-grained, argillaceous, silty, noncalcareous, slightly pyritic, massive; composed of subangular grains of clear quartz with white, gray, and dark rock fragments. Rare streaks of carbonaceous material suggest low (under 5°) dip. One-inch bed of claystone at 2,814 ft. Faint odor of oil through the sandstone, with very pale-yellow cut and yellow residue in CCl_4 at 2,813 ft, and pale-yellow cut and yellow residue at 2,824 ft. 10 in., claystone, medium-dark-gray, noncalcareous, nonsilty; conchoidal fracture.
57	2, 830–2, 837	Recovered 7 ft: Microfossils absent. Sandstone as in core 56 above, with strong kerosenelike odor. Oil staining darkens sand from medium-light- to medium-gray. Amber cut and brownish-yellow residue in CCl_4 at 2,832 ft, but fluorescence very faint.
58	2, 837–2, 850	Recovered 13 ft: Microfossils absent. 7 in., sandstone as in core 57 above, with strong oil odor. 1 ft, claystone, medium-dark-gray, noncalcareous, with irregular cleavage. Rare carbonaceous streaks. 11 ft 5 in., sandstone, medium-light-gray, fine-grained, slightly silty and argillaceous, noncalcareous, massive, with rare carbonaceous streaks. Very faint oil odor; pale-yellow cut and yellow residue in CCl_4 from 2,841 and 2,849 ft. Sandstone composed of subangular to angular grains of clear and white quartz with gray and dark rock fragments. Grades into fine to medium subangular to subrounded sand grains in central part of core.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	2, 850–2, 870	Sandstone, light-gray, fine-grained, slightly calcareous to noncalcareous; and medium-dark-gray silty clay shale; trace of pyrite.
-----	2, 870–2, 920	Sandstone, medium-light-gray, fine-grained (very fine grained in bottom 10 ft), silty, argillaceous, noncalcareous; trace of light-bluish-gray argillaceous bentonite in center of interval; small amount of claystone at 2,900–2,920 ft.
59	2, 920–2, 940	Recovered 18 ft: Microfossils abundant. 3 ft 5 in., siltstone, medium-light-gray, noncalcareous, with abundant faint very thin laminae of medium-dark-gray carbonaceous clay; irregular fracture. Thin (less than 1 in. thick) irregular beds of clay shale in lower 10 in. of siltstone. 6 ft 2 in., sandstone, medium-light-gray, very fine-grained, noncalcareous, very silty and argillaceous. Very thin carbonaceous silty laminae dipping 15° result in poor to good shaly cleavage in upper 2 in.; sandstone is massive below. 4 ft 6 in., siltstone as above, with thin beds and intercalations of medium-dark-gray clay shale 6 in. below top and 6 in. above base of interval; a 1-in. sandy interval 1½ ft below top. Dip 14°. 9 in., sandstone, as above, massive. 2 ft 7 in., siltstone as above, with an 8-in. interval of claystone and siltstone with "swirly" bedding 15 in. below top of siltstone. Laminae dip 16°. 7 in., sandstone, massive, as above.
-----	2, 940–2, 960	Siltstone, medium-gray, noncalcareous, with rare carbonaceous partings; small amount of very fine-grained sandstone.
-----	2, 960–2, 970	Sandstone, very fine- and fine-grained, with small amount of clay shale and siltstone.
-----	2, 970–2, 989	Sandstone, fine-grained, salt-and-pepper, silty, argillaceous, noncalcareous.
60	2, 989–3, 009	Recovered 15 ft 6 in.: Microfossils absent. Sandstone, medium-light-gray, very fine-grained, noncalcareous, silty, argillaceous, micaceous (muscovite); massive except for faint carbonaceous micaceous clay laminae in lower 1½ ft that dip 11°, composed of angular to subangular grains of clear and white quartz, with dark rock fragments. No odor or cut of oil present.
-----	3, 009–3, 020	Sandstone as in core 60 above.
-----	3, 020–3, 030	Clay shale, with sandstone and siltstone.
-----	3, 030–3, 080	Sandstone, very fine-grained, silty, argillaceous, noncalcareous, with minor clay shale. Trace of very light-yellowish-gray translucent cryptocrystalline limestone, at 3,040–3,050 ft; trace of white bentonite at 3,060–3,070 ft. Top of Topagoruk formation at 3,075 ft.
-----	3, 080–3, 090	Sandstone, with some clay shale and siltstone, and trace of white bentonite.
-----	3, 090–3, 100	Clay shale, sandstone, and siltstone.
-----	3, 100–3, 130	Clay shale, medium-dark-gray, silty, with minor siltstone.
-----	3, 130–3, 140	Siltstone, with small amount of claystone.
-----	3, 140–3, 150	Clay shale and siltstone, with minor sandstone.
-----	3, 150–3, 170	Clay shale, with minor siltstone and trace of bluish-white bentonite.

Lithologic description—Continued

Core	Depth (feet)	Remarks
-----	3, 170–3, 180	Siltstone with minor clay shale.
-----	3, 180–3, 230	Clay shale, medium-dark gray, silty, with minor siltstone in upper part.
-----	3, 230–3, 240	Clay shale and bentonite, bluish-white; small amount of white bentonite with abundant biotite.
-----	3, 240–3, 290	Clay shale, medium-dark-gray, very silty, with small amount of siltstone decreasing with depth; trade of bluish-white bentonite at top.
61	3, 290–3, 303	Recovered 13 ft: Microfossils very abundant. Claystone, medium-dark-gray, noncalcareous, nonsilty; subconchoidal fracture; with irregular beds (up to 6 in. thick) and intercalations of silty medium-gray claystone with irregular fracture. Silty clay totals approximately 50 percent of core. Dip irregular, except for a few laminae at 3,295 ft which dip 14°.

CORE ANALYSES

Porosity, permeability, and carbonate content of core samples from Umiat test well 11 are shown in the following table. The effective porosity and air permeability were determined using equipment described on page 127.

Analyses of core samples from Umiat test well 11

Core	Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)	Carbonate content (percent by weight)
1	118	10.2	----------	----------
1	128	13.1	<1	----------
2	140	15.35	6.2	----------
3	233	17.85	<1	----------
4	243	11.75	0	----------
6	331	13.94	0	----------
9	483	7.98	0	----------
10	514	15.90	0	----------
11	519	16.75	(1)	----------
11	526	18.0	26	17.5
12	545	14.9	<1	----------
15	746	18.25	5.1	----------
15	754	17.7	7.0	----------
16	763	12.7	0	7.82
16	771	20.64	48	----------
21	1,328	18.4	27	----------
22	1,331	.55	0	43.4
23	1,343	6.46	0	----------
25	1,358	7.03	0	----------
25	1,365	10.1	0	----------
29	1,824	9.66	0	10.30
35	2,049	10.58	0	14.25
36	2,056	12.23	0	14.52
36	2,060	11.79	0	8.30
36	2,068	13.32	0	10.22
37	2,075	13.05	0	8.72
38	2,080	7.39	0	19.10
38	2,085	11.55	0	14.05
38	2,093	10.41	0	----------
39	2,110	14.50	29	----------
39	2,117	13.45	14	----------
39	2,120	13.40	28	----------
39	2,128	15.65	56	----------
40	2,139	15.50	51	----------
43	2,200	12.40	0	23.00
45	2,235	15.65	125	----------
46	2,253	5.76	0	----------
47	2,298	19.80	550	----------
47	2,305	16.15	13	----------
49	2,378	19.60	102	----------
49	2,386	16.78	10	----------
52	2,445	17.60	120	----------
53	2,450	16.45	81	----------
53	2,453	14.83	18	----------

See footnote at end of table

Analyses of core samples from Umiat test well 11—Continued

Core	Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)	Carbonate content (percent by weight)
53	2,460	14.95	27	----------
54	2,532	18.96	235	----------
56	2,813	16.35	100	----------
56	2,824	17.35	158	----------
57	2,832	17.1	280	----------
58	2,841	14.71	(1)	----------
58	2,849	19.25	400	----------
59	2,925	11.96	0	----------
60	2,990	13.5	<1	----------
60	2,997	12.85	2.3	----------
60	3,005	10.2	0	----------

[1] Sample too friable to test.

