Core Tests and Test Wells Barrow Area, Alaska

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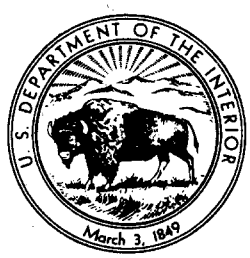
PART 5, SUBSURFACE GEOLOGY AND ENGINEERING DATA

GEOLOGICAL SURVEY PROFESSIONAL PAPER 305-K

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



Core Tests and Test Wells Barrow Area, Alaska

By FLORENCE RUCKER COLLINS

With a section on Temperature Measurement Studies
By MAX C. BREWER

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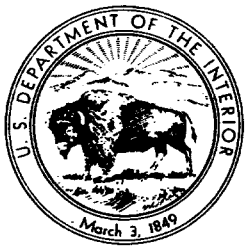

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EXPLORATION OF NAVAL PETROLEUM RESERVE NO. 4 AND ADJACENT AREAS, NORTHERN ALASKA, 1944–53

CORE TESTS AND TEST WELLS, BARROW AREA, ALASKA

By Florence Rucker Collins

ABSTRACT

Between 1944 and 1953 exploration of Naval Petroleum Reserve No. 4, northern Alaska, by the U.S. Navy, resulted in the drilling of 10 test holes in the vicinity of Point Barrow. Five were relatively shallow core tests, drilled for stratigraphic information; five were test wells 2,505 to 4,020 feet deep, two of which produced a flow of gas sufficient to heat the Navy's base camp near Point Barrow. The rocks penetrated by one or more of the holes include sand, gravel, and silt of the Gubik formation of Pleistocene age, Cretaceous shale with a little interbedded sandstone in the upper part, Jurassic siltstone, sandstone, and shale, Triassic limonitic oolites, limestone and siltstone, and pre-Mesozoic argillite, siliceous dolomite, and chert. The gas came primarily from the Jurassic beds, although some may have been held in fractures in the argillite. The area is structurally complex, with steep dips not only in the pre-Mesozoic but in the Mesozoic beds as well, in the easternmost test; the pre-Mesozoic rocks are about 4,000 feet nearer the surface in the Barrow area than anywhere else in the coastal plain.

INTRODUCTION

Between 1944 and 1953 the U.S. 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 U.S. Geological Survey, as a cooperating agency, studied the geology of the area; Arctic Contractors, under contract to the Navy, drilled test wells and core tests in many localities throughout the Reserve, including several near Point Barrow. The history of this exploration program is presented in a report by John C. Reed (1958), which contains photographs of several of the test wells in the Barrow area.

Point Barrow is on the northern shore of Alaska, on the Arctic coastal plain, which is characterized by swampy, lake-dotted tundra and meandering streams, and is bounded by the Arctic Ocean. (See fig. 49.) The ground is permanently frozen to a depth greater than 600 feet, except for a few inches at the surface which thaw in summer. Low wave-cut banks and cliffs which rise gradually from a height of a few feet near Point Barrow to about 50 feet near Skull Cliff core test 1, 40 miles to the southwest, expose the only outcrops of consolidated rock in the area. These strata of Cretaceous age underlie unconsolidated Pleistocene sand, gravel, and silt. The stratigraphy and structure of the region have consequently been studied primarily by means of seismic and gravity surveys and the 10 test holes drilled in the area.

In 1944, Construction Battalion Detachment 1058 of the U.S. Navy established a camp on the gravel beach between Point Barrow and the village of Barrow, 10 miles to the southwest. Heavy equipment and nonperishable supplies were brought to the base by U.S. Navy ships, and an airstrip suitable for multiengined aircraft was built near the northern end of the camp to facilitate transportation of personnel and perishable goods. In September and October of the same year, the Battalion drilled three shallow holes in and near the camp (see fig. 50) to test the drilling equipment and to become familiar with drilling operations in the Arctic.

Attention was first drawn to the unusually high structural position of the rocks in the vicinity of Barrow by a gravity survey, made by the United Geophysical Co., Inc., in 1946, which showed a small area south of the camp to have the highest observed gravity on the coastal plain. A year later, Arctic Contractors drilled a core test at Skull Cliff; this drilling was followed by a 1,442-foot core test near the earlier Construction Battalion holes.

In 1948, seismic refraction profiles shot in the Barrow area and in the vicinity of Simpson test well 1, 35 miles to the southeast (see fig. 49), demonstrated that high-velocity strata at a depth of 6,700 feet in the Simpson test apparently rise to 2,400 feet just south of Point Barrow, corroborating the presence of a structural high south of the latter. The first of five test wells drilled was the South Barrow test well 1, drilled in the fall of 1948 to a depth of 3,553 feet; it was followed by South Barrow test well 2, drilled in the winter of 1948–49. South Barrow 1 was a dry hole, but South Barrow 2, drilled to 2,505 feet discovered the South Barrow gasfield and produced enough gas to replace diesel fuel as a source of heat for Barrow camp. South Barrow test well 3, a few miles south of test well 2

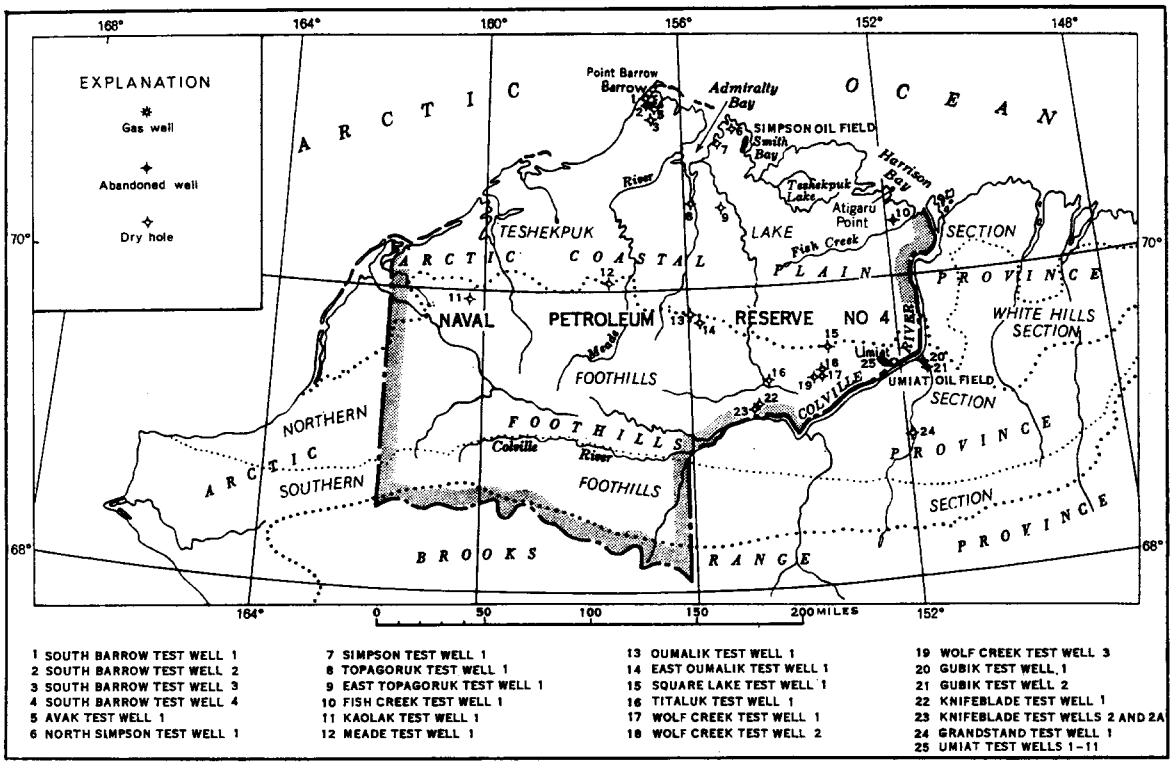

FIGURE 49.—Index map of northern Alaska, showing location of test wells and oil fields.

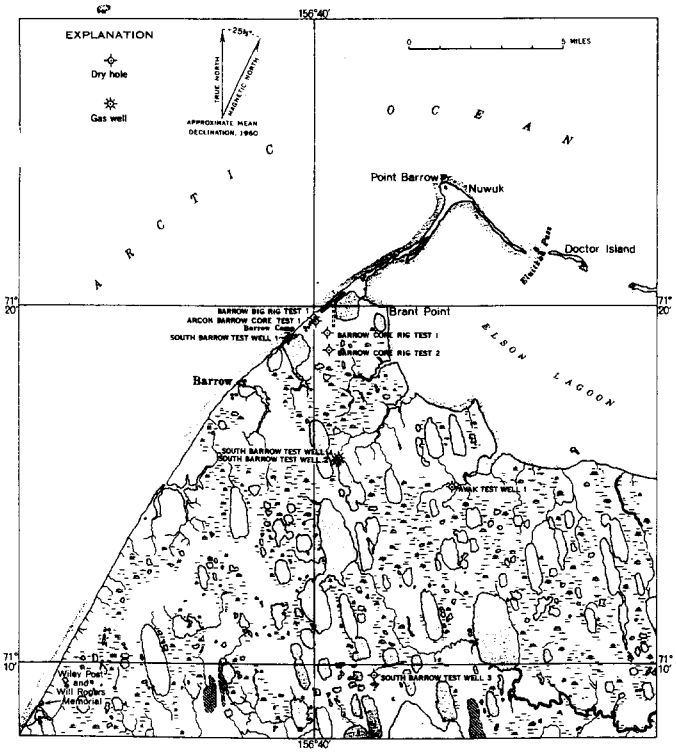

FIGURE 50.—Index map of core tests and test wells drilled in the vicinity of Point Barrow, Alaska.

(see fig. 50), was drilled in 1949, and a second gas well, South Barrow test well 4, was put down as a standby hole close to South Barrow test well 2, in 1950, in order to assure a reliable gas supply for the camp. The last hole drilled by Arctic Contractors in the Barrow area was Avak test well 1, drilled on the north side of an area which gave no seismic reflections; the test revealed steeply dipping beds. South Barrow test well 5, located between test wells 2 and 4, was drilled by the U.S. Air Force in 1955 (after the U.S. Navy had suspended its program in the Reserve) to replace South Barrow 2 which was destroyed by fire in April 1950. All the wells penetrated Pleistocene and Cretaceous beds, and the deeper holes were drilled into Jurassit and pre-Mesozoic rocks. However, South Barrow tesc well 3, drilled to 2,900 feet, was the only test to penetrate beds of Triassic age. The paragraphs on stratigraphy describe a composite section based on all the tests; no one hole penetrated a complete sequence.

This report includes detailed geologic and engineering data obtained by drilling the 10 holes, much of which is shown graphically. Technical data used herein were recorded by Arctic Contractors, the U.S. Geological Survey, as well as United Geophysical Co., Inc., which made geophysical surveys, and the Schlumberger Well Surveying Corp., which made electric logs. Cretaceous and Jurassic megafossils recovered from the test wells were studied by Ralph W. Imlay and Arthur L. Bow-

sher, and Triassic megafossils by Bernhard Kummel, all of the Geological Survey; microfossils were studied by Harlan R. Bergquist, also of the Survey. The heavy-mineral data given in this report is part of a regional study on the heavy-mineral zones by Robert H. Morris of the U.S. Geological Survey, and petrographic studies were made by Charles Milton, S. T. Yuster, and P. D. Krynine. The help of many other engineers, geophysicists, and geologists connected with the above organizations is gratefully acknowledged.

The location of the holes (fig. 50) has been determined with respect to latitude and longitude as shown on the Barrow, Alaska map, 1:250,000 scale, of the U.S. Geological Survey Alaska Reconnaissance Topographic Series, printed in 1949. Depths in the holes were measured from the kelly bushing of the drilling rig.

Cores from Barrow Big Rig test 1, and both cores and ditch samples from the later tests, were described dry, and color was determined by comparison with the Rock Color Chart (Goddard, 1948). The use of the term "argillite" in this paper follows the definition given by F. J. Pettijohn (1949, p. 269). Effective porosity of samples from holes drilled before 1949 was determined by the Washburn-Bunting method, and from later wells by the Barnes method. Permeability of earlier samples was measured with a Hayward permeameter, and of later ones with a permeameter built to specifications listed in the American Petroleum Institute Code No. 27, second edition, April 1942. Oil shows in cores from the test wells were studied in the Fairbanks laboratory by grinding a small piece of rock and shaking the sediment in a bottle of carbon tetrachloride. The color of the filtrate against a white porcelain background determined the cut; the term residue applies to the filtrate after evaporation of the carbon tetrachloride.

STRATIGRAPHY

QUATERNARY SEDIMENTS

GUBIK FORMATION

The Gubik formation, of Pleistocene age, is the youngest sediment identified in test wells drilled in the Barrow area. It consists of gravel, sand, and silty clay cemented by interstitial ice and containing masses of clear ice typical of frozen ground. The thickness of the formation ranges from 40 to 120 feet, varying with irregularities both on the surface and in the underlying rocks on which it rests. The gravel is made up primarily of black, gray, or yellow well-rounded chert granules and pebbles as much as one-half of an inch in diameter. Sand grains are also very well rounded, and most are polished. The light-yellowish-gray coarse- to fine-grained sand consists of clear, yellow, and orange quartz, and some dark chert. The clay is medium gray or olive gray, and makes up a comparatively small part of the sediment. The formation is typified by calcareous Foraminifera, ostracodes, and pelecypod fragments and was deposited in a marine environment.

CRETACEOUS ROCKS

GRANDSTAND FORMATION

The uppermost consolidated rocks penetrated are sandstone and shale of the marine Grandstand formation of the Nanushuk group of early Cretaceous age. The formation underlies the Gubik formation in Arcon Barrow core test 1, South Barrow test well 1, and Skull Cliff test well 1, where it is 310, 320, and 400 feet thick, respectively; it is missing in the other Barrow area tests, where the Gubik formation rests on older rocks. In the first two holes, the Grandstand formation is dominantly sandstone, with some interbedded clay shale and siltstone; but in Skull Cliff test well 1, clay shale makes up most of the rock. In each hole, however, the base of the formation is at the base of the lowest massive sandstone bed.

The sandstone is medium light gray, very fine grained, slightly argillaceous, and only rarely slightly calcareous. It is commonly friable and massive. The sand grains are subangular and are clear or white quartz with some chert and other rock particles, carbonaceous material, mica, and pyrite. The clay shale is medium light gray to medium gray, and some is silty or calcareous; it commonly has good shaly cleavage. Pelecypod shell fragments (particularly from *Inoceramus*), worm tubes (*Ditrupa* sp.) and Foraminifera of the *Verneuilinoides borealis* faunal zone are present, particularly in the shaly beds.

TOPAGORUK FORMATION

The Topagoruk formation of Early Cretaceous age is a marine clay shale sequence underlying the Grandstand formation, with which it shares the *Verneulinoides borealis* microfauna. The distinction between the two formations is based on grain size; the upper unit contains sandstone, and the lower one is dominated by clay shale. The clay shale of the Topagoruk formation is commonly slightly darker than that in the Grandstand formation, but otherwise is very similar. The few thin beds of sandstone and sandy siltstone it contains are likewise similar in composition and texture to those of the overlying formation. The thickness of the Topagoruk formation varies as a result of beveling of its upper surface; its maximum thickness in the area, nearly 1,800 feet, is disclosed in South Barrow test well 1. The lower part of the formation in the same test well has thin beds of sandstone interbedded with the clay shale; the base of the formation is placed at the bottom of this sandy sequence. In the other holes,

however, the sandstone beds are much less numerous, and the lower beds are apparently represented by clay shale.

OUMALIK FORMATION

The Oumalik formation of Early Cretaceous age is also composed of medium-dark-gray clay shale, and because of its lithologic similarity to the overlying Topagoruk formation, the contact between the two units is difficult to locate precisely. The Oumalik formation lacks the *Verneuilinoides borealis* microfauna; however, it does contain, particularly in the lower part of the section, pyritic casts of the radiolarian *Lithocampe* sp., which distinguish it from the younger strata. In the Barrow area the dips recorded for the Oumalik formation differ sharply from those of the overlying Topagoruk formation; in South Barrow test well 1, for instance, the Oumalik formation dips 10°–30°, but the Topagoruk formation is nearly flat; in South Barrow test well 2, on the other hand, the younger formation dips 10°–25°, toward the base, and the Oumalik formation dips less than 4°. The change in relative dip from well to well is probably the result of differential folding in the area, but between formations the difference in dips may represent an unconformity. The Oumalik formation is much thinner in the Barrow area than elsewhere in Naval Petroleum Reserve No. 4. Nearly 700 feet of it is present in South Barrow test well 1, but in the other South Barrow test wells, which were drilled at higher points structurally, the Oumalik formation is only about 200 feet thick, and in Avak test well 1 it is missing entirely.

LOWER CRETACEOUS

A very uniform lithologic unit that consists of about 400 feet of hard black clay shale is found in all four South Barrow test wells. Scattered through it are very well rounded polished or pitted clear quartz grains of granule to fine-sand size, with a few well-rounded black chert granules and pebbles. The grains are present singly or in small groups at random through the rock which generally has poor shaly cleavage. A foraminiferal assemblage and a few pelecypod shells demonstrate the marine origin and Early Cretaceous age of this distinctive lithologic unit, informally referred to as pebble shale, in the Barrow area. Abundant grains of pyrite suggest the possibility of anaerobic conditions of deposition. At the base of the unit an increase in the size and quantity of rounded chert pebbles results in a basal conglomerate nearly 20 feet thick.

In Avak test well 1, the youngest consolidated rock found was the pebble shale; in that hole it is interbedded, or perhaps interfaulted, with gray very argillaceous sandstone; erratic dips make its thickness and stratigraphic position difficult to determine.

JURASSIC ROCKS

In South Barrow test well 3, light-olive-gray very argillaceous siltstone and sandstone, mottled with streaks of clay shale and interbedded with olive-gray to medium-dark-gray pyritic clay shale, contain ammonites which are diagnostic of the lower Toarcian and upper Pliensbachian subdivisions of the Lower Jurassic (Imlay, 1955, p. 73). These beds are underlain by gray to reddish-brown claystone with interbedded olive-gray bentonite. The Jurassic is represented in South Barrow test wells 2 and 4 by about 120 feet of light-olive-gray siltstone and sandstone. A Middle Jurassic (Bajocian) ammonite, *Tmetoceras* sp. (Imlay, 1955, p. 82), was found in South Barrow test well 2; its presence indicates that these beds are not correlative with the fossil-bearing beds in South Barrow test well 3, although they may be the equivalent of strata immediately below the pebble shale which are unfossiliferous.

In Avak test well 1, about 950 feet of interbedded medium-dark-gray clay shale and greenish-gray silty sandstone is present below the pebble shale and above pre-Mesozoic argillite. A Sinemurian (Lower Jurassic) ammonite, *"Arietites"* cf. *"A." bucklandi* (Sowerby) (Imlay, 1955, p. 73), is older than the diagnostic ammonites of South Barrow test well 3, but because it came from the lower part of the section and those from South Barrow test well 3 came from the upper part, the entire sequence may be represented in both holes.

In South Barrow test well 1, the pebble shale apparently rests directly on argillite. A few fragments of rock similar to the Jurassic sandstone were recovered in cores near the base of the pebble shale, but recovery was very poor, the cores consisting of a few rock fragments in a large amount of drilling mud, and the presence of chert pebbles and argillite fragments suggests that the various rock types were part of a basal conglomerate.

The Jurassic sandstone produced enough gas from South Barrow test wells 2 and 4 to heat the base camp nearby; South Barrow test well 5 also produced gas sufficient to supply the base.

TRIASSIC ROCKS

The Lower Jurassic rocks in all the test wells except South Barrow test well 3 rest unconformably on pre-Mesozoic argillite, but in the latter hole, a 189-foot section of Triassic beds intervenes. Lithologically, these rocks are quite different from Triassic rocks found elsewhere in the Reserve, but fossils identified by Bernard Kummel as specimens of the diagnostic Upper Triassic (Norian) pecten *Monotis subcircularis* (Gabb) are common. The sequence consists of alternating silty limestone and calcareous siltstone, both light

olive gray, with abundant pellets of glauconite. Oolite beds composed of limonite ooids, commonly with a hematitic coating and calcareous cement, are interbedded with the limestone. Shell fragments are present in both rock types, and the base of the unit is marked by a thin bed of shell fragments in a matrix of clay and calcite.

PRE-MESOZOIC ROCKS

Steeply dipping bluish-gray to black argillite underlies the Mesozoic beds in the Barrow area. The rock is hard and siliceous, with conchoidal fracture to splintery cleavage. The silica content is greatest in the lighter colored rock; the black beds are somewhat carbonaceous. Calcite or quartz veinlets are rare to common. Pyrite is common, and at a depth of 2,865 feet in South Barrow test well 3 it is present in the form of minute spines that may be of organic origin. In South Barrow test well 1, at 3,495 feet, a light-gray porous siliceous rock may be radiolarian chert. In Avak test well 1, which penetrated the longest section of argillite, siliceous dolomite and dolomitic chert are interbedded with the black carbonaceous siliceous argillite.

CONSTRUCTION BATTALION TEST HOLES

In 1944, Construction Battalion Detachment 1058 of the U.S. Navy drilled three shallow core holes near Barrow camp, between Point Barrow and the Eskimo village of Barrow. Barrow Big Rig test 1 and Barrow Core Rig test 1 were planned to test the equipment and to familiarize drilling crews with drilling operations in the Arctic; Barrow Core Rig test 2 was drilled for structural information.

Lithologic and engineering information from the core rig tests was recorded by Lieutenant Hagestad of the U.S. Navy during the drilling. (See pl. 39.) The tests were drilled with a Sprague and Henwood drilling machine, using 2¾-inch fishtail bits; cores were taken with a Sprague and Henwood 2⅜-inch core barrel in Barrow Core Rig test 1, and a 2⅜-inch barrel in Barrow Core Rig test 2. Both holes penetrated unconsolidated sediments of the marine Gubik formation of Pleistocene age, and probably penetrated some of the underlying Cretaceous rocks as well, but paleontologic data are lacking, and the lithologic description is too generalized to permit exact boundaries to be drawn.

Barrow Big Rig test 1 was drilled with a National 50 rig, using Hughes Tricone bits, and conventional core barrel. The rock penetrated was described by the driller; additional study of the cores was made in the Fairbanks laboratory of the U.S. Geological Survey. (See pl. 39.)

In Barrow Core Rig test 1, the Pleistocene-Cretaceous boundary is tentatively placed at 85 feet, just above the first bentonitic beds and consolidated rock; in Core Rig test 2, it is put even more doubtfully at 100 feet, just above the occurrence of sticky shale that may represent bentonitic beds.

The Big Rig test was 685 feet deep, and was drilled in Cretaceous sandstone and shale for most of its depth. The thickness of the overlying Gubik formation is probably about 100 feet, but cannot be determined exactly. Foraminifera characteristic of the Gubik formation were recovered from a washed sample of core 1, at 100 to 120 feet, but the sample also contains subangular white and clear quartz silt, like that found in Cretaceous rocks, which is quite different from the well-rounded clear yellow and black grains of the Gubik formation. Consequently the age of the clay (and hence the top of the Cretaceous beds) is uncertain: It may be Cretaceous, and the Foraminifera contamination from above, or it may be part of the Gubik formation, and the silt atypical.

BARROW CORE RIG TEST 1

Location: Lat 71°19′25″ N., long 156°39′02″ W.
Elevation: Ground, 10.4 feet; top of surface pipe, 13 feet.
Spudded: September 17, 1944.
Completed: October 7, 1944. Dry and abandoned.
Total depth: 344 feet.

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

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

Core	Depth (feet)	Remarks
------	0–2. 6	Top of pipe to ground.
------	2. 6–7	Tundra and frozen clay.
------	7–12	Ice streaks and frozen clay.
------	12–30	Sand and ice.
------	30–45	Shale.
------	45–53	Shale and hard sand.
------	53–76	Mud and sand, soft and sticky.
1	76–81	Recovered 2 ft: Clay-silt, soft when the core was first taken out of the barrel, later setting to firm silt.
2	81–83	No recovery.
------	83–84	Mud, soft and sticky.
3	84–92	Recovered 1 ft: Clay-silt, gray, slightly bentonitic.
4	92–96	No recovery.
5	96–106	Recovered 1.4 ft: Clay-silt, dark-gray, soft, slightly bentonitic, with a few small white inclusions.
------	106–162	Shale, sandy, soft.
------	162–163	Shale, sandy, hard.
------	163–164	Clay and shale.
6	164–166	No recovery.
------	166–168	Clay and shale.
------	168–169	Limestone, hard.
7	169–171	Recovered 0.9 ft: 0.1 ft, Clay-silt, gray, medium-hard. 0.8 ft, Limestone, hard.
------	171–172	Sandy shale.
8	172–174	Recovered 0.8 ft: Clay shale, gray, soft to firm, contains a large amount of bentonite.
------	174–197	Shale, sandy.

Lithologic description—Continued

Core	Depth (feet)	Remarks
9	197–199	Recovered 0.8 ft: Silt, dark-gray to black, soft.
------	199–200	Shale, sandy, hard.
------	200–215	Shale, sandy, and sand.
------	215–230	Shale, blue, sticky.
10	230–232	No recovery.
------	232–254	Shale, hard.
11	254–257	Recovered 0.6 ft: Silty shale, dark-gray to black, bentonitic, soft; contains some biotite.
------	257–263	Shale, sandy.
------	263–295	Shale, sandy, soft.
12	295–297	Recovered 0.8 ft: Clay shale, dark-gray to black, bentonitic, soft. Contains some mica and is of finer texture than silty shale above.
------	297–315	Clay, blue, sticky.
------	315–319	Shale, sandy, hard, and sticky shale.
------	319–344	No data.

DRILLING OPERATIONS

Notes from drilling records

Depth (feet)	*Remarks*
7	Installed and cemented 10 ft of 4-in. casing at 7 ft.
12	Cement washed out from around casing, and circulation was lost.
13⅓	The 4-in. casing was pulled out and reset at 13 ft 4 in.
30	Bit sanded up and drill pipe stuck but was jarred loose.
76	The 4-in. casing was pulled out, and 3-in. casing was run to 21 ft. It was pulled out, and hole reamed to 4½ in.
81	Set 3-in. casing at 49 ft.
83	Bit stopped by ice in casing when lowered to take a core. Hole was cleaned out, but bit froze in hole after coring 2 ft. It was jarred loose, and hole cleaned out with 2½-in. bit from 22 to 62 ft. Circulation lost around 3-in. casing, and regained after driving casing 4 in. lower.
106	Two joints of drill rods lost while reaming and recovered. After working on pump for 8 hr, hole was frozen and ice had to be cleaned out from 5 to 76 ft. Circulation lost, and casing driven down 1 ft before ice could be cleaned out to 106 ft. Myers 3- by 4-in. pump had small bore and low pressure and could not circulate mud fast enough through the small drill rods to keep mud from freezing to walls of 2¾-in. hole. Oil burner immersion heater in mud pit heated mud sufficiently to keep circulation as long as pump could be kept running, but it often needed fixing, and mud froze in hole during even a short shutdown.
163	After working on pump for 20 hr, ice and frozen mud were cleaned from 24 to 163 ft.
196	Hole froze and ice had to be cleaned out from 165 to 196 ft. Salt water mixed with the mud for circulation.
344	Frozen mud cleaned out from 210 to 240 ft, and from 270 to 285 ft. Mud froze around drill pipe, and circulation was lost. Derrick legs were bent pulling drill pipe out, and new legs were installed before pulling out casing and abandoning hole.

BARROW CORE RIG TEST 2

Location: Lat 71°19′00″ N., long 156°38′59″ W.
Elevation: Ground, 13.45 feet; bottom of swivel head, 15.75 feet.
Spudded: October 9, 1944.
Completed: October 17, 1944. Junked and abandoned.
Total depth: 236 feet.

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

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

Core	Depth (feet)	Remarks
------	0–2. 3	Swivel head to ground level.
------	2. 3–16	Tundra and ice.
------	16–28	Ice and mud.
------	28–63	Sand and shale.
------	63–106	Sandy shale and ice.
------	106–135	Shale, sandy, and streaks of sticky shale.
------	135–149	Sandy shale.
------	149–151	Hard rock.
------	151–156	Sandy shale.
------	156–171	Sandstone and limestone.
------	171–173	Hard sandstone.
1	173–175	Recovered 0.5 ft: Sand, dark-gray, fine to silty, grains well rounded.
2	175–177	No recovery.
------	177–185	Sandy shale.
3	185–195	No recovery.
------	195–222	Sand and shale, soft.
------	222–236	Shale, sandy, and streaks of sticky shale.

DRILLING OPERATIONS

Notes from drilling records

Depth (feet)	*Remarks*
7	Drilled 4½-in. hole to 7 ft and set 6-in. pipe at that depth.
16	Lost circulation around pipe.
38	Drove 3-in. casing in 2¾-in. hole to 38.5 ft.
63	Lost circulation around 3-in. casing.
175	Reamed frozen mud from 110 to 170 ft. Plugged bit was pulled out of hole, and pump repaired. Ice cleaned out from 90 to 175 ft.
195	Mud froze and had to be circulated out of hole, and cleaned out to 195 ft. Circulation broke out around pipe; operations shut down several hours waiting for the mud to freeze.
236	Diesel heating stove exploded, and about three-fourths of equipment and rig were lost in the fire. The flame in the stove had probably been extinguished by a gusty wind, or by soot on drip-burner tip. Oil collected on fire bricks at bottom of stove and exploded, breaking fuel line. Flaming oil from broken line ignited plywood housing, and fire could not be controlled in the gusty wind.

BARROW BIG RIG TEST 1

Location: Lat 71°19′44″ N., long 156°40′06″ W.
Elevation: Ground, 8.5 feet; kelly bushing, 16 feet.
Spudded: October 13, 1944.
Completed: October 22, 1944. Dry and abandoned.
Total depth: 685 feet.

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

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

Core	Depth (feet)	Remarks
------	0–7. 5	Kelly bushing to ground level.
------	7. 5–75	Gravel and sand.
------	75–82	Sand and gravel.
------	82–100	No record.
1	100–120	Recovered 4 ft: Clay, medium-light-gray, slightly silty, noncalcareous. Foraminifera (*Nonion* sp., *Cassidulina* sp., several specimens of Elphidiidae) were found in a washed sample, which was made up primarily of subangular white and clear quartz silt.
------	120–170	Shale, blue.
2	170–188	Recovered 13 ft: Sandstone, light-gray, very fine grained, silty, noncalcareous, friable, massive; composed of subangular to subround grains of clear and white quartz; rare yellow and dark grains. Sandstone becomes slightly coarser and darker with depth. Effective porosity, measured by Washburn-Bunting method, is 38.4 percent at 171 ft, 36.1 percent at 176 ft, 37.0 percent at 180 ft, and 33.1 percent at 185 ft; rock too friable for permeability tests. Sieve analysis of sample at 176 ft showed rock to be composed of 14.2 percent fine sand (particles caught on 120-mesh sieve), 46.9 percent very fine sand (between 120- and 230-mesh sieves), and 38.7 percent silt and clay (pass through 230-mesh sieve).
3	188–206	Recovered 18 ft: Sandstone as above. Effective porosity 36.4 percent at 190 ft, 33.5 percent at 195 ft, 30.1 percent at 200 ft, and 37.1 percent at 205 ft. Rock too friable for permeability tests. Two sieve analyses, at 190 and 205 ft, gave the following results: At 190 ft, rock composed of 1.96 percent fine sand, 56.3 percent very fine sand, and 41.8 percent silt and clay; at 205 ft, of 24.5 percent fine sand, 53.0 percent very fine sand, and 22.3 percent silt and clay. At 191 ft, specific gravity of sandstone was 1.78.
------	206–310	Shale, sandy.
4	310–317	Recovered 1 ft: Clay shale, medium-light-gray, slightly silty, slightly calcareous; fair shaly cleavage. Mixed with drilling mud. Beds lie flat.
------	317–347	Shale.
------	347–425	Shale, blue.
------	425–605	Shale.
------	605–665	Shale, sandy.
------	665–667	Shale.
5	667–685	Recovered 12 ft: Clay shale, medium-light-gray, slightly silty in part, slightly calcareous, fissile in part. Beds lie flat.

DRILLING OPERATIONS

Setting up the National 50 drilling rig was begun on October 1, 1944 and completed on the 11th of the month. The rig was not housed. The mud pits were made of two pontoons welded together.

Notes from drilling records

Depth (feet)	*Remarks*
82	Hole drilled to 82 ft with 14¾-in. bit. When 11¾-in. casing was set at 67 ft, operations were shut down for 24 hr so the casing would freeze in place. Casing then cleaned out and drilling continued with a 10⅝-in. bit. Attempts at coring were unsuccessful, as slush ice plugged openings of core bit.
120	Mud pipes froze during coring because of wind, cold, and snow, but were thawed with a flamethrower. A Sullivan air compressor was successful in blowing mud out of pipes while mud was not being circulated.
667	Mud became warm at this depth (possibly the bottom of the permafrost at well site).

SKULL CLIFF CORE TEST 1

Location: Lat 70°54′ N., long 158°36′ W.
Elevation: Ground, 9 feet lower; kelly bushing, approximately 50 feet.
Spudded: Februarv 2, 1947.
Completed: March 17, 1947. Junked and abandoned.
Total depth: 779 feet.

Skull Cliff core test 1 is 1¼ miles inland from the shore of the Arctic Ocean, and about 40 miles southwest of Point Barrow. The coastline in this area is bordered by a cliff some 50 feet high, in which Pleistocene and Cretaceous beds crop out. Oil drips slowly from a seep at the base of the cliff; Edward J. Webber described it (written communication, 1947) as coming from a spot a few inches across, in a sandstone bed which crops out along the edge of the ocean. Except for the cliff face, there are no outcrops anywhere in the area, and the need for additional stratigraphic information, as well as the oil seep, determined the location of the hole. It was planned as a 1,500-foot test, but mechanical difficulties caused abandonment at a total depth of 779 feet.

DESCRIPTION OF CORES AND CUTTINGS

The hole was cored through an estimated 40 feet of unconsolidated sand and gravel of the Gubik formation, Cretaceous sandstone and shale of the Grandstand formation from 50 to about 450 feet, and the Topagoruk formation from about 450 feet to the bottom of the hole. (See pl. 39.) No shows of oil or gas were noted, and the rig was removed and sent back to Barrow.

Lithologic description

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

Core	Depth (feet)	Remarks
------	0–9	Kelly bushing to ground level.
------	9–15. 25	No sample.
------	15. 25–30	Sand, yellowish-brown, fine- to very fine-grained; composed of well-rounded clear quartz and some yellow quartz, yellow, gray, and black chert, and rare red chert. Rare chert granules.
------	30–40	Sample composed entirely of cement.
------	40–50	Chert pebbles, black, well-rounded; a few pebbles of other rocks.
------	50–100	Sandstone, medium-light-gray, very fine grained, very silty and argillaceous, very slightly calcareous; composed of subangular clear and white quartz and some gray chert and dark rock fragments. Chert pebbles, contamination from above, make up over half of each sample representing this interval of rock.
1	100–109	Recovered 3 ft: 8 in., drilling mud containing 1-in. rounded black chert pebbles. 2 ft 4 in., clay shale, medium-light-gray, slightly calcareous, soft; good shaly cleavage. Beds lie flat.
2	109–119. 6	Recovered 10 ft: 1 ft 1 in., sandstone, medium-light-gray, very fine grained, silty, argillaceous, moderately calcareous, massive; composed of angular to subangular clear and white quartz and rare gray and dark rock fragments, muscovite, and carbonaceous particles. 5 ft 6 in., clay shale, medium-light-gray to medium-gray, slightly calcareous, slightly to very silty, slightly to very micaceous (dominantly muscovite); siltstone partings common; fair shaly cleavage. Beds lie flat. Irregular 1-in. bed of light-gray crossbedded very fine grained sandstone with carbonaceous partings present at 112 ft. Clay shale grades into unit below. 7 in., siltstone, medium-light-gray, very argillaceous, slightly calcareous, micaceous, massive. 2 ft 10 in., clay shale as above.
3	119. 6–129. 6	Recovered 10 ft: Clay shale as above, with rare silty partings.
4	129. 6–139. 6	Recovered 9 ft: Clay shale as above, medium- to medium-dark-gray; rare ½- to 2-in. beds of light-gray argillaceous siltstone and medium-dark-gray clay shale with carbonaceous plant flakes.
5	139. 6–149	Recovered 10 ft: 1 in., clay ironstone, light-yellowish-gray, noncalcareous, hard, dense; conchoidal fracture; effervesces slightly in cold dilute hydrochloric acid. 1 ft 1 in., clay shale as above, fissile, abundant carbonaceous plant flakes and fragments in lower 1 in. 10 in., siltstone, medium-light-gray, very argillaceous, very slightly calcareous, massive. Rare very fine and fine-grained sandstone streaks intermingled in upper 1 in. of siltstone. Rare patches of medium-gray clay. 7 in., clay shale as above. 1 ft, siltstone as above; carbonaceous partings in lower 2 in. 6 in., claystone, medium-gray, very slightly calcareous; conchoidal fracture. 3 in., sandstone, medium-gray, fine-grained, slightly silty, noncalcareous, friable, massive; composed of subangular grains of clear and white quartz and carbonaceous particles. Carbonaceous streaks common. 1 ft 3 in., intermingled very irregular lenses and laminae of light-gray, fine- and very fine grained sandstone; medium-gray siltstone, and medium-dark to dark-gray carbonaceous clay shale. 11 in., clay shale, dark-gray, fissile; coaly partings and abundant carbonaceous plant fragments. Beds lie flat. 10 in., siltstone, medium-light-gray, very argillaceous, noncalcareous, massive; patches of medium-gray clay and carbonaceous material. 2 ft 8 in., interbedded clay shale, medium-gray; dark-gray carbonaceous fissile clay shale; and light-yellowish-gray claystone. Beds are 2–3 in. thick.
6	149–159	Recovered 5 ft 6 in.: Sandstone, medium-light-gray, fine-grained, slightly silty and argillaceous, noncalcareous, friable, massive; composed of subangular to subrounded clear and white quartz with some gray chert and dark rock fragments; rare carbonaceous particles and muscovite.
7	159–169	Recovered 9 ft 6 in.: Sandstone as above, fine- to very fine grained.
8	169–179	Recovered 9 ft: 6 ft 3 in., sandstone as above, fine-grained. 2 ft, sandstone, very fine grained; medium-light-gray calcareous siltstone; abundant irregular laminae and small lenses medium-gray claystone and carbonaceous patches totaling about one-third of the rock. 9 in., drilling mud with sandstone and siltstone fragments.
9	179–189	Recovered 2 ft: Clay shale, medium-gray, slightly calcareous, subconchoidal to good shaly cleavage. Beds lie approximately flat.
10	189–199	Recovered 9 ft: 5 ft 1 in., clay shale as above. 2 ft 9 in., claystone, light-olive-gray, very silty, very slightly calcareous, irregular fracture; small scattered carbonized plant fragments. A 3-in. bed of medium-light-gray fine-grained very slightly calcareous

Lithologic description—Continued

Core	Depth (feet)	Remarks
		sandstone with rare carbonaceous partings present at 196 ft. 1 ft 2 in., siltstone, medium-light-gray, slightly sandy, very argillaceous, noncalcareous, massive.
11	199–209	Recovered 8 ft: 11 in., clay shale, medium-gray, slightly silty in part; some siltstone partings dip less than 5°. 1 ft 10 in., sandstone, medium-light-gray, very fine grained, slightly silty, very slightly calcaerous, massive; composed of subangular clear and white quartz, and some yellow, gray, and dark rock fragments and rare carbonaceous particles. 1 ft 11 in., claystone, light-olive-gray, slightly to very silty, noncalcareous, massive. 6 in., siltstone, medium-light-gray, slightly argillaceous, slightly calcareous, massive. 2 ft 4 in., claystone, medium-light-gray, slightly silty, slightly micaceous, noncalcareous; irregular cleavage; fair shaly cleavage in a few places is caused by micaceous partings. 6 in., siltstone as above.
------	209–211	No sample.
12	211–216	Recovered 1 ft: Chert pebbles, black, 1–2 in. in diameter, rounded; contamination from surface gravel. 3 in., siltstone as above.
13	216–226	Recovered 9 ft: 8 in., siltstone as above, grades into unit below. 9 in., sandstone, medium-light-gray, very fine grained, very argillaceous, very slightly calcareous, massive; rare slightly carbonaceous partings. Composition same as core 11 sand. 1 ft 7 in., clay shale, medium-light-gray, slightly to very silty and micaceous, noncalcareous; poor shaly cleavage. Beds lie approximately flat. 4 in., siltstone, medium-light-gray, very argillaceous, noncalcareous. 4 in., clay shale as above. 2 ft, siltstone as above, slightly calcareous in part, massive; rare carbonaceous partings. 3 ft 4 in., siltstone and clay shale, interbedded, as above; beds are 2–6 in. thick and are about half claystone and half siltstone.
14	226–236	Recovered 10 ft: 1 ft 6 in., siltstone, similar to siltstone above; abundant carbonaceous partings composed of particles and flakes of carbonized plants as much as one-half in. long. Partings lie approximately flat. Clay shale laminae common in basal few inches. 3 ft 6 in., interlaminated and interbedded siltstone and clay shale; beds are ¼–4 in. thick. 5 ft, clay shale, medium-gray, slightly to very silty, fissile to poor shaly cleavage. A 3-in. bed of siltstone present 1½ in. above base of core.

Lithologic description—Continued

Core	Depth (feet)	Remarks
15	236–246	Recovered 4 ft: Claystone, medium-gray, very slightly silty, noncalcareous; fair to good conchoidal fracture; rare thin (less than 1 in.) beds silty claystone.
16	246–256	Recovered 9 ft 6 in.: Claystone, as above, but lacks silty laminae.
17	256–266	Recovered 10 ft: Intergraded claystone and clay shale, medium-dark-gray, noncalcareous, slightly silty in part; conchoidal fracture to fissile: flat lying.
18	266–276	Recovered 9 ft 6 in.: Intergraded claystone and clay shale as above; rare flat-lying laminae and beds (less than 1 in.) of siltstone.
19	276–286	Recovered 2 ft 6 in.: Clay shale and claystone as above.
20	286–296	Recovered 10 ft: 11 in., clay shale, medium-light-gray, very silty, noncalcareous; poor shaly cleavage. 9 ft 1 in., siltstone, medium-light-gray, slightly to very sandy, argillaceous. Abundant argillaceous slightly carbonaceous partings that are rarely crossbedded dip 7°. Two 2-in. beds of medium-gray clay shale present 6 in. apart, at 289 ft. Siltstone rarely grades into an in. or so of very fine grained very argillaceous silty sandstone.
21	296–306	Recovered 9 ft: 2 ft 6 in., sandstone, medium-light-gray, fine-grained, slightly silty, noncalcareous, massive; composed of subangular to subround grains of clear and white quartz, small amount of gray chert and dark rock fragments, and rare yellow grains and carbonaceous particles. 6 ft 6 in., sandstone as above, but very fine grained. A 2-in. bed of medium-gray clay shale present at 303 ft.
22	306–316	Recovered 10 ft: Sandstone as above, very fine grained; rare argillaceous, carbonaceous laminae. A 2-in. bed of medium-gray claystone with conchoidal fracture 1 ft above base of core; lower contact between claystone and sandstone has ½-in. rounded pebbles of claystone in the sandstone. Beds lie approximately flat.
23	316–326	Recovered 10 ft: 6 ft, sandstone as above. 4 ft, claystone, medium-light-gray, very slightly silty in part, noncalcareous; conchoidal fracture.
24	326–336	Recovered 10 ft: Clay shale, like claystone above but with fair shaly cleavage; infiltrated with drilling mud. Beds lie approximately flat.
25	336–346	Recovered 6 ft: Clay shale as above; rock badly infiltrated with drilling mud.

