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Core Tests and Test Wells Oumalik Area, Alaska

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

PART 5, SUBSURFACE GEOLOGY AND ENGINEERING DATA

GEOLOGICAL SURVEY PROFESSIONAL PAPER 305-A

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

Drucker

Core Tests and Test Wells Oumalik Area, Alaska

By FLORENCE M. ROBINSON

With Paleontology of Test Wells and Core Tests in the Oumalik Area, Alaska

By HARLAN R. BERGQUIST

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

PART 5, SUBSURFACE GEOLOGY AND ENGINEERING DATA

INTRODUCTION

By Florence M. Robinson

In 1944 the United States Navy began large-scale exploration of Naval Petroleum Reserve No. 4, northern Alaska (see fig. 1), to determine the petroleum possibilities. This area of approximately 35,000 square miles includes parts of the Arctic coastal plain, the Arctic foothills, and the Brooks Range provinces. The factors of climate, terrain, and geographic location made this a unique operation. The winters are very cold with temperatures as low as the minus sixties, the summers, cool and short. Daylight lasts almost 24 hours a day unbroken from May through July; darkness is continual through most of December and January. Permafrost underlies much of the area, in places to a

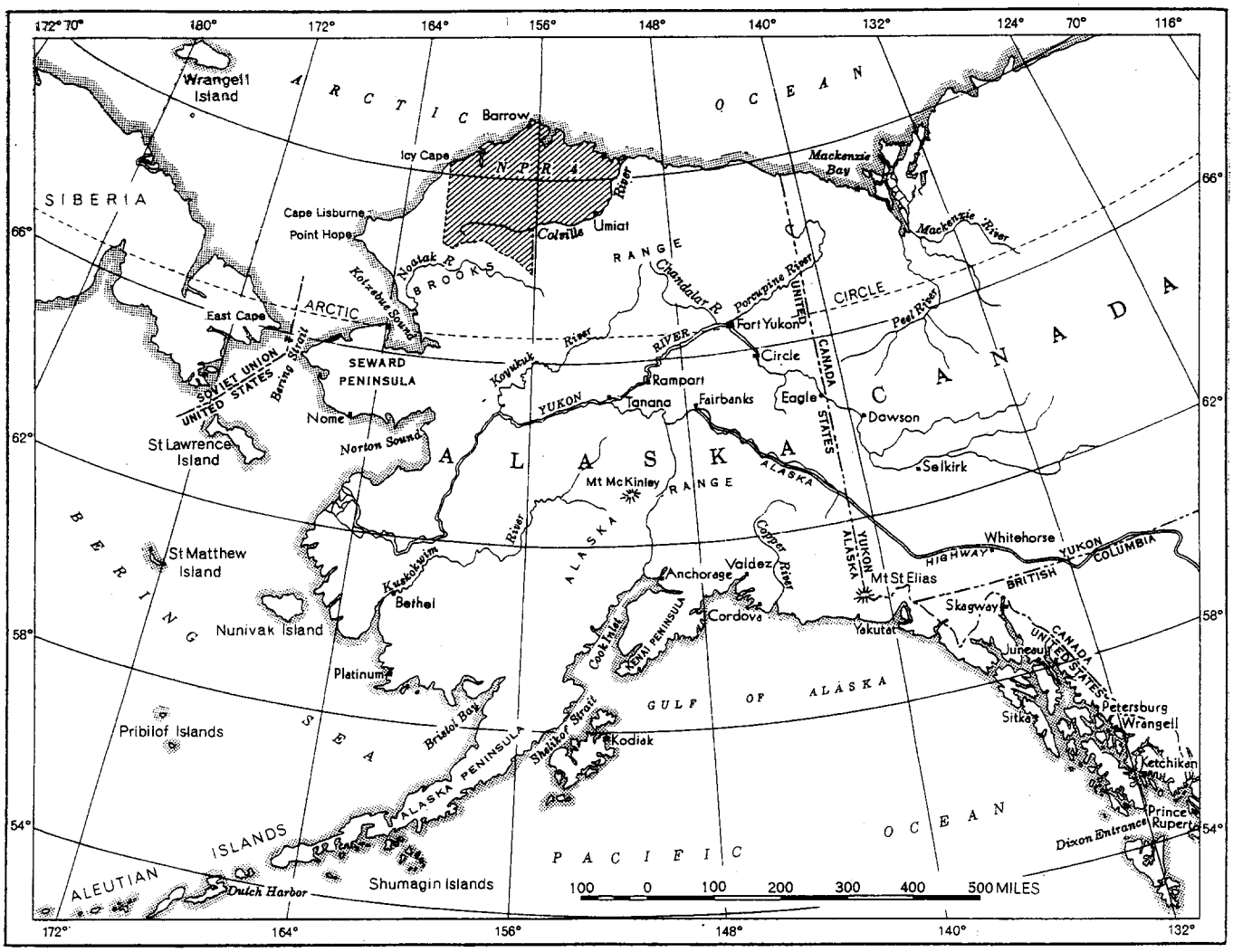

Figure 1.—Index map of Alaska showing location of Naval Petroleum Reserve No. 4.

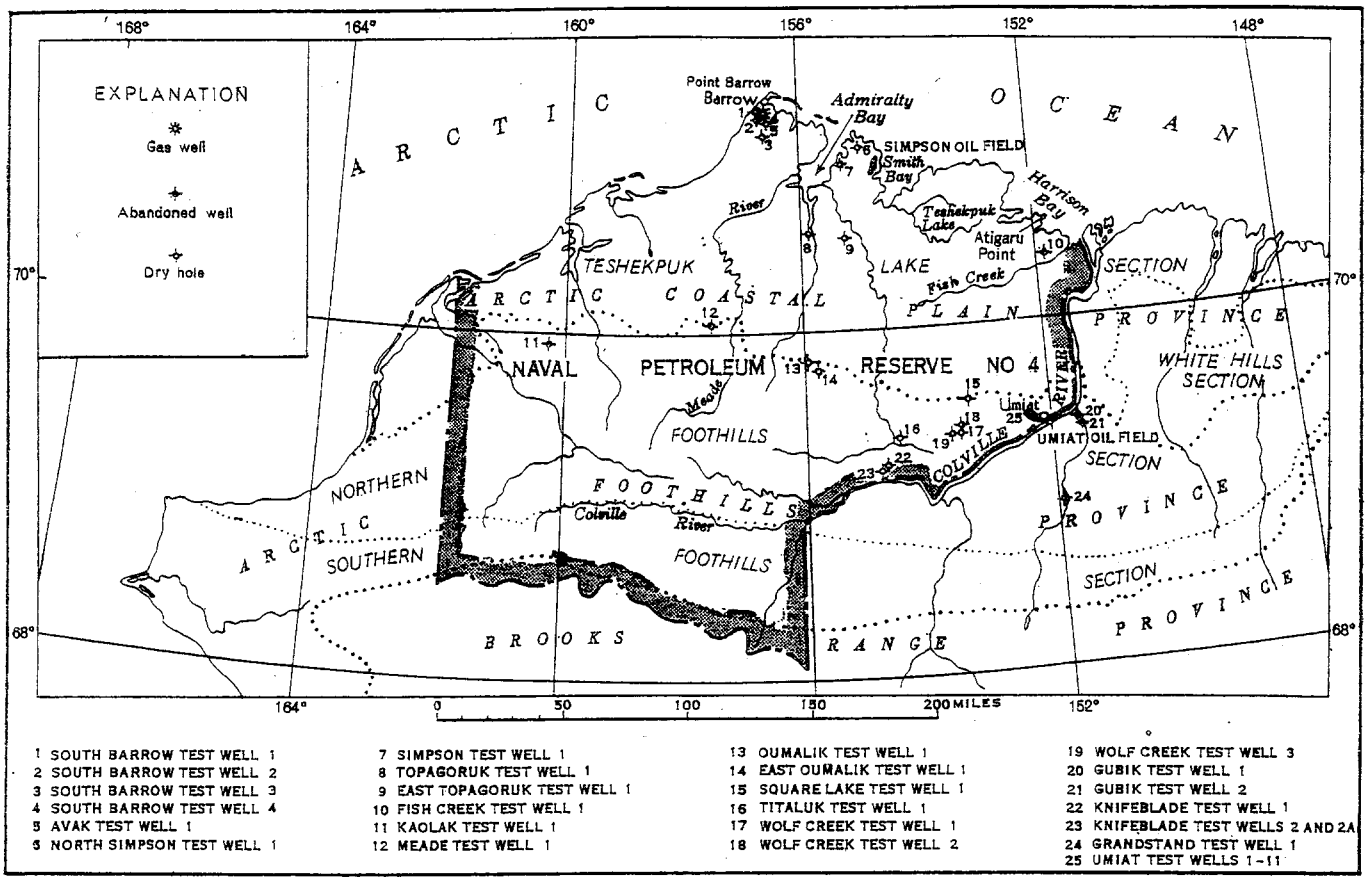

FIGURE 2.—Index map of northern Alaska, showing location of test wells and oilfields.

depth of 1,000 feet, which creates serious logistic and construction problems. The Arctic coastal plain is very flat and covered with innumerable lakes and winding streams. In the summer about 60 percent of the surface is water; the rest is mosquito-infested marshy tundra. The topography of the adjacent northern foothills of the Brooks Range is rolling, with low tundra-covered ridges and broad, shallow valleys. The general altitude is less than 1,000 feet.

From 1944 to 1952 a total of 81 test holes were drilled in widely separated parts of the area. (See fig. 2.) The holes, the first in North America north of the Arctic Circle, were located both in the foothills and on the coastal plain. Of these, 36 were test wells, and 45 were core tests. The first 16 holes were drilled by the Seabees; the remainder, by Arctic Contractors under contract to the Navy.

The tests were located on structural features defined by surface mapping, by geophysical methods or by a combination of the two. Equipment and supplies were delivered by U. S. Navy boats to Point Barrow during the open-water season and were carried from there to the test sites by Caterpillar-tractor-drawn trains over the ice and snow in winter. Therefore, it was necessary to locate the drill sites a year or more in advance of actual drilling in order to plan delivery of equipment.

Wells were drilled in the following places:

Barrow: 5 test wells, 5 core tests; several holes reached Paleozoic(?) rocks at shallow depth; 2 wells produced gas from Jurassic rocks.

Fish Creek area: 1 test well; drilled in the Upper Cretaceous basin in the northeastern part of the reserve; produced a small amount of very heavy oil.

Grandstand anticline area: 1 test well; the most southerly test; in Cretaceous rocks.

Gubik anticline area: 2 test wells on a large gas-productive anticline.

Kaolak River area: 1 test well; located in the western part of the reserve; a primarily nonmarine sequence of Cretaceous strata were drilled.

Knifeblade Ridge: 3 test wells; shallow tests on an anticline in the northern foothills.

Meade River area: 1 test well; near the central part of the river; had shows of gas.

Oumalik River area: 2 test wells; 5 core tests; includes the deepest hole drilled in the reserve; 1 test well had shows of gas.

Sentinel Hill: 1 core test; penetrated Upper Cretaceous rocks.

Simpson peninsula: 2 test wells; includes 1 of the earlier deep holes which furnished important stratigraphic information.

Simpson Seeps: 34 core tests; a shallow oilfield was defined by the series of core tests.

Square Lake: 1 test well; a prospect northwest of Umiat defined by seismic and photogeologic techniques.

Titaluk River area: 1 test well; located on an anticline mapped primarily by field and photogeologic methods.

Topagoruk River area: 2 test wells; in the central part of the coastal plain; a deep test penetrated rocks ranging in age from Devonian to Pleistocene.

Umiat: 11 test wells; many produced oil.

Wolf Creek area: 3 test wells; relatively shallow tests; shows of gas.

The test holes range in depth from 47 to 11,872 feet, and the drilling penetrated rocks of Paleozoic, Mesozoic, and Quaternary age. Most of the footage was drilled of Cretaceous rocks, and all the oil-bearing beds found are in this age. Figure 3 shows diagrammatically the relationships of the Cretaceous rocks. Paleozoic, Triassic, and Jurassic sedimentary rocks were penetrated in the drilling of a few holes in the northern part of the Reserve, but only a small amount of gas was found in these older rocks. Oilfields were discovered at Umiat and Simpson seeps and gasfields at Barrow and Gubik. Some shows of oil or gas were also noted in other holes.

The United States Geological Survey participated in the program as a cooperating agency. Drill cores and cuttings from the tests were shipped from the reserve to the Survey laboratory in Fairbanks where they were processed, described, and analyzed. Detailed subsurface information based on laboratory studies and analyses by the authors has been compiled by groups of related wells; in addition, logistic, engineering, and drilling operational data have been abstracted from the files and reports made to the Navy by Arctic Contractors, United Geophysical Co., Inc., the Schlumberger Well Surveying Corp., the U. S. Bureau of Mines, and the National Bureau of Standards. These data as well as a geological interpretation of the subsurface information constitute this paper.

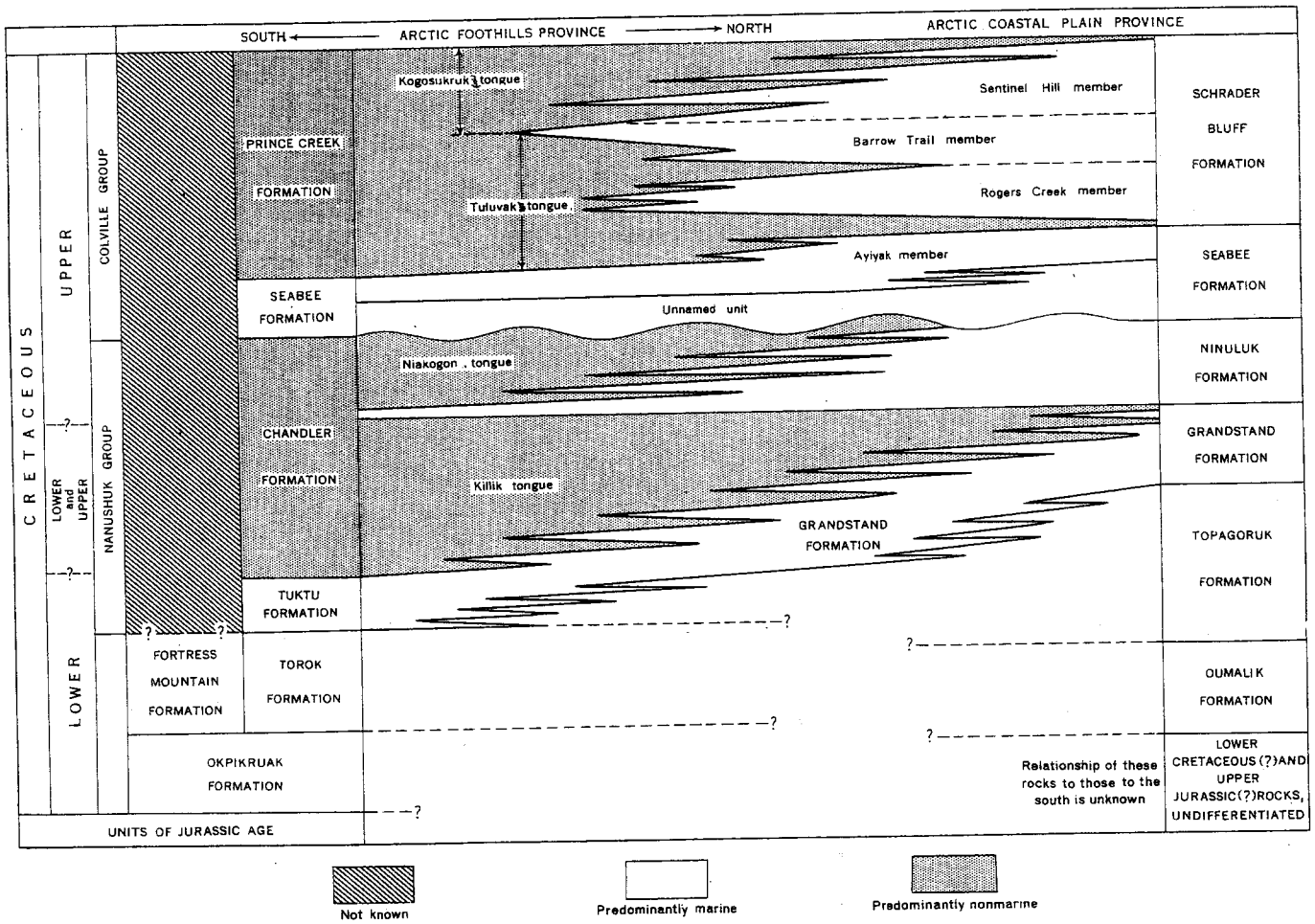

FIGURE 3.—Nomenclature of the Cretaceous rocks of northern Alaska.