HEAVY-MINERAL ANALYSIS

Heavy-mineral studies were made by Robert H. Morris, who has concluded that "three heavy-mineral zones are recognizable in Umiat test well 11. The biotite zone ranges from 118 to 1,824 feet. The hornblende zone ranges from 2,049 to 2,386 feet. The zoned zircon zone is represented by samples from 2,813 feet to 3,005 feet." The heavy minerals noted are shown in greater detail on plate 10.

OIL AND GAS

OIL AND GAS SHOWS

Although several shows of oil and gas were found, none indicated producing strata. The samples given in the table below were tested in the Fairbanks laboratory one to several days after the cores were boxed, depending on the availability of transportation from Umiat to Fairbanks. The sandstone was crushed to approximately single-grain particles, CCl_4 added, and the mixture shaken. Any color appearing in the CCl_4 after settling and filtering was described as the cut; the residue is any material left in the dish after evaporation of CCl_4. The consistency of the residue ranged from a greasy film to an oily liquid.

Tests of rocks from Umiat test well 1 for oil stain in CCl_4

Core	Depth (feet)	Cut	Residue
9	483	None	Faint greasy stain.
11	535	None	Yellowish stain.
12	545	None	Yellowish stain.
35	2,060	Light yellow	Yellow.
37	2,075	Light yellow	Yellow.
38	2,085	Pale yellow	Yellow.
39	2,110	Light yellow	Brownish yellow.
39	2,117	Light yellow	Brownish yellow.
39	2,120	Yellow	Yellow.
39	2,128	Light yellow	Yellow.
40	2,133	Pale yellow	Yellow.
47	2,298	Light yellow	Yellow.
47	2,305	Light yellow	Yellow.
49	2,378	Light yellow	Yellow.
49	2,386	Light yellow	Yellow.
54	2,532	Very pale yellow	Pale yellow.
56	2,813	Very pale yellow	Yellow.
56	2,824	Pale yellow	Yellow.
57	2,832	Amber	Brownish yellow.
58	2,841	Pale yellow	Yellow.
58	2,849	Pale yellow	Yellow.
60	3,005	None	None.

Gas or oil shows were also reported by the driller or by Arctic Contractors' petroleum engineer Everette Skarda:

1. Drilling at 804 feet: free oil was observed on the ditch; it apparently was not from the oil-emulsion mud.
2. Coring at 2,081 feet: slight amount of gas was observed in the ditch. Gas in the core barrel flared, and some gas broke the sheath of core 38 (taken from 2,077.5 to 2,097 feet). Fluorescence and some free oil were noted in thin sandstone beds between 2,077.5 and 2,142 feet.
3. A good odor and cut were observed in core 52 (2,444–2,448 ft.).
4. Slight fluorescence was noted from 2,830–2,837 feet; a slight amount of gas came to the surface after 3 hours on Johnston formation test 11, from 2,832–2,850 feet.

Johnston formation tests at all these depths, except that at 2,444–2,448 feet, which had a water-bearing core immediately below it, recovered no oil and only a trace of gas.

FORMATION TESTS

Although there were some slight shows of oil and gas in the hole (see preceding table), the 10 successful formation tests recovered only drilling mud or salty water. The detailed descriptions given below are based on data from reports by Everette Skarda.

Test 1, 511.5–549 feet.—An 8⅝-inch packer was set at 511.5 feet, with 37.5 feet of tailpipe, including 6 feet of perforated pipe and 2 pressure recorders on the bottom; a 5/16-inch bean was used. The trip valve did not open, and the test was unsuccessful.

Test 2, 511.5–549 feet.—The same tools were used as in test 1, except that the trip valve was placed above the drill collars. The valve was open 2 hours and 52 minutes, but no gas came to the surface and flow pressure was zero. The valve was closed for 10 minutes; the packer was pulled from the seat while attempting to obtain a closed-in pressure. Seventy feet of drilling mud with a salinity of 390 parts per million of chloride was recovered—the circulated mud had a salinity of 400 ppm.

Test 3, 735–782 feet.—An 8⅝-inch packer was set at 735 feet, with 46.55 feet of tailpipe, including 7 feet of perforated pipe and 2 pressure recorders on the bottom; a 5/16-inch bean was used. The valve was open 3 hours and 3 minutes; no gas came to the surface; the valve was closed for 24 minutes, and bottom-hole flow pressure and closed-in pressure were zero. Fifty feet of drilling mud with a salinity of 390 ppm—circulated mud had a salinity of 386 ppm—were recovered.

Test 4, 792–805 feet.—An 8⅝-inch packer was set at 792 feet, with 13 feet of tailpipe, including 2 feet of perforated pipe, and 2 pressure recorders on the bottom; a 5/16-inch bean was used. The valve was open 3 hours and 2 minutes, but no gas came to the surface; the valve was closed for 15 minutes, and bottom-hole flow pressure and closed-in pressure were zero. Twenty-five feet of drilling mud with a salinity of 400 ppm was recovered—circulated mud had same salinity.

Test 5, 1,325–1,355.5 feet.— A 5¾-inch packer was set at 1,325 feet, with 31 feet of tailpipe, including 21.2 feet of perforated pipe and 2 pressure recorders on the bottom; a 5/16-inch bean was used. The valve was open 3 hours and 5 minutes; no gas came to the surface; bottom-hole flow pressure and closed-in pressure were zero. The test recovered 127 feet of drilling mud with a salinity of 250 ppm—circulated mud had the same salinity. The large amount of mud recovered may have been due to its flowing past the packer when the packer was off the seat; it presumably entered the tool when the packer was reseated while trying to close retaining valve.

Test 6, 2,052.5–2,097 feet.—A 5¾-inch packer was set at 2,052.5 feet with 44.5 feet of tailpipe, including 19.5 feet of perforated pipe and 2 pressure recorders on the bottom; a 5/16-inch bean was used. The valve was open for 2 hours and 55 minutes; a very slight blow at surface was exhausted after 30 minutes; the valve was closed for 20 minutes, and bottom-hole pressure was zero. Ninety feet of slightly water-cut (?) drilling mud with a salinity of 350 ppm was recovered.

Test 7, 2,094.5–2,145 feet.—An 8¾-inch packer was set at 2,094.5 feet with 50.5 feet of perforated tailpipe and 2 pressure recorders on the bottom; a 5/16-inch bean was used. The valve was open for 4 hours and 4 minutes; there was a slow steady displacement of air from the drill pipe, by entering bottom-hole water. The valve was closed for 25 minutes; bottom-hole flow pressure built up to 500 psi, and closed-in pressure was 500 psi. The test recovered 950 feet of water with a salinity of 4,290 ppm—salinity of circulated mud was 350 ppm.

Test 8, 2,375–2,411 feet.—A 5¼-inch packer was set at 2,375 feet with 31 feet of tailpipe, including 21 feet of perforated pipe and 2 pressure recorders on the bottom; a 5/16-inch bean was used. The valve was open for 4 hours; air was slowly and steadily displaced from the drill pipe; the valve was closed for 30 minutes. Bottom-hole flow pressure built up to 400 psi; apparent closed-in pressure, 425 psi. The test recovered 1,027 feet of water with a salinity of 1,550 ppm—salinity of circulated mud was 450 ppm. The water had an odor of hydrogen sulfide.