Lithologic description—Continued

Core	Depth (feet)	Remarks
26	346–356	Recovered 10 ft: Clay shale as above but with a 6-in. bed of siltstone that is medium gray, very argillaceous, very slightly calcareous in part, and massive.
27	356–366	Recovered 8 ft 6 in.: Clay shale as above; badly infiltrated with drilling mud.
28	366–376	Recovered 7 ft: Clay shale as above; badly infiltrated with drilling mud in upper part.
29	376–386	Recovered 10 ft: Interbedded and interlaminated clay shale and siltstone; some micaceous carbonaceous partings in the siltstone. Beds range from ¼ to 4 in. in thickness, and are approximately half clay shale and half siltstone. A 1-ft siltstone bed present at 379–380 ft. Siltstone is medium light gray, very argillaceous, and very slightly calcareous in part. Clay shale is medium gray, slightly to very silty in part, noncalcareous.
30	386–396	Recovered 10 ft: Clay shale as above. Rare small carbonized plant flakes. A 6-in. bed of medium-light-gray argillaceous slightly sandy siltstone present at 394 ft.
31	396–406	Recovered 6 ft: Clay shale fragments, medium-gray, slightly silty in part, noncalcareous; fair shaly to subconchoidal cleavage. Beds lie approximately flat.
32	406–416	Recovered 10 ft: 2 ft, clay shale as above. 1 ft, sandstone, medium-light-gray, very fine grained, very silty and argillaceous, noncalcareous, massive. 7 ft, clay shale as above.
33	416–426	Recovered 3 ft 6 in.: 1 ft 3 in., clay shale as above. 2 ft 3 in., siltstone, medium-light-gray, very sandy and argillaceous, noncalcareous, massive.
34	426–436	No recovery.
35	436–446	Recovered 9 ft 6 in.: Sandstone, medium-light-gray, very fine grained, argillaceous, noncalcareous, massive; composed of subangular grains of clear and white quartz, some dark rock fragments, and rare mica, and yellow grains.
36	446–456	Recovered 6 ft: Clay shale as above; two 2-in. beds of medium-light-gray very fine grained sandstone are one-half in. and 1 ft below top of core, respectively. Top of Topagoruk formation at approximately 450 feet.
37	456–466	Recovered 10 ft: Clay shale, medium-gray, very slightly silty in part, noncalcareous; very rare micaceous partings.
38	466–476	Recovered 10 ft: Clay shale as above.
39	476–486	Recovered 10 ft: 7 in., clay shale as above. 1 ft, siltstone, medium-gray, very argillaceous, noncalcareous, massive. 8 ft 5 in., clay shale as above; 4-in. bed of siltstone at 483 ft.
40	486–496	Recovered 10 ft: Clay shale as above but with rare siltstone beds ½–6 in. thick, in upper two thirds of core. Beds lie approximately flat.
41	496–506	Recovered 10 ft: Clay shale as above but with rare thin (½–1 in.) siltstone beds in upper part; beds lie approximately flat.
42	506–516	Recovered 2 ft 6 in.: Drilling mud but with fragments of clay shale as above.
43	516–526	Recovered 7 ft. 6 in.: Clay shale as sbove; badly infiltrated with drilling mud in part.
44	526–536	Recovered 10 ft: Clay shale as above but with very rare thin (½–2 in.) beds siltstone, and a 6-in. medium-light-gray very fine grained noncalcareous silty sandstone bed at 532 ft. Beds lie flat.
45	536–546	Recovered 10 ft: Clay shale as above but medium- to medium-dark-gray; rare silty laminae in upper third. Beds lie flat.
46	546–556	Recovered 7 ft: Clay shale as above but fissile, infiltrated with drilling mud. A 6-in. bed of medium-light-gray crossbedded siltstone has carbonaceous or argillaceous partings dipping 1°–10°. Clay shale beds lie flat.
47	556–566	Recovered 8 ft. 6 in.: Clay shale, medium-dark-gray, slightly to very silty in part, noncalcareous; fair shaly cleavage to fissile.
48	566–576	Recovered 10 ft: Clay shale as above. Beds lie flat.
49	576–586	Recovered 10 ft: Clay shale as above but with rare 1-in. beds of medium-light-gray argillaceous siltstone in upper 2 ft. Beds lie flat.
50	586–596	Recovered 10 ft: 5 ft, interbedded argillaceous siltstone and clay shale; beds are 2–8 in. thick, approximately half siltstone and half clay shale, and lie flat. 5 ft, clay shale as in core above but with rare laminae of very argillaceous siltstone, and a 1-in. bed of siltstone at the top. Beds lie flat.
51	596–606	Recovered 10 ft: Clay shale as above but with 1-in. bed of siltstone at top. Beds lie flat.
52	606–616	Recovered 10 ft: 3 ft., clay shale as above. 1 ft 6 in., sandstone, light-gray, very fine grained, slightly silty, very slightly calcareous, massive; composed of subangular grains of clear and white quartz with rare dark rock grains. 4 ft 3 in., clay shale as above. 8 in., sandstone as above. 7 in., clay shale as above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
53	616–626	Recovered 7 ft: Clay shale, medium-dark-gray, slightly to very silty in part, noncalcareous; fair shaly cleavage to fissile. Beds lie flat.
54	626–636	Recovered 10 ft: Clay shale as above but with a 4-in. bed of light-gray very fine grained sandstone that is very silty and argillaceous, slightly calcareous, at 633 ft.
55	636–646	Recovered 5 ft 6 in.: 5 ft, clay shale as above. Beds lie flat. 6 in., drilling mud with some clay shale fragments.
56	646–656	Recovered 7 ft 6 in.: 2 ft 6 in., clay shale as above; badly infiltrated with drilling mud. 2 ft 7 in., siltstone, medium-light-gray, very argillaceous and micaceous, noncalcareous, irregular fracture; scattered flakes of carbonized plants. Siltstone grades to very fine grained very argillaceous sandstone at base. 2 ft 5 in., clay shale as above.
57	656–666	Recovered 10 ft: Clay shale as above.
58	666–676	Recovered 10 ft: 6 ft 6 in., clay shale, medium- to medium-dark-gray, slightly to very silty, noncalcareous; common thin (½–4 in.) beds of medium-light-gray very argillaceous noncalcareous siltstone, decreasing to rare at base. 2 ft 3 in., sandstone, medium-light-gray, very fine grained, very silty and argillaceous; common thin irregular carbonaceous and argillaceous laminae and partings in upper part; grades to massive in lower part. 1 ft 3 in., clay shale, medium-dark-gray, slightly to very silty in part, micaceous, noncalcareous; very poor shaly cleavage. Beds lie flat.
59	676–686	Recovered 10 ft: Clay shale as above. Beds lie flat.
60	686–696	Recovered 4 ft: Clay shale as above; infiltrated with drilling mud in lower part. Beds lie flat.
61	696–706	Recovered 10 ft: Clay shale, medium-dark-gray; very slightly silty in part; fissile to subconchoidal fracture. Beds lie flat.
62	706–716	Recovered 10 ft: Clay shale as above. Beds lie flat.
63	716–726	Recovered 10 ft: Clay shale as above. Beds lie flat.
64	726–736	Recovered 10 ft: 2 ft 6 in., clay shale as above. 10 in., siltstone, medium-gray, argillaceous, noncalcareous, micaceous; abundant carbonaceous and micaceous partings totaling half of the rock in upper 2 in. and decreasing to less than 10 percent at base. Upper few inches has excellent pokerchip cleavage along partings; core breaks into smooth, circular chips less than 1/16 in. thick. Beds lie flat. 2 ft 8 in., clay shale as above. 3 ft 6 in., siltstone, medium-light-gray, very sandy, slightly argillaceous, noncalcareous, massive; faint carbonaceous partings in lower part are crossbedded, dip as much as 10°. 6 in., clay shale as above.
65	736–746	Recovered 10 ft: Clay shale as above.
66	746–756	Recovered 10 ft: 2 ft 4 in., clay shale as above. 5 ft 8 in., siltstone, medium-light-gray, slightly sandy and argillaceous, noncalcareous; massive in upper part but has rare faint carbonaceous partings in lower part. A 2-in. bed of clay shale is 1½ in. below top of siltstone. 2 ft. Clay shale as above but with rare thin beds (less than ½ in.) of siltstone.
67	756–766	Recovered 8 ft: 3 ft., clay shale as above; infiltrated with drilling mud; rare beds, less than 2 in. thick, of medium-light-gray siltstone. 5 ft, clay shale as above; infiltrated with drilling mud in part.
68	766–776	Recovered 10 ft: Clay shale, medium-dark-gray, slightly silty in part, noncalcareous; shaly cleavage; fissile in part.
	776–779	No sample.

CORE ANALYSES

Core samples from Skull Cliff core test 1 were analyzed by the personnel of the Geological Survey laboratory at Fairbanks, Alaska, and by S. T. Yuster at Pennsylvania State College. Porosity and permeability were measured by various methods, as given in the following table on porosity and permeability, and found to be very high (as much as 2,370 millidarcys of permeability and 35.6 percent porposity) in sandstone samples from depths of 110, 310, and 748 feet. The three samples studied at Pennsylvania showed a large drop in permeability to fresh water, compared to air or brine. Sieve analyses in the following table show the sandstones to be composed primarily of fine to very fine sand and a considerable amount of silt and clay. Petrographic analyses of the same three samples, in the table on petrographic characteristics, show that quartz is the most abundant constitutent and that slate or phyllite particles and chert make up most of the rest of the rock. Interstitial material includes clay minerals and a small amount of carbonate cement. The specific gravity ranges from 1.85 to 2.38; the lightest rocks are sandstone, and the heaviest ones clay shale—as shown in the following table on specific gravity.

Heavy minerals were studied by Robert H. Morris who determined that the zoned-zircon zone is present in the hole between the depths of 110 and 450 feet, as shown in plate 40.

Porosity, permeability, and carbonate content of core samples from Skull Cliff core test 1

Depth (feet)	Determined at Geological Survey Fairbanks laboratory							Determined at Pennsylvania State College by S. T. Yuster					
	Carbonate content (percent by weight)	Air permeability (millidarcys)				Effective porosity (percent)		Effective porosity (percent)	Permeability (millidarcys)				
		Hayward permeameter tests in—			API permeameter	Washburn-Bunting method	Barnes method		Air	Klinkenberg		Brine	Fresh water
		1947		1950						Before liquid flow	After liquid flow		
		No. 8 [1]	No. 7 [1]	No. 7 [1]									
110 [2]			50			25. 1		23. 2		43. 8	35. 3	18. 9	0
150	7. 86	745											
150				1, 250			28. 8						
150									870				
152	5. 36	1, 600											
152									1,800–1,850				
154	5. 72	1, 600											
154				1, 500	>1, 020		27. 8						
154									1, 800				
157	8. 23	745											
157				2, 370			31. 05						
159	7. 62	1, 100											
159				1, 220	>1, 020		35. 6						
162	8. 66												
162				1, 540	>1, 300		30. 09						
164	9. 72	675											
164				710	715		28. 5						
166	8. 12	780											
166				680	690		28. 15						
169	6. 97	1, 350											
169							30. 6						
171	4. 2	2, 470											
171				2, 920	>2, 150		34. 0						
173				3, 700	>3, 000		34. 0						
173	5. 12												
176	17. 6	7. 5						14. 0	17. 0				
176				10±	15		15. 25						
291			76			16. 6							
295			16. 5			22. 4							
297	13. 2	11. 2											
297								20. 7					
298	10. 4	48											
298				450	420		26. 6						
301	17. 35	49. 5											
301				96	110		24. 1						
301								21. 5	60. 0				
303	11. 2	157											
303				225	205		24. 7						
303								22. 6	153. 0				
304	7. 0	190											
304				160	170		25. 6						
304								11. 5	193. 0				
306	10. 8	450											
306				560	515		26. 8						
306								24. 3	505. 0				
310			530			28. 2							
310 [2]								26. 3		268	143	113	0
314			285			27. 3							
317	13. 3	240											
317				220	210		24. 6						
317								24. 0	214. 0				
319	28. 6	<10											
319				500	470		26. 3						
319									<10				
321	23. 2	<10											
321					0		9. 07						
321								10. 6	1. 3				
437	8. 9	86											
437					54		23. 3						
437								25. 0	104. 0				
439	15. 0	78											
439					68		22. 1						
439								24. 0	97. 3				
441	10. 8	87											

[1] Number of instrument.
[2] Petrographic data on these three samples is given on p. 581.

Porosity, permeability, and carbonate content of core samples from Skull Cliff core test 1—Continued

Depth (feet)	Determined at Geological Survey Fairbanks laboratory							Determined at Pennsylvania State College by S. T. Yuster					
	Carbonate content (percent by weight)	Air permeability (millidarcys)				Effective porosity (percent)		Effective porosity (percent)	Permeability (millidarcys)				
		Hayward permeameter tests in—			API permeameter	Washburn-Bunting method	Barnes method		Air	Klinkenberg		Brine	Fresh water
		1947		1950						Before liquid flow	After liquid flow		
		No. 8 [1]	No. 7 [1]	No. 7 [1]									
441					65		22.9						
441								24.6	97.0				
443	21.0	37											
443					38		20.8						
443								23.0	44.6				
446	11.3	45											
446					27		20.7						
446								23.3	61.0				
610			148			28.0							
732			16.8			22.2							
748			115			29.2							
748 [2]								23.6	<10	99.1	99.7	60.6	38.1
752			5.8			23.6							

[1] Number of instrument.
[2] Petrographic data on these three samples is given below.

Sieve analyses of samples from Skull Cliff core test 1

Depth (feet)	Wentworth scale sand grain size, (percent)					
	40-mesh (>0.42 mm)	60-mesh (0.42–0.25 mm)	100-mesh (0.25–0.149 mm)	200-mesh (0.149–0.047 mm)	200-mesh (<0.047 mm)	Total
136	1.75	8.50	56.10	16.20	17.50	100.05
150	2.02	8.70	56.15	21.65	11.44	99.96
152	2.30	12.80	62.25	11.75	10.85	99.95
157		9.30	57.80	15.80	17.10	100.00
159		13.10	54.20	19.90	12.80	100.00
162		7.60	58.60	24.95	8.90	99.95
164		.42	29.20	37.90	32.45	99.97
166	.82	9.23	48.65	23.65	17.65	100.00
169	1.40	4.60	56.80	16.20	19.00	100.00
171	3.00	18.60	71.20	3.40	3.80	100.00
173		25.50	57.70	3.10	13.80	100.10
176		4.50	23.60	44.80	27.00	99.90
297		.40	12.80	33.00	53.80	100.00
298		7.65	19.15	33.20	40.00	100.00
301		.72	22.50	35.60	41.10	99.92
303		2.90	38.70	27.45	30.80	99.85
304		2.76	55.00	24.30	18.00	100.06
306		6.10	57.80	15.80	20.20	99.90
317		6.60	37.20	36.80	19.30	99.90
319		8.20	29.75	34.50	27.45	99.90
321		.55	30.10	44.90	24.40	99.95
437		7.40	15.40	40.90	36.30	100.00
439		6.20	10.20	41.90	41.60	99.90
441		3.30	10.00	44.60	42.00	99.90
443		6.60	9.80	35.90	47.60	99.90
446		2.40	7.20	32.20	58.20	100.00

Petrographic characteristics of sandstone from Skull Cliff core test 1

[Determined by Paul D. Krynine]

Characteristic	Samples by depth		
	110 feet	310 feet	748 feet
Texture			
Average diameter range—mm	0.03–0.18	0.04–0.18	0.02–0.08
Principal mode—mm	0.08	0.11	0.065
Grains: matrix: cement, ratio in percent	70:15:15	85:12:3	90:5:5
Grain composition in percent			
Quartz	27	34	48
Chert	13	19	5
Feldspar	8	8	5
Mica flakes, large	3	Tr.	Tr.

Petrographic characteristics of sandstone from Skull Cliff core test 1—Continued

Characteristics	Samples by depth		
	110 feet	310 feet	748 feet
Grain composition in percent—Continued			
Slate, phyllite	17	21	30
Quartzite, schist	Tr.	1	1
Volcanic rocks	Tr.	3	2
Biotite	Present		
Chlorite	Present		
Interstitial material in percent			
Chlorite	2	2	
Sericite	1	1	
Illite	8	3	3
Montmorillonite, kaolinite	5	6	2
Carbonates	15	3	4
Pore space and characteristics			
Pore size, principal mode—microns	45	60	35
Visible porosity—percent	15	25	20
Residual porosity	Good	Very good	Good
Clay-coated wall area—percent	60	30	25
Wall coating—type	Illite, kaolinite, montmorillonite	Kaolinite, montmorillonite	Illite, kaolinite, montmorillonite
Potential hydration	Very high	Very high	Moderate

Specific gravity of samples from Skull Cliff core test 1

Depth (feet)	Specific gravity	Rock type
120	2.31	Clay shale.
160	1.85	Fine-grained sandstone.
220	2.35	Clay shale.
300	2.05	Very fine grained sandstone.
400	2.34	Clay shale.
440	2.00	Very fine grained sandstone.
500	2.31	Clay shale.
660	2.19	Siltstone.
760	2.38	Clay shale.

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LOGISTICS

A tractor train hauling 500 tons of equipment and supplies to the well site left Barrow on January 20, 1947, and reached Skull Cliff 6 days later. The next week was spent rigging up and searching for a water supply. A Failing 314-C rig was used in this test. Nearby lakes and streams were probed with steam points and found to be frozen solid; water sufficient for drilling operations was not found until a passing Eskimo pointed out a lake 2 miles away where 4 feet of ice covered 15 feet of water. Wanigans (small one-room buildings generally mounted on runners or skids to facilitate moving) were used to haul water to the rig, and to house both the personnel and the equipment. The major items of equipment used are described on page 585. The 6- by 6- by 3-foot cellar was used for a mud sump before casing was set; a steel drum with the ends cut out was frozen in as a conductor pipe, to prevent mud and cuttings from washing down the hole.

DRILLING OPERATIONS

Depth (feet)	*Notes from drilling records*	*Remarks*
30	Seven-inch casing set at 30 ft and cemented with 10 sacks of cement. It was left under pressure for 14 hr, and then steamed. Steam forced in hole formed bubbles in the cement that twice caused explosions that blew all the water out of the hole, before it was found that the cement plug was higher than the bottom of the pipe and the steam point was being submerged in it. Bubble was prevented from forming again by keeping steam point moving, and cement set satisfactorily.	
100	Hole drilled to 100 ft with 6⅛-in. rock bit.	
779	Below 100 ft the hole was cored with a Reed Kor-King 5⅞-in. core barrel. Below 150 ft mud made by shale was very viscous, but almost continuous addition of water maintained desired viscosity, although some caving was noticed from upper sand and gravel. Mud temperature kept near 36° F. Outdoor temperatures were as low as 54° below zero, and wind velocities were 10–50 mph.	
	While drilling at 779 ft, drill pipe parted at 527 ft, and could not be recovered. Mud not circulated for 20 hrs while a spiral guide was being sent from Barrow, and hole froze solid from surface to 250 ft and had ice on the wall at least as low as 525 ft. After cleaning out, fishing began again, but unsuccessfully. During another wait, for a hydraulic hook, the mud was heated and circulated through the hole, but ice had to be reamed from the wall before the hook could be lowered. It went down to 290 ft, and was stopped by ice; it was pulled out, and hole abandoned. Mud was bailed down to 527 ft, and allowed to stand for 24 hrs. Hole was then filled with 16 bbl diesel fuel, and after standing for 16 hrs, fluid level had dropped a foot. Hole was capped with wooden plug driven in top of casing and marked with an 8-ft piece of 2- by 4-board nailed to the plug in an upright position.	

The wanigans were thawed free of the ground, and the tractor train began the trip back to Barrow on March 17, 1947.

In August of 1948 J. H. Swartz and G. R. MacCarthy of the U.S. Geological Survey visited the well site and, after knocking out an ice bridge 5 ft down, lowered a thermistor cable into the hole. Preliminary computations of the temperature at various depths determined from the thermistor data are shown in the following table on temperatures.

Temperatures in Skull Cliff core test 1, in August 1948

Depth (feet)	*Temperature (°F)*
5	−0.7
10	−5.0
20	−9.1
30	−9.3
40	−9.2
50	−9.2
60	−9.1
70	−9.3
80	−9.5
90	−9.5
100	−9.6
200	−9.6
300	−8.8
400	−7.8
500	−6.7

ARCON BARROW CORE TEST 1

Location: Lat 71°19′40″ N., long 156°40′01″ W.
Elevation: Ground, 10.5 feet; kelly bushing, 18.5 feet.
Spudded: March 29, 1947.
Completed: May 3, 1947. Dry and abandoned.
Total Depth: 1,442 feet.

After returning the Failing 314–C drilling rig used at Skull Cliff to the camp at Barrow, it was rigged up within the camp area to drill for stratigraphic information and to experiment with reverse circulation for coring. The test drilled through about 60 feet of gravel and sand with some ice and mud, representing the Gubik formation of Pleistocene age. At 100 feet, coring with reverse circulation was begun, but this procedure was unsuccessful because the mud leaked around the casing and went into the rock instead of back up the drill pipe. The method was abandoned, and conventional circulation adopted for further work. The test was drilled in sandstone beds underlain by a sequence of clay shale that represented the Grandstand formation (60(?)–410 ft) and the Topagoruk formation (410 ft to the bottom of the hole), both of Cretaceous age. (See pl. 39.) The test was abandoned at 1,442 feet, the safe drilling limit of the rig. No oil or gas was found, but bailing at 125 feet, after the well had reached the total depth, showed that salt water was entering the hole.

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

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

Core	Depth (feet)	Remarks
------	0–8	Kelly bushing to ground level.
------	8–60	Gravel, composed of well-rounded black, gray, and light-brown chert; small amount of coarse to very fine grained well-rounded sand composed of clear and yellow quartz and some black chert.
------	60–100	No sample: the well geologist described frozen mud, bentonite, and streaks of sand. Top of Grandstand formation maybe at 60 ft.
------	100–143	An unnumbered core taken with reverse circulation consisted of drilling mud with small chips of medium-light gray slightly silty noncalcareous claystone; the part received in the Fairbanks laboratory represented interval of rocks from 120 to 143 feet.
------	143–144	No sample.
1	144–146. 7	Recovered 1 ft 6 in.: Sandstone, medium-gray, very fine grained, very silty, argillaceous, and calcareous, hard, massive; composed of subangular grains of clear and white quartz, some dark rock fragments, and rare mica.
------	147–165	Sandstone, medium-light-gray, very fine grained, very argillaceous, silty, and calcareous.
2	165–175	Recovered 4 ft: Sandstone, light-olive-gray, very fine grained, slightly silty and argillaceous, noncalcareous, friable, massive.
3	175–185	Recovered 8 ft 6 in.: Sandstone as above.
4	185–195	Recovered 10 ft.: Sandstone as above.
5	195. 7–203. 7	Recovered 1 ft: 3 in., clay shale, medium-gray, calcareous. 9 in., claystone, medium-gray, silty, very calcareous, hard; conchoidal fracture.
------	203. 7–205	No sample.
------	205–215	Sandstone, as in core 2.
------	215–218	No sample.
6	218–226. 7	Recovered 2 ft 6 in.: 1 ft 6 in., siltstone, medium-light-gray, slightly argillaceous, sandy, noncalcareous, friable. A 1-in. bed of light-olive-gray noncalcareous clay ironstone with conchoidal fracture present at base of siltstone. 1 ft, claystone, medium-gray, very silty, noncalcareous; irregular fracture.
7	226. 7–236. 7	Recovered 4 ft: Sandstone, medium-light-gray, very fine grained, very silty and argillaceous, noncalcareous, friable; composed of subangular grains of clear and white quartz and some dark rock fragments.
8	236. 7–246	Recovered 1 ft 6 in.: Claystone, medium-gray, very silty, noncalcareous, friable.
9	246–256	Recovered 2 in.: Sandstone as in core 7.
10	256–266	Recovered 7 ft: Sandstone as in core 7.
11	266–276	Recovered 5 ft: Sandstone as in core 7. Note: Ditch samples below 276 ft consist almost entirely of sand and sandstone. As cores in this part of well are clay shale, it is probable that the argillaceous material was washed out of ditch samples, and a small amount of sand contamination from upper part of hole is all that remained. Consequently, unless sandstone chips were present, samples consisting entirely of loose sand are shown on graphic log as clay shale. Though this is not an exact picture of the lithology, it is probably more accurate than plotting the interval of rock as sandstone. The electric log also suggests that the rock below 276 ft is dominantly clay shale. Description below gives contents of samples, rather than presumed lithology of intervals of rock they represent.
------	276–291	Sand composed of subangular and subrounded clear and white quartz and some dark rock fragments and rare mica and pyrite. Medium-gray argillaceous slightly sandy calcareous siltstone is very rare at base.
------	291–301	Sand as above; small amount of very fine grained calcareous sandstone is very rare at the base.
------	301–306	Sandstone and sand.
------	306–311	Sand; small amount of sandstone, siltstone and medium-gray very slightly silty slightly calcareous clay shale.
------	311–316	Sandstone and sand; very small amount of siltstone and clay shale.
------	316–321	Sandstone and very small amount of sand, siltstone, and clay shale.
------	321–326	Sand and very small amount of sandstone.
------	326–331	Sandstone and small amount of sand.
------	331–336	No sample.
------	336–341	Sandstone and very small amount of sand and rare siltstone and shale.
------	341–346	No sample.
------	346–354	Sand and rare sandstone and shale.
12	354–364	Recovered 3 ft: 1 ft, claystone, medium-gray, very silty, noncalcareous, friable. A pelecypod shell fragment (*Pecten*? sp.) occurred 6 in. below top. 2 ft, drilling mud.
------	364–375	Sand and rare sandstone and clay shale.
------	375–380	Sand and some sandstone and very small amount of siltstone.
------	380–385	No sample.
------	385–390	Sand and very small amount of sandstone and siltstone.
------	390–395	Sand and sandstone.
------	395–440	Sand; rare medium-gray slightly calcareous shale at 430 ft. Top of Topagoruk formation at 410 ft.
------	440–445	Sand and some sandstone.
------	445–447	No sample.
13	447–457	Recovered 7 ft: One-half in., clay ironstone, light-yellowish-gray, calcareous, conchoidal fracture. 6 ft 11½ in., clay shale, medium-gray, slightly silty in part, noncalcareous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		fair shaly cleavage; beds lie approximately flat. Grades to claystone in lower part. Badly infiltrated with drilling mud.
------	457–470	Sand and rare sandstone and siltstone.
------	470–500	Sand.
------	500–505	No sample.
------	505–510	Sand; a very small amount of sandstone, and very rare siltstone and shale.
------	510–548	Sand.
14	548–558	Recovered 7 ft 6 in.: Clay shale as above, but slightly calcareous; infiltrated with drilling mud.
15	558–568	Recovered 1 ft 6 in.: Clay shale as in core 13, fragments in drilling mud.
16	568–578	Recovered 2 ft: Clay shale as in core 13, fragments in drilling mud.
17	578–588	Recovered 7 ft: Clay shale as in core 13, fragments in drilling mud; a ½-in. fragment of medium-light-gray very fine grained sandstone may be contamination from another core.
18	588–599	Recovered 4 ft: Clay shale fragments in drilling mud, as above.
19	599–609	Recovered 5 ft: Clay shale as above, fragments in drilling mud.
------	609–614	Sand and a very small amount of sandstone.
------	614–619	Clay shale and sand.
------	619–649	Sand and very small amount of sandstone at 630 ft.
------	649–651	No sample.
20	651–661	Recovery 7 ft: Clay shale as above, fragments in in drilling mud.
------	661–752	Sand and very rare calcareous sandstone at 665 ft and 680 ft.
21	752–762	Recovered 1 ft 6 in.: Clay shale as above, fragments in drilling mud.
------	762–855	Sand.
------	855–857	No sample.
22	857–867	Recovered 7 ft: Clay shale as above, fragments in drilling mud.
------	867–950	Sand.
23	950–960	Recovered 7 ft: Clay shale as above, fragments in drilling mud.
------	960–965	Sand.
------	965–970	Sand and rare sandstone, medium-light-gray, very fine grained, silty, argillaceous, calcareous.
------	970–1, 021	Sand; piece of shale at 985 ft is medium-gray, silty, micaceous; slightly calcareous.
24	1, 021–1, 031	Recovered 8 ft 6 in.: Clay shale as above, fragments in drilling mud; very silty in lower 6 in.
------	1, 031–1, 130	Sand, and rare medium-gray slightly silty slightly calcareous clay shale at 1,045 ft and 1,100 ft.
------	1, 130–1, 142	No sample.
------	1, 142–1, 152	Sand.

Lithologic description—Continued

Core	Depth (feet)	Remarks
25	1, 152–1, 162	Recovered 4 ft: Clay shale as above, fragments in drilling mud; fragments of very silty very micaceous claystone and very argillaceous very micaceous olive-gray siltstone are common in lower part.
------	1, 162–1, 207	Sand, and rare sandstone at 1,190 ft.
------	1, 207–1, 212	Sand and small amount of sandstone, siltstone, and shale. Sandstone is very fine grained, argillaceous, silty, calcareous; siltstone is medium light gray, argillaceous, calcareous; clay shale is medium gray, slightly silty, slightly calcareous.
------	1, 212–1, 222	Sand.
------	1, 222–1, 227	Sand and very small amount of clay shale as above.
------	1, 227–1, 231	Sand.
26	1, 231–1, 241	Recovered 10 ft: 3 ft 4 in., clay shale, medium-gray, slightly silty in part, noncalcareous; fair shaly cleavage. Beds lie approximately flat. 6 ft 8 in., claystone, medium-gray, very silty, slightly sandy, very micaceous, noncalcareous, irregular fracture; scattered small flakes of carbonaceous material.
------	1, 241–1, 342	Sand and common pyrite grains, and very rare sandstone at 1,294 ft.
27	1, 342–1, 352	Recovered 3 ft: 1 ft 6 in., claystone and clay shale as in core 26, fragments in drilling mud. 1 ft 6 in., drilling mud.
------	1, 352–1, 422	Sand. Rare small fragments light-bluish-gray limestone between 1,387 and 1,402 feet.
------	1, 422–1, 432	No sample.
28	1, 432–1, 442	Recovered 10 ft: 4 ft 6 in., drilling mud. 6 in., clay shale, medium-gray, very slightly silty in part, noncalcareous. Fair shaly cleavage. Beds lie flat. 2 ft, drilling mud. 3 ft, clay shale as above.

CORE ANALYSES

The sandstone beds, which are concentrated in the upper part of the section penetrated, have effective porosities ranging from 28.9 to 38.8 percent, as measured by the Washburn-Bunting method; air permeability of samples well enough indurated to test with a Hayward permeameter ranged from less than 10 to 780 millidarcys. Results of the tests are shown in the following table on porosity and permeability. Two additional samples from 180 and 192 feet which were studied at Pennsylvania State College had porosities of 37.1 and 30.2 percent, and Klinkenberg permeabilities (before liquid flow) of 252 and 969 millidarcys, respectively. The sample from 180 feet also had a permeability of 113 millidarcys for brine, and 38 millidarcys for fresh water.

Porosity and permeability of samples from Arcon Barrow core test 1

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)	Remarks
168	30.2		Too friable to make plug.
173	31.6		Do.
177	32.1	189	
180	37.6	197	Plug chipped.
182	35.5		Plug broken.
184	35.8	780	Plug chipped.
187	36.4		Plug broken.
190	36.9	660	Plug chipped.
192	36.9	680	Do.
195	37.6		Plug broken.
222	28.9	21.6	
229	28.9		Too friable to make plug.
231	32.2	56	Plug chipped.
263	37.4		Too friable to make plug.
265	38.8	<10	
268	37.4		Too friable to make plug.
274	35.4		Do.

A sieve analysis of sandstone from 173 feet showed the sample to be composed of 5.6 percent fine sand, 67.6 percent very fine sand, 2.3 percent silt, and 24.4 percent silt and clay, according to Wentworth's size classification. The specific gravity of several samples of claystone and siltstone is given in the following table on specific gravity.

Specific gravity of samples from Arcon Barrow core test 1

Depth (feet)	Specific gravity	Rock type
753	1.94	Clay shale.
864	2.10	Claystone.
959	2.20	Do.
1,028	2.35	Clay shale.
1,157	2.34	Siltstone.
1,233	2.39	Claystone.
1,240.5	2.63	Sandy siltstone.
1,350	2.32	Clay shale.

OIL, GAS, AND WATER ANALYSES

No shows of oil or gas were found in the hole. After an electric log had been run, the hole was bailed down to 125 feet, but the fluid level could not be lowered further. A sample of the salty water in the hole was analyzed by Cleo Rall, of the U.S. Bureau of Mines; the water contained 357 parts per million of calcium, 1,078 of magnesium, 8,478 of sodium, 260 of bicarbonate radical, 1,244 of sulfate, and 15,778 of chloride. The specific gravity was 1.018.

LOGISTICS

A drilling foreman, 2 other drillers, 3 floormen, a mechanic and an electrician made up the crew employed in drilling Arcon Barrow core test 1; they were housed at the Navy camp at Barrow. The equipment used in drilling the test was the Failing 314–C rig used for Skull Cliff core test 1 and, as listed by Arctic Contractors, included the following:

1 Failing 1500 drilling rig, model 314–C, with tubular mast, powered by Chrysler engine.
1 Gardner-Denver 4- by 5-in. mud pump, mounted in drilling wanigan.
1 Gardner-Denver 4- by 5-in. mud pump powered by Chrysler engine and mounted in pump wanigan.
1 Dravo heater, used for heating drilling rig and mud.
1 250-gal water tank mounted in drilling wanigan.
1 25-bbl tank made of pontoon section, mounted on sled.
1 O'Keefe and Merritt 15-kw a-c generator unit, model N–15.

The equipment and supplies were hauled from Skull Cliff by tractor train; a Caterpillar RD8 tractor with winch and blade and a weasel were used locally while the hole was being drilled. Both water and diesel fuel were brought from the Barrow camp.

DRILLING OPERATIONS

The drilling rig was set up on 12 by 12-inch timbers to a height of 24 inches above the ground, and enclosed with canvas. Instead of digging a cellar, a box 5 feet square and 2 feet high, constructed from 2- by 12-inch planks was used as a mud pit. The sides were waterproofed with cement. The petroleum engineer, J. R. Coleman, recorded the drilling operations discussed below.

Notes from drilling records

Depth (feet)	Remarks
60.75	A 9⅞-in. hole was drilled with a Hughes OSC–2 rock bit, and 2 joints (52.7 ft) of 7-in. casing cemented at 60.75 ft with 13 sacks of cement. After setting under pressure for 13 hr., hole was steamed for 48 hr. to prevent cement from freezing.
100	A 6⅞-in. Hughes rock bit was used to drill to 100 ft. At that depth a Failing reverse circulation head, swivel, and drill pipe were installed, replacing conventional circulation system, and were used to core from 100–143 ft. System unsatisfactory, because drilling mud went into rock instead of back up drill pipe. It also broke out around casing. Changed back to conventional coring and adding more mud corrected the trouble.
144	From 144 ft to total depth, hole drilled with Reed and Failing core and drill bits that were 5⅞ in. in diameter.
144.5	Two bolts dropped in hole; one pressed into wall and other recovered with homemade junk basket.
200	Deviation ½°.
600	Deviation 1¾°.
700	Deviation ½°.
900	Deviation 4½°. No deeper deviation measurements could be made because only available cable was 925 ft long.
1,442	Drill-pipe threads eroded away on several joints, while lower part of hole was being drilled. When total depth was reached, drill pipe was put in the hole and mud circulated preparatory to running and electric log. Pipe stuck at 507 ft, but was freed after 4 hr of work. Electric log was

Notes from drilling records—Continued

Depth (feet)	*Remarks*
1,442—Con.	run with improvised equipment, except for Schlumberger measuring instruments. It was run between bottom of casing and bridge in hole at 1,154 ft. Resistivity curve gave an adequate representation of rock types found in hole. Spontaneous-potential curve affected by stray surface currents, but does reflect, to some extent, variations in porosity and permeability of the rock. Electric log gave no evidence of presence or lower limit of permafrost, but base of permanently frozen ground is believed to be at about 1,000 ft.
	After log was run, hole was bailed to 125 ft, but fluid level could not be lowered further. In order to prepare hole for temperature tests in future, 708 ft of 2½-in. tubing was put into hole and clamped to casing. Tubing filled with about 3½ drums of diesel fuel, and casing filled with drilling mud. Tubing fitted with 2-in. valve for easy access, and hole covered and marked.

SOUTH BARROW TEST WELL 1

Location: Lat 71°19′12″ N., long 156°42′16″ W.
Elevation: Ground, 5 feet; derrick floor, 18 feet.
Spudded: August 15, 1948.
Completed: November 11, 1948. Dry and abandoned.
Total depth: 3,553 feet.

South Barrow test well 1, the first of the deeper tests near Point Barrow, was drilled for more information about the age and character of the rocks in the area. Seismic work had shown the region to be unusually high structurally. The test well, located 1,500 feet inland from the shore of the Arctic Ocean and less than a mile southwest of Barrow Camp (see fig. 50), was on a site which had the most favorable foundation conditions in the vicinity of the anomaly.

Rig building started late in July 1948, and the hole was spudded in on August 15th. Below nearly 60 feet of sand, gravel, and clay of the Gubik formation, the test penetrated the top of the Grandstand formation, of Cretaceous age. The contact is placed at 70 feet, where the first abundant subangular, clear and white quartz sand typical of the Nanushuk group was noted, contrasting with the clear, yellow, or black well-rounded quartz and chert of the overlying Gubik formation. The first Cretaceous fossil, a fragment of an *Inoceramus*, was recovered from 105 feet. The Grandstand formation consists of 250 feet of massive sandstone beds separated by clay shale. All the formation is within the zone of permafrost, as ice was found in the hole to a depth of 615 feet.

The underlying Topagoruk formation also consists of clay shale and sandstone, but the latter is very fine grained, and the beds are very thin and comparatively rare; the contact with the Grandstand formation is at 320 feet, at the base of the lowest massive sandstone bed.

Both the Topagoruk and the Oumalik formations are thicker in this test than elsewhere in the area. The Topagoruk formation, underlying and gradational with the Grandstand formation, is 1,780 feet thick (320–2,100 ft.), and the Oumalik formation is 725 feet thick (2,100–2,825 ft).

The pebble shale is also thicker in this test than in other South Barrow test wells. The uppermost typical quartz grains appeared at 2,825 feet, and the section, including the basal conglomerate, is 560 feet thick. The cores from the lower part of the interval of rocks are poor, however, and fragments of rock resembling the Jurassic sandstone may represent a few feet of Jurassic beds in the well, instead of being part of the basal conglomerate, as they are here considered. Fragmental remains of actinopterygian fish were found in the lower part of the formation. Below 3,352 feet, cored intervals of rocks had no recovery or were represented only by drilling mud and rock fragments. The 1 foot recovered from the rocks cored at 3,355–3,360 feet included fragments of claystone similar to that in overlying beds and some small pieces of argillite like that drilled below 3,385 feet. The other cores and ditch samples between 3,355 and 3,385 feet contain the claystone and chert pebbles of the overlying beds but lack the argillite. The argillite is hence considered to be part of the basal conglomerate. The recovered rock was badly broken through the interval, however, and the argillite at 3,355 to 3,360 feet might represent the top of the pre-Mesozoic beds and the cores between 3,360 and 3,385 feet cavings from above. The electric log shows no sharp break through this 30-foot interval of rock which would indicate the position of the contact.

The argillite of pre-Mesozoic age is the oldest rock drilled in the test well. It differs from the overlying strata by being harder, more siliceous, more fractured, and very steeply dipping. It was described by Charles Milton, of the U.S. Geological Survey, as being a black cherty rock possibly made up of volcanic ash and radiolarian chert. (See p. 590.) The test penetrated these beds from 3,385(?) feet to the total depth of 3,553 feet, but the rocks in this interval represent only about 80 feet of strata, because of the steep dip.

The only indications of oil were faint shows in thin sandstone beds between 3,045 and 3,165 feet; formation tests recovered no oil or gas. After the total depth had been reached, salt water entered the hole, and the test was abandoned on November 11, 1948. Plate 41 presents much of the available data graphically.

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

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

Core	Depth (feet)	Remarks
------	0–13	Kelly bushing to ground level.
------	13–15	Ground level to cellar floor.
------	15–39	No samples received in Fairbanks laboratory. Well geologist, W. C. Fackler, describes material in this interval as gravel, composed of pea-sized grains of black, brown, and gray chert, quartzite, and quartz, and a small amount of coarse sand. Material was frozen.
------	39–70	The washed ditch samples from this interval consist of gravel, cement, and rare coal particles; described by the well geologist, however, as being soft sticky blue-black to brown clay. Latter description probably correct, and gravel is contamination from above; composition shown on graphic log (pl. 41) has been based on this assumption.
------	70–110	Of the washed ditch samples, one-third consists of rounded sand and gravel and two-thirds of very fine grained subangular sand grains of clear and white quartz with some black and green grains and mica and rare pyrite. Described by well geologist as dark-gray clay shale. Hole probably penetrated clay shale interbedded with friable, very fine grained sandstone; rounded coarse sand and gravel presumed to be contamination from above. *Inoceramus* shell fragment present at 105 ft. Top of Grandstand formation at 70 ft.
------	110–165	Samples similar to those just above, except for addition of small amount of soft yellowish-gray calcareous material that is probably drilling mud (but may represent clay shale or clay ironstone). Glauconite common at 115–120 ft. Sand at 145 ft contains larger proportion of clear quartz than overlying sand.
------	165–195	Sandstone, medium-gray, very fine grained, slightly silty and argillaceous, very calcareous; composed of subangular grains of clear and white quartz and chert, common carbonaceous particles, pyrite, and biotite particles.
------	195–200	Sandstone as above but with light-yellowish-gray clay ironstone.
------	200–230	Sandstone as above but friable and noncalcareous in upper 5 feet. Medium-gray slightly silty noncalcareous clay shale at the base.
------	230–260	Siltstone, medium-gray; slightly calcareous toward base; some friable noncalcareous sandstone, and some yellowish-gray clay ironstone.
------	260–275	Sandstone, medium-gray, very fine grained, slightly argillaceous and silty, partly calcareous; contains small amount of chlorite.
------	275–285	Clay shale, medium-gray, slightly silty, noncalcareous.
------	285–305	Siltstone, medium-light-gray, slightly argillaceous, very calcareous; gray clay shale and some pyrite in lower part; crinoid ossicle (*Balanocrinus* sp.) at 285–290 ft.
------	305–320	Sandstone, medium-gray, partly calcareous.
------	320–360	Siltstone, light-olive-gray, partly sandy, very argillaceous in part. Common minute pyrite concretions. Top of Topagoruk formation at 320 ft.
------	360–390	Siltstone and clay shale; rare pyrite. Crinoid (*Balanocrinus* sp.) ossicle at 380–390 ft.
------	390–441	Clay shale, gray to dark-gray, bentonitic; described as soft by well geologist.
------	441–570	Clay shale as above but with 2 thin sandstone beds at 530 and 560 ft and pieces of pyrite at 420, 440, and 460 ft. Crinoid (*Balanocrinus* sp.) ossicles at 450–460, 460–470, 550–560, 560–570 ft; echinoid spine at 540–550 ft; ophiuroid fragments at 550–560 ft.
------	570–600	Sandstone, medium-light-gray, very fine grained, slightly silty, friable; particles of biotite and carbonaceous material and pyrite.
------	600–660	Sandstone and clay shale, and, in bottom 5 ft, some black shiny coal that has blocky to conchoidal fracture.
------	660–695	Sandstone, gray, friable; some coal between 665 and 680 ft.
------	695–700	Siltstone, medium-gray, sandy, argillaceous, very calcareous.
------	700–725	Siltstone, partly very sandy, clay shale, and rare sandstone. Carbonaceous particles common.
------	725–950	Clay shale; some sandstone and siltstone. Sandstone is medium light gray, very fine grained, silty, very argillaceous in part, calcareous in part. Sand is composed of subrounded clear and white quartz, some dark rock fragments, rare biotite, and very rare pyrite. Siltstone is medium to medium light gray, argillaceous, calcareous in part, with rare light-yellowish-gray very calcareous siltstone. Clay shale is medium gray, slightly to very silty, calcareous, micaceous in part.
------	950–1, 200	Clay shale; small amount of sandstone and siltstone. Clay shale is medium gray, slightly to very silty, and slightly calcareous. Rare pyrite nodules. A few pieces of medium-gray dense argillaceous limestone present in sample from 1,175 ft.
1	1, 200–1, 210	Recovered 5 ft: Drilling mud and small fragments of medium-gray noncalcareous slightly micaceous clay shale.
------	1, 210–1, 215	Clay shale.
------	1, 215–1, 225	Siltstone, medium-gray, argillaceous, calcareous, and medium-light-gray silty argillaceous calcareous sandstone.
------	1, 225–1, 285	Interbedded sandstone, siltstone, and clay shale.