CORE TEST AND TEST WELLS, OUMALIK AREA, ALASKA

By Florence M. Robinson

ABSTRACT

The Oumalik test wells and core tests were drilled in the years 1947–51 as a part of the exploration program of Naval Petroleum Reserve No. 4, northern Alaska. These tests are located on the Oumalik anticline about 100 miles south-southeast of Point Barrow. Oumalik test well 1 and East Oumalik test well 1 were drilled primarily to test sandstones of Cretaceous age on the structure, which was delineated by geophysical means. The core tests, which were drilled before the deeper holes, served primarily for stratigraphic and foundation studies.

The depth of the holes ranges from 47 feet in a foundation test to 11,872 feet in Oumalik test well 1, the deepest test well drilled in the Petroleum Reserve. The stratigraphic section penetrated consists of the Nanushuk group and the Topagoruk and Oumalik formations, of Early and Late Cretaceous age, plus a unit of Late Jurassic(?) and Early Cretaceous(?) age. Shows of oil were negligible. Drilling of Oumalik test well 1 revealed some shows of high-pressure and low-volume gas which is of little present commercial value.

INTRODUCTION

Five core holes, ten foundation tests, and two test wells were drilled in the Oumalik River region on the Oumalik anticline, near the northern boundary of the Arctic foothills province, at lat 69°50′ N. and between long 155°15′ W. and 156°15′ W. The name "Oumalik" comes from the Eskimo name of a small river which heads in the area.

The core holes were preliminary tests drilled on an anticline discovered in 1947 by reflection seismograph. Geophysical and geological investigations in this area led to the drilling in 1949 and 1950 of the two deep tests: Oumalik test well 1 on the crest of the anticline and East Oumalik test well 1 on a subsidiary high at the east end. Inasmuch as rock exposures are practically nonexistent, the stratigraphy of the area is known only from cores and cuttings from the wells. This report describes in detail the strata penetrated, as well as the logistics, engineering, and drilling operations.

ACKNOWLEDGMENTS

Information for this report was compiled from daily and final reports made to the U. S. Navy by Arctic Contractors, United Geophysical Co., Inc., The Schlumberger Well Surveying Corp., and the U. S. Geological Survey. Gas analyses were made by the National Bureau of Standards, Washington, D. C., the U. S. Bureau of Mines, Amarillo, Tex., and the Smith-Emery Co., Los Angeles, Calif. The help of the personnel connected with the above organizations is gratefully acknowledged.

Unless otherwise noted, the core and cutting analyses were made by the staff of the U. S. Geological Survey in Fairbanks, Alaska. Microfossils were identified by Harlan R. Bergquist. The stratigraphic distribution of fossils in the test wells of northern Alaska will be presented by him in another chapter of this series. Megafossils were identified by Ralph W. Imlay and Roland W. Brown. P. D. Krynine and S. T. Yuster made reservoir analyses and furnished some additional data on porosity and permeability. The heavy-mineral zones were determined as part of a regional study of heavy minerals by Robert H. Morris. A summary of thermal investigations of Oumalik test well 1 was furnished by Max C. Brewer.

STRUCTURE

The Oumalik area (fig. 4) was first explored by the U. S. Geological Survey in cooperation with the Navy, using an airborne magnetometer, during 1945 and 1946. United Geophysical Co., Inc., made a reconnaissance gravity survey and a limited detailed survey of the area in 1947. These surveys indicate that the Oumalik anticline lies in a regional gravity low southwest of a gravity high that extends from a point northwest of Umiat to Smith Bay (Payne and others, 1951, sheet 2, fig. 9). In general, the observed gravity low covers most of the southwestern part of Naval Petroleum Reserve No. 4.

The Oumalik anticline was discovered later in 1947 by reflection seismograph (United Geophysical Co.), in the course of checking magnetic anomalies to the northeast. Additional seismic surveys, both reflection and refraction, were made in the Oumalik–middle

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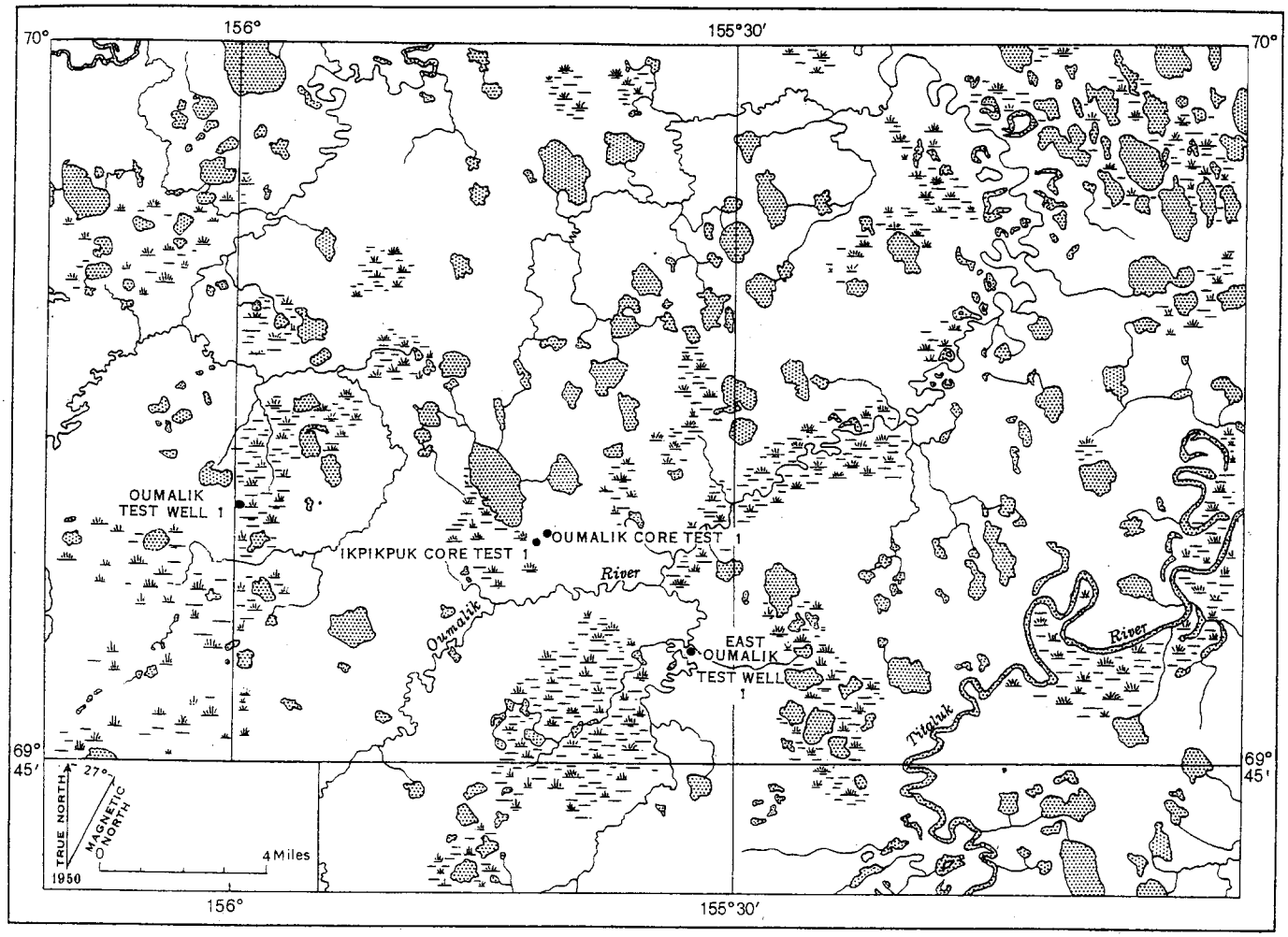


FIGURE 4.—Map showing location of Oumalik test well 1, East Oumalik test well 1, Oumalik core test 1, and Ikpikpuk core test 1.

Meade Rivers region in 1948, 1949, and 1950. The Oumalik anticline, on the same structural trend as the Meade, Square Lake, and Umiat anticlines (Payne and others, 1951, sheet 1, fig. 1), is about 20 miles long and 5 miles wide; the axis strikes N. 70° W. It plunges steeply to the west and less steeply to the east, with relatively low dips on the flanks. It has a minimum closure of 450 feet, encompassing an area of approximately 43 square miles. The total closure is not known, as seismic data for the west flank are lacking. On the flanks, particularly on the northeast side, the section thins toward the apex, as indicated by a marked truncation of reflecting horizons. The anticline is not necessarily related to any gravimetric or magnetic anomaly.

The structure-contour map of the Oumalik anticline (fig. 5) shows the shallow reflecting Lower Cretaceous sandstone strata (seismic horizon *A*). The anticline persists through the first 5,000 feet of section. Below this is a thick shale sequence characterized seismically by weak energy return, poor continuity, and erratic dips. No deep reflections, such as are typical of Triassic or Paleozoic rocks farther north, were obtained under the Oumalik test sites, but interpolation from surrounding areas suggests regional southward-dipping beds in the Jurassic or older rocks.

PURPOSE OF TESTS

Ikpikpuk core test 1 (fig. 4) was drilled in 1947 to obtain stratigraphic and structural information about the Oumalik anticline, in conjunction with the geophysical program in that area. It was originally planned that one core test would be drilled to a depth of 400 feet or more. However, as Ikpikpuk core test 1 had to be abandoned at a shallow depth because of mechanical difficulties when the objectives of the test were only partly realized, another hole, Oumalik core test 1, was drilled nearby. A third test, Oumalik core test 2 (fig. 6), was drilled about 6 miles west of the first two before the close of the summer season.

It was assumed that the thickness of the permafrost was about 900 feet, so in 1948, when it was decided to drill a deep test in the area, extensive foundation tests were made on the problems pertaining to the thawing of the frozen ground, which might result from the circulation of hot drilling mud. Ten core holes were drilled. (See fig. 6.) Lenses of ice as much as 40 feet thick were discovered in some of these test holes which were themselves only about 50 feet deep. Most of the ice lenses occur in frozen, but otherwise unconsolidated, sediments.

Oumalik core tests 11 and 12, numbered consecutively with the foundation tests, were also located close to the site of the proposed deep test and were drilled for both stratigraphic and foundation information.

Oumalik test well 1, the deepest test in the Reserve, was drilled in 1949–50 on the apex of the Oumalik anticline to determine the oil, gas, and water content of the formations as well as the stratigraphic section. Because seismic and regional studies suggested that sandstone of the Nanushuk group (Lower Cretaceous) would be penetrated completely above 6,000 feet, the hole was originally scheduled to that depth, but was rigged with equipment capable of drilling to 15,000 feet, if later developments warranted. The well was actually drilled to 11,872 feet in order to determine more conclusively the stratigraphy and oil possibilities of the Oumalik formation and pre-Oumalik strata in that part of the reserve. It disclosed some gas of low volume in sandstones of the Nanushuk group and Oumalik formation.

East Oumalik test well 1 was drilled to test the relatively shallow gas-producing sands on a subsidiary high at the east end of the Oumalik anticline. Seismic evidence indicated local closure of 200 feet or more and suggested a thickening of the sandstone beds on the flanks with the possibility of a stratigraphic as well as a structural trap. The hole was drilled to 6,035 feet but was dry.