Test 9, 2,447–2,461 feet.—A 5¼-inch packer was set at 2,447 feet with 14 feet of tailpipe, including 4 feet of perforated pipe and 2 pressure recorders on the bottom; a 5/16-inch bean was used. The valve was open 4 hours;

the packer was pulled from its seat while attempting to close equalizing valve. Bottom-hole flow pressure built up to 550 psi. The test recovered 1,304 feet of water with a salinity of 2,723 ppm—salinity of circulated mud was 375 ppm.

Test 10, 2,814–2,830 feet.—A 5¼-inch packer was set at 2,814 feet with 15 feet of tailpipe, including 5 feet of perforated pipe and 2 pressure recorders on the bottom; a 5/16-inch bean was used. The valve was open 4 hours and 6 minutes; entering bottom-hole water steadily displaced air from drill pipe; the valve was closed for 24 minutes. Bottom-hole flow pressure built up to 840 psi; closed-in pressure, 850 psi. The test recovered 1,944 feet of water with a salinity of 3,340 ppm—salinity of circulated mud was 225 ppm.

Test 11, 2,832–2,850 feet.—A 5¼-inch packer was set at 2,832 feet with 18 feet of tailpipe, including 8 feet of perforated pipe and 2 pressure recorders on the bottom; a 5/16-inch bean was used. The valve was open 3 hours and 30 minutes; air was steadily displaced from drill pipe at surface. Bottom-hole flow pressure built up to 1,000 psi. The test recovered 2,285 feet of water with a salinity of 3,300 ppm—salinity of circulated mud was 225 ppm.

WATER ANALYSES

Four analyses of water from Umiat test well 11 were made by the U. S. Bureau of Mines. (See table following.) The water was recovered during formation tests 7, 8, 9, and 11. The fluid from test 6 was composed of a mixture of water and drilling mud and consequently could not be analyzed.

Analyses of water from Umiat test well 11

[L. Cornutte, analyst. Results in parts per million, except as indicated]

	Test 7 [1]	Test 8	Test 9	Test 11
Barium++		Trace	1	Trace.
Calcium++	42	30	8	14.
Magnesium++	5	9	3	4.
Sodium+		2,190	2,030	2,190.
Carbonate—		96	390	126.
Bicarbonate—		2,960	3,120	2,240.
Sulfate—	42	21	28	19.
Chloride—		1,600	865	1,950.
Total solids		6,906	6,434	6,543.
Hydrogen sulfide	None detected.	None detected.	None detected.	None detected.
Specific gravity at 60°F	1.005	1.004	1.003	1.003.

[1] The sample was largely drilling mud and could not be separated for further analysis.

LOGISTICS

Personnel and housing.—The supervisory staff was made up of 1 drilling foreman, 1 petroleum engineer, and 1 geologist. The rig crew consisted of 2 drillers, 2 derrickmen, 5 floormen, 2 firemen, 1 heavy-duty-equipment mechanic, and 1 oiler; 2 cooks and 2 kitchen helpers were also employed.

All temporary workers (carpenters, laborers, welders, warehouseman, radio repairman, electrician, and Schlumberger engineer) were sent from Umiat camp as needed.

Six wanigans housed the boiler, mud tank, shop, Schlumberger equipment, generator, and cement; three were used for utilities, storage, and a geological and engineering laboratory.

Six jamesway huts were also used, 1 each for kitchen and galley and 4 for sleeping quarters.

Vehicles and heavy equipment.—Two weasels and one T–9 small crane (cherry-picker) were used for transportation at the drill site. One each of the following major items of drilling equipment was listed by the Arctic Contractors as having been used.

American Steel Production 64-ft derrick, with 7-ft bottleneck extension.
Cardwell model H drawworks, skid-mounted, complete with cat heads and rotary drive assembly.
Caterpillar D8800 diesel engine for drawworks.
Lee C. Moore crown block, with four 30-in. sheaves, model CSBKAA B–2266, grooved for 1-in. diameter line.
Baash-Ross 100-ton traveling block, unitized with three 30-in. sheaves grooved for 1-in. wire line without link adapter.
Emsco swivel, type AB–4.
Ideal 17½-in. rotary table, type FE.
Gardner-Denver 7¼- by 10-in. circulating pump, type FX.
Caterpillar D13000 diesel engine for circulating pumps.
Mud tank, 60-bbl capacity.
Kewanee 35 hp boiler.
Cementing unit complete with two cementing pumps.
Caterpillar D8800 diesel engine for cement pumps.
Mercury V–8 industrial engine for cement pumps.
Shaffer blowout preventer.

Fuel, water, and lubricant consumption.—Gasoline and diesel fuel consumptions were 1,034 gallons and 35,882 gallons, respectively. Water was pumped from Bearpaw Creek; no record was kept of amounts used. Lubricating compounds used totaled 402 pounds of oil and 180 pounds of grease.

DRILLING OPERATIONS

DRILLING NOTES

The derrick used in drilling Umiat test well 11 was mounted on a sled constructed of heavy drill pipe. Pilings were driven into the permafrost with the aid of a steam point, and the rig was mounted on timbers supported by the pilings. A standard concrete cellar 8 by 8 feet and 4 feet deep was used. Drilling operations were recorded by Everette Skarda, petroleum engineer.

Notes from drill records

Depth (feet)	*Remarks*
112	Ran 89.15 ft of 13⅜-in. outer-diameter J–55 slip-jointed 54.5-lb seamless casing to 110 ft; top 57.7 ft of casing jacketed with 16⅝-in. casing; cemented with 65 sacks of Cal-Seal, using top and bottom plugs and guide shoe. Cemented top of annulus with 15 sacks Cal-Seal.

Notes from drill records—Continued

Depth (feet)	*Remarks*
115	Converted from water-base to 30 percent oil-emulsion mud.
549	Opened 12½-in. hole to 14 in. with Grant under-reamer from 112 to 361 ft. Ran 10¾-in. outer diameter, R-2, N-80 8-round thread 55.5-lb seamless casing to 486 ft and cemented with 192 sacks of High-Early cement.
1,823	Drum on main cathead-drive clutch broke; countershaft removed and sent to shop at Barrow base camp for replacement of clutch, returned, and reinstalled. Rig-down time for this repair was 32 hr.
2,721	Clutch on D13000 Caterpillar engine powering Gardner-Denver circulating pump burned out and was replaced.
3,303	Plugged hole with 24 sacks High Early cement from 440 to 480 ft. A 10¾-in. riser protruding 1.6 ft above ground level was welded on casing collar.

DRILL AND CORE BITS

Thirty-two bits ranging in size from 19 to 9⅝ inches, a 17½-inch Reed hole opener, and a Grant under-reamer were used in drilling Umiat test well 11; they included Hughes OWS, OSC-1, OSC-3, and OSQ-2, Smith DDT, Reed type 2, and a Globe basket. At some depths one bit was used for short alternate intervals of drilling and reaming; to avoid confusion on the graphic log (pl. 12), these bits are shown as having drilled only. The coring was done with 43 Reed K-24 and K-25 core bits, all 6¼ inches in diameter except no. 43, which was 7½ inches in diameter.

DRILLING MUD

A water-base mud was used in spudding and drilling Umiat test well 11 to a depth of 115 feet. At that depth viscosity was 28 Marsh funnel seconds; gel strength, 14 grams at 0 minutes, 25 grams at 10 minutes; water loss, 8.6 cubic centimeters, API. Treatment of this mud with 3 pounds of quebracho, half a pound of caustic soda, a quarter of a pound of Driscose per barrel, and 30 percent by volume of crude oil from Umiat test well 5 topped to 325°F resulted in an oil-emulsion with the following characteristics: Viscosity, 85 Marsh funnel seconds; gel strength, 2 grams at 0 minutes, 10 grams at 10 minutes; and water loss of 2.0 cubic centimeters, API. (See table following.) This type of mud was used in the drilling of the rest of the hole.