Lithologic description—Continued

Core	Depth (feet)	Remarks
------	1, 285–1, 525	Clay shale, medium-gray, noncalcareous; some light-olive-gray clay shale at 1,415 ft, and some clay ironstone at 1,345–1,365 and 1,495–1,505 ft. Pyrite is abundant at 1,340–1,380 ft and in rocks between 1,455 and 1,525 ft; many small tubes, rods, and twig-shaped pieces of pyrite at 1,345–1,350 ft.
------	1, 525–1, 575	Clay shale as above but with thin beds of sandstone and very pyritic siltstone.
------	1, 575–1, 600	Clay shale; abundant pyrite.
2	1, 600–1, 610	Recovered 8 ft: Clay shale, medium-gray, very slightly micaceous in part, noncalcareous; fair shaly cleavage suggests beds dip less than 5°.
------	1, 610–1, 775	Clay shale, medium-gray, silty; very small amount of pyrite, and rare thin beds of medium-gray very argillaceous slightly calcareous micaceous siltstone. Carbonaceous or coaly particles scattered through the rock, especially in lower part. *Balanocrinus* sp. ossicle at 1,720–1,730 ft.
------	1, 775–1, 810	Clay shale as above but with thin beds of siltstone and sandstone.
------	1, 810–1, 875	Clay shale and sandstone, interbedded.
------	1, 875–1, 895	Sandstone, medium-light-gray, very fine grained, silty, argillaceous, micaceous, very slightly calcareous; composed of subangular clear and white quartz with dark rock fragments and carbonaceous particles.
------	1, 895–1, 906	Clay shale as above.
3	1, 906–1, 916	Recovered 8 ft 2 in.: 10 in., siltstone, medium-gray, argillaceous, micaceous, noncalcareous; irregular fracture. 7 ft 4 in., sandstone, light-gray, fine to very fine grained, slightly silty and argillaceous, slightly micaceous, noncalcareous; friable in part; composed of subangular grains of clear quartz with some white quartz, dark rock fragments, and gray chert.
------	1, 916–1, 955	Sandstone, medium-light-gray, very fine grained, friable; a few thin beds of clay shale.
------	1, 955–2, 000	Clay shale interbedded with sandstone and siltstone.
------	2, 000–2, 094	Clay shale; a few beds of siltstone in lower half.
4	2, 094–2, 100	Recovered 6 ft: 1 ft, sandstone, light-gray, fine to very fine grained, slightly silty and argillaceous, slightly micaceous, noncalcareous; friable in part; composed of subangular clear and white quartz, gray chert, and dark rock fragments. 5 ft, claystone, medium-gray to medium-dark-gray, very silty and micaceous, noncalcareous, massive; irregular fracture. Small carbonized plant fragments scattered through the rock.
------	2, 100–2, 335	Claystone as in core 4. Top of Oumalik formation at 2,100 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
------	2, 335–2, 345	Siltstone, light-yellowish-gray, argillaceous, calcareous.
------	2, 345–2, 352	Clay shale, medium-gray, silty.
5	2, 352–2, 360	Recovered 6 ft 6 in.: Claystone as in core 4; irregular streaks of medium-light-gray sandstone at 2,354 ft dip 10°–20°; dip may represent crossbedding.
------	2, 360–2, 625	Clay shale, medium-gray; rare thin beds of siltstone. Pyrite grains common to abundant. *Balanocrinus* sp. ossicles at 2,380–2,390 and 2,390–2,400 ft.
6	2, 625–2, 635	Recovered 10 ft: Clay shale, medium-dark-gray, slightly silty in part, micaceous, noncalcareous; rare silty micaceous partings and good shaly cleavage dip about 30°.
------	2, 635–2, 785	Clay shale as in core 6.
------	2, 785–2, 815	Clay shale containing flakes of black very carbonaceous very fissile clay shale.
------	2, 815–2, 825	Clay shale, dark-gray, carbonaceous; very pyritic in part; silty in part; some is fissile.
------	2, 825–2, 847	Claystone, dark-gray; rare well-rounded quartz grains as in core 8. A few pieces of light-greenish-gray bentonite at base of interval. Top of pebble shale at 2,825 ft.
7	2, 847–2, 853	Recovered 6 in.: Claystone, medium-dark-gray, noncalcareous; irregular fracture; minor amount of medium-gray noncalcareous siltstone present.
8	2, 853–2, 856	Recovered 1 ft 6 in.: Claystone, dark-gray, very silty, micaceous, noncalcareous; irregular fracture. Rare well-rounded clear quartz sand grains scattered through the rock.
------	2, 856–3, 035	Claystone as in core 8, but with greenish-gray and pale-greenish-yellow bentonite in upper part. Black chert pebbles, well-rounded and less than ¼-in. in diameter, are very rare. Electric log suggests presence of some sandstone similar to that in core 17 at 2,875 and 2,970 ft.
------	3, 035–3, 036	No sample.
9	3, 036–3, 046	Recovered 10 ft: Clay shale, dark-gray, slightly to very silty, micaceous, noncalcareous; contains fine- to coarse-grained well-rounded clear quartz grains and very rare well-rounded black chert granules scattered through the rock. Lines and small streaks of pyrite as much as three-quarters of an inch long are abundant, and show no orientation. Poor shaly cleavage to subconchoidal fracture suggests beds lie flat.
10	3, 046–3, 056	Recovered 6 in.: Drilling mud with fragments of medium-light-gray very fine to fine grained very silty and argillaceous slightly calcareous sandstone composed of subangular to subrounded clear and white

Lithologic description—Continued

Core	Depth (feet)	Remarks
		quartz with some chert and dark rock fragments. Rare mica, pyrite, and carbonaceous particles; large rounded quartz grains absent.
11	3, 056–3, 059	Recovered 8 in.: Claystone, dark-gray, very silty, micaceous, noncalcareous; scattered lines of pyrite and clear quartz grains as in core 9 above.
12	3, 059–3, 064	Recovered 2 ft 10 in.: Claystone as above but with common quartz grains and lines and streaks of pyrite.
13	3, 064–3, 067	Recovered 3 ft: Clay shale like claystone in cores above. Poor shaly parting suggests beds lie approximately flat.
14	3, 067–3, 069	Recovered 2 ft: Clay shale as in core 13 above.
15	3, 069–3, 071	Recovered 2 ft: Clay shale as in core 13 above.
16	3, 071–3, 076	Recovered 5 ft: Clay shale as in core 13 above but with very rare small carbonized plant fragments.
17	3, 076–3, 079	Recovered 11 in.: Sandstone, light-olive-gray, very fine grained, very silty and argillaceous, very slightly calcareous; composed of angular grains of clear and white quartz and some dark rock fragments.
18	3, 079–3, 083	Recovered 3 ft 6 in.: Clay shale as in core 13 above.
19	3, 083–3, 088	Recovered 5 ft: Clay shale as in core 13 above but with a 4-in. interval of dark-brownish-gray slightly calcareous clay ironstone in upper 1 ft of core.
20	3, 088–3, 093	No recovery.
21	3, 093–3, 098	Do.
22	3, 098–3, 099	Do.
23	3, 099–3, 100	Do. Note: Depth corrected from 3,100–3,095.5 ft.
24	3, 095. 5–3, 115	Recovered 20 ft 6 in.: Claystone as in core 9; abundant lines of pyrite are straight or curved, have no orientation except that they have little or no dip. Some may be plant-stem replacements. Rare carbonaceous particles. Slickensides at 3,107 ft dip 28°. Specimen of *Thracia*? sp. at 3,108 ft.
25	3, 115–3, 125	Recovered 5 ft 6 in.: 6 in., sandstone, light-olive-gray, fine to very fine grained, silty, argillaceous, calcareous, massive; composed of angular clear quartz and some white quartz grains and gray chert; lacks pyrite. Contact with claystone sharp, approximately horizontal. 5 ft, claystone as in core 9, very uniform. Pelecypods *Thracia kissoumi* McLearn, *Astarte* n. sp., and *Entolium* sp. came from 3,118, 3,120, and 3,121 ft, respectively.
26	3, 125–3, 133	Recovered 8 ft: 7 ft, claystone as in core 9. Gastropod, *Epitonacea*? recovered from 3,125 ft, and a worm tube and brachiopod from 3,126 ft. 1 ft, sandstone as in core 25.
27	3, 133–3, 144	Recovered 10 ft 10 in.: 1 ft, claystone, dark-gray, silty, noncalcareous; irregular patches and lenticles of light-olive-gray fine-grained silty noncalcareous sandstone ⅛–4 in. thick, as much as 3 in. in diameter, with variable dip which may be as much as 30°. They total 5–10 percent of the rock. 6 in., claystone as in core 9. 1 ft 2 in., claystone with sandstone as at top of core. 8 ft 2 in., claystone as in core 9. A 1-in. bed of light-brownish-gray noncalcareous clay ironstone with conchoidal fracture present at 3,142 ft. Specimen of *Thracia kissoumi* McLearn found at 3,138 ft.
28	3, 144–3, 163	Recovered 19 ft: 4 ft 3 in., claystone as above. 2 ft 8 in., sandstone as in core 25; sharp, approximately horizontal contact with claystone above and below. 11 ft 7 in., claystone as above, with a well-rounded pebble (¼ in. thick and 2 in. in diameter) of hard black micaceous shale containing minute grains of chert (and quartz?). Pebble in an approximately horizontal position, at 3,154 ft. 6 in., sandstone as above.
29	3, 163–3, 181	Recovered 18 ft: 6 in., sandstone as above. 17 ft 6 in., claystone as above. Well-rounded 2½-in. pebble of black silty micaceous hard claystone noted at 3,174 ft, and pelecypod fragments at 3,169 and 3,174 ft.
30	3, 181–3, 193	Recovered 12 ft: Claystone as above; cycad and pelecypod fragments at 3,190 ft.
31	3, 193–3, 207	Recovered 4 ft 11 in.: Claystone as above but with a 6-in. bed of sandstone 2½ in. above base of core. Pelecypod shell (cf. *Psilomya*) and fish vertebrae at 3,193 ft.
32	3, 207–3, 217	Recovered 10 ft: Claystone as above.
33	3, 217–3, 226	Recovered 9 ft: Claystone as above; specimen of pelecypod *Entolium* sp. and an unidentified gastropod found at 3,221 ft.
34	3, 226–3, 237	Recovered 8 ft 6 in.: Claystone as above.
35	3, 237–3, 250	Recovered 4 ft 6 in.: Claystone as above but with a specimen of pelecypod *Solecurtus*? sp. at 3,235 ft.
36	3, 250–3, 260	Recovered 3 ft: Drilling mud.

Lithologic description—Continued

Core	Depth (feet)	Remarks
------	3, 260–3, 305	Claystone as in cores above.
------	3, 305–3, 330	Interbedded siltstone and claystone with rare sandstone. Siltstone and sandstone are light olive gray, argillaceous, noncalcareous, and nonmicaceous. Claystone is light olive gray, very slightly calcareous, slightly bentonitic.
37	3, 330–3, 341	Recovered 11 ft: 5 in., claystone, light-olive-gray, slightly bentonitic, very slightly calcareous; conchoidal fracture with a smooth feel; grader to light-olive-gray siltstone. 1 ft 4 in., siltstone, light-olive-gray; abundant irregular patches, ¼–2 in. in diameter, of medium-gray claystone; common patches of light-gray fine and very fine grained sandstone. Sandstone decreases with depth and rock grades into unit below. 9 ft 3 in., claystone, medium-dark-gray, very silty, micaceous, noncalcareous, pyritic (with pyrite nodules and lines); rare small fragments of carbonized plants. Patches of medium-gray siltstone in lower part increase from rare to abundant, totaling over half the rock about 1 ft above base. Basal 1 ft, however, has only rare siltstone patches.
38	3, 341–3, 346	Recovered 1 ft: Drilling mud, and rounded pebbles of gray and black chert (as much as 3/16-in. in diameter), rounded chert fragment 2 in. in diameter, and rare fragments of medium-dark-gray claystone and 1 or 2 pieces of light-olive-gray claystone as at top of core 37.
39	3, 346–3, 349	Recovered 2 ft: Drilling mud and rock fragments as in core 38.
40	3, 349–3, 352	Recovered 3 ft: Drilling mud and rock fragments as in core 38. Some medium-dark-gray claystone fragments 3 in. in diameter. A few inches of core are of light-greenish-gray very argillaceous conchoidal-fracturing bentonite that has patches of siltstone up to 1 in. in diameter and minute (less than ¼-in. long, 1/16-in. wide) inclusions of medium-light-gray bentonite.
41	3, 352–3, 355	No recovery.
42	3, 355–3, 360	Recovered 1 ft: Claystone and siliceous argillite fragments; former dark to medium dark gray, silty, pyritic; rare coarse well-rounded clear quartz and chert grains. Siliceous argillite is dark bluish gray, hard, as in core 48 below.
43	3, 360–3, 362	No recovery.
------	3, 362–3, 368	Claystone as above.
44	3, 368–3, 374	Recovered 1 ft 2 in.: Drilling mud and rock fragments as in core 38.
45	3, 374–3, 376	Recovered 2 ft: Drilling mud and rock fragments as in core 38.
------	3, 376–3, 382	Claystone as above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
46	3, 382–3, 382. 5	Recovered 6 in.: Drilling mud and rock fragments as in core 38.
------	3, 382. 5–3, 385	Claystone as above.
------	3, 385–3, 402	Argillite fragments, dark-bluish-gray, very siliceous; abundant quartz veinlets; light-bluish-gray where most siliceous. Top of pre-Mesozoic rock at 3,385(?) ft.
47	3, 402–3, 410	Recovered 1 ft 6 in.: Drilling mud with rock fragments as in core 38.
------	3, 410–3, 448	Argillite, medium- to dark-bluish-gray, siliceous, hard; blocky fracture; white quartz veinlets. Some is darker, less siliceous, and somewhat fissile.
48	3, 448–3, 451	Recovered 2 in.: Argillite, bluish- to grayish-black, siliceous, noncalcareous, hard; blocky fracture: scattered minute pyrite particles.
49	3, 451–3, 452. 8	Recovered 2 in.: Argillite, siliceous, as above, but with rare minute quartz veinlets. A fragment was described by Charles Milton as being a black cherty rock, grading into carbonaceous shale, which has irregular whitish contorted siliceous streaks. It contains two types of material: a fine-grained carbonaceous siliceous sedimentary rock, possibly volcanic ash originally, and clear quartz, in eucrystalline masses and flaring chalcedonic aggregates. Sedimentary rock contains numerous spheroidal quartz aggregates that suggest Radiolaria and other marine microfossils, and lozenge-shaped masses of quartz that are presumably siliceous replacements of dolomite crystals. The rock also contains minute euhedral pyrite crystals.
------	3, 452. 8–3, 495	Argillite, siliceous, as in cores 48 and 49.
50	3, 495–3, 497	Recovered 1 ft: 4 in., argillite fragments, as above. 8 in., chert, light-gray with scoriaceous texture on surface of core; grades to medium-gray with sandy texture in center, where the rock is very porous and sugary. Two thin (less than 1/8 in.) beds of medium-dark-gray clay shale dip 60°–70°, and are paralleled by a quartz veinlet. A fragment studied by Charles Milton (written communication, Jan. 19, 1949) was described by him as a gray highly porous somewhat calcareous siliceous rock with disseminated pyrite and irregular carbonaceous aggregates. The quartz, in a mosaic of tiny anhedral grains, comprises about four-fifths of the rock, with calcite making up about one-tenth. A mineral with low birefringence, moderate refractive indices (about 1.61), and a tabular hexagonal habit makes up part of the remaining

Lithologic description—Continued

Core	Depth (feet)	Remarks
		one-tenth; it is probably a secondary chlorite mineral. The rock resembles phtanite, a sediment of original siliceous composition which is commonly rich in radiolarians and carbonaceous material. No detrital minerals were observed in this sample, and "the rock probably originated as an organic marine sediment, with siliceous organisms predominant. The chlorite may represent clayey material of volcanic origin."
------	3, 497–3, 537	Argillite, siliceous, as in cores 48 and 49 above.
51	3, 537–3, 539	Recovered 6 in.: Argillite, siliceous, as in core 48 above, with quartz veinlets paralleled by finely grooved slickensides.
------	3, 539–3, 551	Argillite, siliceous, as above.
52	3, 551–3, 553	Recovered 8 in.: Argillite, siliceous, as above but with layers and small lenses of medium-gray argillaceous siliceous siltstone and minute quartz veinlets dipping about 40°.

CORE ANALYSES

Sandstone beds in the Grandstand formation, present in the upper part of the test, were not cored. Thin sandstone beds lower in the hole have been analyzed in the Fairbanks laboratory for porosity by the Washburn-Bunting method, and for permeability with a Hayward permeameter, with the results shown in the following table on porosity and permeability. Most of the sandstone is noncalcareous; samples for which the carbonate content was measured also appear in the following table.

Porosity, permeability, and carbonate content of some sandstone samples from South Barrow test well 1

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)	Content of carbonate minerals (percent by weight)
1,908	23. 1	15. 5	----------
1,911	23 7	16. 7	----------
1,914	28. 2	----------	----------
2,094	24. 5	----------	----------
3,046	14. 8	10. 5	----------
3,078.5	14. 9	----------	----------
3,115.5	9. 1	5. 0	18. 2
3,132	13. 1	<4	----------
3,153	18. 1	24. 3	----------
3,154	16. 6	9. 8	14. 5
3,163	18. 2	62. 0	9. 5
3,185.5	14. 4	7. 0	----------
3,198	11. 0	<5	----------

Sieve analyses of some sandstone samples, and specific gravity determinations on several rock types cored in the hole are given in the following two tables.

Sieve analyses of sandstone samples from South Barrow test well 1 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 and clay)	<325 mesh (clay)	Total
1,911	Tr.	0.2	38.8	38.1	8.7	14.3	100.1
3,078.5	-------	1.9	58.6	25.8	3.6	10.1	100.0
3,115.5	-------	4.8	66.9	15.4	3.8	9.1	100.0
3,132	-------	.9	67.1	17.5	4.6	9.9	100.0
3,154	-------	1.6	73.2	14.0	3.2	8.0	100.0
3,163	Tr.	1.8	67.0	19.2	3.0	9.1	100.1

Specific gravity of rock samples from South Barrow test well 1

Depth (feet)	Specific gravity	Rock type
1,205	2. 33	Clay shale.
1,601	2. 35	Do.
1,911	2. 04	Argillaceous sandstone.
2,356	2. 32	Clay shale.
3,042	2. 46	Black shale.
3,115	2. 41	Sandstone.
3,150	2. 39	Black shale.
3,331	2. 40	Sandstone.
3,340	2. 48	Silty shale.
3,497	1. 74	Porous siliceous rock.
3,536	2. 49	Argillite.

Three samples of sandstone (from 3,046, 3,076, and 3,115 ft) were sent to S. T. Yuster, who studied them for reservoir properties. After measuring the Klinkenberg air permeability, and the permeability to brine (a 1-percent solution of sodium chloride), fresh water, and oil, the oil-saturated samples were tested for their permeability to brine. After extracting the fluids from the samples, a final test of permeability to air gave figures much higher than before, an unusual result apparently caused by the removal of soluble or colloidal cement and interstitial material (primarily gypsum and clay minerals) by the liquids used in the tests. Data from the experiments, presented in the following table on reservoir properties, indicate that reservoir properties of these rocks are poor, because the porosity and permeability are too low to furnish adequate storage or yield of oil. Samples of these rock specimens were also studied by P. D. Krynine, who measured the percent of fine material (smaller than 325 mesh, 44-micron sieve) and determined its mineral composition by X-ray analysis. His results are shown in the following table on X-ray analyses.

Reservoir properties of sandstone samples from South Barrow test well 1

[Analysis by S. T. Yuster]

Depth (feet)	Porosity (percent)	Klinkenberg permeability (millidarcys)		Liquid permeability (millidarcys)			
		Before liquid flow	After liquid flow	Brine	Fresh water	Oil (through brine-filled sample)	Brine (through oil-filled sample)
3,046	13.1	2.38	24.7	1.80	1.30	0.67	0.3
3,076	13.4	4.25	7.47	3.57	3.12	1.19	.044
3,115	13.0	10.6	46.6	7.50	4.90	6.85	.24

X-ray analysis of fine (less than 325 mesh) material of sandstone samples from South Barrow test well 1

	Depth of sample (feet) and percent of total rock		
	3,046	3,076–3,079	3,115–3,125
	33	40	25
Quartz	49	47	50
Albite	6.5	5	6
Montmorillonite	0	0	5
Kaolinite	2	12	2.5
Illite	20	10	17
Chlorite	3	(?)	5
Calcite	20	21	15

Two heavy-mineral zones were recognized by R. H. Morris, who studied heavy minerals from this test well. One sample, at 165 feet, is representative of the glaucophane zone; the zoned-zircon zone is present between 1,907 and 3,330 feet. The stratigraphic value of these zones is uncertain; both are found in more than one formation in the Nanushuk group, and the zoned-zircon zone occurs in earlier beds, as well. Plate 40 shows the abundance of the various heavy minerals in the samples studied.

Petrographic studies were made of 13 core samples by P. D. Krynine. The rock is subgraywacke and consists primarily of angular subequant grains of quartz, chert, and rock particles, with much silt and clay interstitial material. The quartz was originally from veins or intrusive rocks which were probably metamorphosed before being eroded to furnish quartz to the sediments. The detrital chert grains are colorless, yellow, or dark gray, and cryptocrystalline to coarse (crystals as much as 20 microns in diameter). Some, particularly from samples taken below 3,100 feet, contain 5–15 percent of dolomite rhombs. Rock fragments include dark shale, micaceous siltstone, and siliceous shale. Fragments of low-rank metamorphic rocks such as phyllite, slate, and chlorite schist make up a large part of the sediment and increase in abundance with depth; high-rank metamorphic rocks (predominantly mica schist), granite, and volcanic rocks are only a minor constituent and are slightly more common in the upper part of the test well. Some authigenic minerals are also present. Illite, the most abundant mineral, makes up most of the clay coatings on the sand grains; chlorite, kaolinite, and montmorillonite are not as common, but the latter is present in great enough quantities, in most specimens, to cause a decrease in permeability on hydration. The proportion of carbonate minerals varies widely, is nearly absent in some samples, and constitutes as much as 30 percent of the rock in others. More details of the study are given in the following table on petrographic characteristics.

OIL AND GAS

Only very slight shows of oil and gas were found in this test well. The gas detector showed slight intermittent indications of gas below 2,800 feet, but none was noticed in the ditch. Faint shows of oil were present in 9 thin beds (less than 3 ft thick) of sandstone between 3,045 and 3,165 feet, but no oil was seen on the ditch, and the formation tests recovered no shows of oil or gas.

With the depth of the hole at 3,226 feet, the wall packer was set for the first Johnston formation tester at 3,030 feet; perforated pipe hung at 3,040–3,053 and 3,140–3,157 feet. The packer failed to hold, and the tool contained seven stands of drilling mud with no shows when it was pulled out. For the second test, the packer was set at 3,042.5 feet, after 12 feet of perforated pipe was removed. Perforations were then at 3,047.5–3,052 and 3,143–3,154 feet. The packer held for 1 minute, and then failed. No shows of oil or gas were noted in the 8¼ stands of drilling mud recovered.

When the total depth of 3,553 feet had been reached and various surveys made in the hole, tubing was lowered to 3,040.5 feet, and the fluid level was swabbed down to 580 feet. Continuous swabbing could not lower the fluid level below 600 feet, and it rose to 375 feet with the entrance of salt water. The dilution of the drilling mud raised its salinity from less than 50 to 396 grains per gallon.

The third formation test was made with the packer at 3,013 feet, and the pipe was perforated at 3,038.5–3,049.5 and 3,139.5–3,156 feet. The tubing filled with water before the packer was set. The trip valve did not open, and an attempt to reset the packer was not successful, probably because the hole was irregularly enlarged.

Petrographic characteristics of sandstones from South Barrow test well 1

[Determined by Paul D. Krynine]

Depth	1,911 ft	2,094 ft	3,046 ft [1]	3,046 ft	3,076 ft [1]	3,115 ft [1]	3,115.5 ft	3,132 ft	3,153 ft	3,154 ft	3,163 ft	3,185.5 ft	3,198 ft
Texture													
Average diameter range, mm	0.02–0.20	0.04–0.24	0.03–0.17	0.04–0.13	0.04–0.18	0.07–0.28	0.05–0.20	0.01–0.20	0.03–0.21	0.02–0.25	0.04–0.20	0.02–0.30	0.03–0.90
Principal mode, mm	.11	.17	.08	.10	.12	.15	.16	.14	.14	.15	.14	.135	.18
Grains: matrix: cement, ratio, in percent	80:18:2	85:13:2	72:18:10	70:20:10	75:17:8	75:12:12	75:8:17	85:11:4	81:15:4	80:12:8	88:9:3	84:13:3	80:11:9
Grain composition, in percent													
Quartz	40	31	30	30	35	32	35	27	36	28	42	35	32
Chert	14	22	5	7	12	10	12	30	25	29	14	15	16
Feldspar	8	8	3	3	5	4	7	2		Trace	2.5	2	2
Mica flakes (large)	Trace	1	Trace		1			Trace		Trace		Trace	
Slate, phyllite	18	18	25	20	20	25	17	26	24	20	26	32	36
Quartzite, schist	Trace	2.5	2	3–4	2	5	2	Trace		Trace	3	Trace	
Volcanic rocks	1	1.5	3	4	2	2	3						
Biotite					Present					Present			
Chlorite		Present	Present		Present			Present		Present			
Muscovite	Present	Present	Present										
Glauconite			Present		Present			Present					
Zircon								Present					
Interstitial material, in percent													
Chlorite	1	1	2	3	3	1	1	1–2	2	4	1	2	1
Sericite	5	4	4	4	2	3	2	2	4	3	6	8–9	2
Illite	4	3	8	10	6	3	2	6	5	3			5
Montmorillonite			?	?	?	2	2		4	2	1	1–2	1
Kaolinite	8	7	2–3	3	6	3	1	1–2	Trace	1	1.5	2.5	Trace
Silica cement	Trace	Trace	Trace	Trace	1–2	2	1–2	1	4	7	2	1	8
Carbonates	2	2	10	9	7	11	15	2.5					
Glauconite			2	2									
Gypsum					Trace	Trace	1				1		(?)
Pyrite												Trace	
Barite													
Pore space and characteristics													
Pore size, principal mode, microns	33	53	20	15	25	25	30	30	48	37	35	30	26
Visible porosity, percent	7	8	1	2	2	2.5	2.5	3	6	4.5	5	2	2
Residual porosity	Good	Good	Poor	Poor	Poor	Poor	Poor	Poor to fair	Good	Fair	Fair to good	Poor	Poor
Bonding material	Clay, illite	Clay	Illite	Illite	Illite	Illite, carbonate	Carbonite, illite	Illite	Illite	Illite	Illite, silica	Silica, illite	Illite, carbonate
Clay-coated wall area, percent	55–60	55	80–85	70–80	80	70–75	65	75	55	58	60	80	80
Wall coating, type	Kaolinite, illite	Kaolinite, illite	Illite	Illite	Illite	Illite	Illite	Illite	Illite	Illite	Illite	Illite, silica	Illite, carbonate
Potential hydration	High	High	High	High	High	High	Moderate	Moderate	Moderate	Moderate	Moderate	Moderate	Very high

[1] Samples analyzed by S. T. Yuster (see p. 592).

LOGISTICS

Personnel and housing.—Four supervisors (a drilling superintendent, a petroleum engineer, a geologist, and a drilling foreman) were in charge of the drilling. The 2 rig crews which made up the rest of the permanent personnel included 2 drillers, 2 derrickmen, 6 floormen, a welder and mechanic, and 2 boiler firemen. Other helpers came from the Barrow camp when special services were needed.

The crew slept at Barrow camp, except for the drilling foreman who had a sleeping wanigan at the rig site. Meals were eaten at the camp except for the midtour meal, which was brought from the camp to the rig in insulated containers, and eaten in a wanigan provided for the purpose. Other wanigans housed the geologist's and petroleum engineer's office, and the boiler that heated the rig.

Vehicles and heavy equipment.—Three weasels (military tracked vehicles) and a T–9 crane were assigned to the well site; other vehicles were brought from Barrow camp as they were required. Major items of equipment used in drilling the well were listed by Arctic Contractors as follows:

1_____ National 50 drawworks.
2_____ Gardner-Denver 7¼- by 10-in. slush pumps.
1_____ Ideco 122-ft standard steel derrick.
1_____ 7¼-ft derrick substructure.
1_____ Ideco 200-ton crown block.
1_____ Emsco traveling block, type NC–36–4.
1_____ Emsco swivel, type AE–6.
1_____ National 17½-in. rotary table.
1_____ Byron-Jackson 125-ton hook.
1_____ Baash-Ross square kelly, 4½-in. by 33 ft.
1_____ Wilson Super winch.
1_____ Buda K–428 engine.
1_____ Kewanee 40-hp boiler.
1_____ Shaffer double-gate blowout preventer.
1_____ Link-Belt 48- by 60-in. mud screen.
1_____ International type PD cementing unit.

Fuel, water, and lubricant consumption.—Water was brought by wanigan during the night shift from the fresh-water lake which supplied the Barrow camp. Diesel oil was supplied by the Barrow camp fueling vehicles. A total of 218,400 gallons of water, 23,850 gallons of diesel fuel, 1,246 gallons of gasoline, and 954 gallons of lubricating oil (including 340 gallons of SAE weight 10 oil, 536 gallons of weight 20 oil, and 78 gallons of weight 90 oil), besides 173 pounds of general-purpose grease, were used during the drilling.

DRILLING OPERATIONS

The rig foundation was a mat of timber laid on a pierced-plank mat (sheets of steel matting pierced by rows of closely spaced holes) which rested on the gravel of the beach. A concrete apron drained into the concrete cellar under the derrick floor. The pumps and their motors were also set on a pierced plank mat, which allowed waste to drain into the gravel. The derrick cover, made of a single thickness of canvas on a frame of 2- by 4-inch boards, was built and used at Umiat camp, and taken to Barrow by tractor train, where it was reassembled. The righouse was built of plywood panels, and had a canvas and wood-frame roof. Heat, supplied by the 40-hp boiler housed in a wanigan set beside the righouse, kept the interior at an average of 50°F, compared to outdoor temperatures which were approximately 40° lower.

Depth (feet)	*Notes from drilling records*
43	Hole spudded in with 15½-in. bit and drilled to 43 ft where it was steamed out and 16-in., 60-lb casing driven in the tight hole and cemented at 42 ft with 32 sacks of cement.
615	Casing (11¾-in., 42- and 47-lb) was set at 441 ft, and cemented with 220 sacks of construction cement mixed with water at 80° F. While waiting for cement to set, rotary hose, kelly, and standpipe froze and had to be thawed for 13½ hr before using. After cement plug and shoe had been drilled out, ice was found in the hole between 574 and 615 ft.
1,030	Cuttings contained enough sand to erode pump valves; so mud pits were emptied, cleaned, and filled with new mud.
3,095.5	Hole depth corrected from 3,100 to 3,095.5 ft.
3,553	After making velocity and temperature surveys in the hole, tubing was lowered and hole was swabbed down to 600 ft. Continued swabbing did not lower fluid level any further, and salt water began to enter the hole. Salinity of drilling mud was normally less than 50 grains per gal; admixed salt water raised salt content to 396 grains per gal. After cleaning hole to 3,550.5 ft and attempting a formation test (unsuccessful because packer would not hold), the hole was filled with water; 500-ft and 100-ft thermistor cables were installed for future temperature measurements; and the well was abandoned. Cover plate welded on top of 11¾-inch casing, just below ground level, and 4½ ft of 4-in. pipe welded to top of that, as a marker.

DRILL AND CORE BITS

Above 3,100 feet, a Barrett-Robishaw wire line core barrel with 3-way drag or hard formation bits was used for coring, but the last few cores taken with the wire line barrel had poor recovery; so a conventional barrel (Reed Kor King) was used below that depth. Below 3,341 feet the rock was unusually hard, and the hard-formation rock bits could cut only a few feet before the teeth were worn off, the bit was undergauge, and the bearings worn out.

Thirty-one drilling bits, 7⅞–15½ inches in diameter, were used in the hole, and two others (a 6⅛-in. Hughes W7R and a 7⅞-in. Reed 2HM) were used for cleaning out the hole after the total depth had been reached. Most of the bits were Hughes OSC 8¾-inch bits. All the bit types and sizes, and the footage drilled by each bit, are shown on the graphic log (pl. 41).

DRILLING MUD

The hole made mud naturally, and water had to be added continually, to keep the mud from getting too heavy. Excess mud was discarded, and Aquagel occasionally added to the remainder to decrease the water loss; about 74 sacks of Aquagel, and 166 pounds of Stabilite–8 were used for this purpose. At 1,030 feet, the mud contained enough angular sand to erode the pump valves; so it was discarded, the pits were cleaned, and new mud was mixed. Characteristics of the mud at various depths during the drilling are shown in the following table on drilling mud.

Drilling-mud characteristics of South Barrow test well 1

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec API)	Water loss (cc per min)	Temperature (° F)
580	77. 0	40		42
750	78. 0	36		43
905	78. 5	40		52
1,020	66. 5	33		
1,130	70. 0	34		
1,210	72. 5	36		52
1,325	68. 0	35	8. 5	58
1,442	74. 0	41	6. 0	57
1,600	76. 0	41	7. 0	62
1,750	79. 0	43	6. 0	62
1,825	78. 0	39	7. 0	61
1,967	80. 0	42	6. 0	60
2,015	80. 0	39	7. 5	63
2,080	80. 5	37	8. 2	43
2,142	81. 0	38	8. 3	43
2,242	81. 5	37	8. 0	62
2,350	79. 0	35	9. 5	62
2,390	81. 0	39	8. 8	62
2,445	82. 0	41	6. 0	62
2,535	82. 0	38	6. 5	62
2,615	84. 0	38	7. 0	63
2,660	86. 0	41	5. 5	61
2,700	87. 0	42	5. 0	61
2,792	87. 0	42	4. 7	
2,850	87. 0	43	4. 5	60
2,867	88. 0	40	4. 2	60
2,887	86. 0	40	5. 2	54
2,933	88. 0	40		
2,980	88. 5	42	4. 0	61
3,030	88. 0	42	4. 5	63
3,060	88. 0	43	4. 7	60
3,075	88. 5	45	5. 0	60
3,100	87. 0	43	4. 7	61
3,122	88. 0	44	4. 7	61
3,135	88. 5	46	4. 5	62
3,145	88. 5	44	4. 5	62
3,182	88. 0	45	4. 5	62
3,195	87. 5	43	5. 0	62
3,210	87. 0	43	5. 0	63
3,230	88. 0	47	4. 7	62
3,250	88. 0	45	5. 2	63
3,265	87. 0	44		64
3,300	87. 0	45	5. 0	68
3,335	87. 0	43	5. 5	68

Drilling-mud characteristics of South Barrow test well 1—Continued

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec API)	Water loss (cc per min)	Temperature (° F)
3,347	87. 0	43		68
3,352	87. 0	44		68
3,357	86. 5	43	5. 5	67
3,360	86. 5	45	5. 4	66
3,370	87. 0	44		66
3,390	87. 0	46	5. 4	65
3,405	87. 0	44	5. 5	65
3,420	87. 0	41	5. 6	67
3,450	87. 0	46		67
3,470	88. 0	46	5. 6	69
3,498	89. 0	47	5. 5	69
3,505	89. 0	44		69
3,518	90. 5	43		70
3,535	92. 5	48	4. 7	71
3,550	92. 5	45		68

HOLE DEVIATION

South Barrow test well 1 was less than a degree off vertical for most of its length. Except at 3,085 feet, where the deviation was 1°30′, and at 3,420, where it was 1°10′, the deviation was irregular, ranging from 0–55′. The individual deviation measurements, made with the Totco (Technical Oil Tool Co.) Recorder are shown on the graphic log (pl. 41).

ELECTRIC LOGGING

Electric logs in the hole were run with Schlumberger hand-recording equipment. Five runs were made:

Run	*Depth (feet)*
1	441–1,196
2	441–2,886
3	2,886–3,225
4	3,225–3,328
5	3,328–3,548

The first run was begun at the bottom of the 11¾-inch casing; it was overlapped by run 2, as a check on equipment and technique. The two records agreed very closely, and only the lower part of run 2 is shown on the graphic log with the other runs (pl. 41). The long normal curve shown as part of run 4 was actually recorded when run 5 was made, as no long normal was recorded with the former run.

The temperature survey was also made with Schlumberger equipment. The curve showed a gradual increase from 35°F in the upper 200 feet of the hole to 84°F at the bottom. Above 800 feet the curve was slightly irregular, but below that depth it was smooth, with an increase of 5° for every 300 feet, except between 1,650 and 2,200 feet where the 5° rise in temperature took place over a 550-foot increase in depth.

VELOCITY SURVEY

A velocity survey was made by the United Geophysical Co., Inc., with a 60-foot shot point 750 feet S. 12°49′ W. of the hole. The average velocity was found to increase gradually from 7,255 feet per second in the

upper part of the test well to 8,883 feet per second at the base. Vertical velocity through the siliceous rock penetrated at the base of the test was computed at 17,500–19,500 feet per second.

There was no evidence of unusually high velocities, indicative of permanently frozen strata, which had been noted in some test wells in the Reserve, but ice formed in the hole as deep as 615 feet, indicating the presence of permafrost to that depth in the vicinity.

TEMPERATURE-MEASUREMENT STUDIES, SOUTH BARROW TEST WELL 1

By Max C. Brewer

South Barrow test well 1 is on the landward side of the present beach ridge, about 400 feet from the edge of the Arctic Ocean and just west of Barrow Camp. It was completed at a depth of somewhat more than 3,550 feet in February 1949. Two cables manufactured by Humble Oil Co. and containing copper-wound resistance coil thermal elements were installed to a maximum depth of 500 feet by Arctic Contractors under the supervision of Mr. William C. Fackler, Jr., geologist for Arctic Contractors. Frequent readings were made on these cables from the time of installation until 1953.

The geothermal profile for the well on January 10, 1952, which closely approximates the predrilling equilibrium geothermal profile, is shown as figure 51. A short extrapolation of the profile indicates a probable depth of permafrost (0° C isotherm) of 670 feet, approximately one-half the depth indicated at South Barrow test well 3, 8 miles inland. The temperatures shown are also considerably higher than those from comparable depths at wells farther inland. These anomalous temperature results are readily traceable to the nearness of the ocean and a brackish lagoon lying between the well and the nearby camp. After computing and subtracting the influence of these bodies of water on subsurface temperatures at South Barrow test well 1, Arthur H. Lachenbruch, U.S. Geological Survey, obtained a curve almost identical with the profile from South Barrow test well 3.

The inverse geothermal gradient at South Barrow test well 1 is approximately 80 feet per degree centigrade. This gradient is lower than those found in other permafrost areas in Alaska such as inland from Barrow, Cape Simpson, Umiat, Fairbanks, and Glennallen, but is to be expected as a result of the influence of the nearby bodies of water on the temperatures at depth in this well.

SOUTH BARROW TEST WELL 2

Location: Lat 71°15′49″ N., long 156°38′03″ W.
Elevation: Ground, 23.5 feet; kelly bushing, 34.5 feet.
Spudded: December 18, 1948.
Completed: April 15, 1949. Gas well; junked and abandoned.
Total depth: 2,505 feet.

South Barrow test well 2 was the first hole in the Reserve to produce a useful quantity of gas. Oil heaters at Barrow camp, 5 miles to the north, were converted to gas, and the well supplied enough fuel to heat the camp. The location of the test was based on seismic surveys which outlined a small area where a structural trap was formed by faults on the southwest and east sides of a block of sediments that dip northwest.

The hole penetrated about 70 feet of marine Pleistocene sediments (Gubik formation, 11–80 ft) and then entered Cretaceous beds. The Topagoruk formation, the youngest Cretaceous unit found here, is dominantly shale and had no shows of oil or gas. It is present from 80 to 1,730 feet and is underlain by 200 feet of the Oumalik formation (1,730–1,930 ft). (See pl. 42.)

Below the dark shale of the Oumalik and Topagoruk formations, a 400-foot section of pebble shale is present from 1,930–2,328 feet.

Below 2,328 feet, the well penetrated more than 100 feet of light-olive-gray sandstone and siltstone of Middle Jurassic age which had an odor of oil and showed a light oil stain. Between 2,443 feet and the bottom of the hole at 2,505 feet, bluish-black siliceous or carbonaceous argillite constituted the oldest rocks drilled.

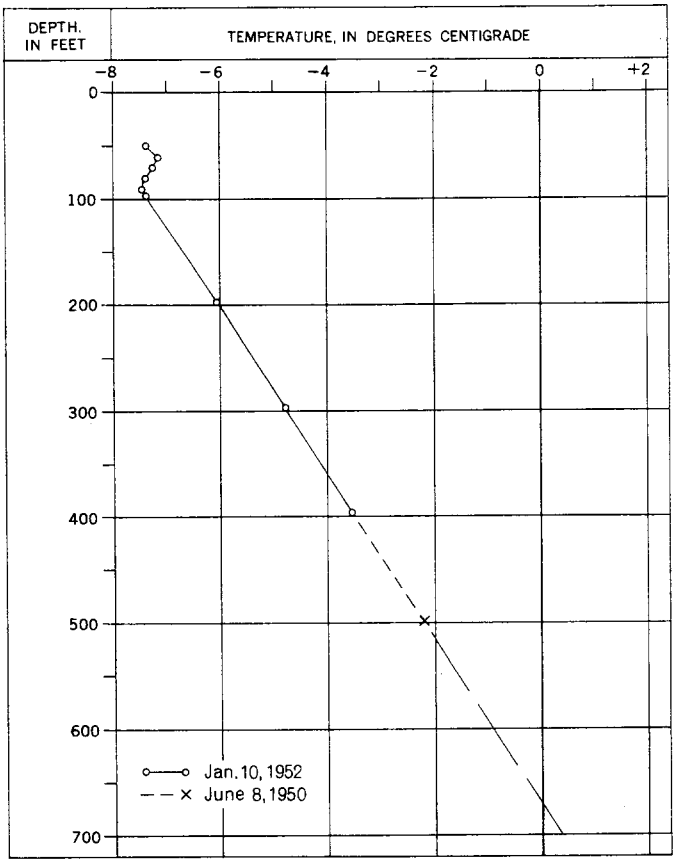

FIGURE 51.—Geothermal profile for South Barrow test well 1.

Formation tests of the Jurassic rocks and the argillite recovered no oil, but a small amount of gas was noted. After setting casing at 2,260 feet, the hole flowed gas-cut mud; and following some difficulty caused by frozen mud in the hole, the well was completed, producing gas with a trace of condensate and water. The flow presumably came from the Jurassic beds, but fractures in the argillite may also contain some of the gas. On July 29, 1949, the well began supplying gas to Barrow camp. Production varied with camp needs, rising to 500,000 cu ft per day in February 1950, as more stoves were connected. Casing and tubing pressure normally remained at 1,020 psi. Hydrates and ice blocked the tubing occasionally, but it was cleared by blowing the well down for short periods. At the end of March, plans were made to kill the well in order to investigate a suspected leak in the 7-inch casing, but before it could be done the well caught fire from a broken gasline, the installations were destroyed, and the well was killed with mud. An impression block then showed that the 7-inch casing had collapsed, probably from ice pressure. The well, full of mud which was already freezing, was abandoned, and gas for the camp was obtained thereafter from South Barrow test well 4, nearby.

568535 O—61——3

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

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

Core	Depth (feet)	Remarks
------	0–11	Kelly bushing to ground level.
------	11–15	Ground level to cellar floor.
------	15–25	No sample received in Fairbanks laboratory. The well geologist, W. C. Fackler, reported ice and tundra, with some gravel mixed with them, below 17 ft.
------	25–30	Gravel of well-rounded black and brownish gray chert pebbles.
------	30–65	Sand, light-brownish-gray, fine- to very coarse-grained; composed of well-rounded black and brownish-gray chert and clear and yellow quartz grains with some light-yellowish-brown very silty clay in the upper 10 ft, and some gravel.
------	65–80	Gravel; composed of black chert with a few pebbles of other rocks.
------	80–115	Samples from 80–90 ft consist primarily of sand and gravel as described above, but a small amount of rather dissimilar sand, which resembles that described at 115–250 ft below, suggests that the top of the Cretaceous beds (Topagoruk formation) is at 80 ft. A Cretaceous foraminifer from 95–100 ft also indicates that the top is above 100 ft. Samples between 90 and 115 ft are made up of cement and hence furnish no information on lithology of that interval; electric log suggests that it is predominantly clay shale.
------	115–250	Samples taken from this interval consist of loose sand, with a small amount of cement, and in upper part a rather large amount of gravel. Gravel and cement are contamination from above, and sand is from thin beds. Clay shale, which actually makes up all but a very small percent of the rock drilled, was described by well geologist as sticky and blue gray. Although the clay shale is not represented in samples, the electric log corroborates its presence in the well. Sand is light greenish gray, fine to very fine grained and is made up of subrounded to subangular clear and white quartz, and some green and dark rock fragments. Pyrite rare to absent.
------	250–260	Clay shale as above, with some light-yellowish-gray very slightly calcareous clay ironstone.
------	260–270	Siltstone, medium-light-gray, very argillaceous, calcareous.
------	270–385	Clay shale as in core 1 below but with a small amount of siltstone as above.
------	385–390	Clay shale with a small amount of sandstone, medium-light-gray, fine to very fine grained, silty, noncalcareous, micaceous, of subangular to subrounded clear and white quartz grains and a few dark rock fragments.
------	390–425	Clay shale as in core 1.