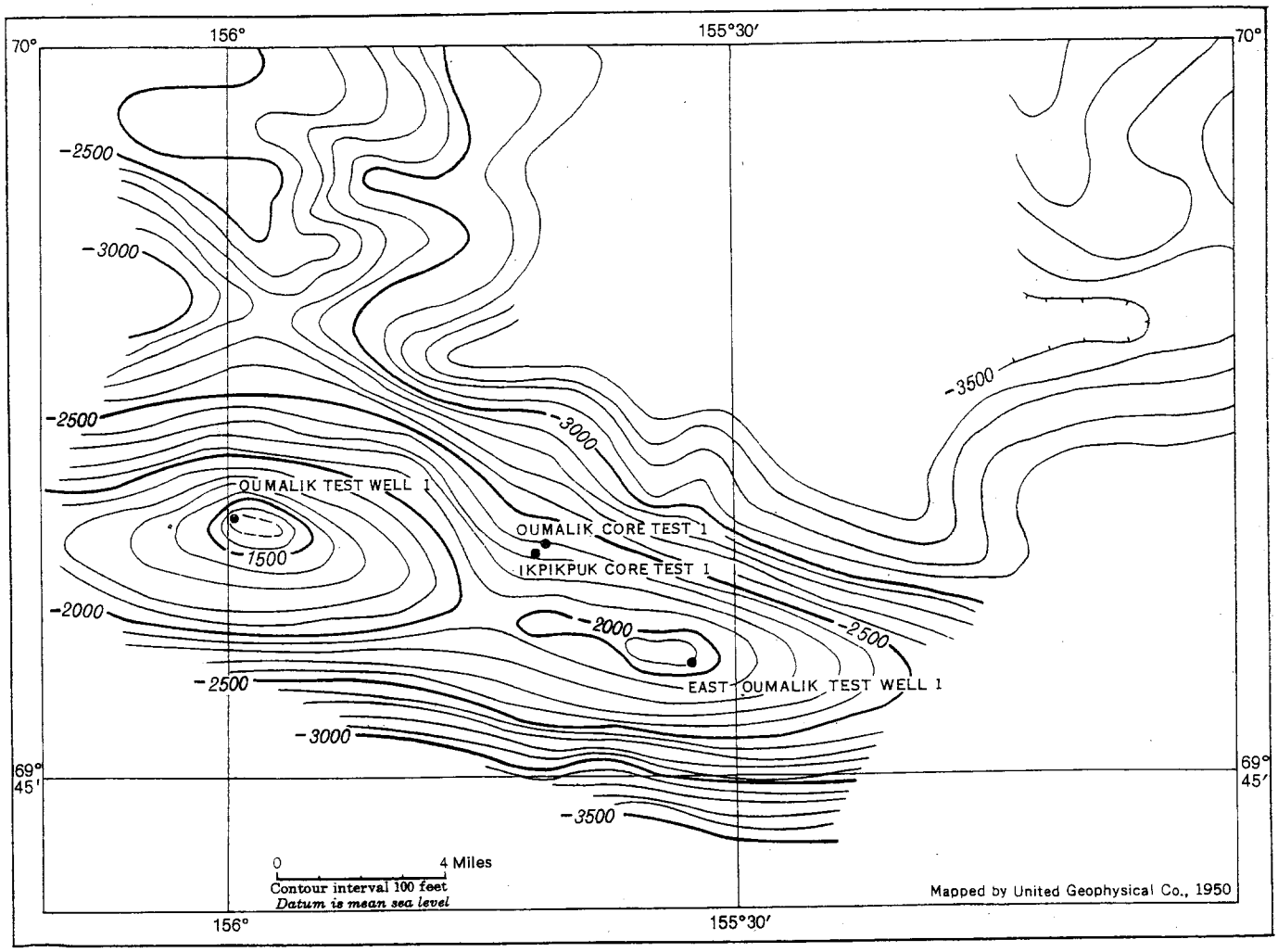


FIGURE 5.—Structure-contour map of the Oumalik anticline, contoured on a shallow phantom horizon (seismic horizon *A*) in Cretaceous rocks.

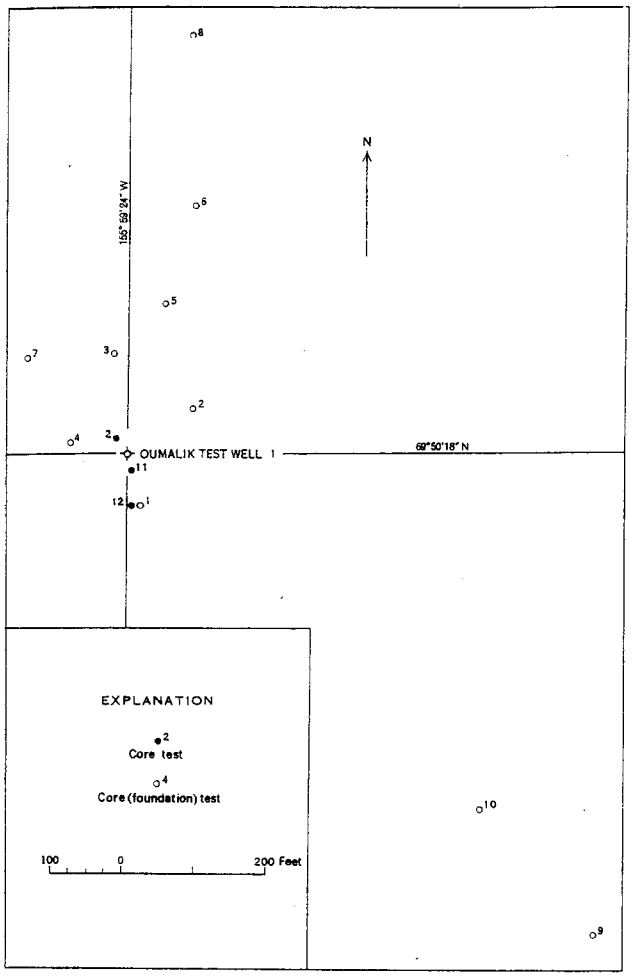


FIGURE 6.—Map showing location of Oumalik test well 1, Oumalik core tests 2, 11, 12, and Oumalik core (foundation) tests 1–10.

STRATIGRAPHY

The Oumalik tests were drilled in rocks that were deposited in the deepest part of a basin or trough in Cretaceous time. Five units have been distinguished, ranging in age from Late Jurassic(?) and Early Cretaceous(?) to Late(?) Cretaceous (Killik tongue, Chandler formation.) These rocks are mantled by Pleistocene and Recent deposits.

QUATERNARY DEPOSITS

GUBIK FORMATION—PLEISTOCENE

The unconsolidated surficial mantle, as much as 40 feet thick over most of the Oumalik region, is made up of river material of Recent age or of the Gubik formation of Pleistocene age, or both. The sediments consist of silt, sand, gravel, and clay containing ice lenses and wedges near the surface and largely covered by tundra. Yellowish-gray and light-olive-gray clay and silt beds are probably the most common. The yellowish-brown sand is fine to coarse grained and contains grains of subangular to rounded clear and white quartz and yellow, dark-gray, and black chert. Well-rounded sand grains are characteristic of the Gubik as contrasted to the angular and subangular grains of the underlying Cretaceous formations. The pebbles and granules in the gravel are various shades of brown, green, gray, and black polished chert. Angular pieces of orange to brown clay ironstone and yellowish quartzite are also present. In some areas the Gubik formation does not contain coarse sediments. White shell fragments and nonmarine ostracodes have been found.

CRETACEOUS ROCKS

CHANDLER FORMATION (KILLIK TONGUE)

Rocks of the Nanushuk group (fig. 3; see Gryc, and others, 1956, and Gryc, Patton, and Payne, 1951) underlie the Gubik formation. The youngest Cretaceous strata penetrated by the Oumalik tests are the nonmarine Killik tongue of the Chandler formation. Very little of this tongue is present at the apex of the anticline, but it is about 700 feet thick in East Oumalik test well 1. It is predominantly clay shale and coal interbedded with some sandstone and siltstone. The sandstone beds are light gray and medium soft, but a few are hard with a calcareous matrix. The grains are very fine to fine and are composed mostly of subangular white and clear quartz, mica, and coal particles in an argillaceous matrix. The sandstone has low porosity and permeability. The siltstone beds are similar to the sandstone but are generally darker. The clay shale is light gray to black and is rather soft and fissile where associated with carbonaceous material. Very rare, very thin beds of hard medium- to dark-gray argillaceous lithographic limestone are also present.

The coal and carbonaceous material which occur as thin beds, partings, and plant fragments throughout the sequence are characteristic of the Killik tongue. The coal is grayish black to black and has a dull to vitreous luster. Yellowish-gray hard clay ironstone concretions and nodules are also common in this tongue. The presence of coal and charophytes and the absence of marine fossils indicate that these beds are of nonmarine origin.

GRANDSTAND FORMATION

The transition from the Killik tongue to the Grandstand formation is gradational, and there are a few nonmarine beds of the Killik tongue in the upper part of the Grandstand. The thickness of the Grandstand formation on the Oumalik structure ranges from at least 2,300 to 2,800 feet. About 600 feet of the total thickness is made up of sandstone and siltstone. The sandstone is light to medium light gray, the siltstone is slightly darker. It is made up of 60 percent or more

of subangular, rarely subrounded, white and clear quartz grains and varying amounts of dark-gray chert, coal, and rock fragments. Grain size decreases from medium to very fine with depth. The sandstone is silty, very argillaceous, and moderately hard to hard and has rare carbonaceous and micaceous laminae. The sandstone beds are similar to those in the Killik tongue except that they are thicker, harder, and more massive and the average grain size is slightly larger and the matrix is more calcareous. Ripple marks and excellent small-scale crossbedding with dips as high as 20° are present, particularly in the lower 1,000 feet of section. Some contorted beds suggesting soft rock flowage were found.

The clay shale and claystone, making up the rest of the formation, are medium light to medium dark gray, hard, have micaceous partings, contain very rare pyrite, and in places grade into hard massive claystone with very irregular to conchoidal fracture. In the first 900 feet and rarely in the lower part the shale is medium dark gray to grayish black, very carbonaceous and fissile. There are no very thick beds of coal, but very thin ones (1 inch or less) interbedded with the shale are relatively common in some parts of the section, particularly in the first 900 feet. The coal is vitreous to dull black; brownish lignite is also present. This dark shale and coal is considered to belong to the Killik tongue. Black carbonaceous fragments and plant impressions are relatively abundant throughout.

In the Oumalik area the Grandstand formation is more calcareous than in other areas studied. Almost all the sandstones have a somewhat calcareous matrix which reduces the porosity and permeability. Hard thin medium- to dark-gray argillaceous limestone beds are rare.

The presence of Foraminifera, a few mollusk, and crinoid fragments throughout much of the section indicates that the Grandstand formation is largely marine in origin.

TOPAGORUK FORMATION

No sharp lithologic break exists between the Grandstand and Topagoruk formations; the bottom of the Grandstand is picked as the base of the predominantly sandy section. The Topagoruk is 90 percent clay shale and silty clay shale and 10 percent siltstone and sandstone, with a trace of coal. The proportion of coarser material decreases with depth. The formation is about 2,100 feet thick.

Lithologically, the clay shale and siltstone are essentially the same as in the Grandstand formation above but are slightly darker. Most of the rocks are medium hard but in a few places have been reported by the driller as soft, waxy, or possibly slightly bentonitic. The porosity and permeability are low, and the carbonate content, high. The section is marine and fossiliferous.

OUMALIK FORMATION

The Oumalik formation in Oumalik test well 1, the only hole on the structure that was drilled through the entire formation, is about 6,000 feet thick and can be divided into two marine units—an upper shale unit, 4,410 feet thick, and a lower sandy shale, 1,610 feet thick.

The upper shale unit is a monotonous section of clay shale, medium dark to dark gray, slightly micaceous, carbonaceous, and pyritic. Shaly cleavage parallel to the bedding is good to poor. Where cleavage is poor, the rock can be considered a claystone. Siltstone and sandy siltstone occur very sparingly in the section. The siltstone occurs in thin medium-light- to medium-gray laminae which are a little harder than the clay shale. The siltstone shows very rare ripple marks and small-scale crossbedding. The upper unit is noncalcareous.

The lower sandy shale unit of the Oumalik formation is made up of about 40 percent siltstone and sandstone, in addition to clay shale of the type described above. The upper unit grades into the lower, but the contact is placed at the top of the first sandstone of appreciable thickness; none of the sandstone beds are more than 30 feet thick. The sandstone and siltstone are medium light to medium gray, hard, massive, silty, and very fine to fine grained. The grains are subangular to angular and estimated to be 50 percent white and clear quartz and 15 percent shiny black carbonaceous material or bitumen; the remainder is mica, altered feldspar (?), and other minerals cemented by argillaceous material or perhaps by a small amount of calcite or dolomite. Excellent small-scale crossbedding and some ripple marks are also present in this lower unit.

The carbonate content is relatively high, and the porosity, low; the sandstone is almost impermeable.

A few chips of bluish-gray clay shale (bentonitic?) occur very rarely in the cuttings in the lowest 500 feet of the formation. Cuttings from the basal part of the lower unit also contain rare chips having lithologic characteristics suggestive of the Upper Jurassic(?) and Lower Cretaceous(?) below—they may possibly contain reworked material. These chips of shale contain rounded medium to coarse quartz grains and a small amount of medium-olive-gray quartzitic-appearing siltstone.

Partings of bitumen and carbonaceous plant fragments or impressions are very rare in the Oumalik formation.

In the deeper parts of the Lower Cretaceous basin, in which the Oumalik test wells are located, the upper

contact of the Oumalik formation appears to be gradational into the overlying Topagoruk formation, although an angular unconformity between these formations can be demonstrated in other areas. The contact in this well was placed below the silty section of the Topagoruk formation, beneath the lowest occurrence of the fauna of the Nanushuk group, and at the first occurrence of *Dorothia chandlerensis* Tappan, an index microfossil of the Oumalik formation. Shale of the Oumalik formation is darker than shale of the Topagoruk formation. The sandstones are also slightly darker because they contain less white and clear quartz in proportion to the other minerals and matrix. The sand grains are more angular than those of the Topagoruk.

UPPER JURASSIC(?) AND LOWER CRETACEOUS(?) ROCKS

The most pronounced lithologic break in Oumalik test well 1 is between the Oumalik formation and the underlying rocks, and it may represent an unconformity. The age of the 992 feet of beds immediately below this break in Oumalik test well 1 is doubtful. Lithologically, the section is the same throughout, and the bottom of the unit was not reached. The beds may be a part of the Okpikruak formation of Early Cretaceous age; they may be Late Jurassic in age; or they may be gradational from Upper Jurassic to Lower Cretaceous. The various possibilities are discussed from a paleontological point of view by Harlan R. Bergquist on pages 65–68. Lithologically, this section of doubtful age does not closely resemble the Okpikruak formation of the outcrop 90 miles to the south, but it has some of the peculiarities of the Upper Jurassic section in Topagoruk test well 1, which is 55 miles north. Perhaps the upper few hundred feet of rocks, containing *Aucella sublaevis* Keyserling, can be correlated with the Okpikruak formation, but the relation of these upper beds to the Okpikruak formation found in the outcrop is dubious.

These Upper Jurassic(?) and Lower Cretaceous(?) rocks are made up of clay shale interbedded with as much as 10 percent siltstone and very fine sandstone. The clay shale is dark gray to grayish black, is moderately hard, and has plates of mica, larger than those in the formations above, scattered abundantly throughout. Very rare to common well-rounded, slightly frosted clear quartz grains up to very coarse size are embedded, individually or as streaks, in shale. Also present in the shale are soft pellets, very fine to medium grained, of pale-green clay or glauconite (?). Some of the rounded quartz grains are surrounded by crystalline pyrite.

The siltstone and sandstone range from medium light gray to medium olive gray. The medium-olive-gray material is made up almost entirely of colorless and transparent or clear brownish angular to subangular quartz; it is very hard and tight, has a slight glassy quartzitic sheen in the hand specimen, and is very slightly calcareous to noncalcareous. No pyrite, glauconite, or rounded grains were observed in the sandstone and siltstone.

Very rare pebbles and granules of dark chert and quartz are present. Large chips of pyrite were found in the ditch, and nodules, in the bottom-hole core.

Rocks older than the Upper Jurassic(?) are not known in the Oumalik area. Geophysical surveys failed to detect a high-velocity break which might be indicative of limestone of Paleozoic age. Interpolation from areas to the west suggests that the depth to "basement" (Paleozoic?) rocks of the type found near Barrow may be about 20,000 feet.