Thick sections of bentonite and bentonitic shale were drilled without trouble; there seemed to be very little or no caving. Viscosity was controlled by using quebracho and caustic soda. The long drilling time and slow rate, resulting from attempts to straighten the hole, permitted the maximum amount of bentonite in the formation to hydrate. Oil from the mud did not penetrate cores of permeable sandstone and did not affect the electric logs.

Drilling-mud characteristics and additives, Umiat test well 11

Depth (feet)	Characteristics			Additives							
	Water loss (cc/30 min)	Viscosity (Marsh funnel seconds)	Weight (lb/cu ft)	Umiat crude oil (bbl)	Tetrasodium pyrophosphate (lb)	Sodium bicarbonate (lb)	Quebracho (lb)	Driscose (lb)	Sodium hydroxide (lb)	Baroid (lb)	Sodium acid pyrophosphate (lb)
115				19			300	15	25	5,000	
156	2.0	82	78								
215										2,500	
263 [1]	1.9	62	70	28			400	18	28		
290										10,000	
349	1.8	90	78								
476	1.8	85	78								
549 [2]	2.0	96	78								
549 [3]	3.0	59	75			260	200	25	15		
571	2.7	70	76								
710	2.2	85	75	24						2,500	
740										2,500	
782	2.0	83	78								
803	2.4	86	78								
848	2.0	90	80				50		5		
960	2.0	110	80				25		5		
1,030	2.0	85	81	10					5		
1,145	2.0	109	82.5								
1,200				10			25		15		
1,220	1.7	109	82.5								
1,278	2.0	115	84.5				25		10		
1,311	1.9	130	85								
1,355	1.8	90	85	5			75		10		
1,360	2.0	110	85							500	
1,377	2.0	105	85				50		25	200	
1,400	2.0	91	84						5		
1,430	2.1	100	85				25		5	600	
1,450	2.1	100	85							200	

See footnotes at end of table.

Drilling-mud characteristics and additives, Umiat test well 11—Continued

Depth (feet)	Characteristics			Additives							
	Water loss (cc/30 min)	Viscosity (Marsh funnel seconds)	Weight (lb/cu ft)	Umiat crude oil (bbl)	Tetrasodium pyrophosphate (lb)	Sodium bicarbonate (lb)	Quebracho (lb)	Driscose (lb)	Sodium hydroxide (lb)	Baroid (lb)	Sodium acid pyrophosphate (lb)
1,470	2.4	110	85.5								
1,496	2.5	100	85								
1,505										300	
1,525	2.2	105	85				25		5		
1,561	2.5	130	85.5								
1,650							25				
1,695	2.6	115	86								
1,710							20		5		
1,740	2.0	130	86								
1,810	2.0	135	87.5								
1,830	2.0	91	81	12			150		15		
1,862	2.0	94	82.5							400	
1,900								15			
1,930	2.0	95	82.5								
1,950										200	
1,965	1.9	110	85.5				50		10		
1,975										400	
2,000	2.4	95	86					10			
2,055	2.0	80	81	20			200		32		
2,095	2.0	95	82								
2,100	2.2	94.8	82.5								
2,115										200	
2,140	2.0	100	81							200	
2,145	2.2	85	81								
2,160										200	
2,175	2.0	88	85							600	
2,190										200	
2,202	2.0	82	85							200	
2,220	1.8	80	85							200	
2,252	2.0	85	85							200	
2,260	2.0	85	86							200	
2,271	2.0	85	87								
2,300										200	
2,325	2.4	85	86							200	
2,329		81	89							200	
2,340										200	
2,350	2.5	85	89				25		3		
2,390	2.3	94	90							400	
2,400										200	
2,410	2.0	90	91							200	
2,430	2.5	80	84	15			200		30		
2,455								15		400	
2,480	2.5	85	85								
2,490										200	
2,514	2.2	95	86								
2,535	1.5	95	86								
2,542										200	
2,561	2.6	100	87								
2,602	3.0	105	86							200	
2,682	3.6	146	89				25		5		
2,700							25		5	500	
2,720	2.5	80	78	30	10		350		25		
2,728	2.3	95	81								
2,800	2.0	79	82							200	
2,810										200	
2,830	2.4	115	84							200	
2,840	2.4	115	84		15					400	
2,850	2.1	85	82.5	9			100		6		
2,900	2.4	89	83								
2,940	2.1	95	85							300	
2,960					15						
2,982										400	
2,990	2.2	110	85								
3,010							150		5	200	
3,050	2.2	95	84	14							
3,090											15
3,112	2.3	109	86							400	15
3,150							25				
3,181	2.2	115	87							400	20
3,212											30
3,232										400	
3,240	2.3	110	87.5								
3,270				8			100		5		
3,290	2.2	95	87							200	

[1] Added 700 lb Aquagel. [2] Before reconditioning. [3] After reconditioning.

HOLE-DEVIATION RECORD

The hole had a minimum deviation, according to the Totco Recorder, of 0°15′ at 516 feet, and a maximum deviation of 3°50′ at 2,483 feet. Below 550 feet the hole was commonly 2°–3° from vertical, although attempts to straighten it reduced the deviation somewhat.

ELECTRIC LOGGING

Schlumberger electric logs were run from 107 to 3,285 feet in Umiat test well 11. Spontaneous potential, normal, and lateral curves were made in runs 1, 2, 3, and 4 from 107 to 522 feet, 522 to 1,466 feet, 1,466 to 2,525 feet, and 2,525 to 3,285 feet, respectively. Microlog records were made in runs 1, 2, and 3; run 5, from 2,525 to 3,214 feet, was also a microlog. An anomaly is present between 2,637 and 2,644 feet on the normal and spontaneous potential curves originally recorded at a scale of 50 feet to the inch (shown on pl. 12 at a scale of 100 feet to the inch) but is not present on the log recorded at a scale of 20 feet to the inch (not illustrated). However, a similar anomaly between 2,674 and 2,678 feet is present on both curves at both scales. No pieces of iron were found at that depth in the hole, and the anomalies are unexplained. Most of the beds in this well are too thin to cause distinctive curves on the lateral curve which had an electrode spacing of 24 feet; the microlog indicated that the hole had not caved and did not have any other characteristic of particular interest.

TEMPERATURE MEASUREMENT STUDIES

By Max C. Brewer

This test well is located near the bottom of the valley of Bearpaw Creek, near Umiat, Alaska, in an area of gentle relief (200–300 ft). The drill hole extended many hundreds of feet below the bottom of permafrost, and was plugged near the bottom of the casing (486 ft) before abandonment on August 29, 1952. A 100-foot thermistor cable, installed in the upper air-filled part of the hole on August 30, 1953, was read periodically until it was removed on August 18, 1955. On July 31, 1954, a thermistor cable was lowered to a depth of 337 feet, where it ran into an obstruction, probably frozen drill mud above the plug, and readings were taken the following day. This cable was then removed for use elsewhere in northern Alaska.

The well had been abandoned for 23 months when the temperatures shown in figure 10 were obtained, and the temperatures should have been within a few tenths of a degree centigrade of the final equilibrium temperatures for these depths. The temperature-depth profile does not exhibit the smooth outline characteristic of similar profiles for Umiat test wells 4, 6, and 9. No satisfactory explanation is presently available to account for this irregularity.