Lithologic description—Continued

Core	Depth (feet)	Remarks
------	425–430	Sandstone, medium-light-gray, fine to very fine grained, noncalcareous, slightly micaceous; composed of subangular to subrounded clear and white quartz and some dark rock fragments.
------	430–459	Clay shale as in core 1 but with small amount of sandstone; crinoid (*Balanocrinus* sp.) fragment at 440–450 ft.
1	459–469	Recovered 10 ft: Clay shale, medium-gray, very slightly micaceous in part, noncalcareous; rare carbonaceous particles. Good shaly cleavage dips less than 5°. Laminae of medium-light-gray silty clay shale and siltstone are very rare. Slightly infiltrated with drilling mud.
------	469–505	Clay shale as in core 1.
------	505–515	Siltstone, medium-light-gray, very argillaceous; and medium-gray very silty clay shale.
------	515–525	Siltstone, medium-bluish-gray, argillaceous, very calcareous, dense.
------	525–530	No sample.
------	530–545	Clay shale and siltstone.
------	545–660	Clay shale, medium-gray, silty, slightly calcareous; small amount of siltstone and rare grains of pyrite in upper part.
2	660–670	Recovered 10 ft: Clay shale, medium-gray, slightly micaceous in part, noncalcareous; rare carbonaceous particles. Rare silty laminae and good shaly cleavage dip 5°.
------	670–700	Clay shale as in core 2 above.
------	700–710	Limestone, medium-bluish-gray, silty to very argillaceous, dense.
------	710–860	Clay shale as in core 2 above; very rare very thin, beds of siltstone in lower part.
3	860–870	Recovered 10 ft: Clay shale, medium-gray, partly silty, noncalcareous; carbonaceous particles. Beds dip 5°, and slickensides are present at 864 ft.
------	870–960	Clay shale as above. Samples composed of loose sand, contamination from thin sandstone beds higher in the hole. A few rare chips of shale represent the rock penetrated here.
4	960–975	Recovered 13 ft 6 in.: Clay shale, medium-gray, slightly silty and micaceous, noncalcareous; rare carbonaceous parcles; good shaly cleavage dips less than 5°. Rare laminae of silty medium-light-gray clay shale contain carbonaceous particles and are micáceous in part.
5	975–995	Recovered 19 ft 4 in.: Clay shale and rare silt laminae as above; badly infiltrated with drilling mud.
6	995–1, 003. 5	Recovered 8 ft 5 in.: Clay shale and rare silt laminae as above.
7	1, 003. 5–1, 022	Recovered 19 ft: Clay shale and rare silt laminae as above.

Lithologic description—Continued

Core	Depth (feet)	Remarks
8	1, 022–1, 042	Recovered 16 ft: Clay shale as above.
9	1, 042–1, 059	Recovered 17 ft: 14 ft, jammed in core barrel and lost. 3 ft, clay shale as above.
10	1, 059–1, 077	Recovered 17 ft: Clay shale as above. Dip 2°–4°.
11	1, 077–1, 096	Recovered 18 ft: Clay shale as above.
12	1, 096–1, 111	Recovered 16 ft 9 in.: Clay shale as above. Very good shaly cleavage dips 2°–4°.
13	1, 111–1, 130	Recovered 18 ft 6 in.: Clay shale as above but more silty; common siltstone laminae. Siltstone rarely slightly calcareous. Dip 2°–4°.
14	1, 130–1, 150	Recovered 18 ft: Clay shale as above but becomes claystone, with irregular fracture, in basal 1 ft.
15	1, 150–1, 169	Recovered 19 ft: 15 ft, claystone, medium-gray, slightly to very silty, micaceous, noncalcareous; rare slightly calcareous laminae. Slickensides at 1,154 ft dip about 45°. 4 ft, clay shale, medium-gray, very slightly micaceous, noncalcareous; very good shaly cleavage. Very fine laminae and partings of siltstone common. Dip 3°.
16	1, 169–1, 189	Recovered 19 ft: 7 ft 6 in., clay shale as at base of core 15. 5 ft, claystone as at top of core 15. Rock breaks at 45° angle more commonly than along bedding planes, which lie approximately flat. Some slickensides dip 45°. 2 ft, clay shale with good shaly partings; common laminae siltstone. 3 ft, claystone as above. 1 ft 6 in., clay shale, as above.
17	1, 189–1, 208	Recovered 17 ft 6 in.: Clay shale as above but with fair shaly cleavage dipping 2°–4°.
18	1, 208–1, 227	Recovered 19 ft: Claystone as in core 15. Small carbonaceous plant fragments common at 1,213 ft. Fair shaly cleavage present in a few short (under 6 in.) intervals.
19	1, 227–1, 247	Recovered 20 ft: Claystone as above but with carbonaceous plant fragments at 1,235 ft.
20	1, 247–1, 267	Recovered 19 ft: Clay shale, as in cores above. Good shaly cleavage except at few short intervals of rock where cleavage is poor. Beds dip 2°–3°. Two 2-in. beds of light-gray noncalcareous sandy siltstone between 1,259 and 1,260 ft. At 1,264 ft is a 6-in. bed of interlaminated light-gray siltstone and medium-gray clay shale; laminae and thin beds (as much as 1 in. thick) of friable siltstone abundant between 1,265 and 1,266 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
21	1, 267–1, 284	Recovered 17 ft: 1 ft 5 in., clay shale as above. 11 in., siltstone, light-gray, very sandy, slightly argillaceous, very calcareous, friable; rare carbonaceous partings. 3 ft, 1 in., clay shale as above. 6 in., siltstone, light-gray, very sandy, slightly argillaceous, noncalcareous, friable; carbonaceous partings abundant in upper 1 in. of siltstone, totaling about half the rock. 9 ft 5 in., clay shale as above but with common light- to very light-gray siltstone laminae and beds as much as 2 in. thick, totaling about 15 percent of the rock. Carbonaceous partings present in some of the siltstone. Beds lie approximately flat. 1 ft 8 in., siltstone, light- to medium-light-gray as above but with common carbonaceous and argillaceous laminae in upper part.
22	1, 284–1, 296	Recovered 11 ft: 7 ft 3 in., interbedded claystone, medium-gray, very silty, and very argillaceous light-gray friable noncalcareous siltstone; all broken and infiltrated with drilling mud. Beds are ½–8 in. thick and are predominantly shale in upper part and siltstone in lower part. Dip less than 3°. 3 in., sandstone, medium-light-gray, fine- to very fine grained, very calcareous, hard. 2 in., sandstone, light-gray, very silty and argillaceous, noncalcareous, friable; grades into unit below. 10 in., siltstone, light-gray, very sandy at top; grades to medium-light-gray, slightly sandy and argillaceous at base. 2 ft 6 in., claystone, medium-gray, slightly to very silty, slightly micaceous, noncalcareous; scattered flakes of carbonized plants.
23	1, 296–1, 316	Recovered 17 ft: 2 in. claystone as at base of core 22. 7 ft 3 in., siltstone, light-gray and very sandy to medium-gray and very argillaceous, noncalcareous, friable; rare to abundant medium-gray clay shale laminae and rare carbonaceous partings. Beds lie approximately flat. 9 ft 7 in., clay shale, medium-gray, slightly silty, noncalcareous; fair to poor shaly cleavage. Rare silty laminae. A 1-ft interval of rock between 1,309 ft and 1,310 ft has irregular fracture instead of shaly cleavage. Beds dip less than 3°.
24	1, 316–1, 336	Recovered 19 ft: 9 ft, claystone, medium-gray, slightly to very silty, micaceous, noncalcareous. Irregular fracture, commonly breaks at 40–50°

Lithologic description—Continued

Core	Depth (feet)	Remarks
		angle; some surfaces have slickensides. 9 in., siltstone, medium-light-gray, very argillaceous, noncalcareous, massive. Base of bed dips 30°. 9 ft 3 in., claystone as above.
25	1, 336–1, 355	Recovered 18 ft 6 in.: Clay shale, as at base of core 23, but with scattered flakes of carbonized plants; fair shaly cleavage dips about 25°. Shells of *Yoldia* cf. *Y. kissoumi* McLearn, a pelecypod at 1,353 and 1,354 ft.
26	1, 355–1, 375	Recovered 16 ft, 3 in.: Clay shale as above; poor shaly cleavage dips 15°–20°. Lower 4 ft of core not silty, and has slickensides dipping 20°–40°. Rock infiltrated with drilling mud.
27	1, 375–1, 395	Recovered 12 ft: 11 ft, drilling mud and clay shale fragments as at base of core 26. 1 ft, claystone fragments, medium-gray, very silty, noncalcareous.
28	1, 395–1, 415	Recovered 18 ft: 10 ft, clay shale, medium-gray, very slightly silty, noncalcareous. Poor shaly cleavage dipping 10°–15°. Carbonaceous particles common in part; silty laminae very rare. Bedding-plane slickensides rare. 8 ft, claystone. Like clay shale above but with irregular fracture.
29	1, 415–1, 435	Recovered 18 ft: Clay shale as in core 21 above but with common slickensides dipping 10°–50°. Very poor shaly parting dips 15°–20°.
30	1, 435–1, 453	Recovered 15 ft: Clay shale as above but with intervals of clay shale fragments mixed with drilling mud.
------	1, 453–1, 653	Clay shale as in cores above.
31	1, 653–1, 663	Recovered 5 ft 8 in.: Clay shale, medium-dark-gray, very slightly micaceous and silty, noncalcareous. Very poor shaly cleavage dips about 10°.
------	1, 663–1, 752	Clay shale, medium-gray, silty in part, noncalcareous; some thin beds of light-gray calcareous siltstone and light-gray very fine grained silty calcareous sandstone. Sandstone slightly pyritic in part. Top of Oumalik formation at 1,730 ft.
32	1, 752–1, 772	Recovered 13 ft 6 in.: 5 ft, clay shale fragments, medium-dark-gray, very slightly silty and micaceous, noncalcareous; badly infiltrated with drilling mud. 2 ft, sandstone, light-gray, very fine grained, very silty and argillaceous, noncalcareous, composed of subangular grains of clear and white quartz and some dark rock and rare yellow grains. Small flakes of carbonized plants common on some bedding planes. 6 ft 6 in., clay shale, medium-dark-gray, slightly silty in part, noncalcareous; common laminae light-gray siltstone and good shaly cleavage dipping less than 4°. Some partings carbonaceous. Light-yellowish-gray clay ironstone present at top.
33	1, 772–1, 792	Recovered 20 ft: 15 ft 6 in. Clay shale, as above, but with very poor shaly cleavage possibly dipping as much as 10°. A 6-in bed of light-gray very fine grained argillaceous, micaceous sandstone present at 1,774 ft. 4 ft 6 in., clay shale as at base of core 32 above. Beds dip less than 4°.
------	1, 792–1, 930	Clay shale, medium-gray, very slightly silty, noncalcareous.
------	1, 930–1, 950	Clay shale, black, fissile, very pyritic; well-rounded fine to coarse grains of clear quartz commonly with polished or pitted (not frosted) surfaces, scattered throughout. Top of pebble shale at 1,930 ft.
34	1, 950–1, 970	Recovered 20 ft: Clay shale, dark-gray to grayish-black, silty, slightly micaceous, noncalcareous; rare to common grains, lines, and nodules of pyrite. Small roughly cylindrical masses of finely crystalline pyrite also common; some are as much as ¼-in. in diameter and 1 in. long, with the long axis nearly vertical; some have irregular bits of white calcite in the center, and others have a thin coating of calcite separating the pyrite from the enclosing shale. Fine longitudinal, closely spaced lines, resembling structure commonly preserved in carbonized wood, rarely present and suggest that the pyrite may have replaced twigs or small fragments of wood. Well-rounded, fine to coarse grains of clear quartz and gray or black chert scattered, singly or in very small groups, through the rock. Well-rounded granules (as much as ½-in. in diameter) of black chert rare and isolated. Rock has very poor shaly cleavage and probably lies flat. White pelecypod shell fragments at 1,954 ft.
35	1, 970–1, 971. 5	Recovered 6 in.: Clay shale as above.
36	1, 971. 5–1, 990	Recovered 18 ft 6 in.: Clay shale as above. A 6-in. bed of brownish-gray very dense argillaceous limestone with conchoidal fracture present 3 ft below top. Rare rounded chert pebbles. Common fragments of pyritized wood. Worm tube(?) found at 1,973 ft, and a pelecypod *Lima* sp, at 1,977 ft.
37	1, 990–2, 010	Recovered 15 ft 10 in.: 4 ft 1 in., clay shale as above; pelecypod shell fragment at 1,994 ft. 9 in., sandstone, olive-gray, very fine grained, very silty and argillaceous, slightly calcareous, thin-bedded; some carbonaceous particles on partings; composed of angular to subangular grains

Lithologic description—Continued

Core	Depth (feet)	Remarks
		of clear and white quartz and dark rock fragments. Well-rounded clear quartz grains typical of clay shale above and below are absent. Beds dip less than 5°.
		11 ft, clay shale as above. Nine sidewall cores taken between 1,996 and 2,008 ft; seven of these, at 1,992, 1,996, 1,998, 2,000, 2,002, 2,006, and 2,008 ft consisted of clay shale as in the core; the other two were not available, but were described at well site as shale.
38	2, 010–2, 030	Recovered 20 ft:
		Clay shale as above; pelecypod shell fragments at 2,011, 2,013, and 2,016 ft.
39	2, 030–2, 050	Recovered 20 ft:
		Clay shale as above but with very poor shaly cleavage dipping about 5°. A 6-in. bed of light-olive-gray very fine grained sandstone as in core 37 present at 2,047 ft; contact of shale and sandstone is sharp, and dips 7°. Pelecypod shell fragments rare; specimen of *Astarte* sp. was found.
40	2, 050–2, 070	Recovered 17 ft 10 in.:
		10 ft 10 in., clay shale as above but with 6-in. bed of sandstone as above, at 2,056 ft. Clay shale grades into unit below.
		7 ft, claystone, similar to clay shale, but slightly calcareous in upper part and with irregular fracture. Pyritized plant fragment at 2,069 ft.
41	2, 070–2, 087	Recovered 17 ft:
		Drilling mud with chips of clay shale as above.
42	2, 087–2, 106	Recovered 14 ft 6 in.:
		Clay shale as above but with poor cleavage dipping less than 5°. Basal 2½ ft is in fragments and is mixed with drilling mud.
43	2, 106–2, 116	Recovered 10 ft:
		5 ft, clay shale as above. Beds lie approximately flat. An 8-in. bed of brownish-gray hard calcafeous clay shale present at 2,108–2,109 ft; fishbone fragment was embedded in it.
		8 in., sandstone, light-brownish-gray, very fine grained, moderately calcareous, massive; scattered small flakes of carbonaceous material.
		4 ft 4 in., clay shale as above.
44	2, 116–2, 136	Recovered 17 ft:
		8 ft 6 in., clay shale as above.
		2 ft 4 in., sandstone, light-brownish-gray, very fine grained, very silty and argillaceous, noncalcareous; composed of subangular grains of clear and white quartz and dark rock fragments.
		1 ft 2 in., clay shale, brownish-gray, slightly silty, micaceous, noncalcareous; poor shaly cleavage.
		5 ft, clay shale as at top of core.
45	2, 136–2, 153	Recovered 17 ft:
		Clay shale as above but with fishbone fragments scattered in lower 5 ft. Slickensides at 2,150 ft.
46	2, 153–2, 171	Recovered 20 ft:
		Clay shale as above but with flat well-rounded nodule of hard black noncalcareous very silty clay stone at 2,165 ft. Slickensides at 2,170 ft. Pelecypod shell fragment at 2,157 ft.
47	2, 171–2, 178	Recovered 6 ft 9 in.:
		5 ft 6 in., clay shale as above; pelecypod shell fragment at 2,176 ft.
		3 in., sandstone, light-olive-gray, very fine grained, moderately calcareous.
		1 ft., clay shale, light-brownish-gray, very slightly silty, calcareous. Poor shaly cleavage dips less than 5°.
48	2, 178–2, 198	Recovered 19 ft:
		Clay shale as at top of core 47 above; siltstone and sandstone laminae common in a 3-in. interval at 2,187 ft. A 9-in. bed of light-olive-gray very fine grained sandstone is at 2,188 ft. A 1-in. fragment of carbonized and pyritized wood present at 2,194 ft.
49	2, 198–2, 218	Recovered 20 ft:
		Clay shale as above but with ½-in. bed of brownish-gray noncalcareous claystone with conchoidal fracture, at 2,217 ft. Pelecypod *Entolium* sp. and unidentified brachiopod found at 2,212 ft.
50	2, 218–2, 228	Recovered 3 ft:
		2 ft, clay shale as above.
		1 ft, sandstone, medium-light-gray, very fine grained, silty, argillaceous, calcareous, thin-bedded; composed of subangular to angular grains of clear and white quartz, gray chert, and dark rock fragments. Base of sandstone contains flakes of black shale as much as one-eighth-in. in diameter. Beds lie approximately flat.
51	2, 228–2, 248	Recovered 20 ft:
		11 in. clay shale as in core above.
		8 in., sandstone as in core 50.
		18 ft 5 in., clay shale as above. Beds lie approximately flat.
52	2, 248–2, 265	Recovered 12 ft 4 in.:
		4 ft 8 in., clay shale as above.
		1 ft 4 in., sandstone, medium-light-gray, fine to very fine grained, silty, calcareous, massive; composed of angular to subangular grains of clear and white quartz with some gray chert and dark rock fragments.
		6 ft 4 in., clay shale as above. A 3-in. bed of light-olive-gray claystone with conchoidal fracture present at base of core.
53	2, 265–2, 279	Recovered 14 ft:
		Clay shale as above, but with pelecypod *Entolium*? sp. at 2,275 ft, *Pleuromya* sp. at 2,276 ft, and *Flaventia*? at 2,277 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
54	2, 279–2, 287	Recovered 8 ft: 6 ft 8 in., clay shale as above. 1 ft 4 in., sandstone as in core 52 but noncalcareous.
55	2, 287–2, 307	Recovered 19 ft 6 in.: 1 ft, sandstone, medium-dark-gray, slightly silty and argillaceous, slightly calcareous; composition as in sandstone above. Dark color caused by coating of dark-brown organic material (carboniferous or petroliferous?) on and between grains. 3 ft 6 in., clay shale as above but with gradual increase in coarse sand grains and granules, so that the lower part of the rock is dark-gray conglomeratic silty sandy claystone. Pebbles are of well-rounded black chert, and sand grains are well-rounded dark chert and clear quartz, as in overlying rock, with some pebbles of hard black clay shale. 15 ft, clay shale, dark-gray, silty; scattered well-rounded grains of clear quartz and chert, as in clay shale in core 54. Beds lie approximately flat, but slickensided fractures in lower 4 ft of core dip 30°–40°.
56	2, 307–2, 322	Recovered 15 ft: 13 ft, clay shale as at base of core 55. Fishbone fragments at 2,308 ft. 2 ft, claystone, grayish-black, conglomeratic, carbonaceous; composed of well-rounded sand grains, granules, and pebbles of chert and clear quartz scattered through matrix.
57	2, 322–2, 328	Recovered 5 ft: Conglomeratic claystone as at base of core 56.
58	2, 328–2, 332	Recovered 3 ft: 6 in., conglomeratic claystone as above. Base of claystone consists of a layer of granules and pebbles partly embedded in top of underlying sandstone. Contact is sharp and flat lying and has only minor irregularities. 2 ft 6 in., sandstone, light-olive-gray, very fine grained, silty, argillaceous, noncalcareous; composed of angular to subangular grains of clear quartz and some white quartz and dark rock fragments; sandstone is massive.
59	2, 332–2, 341	Recovered 9 ft: 6 in., sandstone as above. 8 ft 6 in., siltstone, light-olive-gray, slightly to very argillaceous; rare to abundant small irregular patches and streaks of medium-gray clay shale ranging from 2 to 50 percent of the rock.
60	2, 341–2, 356	Recovered 10 ft: Siltstone as above.
61	2, 356–2, 375	Recovered 9 in.: Siltstone as above.
62	2, 375–2, 391	Recovered 14 ft: Sandstone, light-olive-gray, very fine grained, very silty and argillaceous, noncalcareous; intergrades with siltstone and streaks and patches of medium-gray clay shale totaling 5–30 percent of the rock. Gastropod found at 2,379 ft and ammonite, *Tmetoceras* sp., of Middle Jurassic age, at 2,391 ft. (Imlay, 1955, p. 82.)
63	2, 391–2, 400	Recovered 9 ft: Sandstone as in core 62. Rare white oolites, the size of medium sand grains, in some of the rock. Pelecypod *Oxytoma* sp. found at 2,399 ft.
64	2, 400–2, 420	Recovered 18 ft 6 in.: Sandstone as above. A 4-in. and a 6-in. bed of sandstone present at 2,406 and 2,413 ft, respectively, are brownish gray, quartzitic, very fine grained, very silty and argillaceous, and hard and have subconchoidal fracture that breaks across grains. Sand composed of subangular grains of clear quartz and some white quartz and large amount of brownish-gray silty noncalcareous cement. Rare fragments of pyritized and carbonized wood as much as 2 in. long and 1 in. in diameter.
65	2, 420–2, 440	Recovered 7 ft: Sandstone as above.
66	2, 440–2, 443	Recovered 2 ft 4 in.: Sandstone as above but with 2-in. bed of hard light-gray-green bentonitic clay shale at base, and some argillite fragments.
67	2, 443–2, 445	No recovery.
68	2, 445–2, 446	No recovery.
------	2, 446–2, 454	Argillite; some is black, siliceous, carbonaceous, fissile, and some is bluish black, very siliceous, and hard, and has blocky fracture.
69	2, 454–2, 457	Recovered 4 in.: Argillite, bluish-black, siliceous, slightly carbonaceous and pyritic, hard; splintery fracture that breaks more easily parallel to faint traces of bedding. Rock was described by Charles Milton (written communication, August 1949) as a "black siliceous carbonaceous shale, slightly pyritic in spots. * * * It is a marine sediment, possibly of volcanic origin, with a radiolarian(?) fauna. Soon after deposition continuing volcanic activity (nearby intrusive rocks or lava flows?) may have carbonized the organic matter of the sediments, and hydrothermal silica replaced alumina, etc., of the ash, and earlier formed crystals."
70	2, 457–2, 470	Recovered 4 in.: Argillite as above.
------	2, 470–2, 482	Argillite as above.
71	2, 482–2, 487	Recovered 1 ft: Argillite, bluish-black, siliceous, small fragments, as in core 69.
------	2, 487–2, 505	Argillite as above but with some bluish-gray to medium-light-gray chert in basal 5 ft.

CORE ANALYSES

Porosity and permeability tests on sandstone samples from South Barrow test well 2 (see following table) were made with the same equipment as that used for the first Barrow test well. In many tests, two plugs were made from the same sample so that the permeability could be tested with the air flow both perpendicular and parallel to the bedding. Porosity was usually tested on only one of the two plugs. It was found to range from 5.5 to 25.3 percent, and most determinations were more than 10 percent. Permeability ranged from 5.0 to 108 millidarcys, and the rock was generally more permeable parallel to the bedding than normal to it.

Carbonate content was determined for a few samples—at 1,762 feet it was 8.8 percent; at 1,999 feet, a trace; and at 2,023 feet, 19.6 percent. Two samples from 2,397 feet had 2.9 and 2.8 percent carbonate, and 2 samples at 2,416 feet had 1.7 and 1.6 percent.

Porosity and permeability of sandstone samples from South Barrow test well 2

Depth (feet)	Porosity (percent)	Permeability (millidarcys)	Depth (feet)	Porosity (percent)	Permeability (millidarcys)
1,299	25.3	50.0	2,286P	9.1	8.0
1,299	22.3	40.0	2,287N	18.4	59.5
1,762	24.4	8.2	2,287P	19.2	97.0
1,774	24.3	14.5	2,288N	18.8	80.0
1,999N [1]	16.2	14.3	2,288P	18.4	104.0
1,999P [2]		19.2	2,330N	20.8	32.7
2,023N	18.3	50.0	2,330P	20.6	70.0
2,023P		80.0	2,331N	20.1	78.0
2,024N	19.8	70.0	2,331P		108.0
2,024P		67.0	2,341N	22.5	8.8
2,047N	13.7	5.3	2,341P	20.0	13.3
2,047P	14.1	6.8	2,346N	17.0	<9
2,056N	20.0	11.7	2,346P		<9
2,111N		<7.0	2,356N	7.8	<8
2,111P	8.8	<7.0	2,356P	9.2	<9
2,126P	19.2		2,375N	21.4	13.2
2,126N	21.1	25.5	2,375P		17.8
2,170N	16.9	32.7	2,378N	21.9	11.7
2,170P	17.0	45.0	2,378P		19.5
2,176N		<6.0	2,383N	24.0	62.5
2,176P	7.3	<7.0	2,383P		91.0
2,188N		6.8	2,397N	16.1	10.4
2,188P	10.5	4.8	2,397P		<6.0
2,198N		<7.0	2,404N	19.2	17.1
2,198P	6.4	<7.0	2,404P		<11.0
2,227N		<11.0	2,406N	19.9	12.0
2,227P	5.5	<8.0	2,406P		8.3
2,229N	17.0	34.5	2,416N	15.4	5.7
2,229P	16.4	49.5	2,416P		<5.0
2,254N	12.5	13.0	2,430N	12.2	9.7
2,254P	11.9	9.0	2,430P		<4.0
2,286N		11.0			

[1] N, plug cut normal to the bedding.
[2] P, plug cut parallel to the bedding.

A study of the reservoir characteristics made at Pennsylvania State College by S. T. Yuster tested the permeability of selected sandstone samples to brine, fresh water and oil, as well as air. (See following table on reservoir properties.)

Reservoir properties of sandstone samples from South Barrow test well 2

Depth (feet)	Porosity (percent)	Klinkenberg permeability (millidarcys)		Liquid permeability (millidarcys)		
		Before liquid flow	After liquid flow	Brine	Fresh water	Oil (through brine-filled sample)
2,023	16.8	18.3	12.3	4.52	1.81	6.9
2,124	17.6	40.4	28.1	7.65	4.35	
2,170	13.7	37.4	11.6	1.18	1.00	
2,178	10.4	.57	.1	.038	.0275	

The sandstone is composed primarily of very fine and fine-grained sand, with some silt and clay. (See following table on sieve analyses.) Petrographic analyses by Paul D. Krynine show the constituents to be quartz, chert, rock fragments, and a small amount of feldspar and other minerals, and he classifies the rock as graywacke. Results of his analyses, made on thin sections, are presented in the following table on petrographic characteristics.

Specific gravity determinations of sandstone and shale samples are given in the following table on specific gravity.

Sieve analyses of sandstone samples from South Barrow test well 2 using American Society for Testing Materials sieves

Depth (feet)	Grain sizes (percent)							
	18 mesh (coarse)	35 mesh (coarse)	60 mesh (medium)	120 mesh (fine)	230 mesh (very fine)	325 mesh (silt and clay)	<325 mesh (clay)	Total
1,762			Tr.	4.3	66.0	9.3	20.5	100.1
1,999			Tr.	16.8	59.2	8.0	16.1	100.1
2,023			Tr.	41.6	41.9	5.7	10.9	100.1
2,047			Tr.	46.2	37.5	5.2	11.1	100.0
2,056			Tr.	42.0	40.4	5.0	12.6	100.0
2,111		0.82	2.03	55.5	27.5	4.7	9.43	99.98
2,126			Tr.	52.8	32.7	5.1	9.3	100.0
2,170		Tr.	2.16	67.40	19.30	3.67	7.48	100.01
2,176			.57	64.60	20.90	4.59	9.35	100.01
2,330		.04	.74	32.2	53.7	7.16	6.2	100.04
2,383	0.41	.16	.04	6.59	77.20	4.12	11.5	100.02
2,406				51.8	28.1	4.0	16.8	100.7

Petrographic characteristics of sandstone from South Barrow test well 2

[Determined by Paul D. Krynine]

	Depth in feet														
	1,762	1,999	2,023	2,047	2,056	2,111	2,126	2,170	2,176	2,188	2,198	2,331	2,356	2,397	2,430
Texture															
Average diameter range mm	0.02–0.11	0.015–0.15	0.04–0.20	0.02–0.20	0.03–0.35	0.04–0.30	0.03–0.20	0.04–0.30	0.04–0.20	0.03–0.21	0.04–0.30	0.04–0.20	0.02–0.12	0.05–0.20	0.03–0.22
Principal mode mm	.07	.09	.14	.10	.11	.13	.13	.15	.14	.135	.16	.13	.10	.17	.15
Grains: matrix: cement ratio in percent	77:20:3	77:15:8	82:17:1	77:15:8	76:20:4	71:8:20	78:17:5	82:11:7	74:8:18	67:18:15	76:9:15	85:14:1	65:5:30	78:29:3	70:29:8
Grain composition in percent															
Quartz	50	45	37	38	27	25	32	35	35	33	45	38	45	46	48
Chert	10	13	20	20	20	28	22	27	30	22	18	28	15	22	18
Feldspar	6	3	7	2	2	3	5	2	1.5		1	Trace			1
Mica flakes (large)		1	Trace	2	2			Trace	Trace		Trace				
Slate, phyllite	5	13	20	14	20	12	12	14	9	11	12	20	4	Trace	1.5
Quartzite, schist	1.5	Trace	Trace	1	3	2	3	1.5	1	2	1.5	1	Trace		2.5
Volcanic rocks	1.5	2	3	2	2	3	1	2			1		Trace		Trace
Biotite					Present				Present						
Chlorite		Present	Present	Present	Present			Present							
Muscovite											Present				
Glauconite		Trace										Trace		Trace	
Zircon							Trace						Present		
Tourmaline											Present		Present		
Ilmenite													Present		
Limestone														Present	
Interstitial material in percent															
Chlorite		2	1	5	6	2	1	Trace	Trace	1	Trace	1–2			2–3
Sericite	13–15	3	3	6	10	4	2	6	3	2	2	8–9	5		14–17
Illite		7	8				9			12	5			29	
Montmorillonite, kaolinite	5–7	3	5	4	4	2	5	4	5	5	1–2	4			3–5
Silica cement	Trace	1	1	1	2	2	1	3	Trace	3	1.5	1	Trace	Trace	Trace
Carbonates	3	5	Trace	7	2	18	4	4	18	12	9	Trace	30	2	7.5
Pyrite		2									4		3	1	1.5
Pore space and characteristics															
Pore size, principal mode microns	14	35	65	30	32	20	55	50	10	23	24	32		30	12
Visible porosity percent	1	5	8	3	6	<1	8	6	1	2	1.5	4		2	1
Residual porosity	Poor	Fair-poor	Good	Poor	Good	Poor	Good	Fair	Poor	Poor	Poor	Fair-poor		Poor	Poor
Bonding material	Illite	Illite	Illite	Illite, carbonates	Illite, chlorite	Carbonate	Illite, clay	Carbonate, silica, illite	Carbonate	Carbonate, illite	Carbonate, silica	Illite	Carbonate	Illite-siderite	Illite, sericite
Clay-coated wall area percent	90	70	50	90	70	60	45	60	80	85	65	75	100	90	90
Wall coating, type	Illite, kaolinite	Illite	Illite	Illite, chlorite	Illite, chlorite	Carbonate, illite	Illite	Illite, clay	Carbonate, illite	Illite	Illite	Illite	Carbonate, illite	Illite	Illite, sericite
Potential hydration	High	Moderate	High	High	Moderate	Moderate	High	High	High	Moderate	Moderate	Moderate	Low	High	High

Specific gravity of selected samples from South Barrow test well 2

Depth (feet)	Specific gravity	Rock type
446	2.23	Clay shale.
665	2.27	Do.
965	2.33	Do.
1,097	2.32	Do.
1,265	2.21	Clay shale and sandstone.
1,323	2.34	Siltstone.
1,447	2.38	Clay shale.
1,754	2.09	Interbedded sandstone and clay shale.
1,762	2.14	Sandstone.
1,965	2.40	Siltstone.
1,999	2.18	Sandstone.
2,020	2.37	Siltstone.
2,023	2.14	Sandstone.
2,037	2.42	Do.
2,047	2.17	Do.
2,056	2.16	Do.
2,062	2.41	Do.
2,111	2.33	Do.
2,152	2.30	Siltstone.
2,170	2.27	Sandstone.
2,176	2.64	Do.
2,188	2.27	Do.
2,227	2.46	Do.
2,229	2.18	Do.
2,255	2.28	Do.
2,288	2.14	Do.
2,330	2.21	Do.
2,440	2.61	Siltstone.
2,484	2.44	Argillite.

At South Barrow test well 2, R. H. Morris, who studied the samples, identified two heavy-mineral zones. He writes that:

> the zoned-zircon zone is well represented by samples from 1,990–2,330 feet. Two samples at shallower depths probably belong within this zone but zoned-zircon grains are lacking. The prismatic-tourmaline zone is represented by one sample at 2,383 feet. (Written communication, 1954.)

The distribution and abundance of heavy minerals is shown on plate 40.

OIL AND GAS

OIL AND GAS SHOWS

Shows of gas and oil were noted by Arctic Contractors' geologists who studied the samples of rock from the well while it was being drilled. The oil was not present in sufficient quantity to be produced, but the gas flowed at a rate high enough to furnish heat for the camp at Barrow. No shows were present above 1,850 feet in the well; those from below that depth are given in the following table on oil and gas shows.

Oil and gas shows in South Barrow test well 2

Depth (feet)	Recorded by Arctic Contractors' geologist, William C. Fackler	Recorded by Fairbanks laboratory
1,950–2,010	Cores of shale, siltstone, and sandstone had a gas odor and bled oil and gas. Fluorescence and a fair oil cut in ether were noted at 2,004 ft.	
2,000	-----	Dark-brown oil cut in petroleum solvent.

Oil and gas shows in South Barrow test well 2—Continued

Depth (feet)	Recorded by Arctic Contractors' geologist, William C. Fackler	Recorded by Fairbanks laboratory
2,023–2,025	Fair show of oil and gas	Sandstone 7 in. thick saturated with oil.
2,047	do	Slight fluorescence, dark-brown cut in petroleum solvent.
2,056	do	Sandstone 6 in. thick had slight fluorescence, dark-brown cut in petroleum solvent.
2,087–2,106	Shale bled slight amount of gas	
2,111	Slight show of oil	Sandstone 6 in. thick is oil stained, showed slight fluorescence.
2,125–2,128	Slight show of oil, light-straw-colored cut in ether.	
2,170	do	
2,176	do	Sandstone 3 in. thick is oil stained.
2,186	Slight show of oil	
2,188	do	Sandstone 9 in. thick is oil stained.
2,218–2,228	do	Sandstone 1 ft thick has slight oil odor.
2,229	Very slight show of oil	
2,254–2,255	do	
2,286–2,289	Slight show of oil, pale-straw-colored cut in lower part.	Sandstone 2 ft 4 in. thick has an oil odor on a freshly broken surface with oil stain and odor in lower part.
2,328–2,340	Stain and odor of oil and straw-colored cut in ether.	
2,329–2,332	-----	Sandstone 2 ft 10 in. thick has a strong oil odor and brown oil stain; it fluoresces pale yellow.
2,332–2,341	-----	Interbedded sandstone, siltstone, and clay shale have an odor of oil.
2,353–2,356	-----	Sandy siltstone has very slight oil odor.
2,375–2,420	-----	Sandstone has very slight oil odor on freshly broken surfaces.

FORMATION TESTS

Several formation tests recovered a small amount of gas but no oil. They are described below.

Test 1, 1,992–2,030 feet.—A Johnston formation tester was set at 1,991 feet in a hole open to 2,030 feet, but the packer did not hold. A second attempt at the same depth also failed, but a third trial made after reaming the hole to 1,992 feet was successful. Perforations in the tail pipe were between 1,995 and 2,006 feet; the pressure recorder was at 2,010 feet, and the bottom of the tailpipe at 2,015 feet. The tool was open 1 hour and 10 minutes, and a weak blow of air was noted. The test recovered 250 feet of drilling mud but no oil or gas.

Test 2, 2,314–2,391 feet.—With the hole open to the total depth (2,391 ft), a Johnston formation tester was set at 2,312 feet. The packer did not hold; so a new seat was reamed for it at 2,314 feet, and it was reset with perforations at 2,329–2,347 feet and a pressure recorder below them. A fair blow of air increased to a strong blow of gas in 12 minutes. The gate valve was closed and the pressure increased to 550 psi in 26 minutes. When the valve was opened, the pressure dropped to 250 psi in 12 minutes, and to 150 psi after 21 minutes. The tester was open for a total of 57 minutes, and then was closed in for 26 minutes. When an attempt was made to remove the tester, the packer stuck, and the drill pipe came unscrewed at 825 feet, and left 33 stands of pipe and the tester in the hole.

Test 3, 2,381–2,443 feet.—With the hole open to the total depth of 2,443 feet, a seat was reamed for a Johnston formation tester packer at 2,382 feet. The packer seated at 2,381 feet, with the perforated tailpipe at 2,391–2,410 feet and a pressure recorder below it. The tool was open for 30 minutes, during which time a weak blow of air was noted. The bottom 95 feet of drill pipe contained gas-cut mud which has 38 grains per gallon of chlorides. The flow pressure was too low to be recorded on the pressure chart.

Test 4, 2,260–2,265 feet.—The packer of the Johnston formation tester was set at 2,211 feet, with 41 feet of perforated pipe below it, and a pressure recorder at 2,223 feet. The hole was cased to 2,260 feet and was open to the cement plug at 2,265 feet. A fair to weak blow of air changed to gas in 29 minutes, at the end of the test. The tool was closed, and 168 feet of heavy gas-cut mud was recovered.

OIL, GAS, AND WATER ANALYSES

Several samples of water and gas and one of condensate were taken from South Barrow test well 2 while the well was being drilled and during the first year of production. Analyses were made by the U.S. Bureau of Mines and the National Bureau of Standards, and are presented as follows.

A sample of gas from 2,320 feet (probably from the formation test at 2,312–2,391 ft) was analyzed by the National Bureau of Standards with a mass spectrometer and was found to consist of 28.6 percent air (nitrogen and oxygen), and 71.4 percent of other gasses; when burned it produced 714.5 Btu per cubic foot. Components of the gas, figured on an air-free basis, were approximately 98.3 percent methane, 1.0 percent ethane, 0.2 percent propane, 0.01 percent n-butane, 0.004 percent n-pentane, and 0.5 percent carbon dioxide; the gas produced 1,014.2 Btu when burned.

A gas sample was taken May 29, 1949, about 6 weeks after the well was completed. It was flowing at an estimated rate of 500,000 cu ft per day, and the welded-casing container was flushed by the flow for about 5 minutes before the sample was taken. The gas temperature and pressure at the tubing head, where the sample was taken, were 28° F and 960 psi, respectively. The gas was analyzed by the Helium Station of the U.S. Bureau of Mines at Amarillo, Tex., with a mass spectrometer; helium and acid gases (carbon dioxide and hydrogen sulphide) were tested by separate special analyses. The gas was found to consist of 97.95 percent methane, 1.00 percent ethane, 0.21 percent propane, 0.07 percent normal butane, 0.01 percent isobutane, 0.73 percent nitrogen and 0.03 percent helium. Its calculated heated value, at 60° F and 30 inches of mercury, was 1,018 Btu per cubic foot.

Two gallons of condensate were taken from the high-pressure separator during the month of January 1950 and were analyzed by three processes. About a quart was submitted to the National Bureau of Standards, where 900 ml (milliliters) were distilled at a fast rate through a 25-mm Podbielniak column. The specific gravity of the sample (at 60° F, compared to that of water at 60° F) was 0.8217, and its refractive index at 20° C was 1.4508. The first 8 fractions, which boiled in the gasoline range, constituted 46.4 percent of the material. The remainder boiled in the kerosene range, but could be divided into other products such as naphtha. High density and refractive indices indicate the presence of a considerable quantity of aromatic hydrocarbons. The motor method octane number (American Society for Testing Materials, D 357) is 68. The results of the distillation are shown in the following table.

Analysis of 900 milliliters of condensate from South Barrow test well 2, made by the National Bureau of Standards

Fraction	Volume (ml)	Volume (sum ml)	Refractive index at 20° C (D-line)	Density at 20° C (g per ml)	Head temperature (° C)
Initial					23
1	50	50	1.4089	0.735	101
2	51	101	1.4271	.770	119
3	50	151	1.4375	.792	142
4	50	201	1.4407	.798	156
5	50	251	1.4444	.806	165
6	50	301	1.4436	.805	172
7	32	333	1.4464	.812	173
7a	35	368	1.4452	.809	181
8	50	418	1.4530	.826	[1] 205
9	50	468	1.4546	.829	211
10	50	518	1.4553	.830	219
11	50	568	1.4567	.833	227
12	50	618	1.4586	.836	233
13	50	668	1.4598	.838	237
14	50	718	1.4612	.840	247
15	50	768	1.4640	.845	263
16	55	823	1.4678	.862	275
17	13	836	1.4731	.853	276
Residue [2]	33	869		.878	

[1] Distillation was carried out at reduced pressures after fraction 7a was collected because the material appeared to be cracking. The pot temperature at that time was 223° C. Temperatures from fraction 8 through 17 were corrected to 760 mm. Hg by means of Lippincott's chart.
[2] Loss, 31 ml.

A second sample of the condensate was sent to the U.S. Bureau of Mines laboratory at Bartlesville, Okla., and the results of their routine analysis are shown in the following table. The sample is unusual because almost all the material is in the naptha and light gas oil range, and hydrocarbons boiling below 200° F, common in most condensate samples from gas wells producing little liquid, are nearly lacking. A comparison with an analysis made in Fairbanks, Alaska (see below) indicates that the sample sent to the Bureau of Mines had weathered before the analysis could be made.

Analysis of a sample of condensate from South Barrow test well 2, by the U.S. Bureau of Mines

[General characteristics of sample: Sp gr, 0.822; sulfur, <0.1 percent; Saybolt Universal viscosity at 100° F, 32 sec; gravity, 40.6° API; pour point, −70° F; color, lighter than Natl. Petroleum Assoc. color No. 1]

Distillation, Bureau of Mines routine method

Fraction	Cut at— (° C)	Cut at— (° F)	Percent	Sum (percent)	Specific gravity [1]	Gravity (° API at 60° F)	Correlation index	Aniline point (° C)
STAGE 1—Distillation at atmospheric pressure, 750 mm Hg; first drop, 75° C (167° F)								
1	50	122						
2	75	167						
3	100	212	1.8	1.8	0.721	64.8		
4	125	257	3.4	5.2	.754	56.2	28	47.2
5	150	302	7.9	13.1	.782	49.5	34	45.8
6	175	347	19.1	32.2	.804	44.5	38	47.9
7	200	392	26.3	58.5	.822	40.6	40	52.5
8	225	437	26.7	85.2	.838	37.4	42	56.0
9 [2]	250	482	12.1	97.3	.855	34.0		58.6
Residuum [3]			2.6	99.9	.879	29.5		

[1] Specific gravity at 60° F compared to water at 60° F.
[2] Distillation discontinued at 249° C (480° F), flask dry.
[3] Carbon residue of residuum, less than 0.1 percent; carbon residue of crude, less than 0.1 percent.

Approximate summary

Constituent	Percent	Specific gravity	Gravity (° API)	Saybolt Universal viscosity
Light gasoline	1.8	0.721	64.8	
Total gasoline and naphtha	58.5	.804	44.5	
Kerosene distillate				
Gas oil	38.8	.843	36.4	
Nonviscous lubricating distillate				50–100
Medium lubricating distillate				100–200
Viscous lubricating distillate				>200
Residuum	2.6	.879	29.5	
Distillation loss	.1			

An analysis was made in the Fairbanks laboratory of the U.S. Geological Survey by E. Lloyd Powers, petroleum engineer, who distilled samples of the condensate at atmospheric pressure. One 100-ml sample had an initial boiling point of 100° F, and 2 percent of the liquid was distilled at less than 120° F. The end point was 360° F. The second 100-ml sample had an initial boiling point of 90° F, and an end point of 380° F. Distillation ranges, specific gravity, and API gravity of the various cuts are shown in the following table. The gallon of condensate from which the distillation samples were taken contained approximately 20 cc of water that was strongly alkaline. It was tested for $CaCl_2$, which had been introduced into the well, but the result was negative.