CORE TESTS

DESCRIPTION OF CORES AND CUTTINGS

The following lithologic descriptions, with the exception of Oumalik core (foundation) tests 1–10, were made by the author. The brief descriptions of the foundation tests were made by the driller or geologist at the time the holes were drilled. All material was described dry; colors were determined by comparison to the Rock Color Chart (Goddard and others, 1948). The term "trace" as used here is defined as less than 3 percent and in most cases less than 1 percent. Clay ironstone is a sideritic, dense, and rather hard mudstone that generally effervesces very slowly in cold dilute hydrochloric acid.

Abundance of microfossil specimens mentioned at the beginning of each core description in Oumalik core tests 11 and 12 and in the test wells is defined as follows: 1-4 very rare, 5-11 rare, 12-25 common, 26-50 abundant, and over 50 very abundant.

The latitudes and longitudes of these core tests are based on preliminary surveys and are subject to correction. All elevations in the area, including those used on seismic lines, were taken from a base elevation established at an airstrip by numerous aircraft altimeter readings.

IKPIKPUK CORE TEST 1

Location: Lat 69°49′36″ N., long 155°41′57″ W.
Elevation: Ground, 170 feet; kelly bushing, 180 feet.
Spudded: July 9, 1947.
Completed: July 17, 1947, junked and abandoned.
Total depth: 178 feet.

Ikpikpuk core test 1 was located near the campsite occupied by United Geophysical Co.'s seismo-

graph party 46. Seismic evidence indicates that the hole was located off the crest on the north flank of the Oumalik anticline (see fig. 5), as contoured on shallow sandstone strata of Cretaceous age. The top of the Cretaceous section in this hole is approximately 400 feet stratigraphically higher than the uppermost Cretaceous penetrated in drilling East Oumalik test well 1. (See p. 8.)

No samples were received for the upper 39 feet of the hole. The first sample, at 39 feet, is Cretaceous, with surface contamination suggesting that the Pleistocene and (or) Recent mantle is 30 feet thick or less. The hole from 39 feet to total depth is in both the Lower and Upper Cretaceous, probably in the nonmarine Chandler formation of the Nanushuk group. (See pl. 3.)

The hole was abandoned when the N-rods twisted off at 90 feet.

The samples from this test are very poor. The cuttings consist almost entirely of contaminating material from the surface and are not necessarily indicative of the formations penetrated. The cores are also poor and badly infiltrated by drilling mud. All depths are measured from the kelly bushing.

Lithologic description

[Where no core number is given, description is from cuttings]

Core	Depth (feet)	Description
----	0–10	Kelly bushing to ground level.
----	10–39	No samples received.
----	39–98	Sand, light-olive-gray, unconsolidated, medium- to coarse-grained; grains round to subround and made up of 80 percent clear, yellow, and white quartz, 20 percent dark-gray and black chert. A few shiny black coal chips at 84–94 ft. Clay (drilling mud) loosely cements some of the grains; white pelecypod shell fragments and ostracodes present. Trace of light-gray very calcareous cement throughout.
1	98–108	Recovered 4 ft: Clay shale, medium-light- to medium-gray, fissile, soft; rare dark-gray carbonaceous noncalcareous clay shale. This part of core badly broken by drill and infiltrated by drilling mud. Well-rounded black and yellow chert granules and pebbles found in mud in middle of recovered section are probably surface contamination. Dip of beds indeterminate.
----	108–149	Sand and drilling mud as above. Larger proportion of subangular grains with increasing depth. Also a gradual increase in proportion of white and clear quartz to yellow quartz. No sandstone chips recovered.
2	149–159	Recovered 5 ft: 1 ft 6 in., sand, unconsolidated. This sand is ground-up medium-grained sandstone of Cretaceous age (subangular white and clear quartz and carbonaceous particles) and a liberal amount of surface material (subround yellow and clear quartz grains, a few rounded chert granules), chips of clay shale, and black low-grade coal, all loosely embedded in drilling mud. Some calcareous material in mud probably is ground-up cement. 3 ft 6 in., siltstone, medium-light-gray, hard, with irregular fracture; grains mostly white and clear quartz and minute particles of carbonaceous material; beds approximately flat lying, some small-scale crossbedding.
----	159–178	Sand and drilling mud. Sand grains are very fine to fine, made up of 85 percent white and clear quartz; remainder is yellow quartz, gray and black chert, dark-colored rock fragments and black carbonaceous material. This sand is a mixture of surface material and ground-up sandstone of Cretaceous age.

OUMALIK CORE TEST 1

Location: Lat 69°49′45″ N., long 155°41′30″ W.
Elevation: Ground, 245 feet; kelly bushing, 255 feet.
Spudded: July 21, 1947.
Completed: July 29, 1947, junked and abandoned.
Total depth: 392 feet.

Oumalik core test 1 is located approximately one-quarter of a mile northeast of Ikpikpuk core test 1. (See fig. 4.) Although they are relatively close together, Oumalik core test 1 probably started as much as 100 feet higher in the section because of its higher elevation and position farther downdip on the flank of the anticline. Correlation between the two holes is difficult, owing to poor samples.

Samples were not obtained from the upper 30 feet of the hole. The sample from 30-foot depth is Cretaceous in age. Contamination in this and lower samples indicates that overlying Pleistocene and (or) Recent sediments are the same as those in Ikpikpuk core test 1; that is, rounded fine to coarse sand, rounded granules of yellow and black chert, and soft light-olive-gray to dusky-yellow clay.

The Lower and Upper Cretaceous rocks, probably of the Chandler formation, drilled in the rest of the hole are mostly clay shale with a few beds of sandstone and siltstone. The hole was abandoned when the drillers were unable to recover a core barrel stuck at 88 feet.

The cuttings from this test are very poor. About 95 percent of the samples represents contaminating cement, drilling mud, and near-surface Pleistocene or Recent sand and is not necessarily indicative of the formations penetrated. All depths are measured from the kelly bushing.

Lithologic description

[Where no core number is given, description is from cuttings]

Core	Depth (feet)	Description
----	0–10	Kelly bushing to ground level.
----	10–30	No samples received.
----	30–102	Silt and clay (or drilling mud), light-olive-gray; some sand with rounded varicolored grains. As much as 90 percent white cement contamination.
1	102–112	Recovered 3 ft 6 in.: Clay, light-olive-gray to dusky-yellow, soft; contains relatively modern appearing tundra plant fragments; moderately calcareous, without visible bedding; streaks of yellowish clay which effervesce with HCl are probably sideritic.
----	112–152	Cement contamination as much as 90 percent, also clay, silt, and sand in every sample. About 30 percent of sand made up of subangular Cretaceous sand grains, but horizon from which they came cannot be determined.
2	152–162	Recovered 7 ft: 2 ft 9 in., sandstone, light-gray, hard, argillaceous, moderately calcareous. Dip 10°–15°. 9 in., clay shale, medium-gray, soft, sandy. 1 ft 3 in., siltstone, yellowish-gray, medium-hard, slightly sandy. 2 ft, clay shale, yellowish-gray, soft to medium-hard. 3 in., claystone, yellowish-gray, medium-hard, noncalcareous.
----	162–170	Cement contamination 50 percent, near-surface sand 20 percent. Clay shale, medium-light-gray. Sandstone, light-gray, medium-grained; grains are subangular and made up of 75 percent white and clear quartz; remainder is dark rock fragments, chert and coal; calcareous. Clay ironstone present, moderate yellowish brown.
----	170–180	Cement 30 percent, near-surface sand 30 percent, also sandstone, clay shale, clay ironstone. Some clay shale is medium dark gray.
----	180–199	Cement contamination 85 percent. Clay shale, medium-light-gray. Surface sand, fine- to coarse-grained, and granules of yellow and black chert.
3	199–209	Recovered 1 ft 6 in.: Clay shale, medium-light-gray to grayish-black; recovery consists almost entirely of broken chips. Upper 6 in. made up of drilling mud with chips of shale embedded, also some sand grains. Some of the shale is very dark and carbonaceous. Rare fragments of shiny black coal. A few specks of amber found in the carbonaceous beds. Lowest 2 in. of recovery consists of very light-gray sandy siltstone, that contains rare carbonaceous particles. The "siltstone" may possibly be cement contamination. Clay shale is noncalcareous. Parts of drilling mud very calcareous.

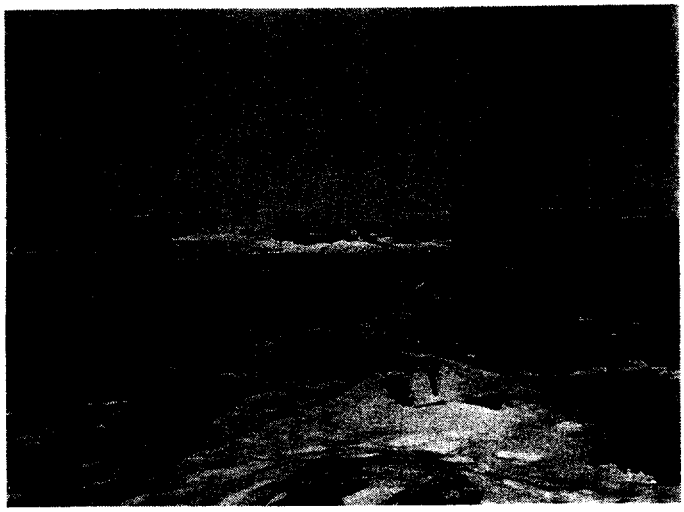
Lithologic description—Continued

Core	Depth (feet)	Description
4	209–219	Recovered 1 ft 6 in.: 1 ft, drilling mud, contains small chips of clay shale, sand, pebbles; calcareous. 6 in., claystone, medium-light-gray, medium-hard, irregular fracture, contains numerous dark-gray plant fragments, also a clear yellow piece of amber in the claystone.
----	219–252	Clay lumps (mostly drilling mud) mixed with sand. Sand, unconsolidated, light-olive-gray, medium-grained; grains subrounded to rounded, made up of 90 percent clear and some white quartz with a yellowish cast, also black chert, and a few rock particles. This sand is mostly near-surface contamination.
5	252–262	Recovered 8 ft: Siltstone, light- to medium-light-gray, hard, noncalcareous; has irregular fracture, very argillaceous and grades into silty claystone. Silt made up of 90 percent white and clear quartz; remainder is carbonaceous and micaceous particles; dip 10° (?); a few steeper dips probably represent cross-bedding.
----	262–300	Clay lumps mixed with sand as at 220–250 ft, some cement contamination. Dull black coaly particles at 290–300 ft.
6	300–310	Recovered 8 ft: 2 ft, siltstone, light-gray, hard, moderately calcareous. 6 ft, interbedded siltstone, clay shale, and coal, soft to medium-hard, dark-greenish-gray to medium-gray. Entire core badly fractured; carbonaceous material in the shale.
----	310–320	Sand and clay.
----	320–330	Clay shale 60 percent, medium-gray and small amount of dark-gray; remainder is sand.
----	330–340	Sand 50 percent, medium-light-gray clay shale 50 percent.
----	340–350	Sand; trace of clay shale, medium-light-gray and dark-gray.
----	350–360	Sand with trace of dark-gray clay shale.
----	360–370	Sand with trace of medium-light-gray clay shale.
----	370–383	Sand, clay shale, clay ironstone, cement.
7	383–392	No recovery. Lost tool in hole.

OUMALIK CORE TEST 2

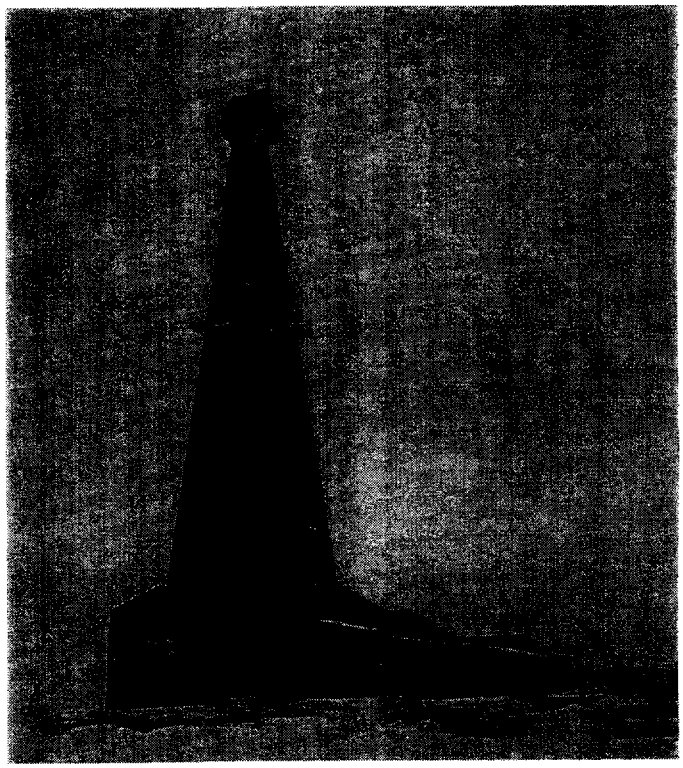
Location: Lat 69°50′18″ N., long 155°59′24″ W.
Elevation: Ground, 178 feet; kelly bushing not known.
Spudded: Sept. 8, 1947.
Completed: Sept. 10, 1947, junked and abandoned.
Total depth: 190 feet.

The drill site for Oumalik core test 2 is on the apex of the anticline approximately 6 miles west of Ikpikpuk core test 1 and just 26 feet northwest of Oumalik test well 1. (See fig. 6.) This hole was drilled with geo-



A. OUMALIK CORE TEST 1

Adjoining casing rack piling and barrels mark the site chosen for Oumalik test well 1.



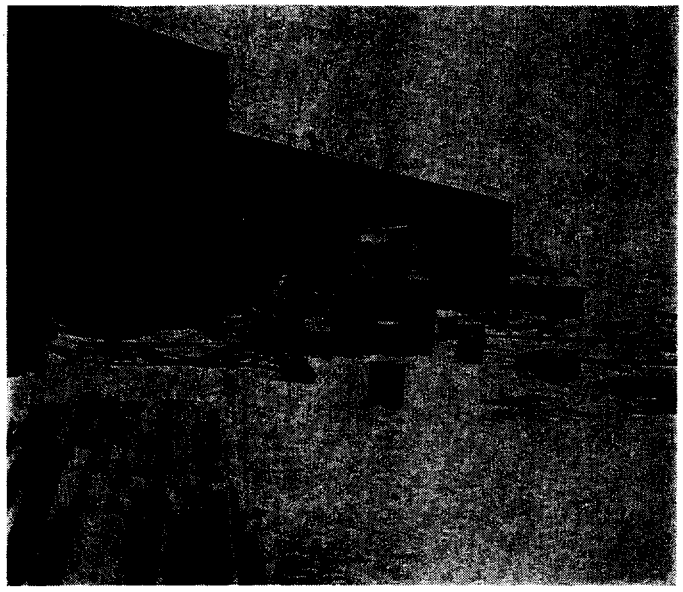
B. OUMALIK TEST WELL 1

General view of derrick and righouse showing protective covering on rig. This cover is necessary for drilling under Arctic conditions. Taken on Feb. 7, 1950.