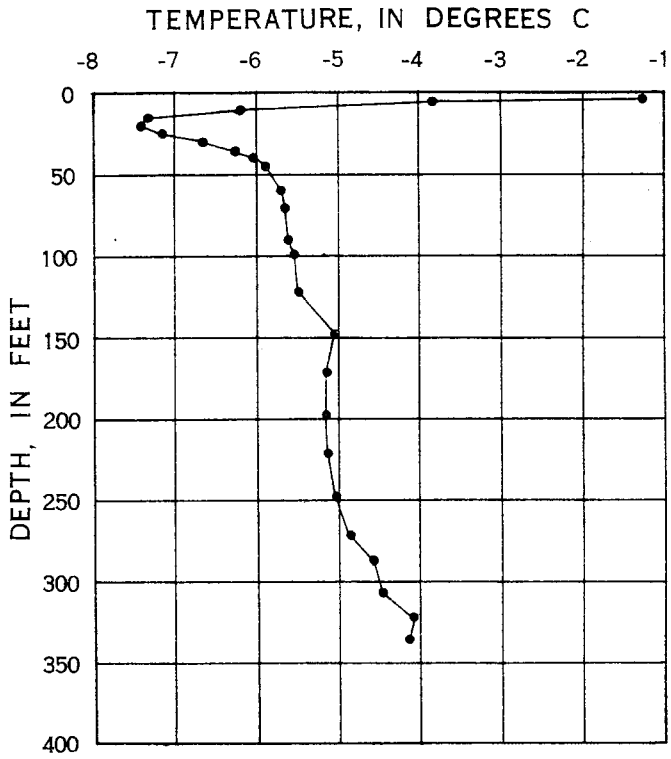

FIGURE 10.—Geothermal profile at Umiat test well 11 on August 1, 1954.

A comparison of the temperature-depth profile for Umiat test well 11 with the profiles for other Umiat wells suggests a depth of permafrost approximately the same as at Umiat test well 6 where 770 feet of permafrost was indicated. The minimum average annual permafrost temperature is within the depth where measurable seasonal temperature fluctuations are evident (0–70 ft); thus, it is difficult to determine accurately the minimum average annual permafrost temperature (about −6°C) in the hole or the depth (possibly 50–60 ft) at which it occurs. Umiat test well 11 is similar in this respect to wells 6 and 9 but differs from Umiat test well 4 and the rest of the wells within Naval Petroleum Reserve No. 4 in which measurements have been made. A detailed study of secular change in different areas may eventually allow an interpretation of this difference.

The effects of air convection in this air-filled hole have been disregarded in considering these data. Some degree of convection is known to be present in the upper part of the hole (to 30 or 40 ft), and it may extend to somewhat greater depths.

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MICROPALEONTOLOGIC STUDY OF THE UMIAT FIELD, NORTHERN ALASKA

By Harlan R. Bergquist

Ditch and core samples from all the test wells of the Umiat field were washed and examined for microfossils in the Fairbanks laboratory of the U. S. Geological Survey. Test wells 1–3 were drilled in 1945–47, and preliminary examination of the microfossils from these wells was made by Mrs. Helen Tappan Loeblich in Washington, D. C. Umiat test wells 4–11 were drilled in 1950–52; the samples were processed in Fairbanks, and the fossils were studied there by me. I later rechecked the entire suite of microfossils from all the wells to analyze their stratigraphic distribution. Many of the species listed here were recently described by Mrs. Loeblich (Tappan, 1951, 1957) and others are identified with species described from western Canada by Canadian paleontologists (Wickenden, 1932, Nauss, 1947, and Stelck and Wall, 1954, 1955).

Sedimentary rocks of both Early and Late Cretaceous age were penetrated in the test wells in the Umiat field. Beds of the Seabee formation (Upper Cretaceous) of the Colville group were penetrated in test wells 1, 6, 7, 8, 10, and 11. A Turonian age for these beds is established by the presence of a small ammonite, *Borissiakoceras* sp. (Gryc, *in* Payne and others, 1951) in the lower shale beds of the formation. The very lowest beds, however, are characterized by a concentration of a few arenaceous species of Colville group Foraminifera, whereas the uppermost part of the formation, the Ayiyak member, has two diagnostic Foraminifera which are restricted to it, *Pseudoclavulina hastata* (Cushman) and *Arenobulimina torula* Tappan.

Beneath the Seabee formation is the Ninuluk formation (of the Nanushuk group), which was penetrated in all the test wells except 2, 3, and 4. The beds of the Ninuluk are identified by an abundance of specimens of *Gaudryina canadensis* Cushman and *Trochammina rutherfordi* Stelck and Wall, two species of Foraminifera which constitute a faunal zone within the formation. The species *T. rutherfordi* was described from beds of Cenomanian age in the lower part of the Kaskapau formation in the Peace River area of western Canada (Stelck and Wall, 1954) and suggest a Cenomanian age for these beds.

A few hundred feet of nonfossiliferous nonmarine sediments, the Killik tongue of the Chandler formation, underlies the Ninuluk formation. Thin tongues of shallow-water marine beds occur within the lower part of this tongue. These carry a few Foraminifera that are part of the fauna of an extensive zone developed below the Killik tongue. This is the *Verneuilinoides borealis* faunal zone, which is several thousand feet thick in the subsurface. In areas of outcrop the *V. borealis* faunal zone includes the Grandstand and Tuktu formations and the upper part of the Torok formation.

The *Verneuilinoides borealis* zone carries a large microfauna of about 60 species of Foraminifera, but is dominated by the species from which it is named. Arenaceous foraminifers predominate in this faunal zone, but a few calcareous species also characterize it. A few of the calcareous Foraminifera are the same as species found in Albian beds in Europe, and some of the arenaceous Foraminifera have been described from Albian beds in western Canada. Associated with the microfossils in many of the samples are worm tubes of the genus *Ditrupa*, which were identified by R. W. Imlay. Imlay (oral communication, Nov. 1956) has also determined that certain of the mollusks found in the outcropping Grandstand and Tuktu formations and the upper part of the Torok formation are of middle Albian age. Inasmuch as the Foraminifera of the *Verneuilinoides borealis* zone indicate the close affinity of these outcropping formations to equivalent subsurface sections, it can be assumed that the latter are also of Albian age.

The *Verneuilinoides borealis* zone is well developed in the Umiat area, and within it diagnostic horizons can be traced from well to well across the anticline. From the top of the zone downward, the species found which identify these horizons are *Ammobaculites fragmentarius* Cushman, *Ditrupa* sp., *Ammobaculites* n. sp., and *Trochammina umiatensis* Tappan. The range of these and other species are discussed on the following pages.

Beds older than the *Verneuilinoides borealis* zone were penetrated in test wells 1 and 2, but the meager fossils give no indication of age. By superposition of strata, however, these beds would be equivalent to the middle and (or) lower part of the Torok formation. Since Imlay's studies (oral communication, Nov. 1956, and Imlay and Reeside, 1954) indicate that the age of the lower part of the Torok is probably early Albian, it follows by analogy that the beds of the Oumalik in the Umiat area must also be of Albian age and are probably early Albian.

UMIAT TEST WELL 1

Seabee formation (9–915 ft).—In the interval from 9 to 350 feet in Umiat test well 1, the only fossils were a few pyritic casts of a radiolarian (*Zonodiscus* sp.) in core samples from 232–265 feet. In several core samples from 292 to 447 feet were *Inoceramus* prisms and shell fragments. Casts of a small ammonite, *Borissiakoceras* sp., occurred in the cored interval from 377 to 417 feet. In cores from 374 to 387 feet 2 species of Radiolaria, *Dictyomitra* cf. *D. multicostata* Zittel and *Spongodiscus* sp., were common, and *Cenosphaera* sp. was abundant. From 477 to 529 feet a few microfossils diagnostic of the Colville group were common to abundant. These are *Trochammina whittingtoni* Tappan, *Gaudryina irenensis* Stelck and Wall, and *Spongodiscus* sp., with a few specimens of *Saccammina* sp., *Trochammina diagonis* (Carsey), *Praebulimina seabeensis* Tappan, and *Zonodiscus* sp. In most of the cores from 574–750 feet, *Saccammina* sp. and *Gaudryina irenensis* occur most commonly, but *Praebulimina seabeensis* and *Gümbelitria albertensis* Stelck and Wall are common in two of the cores. The last mentioned species is also common at 865–870 feet.

Ninuluk formation and Killik tongue of Chandler formation (915–1,309 ft).—This section was barren except for a few charophyte oogonia in ditch samples.