Atmospheric distillation of condensate from South Barrow test well 2

Distillation temperature, °F	Sum percent distilled	Cut No.	Specific gravity	Gravity °API
First sample				
<120	2.0			
140–165	12.5	1	0.7650	52
180–240	35.0	2	.7960	46
280–360	90.0	3	.8256	40
Second sample				
170	6			
190	15	1	0.7380	60.2
240	25			
280	35	2	.8078	43.7
340	77			
380	90	3	.8335	38.3

On January 30, 1950, two gas samples were caught in steel bombs; one, 320 ml taken at 1,020 psi and 27.5° F, came from the well head; the other, 320 ml at 80 psi and 29° F, was taken after dehydration. Valve packing leaked during transport of the samples to the National Bureau of Standards, lowering the pressure of the former to 400 psi and the latter to a value almost too low to determine the water content. Analyses are shown in the following table on mass spectrometer analyses; the water content, determined by the Weaver calorimetric method, was 0.66 percent for the well-head sample, and 0.11 percent for the sample that had passed through the dehydrator. This quantity of water was too small to be detected by the mass spectrometer; the table shows that treatment by the dehydrator did not change the composition of the gas significantly, except for the water content.

Mass spectrometer analyses of two gas samples from South Barrow test well 2

[Analysis by Natl. Bur. Standards]

Component	Well head sample (mole percent)	Dehydrated sample (mole percent)
Methane	97.7	97.7
Ethane	1.04	1.04
Nitrogen	.94	.94
Carbon dioxide	.20	.20
Propane	.03	.03
Butane [1]	.04	.03
Pentane [1]	.02	.03

[1] Maximum.

LOGISTICS

Personnel and housing.—Supervisors employed at the well were the drilling foreman, petroleum engineer, and geologist. The rig crew included 2 drillers, 2 derrickmen, 6 floormen, a fireman, and a heavy-duty-equipment mechanic and welder; 2 LVT operators also worked at the site, hauling crews and water and operating the crane and tractors. Such temporary workers as rig builders, carpenters, laborers, electricians, and mechanics were sent from Barrow camp as their services were required.

The men slept and ate at Barrow camp, except for the midshift meal. One wanigan was used to serve it in, and one was kept for sleeping, in case transport to Barrow were impossible. A geologist's wanigan, and boiler, cement, and water wanigans made up the rest of the camp.

Vehicles and heavy equipment.—A bulldozer, a crane, two weasels, and an LVT moved men and materials; Schlumberger electric logging equipment was mounted

on a special truck. Equipment used in drilling was listed by Arctic Contractors as follows:

1--Ideco 62-ft cantilever mast with crown block, racking platform and finger.
1--Cardwell drawworks, model H, skid-mounted, with controls, cathead, and rotary drive assembly.
1--Caterpillar D–8800 engine for the drawworks.
1--Ideal 17½- by 44-in. rotary table.
1--Gardner-Denver 7¼- by 10-in. FXO–FO mud pump.
1--Caterpillar D–13000 engine for the pump.
1--Gardner-Denver 4- by 5-in. pump.
1--Chrysler Industrial engine, for 4 by 5 pump.
1--Marlow 4-in. Mud Hog pump.
1--Baash-Ross 100-ton traveling block with three 30-in. sheaves, grooved for 1-in. line.
1--Web Wilson improved 100-ton connector.
1--Byron-Jackson 100-ton hook.
1--Kewanee 32-hp boiler, No. 578, 100 lb working pressure.
1--Link-Belt mud screen, type NRM–145.
Shop-made 100-lb. mud tanks.

Fuel, water, and lubricant consumption.—Fuel burned during the drilling totaled 30,642 gallons of diesel oil and 5,670 gallons of gasoline, and 247 pounds of grease and 909 quarts of oil were used for lubrication. Water consumption was 460,500 gallons; the source was a nearby lagoon.

DRILLING OPERATIONS

The drilling rig was set on pilings, and the frozen ground showed no tendency to thaw because both rigging up and drilling took place during the winter. Outside temperatures were as low as 40° below zero (Fahrenheit) during November, December, and January and down to 60° below zero in February. The interior of the rig was between 20° and 40° above zero most of the time, and rarely above 50°; its fluctuations were roughly correlative with those of the outside temperature. Operations described below were recorded by Karl VonderAhe, Arctic Contractors' petroleum engineer.

Notes from drilling records

Depth (feet)	*Remarks*
87	Cement was stacked on platform, covered with a tarpaulin, and heated with a Herman-Nelson heater; 16-in. (inner diameter) 42-lb Western Pipe and Steel slip-joint casing was set at 69 ft with 47 sacks of construction cement mixed with water heated to 98° F and treated with 2 percent $CaCl_2$. Top of casing cemented with 24 additional sacks of cement.
	Light-plant breakdown caused operations to be shut down for 4½ hr.
1,059	Set 11¾-in. 47-lb grade J–55, 8-round thread API. seamless casing at 960 ft with 130 sacks of construction cement, with last 15 sacks treated with $CaCl_2$, and water heated to 80° F. Annulus between 11¾ and 16-in. casings filled to cellar floor with 2½ sacks of cement.
2,391	Johnston tester and 33 stands of drill pipe stuck in hole for a short time, but all recovered successfully.

Notes from drilling records—Continued

Depth (feet)	*Remarks*
2,505	After heating cement, drill pipe was lowered to 2,504 ft and 47½ sacks of construction cement were pumped down in order to plug hole back to 2,417 ft. Cement did not harden and was cleaned out to 2,497 ft. Drill pipe removed and 7-in. 23-lb J–55 Range 2 casing set at 2,325 ft with 88 sacks of construction cement. Pumped 90 cu ft of water in ahead of cement, with a cementing plug on top of cement.
	When about a third of the cement had been forced out of the pipe, casing was pulled up to 2,308 ft. After being shut in for 39 hr, pipe was loose, and it was then pulled up to 2,275 ft. and plug fished out. The 7-in. casing was reset successfully at 2,260 ft.
	Drill pipe lowered to 2,228 ft and drilling mud circulated to replace cement-cut mud. Well started to flow gas-cut mud which was light and very viscous. Well closed in and pressure built up to 230 psi, 5 hr after hole first started to flow. Valve opened a day later, after pressure dropped to 65 psi, but well began to flow mud again. It was again shut in, and pressure built up to 200 psi; so a Shaffer control head was installed. Gas pressure dropped, because drilling mud froze in hole. When it was drilled out, from 58 to 141 ft, gas pressure was still present. Drill pipe lowered to 1,951 ft, and as old gas-cut mud was circulated out of hole, gas pressure at surface dropped, and no more gas came to surface.
	After feeling unsuccessfully for 7-in. casing shoe with an underreamer, an electric log located it at 2,260 ft.
	Heated mud circulated in hole in effort to thaw frozen mud in annulus between 11¾- and 7-in. casing, but annulus remained blocked at pressures as high as 1,300 psi, which were great enough to force some mud into the rock.
	Plug of 30 sacks of construction cement mixed with 18 cu ft of water was put at 2,289 ft and another, of 20 sacks of construction cement treated with 1 percent $CaCl_2$, at 2,265 ft, but both were unsuccessful. A third plug, made of 20 sacks of Oil Well regular cement and 38 lb of $CaCl_2$ mixed with enough water to make a 122½-lb slurry, was placed at 2,265–2,289 ft.
	Small amount of fluid could be forced into the rock with pressures of 1,400 psi, but most flowed back into mud pit when pressure was released.
	Cement was squeezed into annulus between 7-in. and 11¾-in. casing, and circulation was obtained through the annulus as the last of the cement was being put in place. Cement cleaned out of 7-in. casing, and formation test 4 made. After test, cement plug cored between 2,265 and 2,289 ft, and hole cleaned out to bottom; gas and faint stain of oil noticed in mud below 2,400 ft.
	Wall surface of open hole scraped, and mud circulated to condition hole; 280 ft of 5½-in. 17-lb Grade J–55 Emsco liner (with 24 rows of 20-mesh by 2-in. vertical slots on 4-in. centers superimposed on slots) was set at 2,224 ft, with a

Notes from drilling records—Continued

Depth (feet)	Remarks
2,505—Con.	packer at 2,226 ft. Perforations were at 2,282–2,402 and 2,473–2,504 ft, and the bottom of the liner was at 2,504½ ft. Seventy-eight joints of tubing (2½-in. external-upset 6.5 lb H–40 8 round thread range 2 API seamless) were set at 2,468 ft. Christmas tree installed, and well began to flow gas as mud was displaced with water.

PRODUCTION HISTORY

A day after the well was completed, tubing pressure was 670 psi, and casing pressure 820 psi, with a $^{30}/_{64}$-inch bean, and the estimated production was 4.1 million cubic feet of gas. While the well continued to flow, producing a small amount of muddy water with the gas, the gages froze shut and had to be thawed with steam. Ice bridges formed in the hole and shut off the flow of gas. Hot $CaCl_2$ solution was added, with little effect. The bean was opened to lower the pressure in order to put sticks of fused $CaCl_2$ into the hole; the well blew gas by heads, with some mud and a few pieces of ice, followed by the rest of the ice plug, and gas flowed through the ¾-inch bean with great force. Tubing pressure dropped slowly to 450 psi, and the casing pressure to 800 psi. With a $^{28}/_{64}$-inch bean, tubing pressure rose to 820 psi and casing pressure to 900 psi in 12 hours. Shut-in pressures were 1,020 psi on both. A high-pressure trap was installed, and flow tests were made, the produced gas being burned at the end of a flare line.

The well flowed steadily through a $^{19}/_{64}$-inch bean for 3 weeks; during this time about a quart of muddy water was recovered from the trap. Tubing and casing flowing pressures rose gradually to 1,000 and 1,010 psi, respectively, while the well produced at the approximate rate of 507,000 cubic feet per day.

On July 29, 1949, the well was put on production and supplied gas for Barrow camp. In the following two months, production increased gradually from 46,000 to 216,000 cubic feet per day with a tubing pressure of 1,010 psi and casing pressure increasing from 420 to 700 psi. During four weeks ending on October 23, 1949, 7,276,000 cubic feet of gas was produced. On November 4, 1949, production ceased because the tubing was plugged by hydrates that were apparently formed because the temperature in the hole was lowered by the increased production.

Caustic soda was put in the well, and the well was allowed to blow itself out several times, but the plugs of frozen material were not completely removed. Heated diesel oil was then circulated in the hole, and in 2 weeks the drill pipe through which the oil flowed was gradually lowered to 736 feet. Tubing and casing were cleared of obstructions, and gas was again furnished to the camp, with casing and tubing pressures of 1,020 psi. A few days later, however, in early December, the temperature in the tubing dropped to 27.5° F, and the tubing again became plugged by frozen water and hydrates. Above-freezing temperatures outside the tubing failed to thaw it out, but 30 gallons of glycol, put in the tubing on December 23, cleaned out the blockage; and the tubing cleaned itself when it was open for 15 minutes, 3 days later. The well then produced 530,000 cubic feet of gas and about a pint of fluid per day. More glycol, added in small amounts, kept the well flowing.

After the first week in January, the flow was lowered to about 430,000 cubic feet per day; wellhead temperatures ranged from 29° to 27° F, except when heat was turned off the Christmas tree radiators in order to freeze a suspected leak in the 7-inch casing. Diesel fuel, put in the hole to locate the break, was not recovered. In late January, production again dropped somewhat, camp use fluctuating from 336,000 to 442,000 cubic feet per day during February. At the end of the month, as more stoves were connected to the line, it again was between 450,000 and 500,000 cubic feet per day. Casing and tubing pressures held steady at 1,020 psi. Dehydration of the gas, as its temperature dropped during production, took place mostly within the well, but enough water vapor was present in the gas as it flowed through the surface connections to cause the regulators to freeze and stick.

Steam jackets installed on February 20th were successful in preventing hydrates and ice from forming in the regulators by raising the gas temperature from 17° to about 100° F.

On March 19th, the tubing was blown down through a ¾-inch bean for 30 minutes, and about a gallon of condensate and mud was recovered from the separator. The well flowed an estimated rate of 6 million cu ft per day, and tubing pressure dropped from 1,020 to 640 psi. When it was again returned to normal production, the pressure rose to 1,020 psi in 10 minutes.

A few days later, a small leak was located in the 11¾-inch casing at the wellhead, and a larger one was suspected in the 7-inch casing at some depth in the hole; so plans were made to kill the well with mud in order to locate the leak. At 2:45 p.m. on April 5th, however, the well caught fire when a Caterpillar tractor clearing snow near the gasline apparently hit the line and broke it. A strong wind blew gas from the break toward the control room and wellhouse, and when it was ignited by the reboiler of the dehydration unit, they caught fire and blew up. When the fire was under control several hours later the wellhouse and meterhouse had been destroyed, and the well killed with mud. On April 22d, a derrick was moved (from South Barrow test well 4, nearby), to South Barrow test well 2, and

the 2½-inch tubing was pulled out. It pulled hard and when an impression block was lowered to 565 feet, it showed that the 7-inch casing had collapsed. Because the collapse was within the zone of permafrost and had presumably been caused by ice, the 11¾-inch casing was probably also damaged. Consequently the well was abandoned and left full of the heavy mud which, according to the thermistor installed in the hole, was already freezing.

DRILL AND CORE BITS

A Reed Kor-King conventional core barrel with 6⅛-inch and 6¼-inch bits was used to core 1,089 feet. The 21 soft-formation bits and 26 hard-formation bits recovered about 90 percent of the rock cored (above the argillite).

Eighteen drilling bits, 7⅞–20 inches in diameter, were used to drill the hole. Most of them were Reed bits, but some Crum Brainard and Hughes bits were also employed.

DRILLING MUD

The hole made mud while it was being drilled, and except for water, used to reduce the mud weight, the only additives were a small amount of Aquagel to increase the colloid content, with Stabilite-8 and pyrophosphate to control viscosity. After setting the 7-inch casing, the mud was treated with sodium bicarbonate to combat cement contamination, and new mud was added. Continued work with the casing caused more contamination, and when the well began flowing gas, sodium bicarbonate, Aquagel, Baroid, and pyrophosphate were used to maintain the desired weight and viscosity. The addition of 90½-pound newly mixed mud stopped the gas flow, as the gas-cut mud was replaced. Two unsuccessful attempts to set cement plugs contaminated the mud again, so it had to be discarded and more new mud added. The mud materials used in drilling and completing the hole totaled 83 sacks of Aquagel, 65 pounds of Stabilite-8, and 85 pounds of sodium bicarbonate; the following shows the mud characteristics and additives during drilling.

Drilling-mud characteristics in South Barrow test well 2

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec API)	Water loss (cc/ 30 min)	Temperature (° F)	Additives
15					Mixed 25 lb Stabilite-8, 12 sacks Aquagel.
87					Added 47 sacks Aquagel.
100	72				
200	72	40			
250	73				
260		39			72 bbl of mud were dumped.
300	73	47			
330	73				
350	75	41			
366					Added 25 lb Stabilite-8.
430	78	39			
460	79	45			
480	79	40			
530	79	40			
575		39			

Drilling-mud characteristics in South Barrow test well 2—Con.

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec API)	Water loss (cc/ 30 min)	Temperature (° F)	Additives
585	80				
600	80				
625	80	38			
645		40			
655	81				
680	81	37			
740	82	40			
780	82				
795		40			
840	84	41			
860	84	41			
880	84	41			
950	82	38			
975	85	41			
990	83	35			
1,003					Added 3 sacks Aquagel.
1,015	82	40			Added 10 lb Stabilite-8.
1,020	81	42			
1,050	83	42			
1,060	85	44			Added 6 sacks Aquagel, 85 lb $NaHCO_3$.
1,080	79	38	65	52	
1,104					Added 6 sacks Aquagel.
1,110	79	37	60	53	
1,150	81	39	60	55	
1,210	82	48	45	55	
1,250	82	46	60		
1,265	82	42	60		
1,300	84	44	60		Added 5 lb Stabilite-8.
1,335	83	41	60		
1,365	83	41	60		
1,450	84	42	55		
1,550	85	40	55		
1,650	86	41	50		
1,705	87	43	50		
1,753					Dumped 42 bbl mud and added water because of increasing mud weight.
1,790	86	40	50	55	
1,840	87	39	50	65	
1,921					Dumped 77 bbl mud and added water because of increasing mud weight.
1,950	87	42	53	65	
1,970	85	39	55	64	
2,030	84	38	55	64	Added 4 sacks Aquagel.
2,115	84	39	55	48	Dumped 53 bbl mud.
2,130	85	41	60	40	
2,175	85	42	50	50	
2,185	85	40	65	51	
2,220	84	38	65	51	
2,255	86	43	45	57	
2,270	85	40	80	56	
2,305	84	38	50	59	
2,325	86	41	50	60	
2,345	85	39	57	57	
2,380	84	40		57	
2,390	84	40	57	59	Added 5 sacks Aquagel.
2,415	85	43	57		
2,440	83	45	55	48	
2,445	83	43	55	50	
2,455	83	43	55	59	
2,465	84	43	50	55	
2,485	85	44	55	56	
2,505	84	41	55	56	

HOLE DEVIATION

The upper part of the hole was less than a degree off vertical, as measured by Totco. Below 1,300 feet, deviation increased gradually to 3°20′ at 2,400 feet, the lowest point at which a reading was taken. Deviation at each depth checked is plotted on the graphic log (pl. 42).

ELECTRIC LOG AND VELOCITY SURVEYS

Schlumberger hand-recording equipment was used to make five electric log runs which recorded spontaneous potential and long and short normal resistivity curves for the hole from 69 to 2,502 feet. (See pl. 42.) A sixth run, from 2,250 to 2,287 feet was made in order to locate the shoe of the 7-inch casing.

A velocity survey was made by United Geophysical Co., Inc., with a single shothole 411 feet north of the well. Velocity above the argillite increased approxi-

mately from 6,700 to 8,400 feet per second with depth; vertical velocity within the argillite is approximately 18,000 feet per second.

SOUTH BARROW TEST WELL 3

Location: Lat 71°09′46″ N., long 156°34′44″ W.
Elevation: Ground, 30 feet; kelly bushing, 44 feet.
Spudded: June 23, 1949.
Completed: August 26, 1949. Dry and abandoned.
Total depth: 2,900 feet.

The third test well drilled in the Barrow area is South Barrow test well 3, about 7 miles south by east of South Barrow test well 2. (See fig. 50.) The well site is in a structurally high area with a closure, according to seismograph surveys, of 200 feet on upper horizons, lessening to 100 feet with increasing depth. The seismograph work also suggested that the top of the argillite was somewhat deeper than it is to the north and that it was separated from the overlying beds by sedimentary strata not present in South Barrow test well 2. Drilling confirmed this interpretation. Triassic strata, absent in other tests in the Barrow area, are 252 feet thick in South Barrow test well 3, and the overlying Lower Jurassic is 902 feet thick compared to less than 60 feet in test wells to the north. (See pl. 41.)

The Gubik formation is presumed to be present in this test to a depth of 65 feet; no samples were available from shallower depths and samples below that depth resemble Cretaceous rocks. Below the Gubik formation (14-65? ft), Cretaceous rocks in the test (the Topagoruk formation, 65?–1,080 ft; the Oumalik formation, 1,080–1,285 ft; and pebble shale, 1,285–1,645 ft) consist almost entirely of shale, with some thin sandstone beds near the top. A basal conglomerate with chert pebbles as much as 1½ inches in diameter is present at the base of the pebble shale. The Lower Jurassic beds, (1,645–2,610 ft) are light-olive-gray siltstone and contain a large amount of argillaceous interstitial material; an upper sandy section of this rock is separated from the lower siltstone sequence by about 400 feet of olive-gray to medium-dark-gray pyritic clay shale.

The lowest 60 feet of Jurassic beds are composed of olive-gray reddish-brown or medium-dark-gray clay shale and some thin beds of light-olive-gray bentonite. The base of the unit is placed at 2,610 feet, below a core which had very poor recovery; sidewall cores taken between 2,596 and 2,610 feet recovered rock similar to that in the overlying beds. In the upper Triassic strata, 2,610–2,799 feet, limonite oolite layers are interbedded with limestone and very calcareous siltstone and sandstone. The underlying argillite, 2,799–2,900 feet, is similar to that in the other test wells. Some slight oil shows were recorded in the Mesozoic beds, but none were sufficient to produce oil in drill-stem tests, and the test was abandoned.

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

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

Core	Depth (feet)	Remarks
------	0–14	Kelly bushing to ground level.
------	14–40	No samples recovered from this section; well geologist described sediment penetrated as soft blue-gray clay. Gravel in samples from lower depths may have fallen down from this part of the hole.
------	40–65	Well geologist described section as soft blue-gray clay with carbonaceous particles and sandy streaks.
------	65–200	Clay, medium-gray, and small quantity of gray silt and very fine sand. Top of Topagoruk formation at 65 ft.
1	200–220	Recovered 8 ft: Microfossils absent. 6 in., clay shale, light-gray, noncalcareous. 3 in., sandstone, very fine grained, silty, noncalcareous, thin-bedded. Beds lie flat; partings marked by carbonized plant fragments. Sand grains are angular with low sphericity and usually clear quartz, with some gray chert and translucent to opaque yellow or white quartz. Mica rare and predominantly clear to light green or gray, though a few biotite flakes were found. 1 ft 6 in., sandstone, light-gray, fine to very fine grained, slightly silty, noncalcareous, massive. 3 ft 9 in., sandstone as above but with a few partings, marked by carbonized plant fragments, increasing with depth. Clay laminae rare. Straw-colored oil cuts in CCl_4 at 204 ft and 206 ft. Porosity and permeability at 204 ft in a plug cut parallel to bedding are 28.4 percent and 390 millidarcys, respectively; perpendicular to the bedding, they are 27.3 percent and 199 millidarcys. 2 ft claystone, silty, light-olive-gray, micaceous, noncalcareous.
2	220–240	Recovered 20 ft: Microfossils vary rare. 4 ft 6 in., siltstone, medium-gray, argillaceous, slightly calcareous, interlaminated with carbonaceous partings in top 3 in.; shaly cleavage in botton 6 in. 5 ft 6 in., sandstone, light-gray, fine to very fine grained, argillaceous, thin-bedded, noncalcareous; partings of macerated carbonized plant remains; 3-in. bed at 226 ft has more abundant carbonaceous material and also has numerous laminae of crossbedded medium-gray clay shale, with dips to 7°; light-amber oil cuts obtained in CCl_4 from 224 ft and 229 ft. Porosity and permeability of plug cut parallel to bedding at 229 ft are 29.1 percent and 370 millidarcys, respectively; from 1 cut normal to the bedding they are 28.2 percent and 242 millidarcys. 10 ft, siltstone, light- to medium-greenish-gray, argillaceous, slightly micaceous, noncalcareous to slightly calcareous; rare carbonized plant flakes.

Lithologic description—Continued

Core	Depth (feet)	Remarks
------	240–400	Siltstone, medium-gray, argillaceous; some clay shale and streaks of very fine sand. Gravel in ditch samples from 290–420 ft is from beach sand packed around conductor pipe.
3	400–414	Recovered 8 ft: Microfossils very rare. Siltstone as in core 2 above.
------	414–602	Lithology as in core 3 above, but with clayshale.
4	602–622	Recovered 15 ft: Microfossils very rare. 1 ft 5 in., claystone, medium-dark-gray, slightly silty, noncalcareous. 2 in., shaly siltstone, light-olive-gray, noncalcareous; interlaminated with carbonaceous films. Dip 15°. 1 ft 5 in., siltstone, light-olive-gray, noncalcareous; carbonized macerated plant flakes scattered throughout; 2 beds (2–3 in. thick) of interlaminated shaly siltstone and carbonaceous partings as described above, with a 15°–20° dip. 3 in., claystone as above. 1 ft 1 in., siltstone as above but with some decrease in carbonaceous material. 3 in., claystone as above. 8 in., siltstone as above. 2 in., claystone as above. 1 ft 2 in., siltstone as above. 2 ft 1 in., claystone as above but with carbonized macerated plant flakes. Probable slickensides present at approximately 612 ft, and streaks of siltstone in bottom 4 in. 11 in., siltstone as above. 3 in., claystone as above. 3 in., siltstone as above. 3 ft 10 in., claystone as above but slightly siltier toward bottom. 1 ft, siltstone as above. 1 in., claystone as above.
------	622–774	Lithology as in core 4 above.
5	774–794	Recovered 18 ft: Microfossils common. Claystone, dark-gray, slightly micaceous, noncalcareous; conchoidal to subconchoidal fracture; a few laminae of medium-gray clay shale. Possible slickensides noted at 779–780 and 784 ft.
------	794–990	Lithology as in core 4 above to 885 ft. Silt increases downward from 855 to 955 ft and decreases from 955 to 990 ft. Pyrite common at 835–865 ft.
6	990–1,010	Recovered 7 ft 6 in.: Microfossils absent. Claystone, medium-gray to medium-dark-gray, noncalcareous; scattered small streaks and patches of siltstone and rare 1- to 2-in. beds of light-olive-gray noncalcareous argillaceous siltstone.
------	1,010–1,030	Lithology as in core 6.
7	1,030–1,050	Recovered 19 ft 6 in.: Microfossils rare. 14 ft 3 in., claystone as above; siltstone streaks contain some very fine sand and are slightly calcareous. Silty patches give mottled appearance to clay surfaces. Lenses and streaks commonly dip 15°–20°. At 1,034 ft a ½-in. layer of interlaminated light- to dark-gray shaly clay lies flat. 5 ft 3 in., clay shale, interlaminated dark- to light-gray, noncalcareous, fissile in part. Beds lie flat.
------	1,050–1,210	Pink stain on clay and cement grains in ditch samples from 1,055 ft down is from quebracho, which was added to drilling mud at that depth. Lithology same as in core 7 to 1,185 ft; from that depth to 1,210 ft, there is a slight increase in sand. Top of Oumalik formation 1,080 ft.
8	1,210–1,222	Recovered 12 ft: Microfossils absent. Clay shale, medium-dark-gray, noncalcareous; hackly to subconchoidal fracture; a few somewhat silty, light-gray laminae. Silt content increases slightly with depth, and silty layers show faint crossbedding and lensing, especially toward bottom of core. At 1,217 ft, no cut, but a faint yellow residue in CCl_4.
------	1,222–1,285	Lithology as in core 8; thin coal bed near 1,260 ft.
------	1,285–1,388	Clay shale, dark-gray, pyritic, with quartz grains as in core 9. Top of Lower Cretaceous pebble shale at 1,285 ft. Layer of light-brown limestone at 1,375 ft.
9	1,388–1,406	Recovered 18 ft: Microfossils abundant. Clay shale to claystone, dark-gray, micaceous, noncalcareous, well-indurated. Well-rounded polished or pitted grains of clear quartz scattered at random through clay shale; grains and granules of black chert very rare and very well rounded. Fine streaks and lines of pyrite, possibly replacing plant material, are scattered throughout. At 1,405 ft is a 2-in. bed of very fine grained light-olive-gray slightly argillaceous slightly calcareous sandstone with a good odor of oil; an amber cut and yellowish-brown residue in CCl_4 at 1,404 ft.
10	1,406–1,416	Recovered 7 ft 6 in.: Microfossils common. Clay shale and claystone as above; at 1,414 ft is a 1-in. bed of brownish-gray dense limestone with faint laminae that are due possibly to a slight variable amount of clay.
------	1,416–1,613	Lithology as in core 9.
11	1,613–1,625	Recovered 3 ft: Microfossils very rare. Clay shale and claystone as core 10 above.
12	1,625–1,639	Recovered 13 ft: Microfossils abundant. 2 in., same as above. 2 in., sandstone, olive-gray, very fine grained, slightly argillaceous, noncalcareous, pyritic, well-indurated. 5 in., clay shale as above. 12 ft 3 in., clay shale, black; contains well-rounded gray and black quartz and chert pebbles, 1/16–1½ in. in diameter. Subangular to rounded grains of chert and quartz ranging from silt to coarse sand scattered throughout the rock, and are also arranged in small lenses. Bedding planes irregular and apparently undisturbed by pebbles, which are unoriented. Carbonaceous material and pyrite streaks and grains common, and pyritic nodules as much as one-half an inch in diameter also present.

Lithologic description—Continued

Core	Depth (feet)	Remarks
------	1, 639–1, 645	Pebble shale as in core 12.
------	1, 645–1, 739	Siltstone, light-olive-gray, sandy, noncalcareous; coarsens downward. Top of Lower Jurassic at 1,645 ft.
13	1, 739–1, 758	Recovered 19 ft: Microfossils rare. Siltstone and very fine grained sandstone, light-olive-gray; noncalcareous, moderately to well indurated, mottled with streaks and irregular lenses of olive-gray clay. Sand and silt grains are subangular clear (some white) quartz, with very little other material except clay, and rare light colored mica. At 1,746 ft, sieve analysis indicated 39.1 percent very fine sand, 26.8 percent silt, 34.3 percent fine silt and clay. At 1,739 and 1,754 ft, fair to good odor of oil; amber cuts and yellowish-brown residue in CCl_4.
14	1, 758–1, 778	Recovered 20 ft: Microfossils very rare. Siltstone and sandstone as in core 13. Sieve analysis of sample from 1,776 ft showed rock to consist of 36.7 percent very fine sand, 31.0 percent silt, 32.3 percent fine silt and clay. At 1,778 ft, porosity 13.5 percent, and permeability less than 5 millidarcys. Fair to good odor of oil noted in core. Three ammonite specimens, *Dactylioceras* cf. *D. commune* (Sowerby), cf. *D. delicatum* (Bean-Simpson), and cf. *D. crassiuscutosum* (Simpson), recovered at 1,772 ft and identified by R. W. Imlay (1955, p. 82).
15	1, 778–1, 798	Recovered 20 ft: Microfossils very rare. Sandstone and siltstone as above; cephalopod at 1,780 ft. Fair to good odor of oil, amber cut, and yellowish-brown residue obtained in CCl at 1,798 ft.
------	1, 798–1, 979	Ditch lithology samples from 1,798–1,865 ft contain about 50 percent sandstone and siltstone, and 50 percent black shale; below that depth, to 1,979 ft, shale increases rapidly and constitutes 70–90 percent of sample.
16	1, 979–1, 999	Recovered 20 ft: Microfossils very rare. Clay shale, medium-gray, noncalcareous, very uniform; subconchoidal fracture. Pelecypods and cephalopods abundant; worm tubes, some pyrite-filled, also present. Pyrite streaks and lines scattered throughout the rock. Olive-gray limestone concretions 2½ in. in diameter, at 1,998 ft.
17	1, 999–2, 018	Recovered 16 ft: Microfossils very rare. Clay shale as above; a 6-in. bed of medium-gray noncalcareous claystone, with conchoidal fracture, is present at 2,009 ft. Ophiuroidian (brittle star) at 2,010 ft, *Dactylioceras kanense* McLearn from 2,016 ft and *D.* cf. *D. semicelatum* (Simpson) from 2,017 and 2,018 ft, identified by R. W. Imlay (Imlay, 1955, p. 82, 87, 88.)
18	2, 018–2, 028	Recovered 10 ft: Microfossils abundant. Clay shale as above. A limestone concretion, 1 by 1 by 2 in. at 2,023 ft, is similar to concretions at 1,998 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
19	2, 028–2, 048	Recovered 19 ft: Microfossils very rare. Clay shale as above.
20	2, 048–2, 068	Recovered 14 ft: Microfossils rare. 4 ft 6 in., clay shale as above; it is slightly silty and somewhat harder toward base. 7 in., siltstone, olive-gray, slightly calcareous, well-indurated. 8 ft 11 in., clay shale as above but slightly silty and micaceous. A few light-gray silt laminae at 2,061 ft. *Coeloceras* aff. *C. mucronatum* (d'Orbigny) at 2,063 ft identified by R. W. Imlay (Imlay, 1955, p. 88).
21	2, 068–2, 078	Recovered 9 ft: Microfossils rare. Clay shale as above, but without silt laminae. *Amaltheus* sp. at 2,069, 2,073, 2,074, and 2,075 ft.
------	2, 078–2, 079	No sample.
22	2, 079–2, 099	Recovered 20 ft: Microfossils rare. 13 ft 6 in., clay shale, olive- to medium-gray, slightly silty, noncalcareous; pyrite streaks and lines abundant. *Amaltheus* sp. at 2,080, 2,084, 2,085, and 2,090 ft. 8 in., siltstone, olive-gray, argillaceous, calcareous. 5 ft 10 in., silty clay shale as above; slightly calcareous toward base. *Amaltheus* sp. at 2,099 ft.
23	2, 099–2, 119	Recovered 20 ft: Microfossils very abundant. Clay shale, medium-gray, silty, micaceous, slightly calcareous; poor shaly cleavage. Pyrite streaks and nodules abundant; patches of purplish and bluish films, often as aureoles around pyrite streaks, present on some partings. Upper 3 ft contains dark-green waxy (glauconite?) pellets of fine- to medium sand size, scattered, and concentrated in irregular patches. *Amaltheus* cf. *A. margaritatus* (Montfort) at 2,111 ft. (Imlay, 1955, p. 82.)
------	2, 119–2, 120	No sample.
24	2, 120–2, 130	No recovery.
25	2, 130–2, 151	Recovered 20 ft: Microfossils very abundant. Clay shale, medium-dark-gray, slightly silty, micaceous, noncalcareous. Pyritic lines and streaks common; nodules of pyrite present. Rare scattered fishbone fragments. Brachiopods at 2,131 and 2,132 ft.
26	2, 151–2, 170	Recovered 19 ft: Microfossils rare. Clay shale as above.
27	2, 170–2, 179	Recovered 9 ft: Microfossils rare. Clay shale as above.
28	2, 179–2, 199	Recovered 20 ft: Microfossils very rare. Clay shale as above; fishbone fragments present. *Velopecten*? sp. at 2,165 and 2,186 ft, *Amaltheus* cf. *A. depressus* Simpson at 2,186 ft, *A. nudus* (Quenstedt) at 2,198 ft, *Velopecten*? sp. at 2,199 ft (Imlay, 1955, p. 82).
29	2, 199–2, 218	Recovered 19 ft: Microfossils very rare. Clay shale as above, rarely grading to a few inches of silty claystone.
30	2, 218–2, 231	No recovery. Ditch samples suggest lithology is same as in core 29.

Lithologic description—Continued

Core	Depth (feet)	Remarks
31	2, 231–2, 251	Recovered 9 ft: Microfossils absent. Clay shale as above but without claystone. Purplish slightly iridescent film commonly associated with pyrite streaks.
32	2, 251–2, 271	Recovered 20 ft: Microfossils common. Clay shale as above.
33	2, 271–2, 281	Recovered 10 ft: Microfossils very rare. Clay shale, medium-dark-gray, slightly silty, slightly micaceous, noncalcareous. Streaks and lines of pyrite, commonly with purplish and bluish films.
34	2, 281–2, 300	Recovered 19 ft: Microfossils rare. Clay shale, light-olive-gray, slightly silty, slightly micaceous, noncalcareous. Poor shaly cleavage in lower 5 ft.
35	2, 300–2, 320	Recovered 18 ft: Microfossils rare. Claystone, olive-gray, silty, slightly micaceous, slightly calcareous; grades to very argillaceous siltstone. Rare to common pyrite streaks, nodules, and lines. One pelecypod fragment found.
36	2, 320–2, 323	Recovered 3 ft: Microfossils absent. Siltstone, olive-gray, very argillaceous, micaceous, noncalcareous; pyrite streaks scattered throughout.
37	2, 323–2, 343	Recovered 20 ft: Microfossils absent. Siltstone as above but light-olive-gray, with a slight amount of very fine sand, mottled with olive-gray patches. Clay and silt interlaminated with irregular, small lenticles of sandy silt separated by clay partings. Odor of gas noted on a freshly fractured surface at 2,339 ft. No cut and only very slight colorless greasy stain as residue were obtained in CCl_4, at the same depth. Porosity at 2,339 ft 10.5 percent.
38	2, 343–2, 363	Recovered 19 ft: Microfossils absent. Siltstone, medium-light-gray, sandy, argillaceous, mottled with irregular flakes and small patches dark-gray carbonaceous clay totaling 1–20 percent of the rock. Siltstone slightly calcareous, well indurated. Bedding planes (due to a few continuous clay laminae) at 2,353 ft dip 10°.
39	2, 363–2, 380	Recovered 17 ft: Microfossils absent. Siltstone as above.
40	2, 380–2, 400	Recovered 20 ft: Microfossils absent. Siltstone as above; grades into sandstone of core 41.
41	2, 400–2, 420	Recovered 16 ft: Microfossils absent. Sandstone, light-olive-gray, fine to very fine grained, silty and argillaceous, slightly calcareous; mottled with dark-gray clay and a few carbonaceous films. No visible bedding. Highly calcareous 8-in. layer at 2,410 ft. From 2,410 to 2,411 ft is 1 ft of fine-grained sandstone; less well indurated and somewhat less argillaceous than rest of core. *Oxytoma* sp. at 2,412 ft. (Imlay, 1955, p. 82.)
42	2, 420–2, 430	Recovered 6 ft: Microfossils absent. Sandstone as above with 1 ft of highly calcareous rock 1–2 ft below top of core. One noncalcareous concretion (1 in. in diameter) is in this layer, and another a foot below it. At 2,430 ft, porosity 25 percent; permeability 7.8 millidarcys; calcareous cement 3.56 percent. Sieve analysis of sandstone from 2,430 ft shows rock to contain medium sand (+60 mesh) 0.09 percent; fine sand (+120 mesh) 0.02 percent; very fine sand (+230 mesh) 70.05 percent; silt (+325 mesh) 8.00 percent; fine silt and clay (−325 mesh) 20.03 percent. CCl_4 showed no cut, but had a greasy film as residue.
43	2, 430–2, 450	Recovered 13 ft: Microfossils absent. Siltstone, light-olive-gray, with variable amount very fine sand, slightly calcareous, with many very fine dark gray, irregular argillaceous partings that are rarely pyritic. Pelecypod shell fragments common. Calcareous flakes scattered on surfaces of a few irregular high-angle fractures at 2,447 ft.
44	2, 450–2, 468	Recovered 10 ft: Microfossils very rare. Siltstone as above; becomes gradually darker toward bottom, owing to increase of clay partings. Well indurated. Carbonaceous or pyritic plant remains very rare.
45	2, 468–2, 478	Recovered 9 ft: Microfossils very rare. Siltstone as above. ?*Tropites* (*Anatropites*) sp. shell at 2,470 ft.
46	2, 478–2, 496	Recovered 16 ft: Microfossils rare. 1 ft 6 in., siltstone as above, grades into unit below. 7 ft 6 in., claystone, medium-gray, silty, noncalcareous, slightly pyritic; some pyritized plant remains commonly with associated yellowish to purplish slightly iridescent stains. At 2,480 ft is a 6-in. layer of medium-dark-gray dense noncalcareous claystone, with subconchoidal fracture. Silt increases gradually with depth, and rock grades into. 7 ft, siltstone, medium-gray, very argillaceous, slightly calcareous, with common pyritized plant remains and yellowish stains as above. Fragmentary *Oxytoma* sp. (pelecypod) shells, identified by Bernhard Kummel, are scattered through the rock.
47	2, 496–2, 511	Recovered 10 ft: Microfossils very rare. Siltstone as above; poor shaly cleavage in upper 3 ft. At 2,502 ft is a 4-in. layer of medium-dark-gray dense noncalcareous claystone with subconchoidal fracture.
48	2, 511–2, 527	Recovered 16 ft: Microfossils rare. Siltstone as above; a pelecypod shell fragment at 2,511 ft. At 2,527 ft are a few dense olive-gray slightly calcareous claystone nodules as much as 1 in. in diameter; they are well rounded but have sharp-edged, flat (broken?) ends. Fragment of a septarian nodule also at 2,527 ft.
49	2, 527–2, 547	Recovered 10 ft: Microfossils common. 7 ft 6 in., siltstone, medium-gray, very argillaceous, noncalcareous; poor shaly cleavage in upper 3 ft. A ½-in. bed of nodules occurs 4 ft

Lithologic description—Continued

Core	Depth (feet)	Remarks
		from top of core; 6 in. lower is part of a septarian nodule, sectioned by the side of the core, which has ⅞ in. circular core of medium-gray noncalcareous clay, cut by radial 0.5 mm calcite vein, and surrounded by a circular calcite vein of the same width. A halo of yellow-gray clay ironstone (sideritic?) ¼–¾ in. wide forms a gradational contact with the siltstone matrix. Three in. above bottom of siltstone are 4 pebbles (⅛ in. in diameter); 3 are of black argillite similar to the rock from the bottom of the hole, and 1 is of yellow chert. 2 ft 6 in, clay shale, olive-gray, slightly micaceous, very slightly calcareous. Top 2 in. is dense, and well indurated.
50	2, 547–2, 561	Recovered 14 ft: Microfossils absent. 9 ft, clay shale, olive-gray, noncalcareous, friable; many laminae of light-yellowish-gray bentonite and thin (one-half an inch or less) light-olive-gray beds of bentonitic clay. Lenticular silt laminae rare. Beds between 2,553 and 2,555 ft dip 30°–45°, (probably because of distortion in core barrel); beds above and below lie flat. 10 in., clay shale, reddish-brown; and light-olive-gray bentonitic laminae. 4 ft 2 in., clay shale, olive-gray, bentonitic, as in upper part of core.
51	2, 561–2, 577	No recovery. Sidewall cores taken at 2-ft intervals from 2,562 to 2,572 ft are medium-light-gray bentonitic(?) clay; at 2,574 ft one core contains reddish-gray clay.
52	2, 577–2, 589	Recovered 12 ft: Microfossils very abundant. Claystone, brownish-gray, noncalcareous, very uniform; conchoidal fracture, waxy feel, with rare light-gray silty partings. Bottom 1 ft slightly silty and has poor shaly cleavage.
53	2, 589–2, 595	Recovered 6 ft: Microfossils absent. 2 ft, siltstone, medium-dark-gray, very argillaceous, noncalcareous. A few small streaks of pyrite probably replace plant remains. Grades into siltstone below. 4 ft, siltstone, medium-light-gray, noncalcareous; contains dark-gray clay partings which become less abundant with depth.
54	2, 595–2, 610	Recovered 2 ft: Microfossils absent. Claystone, medium-dark-gray, silty, noncalcareous, with scattered lines of pyrite; grades into argillaceous siltstone toward bottom. Sidewall cores at 2,596 and 2,598 ft are light-olive-gray siltstone; at 2,600 and 2,602 ft sidewall cores are medium-gray slightly silty clay shale; at 2,604 ft one is brownish-gray siltstone; at 2,606 ft one is olive-gray clay shale with red-brown streaks; at 2,608 and 2,610 ft they are light-olive-gray siltstone and clay shale.