C. OUMALIK TEST WELL 1

View of derrick floor; drawworks right background. Taken Feb. 7, 1950, when hole was at 11,007 feet.

DRILLING RIGS, OUMALIK CORE TEST 1 AND OUMALIK TEST WELL 1



A. GENERAL VIEW OF REFRIGERATION SYSTEM

Surge tank with fan and D-8 Caterpillar radiator right center. Six-inch pipe headers and 1-inch distribution hoses lead to pilings under substructure on left. The coolant is pumped from return header through radiator, cooled by fan, into storage tank from which it is pumped into outflow header and distributed throughout rig foundation members.

B. CLOSE UP OF REFRIGERATION SYSTEM

Two 6-inch headers (pipes on left are extras) with 1-inch distribution hoses leading to pilings to the right. Air-cooled diesel oil at subfreezing temperatures is circulated by means of these headers through steel-casing piling and 4-inch pipe wells in the foundation containing subgrade. The cooling process maintains the subgrade in its frozen stable condition.

REFRIGERATION SYSTEM, OUMALIK TEST WELL 1

physical shothole drilling equipment after the seismic program for the 1947 season was essentially completed.

Forty feet of Gubik formation (Pleistocene) consisting of pale-yellowish-brown clay and light-olive-gray sand is present at the top of this test. The rest of the hole is in the Grandstand formation (Lower and Upper Cretaceous) of the Nanushuk group. The beds from 40 to 70 feet are nonfossiliferous and consist of medium-light-gray clay shale and some medium-dark-gray carbonaceous shale, a trace of light-gray siltstone, and 20 to 50 percent black coal with vitreous luster and conchoidal fracture. The coaly beds probably represent a few intertonguing beds of the nonmarine Chandler formation.

The marine *Verneuilinoides borealis* microfauna appears in this core test at 70 feet. From 70 feet to the total depth at 190 feet the Grandstand is made up primarily of medium-light-gray clay shale with some medium-dark-gray clay shale. Some light-gray sandy siltstone and a small amount of medium-bluish-gray hard argillaceous limestone are also present.

The hole was abandoned at 190 feet because of a stuck drill pipe.

The cuttings from Oumalik core test 2 are poor and very contaminated. No cores were taken because no core barrel was available. All depths are measured from ground level.

Lithologic description

[No core; descriptions from cuttings only]

Depth (feet)	Description
0–10	Clay, pale-yellowish-brown. Sand 30 percent, light-olive-gray; grains, medium to coarse, subrounded to rounded, made up largely of clear and white quartz, also many grains of clear yellow quartz, common dark-gray or black chert, and rare chert grains of other colors. Ostracodes, mollusk fragments, and tundra plant fragments present.
10–30	Clay, pale-yellowish-brown, slightly silty. Sand 15 percent, as above. Ostracodes present.
30–40	Gravel, pebbles, and granules of moderate yellowish-brown, dark-yellowish-brown, olive-gray, green, and black chert. Also rare sandstone, quartzite, and yellow quartz pebbles. Fragments of dark-yellowish-orange to light-brown clay ironstone. Chert and rock pebbles are well rounded, but clay ironstone is angular. Sand 15 percent, as described above.
40–50	Coal 50 percent, black, with vitreous luster, conchoidal fracture. Clay shale 10 percent, medium-light-gray, and clay ironstone, light-olive-gray. Sand, 40 percent, is contamination from above.
50–60	Clay shale, medium-light-gray; some medium-dark-gray carbonaceous clay shale, trace of light-gray siltstone. Coal, 20 percent, as above.

Lithologic description—Continued

Depth (feet)	Description
60–70	Clay shale, medium-light-gray, 60 percent. Light-gray siltstone 25 percent, contains small amount of very fine sand and carbonaceous particles; moderately calcareous. Coal 10 percent, vitreous, black, with blocky fracture. Clay ironstone 5 percent, light-olive-gray to olive-gray.
70–100	Clay shale, medium-dark-gray, and light-gray siltstone; trace of coal and ironstone.
100–110	Siltstone, light-gray, slightly calcareous. Medium-light-gray clay shale, 30 percent.
110–120	Limestone, medium-bluish-gray, hard, very argillaceous, with small white veinlets.
120–140	Clay shale, medium-light-gray.
140–150	Clay shale, medium-light-gray, trace of siltstone.
150–160	Clay shale, medium-light-gray, and light-gray sandy siltstone.
160–170	Clay shale, medium-light to medium-gray; 5 percent light-gray siltstone and 5 percent shiny black coal, with conchoidal fracture; trace of very fine sandstone.
170–190	Clay shale, medium-light-gray; coal 30 percent; also traces of very fine-grained sandstone, siltstone, and clay ironstone.

OUMALIK CORE (FOUNDATION) TESTS 1–10

Location: Near Oumalik test well 1. (See fig. 6.)
Elevation: Not known, but probably between 170–180 feet above sea level.
Spudded: October 1948.
Completed: October 1948.

Ten shallow core (foundation) tests and two deeper holes were drilled all within 900 feet of the site of Oumalik test well 1; Nos. 1 and 2 should not be confused with Oumalik core tests 1 and 2, described on pages 11 and 12. None of the samples from these shallow foundation tests were shipped to Fairbanks. The descriptions for 1–8 are from the driller's logs, and the descriptions for 9 and 10 were made at the Barrow soil laboratory.

Soil tests were made in Barrow from February to June 1949. The project was set up primarily for gaining information concerning properties of the soils at Oumalik, in relation to foundation and refrigeration problems. Studied also were the effects of temperature changes on the physical properties of frozen soil and the strength properties of frozen soil. This information was needed for designing rig foundations for future wells to be drilled in the Reserve. Tests and procedures were used which would yield the required engineering data with a minimum of time and expense. Tests and equipment were improvised for adfreeze, bearing, shear, and heat conductivity. Standard testing procedures (American Society for Testing Materials) were used to determine liquid limit, plastic limit, mechanical analysis, moisture content, density, and specific gravity.

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Some of the samples from the Oumalik core (foundation) tests 1–10 were used in the studies.

An examination of the driller's logs suggests that Pleistocene and (or) Recent cover is as much as 40 feet thick in the area, made up of clay, silt, sand, and gravel, and contains numerous ice lenses. Only a very few feet of known Cretaceous strata were penetrated in these shallow holes. Depths are probably measured from ground level.

Lithologic descriptions

Core	Depth (feet)	Description
Oumalik core (foundation) test 1		
1	0–10	Recovered 9 ft: Tundra, clay, and silt with ice lenses.
2	10–20	Recovered 7 ft: Silt with ice lenses and streaks of ice at 16 and 20 ft.
3	20–30	Recovered 9 ft: Silt.
4	30–40	Recovered (unknown): Silt with ice lenses.
5	40–47	Recovered 10 ft: Silt, sand, and gravel (light), with streak of ice at 44 ft.
6	47–50	Recovered (unknown): Sandy shale.
Oumalik core (foundation) test 2		
1	0–7	Recovered 7 ft: Tundra, clay, and silt with streak of ice at 2 ft.
2	7–10	Recovered 3 ft: Ice.
3	10–20	Recovered 10 ft: Ice and silt with streak of clay.
4	20–30	Recovered 10 ft: Ice with streaks of silt.
5	30–40	Recovered 10 ft: Ice with streaks of silt.
6	40–50	Recovered 8 ft 6 in.: Silt and sand with ice lenses.
Oumalik core (foundation) test 3		
1	0–10	Recovered 10 ft: Tundra, clay, and silt with ice lenses (narrow).
2	10–20	Recovered 10 ft: Ice, silt, and clay to 12 ft, ice to 20 ft.
3	20–30	Recovered 5 ft: Ice.
4	30–40	Recovered 10 ft: Silt and sand with ice lenses (narrow).
5	40–50	Recovered 10 ft: Silt and sand with ice lenses and streaks of gravel.

Lithologic description—Continued

Core	Depth (feet)	Description
Oumalik core (foundation) test 4		
1	0–7	Recovered (unknown): Tundra, clay, silt.
2–5	7–36	Recovered 29 ft: Ice.
6	36–40	Recovered 4 ft: Sand and ice.
7	40–47	Recovered 7 ft: Sand with ice lenses.
8	47–50	Recovered 3 ft: Sand, shale, and gravel.
Oumalik core (foundation) test 5		
1	0–10	Recovered 10 ft: Tundra, clay, and ice.
2, 3	10–30	Recovered 20 ft: Ice.
4	30–40	Recovered 10 ft: Silt and sand with ice lenses (narrow).
5	40–49	Recovered 9 ft: Silt and sand, and sandy shale.
Oumalik core (foundation) test 6		
1	0–10	Recovered 10 ft: Tundra, clay, and ice.
2	10–20	Recovered 7 ft: Silt and ice.
3	20–30	Recovered 10 ft: Silt, sandy clay, and ice with a streak of gravel.
4	30–40	Recovered 10 ft: Ice, sand, sandy clay, gravel, and shale.
5	40–48	Recovered 8 ft: Ice and shale with streaks of yellow clay and gravel.
Oumalik core (foundation) test 7		
1	0–10	Recovered 10 ft: Tundra, clay, ice, and silt.
2	10–20	Recovered 10 ft: Silt, ice, sandy clay, and gravel.
3	20–30	Recovered 10 ft: Sand, clay, and ice.
4	30–37	Recovered (?): Sandy clay.
5	37–47	No report.
Oumalik core (foundation) test 8		
1	0–10	Tundra, clay to 2 ft, ice to 10 ft.
2	10–20	Ice to 15 ft, silt and ice to 20 ft.
3	20–30	Silt and ice.
4	30–40	Sand, sandy blue clay, and gravel to 35 ft, sandy clay and ice to 40 ft.
5	40–50	Sandy shale and shale with ice.

Lithologic description—Continued

Oumalik core (foundation) test 9 [1]

Depth (feet)	Description
0–0. 8	Peat, many ice lenses parallel to surface.
0. 8–2. 5	Ice, with some silty clay; strata generally parallel to surface; air pockets in ice.
2. 5–11. 0	Ice, nearly pure, granular, contains air pockets up to one-fifth of an inch. Contains some very fine organic material.
11. 0–12. 0	Ice with some clay; ice lenses oriented nearly vertical.
12. 0–15. 0	Clay, blue-gray; ice lenses up to one-fiftieth of an inch, appears compact; strata of brown peat at bottom.
15. 0–16. 0	Ice and peat, peat well decomposed.
16. 0–16. 5	Clay, blue-gray, no organic material, very few ice lenses.
16. 5–17. 2	Silty clay strata with brown peat; many ice lenses up to one-fiftieth of an inch parallel to surface.
17. 2–18. 0	Silty clay; many ice lenses and dikes.
18. 0–19. 5	Clay and sand, mottled gray and yellow, interstitial ice only, appears compact; strata with bands of clay as much as two-fifths of an inch thick.
19. 5–20. 3	Ice, pure, with many air bubbles and some organic material at bottom.
20. 3–21. 3	Clay, mottled brown-gray, contains some organic material, very few ice lenses, vertical and horizontal ice lenses.
21. 3–22. 1	Clay, mottled brown-gray; angular pebbles; few ice lenses to one-fifth of an inch, ice dikes to one-tenth of an inch.
22. 1–22. 8	Clay, mottled brown-gray, compact, some organic material, long vertical ice dikes, some lenses to one twenty-fifth of an inch.
22. 8–23. 7	Clay, brownish-gray, compact with angular chert pebbles; few ice dikes up to one-third of an inch.
23. 7–24. 3	Clay, compact, ice lenses up to one-tenth of an inch.
24. 3–25. 0	Clay, gray, no ice lenses, interstitial ice is granular.
25. 0–27. 2	Clay, grayish-black, with some chert pebbles; no ice lenses.
27. 2–28. 0	Clay, grayish-black, with chert pebbles; ice lenses one twenty-fifth of an inch thick spaced about one-half of an inch apart.
28. 0–29. 3	Clayey silt, grayish-black, fine-grained; chert pebbles; few small ice lenses.
29. 3–30. 0	Same as above except no pebbles.
30. 0–31. 8	Clayey silt, light-gray; few thin ice lenses.
31. 8–34. 4	Silt, compact, dark-gray background with lighter gray spots; few very small ice lenses.
34. 4–37. 0	Silt, light-gray, compact; no ice structures.
37. 0–38. 8	Silt, mottled grayish-green, compact.
38. 8–40. 0	Silt, mottled grayish-green, turning dark gray at bottom.
40. 0–41. 7	Silt, dark-gray, turning blackish gray at bottom.
41. 7–42. 5	Coal and thin layers of silt.
42. 5–48. 7	Silt, dark-gray, coal pebbles throughout.
48. 7–50. 0	Silt, dark-gray; many vertical ice layers and lenses.

[1] Most core numbers, depths, and recoveries unknown.

Lithologic description—Continued

Oumalik core (foundation) test 10 [1]

Depth (feet)	Description
0. 0–1. 5	Peat, brown, fibrous, gradual change to well-decomposed peat with ice pockets and lenses at bottom; small amounts of clay.
1. 5–4. 7	Clay, light-brownish-gray; many ice lenses and dikes; fine fibrous material, small amount of silt; flows when thawed.
4. 7–5. 5	Peat, fine fibrous, with light-gray clay; many lenses and dikes of ice, with small air pockets.
5. 5–7. 0	Clay, light-brownish-gray; numerous small ice lenses; fibrous peat.
7. 0–9. 6	Clay, light-brownish-gray, silty, lenses of ice, air spaces; flows when thawed.
9. 6–10. 0	Ice, brownish-gray clay, and fibrous material.
10. 0–12. 6	Clay, gray, vertical layers of peat, few very small ice dikes.
12. 6–12. 7	Peat, brown, fibrous.
12. 7–13. 2	Clay, gray, brown fibrous peat not confined to layers.
13. 2–14. 0	Peat and clay.
14. 0–15. 0	Clay, light-gray, little peat.
15. 0–15. 6	Clay, light-gray, few very small ice lenses.
15. 6–15. 9	Sand, fine, light-grayish-brown, pebbles, minute ice crystals and veins.
15. 9–17. 2	Clay, gray, few small ice lenses, trace of peat.
17. 2–18. 3	Silt, light-brownish-gray, streaks of gray clay, minute ice veins.
18. 3–18. 9	Sand, fine, brownish-gray, no clay, ice veins.
18. 9–19. 1	Clay, sandy.
19. 1–20. 0	Sand, fine, no clay.
20. 0–20. 8	Sandstone, fine-grained, buff, chert pebbles as much as one-fourth of an inch in diameter.
20. 8–21. 9	Silt, gray, chert pebbles.
21. 9–23. 0	Silt, clayey brownish-gray, compact, numerous small pebbles, few up to one-half of an inch, very small ice crystals throughout, few large ice lenses and dikes.
23. 0–24. 8	Clay, gray, splotches of brown sand, few large ice lenses and dikes.
24. 8–25. 0	Peat and clay.
25. 0–27. 2	Clay, gray, few lenses and dikes of ice.
27. 2–28. 9	Clay, silty, light-brownish-gray, few ice dikes and lenses.
28. 9–30. 0	Clayey silt, streaks of fine sand, few ice dikes and lenses.
30. 0–40. 0	Recovered 3 ft: 0.0–1.7 ft, silt, clayey, dark-gray, mottled light gray, few brown silt pockets, few small ice lenses and dikes. 1.7–2.3 ft, similar to above. 2.3–3.0 ft, silt, clayey, dark-gray, mottled light gray, very few small ice dikes and lenses, brown chert pebbles on outside of core.
40. 0–50. 0	Recovered 2.4 ft: 0.0–1.5 ft, silt, clayey, dark-gray, mottled light gray, small brown chert pebbles on outside of core, 1 pebble 1¼ x ½ x ¼ in. at 0.2 ft. 1.5–2.4 ft, similar to above.