Verneuilinoides borealis *zone (1,300–5,650 ft).*—A shallow-water marine microfossil zone, the *Verneuilinoides borealis* faunal zone, underlies the barren beds. Cores from 1,305–1,335 feet carried an abundance of *Verneuilinoides borealis* Tappan, *Psamminopelta subcircularis* Tappan, *Miliammina awunensis* Tappan, *Gaudryina canadensis* (Cushman), and common specimens of *Trochammina rutherfordi* Stelck and Wall and *Psamminopelta bowsheri* Tappan. Specimens of *T. rutherfordi* were common in a core from 1,383–1,393 feet. *Verneuilinoides borealis* was common, and *Psamminopelta subcircularis*, common to abundant in cores from 1,414–1,434 feet; *Gaudryina canadensis* was abundant in the sample from 1,414–1,424 feet.

In cores from 1,615–1,743 feet, 8 arenaceous species are relatively abundant; namely, *Verneuilinoides borealis*, *Haplophragmoides topagorukensis* Tappan, *Ammobaculites* n. sp., *Textularia topagorukensis* Tappan, *Gaudryina canadensis*, *Miliammina awunensis*, *Psamminopelta subcircularis*, *P. bowsheri*, and *Trochammina umiatensis* Tappan. *T. umiatensis* was found in cores from 1,625–1,651 feet and was repeated again in the core at 2,365–2,370 feet. Abundant specimens of *Corbula?* sp. were in cores from 1,703–1,725 feet. Fragments of calcareous worm tubes (*Ditrupa* sp.) occurred in a few cores.

Haplophragmoides topagorukensis, *Verneuilinoides borealis*, and *Ammobaculites fragmentarius* Cushman were common to abundant in cores from 3,395–3,425 feet. These species were prevalent in ditch samples through the succeeding several hundred feet of section. *Verneuilinoides borealis* is common in cores from 3,507–3,532 feet. Specimens of *Gaudryina nanushukensis* Tappan were present in ditch material from 3,670 feet and were conspicuous in samples in the lower part of the formation. The largest number of species in the Topagoruk formation was found in cored intervals from 4,085–4,114 feet and from 4,176–4,204 feet. Species mentioned above occurred in samples from these intervals as well as *Bathysiphon brosgei* Tappan, *B. vitta* Nauss, and several calcareous species including *Eurycheilostoma robinsonae* Tappan (common in one sample) and a few specimens of each of the following: *Lenticulina macrodisca* (Reuss), *Marginulina gatesi* Tappan, *Saracenaria spinosa* Eichenberg, *Valvulineria loetterlei* (Tappan), *Eponides morani* Tappan, *Pallaimorphina ruckerae* Tappan, and *Globorotalites alaskensis* Tappan. From 4,204 feet to the bottom of the well (6,005 ft), no cores were taken. Common specimens of *Haplophragmoides topagorukensis* and some specimens of a few other species of the *Verneuilinoides borealis* faunal zone occurred in ditch samples throughout this uncored interval. However, it is very likely that most of these Foraminifera were circulated with drilling mud from the upper part of the faunal zone and do not necessarily represent the sample interval.

Oumalik formation (5,650 ft to total depth).—A few pyritic casts of a radiolarian, *Lithocampe?* sp., occurred in samples from 5,790–5,830 feet and are the same as specimens that occur in the type section of the Oumalik formation in Oumalik test well 1. Associated Foraminifera in the ditch samples are drilling contamination from the *Verneuilinoides borealis* faunal zone.

UMIAT TEST WELL 2

Three hundred and fifty-six feet of unfossiliferous beds was penetrated in drilling the upper part of this test well. This includes alluvium and beds of the Killik tongue of the Chandler formation.

Verneuilinoides borealis *faunal zone (365–4,700 ft and 5,100 ft to total depth).*—The top of the *Verneuilinoides borealis* fauna zone is defined by the highest occurrence of fossils. Very abundant specimens of *V. borealis*, common specimens of *Psamminopelta subcircularis*, and relatively rare specimens of *Miliammina awunensis* and *Gaudryina canadensis* were found in a core sample from 365–375 feet. In a somewhat lower core, from 433–439 feet, *Haplophragmoides topagorukensis* and *Ammobaculites fragmentarius* were common. At 465–475 feet these 2 species were very abundant, and *Verneuilinoides borealis* and *Miliammina awunensis* were common. *Ditrupa* sp. occurred in the same core.

Ammobaculites n. sp. and *Haplophragmoides topagorukensis* were common in cores from 640–648 feet and from 680–690 feet. *Trochammina umiatensis*, *Verneuilinoides borealis*, and a few specimens of calcareous species also occurred in the core from 680–690 feet.

The fauna is sparse in the continuously cored interval from 938–1,066 feet. There were a few specimens in the lowest core, and the cores from 979–986 feet and 990–992 feet had an abundance of *Haplophragmoides topagorukensis*, and a few specimens of *Ammobaculites* n. sp., *V. borealis*, and *Lenticulina macrodisca*.

Very few fossils came from the cores in the succeeding 1,000 feet of section, but in the ditch samples were many specimens of *Haplophragmoides topagorukensis* and *Verneuilinoides borealis*. *V. borealis* was common and fragments of tubes of *Ditrupa* sp. were abundant in core 73, from 1,429–1,439 feet. *Haplophragmoides topagorukensis* was abundant in core 75, from 1,850–1,855 feet. Both *V. borealis* and *H. topagorukensis* were common in core 76, from 2,145–2,150 feet. A specimen of an ammonite was found at 2,148 feet; and another, at 2,634 feet. Specimens of *Ammobaculites fragmentarius* were common, and *Haplophragmoides topagorukensis* was abundant in a core sample from 3,000–3,007 feet. The cores between 3,007 and 4,600 feet were either barren or had only a few Foraminifera. An abundance of *H. topagorukensis* and *Ammobaculites fragmentarius?* were found in core 93, from 4,610–4,620 feet, along with common *V. borealis* and a couple specimens of *Gaudryina nanushukensis*.

A lower section of beds appears to be repeated by faulting as 4 of the 7 cores contained Foraminifera of the *Verneuilinoides borealis* faunal zone. In core 98, from 5,585–5,595 feet, and core 100, from 5,883–5,903 feet, small tests of *Haplophragmoides topagorukensis* were abundant, and small tests of *V. borealis* were common. The latter core also contained a few specimens of several other species of the *Verneuilinoides borealis* faunal zone.

Oumalik formation (4,700–5,100 ft).—Two pyritic casts of *Lithocampe?* sp. recovered during the drilling of 400 feet of dark shale beds suggest possible Oumalik beds. The specimens came from samples obtained from depths of 4,840–4,850 feet and 4,960–4,970 feet, respectively. All the Foraminifera in the ditch samples are from the *V. borealis* faunal zone and were undoubtedly introduced into the samples by the drilling process. Foraminifera in the 2 or 3 cores are few and nondiagnostic.

UMIAT TEST WELL 3

No fossils were found in any of the upper beds in this test well. Rocks from the surface to 225 feet probably belong in the nonmarine Killik tongue.

Verneuilinoides borealis *faunal zone (225 ft to total depth)*.—Specimens of *Verneuilinoides borealis* and a few other Foraminifera came from a core sample from 245–249 feet. A core from 320–328 feet contained a few specimens of *Ammobaculites fragmentarius* and common specimens of *Haplophragmoides topagorukensis*. *Gaudryina canadensis* was common in a core from 429–432 feet. *Verneuilinoides borealis* was common to abundant below 463 feet; *Haplophragmoides topagorukensis* was common to abundant below 520 feet. *Ammobaculites* n. sp., was common to abundant in samples from 520 feet and lower. *Trochammina umiatensis* was found scattered in samples from 520 feet to the bottom of the test well. In addition to the fossils cited, specimens of the following were scattered through the samples: *Psamminopelta bowsheri*, *Trochammina* sp., *Lenticulina macrodisca*, *Globorotalites alaskensis* Tappan, and *Gavelinella stictata* (Tappan) (common at 542–547 feet). *Ditrupa* sp. was noted at 410 feet and in a sample from 498–507 feet.