Lithologic description—Continued

Core	Depth (feet)	Remarks
55	2, 610–2, 630	Recovered 17 ft: Microfossils absent. 10 ft, siltstone, medium-dark-gray, argillaceous, slightly calcareous; carbonaceous streaks and partings, and pyritic streaks. Pelecypod shell fragments occur at 2,615 ft. Good odor of oil and yellow cut and brown residue at 2,615 ft. A 1½-in. layer of *Monotis subcircularis* (Gabb) pelecypod shells (identified by Bernhard Kummel) in calcareous silt matrix occurs at 2,621 ft. At 2,623 ft siltstone grades into unit below. 6 in., siltstone, dark-gray to black, argillaceous; slightly calcareous, highly carbonaceous, limonite-stained; contains abundant bean-shaped ooids about 1 mm in diameter, rarely as much as one-eighth of an inch. Ooids made of bright-yellow soft earthy material that resembles limonite but may possibly be goethite. 10 in., oolite of limonite ooids with dark-reddish-brown surface coating in light-brownish-red calcareous sideritic(?) silty matrix. There is a calcite-coated vertical fracture 6 in. long at 2,624 ft. 2 ft 2 in., limestone, mottled light- to dark-gray, with streaks, patches, and single limonite ooids scattered throughout, grading to beds of limonite oolites in a calcareous, silty matrix. Scattered pelecypod shell fragments present. 3 ft 6 in., limonite ooids, reddish brown on surface, in brownish-red calcareous sideritic(?) silty matrix. Pelecypod shells rare. Top of Triassic at 2,610 ft.
56	2, 630–2, 639	Recoverd 9 ft: Microfossils absent. 6 ft 6 in., limonitic oolitic beds as above, with pelecypod shells identified by Bernhard Kummel as *Monotis subcircularis* (Gabb) at 2,631 and 2,635 ft; grades into unit below. 1 ft 4 in., limonite oolite, yellowish-brown; small amount of calcareous silty brown sideritic(?) matrix and, toward bottom, small streaks of black very carbonaceous siltstone. 1 ft 2 in., alternating beds (as much as 1 in. thick) of yellow-brown oolite as above, and 1- to 4-in. beds of crystalline light-olive-gray limestone, with flakes of yellow pelecypod(?) shells and yellow ooids scattered throughout.
57	2, 639–2, 655	Recovered 16 ft: Microfossils absent. 1 ft 6 in., limestone as above. 4 ft, limestone, very silty, light-olive-gray; pellets and specks of light- to dark-green waxy clay or glauconite. Carbonaceous argillaceous films form irregular, wavy partings and are rarely concentrated in dark streaks. Grades into unit below. 10 ft 6 in., siltstone, light-olive-gray, very calcareous; contains small percentage of very fine sand near

Lithologic description—Continued

Core	Depth (feet)	Remarks
		top and carbonaceous streaks as above. Yellow cut and yellowish residue in CCl_4 found in a sample from 2,646 ft; at 2,651 ft porosity 9.3 percent; permeability less than 5 millidarcys; 10.93 percent calcareous cement. Two pelecypod shells at 2,647 ft.
58	2, 655–2, 675	Recovered 7 ft: Microfossils rare. 7 in., clay shale, dark-olive-gray, micaceous, noncalcareous; distorted, probably by coring process; and contaminated with drilling mud. 1 ft 6 in., siltstone as in core 57 above. 1 ft, fragments of clay shale, medium- to olive-gray, noncalcareous, pyritic, in drilling mud. 3 ft 11 in., fragments of clay shale and siltstone as above, and dense olive-gray silty limestone. Siltstone and limestone have a few patches and thin beds of dark-green pellets to light-green flakes of waxy clay or glauconite. Pelecypod shell fragments abundant in one piece of limestone. At 2,675 ft, there is 16.00 percent of calcareous cement by weight.
59	2, 675–2, 681	Recovered 5 ft: Microfossils absent. 2 ft, siltstone, light-greenish-gray, argillaceous, very calcareous; carbonaceous streaks; glauconite in interstices as above. 3 ft, siltstone, medium-dark-gray, argillaceous, carbonaceous, poor shaly cleavage. Grades into unit below.
60	2, 681–2, 701	Recovered 20 ft: Microfossils very rare. 2 ft 8 in., claystone, medium-gray, very silty, noncalcareous; contains a few pyrite lines with associated bluish and purplish slightly iridescent stains. Grades into unit below. 17 ft, limestone, silty, to siltstone, highly calcareous, slightly sandy; rock is light olive gray to gray green and mottled with dark-gray carbonaceous clay. Green interstitial material, probably glauconite, increases with depth. At 2,695 ft, is one-half an inch of dark-gray carbonaceous pyritic clay shale with many small round specks of siltstone forming minute lenses arranged with long axes parallel to bedding; at 2,698 ft, there is 25.40 percent calcareous cement, and porosity parallel to bedding 9.45 percent; permeability less than 5 millidarcys; no cut or residue present in CCl_4. 4 in., drilling mud with rock fragments.
61	2, 701–2, 720	Recovered 19 ft: Microfossils absent. 3 ft, drilling mud with rock fragments. 16 ft, siltstone, highly calcareous, grading to limestone, very silty, slightly sandy; rock is light olive gray, carbonaceous, contains green waxy material (glauconite?) as in siltstones above. Flakes of pelecypod shells scattered throughout.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		No cut or residue obtained in CCl_4 at 2,716.
62	2, 720–2, 732	Recovered 12 ft: Microfossils very rare. 8 ft 2 in., siltstone, medium-light- to medium-dark-gray, rarely slightly sandy, argillaceous, highly calcareous; mottled with dark-gray patches and partings of clay. No green material present. Clay increases toward base, and rock grades into unit below. 7 in., siltstone, olive-gray, slightly calcareous (sideritic?); carbonaceous patches and streaks of limonite ooids; grades into unit below. 1 ft 5 in., limonite, yellowish- to reddish-brown, oolitic; carbonaceous slightly calcareous silty matrix. 4 in., limonite, yellowish-brown, as above oolitic, but with abundant shell fragments. 1 ft 6 in., limestone, light-olive-gray, silty; no limonite ooids. Shell fragments present.
63	2, 732–2, 752	Recovered 10 ft: Microfossils very rare. 2 ft 6 in., limestone, olive-gray, silty, carbonaceous; contains limonite ooids and shell fragments. 5 in., limonite oolite with calcareous carbonaceous matrix; shell fragments common. 2 ft, limestone, medium- to yellow-gray, silty, slightly sandy, limonitic, slightly calcareous; contains abundant shell fragments. 8 in., limonite as above; shell fragments abundant, including *Oxytoma* sp. 4 ft 5 in., limestone as above.
64	2, 752–2, 761	Recovered 1 ft: Microfossils absent. Limestone, medium-light-gray, sandy; carbonaceous partings.
65	2, 761–2, 779	Recovered 17 ft: Microfossils absent. 9 ft, sandstone, medium-light-gray, very fine grained, silty, highly calcareous, massive; carbonaceous streaks and pelecypod shell fragments. At 2,766 ft there is 19.3 percent calcareous cement; porosity 15.8 percent; permeability 10.5 millidarcys. At 2,769 ft are specimens of *Anomia* sp. and *Pecten* sp. 8 ft, limestone, light-olive-gray, silty, and siltstone, highly calcareous, many carbonaceous partings and scattered pelecypod fragments; there is a ½-in. zone of *Monotis* sp. shells at 2,771 ft.
66	2, 779–2, 799	Recovered 19 ft: Microfossils absent. 18 ft, intergrading siltstone and limestone as above; at 2,796 ft is 3-in. bed of white, cream-colored, and dark-gray shell fragments, including those of *Monotis* sp., with silty calcareous cement and very rare slivers of black argillite similar to that in core 67. 3 in., interbedded shell fragments and carbonaceous clay; contains streaks and partings of dark-green, flaky waxy interstitial material. 9 in., limestone, yellowish-gray;

Lithologic description—Continued

Core	Depth (feet)	Remarks
		largely shell fragments cemented by calcite.
67	2, 799–2, 801	Recovered 2 ft: Microfossils absent. Argillite, black, dense; small rare pyrite pockets and a few very small calcite veins. Cleavage slaty to subconchoidal, with cleavage planes dipping 35°–40°. According to V. E. Barnes of the U.S. Geological Survey, the rock in this section is composed of a dark groundmass containing small plates of a birefringent mineral, probably mica, which is somewhat oriented. Pyrite specks abundant, and larger crystals and aggregates also present; latter surrounded by a narrow zone of dolomite(?) and quartz mozaic. Narrow veins contain very small quartz crystals and some dolomite. Top of pre-Mesozoic at 2,799 ft.
68	2, 801–2, 820	Recovered 6 ft: Microfossils absent. Argillite, medium- to dark-gray; very poor slaty cleavage. Small pockets of pyrite and rare very small discontinuous calcite veins; 3 in. below top of core is a 6-in. layer of breccia of medium-gray argillite fragments as much as 1 in. in diameter in dark-gray matrix.
69	2, 820–2, 831	Recovered 2 ft: Microfossils absent. Argillite, gray as above.
70	2, 831–2, 835	Recovered 6 ft: Microfossils absent. Argillite, gray as above.
------	2, 835–2, 836	No sample.
(17?)	2, 836–2, 849	Recovered 5 ft: Microfossils very rare. 4 ft, argillite as above; grades into unit below. 1 ft, argillite, black, as in core 67. Branched pyritic spine similar to those described in core 72.
72	2, 849–2, 869	Recovered 10 ft: Microfossils(?) common. 7 ft 6 in., argillite, black, as above, with minute pyrite spines of probable organic origin, some of which are tubular; they are much smaller than brachiopod spines, being more nearly the size of sponge spicules. They are not identified. 6 in., argillite, gray, as above; probable dip of bedding, (based on 2 subparallel dark-gray layers 2 mm thick and about 6 mm apart) approximately 70°. 2 ft, argillite, black, as above; a 6-in. layer of dark-gray and black breccia in black matrix at 2,867 ft.
73	2, 869–2, 879	Recovered 4 ft: Microfossils absent. Argillite, black, as above.
74	2, 879–2, 898	Recovered 2 ft: Microfossils absent. Argillite, black, as above; pyrite present.
75	2, 898–2, 899	Recovered 6 in: Microfossils absent. Argillite, gray, as above.
------	2, 899–2, 900	No sample.

CORE ANALYSES

Reservoir properties of rock from South Barrow test well 3 were studied by S. T. Yuster, P. D. Krynine, and the personnel of the Fairbanks laboratory. Porosity, permeability, oil and water saturation, and grain and pore size were determined for samples from various depths. Porosity was determined by the Barnes method; a Hayward permeameter was used for permeability studies. Data from the various analyses are given in the following tables on reservoir properties, sieve analyses, and porosity and permeability. Except for friable sandstone above 250 feet in the hole, the rocks tested had low porosity and permeability, and slight oil saturation; they are lacking, therefore, in good reservoir properties.

Reservoir properties of rocks from South Barrow test well 3

Depth (feet)	Determined by Fairbanks laboratory			Determined by Paul D. Krynine						
	Effective porosity (percent)	Air permeability (millidarcys)	Content of carbonate minerals (percent by weight)	Mode of sand grains (microns)	Matrix (percent)	Cement		Mode of visible pores (microns)	Visible pore space (percent)	Sand grain surfaces coated (percent)
						percent	mineral			
204P [1]	28. 4	390	----------	10	10	3	calcite and dolomite	45	8	45
204N [2]	27. 3	199	----------							
229P	29. 1	370	----------	11	5	3	calcite and dolomite	35	10	35
229N	28. 2	242	----------							
1,778P	13. 5	<5	----------	----------	----------	----------	----------	----------	----------	----------
2,339P	10. 5	9. 0	----------	----------	----------	----------	----------	----------	----------	----------
2,430P	25. 0	7. 8	3. 56	7+ 9–10	<5 5–10	Tr. 10+	---------- siderite and glauconite.	15 <10	5 Tr.	75 90
2,651P	9. 3	<5	10. 93	8–9	20+	10–15	siderite and glauconite.	10	Tr.	90
2,675P	7. 5	<5	16. 00	11	<5	25–30		<10	Tr.	60
2,698P	9. 45	<5	25. 40	14	(?)	40+	----------	15	Tr.	(?)
2,766P	15. 8	10. 6	19. 3	----------	----------	----------	----------	----------	----------	----------

[1] P plug cut parallel to bedding.
[2] N plug cut perpendicular to bedding.

Sieve analyses of 3 sandstone samples and 1 sandy shale, from South Barrow test well 3, using American Society for Testing Materials sieves that approximate the Wentworth grade scale

Depth (feet)	18 mesh (coarse)	35 mesh (coarse)	60 mesh (medium)	120 mesh (fine)	230 mesh (very fine)	325 mesh (silt and clay)	<325 mesh (clay)	Total
1,746				Tr.	39.1	26.8	34.3	100.2
1,776					36.7	31.0	32.3	100.0
2,430			0.09	0.02	70.05	8.00	20.03	98.19
1,625–1,639	5.14	1.3	5.7	9.42	3.79	[1] 39.62	34.62	99.59

[1] This material contains some clay which could not be disaggregated completely.

Porosity, permeability, and fluid saturation of samples taken between 1,210 and 1,778 feet in South Barrow test well 3

[Determined by S. T. Yuster]

Depth (feet)	Porosity (percent)	Permeability (millidarcys)	Oil saturation (percent)	Water saturation (percent)	Rock type
1,210	12.6	----------	2.6	83.0	Black friable shale.
1,222	14.7	----------	8.5	85.3	Interlaminated shale and sandstone.
1,741	18.5	5.2	10.3	51.7	Sandstone.
1,743	19.4	.91	10.2	42.0	Do.
1,745	15.5	59.8	8.9	59.8	Laminated argillaceous sandstone.
1,747	12.2	36.6	13.5	67.5	Do.
1,749	10.6	125	14.0	57.3	Do.
1,751	16.7	8.4	12.8	53.3	Very argillaceous sandstone.
1,753	16.3	1.1	9.7	53.4	Argillaceous sandstone.
1,755	13.3	31.2	8.1	38.0	Do.
1,757	16.3	14.7	10.9	54.0	Do.
1,757.5	15.5	1.3	20.8	51.4	Sandstone.
1,758	14.7	7.0	5.9	56.8	Argillaceous sandstone.
1,760	17.1	2.2	12.2	39.8	Sandstone.
1,762	11.3	1.2	4.6	71.0	Argillaceous sandstone.
1,764	17.0	24.0	6.8	59.1	Do.
1,766	16.9	5.1	8.2	52.0	Do.
1,768	17.0	1.1	17.4	20.3	Do.
1,770	19.0	11.6	8.8	49.0	Do.
1,772	17.4	.69	4.6	68.0	Do.
1,774	15.3	.90	11.0	42.8	Do.
1,776	19.5	2.9	13.0	39.0	Do.
1,778	16.1	.61	7.1	23.8	Do.

Three heavy-mineral zones were recognized in this test well by R. H. Morris. (See pl. 40.) The zoned-zircon zone is represented by one sample from 1,405 feet, and the prismatic-tourmaline zone by one sample from 2,430 feet. Samples from 2,651–2,698 feet are assigned to the rounded-tourmaline zone.

OIL AND GAS

Although a few faint shows of oil and gas were found in this test well, none were sufficient to do more than cut the drilling mud during formation tests. The oil and gas shows are given in the following table, and the formation tests are then described.

Oil and gas shows in South Barrow test well 3

Depth (feet)	Recorded by petroleum engineers	Recorded in Fairbanks laboratory
204	----------	Straw-colored cut in CCl_4.
206	----------	Do.
224	----------	Light-amber cut in CCl_4.
229	----------	Do
990–1,010	Faint odor of oil, very very faint ether cut.	----------
1,210–1,222	Pale ether cut	----------
1,217	----------	No cut, faint yellow residue in CCl_4.
1,404	Dark ether cut from 6-in. sandstone.	Good odor of oil, amber cut, yellowish-brown residue in CCl_4.
1,739–1,758	Core bled a slight amount of gas.	----------
1,739 and 1,754	----------	Fair to good odor of oil, amber cuts and yellowish-brown residues in CCl_4.
1,758–1,778	Odor of gas, pale-straw-colored ether cut.	Fair to good odor of oil.
1,798	----------	Fair to good odor of oil, amber cut and yellowish-brown residue in CCl_4.
2,339	----------	Odor of gas, but no cut, very slight colorless greasy stain as residue, in CCl_4.
2,430	----------	No cut, greasy film as residue.
2,594	Pale ether cut in 4-in. sandstone bed.	----------
2,598	Pale ether cut in sidewall core	----------
2,602	Pale ether cut in sidewall core	----------
2,604	Pale ether cut in sidewall core	----------
2,610–2,622	Core bled gas	----------
2,615	----------	Good oil odor, yellow cut and brown residue in CCl_4.
2,646	----------	Yellow cut, yellowish residue in CCl_4.
2,698	----------	No cut or residue in CCl_4.
2,701–2,720	Very slight to slight show of gas bled from cores; fair ether cut came from upper part of interval.	----------
2,716	----------	No cut or residue in CCl_4.

The first Johnston formation test was made with the hole open from the packer at 2,591 to the total depth at 2, 675 feet. The packer did not hold, and only 140 feet of drilling mud was recovered.

A Johnston formation tester rathole packer was set at 2,801 feet, with the hole open to 2,899 feet. A fair blow was received for 35 minutes before the $\frac{5}{16}$-inch flow bean became plugged. The fluid dropped in the hole, probably lost into the rock above the tester. The tool recovered 1,060 feet of drilling mud.

After reaming the hole from 2,879 to the total depth at 2,900 feet, the Johnston formation tester was reset at 2,801 feet. A ½-inch flow bean was used, with 185 feet of water cushion. The tool was open 1 hour, with a slight blow, and then closed in for 37 minutes. The water cushion and 450 feet of drilling mud were recovered, the lower 300 feet of the mud being highly cut with gas. Pressure after being closed in was 375 psi.

LOGISTICS

Fifteen hundred tons of material was transported to the well site; heavy equipment and supplies were freighted by Caterpillar tractor train before the spring thaw, and other material was brought as it was needed.

Personnel and housing.—Twenty-five men were employed at the rig while the well was being drilled. A drilling foreman, a petroleum engineer, and a geologist supervised the work; 2 drillers, 2 derrickmen, 6 floormen, 1 heavy-duty-equipment mechanic and 1 welder-mechanic made up the 2 rig crews. Two men worked as cooks and two as firemen; others were a tractor operator, a tractor-crane operator, a laborer, an oiler, a cook's helper, and a timekeeper-storekeeper-warehouseman. Of the 19 temporary employees, 8 were rig builders, 5 were carpenters, and the others were an

electrician, a plumber, a construction foreman, a crane-operator, a Schlumberger technician, and a cementer.

The campsite consisted of 5 jamesway huts housing 6 men each, 2 quonset huts serving as galley and as a combination warehouse, office, store, and dispensary. Two wanigans were used as lavatories and six others, some of them on steel or wood runners, housed the water tanks and refrigerator for the galley, the geological and engineering office, the cementing equipment, a light plant, a boiler, and the water supply for drilling.

Vehicles and heavy equipment.—A D8 Caterpillar tractor with bulldozer and winch, 2 weasels, 1 Northwest crane, and 5 Micheler sleds were kept at the site; a T–9 (cherrypicker) crane, a Hyster crane, and a D8 Caterpillar tractor with blade were used intermittently. Important items of drilling equipment employed by Arctic Contractors are as follows:

1_____ Ideco 122-ft derrick, SO–622–A, with substructure.
1_____ National 50 drawworks, powered by two D13000 Caterpillar engines.
2_____ Gardner-Denver 7¼- by 10-in. pumps, powered by two D13000 Caterpillar engines.
1_____ Marlow Mud Hog single-diaphragm pump.
1_____ Kewanee 32-hp boiler.
1_____ Ideco 200-ton crown block with six 36-in. sheaves for 1⅛-in. wire rope.
1_____ Emsco NC–36–4 traveling block, grooved for 1⅛-in. wire rope.
1_____ Byron-Jackson 125-ton triplex hook.
1_____ Emsco AB–6 swivel.
1_____ National 17½-in. rotary table.
1_____ Baash-Ross Universal utility block.
1_____ Link Belt NRM–145 shale shaker.
1_____ Square kelly, 4½ in. by 41 ft, forged steel.
2_____ GMC 30-kw generators.
2_____ Round welded water tanks, 25,000-gal.
1_____ Bolted steel fuel tank, 100-bbl.
2_____ Square welded steel mud tanks, 200-bbl.
1_____ Square welded mud mixing tank, 24-bbl.
2_____ Shaffer 1¾-in. double-cellar control gates.
1_____ Howco cementing unit.
1_____ Schlumberger hand-operated unit mounted on GMC truck.
1_____ Wilson winch.
1_____ Baroid gas detector.

Fuel, water, and lubricant consumption.—Diesel fuel and gasoline burned at the rig totaled 17,725 and 404 gallons, respectively; 680 gallons of SAE 20 and SAE 50 lubricating oil was consumed, and, during the last 5 weeks of operation, 65 pounds of grease, 105 pounds of thread lubricant, and 416,200 gallons of water were used.

DRILLING OPERATIONS

The campsite was on tundra which had begun to thaw before the construction was started. As the thawed ground did not support buildings, they were placed on wooden piling that was driven 2 or 3 feet into the ground and cut off 2 feet above it. The rig was mounted on a piling foundation driven 10 feet into ground that was first thawed with steam points. The thawed, muddy ground made transportation around the camp difficult; steel airport matting was used for walkways, but it was hazardous, especially in wet weather, and wooden walkways would have given safer footing.

Notes from drilling records

Depth (feet)	Remarks
109_____	Rotary-counter-shaft bearing failed; 36 hr required for its repair at Barrow camp.
414_____	Mud began circulating around conductor pipe set at 32 ft, 17 ft below cellar floor. Hole reamed to 19½ in., and 16-in. casing set on shoulder at 60 ft with 40 sacks of construction cement. The 41 percent slurry had 3 percent $CaCl_2$, and its final temperature was 80°. Twenty more sacks of cement mixed to a 45 percent slurry was added. Steam was put into the mud in the casing for 15 min each 2 hr to keep cement warm until it hardened. Seven bbl of sand mixed with 17½ sacks of cement, and 6½ bbl of mixture then put around outside of top of casing. After cement stood several hours, ice bridges were cleaned out and drilling resumed.
1,050_____	Set 11¾-in. casing at 1,046 ft and cemented it with 17.5 sacks of construction cement and 85.8 sacks of oil-well cement, mixed with 80 cu ft of water heated to 100°F and treated with 2 percent $CaCl_2$ by weight.
1,232_____	Circulation lost through broken weld between 11¾-in. casing and flange; they were rewelded and drilling continued.
2,428_____	Hole started to take mud, and 175 bbl were lost. Viscosity was increased and weight lowered, to stop the loss; 60 bags of tundra moss and other additives put in the hole, moss-containing mud being put on bottom through drill pipe.
2,752_____	Drill pipe was lowered again, to put tundra moss into hole to stop mud loss. Two days later the hole still taking some mud, and more moss was added.
2,900_____	Hole abandoned, with 800 ft of water in upper part. Plate welded over 11¾-in casing, and 4 ft of 4-in. pipe welded to top of it as location marker, and to support thermistor cables.

DRILL AND CORE BITS

A Reed KorKing conventional barrel was used for all the coring, except for a series of sidewall cores taken (at 2-ft intervals) at 2,562–2,574 and 2,596–2,610 ft) with the Homco (Houston Oil Field Material Co., Inc.) sidewall corer. Of the 53 bits used, 24 were hard-forma-

tion rock bits, 13 were soft-formation, and the rest were the original 13 soft-formation bits rebuilt and renumbered. About a third of the 1,175 feet cored was done by each of the three groups of bits. Recovery was best (92.8 percent) with the new soft-formation bits, and poorest (67 percent) with the hard-formation bits.

The 23 drill bits ranged from 19½ to 7⅞ inches in diameter, and most were Smith or Hughes rock bits. Below 1,979 feet they were used only for reaming, and damage consisted mainly of wornout bearings instead of dulled cutting edges. Type and size of core and drill bits used throughout the well are shown on the graphic log (pl. 41).

DRILLING MUD

Above 2,428 feet, only a little Aquagel and other material were needed to keep the mud in satisfactory condition, as the rock drilled made good mud. At that depth, however, mud began penetrating a 2-foot interval of rock in the hole wall, and circulation was lost. It was regained here, and again at 2,750–2,799 feet, by adding tundra moss to the mud. The fibers of the moss, which grows around the well site, apparently matted against the wall of the hole, effectively sealing off the rock. Below the first zone of lost circulation, viscosity of 55 to 60 Marsh funnel seconds and weight less than 80 pounds per cu ft were necessary to prevent loss of mud into the rock. The following table shows the characteristics and additives of the mud while the test was being drilled.

HOLE DEVIATION

Between 540 feet, where the first measurement was taken, and 2,000 feet the hole deviated 5′–50′ from vertical, as shown by the Totco instrument. At 2,128 feet, deviation was 1°, and below that it increased gradually to 2°40′ at 2,745 feet. All the readings are shown on the graphic log (pl.41).

ELECTRIC LOGGING

Schlumberger hand-recording equipment mounted on a truck was used to make an electric log of the hole. Spontaneous potential and long and short normal curves were recorded, in four runs. Runs 1 and 2 (60–1,048 ft and 1,048–2,672 ft) were made on a 100-ohm-meter resistivity scale, and runs 3 and 4 on a 50-ohm-meter scale. Run 3 overlapped run 2 completely and is shown on the graphic log (pl. 41) with runs 1 and 4, as it shows variations in resistivity more distinctly. Run 4 was taken from 2,672 to 2, 866 feet, the deepest point to which the instrument could be lowered.

Drilling-mud characteristics, South Barrow test well 3

Depth (feet)	Weight (lb per cu ft)	Viscosity (Marsh funnel seconds)	Water loss (cc per 30 min)	Temperature (° F)	Additives
0					41 sacks Aquagel.
600	81	80		41	
710	82	60		40	
775	81	56	5.3	41	
825	83	55	4.5	41	
880	85	49	4.0	43	
965	85	48	4.0	52	
1,010	85	48	4.0	52	
1,050	83	48	4.0	56	6 sacks Baroid, 101 lb pyrophosphate, 5 lb quebracho.
1,180	79	40	4.0	48	
1,216	80	38	4.0	50	
1,230	79	38	4.0	46	
1,275	81	38	4.0	37	
1,390	80	38	4.0	39	15 sacks Baroid, 35 lb pyrophosphate, 22 sacks Aquagel.
1,415	80	38	4.0	46	
1,490	79	40	3.5	46	
1,615	80	42	3.5	43	
1,641	81	52	3.5	50	
1,775	82	54	2.5	52	
1,870	83	54	2.5	50	
1,960	83	50	3.0	52	
2,030	81	40	2.5	57	7.5 sacks Aquagel.
2,080	81	40	3.0	56	
2,125	82	40	2.0	54	
2,179	82	42	3.0	57	
2,230	82	40	3.0	58	
2,280	83	40	3.0	56	
2,340	84	39	3.0	57	
2,420	84	39	3.0	55	135 sacks Aquagel, 25 sacks Baroid, 55 lb pyrophosphate, 60 sacks tundra moss.
2,430	82	52	3.0	56	
2,470	80	60	3.0	55	
2,496	77	72	3.0	57	
2,525	75	58	3.5	47	35 sacks Aquagel, 189 sacks Baroid, 100 lb quebracho, 110 lb pyrophosphate.
2,580	80	52	3.5	49	
2,625	81	54	3.0	51	
2,640	81	54	3.5	51	
2,675	81	62	2.5	54	
2,730	80	52	3.5	52	
2,750	80	48	3.5	51	
2,800	79	50	4.5	52	501 sacks Baroid, 270 sacks Aquagel, 45 lb pyrophosphate, 15 lb quebracho, 4 sacks Gelflake, 165 sacks tundra moss.
2,835	76	60	4.0	52	
2,850	76	60	4.5	53	
2,879	76	64	3.5	53	
2,900	76	70	3.0	52	18 sacks Baroid, 47 sacks Aquagel.

VELOCITY SURVEY

A single shothole, 500 feet from the test well, was used by United Geophysical Co., Inc., to make a velocity survey of the rock penetrated to 2,668 feet, which was the bottom of the hole at the time the survey was made. The average velocity increased from 8,000 feet per second at the top to 8,847 feet per second at the lowest point measured.

SOUTH BARROW TEST WELL 4

Location: Lat 71°15′51″ N., long 156°37′50″ W.
Elevation: Ground, 24 feet; kelly bushing, 43 feet.
Spudded: March 9, 1950.
Completed: May 9, 1950. Shut in gas well. Produces 1,805,000 cubic feet per day.
Total depth: 2,538.

South Barrow test well 4 is 447 feet N. 28° E. of South Barrow test well 2 and was drilled to tap the reservoir and assure the gas supply for Barrow camp. Because of its proximity to the earlier well, the rocks it penetrated are very similar, the only difference being that this test entered a thicker section of the Gubik formation at the top, and went a few feet deeper into argillite at the bottom. The two wells may be com-

pared on plate 42. The Cretaceous and Jurassic rocks in the test include, from the top down, the Topagoruk formation (114–1,750 ft), the Oumalik formation (1,750–1,970 ft), the pebble shale (1,970–2,352 ft), and Middle Jurassic beds between 2,352 and the top of the argillite at 2,471 feet.

Formation tests produced gas from the Jurassic sandstone and apparently from fractures in the argillite below, but the latter also contained salt water which at first was produced with the gas. After the well was shut in for several days, however, pressure built up and a production test showed the well capable of producing 1,805,000 cubic feet of dry gas per day. Between May 23, 1950, and September 11, 1953, when it was shut in, the well furnished the gas to heat the camp at Barrow.

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

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

Core	Depth (feet)	Remarks
------	0–19	Rotary drive bushing to ground level.
------	19–33	No sample.
------	33–114	Samples were caught in cellar and are not truly representative of intervals of rock they represent, according to well geologist, Clifford A. Everett, who described formation in this interval as soft gray clay with a few thin scattered sand lenses. Washed samples composed of loose sand and a few subangular to rounded gray to black chert pebbles. Sand is predominantly fine to very fine grained and subangular to rounded and commonly has frosted surfaces, and is largely clear or white quartz. Clear, angular quartz grains with unweathered surfaces scattered throughout. There is a gradual change from upper samples to a sample taken at 120 ft which contains Cretaceous microfossils. Yellow quartz and black chert grains common in upper samples, but decrease with depth. Faint gray-green tinge, result of increase in gray quartz grains and green (glauconite?) pellets, replaces yellowish color, with depth. Angularity increases slightly; sphericity and grain size decrease. Base of Gubik formation impossible to determine exactly. Pellets of soft light-gray clay, first occurring at 110 ft, show no bedding and may be drilling mud, clay from Gubik formation, or Cretaceous clay shale; seismic shotholes in vicinity (party 47, 1948, line 27, holes 1–9) found Cretaceous microfossils at depths from 90 to 160 ft (130 ft in the hole nearest to South Barrow test well 4).
------	114–120	Clay shale, light-gray, silty, soft. Top of Topagoruk formation at 114 ft.
------	120–700	Clay shale, medium-light-gray, rarely silty, soft, very slightly micaceous, noncalcareous; rare carbonaceous particles. Loose sand in ditch samples is subangular, very fine grained, white or clear quartz with some gray quartz and chert, and rare green (glauconite?) pellets, pyrite, and carbonaceous particles. Electric log may have been distorted by permafrost; well geologist reported slight amount of sand, increasing somewhat with depth.
------	700–900	Clay shale, medium-light-gray, rarely silty, very slightly micaceous, noncalcareous; rare carbonaceous particles. Sand similar to that described above present in varying amounts (10–90 percent); it is believed to be contamination from above, as electric log gives no indication of sand.
------	900–1, 220	Clay shale as above, slightly micaceous; slight amount of siltstone.
------	1, 220–1, 280	Clay shale, similar to clay shale above, but harder; pyrite common.
------	1, 280–1, 340	Sandstone, medium-light-gray, very fine grained, very silty, argillaceous, slightly calcareous; sand grains similar to unconsolidated sand described above; rare pyrite, carbonaceous particles, and green pellets. Interbedded with clay shale.
------	1, 340–1, 598	Clay shale, medium-light-gray, slightly silty, slightly micaceous.
1	1, 598–1, 608	Recovered 10 ft: Microfossils common. Claystone, medium-gray to medium-dark-gray, micaceous, noncalcareous, moderately hard, irregular fracture; scattered carbonaceous flakes.
2	1, 608–1, 618	Recovered 10 ft: Microfossils common. 5 ft 6 in., claystone as above. 4 ft 6 in., clay shale, medium-dark-gray, moderately soft; excellent cleavage; laminae and rare lenses (as much as one-eighth of an inch thick) of medium-gray to medium-light-gray micaceous, noncalcareous siltstone and scattered flakes of carbonaceous material make up 5–10 percent of core. Beds dip 3°–5°.
3	1, 618–1, 628	Recovered 9 ft 6 in.: Microfossils very rare. Clay shale as above.
4	1, 628–1, 638	Recovered 9 ft: Microfossils rare. 8 ft 4 in., clay shale as above, grades into unit below. 8 in., claystone, medium-gray to medium-dark-gray, slightly micaceous, noncalcareous, moderately hard; irregular fracture; carbonized plant fragments; silt laminae absent.
5	1, 638–1, 648	Recovered 10 ft: Microfossils very rare. 2 ft 6 in., claystone as above. 7 ft 6 in., clay shale as above. Beds dip 3°–5°.
------	1, 648–1, 650	No sample.
------	1, 650–1, 970	Clay shale, medium-dark-gray, slightly silty, micaceous, slightly carbonaceous; and medium-gray to medium-light-gray slightly silty micaceous clay shale. Proportion of medium-dark-gray clay shale increases from rare at 1,650 ft to about half of the samples from 1,820 ft down. Streaks of light-greenish-gray, very fine grained, silty, very calcareous sand-

Lithologic description—Continued

Core	Depth (feet)	Remarks
		stone occur at 1,725–1,735, 1,750–1,760, 1,800, and 1,900 ft. Sand grains subangular, white and clear quartz, with a little gray quartz, carbonaceous particles, and rare pyrite, green pellets, and mica flakes. Top of Oumalik formation at 1,750 ft.
------	1, 970–2, 320	Clay shale, dark-gray, carbonaceous; scattered very fine to coarse grains of rounded to very well rounded clear quartz sand; many are frosted or pitted. Chert grains also present, as sand or rarely as small black pebbles. Pyrite abundant throughout, commonly as plant replacements; carbonacous particles common from 1,970 to 2,050 ft, abundant between 2,050 and 2,180 ft, and common to rare from 2,180 to 2,320 ft. Streaks of medium-light-gray very fine grained silty calcareous sandstone composed of angular to subangular grains of clear, white, and gray quartz and gray and black chert, with common carbonaceous and pyritic particles, occur at 2,045, 2,097, 2,150, and 2,308 ft. Brown limestone particles rare. Top of Lower Cretaceous pebble shale at 1,970 ft.
6	2, 320–2, 329	Recovered 9 ft: Microfossils very abundant. 1 ft 6 in., clay shale, medium-gray, very slightly micaceous, noncalcareous; excellent shaly cleavage; beds dip 2°–5°. Contains scattered fishbone fragments and rare carbonaceous particles. 7 ft 6 in., clay shale, medium-dark-gray, infiltrated with mud.
7	2, 329–2, 340	Recovered 10 ft: Microfossils very abundant. 2 ft, claystone, medium-gray to medium-dark-gray, partly silty, micaceous; streaks and lines of pyrite. Basal 2 in. contains oval patches, as much as one-eighth inch in diameter, of lighter colored clay, possibly intraformational conglomerate. 2 in., claystone, dark-gray, carbonaceous; scattered rounded grains of clear quartz, ranging in size from silt to coarse sand. 7 ft 10 in., clay shale, medium-dark-gray, micaceous; streaks and lines of pyrite; rock infiltrated with mud.
8	2, 340–2, 350	Recovered 7 ft: Microfossils very abundant. 4 in., claystone, silty, dark-gray; abundant streaks and lines of pyrite; grades into unit below. 6 ft 8 in., conglomerate, black, with clay matrix, and grains ranging in size from silt to pebbles 1 in. in diam. Pebbles usually very well rounded black chert, rarely of gray quartz. Sand-size grains ordinarily of clear quartz, and a few pitted or frosted. The larger ones very well rounded, but roundness decreases generally with size, some of smaller grains being subangular. Pebbles, sand, and silt all occur at random throughout

Lithologic description—Continued

Core	Depth (feet)	Remarks
		section, with no visible sorting or bedding. Pyrite streaks and lines common.
9	2, 350–2, 354	Recovered 2 ft: Microfossils absent. Rock recovered from this core is in small fragments which are composed of conglomerate as described above and of sandstone similar to that in core 10. Two or three fragments of conglomerate had good oil odor and gave dark-brown residue in CCl_4; one contained well-rounded pebble of dark-gray quartzite 2 in. in diameter. Top of Middle Jurassic at 2,352 ft.
10	2, 354–2, 364	Recovered 10 ft: Microfossils absent. Sandstone, light-greenish-gray, very fine grained, very silty, noncalcareous; poorly to moderately indurated; irregular, discontinuous partings of medium-dark-gray clay common to abundant and indicate possible dip of 10°–15°. Sand grains subangular to angular, commonly with pitted or frosted surfaces and composed of clear quartz, with some white quartz, and rare white or gray chert. Samples from 2,356 and 2,360 ft showed a yellow cut and dirty yellow-brown residue in CCl_4. At 2,360 ft, porosity in plugs cut parallel and normal to the bedding was 11.23 and 10.85 percent, respectively; plugs impermeable. Muddy surfaces of all permeability plugs from South Barrow 4, and presence of discontinouus clay partings in sand, resulted in permeability readings lower than the probable actual permeability of the rock. Pyrite (marcasite?) nodule occurs at 2,363 ft; shell (pelecypod?) fragments at 2,361 ft.
11	2, 364–2, 373	Recovered 9 ft: Microfossils rare. Sandstone as above; grades to short (1–2 in.) sections of olive-gray argillaceous siltstone at 2,365 and 2,371 ft. A yellow cut and dirty yellow-brown residue obtained in CCl_4 from 2,370 ft. At 2,368 ft, porosity and permeability in plugs cut parallel to bedding are 12.36 percent and 26 millidarcys, respectively; perpendicular to bedding, porosity is 15.92 percent, and rock is impermeable.
12	2, 373–2, 383	Recovered 9 ft: Microfossils rare. 1 ft, unconsolidated sand mixed with mud. 8 ft, sandstone as in core 10 above; a yellow cut and dirty brownish-yellow residue in CCl_4 from 2,381 ft; at 2,380 ft porosity of a plug cut parallel to the bedding is 11.99 percent and normal to bedding 14.86 percent; rock impermeable in both directions.
13	2, 383–2, 390	Recovered 3 ft: Microfossils absent. Sandstone as in core 10 above; a pale-yellow cut and dirty yellow residue were obtained in CCl_4 from 2,390 ft. In a plug cut parallel to bedding at 2,378 ft, porosity 11.82 percent and rock impermeable.

Lithologic description—Continued

Core	Depth (feet)	Remarks
14	2, 390–2, 400	Recovered 2 ft 6 in: Microfossils absent. Sandstone, light-greenish-gray, very fine grained, very silty, noncalcareous, moderately indurated. Abundant irregular, discontinuous partings of medium-dark-gray clay and rare streaks of fine sand. Sand grains subangular, commonly with pitted or frosted surfaces and composed of clear quartz, with some white quartz and rare white or gray chert and green pellets (glauconite?). Good oil odor throughout, and a pale-yellow cut and yellow residue obtained in CCl_4 from 2,396 ft.
15	2, 400–2, 410	Recovered 3 ft: Microfossils absent. Sandstone, as in core 14 above; good odor oil throughout; pale-yellow cut and yellow residue in CCl_4 at 2,405 ft. One 2 in. interval of rock at 2,406 ft is well indurated, calcareous.
16	2, 410–2, 420	Recovered 10 ft: Microfossils absent. Sandstone as in core 14 above; possible dip, indicated by clay partings, 10°–15°. Fair to good oil odor throughout; straw-colored cut and pale-yellow residue obtained in CCl_4 at 2,414 ft. At 2,413 and 2,419 ft, porosity in plugs cut parallel to bedding is 9.38 and 8.22 percent, respectively; rock at both depths impermeable.
17	2, 420–2, 425	Recovered 5 ft: Microfossils very rare. Sandstone as in core 14 above; poorly preserved fragment of cephalopod at 2,420 ft. Two inches of calcareous well-indurated sandstone at 2,424 ft; fair to good oil odor noted throughout, with straw-colored cut and pale-yellow stain at 2,423 ft.
18	2, 425–2, 435	Recovered 10 ft: Microfossils absent. Sandstone as in core 14 above; fair oil odor throughout; straw-colored cut and pale-yellow residue in CCl_4 at 2,431 ft. Tiny pyrite-lined cavity at 2,432 ft. Bottom 4 in. of core well indurated but not calcareous. At 2,428 ft, rock impermeable but has porosity of 11.5 percent in plug cut parallel to bedding, and 11.6 percent in one cut perpendicular to it.
19	2, 435–2, 445	Recovered 10 ft: Microfossils absent. Sandstone as in core 14 above; pyritized plant(?) fragments at 2,436, 2,439, and 2,443 ft. Faint oil odor throughout; straw-colored cut and pale-yellow residue in CCl_4 at 2,440 ft. In plug cut parallel to bedding at 2,442 ft, porosity 9.43 percent, and permeability 0.1 millidarcy; in one cut perpendicular to bedding, porosity 6.84 percent and the rock impermeable.
20	2, 445–2, 455	Recovered 7 ft: Microfossils very rare. Sandstone as in core 14 above; well indurated slightly calcareous bed of sandstone 2 in. thick at 2,453 ft. Faint oil odor throughout; straw-colored cut, and pale-yellow residue in CCl_4 at 2,450 ft. At 2,454 ft porosity in a plug cut perpendicular to bedding is 7.59 percent, and permeability 2.0 millidarcys.
21	2, 455–2, 465	Recovered 10 ft: Microfossils absent. Sandstone as in core 14 above; at 2,463 ft is a bed of calcareous well-indurated sandstone 2 in. thick. Faint oil odor throughout; straw-colored cut and pale-yellow residue in CCl_4 at 2,460 ft. At 2,460 ft, plugs cut parallel and normal to bedding have porosities of 9.03 percent and 10.04 percent, respectively; both impermeable.
22	2, 465–2, 475	Recovered 2 ft 6 in: Microfossils absent. Sandstone, yellowish-gray, silty, argillaceous, noncalcareous; irregular intercalations of medium-dark-gray clay abundant, and indicate a possible 10°–15° dip. Sand is fine to very fine grained and consists almost entirely of subangular clear or white quartz, with small amount of gray quartz and chert. No oil odor noted; no cut and only faint greasy stain as residue were obtained in CCl_4. One fragment had porosity of 9.18 percent. One fragment of greenish-gray chert, three-quarters of an inch in diameter, subangular, with subconchoidal fracture. Three fragments of grayish-black siliceous argillite, ¼–¾ in. in diameter. They are almost as hard as the chert, subangular, with subconchoidal fracture; rock dense and homogeneous and no bedding or other structures visible. Top of pre-Mesozoic at 2,471 ft.
23	2, 475–2, 478	Recovered 6 in: Argillite, grayish-black, siliceous as described above; consists of 20–25 subangular fragments, ½–1½ in. in diameter. A few fragments have calcite veinlets 1 mm or less wide; quartz veinlets also present, but are smaller and rare Black carbonaceous (graphitic?) film on 1 or 2 pieces. One subangular fragment, one-half of an inch in diameter, of dark-greenish-gray to olive-gray chert.
------	2, 478–2, 536	Black argillite from 2,478 to 2,510 ft, a little gray chert sample from 2,510–2,521 ft, slightly more is found from 2,521 to 2,530 ft and more than half of the sample from 2,530–2,536 ft is gray chert.
24	2, 536–2, 538	Recovered 1 ft: Entire recovery is subangular fragments ½–2 in. in diameter. Four rock types present—(a) 2 or 3 fragments of grayish-black siliceous argillite as in core 23. (b) Light- to medium-gray chert, with waxy luster, translucent on thin edges, with conchoidal fracture. Some small cracks are bordered with slight yellowish stains, and a few specks of pyrite are present on one fragment (50 percent of the material recovered). (c) Medium- to dark-gray fragments similar to black rock from core 23 in most characteristics, but which have

Lithologic description—Continued

Core	Depth (feet)	Remarks
		been made lighter in color by varying amounts of gray to light-gray chert in veins or small irregular masses. Small patch of microscopic pyrite crystals on one fragment. Boundary of chert and argillite commonly sharp, but in some specimens appears gradational. Chert usually contains fine dark-gray or black lines of carbonaceous or graphitic(?) material; it usually surrounds or interfingers with irregular areas of the darker argillite. Its presence is probably the result of gradual replacement of the argillite with cryptocrystalline silica. Carried to completion, this process might result in the gray pure chert described above. (Almost 50 percent of material recovered.) (d) Five or six well-rounded fragments of gray noncalcareous rock. Megascopically, it is composed of small irregularly lenticular masses of gray chert embedded in a light- to medium-gray soft chalky mass which also contains fine parallel laminae of dark-gray to black carbonaceous(?) material. Microscopically, the earthy mass is white, and contains fine network of black shiny material, ranging from delicate marbled veining to heavy honeycomb in which small patches of white material are enclosed. A few oil stains and gas bubbles reported by well geologist from this material. Appearance of rock suggests formation by leaching of argillite, either during or after formation of chert.