OUMALIK CORE TESTS 11 AND 12

Both of these tests were primarily foundation tests drilled to obtain shallow subsurface information needed for planning the drilling of Oumalik test well 1. Oumalik core test 11 is approximately 25 feet south of, and 12 is approximately 75 feet south of, Oumalik test well 1. (See fig. 6.)

OUMALIK CORE TEST 11

Location: Lat 69°50′18″ N., long 155°59′24″ W.
Elevation: Ground, 171.5 feet; kelly bushing not known.
Spudded: Mar. 9, 1949.
Completed: Mar. 22, 1949, dry and abandoned.
Total depth: 303 feet.

Oumalik core test 11 was cored completely, with about 61 percent core recovery. Only 14 feet of Pleistocene and (or) Recent sediments is present. This consists of soft and friable light-olive-gray clay and silt. Below this is the Grandstand formation (Lower Cretaceous and Upper Cretaceous) of the Nanushuk group, made up of light- to dark-gray clay shale, and light-gray siltstone. A few beds of very fine-grained light-gray sandstone are present. A very small amount of coal, clay ironstone, and a few leaf imprints also were found, but the section is predominantly marine as indicated by the microfauna.

All depths are recorded as having been measured from the cellar floor of nearby Oumalik test well 1 (probably within a few feet of ground level).

Lithologic description

Core	Depth (feet)	Description
1	5¼–14⅙	Recovered 8 ft 11 in.: Microfossils very rare. 6 ft, clay, light-olive-gray, silty, friable, very uniform. 1 ft, silt, light-olive-gray, friable, several subangular pebbles of moderate brown clay ironstone. 1 ft 11 in., clay and silt, light-olive-gray, unconsolidated.
2	14⅙–24⅙	Recovered 2 ft 9 in.: Microfossils very abundant. Clay shale, light- to dark-gray with brownish streaks; carbonaceous; badly broken and infiltrated with drilling mud; color may be a result of infiltration of mud.
3	24⅙–33	Recovered 5 ft 8 in.: Microfossils common. 4 ft, clay shale, light- to dark-gray, friable; infiltrated with drilling mud. Concretions of dense clay ironstone, yellow-brown or gray with yellowish cast, slightly calcareous, as much as ½ x 1½ in. in diameter, with conchoidal fracture. 1 ft 8 in., clay shale, medium- to dark-gray, friable, with a large amount of black carbonaceous shale; scattered small chips of coal; some infiltrated drilling mud.
4	33–39¾	Recovered 10 ft: Microfossils absent. Clay shale with drilling mud; slightly calcareous, dark-gray with large amount of black carbonaceous material and ground-up coal. Piece of coal ⅓ x ¾ x 2 in. suggests coal seam. Coal black, vitreous, laminated, with blocky fracture.
5	39¾–49¾	Recovered 5 ft: Microfossils very rare. 3 ft 9 in., clay shale, medium-gray, friable, with scattered fragments of coal, also scattered dark-gray carbonaceous flakes; core badly infiltrated with drilling mud. 3 in., clay shale or drilling mud, very dark gray; large amount of black carbonaceous shale; chips of coal. Streaks of brown silt. 6 in., clay shale, medium- to dark-gray, friable. Scattered chips of coal. Core badly infiltrated with drilling mud. 6 in., clay shale, medium-gray, friable, with streaks of light-gray siltstone and dark-gray carbonaceous material. Shale slightly calcareous in spots which might be the result of infiltration of drilling mud.
6	49¾–57	Recovered 3 ft 6 in.: Microfossils absent. 7 in., clay or drilling mud, light-gray, moderately calcareous, friable, containing scattered small chips of dark-gray carbonaceous clay shale. 1 in., clay ironstone concretion, 1 x 2 x 2 in., moderate yellowish-brown surface, grading to yellow-gray core; dense, heavy, noncalcareous, has conchoidal fracture. 1 ft, clay shale, light- to medium-gray, noncalcareous, friable, badly infiltrated with drilling mud. 9 in., clay shale, medium- to dark-gray, friable, noncalcareous, with scattered black carbonaceous flakes and black shiny carbonized plant remains. 1 ft 1 in., clay shale, light- to medium-gray, noncalcareous, friable, badly infiltrated with drilling mud. Claystone concretion, light-gray, dense, heavy, noncalcareous, with conchoidal fracture.
7	57–67	Recovered 10 ft: Microfossils absent. 2 in., siltstone, light-gray, noncalcareous, moderately indurated, and unstratified, with scattered flakes of dark-gray to black carbonaceous material. 4 in., siltstone, light-gray, good cleavage interlaminated with dark-gray clay shale; bedding planes marked with black carbonaceous material and minute micaceous flakes.

Lithologic description—Continued

Core	Depth (feet)	Description
		3 in., clay shale, light- to medium-gray, noncalcareous, friable, badly infiltrated with drilling mud; scattered flakes of carbonaceous material.
		1 ft, siltstone, medium-gray, scattered dark-gray to black carbonaceous material that probably is plant remains without orientation of long direction of flakes. Moderately indurated, noncalcareous.
		5 ft, 1 in., siltstone, light-gray with some medium-gray laminae, commonly showing small-scale crossbedding. Bedding planes marked in places by micaceous and black carbonaceous material including probable carbonized plant fragments. Moderately indurated, noncalcareous. Fair vertical jointing at depths of 59, 61, and 62 ft.
		3 ft, 1 in., clay shale, medium-light-gray, with laminae showing small-scale crossbedding, dipping as high as 18°. Sample is noncalcareous, moderately indurated, with scattered carbonaceous material along bedding planes. Color of crossbedded laminae grades from dominantly light at top of section to dominantly medium gray at base. Dip 2°.
8	67–77	Recovered 2 ft 9 in.: Microfossils abundant. Mainly drilling mud, with scattered clay shale fragments throughout, dark-gray, fissile, noncalcareous.
9	77–87	Recovered 7 ft 9 in.: Microfossils common.
		2 ft 9 in., clay shale, medium- to dark-gray, noncalcareous, friable, badly infiltrated with drilling mud; dense, heavy clay ironstone concretion, ¼ x 1 x 1 in., dark-yellowish-brown on surface, light-yellowish-gray interior.
		9 in., clay shale, dark-gray, noncalcareous, fissile, badly infiltrated with drilling mud.
		4 ft 3 in., this part of the core badly contaminated with drilling mud with scattered fragments of medium-gray, friable, noncalcareous clay shale.
10	87–97	Recovered 5 ft: Microfossils very abundant.
		2 ft 9 in., clay shale, dark-gray, moderately indurated with lenses of medium-gray siltstone in the bottom 3 in. Rare specks of black carbonaceous material.
		2 ft 3 in., siltstone, medium-gray, interbedded with very thin layers of highly carbonaceous black clay shale and plant remains. Some of the carbonaceous laminae have a vitreous luster. Some infiltrated drilling mud.
11	97–107	Recovered 10 ft: Microfossils rare.
		1 ft 9 in., clay shale, medium- to dark-gray, friable, with black carbonaceous fragments—probably plant remains. Some infiltrated drilling mud.
		1 ft 9 in., claystone, medium- to dark-gray, moderately well indurated, with black carbonaceous fragments in random orientation. Grades in the last 5 in. into a very fine-grained siltstone. Noncalcareous.
		1 ft 6 in., siltstone, medium-gray, noncalcareous, with vertical jointing and carbonaceous fragments as immediately above. No bedding apparent.
		5 ft, siltstone, medium-gray, grains slightly coarser than part of core immediately above. Noncalcareous, well-indurated. Thin bedding layers apparent as a result of slight changes in color and minute mica flakes. Crossbedding is visible with dips as high as 20°; vertical jointing. About 6 in. from the bottom are a few lenses of dark-gray well-indurated siltstone. Beds approximately flat lying.
12	107–112	Recovered 3 ft: Microfossils absent.
		Siltstone, siliceous, medium-gray, very well indurated, tight, with little or no bedding apparent.
13	112–117	Recovered 4 ft: Microfossils absent.
		2 ft 8 in., siltstone, medium-gray, siliceous very well indurated, grades in last foot of this section of the core into an extremely hard and tight, very fine-grained medium-gray sandstone. Beds flat lying.
		1 ft 4 in., clay shale, medium-gray, friable, nearly fissile, noncalcareous; some infiltrated drilling mud.
14	117–127	Recovered 7 ft 3 in: Microfossils abundant. Clay shale, medium- to dark-gray, friable, noncalcareous. Some infiltrated drilling mud.
15	127–137	Recovered 7 ft: Microfossils very abundant.
		5 ft 3 in., clay shale, dark- to medium-gray, friable, noncalcareous; part of section infiltrated with drilling mud; rare thin (one-sixteenth of an inch) lenses of light-gray siltstone in upper 8 in. Claystone concretion ½ x 1 x 1 in., light-yellowish-gray, dense, at bottom of section. Beds approximately flat lying.
		1 ft 6 in., clay shale, medium-gray, badly infiltrated with drilling mud, friable.
		3 in., claystone, light-gray with yellowish cast, well-indurated, noncalcareous; conchoidal fracture.
16	137–147	Recovered 9 ft: Microfossils common.
		11 in., clay shale, slightly silty, dark- to medium-gray, moderately indurated, noncalcareous.

Lithologic description—Continued

Core	Depth (feet)	Description
		5 in., clay shale, noncalcareous, friable, dark-gray, intercalated with discontinuous vitreous coaly laminae.
		6 in., clay shale, dark-gray, moderately indurated, noncalcareous, with scattered dark-gray flakes of carbonaceous material.
		6 in., drilling mud, containing fragments of black friable clay shale and chips of black vitreous coal.
		10 in., clay shale, medium-gray, slightly silty, friable, noncalcareous, with dark-gray to black carbonaceous flakes, probably plant remains, scattered throughout; infiltrated with drilling mud.
		6 in., clay shale, medium-gray, noncalcareous, moderately indurated, with dark-gray to black carbonized plant remains.
		1 ft 3 in., clay shale, light-gray, noncalcareous, moderately indurated, with dark-gray to black carbonized plant fragments, including rare leaf imprints.
		7 in., clay shale, medium-gray, friable; badly infiltrated with drilling mud; contains scattered flakes of dark-gray carbonaceous material.
		1 ft 10 in., claystone, medium-gray, moderately indurated, noncalcareous, with scattered dark-gray carbonized plant fragments.
		1 ft 1 in., siltstone, light-gray, moderately indurated, with scattered dark-gray flakes of carbonaceous material; slightly to moderately calcareous, possibly owing to infiltrated drilling mud.
		2 in., clay shale, black, moderately indurated, noncalcareous, with much black, shiny carbonized plant remains.
		5 in., black carbonaceous shale, as above; badly infiltrated with drilling mud.
17	147–157	Recovered 7 ft: Microfossils absent.
		5 in., coal fragments, as large as ¾ x ¾ x 1 in., black; subvitreous, conchoidal fracturing; no visible stratification.
		1 ft 10 in., clay shale, medium-gray, slightly silty, moderately indurated, noncalcareous; dark-gray to black carbonaceous material marks bedding planes. Carbonized plant fragments scattered throughout; at 149 ft, a friable noncalcareous 1-in. layer of interlaminated dark-gray shale and black vitreous coaly material.
		9 in., siltstone, medium-gray, well-indurated, noncalcareous; black to dark-gray carbonaceous material and carbonized plant fragments scattered throughout.

Lithologic description—Continued

Core	Depth (feet)	Description
		4 ft., claystone, light-gray, well-indurated, noncalcareous, slightly silty in some sections. Dark-gray carbonaceous plant remains scattered throughout.
18	157–167	Recovered 10 ft: Microfossils absent.
		1 ft 2 in., clay shale, medium-gray, moderately indurated, slightly calcareous.
		2 in., claystone, light-gray with yellowish cast, dense, heavy, with conchoidal fracture, probably is a concretion.
		2 ft 2 in., clay shale, medium-gray, noncalcareous, friable to moderately indurated; partly infiltrated with drilling mud; dark-gray carbonaceous plant remains scattered sparsely throughout.
		3 ft 4 in., sandstone, very fine-grained, light-gray, well-indurated; streaks of dark-gray carbonaceous clay shale with one-half of an inch intercalated laminae of siltstone; very fine sandstone and black carbonaceous material at base.
		8 in., clay shale, medium-gray, moderately indurated, slightly calcareous.
		9 in., sandstone, very fine-grained, light-gray, noncalcareous, moderately indurated, silty and clayey matrix. Numerous dark-gray carbonaceous and micaceous laminae and some partings of clay shale or siltstone mark irregular discontinuous bedding planes. Dip 1°.
		1 ft 9 in., siltstone, otherwise same as above.
19	167–177	Recovered 7 ft 9 in.: Microfossils common.
		1 ft 9 in., siltstone, light- to medium-gray; interbedded with thin layers (up to ⅛ in. in thickness but generally much thinner) of black carbonaceous material; also contains numerous scattered plant fragments. Blocky fracture noted on thicker carbonaceous layers, also vitreous luster—coal (?). The last 3 in. contains lenses of medium-gray clay shale and claystone. Clay ironstone at at the bottom of this core is medium gray with a yellowish cast, has conchoidal fracture. Dip as indicated by bedding in this core is approximately 5° to walls of core. Some crossbedding present, but even more prominent is the curving of the darker laminae over and under lenses of clay shale, distortion possibly the result of slumping or minor reworking of the sediments.
		6 ft, clay shale, medium- to dark-gray, noncalcareous, moderately indurated; a few laminae or lenses of siltstone, also black carbonaceous plant remains scattered throughout. Bedding and dis-