UMIAT TEST WELL 4

No microfossil samples were taken from the first 90 feet of section. Samples from 90–320 feet are nonfossiliferous.

Verneuilinoides borealis *faunal zone (320 ft to total depth)*.—Arenaceous species of the *Verneuilinoides borealis* faunal zone in samples from 325–345 feet indicate the top of the zone. The following were common to abundant: *Verneuilinoides borealis*, *Miliammina awunensis*, *M. ischnia* Tappan, and *Psamminopelta subcircularis*. Samples from 353–415 feet were barren. A few specimens of *Haplophragmoides topagorukensis* and *Ammobaculites fragmentarius* were found in samples from 427–455 feet. *Ditrupa* sp. and *Inoceramus* prisms were in a sample from 427–435 feet. Very few fossils occurred in the samples from the section between 435 and 590 feet. From that depth to the bottom of the hole, a few species of Foraminifera occurred fairly continuously. The most restricted species was *Trochammina umiatensis;* only a few specimens were found in samples from 640–675 feet.

UMIAT TEST WELL 5

A few fish teeth, fishbone fragments and charophyte oogonia were scattered through samples from the upper 335 feet of beds.

The *Verneuilinoides borealis* faunal zone in this well is not marked by any large collection of Foraminifera, and few were found in the interval from 335 to 585 feet. In a sample from 355 feet, *Verneuilinoides borealis* was abundant, and *Miliammina awunensis* was common. *Ammobaculites fragmentarius* was common at 445 feet, where there also were fragments of the tubes of *Ditrupa*

sp. *Miliammina awunensis* was common in a sample from 515–520 feet. The only concentration of the fauna in this test well was from 605 through 730 feet. Within this interval each of the following was common in one or more samples: *Haplophragmoides topagorukensis*, *Verneuilinoides borealis*, *Miliammina awunensis*, and *Trochammina rutherfordi?*. *Inoceramus* prisms and *Ditrupa* tube fragments occurred in most of the samples. *Trochammina umiatensis* was found in samples from 645–690 feet; *Lenticulina macrodisca* and *Gavelinella stictata* occurred in a few samples. Few Foraminifera were found in other samples from 740 feet to total depth, other than common specimens of *Haplophragmoides topagorukensis* at 860–880 feet and at 1,060 and 1,070 feet.

UMIAT TEST WELL 6

Seabee formation (31–220 ft).—A few fossils were found in the Seabee formation; *Inoceramus* prisms and shell fragments were found throughout. One specimen of *Gaudryina irenensis* was found in a sample from 130–140 feet, and a questionable specimen of the same species, in a sample from 200–210 feet. Specimens of *Gümbelitria albertensis* occurred in samples from 180–200 feet. A few Radiolaria (*Cenosphaera* sp., *Spongodiscus* sp., and *Zonodiscus* sp.) were in samples from 200–220 feet.

Ninuluk formation (220–350 ft).—Fossils other than *Inoceramus* prisms occurred in only one sample in this section. These were specimens of *Trochammina rutherfordi* in a sample from 230–240 feet.

Killik tongue of the Chandler formation (350–630 ft).—No fossils occurred within the 280-foot section of the Killik tongue.

Verneuilinoides borealis *faunal zone (630 ft to total depth)*.—Very few fossils were found in the 200 feet of section in the *Verneuilinoides borealis* faunal zone. Specimens were erratic, and the largest number were in samples from 640 and 650 feet. In these samples *V. borealis* was abundant, and *Miliammina awunensis* and *Psamminopelta subcircularis* were common. A few specimens of *Ammobaculites fragmentarius* were found in samples from 730 and 740 feet. A fragment of a worm tube (*Ditrupa* sp.) came from a sample at 740 feet.

UMIAT TEST WELL 7

Seabee formation (50–390 ft).—In the lower part of the section, in a sample from 330–340 feet, there were a few specimens of *Gümbelitria albertensis*. Two widely separated specimens of *Saccammina* sp. were the only other Foraminifera. *Inoceramus* shell material was found in samples throughout the section.

Ninuluk formation and Killik tongue of the Chandler formation (390–795 ft).—These units are unfossiliferous in this well.

Verneuilinoides borealis *faunal zone (795 ft to total depth)*.—Although the *Verneuilinoides borealis* faunal zone was penetrated at 805 feet only *Psamminopelta subcircularis* was common. The only relative abundance of species and specimens was in the interval from 1,080 through 1,180 feet. Throughout most of the samples from this interval, *Haplophragmoides topagorukensis* was common to abundant. *Verneuilinoides borelis* was abundant at 1,160 feet, and *Ammobaculites* n. sp. was common from 1,080 to 1,160 feet. *Trochammina umiatensis* was found in samples from 1,100–1,160 feet. *Lenticulina macrodisca* and *Gavelinella stictata* occurred rarely from 1,057 to 1,160 feet.

UMIAT TEST WELL 8

The upper few hundred feet in this well is almost nonfossiliferous. Most of the ditch samples down to the first core (195–200 ft) are barren, except for *Inoceramus* prisms in samples from 20–40 feet and a specimen of *Glomospira* sp. in a sample from 65–69 feet. In the first core sample (195–200 ft) were found 2 or 3 specimens of *Trochammina ribstonensis* Wickenden?, 1 specimen of *Verneuilinoides fischeri Tappan* a few specimens of *Saccammina?* sp. and a few plant spores. In a sample from 215–220 feet were charophyte oogonia, fish teeth, and *Inoceramus* prisms; and in other ditch samples from 220–400 feet were a few fish teeth and fishbone fragments. In a sample from the second core (400–405 ft), specimens of *Gümbelitria albertensis* were common, and associated with them were 3 specimens of *Saccammina* sp. and a flood of *Inoceramus* prisms. In a ditch sample from 430–435 feet, 3 specimens of *Zonodiscus* sp. were found, and *Inoceramus* prisms were noted.

As the paleontological data are so meager, the age or identity of the section above the second core is problematical. Species of Foraminifera found in the first core occur elsewhere only in the Colville group, but specimens may possibly have been the result of contamination, as the only fossil found in a check sample was a specimen of *Saccammina?* sp. The *Inoceramus* prisms in the sample from 20–40 feet indicate marine beds, but the unfossiliferous beds could be either marine or nonmarine. However, beds of the Seabee formation definitely are represented by the second core (400–405 ft) and may extend from 350 to 445 feet. F. R. Collins and C. L. Whittington (oral communication, 1956) suggest that a fault, somewhere between 300 and 350 feet, has thrust beds of the Ninuluk formation and the Killik tongue over beds of the Seabee formation. Possibly this is so.

An undifferentiated 395-foot section from 445 feet to the top of the *Verneuilinoides borealis* faunal zone

at 840 feet is essentially nonfossiliferous. A fishbone fragment and 1 specimen of *Zonodiscus* sp. were all that came from a core from 640–645 feet; 3 specimens of *V. borealis* were in core sample 7 from 711–716 feet.

Verneuilinoides borealis *faunal zone (711 ft to total depth)*.—An abundance of five species, *Verneuilinoides borealis*, *Gaudryina canadensis*, *Miliammina awunensis*, *Psamminopelta bowsheri*, and *Psamminopelta subcircularis* occurred in samples from 845–855 feet. Microfossils were found in most of the core and ditch samples from the 480 feet of beds of the Grandstand formation penetrated in drilling this test well. *V. borealis* was common to abundant in many of the samples. *Haplophragmoides topagorukensis* was very abundant in a sample from 940–945 feet and in samples from 1,155–1,195 feet. Specimens of *Ammobaculites fragmentarius* were abundant in 1 sample (940–945 ft) and rare in 2 others. *Ammobaculites* n. sp. was abundant from 1,155 through 1,195 feet. *Trochammina umiatensis* specimens were first found in the core from 1,130–1,133 feet and were abundant in the core from 1,183–1,188 feet. A few other species of Foraminifera are sparingly scattered through the samples. *Ditrupa* tube fragments were found at 940–950 feet and 1,183–1,188 feet.