CORE ANALYSES

Porosity and permeability tests were made on several sandstone samples from a 100-foot interval of rock between 2,360 and 2,460 feet. The effective porosity, measured by the Barnes method, ranged from 6.84 to 15.92 percent; most of the samples were impermeable, but one had a permeability to air of 26 millidarcys, according to tests made with a permeameter constructed to meet the general requirements detailed in American Petroleum Institute Code No. 27, second edition, April 1942. The results of the analyses are shown in the following table on porosity and permeability.

Heavy-mineral samples from the same 100 feet of rock are described by R. H. Morris as representing the prismatic-tourmaline zone (pl. 40).

Porosity and permeability of sandstone samples from South Barrow test well 4

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
2,360P [1]	11. 23	Impermeable.
2,360N [2]	10. 86	Do.
2,368P	12. 36	26
2,368N	15. 92	Impermeable.
2,380P	11. 99	Do.
2,380N	14. 86	Do.
2,387P	11. 82	Do.
2,413P	9. 38	Do.
2,419P	8. 22	Do.
2,428P	11. 50	Do.
2,428N	11. 60	Do.
2,442P	9. 43	0.1
2,442N	6. 84	Impermeable.
2,454N	7. 59	2.0
2,460P	9. 03	Impermeable.
2,460N	10. 04	Do.
2,465–2,475P	9. 18	

[1] Plug cut parallel to bedding.
[2] Plug cut normal to bedding.

OIL AND GAS

OIL AND GAS SHOWS

The first indications of oil or gas noted during drilling were at 2,350 feet (see following table on oil and gas shows); below that depth several sandstone beds were slightly stained with oil, and also contained gas. The fractured argillite at the bottom of the hole was also reported to have a few oil stains and gas bubbles.

Oil and gas shows in South Barrow test well 4

Depth (feet)	Recorded by Clifford A. Everett, Arctic Contractors' well geologist	Recorded in Fairbanks laboratory
2, 350–2, 354	Pale ether cut in sandstone	Good oil odor, dark-brown residue in CCl_4, from conglomerate fragments.
2, 354–2, 390	Pale ether cuts from sandstone	Yellow cut, dirty-yellow-brown residue in CCl_4 at 2,356, 2,360, 2,370, and 2,381 ft.; pale-yellow cut, dirty-yellow residue in CCl_4 at 2,390 ft.
2, 390–2, 410	No ether cut; gas in core and from core barrel.	Good oil odor; pale-yellow cut and yellow residue in CCl_4 at 2,396 and 2,405 ft.
2, 410–2, 420		Fair to good oil odor; straw-colored cut, pale-yellow residue in CCl_4 at 2,414 ft.
2, 420–2, 425	Core bled gas; good odor, no ether cut.	Fair to good oil odor; straw-colored cut, pale-yellow greasy stain residue in CCl_4 at 2,423 ft.
2, 425–2, 435	Good odor; possible gas show	Fair oil odor; straw-colored cut, pale-yellow residue in CCl_4 at 2,431 ft.
2, 435–2, 465	Very pale ether cut, good oil odor at 2,455–2,465 ft.	Faint oil odor; straw-colored cut, pale-yellow residue in CCl_4 at 2,440, 2,450, and 2,460 ft.
2, 465–2, 475		No oil odor; no cut, faint greasy stain as residue in CCl_4.
2, 536–2, 538	Rare oil stain and gas bubbles on rock fragments.	

FORMATION TESTS

Four formation tests using the Johnston formation tester recovered gas and some salt water. They are described as follows.

Test 1, 2,317–2,390 feet.—A hook-wall packer was set in the casing at 2,272 feet to test sandstone between 2,353 and 2,390 feet. The tester, which has a 3/16-inch bean, was open 3 hours and 14 minutes, and closed in for 30 minutes. A light blow of gas increased to a stronger blow, and about a barrel of mud was blown out of the hole. Open flow pressure through a ½-inch bean in a critical flow prover was 72 psi at 30° F, equivalent to 511,000 cubic feet per day. When the hole was closed in at the surface for 44 minutes, pressure built up to 900 psi. Seventy-five feet of gas-cut mud was recovered in the drill pipe.

Test 2, 2,389–2,420 feet.—A full-hole packer was set at 2,389 feet to test sandstone beds between 2,390 and 2,420 feet. A 5/16-inch bean was used on the tester, which was open 3 hours and 15 minutes. A weak blow at the start increased to a strong blow, and gas reached the surface in 6 minutes and blew out some mud. Pressure through a ½-inch bean on the critical flow prover was 70 psi at 16° F, and pressure built up to 850 psi; it did not reach equilibrium. Fifty-two feet of drilling mud was recovered in the drill pipe.

Test 3, 2,472–2,538 feet.—The sidewall packer was set at 2,467 feet, but if failed to hold. The packer was pulled out, and the tailpipe shortened 4 feet. The packer held when it was set at 2,472 feet, and the tester was opened through a 5/16-inch bean. A fair blow of gas increased to strong, and mud flowed after the tester was open 45 minutes. The mud gradually changed to water spray, and consequently the flow pressure was not measured, but the flow seemed to be stronger than in the earlier tests. The well was closed in at the surface for 1 hour 53 minutes, and pressure built up to 800 psi.

The tester was closed 3 hours and 51 minutes after it was opened, and the bottom-hole pressure gage registered 1,075 psi. Six hundred and forty feet of gas-saturated salt water was recovered; its salinity was 1,082 grains per gallon.

Test 4, 2,520–2,538 feet.—After 2 unsuccessful attempts, a tester was set with a packer at 2,520 feet and 4¼ feet of perforated tailpipe. A weak blow through the 5/16-inch bean increased to a strong blow in 15 minutes and was flared after 28 minutes. Mud started to flow in 42 minutes and increased in volume until it put out the flame 6 minutes after the first appearance of the mud. The gas was again set alight and continued to burn although salt water began to flow almost immediately. The gas flow was estimated to be greater than 200,000 cubic feet, and bottom-hole flowing prsssure was 470 psi. After it had been open 1 hour and 7 minutes, the tool was closed in for 38 minutes and bottom-hole pressure was 1,075 psi. Five hundred and twenty feet of heavily gas-cut salt water (1,151 grains per gallon) was recovered.

OIL, GAS, AND WATER ANALYSES

Several analyses of fluids from the well were made by the U.S. Bureau of Mines and the National Bureau of Standards while the well was being drilled and after its completion as a gas well. Most of the samples were of gas, which was predominantly methane with minor amounts of heavier hydrocarbons. One condensate sample, from traps on the gasline, was mostly gasoline. The water samples, from a formation test or blown out of the tubing as ice, contained sodium chloride and a small amount of other constituents.

Two gas samples from formation test 1 (2,317–2,390 ft) and one from test 2 (2,389–2,420 ft) were analyzed by the National Bureau of Standards by mass spectroscopy; the results are shown in the following table on gas samples. Two water samples, from test 3 (2,472–2,538 ft), were also analyzed by the Bureau of Standards, and the components are given in the following table on water samples. The samples were described by the Bureau as turbid dirty-gray liquids containing a great deal of sediment. After the pH and the alkalinity were determined and prior to the remainder of the analysis, the samples were filtered.

Analysis of three gas samples from South Barrow test well 4

[Analysis by Natl. Bur. Standards]

Component (percent by volume)	Samples from formation test 1, 2,317 to 2,390 feet		Sample from formation test 2, 2,389 to 2,420 feet
Helium	[1] 0.00	0.00	0.00
Methane	29.80	98.2	97.7
Nitrogen	52.80	.84	1.01
Ethane	.34	.86	.92
Oxygen	16.30	.00	.09
Hydrogen sulfide	.00	.00	.00
Argon	.70	.00	.00
Carbon dioxide	.06	.00	.12
Propane [2]	.03	.02	.06
Butane [2]	.02	.04	.05

[1] This sample was apparently air-contaminated when it was received at the laboratory.
[2] Maximum amounts.

Analyses of two samples of water from South Barrow test well 4 in parts per million (milligrams per liter)

[Analysis by Natl. Bur. Standards [1]]

	Sample A	Sample B
Specific gravity of sample at 25°C compared to water at 25°C	1.016	1.017
pH (hydrogen ion)	7.8	7.6
Carbonate-chloride ratio	.0140	.0135
Radical		
Na^{+}	6,978	7,175
Ca^{+2}	101	92
Mg^{+2}	62	63
Fe^{+2}	.01	.03
SO_4^{-2}	21	13.5
Cl^{-}	11,000	11,300
CO_3^{-2}	Not detected.	Not detected.
HCO_3^{-}	155	152
I^{-}	33	34
SiO_4^{-4}	12	8
S^{-2}	Not detected.	Not detected.
Total	18,362	18,838
Components (percent)		
Alkalies	38.0	38.1
Earths	.89	.82
Strong acids	60.2	60.2
Weak acids	.90	.85
Total	100.0	100.0
Calcium earths	.62	.60
Chloride salinity	98.3	98.5
Sulfate salinity	.23	.15
Chemical Character (percent)		
Primary salinity	96.6	96.9
Secondary salinity	2.4	2.2
Primary alkalinity		
Secondary alkalinity	1.01	.97
Total	100.0	100.0

[1] Both were from formation test 3; 2,472 to 2,538 ft.

Two gas samples taken on January 9, 1951 (1 at 980 psi from the 7-in. annulus and 1 at 80 psi, downstream from the separator) were submitted to the U.S. Bureau of Mines at Bartlesville, Okla., for analysis. The first sample contained 96.1 percent methane, 1.0 percent ethane, less than 0.1 percent propane, and a trace of butane, as well as 2.8 percent noncondensable gases, by volume; the second was too small for accurate analysis, and contained an appreciable amount of gas that was apparently residual air from the container, although the volume was too small to determine its composition. The noncondensable material in the first analysis is presumably composed of the same gases.

A few days later, two gallons of condensate from traps 1–4 on the gas pipeline to Barrow camp were sent to Bartlesville for a routine crude-oil analysis by the Bureau of Mines. (See following table on condensate.) Most of the condensate (87.7 percent) was combined to make a 390°F end-point gasoline, which was tested for octane number and other qualities, as shown in following table on end-point gasoline. The condensate contained a very small proportion of hexane and lighter hydrocarbons, and the gasoline made from it consequently has very low vapor pressure. The addition of suitable lighter material would improve both the vapor pressure and the octane number.

Analysis of a sample of condensate from gas line traps from South Barrow test well 4

[General characteristics of sample: Sp gr, 0.787; sulfur <0.1 percent; Saybolt Universal viscosity 32 sec at 100° F; gravity, 48.3° API; pour point, below −70° 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
Stage 1.—Distillation at atmospheric pressure, 747 mm Hg. First drop, 44 °C(111 °F)								
1	50	122						
2	75	167						
3	100	212	16.4	16.4	0.718	65.6		53.0
4	125	257	22.5	38.9	.753	56.4	28	48.2
5	150	302	16.4	55.3	.782	49.5	34	45.3
6	175	347	17.3	72.6	.808	43.6	39	44.3
7	200	392	12.3	84.9	.827	39.6	42	47.0
8	225	437	8.1	93.0	.849	35.2	45	51.4
9 [2]	250	[2] 482	3.9	96.9	.854	34.2		54.8
10	275	527						
Residuum [3]			2.8	99.7	.875	30.2		

[1] Specific gravity at 60° F, compared to water at 60° F.
[2] Distillation discontinued at 236° C (457° F).
[3] Carbon residue of residuum, less than 0.1 percent; carbon residue of crude, less than 0.1 percent.

Approximate summary

Constituent	Percent	Specific gravity	Gravity, °API
Light gasoline	16.4	0.718	65.6
Total gasoline and naphtha	84.9	.774	51.3
Kerosene distillate			
Gas oil	12.0	.847	35.6
Nonviscous lubricating distillate			
Medium lubricating distillate			
Viscous lubricating distillate			
Residuum	2.8	.875	30.2
Distillation loss	.3		

Data on 390°F end-point gasoline from Barrow condensate, South Barrow test well 4

[Analysis by U.S. Bur. Mines]

Percent by volume of the condensate	87.7
American Society for Testing Materials D86:	
Distillation (°F):	
First drop	158
Percent evaporated:	
5	194
10	206
20	217
30	236
40	254
50	276
60	297
70	316
80	336
90	360
95	376
End point	390
Octane number, American Society for Testing Materials D357 (motor method):	
Clear	69.3
With 3.0 ml tetraethyl lead per gallon	83.6
Sulfur, percent by weight	0.052
Corrosion number, American Society for Testing Materials D130	4
Corrosion, 3 hours at 212° F	Slight
Doctor test	Sour
Reid vapor pressure, pounds	2.0

In March 1951, a gas sample from the 10-inch annulus was also analyzed by the Bureau of Mines and was found to contain 10.1 percent noncondensable gas, 86.9 percent methane, 3.0 percent ethane and higher

boiling constituents, by volume. Another gas sample taken in April 1951, contained 1.5 percent noncondensables, 97.5 percent methane, 0.9 percent ethane, and 0.1 percent propane. The low-temperature distillation was made by the U.S. Bureau of Mines.

Almost 2 years after the well was drilled, chunks of ice ⅝ by 3 inches in diameter were discharged from the tubing, which they had plugged. The melted ice was analyzed by L. Curnutte of the U.S. Bureau of Mines, and it was found to be salt water (see following table on water analysis) with a small amount of bicarbonate and other radicals also present.

Analysis of water melted from ice discharged from tubing of South Barrow test well 4 in parts per million (milligrams per liter)

[Analysis by U.S. Bur. Mines]

Radical	
Calcium	126
Magnesium	65
Sodium	5, 320
Carbonate	0
Bicarbonate	744
Sulfate	42
Chloride	8, 160
Total solids	14, 457

Specific gravity at 15.6° C (60° F) is 1.009.
No Hydrogen Sulfide was detected.

LOGISTICS

Personnel and housing.—Drilling was supervised by a drilling foreman, a geologist, and a petroleum engineer; the rig crew was made up of 2 drillers, 2 derrickmen, 6 floormen, 2 firemen, 2 heavy-duty-equipment mechanics, and 1 oiler. Two additional men operated the crane, the LVT, and the Caterpillar tractor, and hauled crews and water. Temporary workers such as carpenters, laborers, electricians, mechanics, floormen to run casing, and men to do the cementing, electric logging, and formation testing were sent from Barrow Camp as they were needed.

The men slept and ate, except for the midshift meal, at Barrow camp and were brought to and from the rig by LVT. Buildings at the site, besides the rig, were 10 wanigans which housed the geologist's office, Schlumberger equipment, boiler, water supply, cement supply, electrical controls, power supply, a shop, and one each for sleeping (in case of lack of transportation to Barrow) and eating.

Vehicles and heavy equipment.—Two weasels, an LVT, a swing crane, and a D8 bulldozer were used to transport men and materials. The equipment used is listed by Arctic Contractors as follows:

1--Ideco 87-ft derrick with crown block, racking platform, and finger.
1--Cardwell drawworks, model H, skid-mounted, with controls, cathead and rotary drive assembly.
1--Caterpillar D–8800 engine for drawworks.
1--Baash-Ross 100-ton traveling block with three 30-in. sheaves grooved for 1-in. line.
1--Web Wilson improved 100-ton connector.
1--Emsco type AB–4 swivel.
1--Ideal 17½-in. rotary table.
2--Gardner-Denver model FXO–FO 7¼- by 10-in. mud pumps.
2--Caterpillar D–13000 engines for pumps.
1--Marlow 4-in. pump.
1--Briggs-Stratton model ZZR–6 engine, for Marlow pump.
1--mud tank, 125-bbl, shop-made.
1--Kewanee 32-hp boiler, no. 578.
1--Worthington 3- by 2- by 3-in. pump, type BF.
1--Link Belt type NRM–145 shale shaker.

Fuel, water, and lubricant consumption.—No record of consumption was kept for the first 2 weeks of drilling; totals for the last 5 weeks are 353 barrels of diesel fuel, 578 gallons of gasoline, 193 gallons of lubricating oil, 160 pounds of thread lubricant, 74 pounds of grease, and 146,500 gallons of water. The material was all brought from Barrow camp as it was needed.

DRILLING OPERATIONS

The unitized drilling rig was mounted on a steel substructure which was set on a heavy 4-runner sled; the whole ensemble was portable as long as the ground remained frozen. The pump platform, including mud and water tanks, mud pumps and engines, was also portable, as its substructure was mounted on four Athey wagon tracks. Operations described below were recorded by Gordon H. Oosting, petroleum engineer for Arctic Contractors.

Notes from drilling records

Depth (feet)	Remarks
114	Set 91 ft of 16⅝-in. casing (the top 2 joints were jacketed with 23⅝-in. casing) and cemented with 108 sacks of Cal-Seal.
2,317	Set 2,320.5 ft of 10¾-in., 55.5-lb Youngstown casing with Hydril flush joints (the bottom 6 joints were welded) at 2,317 ft and cemented with 270 sacks of construction cement, using 186 cu ft of water (a 45 percent slurry) and 4 percent $CaCl_2$. Temperatures of the cement and water were 22° and 115° F, respectively; temperature of resulting slurry was 96° F.
2,536	Drilling delayed for 9½ hr while mud was shipped to South Barrow test well 2.
2,538	Seven-in. 38-lb casing hung to 2,275 ft, with packer at 2,273 ft, 7-in., 23-lb casing from 2,275–2,502 ft and a 9-in. cone on the bottom. Casing perforated at 2,343–2,502 feet with round holes (3/16 in. in diameter, 3 in. between staggered centers) in 6 rows. There are 24 holes per ft of casing. Four 1-in. holes spirally placed at 2,239–2,240 ft. Casing hung from well head. Seventy-five joints of 2½-in., 6½-lb tubing run to 2,329 ft, and a packer set at 2,263 ft. After swabbing 1 hr 40 min, well started to flow gas-cut mud and salt water spray. It

Notes from drilling records—Continued

Depth (feet)	Remarks
2,538—Con.	flowed 2¾ hr, and then was shut in for 4¾ hr. Pressure was 980 psi. Again allowed to flow through a 48/64-in. bean, well pressures rose from 60 psi after 2 hr to 125 psi in 11 hr. After blowing 12 hr in all, bean was changed to 20/64-in., and in 5 hr pressure built up to 250 psi. Flow killed and tubing and casing pulled out. Schlumberger temperature survey run from 2,100 to 2,538 ft to try to locate gas-water contact, but temperature gradient was normal and contact could not be determined.
	While reaming at 2,506 ft, about 5 bbl of mud was lost to the rock in a half hr. Circulating and conditioning gas-cut mud and mixing new mud corrected the trouble.
	Same 7-in. casing (with perforations as before) was put back in the hole again to the same depth, after the fourth formation test was made. (See p. 625.) Same tubing also used, from surface to 2,468 ft, but without a tubing packer. Mud in hole circulated out through 7-in. and 10¾-in. annulus, and between 7-in. casing and tubing, and was displaced with water.
	An hour and 20 min after swabbing began, well started to flow and pressure built up as the well was cleaned of fluid. About 2 hrs later, the well was shut in and pressure in 2½- to 7-in. annulus built up from 420 to 835 psi, and in the 7- to 10¾-in. annulus from 450 to 880 psi in 20 min. Two days later, shut-in pressure on both casings was 1,000 psi.

PRODUCTION HISTORY

On May 9, 1950, production tests were made with the critical flow prover attached to the 2½- to 7-inch annulus. With a 20/64-inch bean, flowing pressure averaged 225 psi; and the gas, with a temperature of −13° F, flowed at the rate of 1,506,000 cu ft per day. With a 25/64-inch bean, an estimated flowing pressure of 275 psi at −4° F gives an indicated flow of 1,805,000 cu ft per day.

Gas from South Barrow test well 4 was first used in Barrow camp on May 23, 1950, and about 270,000 cu ft was used per day. Pressures ranged from 1,015 to 1,020 psi on the tubing, and from 990 to 1,000 psi on the 7-inch casing. Glycol and alcohol were added through the 7- and 10-inch annuli at the rate of a gallon per week, and the well was allowed to flow open for a few minutes once a week (or as often as pressure dropped 20 to 40 psi) in order to prevent water from accumulating and freezing. The usual discharge of gas (perhaps with chunks of hydrate) continued for about 2 minutes, followed by mud and water for a minute, and then a return to gas.

Production continued at about the same rate, with the same pressures, until December 2, 1951. On that date, however, pressure dropped steadily and ceased after a 9-minute gas discharge, indicating that the tubing was blocked. Alcohol and glycol were put down the 7- and 10-inch annuli, but the material in the tubing did not melt. Seventy pounds of calcium chloride pellets poured into the tubing during a period of 2 hours cleared it. Three days later icing caused a pressure drop in the 10-inch casing, but adding alcohol to the 7- and 10-inch annuli kept them both clear thereafter.

In June 1952, the main valve in the surface control connections on the 10-inch casing was broken; it was temporarily repaired by forcing a brass plug and leather gasket into the opening.

Production during the rest of the year rose steadily from 8,566,000 cu ft in July to 11,922,000 cu ft in December. Although the bean increased from 7/64 to 15/64 inches in diameter, tubing pressure remained at 1,000 psi. The 7-inch casing pressure dropped about 10 pounds in the last 2 months of the year, and the 10-inch casing was shut in until September 8th and maintained a constant pressure of 1,000 psi thereafter. In 1953 the bean size was slowly reduced again, and production dropped gradually to approximately 7.8 million cu ft in July, matching the decreasing need for fuel to heat the Barrow camp as outdoor temperatures rose. Tubing, 7- and 10-inch casing pressures were 1,000, 990, and 1,000 psi, respectively.

At noon on September 11, 1953, the well was shut in, after the gas flow had been stopped with salt water.

DRILL AND CORE BITS

Seven Reed core bits on the PDD wire line core barrel (6 PD–2 hard formation 8¾-in. bits, 1 PD soft formation 9⅝-in. bit) and one Reed Kor-King 7⅝-inch K–24 bit in a conventional barrel cored 219 feet in South Barrow test well 4. Nine feet was cored and eleven feet reamed in cement, with these bits.

Twenty-two drill bits were used, ranging in size from 26 to 6⅛ inches. About a third were Hughes rock bits, a third Reed rock bits, and the remainder Security bits. All but five of the bits used are shown on the graphic log (pl. 42). Those not shown are: a 6⅛-inch Hughes Pilot bit used with the 7⅞-inch bits; the Security Hole Opener; bit No. 15, a 7⅞-inch Reed 2C, which reamed but did not enlarge the hole; bit No. 16, a Reed 7⅞-inch 2 HM bit which was only used to circulate mud; and core bit No. 2, a Reed wire line soft-formation PD bit, which only drilled cement.

DRILLING MUD

Above 2,300 feet, the hole made good mud; mud weight increased to 86 pounds per cubic feet without adding weighting materials, and excess mud had to be discarded as water was added. After setting casing at 2,317 feet, quebracho, sodium bicarbonate, Aquagel, and Baroid were added to counteract cement contamination. Aquagel and Baroid were also used to maintain desirable mud characteristics. After the well was completed, more mud was mixed to kill the flow of gas

while the hole was being readied for production, and some was sent to South Barrow test well 2 to kill the gas flow there. (See p. 609.) The total amount of additives used during and after drilling the well was 69 sacks of Aquagel, 214 sacks of Baroid, 104 pounds of tetrasodium pyrophosphate, 150 pounds of sodium bicarbonate, and 50 pounds of quebracho. Mud additives and characteristics during drilling are shown in the following table.

Drilling-mud characteristics and additives, South Barrow test well 4

Depth (feet)	Weight (lb. per cu. ft)	Viscosity (sec API)	Water loss (cc. per 30 min)	Temperature (° F)	Remarks
0					24 sacks Aquagel.
292	73	37	17.5	48	
570	75	40	11.5	51	
875	75	35	10.0	58	
1,121	81	33	6.0	54	4 lb tetrasodium pyrophosphate.
1,410	82	35	6.0	55	
1,480	79	34	5.5	54	2 sacks Aquagel.
1,300	80	42	6.0	54	
1,647	80	35	5.5	53	
1,712	80	37	6.0	56	
1,905	79	35	6.0	54	
2,122	86	35	4.2	62	
2,287	86	40	4.2	64	
2,298					12 sacks Aquagel, 36 sacks Baroid.
2,320	86	33	4.2	62	3 sacks Aquagel, 15 sacks Baroid, 50 lb quebracho, 150 lb sodium bicarbonate.
2,390	73	34	10.5	52	
2,420					4 sacks Aquagel, 55 sacks Baroid.
2,445	79	35	8.0	53	
2,475	78	35	8.0	54	10 sacks Aquagel, 10 sacks Baroid.
2,500	78	37	7.5	53	
2,530	78	33	8.0	57	
2,538	78	34	5.5	54	

HOLE DEVIATION

Deviation of the hole from vertical, measured with the Totco Recorder, was 1°–15′ from 850–1,480 feet, 1° from 2,000–2,300 feet, and 15′ above, between, and below those intervals. The deviation measurements are shown on the graphic log (pl. 42).

ELECTRIC LOGGING

Four electric log runs were made in South Barrow test well 4, three with Schlumberger equipment, and the other with Widco equipment. The latter was completely overlapped by a Schlumberger run. The logs recorded spontaneous potential and long and short normal resistivity curves; those made by Schlumberger equipment are shown on the graphic log.

Run	Depth (feet)	Type of logger
	114–1, 474	Widco.
1	114–1, 474	Schlumberger.
2	1, 216–2, 314	Do.
3	2, 317–2, 532	Do.

AVAK TEST WELL 1

Location: Lat 71°15′02″ N., long 156°28′06″ W.
Elevation: Ground, 1.8 feet; kelly bushing, 17.3 feet.
Spudded: October 21, 1951.
Completed: January 14, 1952. Dry and abandoned.
Total depth: 4,020 feet.

Just east of South Barrow test well 2, seismic surveys showed a nearly circular area of no reflections, from which faults appeared to radiate in several directions. Avak test well 1 was drilled on the north side of this area, almost 4 miles east-southeast of South Barrow test well 2, in an attempt to determine whether oil or gas were trapped by the anomaly, and also to learn more about the pre-Mesozoic rocks of the area at a place where they were most easily reached by the drill. Although it discovered only slight shows of oil and was abandoned as a dry hole, the test demonstrated that the area is very complex structurally, with Cretaceous and Jurassic beds dipping at many angles from 20° to vertical.

The first sample from the well was taken at 130–173 feet and contains sand and a little gravel which have characteristics of both the Gubik formation and Cretaceous sediments. The latter may be the result of contamination from above, however, as the Gubik formation is rarely much more than 100 feet thick.

The youngest consolidated rock penetrated is the pebble shale, which makes up most of the section from 100(?) to 1,350 feet. Between 310 and 820 feet, however, one core and many of the ditch samples are composed of medium-gray silty and sandy clay shale similar to Lower Jurassic rocks in the area. These beds may well be displaced from their normal position beneath the pebble shale by faulting; the abnormally thick section and variable dips also suggest structural complexity.

Below the lowest pebble shale strata are clay shale and silty sandstone with clay intercalations, typical of Lower Jurassic deposits. A Sinemurian fossil from the sandstone at 1,836 feet (see p. 633) corroborates this age designation. The clay shale is concentrated in the upper and lower parts of the sequence, from 1,350 to 1,600 feet, and from 1,900 to 2,280 feet, the intervening 300 feet is occupied by argillaceous sandstone which had slight shows of oil. The basal 27 feet of the section from 2,280 to 2,307 feet, is composed of conglomerate.

Beneath the conglomerate is argillite similar to that at the bottoms of the other Barrow test wells. This hole, however, drilled through 1,713 feet of pre-Mesozoic rock (2,307–4,020 ft), and the argillite was found to be interbedded with medium-gray siliceous dolomite and dolomitic chert. The beds dip 20°–30° or more, and the total stratigraphic thickness penetrated may be much less than 1,700 feet because of structural complexity.

DESCRIPTION OF CORES AND CUTTINGS

Ditch samples from this test well seem to consist mostly of coarser grains which have been washed free of their shale matrix or are contamination from sandstone beds higher in the hole. They are described in the text, but the lithology shown on the graphic log (pl. 43) is inferred from evidence of cores and electric logs as well as ditch samples.

568535 O—61——5

Lithologic description

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

Core	Depth (feet)	Remarks
------	0–15. 5	Kelly bushing to ground level.
------	15. 5–130	No sample received.
------	130–173	Gravel and sand. Represented by a single sample which has characteristics of both the Gubik formation and older sediments. Contains small amount of gravel (pebbles as much as one-quarter of an inch) of subangular rock fragments and rounded dark chert grains; is largely sand, which consists of coarse to fine very well rounded pitted or polished clear quartz grains and a few yellow chert grains, and medium- to very fine grained angular to subrounded clear and white quartz, white and gray chert and dark rock fragments. Pyrite abundant and *Inoceramus* shell fragments present. Top of Lower Cretaceous pebble shale at 100(?) ft. Except for the very well rounded clear quartz and black chert grains, the sand and gravel in ditch samples between 130 and 310 ft is believed to be contamination from above. The well-rounded quartz and black chert grains are similar to those in cores 1 and 3 and probably were washed out of the claystone matrix.
1	173–182	Recovered 1 ft: Microfossils common. Claystone, dark-gray, slightly silty and micaceous, noncalcareous; rare intercalations of very silty medium-dark-gray noncalcareous claystone. Grains of fine to coarse sand-size clear quartz, well to very well rounded, and polished, are scattered at random through the rock. One *Pecten*-like pelecypod shell found.
------	182–230	Sand and gravel as above but with more dark rock fragments and black chert pebbles and less yellow chert; amount of gravel decreases with depth.
------	230–270	Sand, gravel, and siltstone, light-brown, calcareous; gravel composed largely of black well-rounded chert pebbles 1/16–1/8 in. in diameter. Fine- to coarse-grained subrounded to very well rounded dark chert sand in lower 20 ft.
------	270–310	Sand and gravel as above, with flaky dark-gray-brown shale; some light-brown calcareous siltstone at 290–300 ft.
------	310–378	Sand, very fine grained, angular to subangular; composed of clear quartz with some white quartz; sand is probably residue from very soft sandy silty medium-light-gray shale as in core 2. Rare limestone at 350 ft is medium olive gray, slightly silty, very finely crystalline.
2	378–398	Recovered 20 ft: Microfossils absent. Clay shale, medium-gray, slightly silty and sandy, slightly calcareous, soft; abundant intercalations and laminae of very fine grained sandstone, very-light-gray, calcareous, argillaceous (slightly bentonitic?), giving a streaky, mottled appearance to the core. Sand grains angular to subangular clear quartz, commonly with frosted surfaces; very minor amounts of gray and dark rock fragments, and rare glauconite and pyrite grains. Dips approximately 80°.
------	398–400	Sand as in ditch samples from 310–378 ft.
------	400–408	No sample.
------	408–485	Sand as above but with a minor amount of sandstone, very fine grained, very silty and argillaceous, slightly calcareous at 435–445 ft. Washed microfossil samples have a recurrence of large round clear quartz grains at 445 ft; these probably represent a change in the lithology from very sandy and silty lighter colored shale back to dark-gray sandy pebble shale. Although ditch samples continue to be almost entirely very fine grained angular to subangular sand down to the casing which was set at 816 ft, core 3 at 572–592 ft is dark-gray shale; this suggests that ditch samples are not representative of lithology penetrated through this interval of rock.
------	485–495	Sand as above, with a minor amount of siltstone, medium-gray, argillaceous, very slightly calcareous, hard, with abundant single pyrite grains.
------	495–505	No sample.
------	505–515	Limestone, medium-gray, cryptocrystalline, silty.
------	515–562	Sand as above.
------	562–572	No sample.
3	572–592	Recovered 7 ft: Microfossils very abundant. 2 ft, drilling mud, with small fragments of dark-gray claystone. 5 ft, claystone, as in core 1 above, dark-gray, noncalcareous, with rounded grains of clear quartz and dark chert, and scattered nodules of pyrite. Very slightly silty in lower part. Very poor shaly cleavage suggests dip between 35° and 50°.
------	592–800	Sand as above; 1 piece of sandstone, at 675–685 ft is grayish black, very fine grained; clear subangular quartz grains, and a carbonaceous, micaceous, argillaceous matrix. Small amount of light-brown argillaceous limestone, and very minor amount of dark-gray argillaceous limestone, at 705–715 and 735–755 ft.
4	800–804	Recovered 4 ft: Microfossils very abundant. 1 ft, drilling mud with fragments medium-dark-gray clay shale. 3 ft, clay shale, medium-dark-gray, noncalcareous, slightly micaceous; scattered grains of clear quartz, very fine- to coarse-sand size, subrounded to well rounded, usually finely pitted, and rare scattered dark chert pebbles (as much as one-quarter of an inch in diameter). Common pyrite lines, nodules, and euhedral octahedrons and dodecahedrons. Shaly cleavage poor but indicates a dip of about 40°.
------	804–820	Sand as above. Rock penetrated by drill between 804 and 1,215 ft, judging from electric log, is similar to that in cores 4–10.

Lithologic description—Continued

Lithologic description—Continued

Core	Depth (feet)	Remarks
------	820–850	Cement contamination.
------	850–940	Cement contamination and small amount of gray shale.
------	940–960	Sand as above, with cement contamination.
------	960–980	Flaky gray-brown shale; sand in lower part.
------	980–1, 000	Sand and cement contamination.
------	1, 000–1, 004	No sample.
5	1, 004–1, 013	Recovered 7 ft: Microfossils very abundant. Clay shale, dark-gray, as in core 4.
------	1, 013–1, 019	Sand and cement.
6	1, 019–1, 034	Recovered 15 ft: Microfossils very abundant. Clay shale, dark-gray, as in core 4. No cut or odor were noted, but pale-yellow stain obtained in CCl_4.
7	1, 034–1, 057	Recovered 15 ft: Microfossils very abundant. Clay shale, dark-gray, as in core 4; a subround siliceous medium-gray sandstone pebble 1¼ in. in diameter present at 1,055 ft. No cut or odor noted, but very faint greasy stain obtained in CCl_4. Pelecypod shell fragment at 1,057 ft.
8	1, 057–1, 061	Recovered 4 ft: Microfossils very abundant. 2 ft 6 in., clay shale as above. 1 ft 6 in., sandstone fragments, yellowish-gray, very fine grained, very argillaceous and silty, friable; infiltrated with drilling mud; composed of angular to subangular white and clear quartz, with some gray chert and dark rock fragments. Rounded quartz grains, mica, and pyrite, all typical of shale above and below, not present in sand. Heavy minerals in the sand are typical of zoned-zircon zone, according to R. H. Morris (Morris and Lathram, 1951). Good odor of oil present and light-yellow cut and brown-yellow residue obtained in CCl_4 at 1,061 ft.
9	1, 061–1, 077	Recovered 5 ft: Microfossils very abundant. Clay shale fragments, as in cores above. Slickensides (?) on one fragment.
10	1, 077–1, 092	Recovered 10 ft: Microfossils very abundant. Clay shale as above; a 2-in. bed of clay ironstone at 1,090 ft.
------	1, 092–1, 100	No sample.
------	1, 100–1, 215	Clear round quartz grains, fine to coarse, and rare rounded dark chert grains; very fine sand and cement as above; cement decreases with depth as very fine sand increases. Some very fine grained rounded clear quartz grains present near base of interval.
------	1, 215–1, 217	No sample.
11	1, 217–1, 237	Recovered 7 ft: Microfossils abundant. 1 ft 8 in., clay shale, dark-gray; silty in lower part, slightly sandy; some very fine subangular grains, scattered medium to coarse well-rounded grains of clear quartz that are commonly pitted, and rare rounded black chert pebbles as much as one-eighth of an inch in diameter. Poor shaly cleavage dips approximately 40°. 1 ft 8 in., fragments of claystone, medium-dark-gray, silty; scattered coarse to fine quartz sand grains as above. 1 ft 6 in., sandstone fragments, very fine grained, light-olive-gray, argillaceous, noncalcareous, friable; sand grains angular to subangular white and clear quartz. Heavy minerals in sandstone are typical of zoned-zircon zone, according to R. H. Morris. Brownish-yellow cut and yellowish-brown residue in CCl_4 obtained from sample at 1,230 ft. 2 ft 2 in., clay shale as at top of core.
12	1, 237–1, 258	Recovered 20 ft: Microfossils abundant. Clay shale as at top of core 11 above; beds dip 40°–50°. Lower 5 ft of core is silty, slightly calcareous in part, with a few patches of minute streaks of whitish cryptocrystalline material. Scattered pebbles range from coarse sand to one-quarter of an inch in diameter. No odor, cut, or residue in CCl_4 obtained in sample from 1,237 ft.
13	1, 258–1, 278	Recovered 20 ft: Microfossils abundant. Clay shale as in top of core 11 above. Dips 55°–60°. Pale-straw-colored cut and brownish-yellow residue obtained in CCl_4 at 1,265 ft.
14	1, 278–1, 298	Recovered 7 ft: Microfossils very abundant. Clay shale as in top of core 11 above. Dip 35°–40°.
------	1, 298–1, 314	Sand, very fine, subangular; and coarse rounded sand as above, with flaky dark-brownish-gray clay shale.
15	1, 314–1, 329	Recovered 7 ft: Microfossils very abundant. Clay shale, medium-dark-gray, very slightly silty, noncalcareous; fair shaly cleavage dips 40°–45°. Large quartz grains and pebbles absent.
16	1, 329–1, 348	Recovered 19 ft: Microfossils very abundant. Clay shale; well-rounded quartz grains, as in top of core 11 above. Washed sample from upper half of core has abundant glauconite. Dip 50°–60°(?).
------	1, 348–1, 350	Siltstone, olive-gray; some sand.
------	1, 350–1, 360	Sand, very fine subangluar, and coarse rounded sand as above. Top of Lower Jurassic at 1,350 ft.
------	1, 360–1, 375	Sand, very fine subangular, and coarse rounded sand as above, with 5–30 percent black hard pyritic shale; also present are a few pieces of hard sandstone, composed of clear subangular quartz grains with no argillaceous or other visible cement, probably cemented by overgrowths of silica on the quartz grains.
------	1, 375–1, 378	No sample.
17	1, 378–1, 397	Recovered 19 ft: Microfossils very abundant. Clay shale, medium-dark-gray, very slightly silty, micaceous, noncalcareous; pyrite abundant. Poor shaly cleavage suggests dip of 50°–60°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
------	1, 397–1, 425	Sand, very fine subangular, and coarse rounded sand as above; small amount of soft light-gray shale and minor amount of hard black shale. Pyrite abundant. Electric log, from 1,397 to 1,495 ft suggests interbedded clay shale, siltstone, and sandstone.
------	1, 425–1, 455	Sand, very fine grained; subangular to subrounded, of white and clear quartz grains, and small amount of light-gray soft, very calcareous siltstone at 1,435–1,440 ft. Pyrite abundant.
------	1, 455–1, 518	Sand, light-gray, medium- to very fine grained (mostly very fine grained); composed of angular to subangular clear and white quartz grains, frosted in part, with rare gray rock fragments. Sand increases from two-thirds to all of the material with depth; remainder is dark-gray clay shale.
18	1, 518–1, 536	Recovered 18 ft: Microfossils absent. Clay shale, medium-gray, silty, slightly micaceous, slightly calcareous, friable; abundant irregular lenses, patches, and intercalations of light-gray very fine grained sandstone totaling 20–40 percent of the rock, and increasing with depth. Rock in some intervals composed of finely intercalated clay and silty sand. Shaly cleavage poor, and beds dip 30°(?). Sand grains composed of subangular to well-rounded (mostly subrounded) clear quartz, with some white quartz and rare yellow and dark-colored or black grains. A 6-in. section of mottled yellow and gray very calcareous siltstone present 1 ft below top of core.
19	1, 536–1, 554	Recovered 19 feet: Microfossils absent. Clay shale as above; contains 5–20 percent of sandstone intercalations. One 3-in. bed of grayish-yellow silty calcareous claystone at 1,545 ft; 6-in. bed of similar lithology at 1,548 ft has sharp contact with underlying clay shale; latter dips 45°.
20	1, 554–1, 558	Recovered 3 ft: Microfossils absent. Claystone, medium-gray, slightly calcareous; a minor amount of small intercalations of light-gray very fine grained calcareous sandstone, with same composition as sandstone of cores 18 and 19. Pyrite patch, replacing organic material, present at base of core. Cores between 1,558 and 1,808 ft contain heavy minerals typical of prismatic tourmaline zone, according to R. H. Morris.
21	1, 558–1, 569	Recovered 4 ft: Microfossils very abundant. Claystone as above; crinoid fragment.
------	1, 569–1, 585	Sand, with yellowish tinge, as in cores 18–21.
------	1, 585–1, 636	Sand, finer, more angular, and with fewer yellow and more black grains than that in cores 18–21.
22	1, 636–1, 655	Recovered 19 ft: Microfossils absent. Sandstone, light- to medium-light-gray, very fine grained, very silty and argillaceous, slightly calcareous, friable; minute intercalations of medium-dark-gray clay. Composition of sand differs somewhat from that in cores 18–21; grains subangular, largely clear quartz, with more black grains, fewer yellow grains, and some glauconite. Dip of a few clay laminae approximates 35°. Hard spherical nodule of calcareous sandstone 1 in. across occurs at 1,642 ft. A few short (2–12-in.) sections of light-yellow-gray very calcareous sandstone intergrade with light-gray sandstone between 1,645 and 1,651 ft. Proportion of clay increases with depth, in lower 4 ft of core totaling about 50 percent of the rock at base of core. Good oil odor, with pale-straw-colored cut and brownish-yellow residue, present at 1,640 ft.
23	1, 655–1, 673	Recovered 18 ft: Microfossils very rare. Sandstone; clay intercalations as in base of core 22; grades to claystone with sandy intercalations. Clay ranges from 30–80 percent of the rock. Fair bedding developed between 1,664 and 1,668 ft, on irregularly interlaminated light-gray sandstone and medium-dark-gray clay shale. Laminae dip approximately 50°.
24	1, 673–1, 676	Recovered 3 ft: Microfossils absent. Claystone with sand as in core 23 above.
25	1, 676–1, 695	Recovered 19 ft: Microfossils absent. Sandstone as in upper part of core 22; clay intercalations make up 20–40 percent of the rock. At 1,682 ft sandstone and clay are very finely interlaminated for a thickness of 1 in.; at base of laminae is a carbonaceous parting. Poor evidence of bedding planes suggests dip of approximately 35°. Faint oil odor and pale-yellow cut and brownish-yellow residue in CCl_4 at 1,680 ft, and fair odor, with the same cut and residue, from 1,693 ft.
26	1, 695–1, 714	Recovered 19 ft: Microfossils absent. Sandstone as in core 25 above. Carbonaceous parting at 1,703 ft. A few irregular clay laminae dip 30°. Two 6-in. beds, at 1,704 and 1,711 ft are medium-gray clay shale with scattered small patches of sandstone. Fair to good oil odor, and pale-yellow cut and brownish-yellow residue in CCl_4, at 1,701 and 1,708 ft.
27	1, 714–1, 733	Recovered 19 ft: Microfossils absent. Sandstone as in core 25 above, with 6 in. of medium-gray claystone at 1,715 ft and 4 in. of light-yellow-gray silty claystone at 1,731 ft. Fair to good oil odor, and pale-yellow cut and brownish-yellow residue in CCl_4 at 1,720 and 1,725 ft.
28	1, 733–1, 752	Recovered 19 ft: Microfossils absent. Sandstone as above; clay intercalations unusually evenly distributed throughout the sandstone. Small