Lithologic description—Continued

Core	Depth (feet)	Description
		tortion of laminae essentially as described above. The clay shale less well indurated and somewhat infiltrated with drilling mud in lower foot of section.
20	177–187	Recovered 8 ft 2 in: Microfossils absent. 1 ft, coal, carbonaceous material, and medium-gray friable clay shale. Core badly broken up and infiltrated with drilling mud. Coal chips as much as three-fourths of an inch in thickness present, bedded, black, with vitreous luster and blocky to conchoidal fracture. 8 in., clay shale, medium-gray, moderately indurated. 1 ft, siltstone, medium-gray, grading to very fine-grained light-gray sandstone in middle of this part of core and then back into siltstone. Siltstone, moderately indurated; shows faint bedding approximately at right angles to walls of core. Sandstone, very well indurated, tight, siliceous, massive or with only very faint trace of bedding. Black carbonaceous remains with random orientation throughout this part of core. 1 ft 5 in., silty clay shale, medium-gray, moderately indurated, noncalcareous; black carbonaceous fragments scattered throughout. 3 ft 10 in., siltstone, light-gray, well-indurated, with some thin lenses of sandstone and clay shale; dip of beds not well defined. Swirly bedding; cross-beds with dips as high as 12°; only a few fragments of carbonaceous material. Slightly calcareous in the finer grained layers. 3 in., as immediately above but with larger proportion of clay shale.
21	187–197	Recovered 4 ft 9 in.: Microfossils very rare. 7 in., interbedded clay shale and siltstone medium-gray, moderately indurated, with black carbonaceous fragments; slightly calcareous. 3 ft 2 in., clay shale, medium- to dark-gray, moderately indurated; has some tendency to fracture nearly vertically, effervesces mildly with HCl. Dip 1°. 1 ft, drilling mud with scattered chips of medium-gray clay shale and black carbonaceous material.
22	197–207	Recovered 2 ft: Microfossils absent. 1 ft, claystone, silty, medium-gray, moderately indurated, with scattered dark-gray carbonized plant remains. 1 ft, siltstone, light-gray, moderately indurated, slightly calcareous (possibly owing to infiltrated drilling mud); two claystone concretions, dense, hard, light- to dark-gray, slightly calcareous, 2 x 2 x 1 in. in size.
23	207–217	Recovered 2 ft: Microfossils very rare. 3 in., siltstone, medium-gray, moderately indurated, slightly calcareous; dark-gray carbonaceous material on bedding planes. 1 ft 9 in., clay shale, medium-gray, moderately indurated, slightly calcareous.
24	217–227	Recovered 2 ft: Microfossils common. 9 in., drilling mud, containing chips of medium-gray, friable clay shale. 3 in., coal chips, brownish-black, dull to subvitreous, with blocky fracture. 1 ft, sandstone, fine-grained, light-gray, slightly argillaceous, moderately indurated, massive.
25	227–237	Recovered 2 ft: Microfossils absent. 1 ft 9 in., same as above. 3 in., siliceous sandstone, fine-grained, very well indurated, medium-gray, very slightly calcareous, massive; has conchoidal fracture.
26	237–247	Recovered 9 ft: Microfossils absent. Sandstone, light-gray, very fine-grained, well-indurated, slightly argillaceous, noncalcareous; scattered dark-brown to black carbonaceous laminae mark inclined discontinuous planes dipping as much as 18°, possibly small-scale cross-bedding. Between 238 and 240 ft are pebbles of moderately indurated dark-yellowish-brown slightly calcareous clay ironstone, with cross sections from ½ x ¼ to 1 x 2 in.; pebbles have subrounded to angular outlines, long axes lie at low (maximum 20°) angles. Carbonaceous laminae bend over or under pebbles, or are slightly displaced by them. Borders of pebbles show sandstone-filled network of cracks. Four pebbles visible in one 5-in. core. Effective porosity at 238 ft normal to bedding is 18.8 percent and 19.3 percent parallel to bedding. Air permeability at this depth is 26.2 millidarcys and 13.8 millidarcys respectively.
27	247–257	Recovered 10 ft: Microfossils absent. Sandstone, light-gray, very fine-grained, siliceous, massive, very well indurated. Beds flat lying. The following porosity and permeability determinations were made.

Depth (feet)	Air permeability (millidarcys)	Effective porosity (percent)
250 normal	<9	14.7
250 parallel	<8	16.9
256 normal	<8	
256 parallel	<11	15.5

Lithologic description—Continued

Core	Depth (feet)	Description
28	257–266	Recovered 2 ft: Microfossils very rare. 5 in., sandstone, light-gray, completely ground up and irregularly recemented with drilling mud (?). 1 ft 7 in., clay shale (or drilling mud?), medium- to dark-gray, poorly indurated, noncalcareous. One fragment of interbedded coal and siltstone three-fourths of an inch thick; one pyrite concretion one-third of an inch in diameter.
29	266–276	Recovered 2 ft 9 in.: Microfossils absent. 5 in., siltstone, medium-gray, moderately indurated, noncalcareous. 5 in., claystone. slightly silty, light-gray, well-indurated, noncalcareous. 11 in., siltstone, light-gray, well-indurated, very slightly calcareous. 1 ft, siltstone, medium-gray, siliceous, well-indurated, noncalcareous.
30	276–280	Recovered 4 ft: Microfossils absent. Clay shale, medium-gray, moderately indurated to friable, noncalcareous; mostly infiltrated with drilling mud. Beds flat lying.
31	280–288	Recovered 1 ft 9 in.: Microfossils absent. 1 ft 1 in., clay shale, slightly silty, medium-gray, moderately indurated, noncalcareous. Dense clay ironstone concretions, light-gray with yellowish cast, have conchoidal fracture and are slightly calcareous, ½ x 1 x 1 in. in size. 8 in., sandy siltstone, light-gray, well-indurated, noncalcareous, with scattered dark-gray carbonaceous partings.
32	288–296	Recovered 4 ft 6 in.: Microfossils very rare. 1 ft, clay shale, friable, medium-gray, badly infiltrated with drilling mud. 9 in., clay shale, medium-gray, moderately indurated, slightly calcareous; contains black carbonaceous fragments. 2 ft 9 in., silty claystone, medium-gray, moderately indurated, slightly calcareous; contains black plant remains. Beds approximately flat lying.
33	296–303	Recovered 7 ft: Microfossils common. 8 in., clay shale, silty, medium-gray, slightly calcareous, moderately indurated; scattered flakes of dark-gray carbonaceous plant remains. 1 ft 7 in., siltstone, light-gray, well-indurated, slightly calcareous, with dark-gray carbonaceous material marking bedding planes; scattered intercalations of medium-gray clay shale. 4 ft 9 in., clay shale, medium-gray, well-indurated, slightly calcareous, slightly silty, with scattered black carbonized flakes of plant remains, including a leaf imprint. Two small pelecypods at approximately 302 ft. Dip 1°.

OUMALIK CORE TEST 12

Location: Lat 69°50′18″ N., long 155°59′24″ W.
Elevation: Ground, approximately 172 feet; kelly bushing not known.
Spudded: Probably drilled in April 1949.
Completed: Probably drilled in April 1949; dry and abandoned.
Total depth: 300 feet.

Oumalik core test 12 (see fig. 5) is in essentially the same structural position as core test 11. The approximately 17-foot thickness of Pleistocene and (or) Recent is clay in which ice is interbedded. The Grandstand formation is the same as in core test 11.

No ditch samples were taken from this test, and the section is not completely represented by the recovered cores. Consequently, there are a few parts which could not be described. The datum from which depths were measured is not known but was probably close to ground level.

Lithologic description

Core	Depth (feet)	Description
1	0–10	Recovered 10 ft: Microfossils absent. Clay, medium-dark-olive-gray, soft; much vegetal material. Apparently about 7 ft of the recovery was ice.
2	10–17	No core received in Fairbanks.
3	17–22	Recovered 4 ft: Microfossils abundant. 2 ft, clay, light-brownish-gray, grading to medium-gray clay with grayish-yellow streaks. 1 ft, clay, medium-dark-gray, shaly, with very small shell fragments on some partings; carbonaceous laminae at base. 1 ft, clay, medium-light-gray.
4	22–27	Recovered 4 ft: Microfossils abundant. Clay, medium-light-gray, with streaks of grayish-yellow clay; rare silty or carbonaceous laminae in top 1 if.
5	27–32	Recovered 1 ft 4 in.: Microfossils absent. Clay, medium-light-gray, slightly silty.
6–9	32–42½	No cores received in Fairbanks.
10	42½–47½	Recovered 5 ft: Microfossils absent. 4 ft 8 in., clay shale, medium-gray, with small yellowish-gray streaks throughout; scattered carbonized macerated plant remains. 4 in., claystone, medium-light-gray, very slightly silty, with scattered carbonized plant remains.
11	47½–50	Recovered 1 ft 4 in.: Microfossils absent. Clay shale, medium-gray, with scattered macerated carbonized plant remains; one clay ironstone nodule 1 x 1 x 3 in.
12	50–54	Recovered 3 ft 2 in.: Microfossils absent. 3 ft, claystone and clay shale, medium-gray, silty, with some carbonaceous partings and fragments of carbonized plant remains.

Lithologic description—Continued

Core	Depth (feet)	Description
		2 in., siltstone, medium-light-gray, argillaceous, hard, very slightly calcareous, with scattered carbonaceous partings. Beds approximately flat lying.
13	54–58	Recovered 3 ft: Microfossils very rare. 1 ft 10 in., siltstone, medium-light-gray, argillaceous, with gentle cross-bedding marked by carbonaceous partings; scattered plant fragments. 1 ft 2 in., clay shale, medium-gray, slightly silty, with rare carbonized macerated plant remains.
14	58–59½	Recovered 8 in.: Microfossils absent. Same as above. Dip 1½°.
15	59½–60½	Recovered 1 ft: Microfossils absent. Siltstone, medium-dark-gray, very argillaceous; calcareous or dolomitic (?); with rare fragments of macerated carbonized plant remains. Dip 1½°.
16	60½–65 (?)	Recovered 4 ft 6 in. (?): Not sampled for microfossils. 11 in., same as above. 8 in., clay shale, medium-gray, slightly silty. 2 ft 4 in., siltstone, medium-light-gray, argillaceous with scattered carbonized macerated plant fragments. 6 in., siltstone, dark-gray, dolomitic as above.
17	65–71	Recovered 6 ft: Microfossils absent. Clay shale, medium-gray, very slightly silty in part, with subconchoidal fracture to fissile cleavage. Dip 1°.
18	71–76	No core received in Fairbanks.
19	76–81	Recovered 5 ft: Microfossils very abundant. Clay shale, medium-gray, fissile.
20	81–84½	Recovered 2 ft 8 in.: Microfossils very abundant. Clay shale, medium- to medium-dark-gray, fissile.
21	84½–92	Recovered 5 ft: Microfossils very abundant. Clay shale, medium-dark-gray, fissile, subconchoidal fracture.
22	92–96½	Recovered 3 ft 3 in.: Microfossils very abundant. 6 in., coal. 6 in., clay shale, dark-gray carbonaceous, blocky, with carbonized plant fragments, grades into underlying rock. 6 in., clay shale, medium-dark-gray, with scattered carbonized plant fragments.

Lithologic description—Continued

Core	Depth (feet)	Description
		1 ft, siltstone, medium-dark-gray, argillaceous with numerous carbonized plant remains. 1 ft 3 in., clay shale, medium-dark-gray. Beds flat lying.
23	96½–106½	Recovered 10 ft: Microfossils abundant. 8 ft, clay shale, medium-gray, with subconchoidal fracture to fissile cleavage. 2 ft, clay shale, medium-dark-gray, and interlaminated medium-light-gray siltstone with carbonaceous streaks and macerated carbonized plant remains. Grades to medium-gray carbonaceous siltstone at base.
24	106½–116	Recovered 8 ft 6 in.: Microfossils very rare. 3 ft 6 in., siltstone, medium-gray, sandy, with carbonaceous-argillaceous partings marking moderate to strong (as much as 20°) cross-bedding. Noncalcareous. 5 ft, sandstone, medium-light-gray, very fine grained at top, grading through medium to fine in the bottom 1 ft; very silty and argillaceous, noncalcareous, with carbonaceous lenticles and partings showing cross-bedding as above. Upper half of bottom foot of core contains subrounded fragments of shale, ranging from ⅛ to 1 in. in diameter; they compose about 60 percent of the rock, the matrix of which is like the fine to medium sand immediately above and below. Beds approximately flat lying.
25–27	116–126	No cores received in Fairbanks.
28	126–135	Recovered 8 ft 6 in.: Microfossils rare. Clay shale, dark-gray to medium-dark-gray, micaceous or slightly silty.
29	135–144	Recovered 8 ft: Microfossils rare. 4 in., coal and black carbonaceous clay shale. 6 ft 5 in., clay shale, medium-dark-gray, with shaly to fissile cleavage. 1 ft 2 in., sandstone, medium-light-gray, very fine- to fine-grained, with carbonaceous partings marking crossbedding dipping as high as 20°. Dip of beds 1½°. 1 in, coal.
30	144–147	Recovered 2 ft 2 in.: Microfossils absent. 1 ft, clay shale, medium-dark-gray, fissile, with very thin beds of coal, grades into underlying rock.

Lithologic description—Continued

Core	Depth (feet)	Description
		1 ft 2 in., siltstone, medium-gray, with slight crossbedding marked by carbonaceous laminae.
31	147–151	Recovered 3 ft 9 in.: Microfossils absent.
		2 ft 8 in., siltstone, medium-gray, very argillaceous, noncalcareous, with carbonized plant fragments some carbonaceous streaks and partings. Dip 2°.
		1 ft 1 in., clay shale, medium-gray, with conchoidal fracture.
32	151–157	Recovered 5 ft 9 in.: Microfossils very rare.
		Clay shale, medium-gray, with conchoidal fracture to fissile cleavage.
33	157–162	Recovered 5 ft: Microfossils very rare.
		1 ft 4 in., sandstone, medium-light-gray, very fine-grained, with carbonaceous streaks.
		1 ft 2 in., clay shale, medium-gray, grades into underlying rock.
		2 ft 6 in., siltstone, medium-light-gray, and very fine-grained sandstone, with carbonaceous partings.
34	162–164	Recovered 2 ft: Microfossils absent.
		Siltstone, medium-light-gray as above. Dip 1°.
35	164–174	Recovered 10 ft: Microfossils common.
		5 ft, clay shale, medium-gray, fissile.
		1 ft 3 in., clay shale, medium-dark-gray, silty; grades into underlying rock.
		3 ft 9 in., clay shale, medium-gray, fissile; as above.
36	174–184	Recovered 4 ft 4 in.: Microfossils absent.
		8 in., coal.
		3 ft 8 in., clay shale, medium-gray; badly mixed with drilling mud.
37	184–189	Recovered 5 ft: Microfossils very abundant.
		1 ft, siltstone and clay shale interbedded, micaceous, medium-light- to medium-dark-gray.
		4 ft, clay shale, medium-gray, fissile; poker chip cleavage in lower part.
38	189–192	Recovered 3 ft: Microfossils very abundant.
		Clay shale, medium-gray; as above. Dip 1°.
39	192–195	Recovered 3 ft: Microfossils very abundant.
		Claystone, medium-gray, with numerous carbonized plant fragments; slightly silty; slightly micaceous toward base.
------	195–196½	No sample.