UMIAT TEST WELL 9

Ninuluk formation and Killik tongue of the Chandler formation (0–425 ft).—Two specimens of *Trochammina* sp. and two of *Gaudryina canadensis?* were the only fossils found in these beds.

Verneuilinoides borealis *faunal zone (425 ft to total depth)*.—An abundance of specimens of Foraminifera from the *Verneuilinoides borealis* faunal zone were found at intervals throughout the section below 425 feet in drilling this well. The fauna consists of about 15 species, with *V. borealis* and *Haplophragmoides topagorukensis* occurring most frequently. *V. borealis* leads in frequency and abundance, being found in 35 samples; it was common in 13 samples and abundant to very abundant in 2 samples. *H. topagorukensis* was common in 9 samples; *Ammobaculites* n. sp. was common in 5; and *Miliammina awunensis*, common in 4 samples. Five other species, *Ammobaculites fragmentarius*, *Gaudryina canadensis*, *Trochammina umiatensis*, *Miliammina manitobensis* Wickenden, and *Psamminopelta subcircularis*, were each common in 1 or 2 samples. *Miliammina awunensis* and *Gaudryina canadensis* each were abundant to very abundant in 1 or more samples. A few other species were relatively rare. First occurrences of diagnostic species were as follows: *Ammobaculites fragmentarius* in core 17, from 514–525 feet, *Ammobaculites* n. sp. in core 27, from 649–659 feet, *Trochammina umiatensis* in core 30, from 679–689 feet. *T. umiatensis* occurred again in the lower part of the test well in samples from 1,187–1,218 feet and suggests a repetition of fossiliferous beds of the upper part of the faunal zone.

Shells of *Corbula?* sp. were abundant at 435 feet and in core 36, from 838–845 feet. *Ditrupa* tubes were in core 18, from 525–533 feet and in core 28 from 659–669 feet.

UMIAT TEST WELL 10

Ninuluk formation (70–210 ft).—Fossils occurred only in the lowest samples. These were tests and pyritized specimens of *Trochammina rutherfordi*. The few fossils recovered, indigenous to the Nanushuk group overlying the younger Colville group, show the presence of a thrust fault at 210 feet.

Seabee formation (210–645 ft).—Fossils were rare. *Inoceramus* prisms occurred in samples from 240–370 feet, and a few specimens of *Gümbelitria albertensis*, in samples from 240–270 feet. *Gaudryina irenensis* and *Trochammina ribstonensis* Wickenden occurred sparingly in samples from 360–370 feet. Low in the formation was a similar zone with *Inoceramus* prisms in every sample from 515–630 feet, *Gümbelitria albertensis* from 535–605 feet, and *Gaudryina irenensis?* in one sample (595–605 ft.)

Ninuluk formation (645–765 ft).—The section was unfossiliferous except for the basal core (745–750 ft). In that core *Gaudryina canadensis* and *Miliammina awunensis* were common, and *Trochammina rutherfordi* was very abundant, with few other species of Foraminifera.

Killik tongue, Chandler formation (765–1,025 ft).—All samples were unfossiliferous.

Verneuilinoides borealis *faunal zone (1,025 ft to total depth)*.—The top of the *Verneuilinoides borealis* faunal zone was found in ditch samples from 1,035–1,050 feet where *V. borealis*, *Miliammina awunensis*, and *Gaudryina canadensis* all were common. Succeeding samples for 100 feet were unfossiliferous. Beginning with a sample from 1,145–1,150 feet, the fauna occurred quite consistently to the bottom of the hole, but the lowest core (1,540–1,542 ft) was barren. At the top of the fossiliferous zone *Haplophragmoides topagorukensis* and *Ammobaculites fragmentarius* were common. Samples from 1,370–1,570 feet contained *H. topagorukensis*, *V. borealis*, and *Ammobaculites* n. sp. in abundance. The highest occurrence of *Ammobaculites* n. sp. was at 1,310–1,322 feet. Specimens of *Trochammina umiatensis* were found in several samples with the highest occurrence at 1,350–1,360 feet. *Ditrupa* tube fragments were found at 1,145–1,150 feet and in lower ditch samples. A few specimens of *Lenticulina macrodisca* and *Gavelinella stictata* were in samples from 1,370–1,530 feet.

UMIAT TEST WELL 11

Tuluvak tongue of the Prince Creek formation (22–545 ft).—The section contained only a few specimens of *Trochammina ribstonensis* in a sample from 70–80 feet and specimens of the same species with *Verneuilinoides fischeri* and *Gaudryina irenensis* in a sample from 420–430 feet.

Seabee formation (545–2,040 ft).—Most of the fossils occurred in the upper 200 feet of the section and from 1,670–1,690 feet *Haplophragmoides rota* Nauss was the most common. In one or more samples from the upper 200 feet of section, specimens of *Trochammina ribstonensis, T. whittingtoni,* and *Arenobulimina torula* were common. Fragments of *Pseudoclavulina hastata* were associated with these species. As this fauna appears to characterize the upper part of the Seabee formation at several surface and subsurface localities, I have designated it the *Pseudoclavulina-Arenobulimina* faunal zone.

Prints of *Borissiakoceras* sp., a small Turonian ammonite, were in cores from 1,230–1,235 feet and from 1,427 feet. *Inoceramus* prisms and shell fragments were in several core and ditch samples throughout the section; a few Radiolaria occurred in ditch samples from 1,565–1,595 feet. A sample from a core from 1,670–1,690 feet had abundant specimens of *Haplophragmoides rota, Gaudryina irenensis,* and *Trochammina whittingtoni;* specimens of *Saccammina* sp., *Praebulimina seabeensis,* and pyritic casts of *Zonodiscus* sp. were common in the same core.

Ninuluk formation and *Killik tongue of the Chandler formation (2,040–2,420 feet).*—Most of the section was nonfossiliferous, but in samples from 2,135–2,163 feet *Trochammina rutherfordi* was abundant; and in samples from 2,173–2,192 feet and 2,325–2,335 feet specimens of *Saccammina* sp. were common.

Verneuilinoides borealis *faunal zone (2,420–3,075 ft.)*—Five species of Foraminifera from the *Verneuilinoides borealis* faunal zone were in a ditch sample from 2,426–2,435 feet. *V. borealis, Psamminopelta subcircularis,* and *Miliammina awunensis* were common in the sample. In a core from 2,529–2,545 feet, *M. awunensis* was common, as were specimens of *Psamminopelta subcircularis.* Fragments of tubes of *Ditrupa* sp. were in a sample from 2,655–2,665 feet. From 2,695 to 2,800 feet *Verneuilinoides borealis, Haplophragmoides topagorukensis,* and *Ammobaculites* n. sp. were common. Specimens of *Trochammina umiatensis* were in a sample from 2,730–2,740 feet and were common in samples from 2,750–2,760 feet and one from 2,790–2,800 feet. Six or seven species of calcareous Foraminifera were in samples from the same general interval. Of these *Lenticulina macrodisca* and *Gavelinella stictata* were the most common. *Gaudryina canadensis* and *Miliammina awunensis* were both very abundant in a core from 2,820–2,830 feet.

The bottom core (3,290–3,303 ft) contained a fairly large fauna of 14 species common to the *Verneuilinoides borealis* faunal zone. Most conspicuous of these are *Bathysiphon brosgei, Haplophragmoides topagorukensis, V. borealis, Psamminopelta subcircularis, Miliammina manitobensis,* and *Gavelinella stictata.*

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