Lithologic description—Continued

Core	Depth (feet)	Remarks
		carbonaceous streaks rare. Faint odor, and a cut and residue in CCl_4 at 1,736 and 1,750 ft.
29	1, 752–1, 766	Recovered 2 ft: Microfossils very rare. Sandstone as above.
30	1, 766–1, 784	Recovered 19 ft: Microfossils absent. Sandstone as above; rare carbonaceous patches, and yellow-gray claystone about 4 in. thick at 1,722 ft. Beds dip 20°–45°. Fair to good odor of oil; yellow cut and brownish-yellow residue in CCl_4, at 1,769 and 1,780 ft.
31	1, 784–1, 802	Recovered 16 ft: Microfossils absent. Sandstone as above. Good oil odor and pale-yellow cut and brownish-yellow residue in CCl_4 at 1,787 and 1,795 ft.
32	1, 802–1, 821	Recovered 19 ft: Microfossils absent. Sandstone as above. Straw-colored cut and yellow residue in CCl_4 at 1,805 and 1,815 ft, but no odor of oil.
33	1, 821–1, 836	Recovered 4 ft: Microfossils absent. Sandstone as above but with greater proportion of medium-dark-gray clay, which totals 30–40 percent of the rock. Faint oil odor, and pale-yellow cut and brownish-yellow residue, in CCl_4 at 1,825 ft.
34	1, 836–1, 852	Recovered 16 ft: Microfossils common. Sandstone with gray clay as in core 33 above. "*Arietites*" cf. "*A*". *bucklandi* (Sowerby) (Imlay, 1955, p. 73), an ammonite of Sinemurian (Lower Jurassic) age, found at 1,836 ft, with fragmentary pelecypod(?) shells. The rock had faint odor of oil, and pale-yellow cut and brownish-yellow residue in CCl_4 at 1,840 and 1,846 ft.
35	1, 852–1, 869	Recovered 17 ft: Microfossils absent. Sandstone as above, with a 4-in. bed of yellow-gray calcareous claystone at top of core. Beds dip 35°–45°. Good odor of oil at 1,857 ft and very faint odor at 1,866 ft noticed in samples from which a pale-yellow cut and brownish-yellow residue were obtained in CCl_4.
------	1, 869–1, 871	No sample.
36	1, 871–1, 890	Recovered 19 ft: Microfossils absent. Sandstone, light-gray; medium-dark-gray clay intercalations; grades to clay shale with sandstone intercalations, as in cores above; proportion of clay ranges from 30 to 80 percent. Lower 5 ft of core slightly sandier than upper 15 ft. Beds dip approximately 45°. Fair to good odor of oil and pale-yellow cut and brownish-yellow residue in CCl_4 at 1,875 and 1,886 ft.
37	1, 890–1, 906	Recovered 15 ft: Microfossils absent. 1 ft 8 in., sandstone as in cores above, with 20–40 percent of intercalated clay shale; grades into unit below. 1 ft 9 in., clay shale, medium-dark-gray, noncalcareous; rare discontinuous partings of light-gray sand. Fair shaly cleavage dips 45°; some bedding planes waxy and smooth, possibly representing slickensiding. 1 ft 7 in., claystone, dark-gray, slightly calcareous; makes up about three-fourths of the core, as seen in cross section. Other quarter consists of vertically dipping white silty clay containing rare discontinuous dark-green streaks interbedded with greenish-gray calcareous shale. 3 ft, siltstone, light-gray, very argillaceous, friable; very fine rare intercalations of medium-gray clay. Poorly defined bedding suggests steep dip (70° or more). Base of section marked by 1 in. of thin-bedded steeply dipping (70°) dark-green noncalcareous noncrystalline mineral (glauconite?) with irregular patches of white argillaceous noncalcareous silt. Between this green band and the underlying clay shale is a wedge-shaped mass (5 in. thick on one side of the core and 1 in. thick on the other) of medium-dark-greenish-gray very calcareous very argillaceous siltstone with swirly bedding. Its contact with underlying claystone irregular but sharp. 7 ft, claystone, medium-dark-gray, slightly silty, noncalcareous; rare small patches of light-gray very fine grained sandstone. Dip uncertain, but intercalations suggest that it is steep.
38	1, 906–1, 918	Recovered 10 ft: Microfossils absent. Claystone as immediately above, badly broken and infiltrated with drilling mud. Between 1,908 and 1,909 ft is a section of mottled-gray shale, yellow calcareous claystone (clay ironstone?), and white argillaceous silt. Its base is marked by 1 in. of olive-gray calcareous siltstone with laminae of yellow and white siltstone as in mottled rocks and with basal parting of dark-green noncrystalline mineral (as in core 37 above). Dip of interlaminated section approximately 80°. Nodule of clay ironstone at 1,913 ft.
------	1, 918–1, 960	Sand as in cores above; at 1,918–1,922 and 1,951–1,955 is a minor amount of very fine grained sandstone and siltstone that are light brown, argillaceous, hard, calcareous. Electric log suggests presence of clay shale with thin beds of sandstone and siltstone.
------	1, 960–1, 965	Siltstone, dark-gray, noncalcareous, hard; a few pieces of light-gray to white nonargillaceous limestone (calcite); milky quartz fragments abundant.
------	1, 965–1, 967	No sample.
39	1, 967–1, 986	Recovered 8 ft: Microfossils absent. 6 ft, clay shale, dark-bluish-gray, noncalcareous, friable, fissile; mica on partings. Core fragmentary and infiltrated with drilling mud; dip on apparently undisturbed sections approximates 20°. Contact with underlying rock sharp and dips 20°. 1 ft, sandstone, very light gray, very fine grained, very silty and argillaceous, friable; very irregularly

Lithologic description—Continued

Core	Depth (feet)	Remarks
		mottled with yellow and dark-gray claystone; grades into unit below.
		1 ft, claystone, medium-dark-gray, noncalcareous; and dark-olive-gray calcareous claystone; patches of yellow silty calcareous claystone; rare lenticles of dark-green noncalcareous noncrystalline mineral; rare patches of white sandstone. Planes of green lenticles and white patches suggest recurrence of steep dips (more than 70°); contacts of other sediments very irregular (with swirly bedding), and show no particular orientation.
40	1, 986–2, 006	Recovered 12 ft: Microfossils absent.
		Clay and silt, soft, gray, greenish-gray, yellow, and white, intermingled, with swirly bedding. Thick streaks of dark-green material (as in cores above), and thick irregular (nodular?) patches of yellow to yellowish-brown, hard, calcareous (sideritic?) material
41	2, 006–2, 021	common. Beds dip about 60°.
		Recovered 10 ft: Microfossils abundant.
		Clay shale, medium-gray to medium-dark - gray, slightly calcareous, slightly silty; poor shaly cleava e suggests fairly steep dip (40°–70°). Rock is in fragments, most of which have smooth waxy surfaces resembling slickensides, but generally lacking the striae common on
42	2, 021–2, 036	slickensided surfaces.
		Recovered 7 ft: Microfossils absent.
		5 ft 6 in., clay and silt, intermingled and varicolored, as in core 40 above; grades into unit below.
		1 ft 6 in., clay, very light gray, very silty and sandy, noncalcareous,
43	2, 036–2, 054	friable.
		Recovered 13 ft: Microfossils very rare.
		3 ft., clay as in lower part of core 42, but calcareous and with scattered intercalations of dark-gray clay.
		10 ft., clay, medium-dark-gray; intercalations of white, very sandy, and silty clay. Bedding shows nearly vertical dip; one band of irregular interlaminated dark-gray and light-gray clay can be traced, paralleling side of core, for more
44	2, 054–2, 072	than 2 ft.
		Recovered 12 ft: Microfossils absent.
		Clay as in lower part of core 43 above but with rare sections (6–12 in. thick) of predominantly light-gray sandy and silty clay. Pelecypod(?) shell impressions present in a small irregular mass of clay ironstone at 2,071 ft. Poor indications of bedding planes suggest nearly vertical (more than 80°) dip.
------	2, 072–2, 075	Shale, dark-gray; silty, micaceous, hard, minor amounts of dark-gray noncalcareous siltstone and sand also present.
------	2, 075–2, 080	Shale and sand.
------	2, 080–2, 085	Sand, and one piece of sandstone. Similar to that in ditch sample at 1,370–1,375 ft.
------	2, 085–2, 090	Sand, shale, and siltstone.
------	2, 090–2, 116	Sand, with a minor amount of siltstone and sandstone, light-brown, argillaceous, calcareous, hard. Pyrite common to abundant.
45	2, 116–2, 134	Recovered 18 ft: Microfossils absent.
		Intercalated clay shale, medium-dark-gray, and light-gray sandy and silty clay shale as in core 44; dip apparently nearly vertical (more than 80°).
------	2, 134–2, 141	No sample.
------	2, 141–2, 166	Sand as above but with a minor amount of siltstone, sandstone, and shale; 2 pieces of white chert at 2,141–2,147 ft. A few pieces of silty white limestone and white silty chert at 2,156–2,165 ft.
46	2, 166–2, 178	Recovered 7 ft: Microfossils absent.
		Clay shale, medium-gray, silty, slightly calcareous; abundant intercalations of light-gray sandy silt totaling approximately 20 percent of the rock. Beds dip 20°.
------	2, 178–2, 230	Sand as in ditch above but with minor amount of siltstone, sandstone, and shale. Pyrite common to abundant.
------	2, 230–2, 240	Same as above but contains common very well rounded fine to coarse grains of white quartz.
------	2, 240–2, 278	Same as above but white rounded quartz grains very rare from 2,240 to 2,260 ft, and absent below 2,260 ft.
47	2, 278–2, 280	Recovered 1 ft: Microfossils absent.
		One 4-in. core section has medium-gray clay shale with slickensided surfaces(?) on 1 side of the core. Other side composed of irregular streaks of dark-gray carbonaceous clay shale and calcareous olive-gray clay and light-gray claystone, with small amount of dark green noncrystalline noncalcareous material (glauconite?), all dipping approximately 70°. One 2-in. section composed of medium-dark-gray claystone.
48	2, 280–2, 283	Recovered 3 ft: Microfossils absent.
		1 ft, claystone, black (carbonaceous?) noncalcareous, hard, with 1- by 3-in. subangular pebble of dark-olive-gray claystone.
		2 ft, claystone, black to dark-olive-gray, conglomeratic, slightly calcareous in part; abundant pebbles 1/16–1/2 in. in diameter (average one-eighth of an inch), subround to subangular, composed of light and dark chert and light-gray siliceous or calcareous very fine grained sandstone. Scattered dark subangular clay shale pebbles 1/2–1 in. in diameter. One fragment at 2,282 ft is composed of olive-gray silty claystone with laminae of white silty claystone, and is 3 in. in diameter. One rounded pebble one-half of an inch in diameter is greenish-yellow calcareous siltstone.
49	2, 283–2, 286	Recovered 3 ft: Microfossils absent.
		Claystone, conglomeratic, as above; pebbles similar to those in core 48.
50	2, 286–2, 292	Recovered 5 ft: Microfossils absent.
		Conglomerate; medium-dark-gray claystone matrix, and angular to subangular pebbles 1/16–3 in. in diameter. Most of the pebbles are medium- to dark-gray silty clay

Lithologic description—Continued

Core	Depth (feet)	Remarks
		shale. Some are interlaminated medium-light- and medium-dark-gray clay shale with conchoidal fracture, and some smaller ones (as much as one-half of an inch in diameter) are light-gray to light-yellow-gray siltstone and very fine grained sandstone. No orientation to pebbles, and no visible bedding.
51	2, 292–2, 299	Recovered 5 ft: Microfossils absent. Conglomerate as in core 50 above.
------	2, 299–2, 307	Sand with sandstone and shale a above; represents basal conglomerate as in core 51.
------	2, 307–2, 312	Clay shale, black, carbonaceous, and siliceous dolomite as in core 53 below. Top of pre-Mesozoic at 2,307 ft.
52	2, 312–2, 331	Recovered 5 ft: Microfossils absent. Claystone and clay shale fragments, black, earthy, friable, carbonaceous; a few fragments have good shaly cleavage. Core may represent weathered zone of underlying harder argillite.
------	2, 331–2, 470	Argillite, black, carbonaceous; similar to claystone in core 52, but slightly harder. Pyrite rare; calcite and white quartz particles (from veins in the shale) common.
------	2, 470–2, 528	Interbedded dolomite, medium-gray to medium-dark-gray, siliceous, argillaceous, and dolomitic siliceous argillite as in cores 53 and 54 below; small amount of black carbonaceous argillite. Rare pyrite, calcite, and white quartz particles.
53	2, 528–2, 529	Recovered 1 in: Not sampled for microfossils. Dolomite, medium-dark-gray, siliceous; abundant patches and grains of pyrite scattered through it. Specific gravity 3.15. Cleavage faces of dolomite give granular appearance to surface of specimen. One small sample of the rock contains about 30 percent dolomite by weight; thin section approximately 75 percent dolomite by area. Dolomite occurs as silt-sized patches in matrix of microcrystalline silica (probably quartz). Many patches show rhombohedral cleavage, and their edges are very irregular but not interlocking. A single patch may be isolated and completely surrounded by silica, or may be one of a group whose members have different optical orientation. Boundaries between some members of a group marked by minute amounts of silica while others are in direct contact with each other. Patches subspherical, with few of the interlocking projections and indentations typical of metamorphic dolomite. They are subequal in size, and show no alinement or arrangement. Matrix uniform throughout. Pyrite, as minute euhedral crystals or subhedral patches, occurs within the dolomite, between dolomite and chert, and within chert. No recrystallization or mineralogical changes typical of metamorphism can be identified. Following quotation from report on thin sections from cores 53, 54, and 55, by R. H. Morris (written communication, 1952). "These three thin sections are from a silty calcarenite. The carbonate (calcite or dolomite) content varies considerably from about 80 percent in core 53 to less than 40 percent in core 55. The finer silt-sized particles are predominantly quartz but also contain some carbonate and make up 20 to 50 percent of the rock. Pyrite is common in all samples, occurring as small euhedra and disseminated specks. Locally it forms conspicuous stringers. Grain sizes average 0.25 mm for carbonate, 0.05 mm for pyrite, 0.01 mm for the finer carbonate and quartz grains. The large carbonate grains, some of which enclose pyrite specks, have irregular borders indicating there has been secondary enlargement. Slides of cores 53 and 55 show no lineation, but the one from core 54 shows moderate lineation. Here the silt size grains and pyrite grains sweep around the larger carbonate grains. From all appearances the larger carbonate grains seem to be detrital, hence the classification silty calcarenite."
54	2, 529–2, 536	Recovered 2 ft: Microfossils absent. Argillite, medium-gray, siliceous, dolomitic; poor shaly cleavage that dips 20°–30°. Cleavage surfaces commonly have a slight sheen. Specific gravity of one fragment 1.86. Thin section made perpendicular to cleavage has some microcrystalline silica containing a small proportion (about 10 percent) of unoriented dolomite patches; this grades into a dark shale containing abundant oval bodies of dolomite, silica, and intermingled dolomite and silica. Minute crystals and patches of pyrite are present throughout thin section. Gradual increase of micaceous and argillaceous minerals having approximately parallel orientation, the dolomite and some of the chert are concentrated in very-fine-sand-sized oval masses which have their long axes parallel those of the micaceous material. Minor amount of carbonaceous matter present as distinct streaks in siliceous facies. It is more abundant in argillaceous part, both as streaks which cross orientation of other minerals at angles ranging from 0° to 30°, and concentrated around edges of dolomite and chert bodies. Pyrite crystals and patches scattered throughout section show no particular orientation.
------	2, 536–2, 552	Interbedded black argillite and siliceous dolomite as above.
------	2, 552–2, 560	No sample.

Lithologic description—Continued

Core	Depth (feet)	Remarks
------	2, 560–2, 585	Siliceous dolomite and dolomitic argillaceous chert as described in cores 53 and 54 above, but with small amount of black argillite.
------	2, 585–2, 595	Argillite, black, carbonaceous, hard; rare pyrite and calcite and white quartz veinlets.
55	2, 595–2, 603	Recovered 3 ft: Microfossils absent. Argillite fragments, grayish-black, carbonaceous, hard; poor shaly cleavage which dips 20°–30°. Streaks and grains of pyrite common; calcite veinlets (less than 1 mm thick), usually dipping 35°–50°, are present in some fragments. Many surfaces, some of which parallel the cleavage, have slight sheen which suggests orientation of micaceous minerals parallel to surface, possibly the result of small-scale slipping. Black powder, that resembles soot in appearance, is easily rubbed off the rock fragments. Two or three small pieces from base of core are soft and fissile.
------	2, 603–2, 698	Argillite, black, carbonaceous, hard, as in core 55.
56	2, 698–2, 706	Recovered 4 ft: Microfossils absent. Fragments as above, but with many fractures and minute slickensides along which the rock breaks easily. Pyrite rare, and calcite veinlets present only in 1 piece; latter are 1 mm to 5 mm wide and are concentrated in 1 side of the core, where they are the cementing material for small (2 by 3 in.) mass of breccia of the same rock as the rest of core. Specific gravity of 1 fragment of core is 2.52.
------	2, 706–2, 856	Argillite as in core 56.
57	2, 856–2, 871	Recovered 3 ft: Microfossils absent. Fragments as in core 56 above.
------	2, 871–2, 970	Argillite as above.
------	2, 970–2, 993	Interbedded dolomite, siliceous, argillaceous; dolomitic argillaceous chert; and black argillite; rock in this interval similar to that between 2,470 and and 2,585 ft above but has a larger proportion of black argillite.
58	2, 993–3, 001	Recovered 1 ft: Microfossils absent. Argillite fragments, medium-dark-gray, dolomitic, siliceous, as in core 54; and medium-gray siliceous argillaceous dolomite, as in core 53. Fragments badly crushed and mixed with drilling mud.
------	3, 001–3, 055	Interbedded argillite and dolomite, as between 2,970 and 2,993 ft.
------	3, 055–3, 110	Argillite, black, carbonaceous, hard as in core 56 above; thin bed of siliceous dolomite at 3,090–3,100 ft. Rare pyrite, calcite, and milky quartz.
------	3, 110–3, 130	Dolomite, medium-gray to medium-dark-gray, siliceous, argillaceous; and dolomitic argillaceous chert.
------	3, 130–3, 140	Interbedded argillite, black, hard, and siliceous argillaceous dolomite.
------	3, 140–3, 147	No sample.
59	3, 147–3, 156	Recovered 3 ft: Microfossils absent. Drilling mud with small (as much as 1 in.) fragments of dolomitic siliceous argillite grading to argillaceous siliceous medium-dark-gray to medium-gray dolomite, with fair to fissile cleavage. Slight sheen on some cleavage faces. A few fragments (¼–½ in. across) of milky vein quartz with scattered small streaky inclusions of gray material also present. Following quotation is from report on them by R. H. Morris (written communication, 1952): "The quartz fragments from this core are low-temperature (alpha) quartz. A thin section from one of these grains shows that the quartz is granular with a tendency towards growth normal to what is probably the border of the vein. Most of the grains show strain shadows, borders of the grains are sutured. In the hand specimen only 3 or 4 crystal faces (2110)? were seen. Straining has been great enough to produce biaxial optical properties in many of the grains. Grain size averages over 0.5 mm. Small unidentifiable specks are scattered abundantly throughout the quartz; there were no liquid or gaseous inclusions. Although strained the individual grains were not fractured or shattered; however, the sutures may be healed fractures of formerly larger grains or crystals. Two small (0.01 mm) light-green prismatic grains were seen but could not be identified. According to E. Larsen, F. Wright, E. Holden, H. C. Sorby, and others, all vein quartz is alpha. In none of their studies did they find vein quartz that had been inverted from beta quartz. Even in granite the majority is alpha quartz although inversion from beta quartz was recognized in a few cases." Note: Sections in the electric log which show sharp kicks include intervals represented by cores 53, 58, and 59, which contain dolomite. Cores 55, 56, and 57, which are composed of black carbonaceous argillite were taken in intervals which have exceptionally low resistivity and self-potential.
------	3, 156–3, 185	Dolomite, siliceous, argillaceous, as in interval 3,110–3,130 ft above.
------	3, 185–3, 300	Argillite, black, hard, as in core 56; minor amount of milky quartz and calcite; pyrite rare to common. Large amount of milky quartz at 3,280–3,300 ft.
------	3, 300–3, 310	Dolomite, siliceous, and black argillite; some milky quartz.
------	3, 310–3, 330	Argillite, black, hard, with some milky quartz.
------	3, 330–3, 350	Interbedded black argillite and dolomite, as at 3,000–3,055 ft.
------	3, 350–3, 357	No sample.
60	3, 357–3, 364	Recovered 1 ft: Microfossils absent. Small argillite fragments, black, siliceous, hard; a few fragments of medium-gray dolomitic siliceous argillite, all mixed with drilling mud. Nodules and streaks of pyrite common, and calcite veinlets present in some fragments.
------	3, 364–3, 420	Interbedded argillite and dolomite, as above.
------	3, 420–3, 445	Argillite, black, with a sheen on many shaly cleavage faces.

Lithologic description—Continued

Core	Depth (feet)	Remarks
------	3, 445–3, 555	Interbedded argillite and dolomite as above.
------	3, 555–3, 566	Argillite, black, hard, and dark-gray argillite with sheen on some cleavage surfaces. Common calcite, milky quartz, and pyrite.
61	3, 566–3, 571	No recovery. Core represented by a few chips of medium-gray very argillaceous and siliceous dolomite, with minute calcite veinlets (as in core 53); minor amount of hard dark-gray argillite; recovered sample may be cavings from above.
62	3, 571–3, 581	Recovered 3 ft 6 in.: Microfossils absent. Argillite fragments, black, carbonaceous, and medium-gray siliceous dolomitic argillite mixed with drilling mud. Pyrite crystals and calcite veinlets are common in both types of rock.
------	3, 581–3, 730	Argillite, black, carbonaceous, hard.
------	3, 730–3, 760	Dolomite, siliceous, argillaceous and dolomitic argillaceous chert.
------	3, 760–3, 791	Interbedded argillite and dolomite as in interval of rock from 3,445 to 3,555 ft.
63	3, 791–3, 800	Recovered 1 ft: Argillite, fragments, grayish-black, hard; medium-gray to medium-dark-gray siliceous argillaceous dense dolomite fragments, and interbedded argillite and dolomite fragments. Rocks contain calcite and quartz veinlets and streaks of pyrite.
------	3, 800–4, 000	Argillite, black, carbonaceous, hard; a few thin beds of gray siliceous argillaceous dolomite and dolomitic argillaceous chert.
64	4, 000–4, 020	Recovered 10 ft: Microfossils absent. Shale fragments, black, carbonaceous, very friable to fissile; small (2–3 mm) areas have shiny films on surfaces. Interbedded with medium-gray harder dolomitic argillite with irregular fracture. Patches and streaks of white noncalcareous soft mineral (possibly gypsum) present as crack fillings and coatings. Streaks of pyrite also present.

OIL AND GAS

OIL AND GAS SHOWS

The Arctic Contractors' engineer at the well, R. A. Brooks, noted that cores between 1,019 and 1,906 feet had a fair odor of oil and gas in the core barrel; those above 1,536 and between 1,676 and 1,821 feet gave a light-yellow cut. Cores at 1,914–1,986 feet and from 2,006 to 2,351 feet had an odor of oil. Shows in the following table on oil samples were extracted in CCl_4 at the Fairbanks laboratory.

Test for oil in carbon tetrachloride, Avak test well 1

Depth (feet)	Cut	Residue
1, 025±	None	Pale-yellow greasy stain.
1, 040±	do	Very faint greasy stain.
1, 061	Light yellow	Brownish yellow.
1, 230	Brownish yellow	Yellowish brown.
1, 237	None	None.
1, 265	Pale-straw-colored	Brownish yellow.
1, 640	do	Do.
1, 680	Pale yellow	Do.
1, 693	do	Do.
1, 701	do	Do.
1, 708	do	Do.
1, 720	do	Do.
1, 725	do	Do.
1, 736	do	Do.
1, 750	Straw-colored	Do.
1, 769	Yellow	Do.
1, 780	do	Do.
1, 787	Pale yellow	Do.
1, 795	do	Do.
1, 805	Straw-colored	Yellow.
1, 815	do	Do.
1, 825	Pale yellow	Brownish yellow.
1, 825	do	Do.
1, 840	do	Do.
1, 846	do	Do.
1, 857	do	Do.
1, 866	do	Do.
1, 875	do	Do.
1, 886	do	Do.

FORMATION TESTS

Three formation tests were made, but no gas or oil was recovered except for a small amount of slightly gas cut mud in the second test. A Johnston formation tester was used in each case.

Test 1, 1,025–1,056 feet.—The tester was set with a sidewall packer at 1,025 feet, but the packer failed to hold.

Test 2, 1,030–1,077 feet.—The packer and tool were set as before, but the packer failed to hold. The tester was pulled out, and 13.7 feet of tailpipe was added to it. The packer was set at 1,030 feet, and the interval to 1,077 feet was tested with 46.5 feet of tailpipe (including 26.25 ft of perforated pipe) with a pressure recorder on the bottom, and a $\frac{5}{16}$-inch bean. The tool was open 40 minutes, and there was a slight intermittent blow, but no gas came to the surface, and the tool was closed in for 15 minutes. Flowing pressure was zero, and 80 feet of slightly gas-cut mud was recovered. The salinity of the drilling mud was 59 grains per gallon, and the recovered mud had 70 grains per gallon.

Test 3, 1,641–1,676 feet.—The sidewall packer was set at 1,641 feet, with 35 feet of tailpipe, including 24.5 feet of perforated pipe, below it; the hole was open to 1,676 feet. The tester was open 21 minutes, and a light steady blow decreased after the first 5

minutes to weak and intermittent. No gas came to the surface, and the flow pressure was zero. After the tool was closed in for 10 minutes, it was pulled out, and 30 barrels of drilling mud was recovered.

LOGISTICS

Personnel and housing.—A drilling foreman, a petroleum engineer, and a geologist supervised the drilling. The rig crew consisted of 2 drillers, 2 derrickmen, 6 floormen, 2 firemen, 2 heavy duty-equipment mechanics, and 1 oiler, and other men at the site were 2 cooks, a kitchen helper, a janitor, 2 Caterpillar-tractor operators, and a warehouseman-storekeeper-timekeeper. Carpenters, electricians, a cementer, and a Schlumberger operator came from Barrow camp as they were needed.

Wanigans were used to house both men and supplies. Four were used for sleeping, 2 for the water supply, and 15 more housed the galley, mess, radio and store, food supply, boiler, geological and engineering office, power supply, machine shop, cement supply, cement pumps, Schlumberger equipment, utilities, lavatory, oilfield equipment, and electrical switches.

Vehicles and heavy equipment.—Transportation of men and materials was accomplished with a D8 Caterpillar tractor (bulldozer), a Northwest crane, 2 weasels, and a small (cherry-picker) crane. Important items of drilling equipment used were listed by Arctic Contractors as follows:

1--Ideco derrick, 87- by 24-ft base, with racking platform and finger.
1--Cardwell model H drawworks, with Foster high-speed cathead.
1--Caterpillar D–8800 engine, for drawworks.
1--Ideal model D–12 crown block with 34-in. sheaves grooved for 1-in. line.
1--Ideal model D traveling block with 34-in. sheaves grooved for 1-in. line.
1--Ideal model D swivel.
1--Byron-Jackson Triplex 125-ton hook.
1--Ideal 17½- by 44-in. rotary table.
2--Gardner-Denver 7¼- by 10-in. FXO circulating pumps.
2--Caterpillar D13000 engines, for circulating pumps.
1--Marlow model 445 cellar pump.
1--US 5-hp electric motor.
1--Mud tank with dividing partition; total capacity, 121½ bbl, useable capacity, 65 bbl.
1--Link-Belt model 49 shale shaker.
1--Kewanee 35-hp boiler, 110 psi steam pressure.
1--Shaffer blowout preventer, type 34.
1--Shaffer blowout preventer, type 45.

Fuel, water, and lubricant consumption.—Diesel oil and gasoline were used for fuel; 67,070 and 1,166 gallons, respectively, were burned. Lubricating compounds consumed were 275 pounds of grease, 570 pounds of thread lubricant, 759 gallons of No. 9170 lubricant, and 290 gallons of No. 9500 lubricant. Water used totaled 559,000 gallons.

DRILLING OPERATIONS

The derrick and drawworks were mounted on a steel substructure which in turn was mounted on heavy steel sled runners. The pumphouse was mounted on four Athey tracks so that both pump and rig could be moved over frozen, snow-covered ground. Operations described below were recorded by R. A. Brooks, Arctic Contractors' petroleum engineer.

Notes from drilling records

Depth (feet)	Remarks
130	Three joints of Jones and Laughlin, 13⅜-in. 54.5-lb. grade J–55 8 round-thread seamless casing was set at 123 ft and cemented with 96 sacks of Cal-Seal. Top two joints jacketed with 16½-in., 42-lb grade B butt-weld casing.
820	Thirty-one joints of Youngstown 10¾-in. 55.5 lb grade N–80 Hydril thread seamless casing was set at 816 ft and cemented from top to bottom with 160 sacks of construction cement.
1,890	New rotary table and shale shaker installed; bearings in the former were worn.
3,364	Drill pipe stuck when being pulled out after coring. It was worked loose in an hr, and the tight hole reamed from 3,300 to 3,357 ft.
3,422	Drill pipe stuck at 3,330 ft for 30 min. before being worked loose.
3,566	Tight hole reamed from 3,503 to 3,566 ft.
3,791	Tight hole reamed from 2,560 to 3,490 ft and from 3,515 to 3,791 ft.
3,834	Reamed tight hole from 3,680 to 3,834 ft.
3,867	Operations suspended because of a high wind, and it took 2 days to thaw the rig, make minor repairs, and mix some new mud. When drilling resumed, a tight hole was reamed from 2,427 to 3,867 ft.
3,937	Drill pipe stuck at 3,867 ft, but was worked free in an hr. Tight hole reamed intermittently from 2,500 to 3,937 ft.
4,020	Set plug at 1,348 ft, using 25 sacks of High Early cement. A bailer stuck in the hole but was recovered, and hole was bailed down to 840 ft. After thawing cellar, removed blowout preventer, and welded 10¾-in. riser (with its top 3 ft above the ground) to top of casing. After installing a 200-ft thermistor, the hole was abandoned.

DRILL AND CORE BITS

Except for the first core, which was taken with wire line equipment, coring was done with Reed Kor-King barrel and 6¼-inch hard- or soft-formation bits. Drilling bits ranged from 20 to 8¾ inches in diameter, but most of them were 9⅝-inch Hughes rock bits. Depths at which each bit cored, drilled, or reamed are shown on the graphic log (pl. 43), except for intervals through which the hole was reamed to clean it out, or to bring a tight hole up to the normal diameter.

DRILLING MUD

Aquagel-Baroid was the first mud used in the drilling. After setting casing at 816 feet, contamination by

cement necessitated the addition of sodium bicarbonate to bring the pH to about 10, where quebracho treatment would be most efficient.

Below 2,300 feet, the black pyritic rock darkened the mud to grayish black and rapidly increased the mud weight and sand content. The large amount of water added to reduce the weight increased the water loss, and a thick wall cake built up during round trips of the bit. Sodium acid pyrophosphate was effective in controlling viscosity. Mud characteristics and additives are shown in the following table.

Drilling-mud characteristics and additives, Avak test well 1

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec API)	Water loss (cc per 30 min)	Temperature (° F)	Additives
117	76	36	24.5	60	18 sacks Aquagel.
130	80	41	10.0	58	10 sacks Aquagel, 75 sacks Baroid, 20 lb sodium acid pyrophosphate.
296	80	42	9.0	58	18 sacks Aquagel, 60 sacks Baroid, 60 lb quebracho, 10 lb tetrasodium pyrophosphate.
572	81	46	6.6	64	11 sacks Aquagel, 50 lb quebracho, 30 lb tetrasodium pyrophosphate.
700	85	48	5.0	57	25 lb quebracho, 50 lb tetrasodium pyrophosphate.
810	86	50	4.0	58	25 lb quebracho, 25 tetrasodium pyrophosphate.
819	85	49	4.5	56	50 lb quebracho, 100 lb sodium bicarbonate (200 lb more of each used to make new mud).
990	74	40	6.0	60	24 sacks Aquagel, 27 sacks Baroid, 425 lb sodium bicarbonate.
1,032	82	47	5.5	58	54 sacks Baroid, 100 lb sodium bicarbonate.
1,058	82	46	6.0	56	5 sacks Aquagel, 108 sacks Baroid, 100 lb sodium bicarbonate.
1,075	80	43	6.0	60	
1,129	80	45	6.0	58	9 sacks Aquagel, 75 sacks Baroid, 25 lb quebracho, 75 lb sodium bicarbonate.
1,235	82	48	4.5	74	5 sacks Aquagel, 42 sacks Baroid, 75 lb quebracho, 15 lb caustic soda, 25 lb tetrasodium pyrophosphate, 50 lb Driscose.
1,265	83	48	4.5	60	
1,298					25 lb quebracho, 10 lb tetrasodium pyrophosphate, 5 lb caustic soda.
1,314	82	44	5.0	65	
1,371	83	43	5.0	60	3 sacks Aquagel, 50 lb quebracho, 10 lb caustic soda.
1,520	83	43	6.0	65	
1,570	83	47	4.5	54	
1,638					25 lb quebracho, 5 lb caustic soda
1,670	83	46	4.5	63	
1,712	83	44	4.5	53	
1,765	84	46	5.0	52	
1,802	83	44	4.5	56	
1,870	84	44	4.5	55	
1,890	85	58	5.0	54	8 sacks Aquagel, 36 sacks Baroid.
1,914	86	48	5.0	56	4 sacks Aquagel, 39 sacks Baroid, 10 lb caustic soda, 50 lb Aeroseal.
1,998	87	46	5.0	55	10 lb caustic soda, 50 lb Aeroseal.
2,030	88	47	5.0	54	
2,116	88	47	4.5	56	50 lb quebracho, 10 lb caustic soda.
2,210	88	50	4.5	56	
2,290	92	59	4.5	55	
2,300	92	55	4.0	55	
2,415	92	58	4.5	55	50 lb quebracho, 25 lb tetrasodium pyrophsophate, 10 lb caustic soda.
2,503	92	60	5.0	58	50 lb quebracho, 50 lb tetrasodium pyrophosphate, 10 lb caustic soda.
2,540	94	60	4.0	61	50 lb tetrasodium pyrophosphate.
2,586	94	54	4.5	57	50 lb quebracho, 10 lb caustic soda.
2,638	94	58	4.5	60	25 lb quebracho, 5 lb caustic soda.
2,705	94	54	5.0	59	
2,783					25 lb quebracho, 5 lb caustic soda.
2,790	94	53	5.5	58	
2,850	94	54	5.0	56	50 lb quebracho, 10 lb caustic soda.
2,901	94	50	5.0	58	75 lb quebracho, 20 lb caustic soda.
2,962	94	51	5.0	57	
3,001	94	55	5.5	58	25 lb quebracho, 5 lb caustic soda.
3,055	96	53	5.5	56	50 lb quebracho, 10 lb caustic soda.

Drilling-mud characteristics and additives, Avak test well 1—Con.

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec API)	Water loss (cc per 30 min)	Temperature (° F)	Additives
3,120	97	60	5.5	59	6 sacks Aquagel, 125 lb tetrasodium pyrophosphate.
3,156	98	60	5.0	60	
3,195	98	60	5.5	52	
3,232	98	56	5.0	54	100 lb quebracho, 20 lb caustic soda, 50 lb tetrasodium pyrophosphate.
3,276	98	56	4.0	57	75 lb sodium acid pyrophosphate.
3,310	96	52	5.0	58	50 lb quebracho, 125 sodium acid pyrophosphate, 10 lb caustic soda.
3,360	97	55	5.0	59	100 lb quebracho.
3,373	97	57	5.0	56	7 sacks Aquagel, 50 lb sodium acid pyrophosphate.
3,422	96	60	5.5	57	100 lb tetrasodium pyrophosphate, 75 lb sodium acid pyrophosphate.
3,467	97	56	5.0	56	50 lb tetrasodium pyrophosphate, 75 lb sodium acid pyrophosphate.
3,517	98	60	4.5	59	
3,567	98	53	5.5	57	
3,581	97	55	6.0	59	100 lb quebracho.
3,624	98	56	6.0	58	75 lb quebracho, 10 lb caustic soda, 50 lb sodium acid pyrophosphate.
3,709	99	60	5.5	61	100 lb quebracho, 25 lb sodium acid pyrophosphate.
3,750	98	53	5.5	61	75 lb quebracho.
3,791	99	57	6.0	60	25 lb quebracho, 10 lb caustic soda, 25 lb sodium acid pyrophosphate.
3,815	99	56	5.0	60	
3,835	99	55	5.5	61	
3,867	99	60	6.0	61	5 sacks Aquagel, 150 lb quebracho, 30 lb caustic soda, 50 lb sodium acid pyrophosphate. (12 sacks Aquagel, 50 sacks quebracho additional, in new mud).
3,935	94	56	6.5	60	
4,000	93	54	6.0	59	25 lb quebracho, 25 lb sodium acid pyrophosphate.
4,020	94	53	5.5	62	25 lb quebracho, 25 lb sodium acid pyrophosphate.

HOLE DEVIATION

Above 1,078 feet the hole was 0°45′–2°55′ off vertical, as determined by the Totco Recorder. (At 636 and 657 ft more than 6° of deviation was measured, but repeating the measurement at 657 ft with a new instrument showed the 6° reading to be in error at that depth, and presumably the upper one is also incorrect.) Below 1,078 feet deviation increased gradually to 3°50′ at 1,298 feet, and drilling was slowed in order to reduce the angle. At 2,300 feet the hole was 1°15′ off vertical, but below that depth deviation increased rapidly to 5°45′ at 3,275 feet, The lowest reading, at 3,443 feet, was 3°20′; no lower readings were possible because the drill pipe used below that depth was too small. The deviation data are plotted on the graphic log (pl. 43).

ELECTRIC LOGGING

No electric log was made of this hole before casing was set at 816 feet; after that, two runs (from 3,463 to 815 ft, and from 4,018 to 3,463 ft) were made with Schlumberger equipment, which recorded spontaneous potential, and long- and short-normal resistivity curves. The log is shown on plate 43 except for part of the spontaneous potential curve between 3,460 and 3,760 feet, where a damaged cable resulted in an abnormal record.

SOUTH BARROW TEST WELL 5

Location: Lat 71°15′51″ N., long 156°37′59″ W.
Elevation: Ground, 25 feet; kelly bushing, 38.3 feet.
Spudded: May 17, 1955.
Completed: June 17, 1955. Gas well: maximum stabilized rate of flow, 7.9 million cubic feet per day, with no water.
Total depth: 2,456 feet.

In 1955, after the U.S. Navy had suspended exploratory operations in Naval Petroleum Reserve No. 4, a private construction firm, Puget Sound and Drake, drilled South Barrow test well 5 for the U.S. Air Force installation at Barrow; the well is a standby well for South Barrow test well 4, replacing South Barrow test well 2 which had been abandoned. South Barrow test well 5 is between the two older holes, about a third of the way from test well 2 to test well 4, and penetrated the same section, except that it was not drilled quite as deep. It was successfully completed as a gas well and proved to be better than the the other two, producing at a maximum stabilized rate of 7.9 million cubic feet per day, or at a safe productive rate of 1.4 million cubic feet per day, with no water.

Available data on the well, furnished by the Puget Sound and Drake organization, is presented in the following text; no graphic log has been prepared.

DESCRIPTION OF CORES AND CUTTINGS

Lithologic description

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

Core	Depth (feet)	Remarks
------	0–13	Kelly bushing to ground level.
------	13–26	Gravel, permafrost.
------	26–117	Gravel.
------	117–163	Clay and shale.
------	163	Shale.
------	500	Bits started to get clogged with mud, indicating the bottom of the frozen ground.
------	2, 021–2, 101	Shale with thin hard streaks.
------	2, 101–2, 300	Shale; the bit entered harder shale at 2,170 ft.
1	2, 300–2, 310	Recovered 8 ft 8 in.: 2 ft 4 in., sandstone, light-olive to medium-gray, very fine to fine-grained; slightly calcareous in part, hard, massive; patches of dark-gray carbonaceous argillaceous material. 6 ft 4 in., claystone, grayish-black, silty; scattered very well rounded black chert pebbles and granules 1/16–1/4 in. in diameter, and fine to coarse well-rounded clear quartz grains distributed at random through the rock. Lines and small masses (less than one-eighth of an inch in diameter) of pyrite rare to common. One white quartz pebble three-quarters of an inch in diameter 3 ft below top.

Lithologic description—Continued

Core	Depth (feet)	Remarks
------	2, 310–2, 335	No sample.
------	2, 335–2, 340	Claystone as in core 1, with some granules of black chert.
------	2, 340–2, 374	Subrounded white chert and clear quartz granules grading to coarse sand, with 10 percent black claystone. Rare very well rounded clear quartz grains.
------	2, 374–2, 394	Sandstone, medium-light-gray, fine to very fine grained, slightly argillaceous, slightly calcareous; composed of subangular clear quartz with some white quartz and dark rock fragments.
------	2, 394–2, 413	Sandstone as above but noncalcareous, slightly brownish gray; more clear to slightly smoky quartz, less dark rock fragments and white quartz.
------	2, 413–2, 443	Sandstone as immediately above but with variable amounts of black claystone and rare quartz grains that may be contamination from above.
------	2, 443–2, 450	Sandstone as above but with minor amount of black claystone.
------	2, 450–2, 453	Sandstone, light-gray, very fine grained, noncalcareous; composed of clear and smoky subangular quartz grains. Chert, light- to medium-gray, noncalcareous; conchoidal fracture, uniform texture.
------	2, 453–2, 456	Chert as immediately above.

DRILLING OPERATIONS AND PRODUCTION DATA

A Cardwell rotary rig was used to drill the well, utilizing equipment and materials already available in the U.S. Navy supplies at Barrow and Umiat. The hole was first drilled to 117 feet with 12¼-inch bits, and then opened to 17½ inches and finally to 26 inches, when 117 feet of 18-inch casing was set with 120 sacks of Cal-Seal cement. The upper 86 feet was jacketed with 22⅝-inch casing with a sealed air space between the two casings. Cement fills the annulus between the hole and the jacketing.

A 12¼-inch hole was drilled to 920 feet, and after reaming, 11¾-inch 47-pound J–55 API seamless casing was set to that depth. It was cemented with 390 sacks of construction cement treated with 3 percent calcium chloride, and mixed with water at 150°F. An additional 105 sacks of cement raised the cement level from 105 feet to the surface.

Drilling resumed with a 10⅝-inch hole to 2,320 feet, where 7-inch 29-pound N–80 API seamless long-collar casing was set with 570 sacks of construction cement, using 3 percent calcium chloride and warm water as above. The Hayward stage-cementing collar at 989 feet closed, leaving the casing above it full of cement. Cement in the annulus was found at 420 feet, and an additional 300 sacks of cement was pumped through

1½-inch pipe into the annulus, filling it to the surface. The cement in the casing was then drilled out, and the hole was drilled 5 feet deeper. A Johnston formation tester set with a packer at 2,215 feet and tailpipe at 2,218 feet was opened for 1 hour and 15 minutes. A light puffy blow lasted for 15 minutes, then resumed again 5 minutes later. With a ½-inch orifice, a flow prover measured pressures increasing in 30 minutes from 32 psi to 69 psi, at temperatures decreasing from 52°F to 45°F, indicating a production rate which increased from 293,000 to 485,000 cubic feet per day. Bottom-hole flowing pressures were less than 200 psi, and no fluid was recovered in the drill pipe.

Drilling was continued with 5⅞-inch bits to 2,458 feet, the total depth. The hole was scraped, enlarging it to 6¼ inches in diameter. One hundred and sixty feet of 5¾-inch 17-pound J–55 API seamless liner hung at 2,298 feet was perforated with forty-eight ¼-inch round drilled holes per foot from 2,325 to 2,455 feet. The drilling mud was replaced with salt water, and after building up pressure first in the casing and then in the tubing with gas from South Barrow test well 4, the well flowed gas, mud, and water through the casing. Gas pressure was reapplied to the casing, and the well started to flow through the tubing, producing a little water in the first 8 minutes. The hole was closed in and a critical flow prover with a 1½-inch orifice was installed which gave readings tabulated as follows:

Critical-flow-prover readings, with 1½-inch orifice, taken every 2 minutes for a 14-minute test

Pressure (psi)	Temperature (° F)	Rate (cu ft per day)
170	35	10, 700, 000
150	30	9, 600, 000
125	25	8, 400, 000
120	25	7, 900, 000
115	24	7, 600, 000
120	24	7, 900, 000
120	24	7, 900, 000

The casing pressure also declined from 1,000 to 700 psi and then stabilized at 700 psi as the flow prover settled at 120 psi. No water was produced with the gas.

A second flow-prover test, with a ¼-inch orifice, gave the following results:

Pressure (psi)	Temperature (°F)	Rate (cu ft per day)
965	37	1, 480, 000
960	34	1, 460, 000
960	33	1, 460, 000

During the second test, which took 20 minutes, the casing pressure declined from 1,000 to 980 psi, but 2 minutes after the well was closed in following the test, it rose to its former value of 1,000 psi.

HOLE DEVIATION

Totco Recorder measurements of the deviation of the hole show it to have increased slowly from vertical at 262 feet to 1°50′ at 2,110 feet, and then decreased slightly to 1°40′. The deviation at various depths is as follows.

Depth (feet)	*Inclination*
116	0°30′
262	0°0′
489	0°0′
586	9°15′
920	0°30′
1,046	0°20′
1,432	0°40′
1,831	1°20′
2,110	1°50′
2,235	1°40′

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