Lithologic description—Continued

Core	Depth (feet)	Description
40	196½–201½	Recovered 3 ft 4 in.: Microfossils absent.
		Siltstone, medium-gray, very argillaceous, with rare carbonized plant fragments; grades to medium-light-gray siltstone at base.
41	201½–206½	Recovered 5 ft: Microfossils absent.
		Clay shale, medium-gray, slightly silty, micaceous, and siltstone, badly infiltrated with drilling mud. Two ½-in. beds of grayish-yellow claystone at 204 ft.
42	206½–211½	Recovered 5 ft: Microfossils very rare.
		1 ft, siltstone and clay shale, intrelaminated, medium-dark-gray, with carbonaceous partings.
		4 ft, clay, medium-gray, shaly, very uniform. Dip 1°.
43–47	211½–236½	No cores received in Fairbanks.
48	236½–241½	Recovered 5 ft: Microfossils absent.
		Siltstone, medium-light-gray, sandy, noncalcareous; grading to silty very fine-grained sandstone at bottom.
49, 50	241½–252	No cores received in Fairbanks.
51	252–257	Recovered 5 ft: Microfossils common.
		Sandstone, very fine-grained, silty; as above, with scattered yellowish. gray clay ironstone lenses as much as 1 in. in diameter. Dip 1½°.
52	257–262	Recovered 5 ft: Microfossils common.
		4 ft 9 in, clay shale, medium-dark-gray, with ½-in. yellowish-gray clay ironstone bed at 262 ft.
		3 in., small (maximum one-half inch in diameter) fragments of coal mixed with drilling mud.
53, 54	262–267	Recovered 4 ft 9 in.: Microfossils absent.
		4 ft 6 in., (cores labeled ambiguously) clay shale, medium-dark-gray.
		3 in., siltstone, medium-gray (may be top of core 53).
55	267–272	Recovered 5 ft: Microfossils absent.
		3 ft, claystone, medium-gray, silty, grading into 6 in. of medium-light-gray crossbedded siltstone with carbonaceous partings.
		1 ft 6 in., claystone, medium-gray, silty, as above, with ½-in. bed of yellow-gray clay ironstone at 671 ft.
		6 in., siltstone, medium-gray, very argillaceous. Beds approximately flat lying.
56	272–277	Recovered 5 ft: Microfossils very rare.
		Clay shale, medium-gray, excellent cleavage to fissile.
57	277–280	Recovered 3 ft: Microfossils common.
		Same as above. Beds approximately flat lying.

Lithologic description—Continued

Core	Depth (feet)	Description
58	280–287	Recovered 7 ft: Microfossils common. 1 ft 6 in., same as above, with thin (maximum one-eighth of an inch) beds and laminae of yellow-gray clay ironstone and with increasing amount of silt toward bottom. A 1-in. bed of clay ironstone at 281 ft grades into clay shale above and below. 3 ft, siltstone, medium-light-gray, with carbonaceous partings; alternates with interlaminated medium-dark-gray to dark-gray claystone and medium-light-gray siltstone; some laminae are highly distorted, probably by contemporaneous deformation, while laminae above and below are flat lying or have differing gentle dips (maximum 5°). 2 ft 6 in., clay shale, medium-dark-gray, with ½- to 1-in. clay ironstone beds at 285, 285½, and 286 ft. Beds flat lying.
59	287–296	No core received in Fairbanks.
60	296–300	Recovered 3 ft 6 in.: Microfossils common. 2 ft 6 in., clay shale, medium-gray; badly infiltrated with drilling mud. 1 ft, clay shale, light-olive-gray, waxy; badly mixed with drilling mud.

HEAVY-MINERAL STUDIES

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

Ikpikpuk core test 1 was sampled, but the samples were not processed. No samples were taken from Oumalik core tests 2 and 12, nor were any taken from the foundation tests.

Mineral zones.—The heavy minerals were studied by Robert H. Morris, who found that the opaque heavy minerals were nondiagnostic for zonation purposes. He also found the following criteria useful in delimiting zones of the nonopaque heavy minerals: (1) Relative abundance of certain minerals, (2) proportion of garnet grains etched to garnet grains with conchoidal fracture, (3) presence of diagnostic minerals or mineral suites, (4) degree of rounding, (5) grain shape, or form, such as euhedral or anhedral.

Oumalik core test 1.—The three heavy-mineral samples obtained from Oumalik core test 1 from the depth of 140 to 320 feet are representative of the hornblende zone. (See pl. 6.)

Oumalik core test 11.—The two heavy-mineral samples taken from a depth of 220 to 260 feet in Oumalik core test 11 are assigned to the hornblende zone. (See pl. 6.)

CORE ANALYSES

Core analyses were run on some sandstone and shale cores, and determinations of effective porosity, air permeability, carbonate content, specific gravity, and grain size are contained in the following tables. The porosity and permeability of the one sample from Oumalik core test 1 was determined in 1947 by P. D. Krynine. All other analyses were made in the Fairbanks laboratory of the U. S. Geological Survey. The Washburn-Bunting method was used by the Survey to determine porosity, and a Hayward Permeameter was used to determine permeability. No core analyses were made for Ikpikpuk core test 1, and Oumalik core tests 2 and 12. No records on the shallow foundation tests, other than a few thermistor readings, are available.

In Oumalik core test 1, at a depth of 154 feet (core 2), the effective porosity was 11.2 percent, and the air permeability was 4.9 millidarcys. The carbonate content was insignificant.

Sieve analysis of core 2, 154 feet, Oumalik core test 1

Grain size (Wentworth scale)	Percent (by weight)
Sand:	
very coarse	----------
coarse	----------
medium	1.2
fine	43.6
very fine	20.1
Silt and clay	35.0
Total	99.9

Specific gravity of core samples, Oumalik core test 1

Core	Depth (in feet)	Specific gravity	Lithology
2	153	2.29	Sandstone.
2	155	2.43	Siltstone.
3	205	2.25	Clay shale.

Porosity and permeability of core samples, Oumalik core test 11

Core	Depth (in feet)[1]	Effective porosity (percent)	Air permeability (millidarcys)
26	238 P	19.3	13.8
26	238 N	18.8	26.2
27	250 P	16.9	<8
27	250 N	14.7	<9
27	256 P	15.5	<11
27	256 N	----------	<8

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

OIL AND GAS

No fluid tests were made as these holes were primarily drilled for stratigraphic and foundation information. No shows of oil or gas were found in any of the holes except 11, from which the driller reported a show of gas while pulling core 8 (67–77 feet) as evinced by flow of mud through drill pipe.

LOGISTICS AND DRILLING OPERATIONS

Ikpikpuk core test 1 and Oumalik core test 1.—These two tests were drilled consecutively with the rig used by United Geophysical Co., Inc.'s seismograph party 46 for shothole drilling. Auxiliary equipment was flown in during April by a DC–3 aircraft using a frozen lake for a landing strip. The drilling crew consisted of 1 head driller, 2 regular drillers, and 4 floormen and was supported from the nearby geophysical camp. A geologist from the U. S. Geological Survey was present at the time of the drilling.

The essential items of equipment used by Arctic Contractors in drilling these core tests were—

Failing M 314–C rotary core drill, equipped with tubular mast, powered by Chrysler engine model 108–506.
Gardner-Denver mud pump, 4 x 5 in., mounted in drilling wanigan.[1]
Auxiliary Gardner-Denver mud pump, 4 x 5 in., powered by Chrysler engine.
Reed Kor-King core barrel model K–500, drill rods, 2⅜-in. outer-diameter "N-rods."
Kohler electric plant, model LH, 2 kw, 115 v.
Water tank, 1,300-gallon capacity, mounted in wanigan on Go-Devil sled.
Caterpillar tractor, RD–8, with blade and winch.
Weasel, M–29C.
Hobart welding machine.

Drilling record of Ikpikpuk core test 1

Depth (feet)	
0	Test spudded in July 9, 1947.
39	Casing set. One joint of 7-in. outer-diameter pipe.
63	Mud started channeling behind surface casing and could not be successfully packed off. Trouble was experienced to the total depth.
118	Sub broke between swivel and kelly. Installed new sub.
178	Twisted off N-rods at 90 ft. Unable to free stuck rods. Twisted rods off just above overshot in order to salvage fishing string. Pulled 7-in. surface casing but left overshot, drill collar, 5⅞-in. rock bit, and 7 N-rods in hole. Abandoned July 17, 1947, and moved rig. No electric log run or thermistor cables installed.

[1] Small 1-room building, generally on skids or runners.

Drilling record of Oumalik core test 1

Depth (feet)	
0	Spudded in July 21, 1947.
37	Set 31 ft of 7-in. outer-diameter casing and cemented with 14 sacks of portland cement.
300	Leaks developed around surface pipe. Recemented around pipe from top.
392	Twisted off drill pipe at 88 ft while coring at this depth. Unable to recover fish. Abandoned July 29, 1947, with the casing, 280 ft of drill pipe, the drill collar, and the core barrel left in the hole. No electric logs run or thermistor cables installed.

In the course of drilling the two tests, the following were used: 19 drums of 80-octane gasoline, 1 drum of diesel oil, 25 gallons of lube oil No. 9170, 15 sacks of Aquagel, 5 sacks of Baroid, and 20 sacks of portland cement. Water came from a lake in the vicinity of the camp.

Oumalik core test 2.—This core test was drilled by the shothole crews of seismograph parties 43 and 46 after the geophysical work for the season was finished. The drilling crew consisted of the head of the drillers, 2 regular drillers, and 4 floormen. Only shothole drilling equipment was used as it was not desired to expend the funds or the time required to get additional equipment to the location. Cuttings were relied upon for stratigraphic information as no core barrel was available.

The following major items of equipment were used:

Mayhew shothole drill, model 1000 complete with 100-hp. V–8 Ford engine, 18-ft kelly, fabricated mast, and mounted on pipe sled. Drill equipped with 4½ x 6 in. FXG Gardner-Denver mud pump and 2⅜ in. x 10 ft joints of Mayhew full-hole drill pipe with 3-in. tool joints.
Water tank, 1,300-gallon capacity, mounted in wanigan on Go-Devil sled.
Caterpillar tractor, RD–8, with blade and winch.
Two weasels, M–29C.
Sled, Go-Devil-type, for supplies.
Hobart welding machine.

Drilling record of Oumalik core test 2

Depth (feet)	
0	Spudded in Sept. 8, 1947.
9	Set casing. A 10½-ft surface string made up of a 2-foot bell nipple with mud outlet on top of an 8½-ft joint of 5½-in. outer-diameter casing. Lightweight 5½-in. outer-diameter casing clamps were used.

Drilling record of Oumalik core test 2—Continued

Depth (feet)	
190	While reaming, the casing parted at weld below clamp and dropped to a depth of 42 ft but was fished out. A piece of casing, cut out with a welding torch, fell into the hole, lodged at 42 ft, and was not recovered. Hole abandoned Sept. 10, 1947, with 15 ft of drill rods and a rock bit in the hole. The 5½-in. casing was removed. No electric logs were run or thermistor cables installed.

In the course of drilling the following were used: 120 gallons of 80-octane gasoline, 25 gallons of diesel oil, 10 quarts of lubricating oil SAE 20, and 3 sacks of Aquagel.

Oumalik core (foundation) tests 1–10.—There is no information on the logistics or drilling of Oumalik core (foundation) tests 1–10. Thermistors were installed in some of the holes and temperature records were utilized in designing the foundation for Oumalik test well 1.

Oumalik core test 11.—Oumalik core test 11 was drilled with a Failing 1500 rig. (See pl. 1–*A*.) The crew was supported from a geophysical camp. Details on the rest of the equipment, material, and manpower utilized were not recorded. An Arctic Contractors petroleum engineer and a geologist were present during the drilling of the core test.

Drilling record of Oumalik core test 11

Depth (feet)	
0	Spudded in Mar. 9, 1949.
14.2	Set conductor pipe, 8⅝-in.
127	Lost circulation around conductor pipe. Recemented.
303	Suspended coring operations and bailed hole dry Mar. 22, 1949.

Oumalik core test 12.—No engineering data are available. Thermocouples were probably installed in Oumalik core tests 11 and 12 upon their completion.

OUMALIK TEST WELL 1

Location: Lat 69°50′18″ N., long 155°59′24″ W.
Elevation: Ground, 176 feet; kelly bushing, 194 feet.
Spudded: June 11, 1949.
Completed: Apr. 23, 1950, plugged and abandoned.
Total depth: 11,872 feet.

Oumalik test well 1 (pl. 1–*B*) is located on the apex of the Oumalik anticline (see fig. 5) in an area of low hummocks and ridges, in a slight depression that covers several square miles, and away from any major drainage. The latitude and longitude given above is subject to correction as no detailed topographic surveys have been made in the area. However, the location as shown in figure 4 is accurate with respect to the local drainage.

The following is a list of depths at which the different stratigraphic units are found in Oumalik test well 1.

Depth (feet)	
18–30	Recent and (or) Gubik formation.
30–2,825	Grandstand formation.
2,825–4,860	Topagoruk formation.
4,860–10,880	Oumalik formation.
10,880–11,872 (total depth)	Upper Jurassic(?) and Lower Cretaceous(?)

The first sediments penetrated (from 18 to 30 feet) in the well are river material of Recent age and (or) Gubik formation of Pleistocene age. The sediments consist of silt, sand, gravel, and clay with tundra and ice as described on page 8. Actually, not much clay was found, but some was probably present and was washed out during preparation of the samples. Rare white shell fragments of Pleistocene or Recent age were found.

The youngest Cretaceous rock penetrated in Oumalik test well 1 is the Grandstand formation, at 30–2,825 feet. Because Oumalik test well 1 is structurally higher than East Oumalik test well 1, the former started some 700 feet stratigraphically lower. Thus, except for possibly a few thin beds, the Killik tongue of the Chandler formation is not present in Oumalik test well 1. The Grandstand formation is 2,795 feet thick in the well and is made up of approximately 45 percent sandstone and siltstone, 50 percent clay shale, and 5 percent coal or carbonaceous material.

Although this section is quite calcareous, very little true limestone was found—22 inches in the core at 528 feet is medium-gray dense hard limestone with much brown drusy siderite lining incipient fractures. Identical material was noted in the cuttings at 550 feet. Some medium-dark-gray crystalline limestone was found in the ditch at 690–700 feet. The carbonate (probably partly dolomite) content of the sandstone and siltstone ranges from 8 to 47 percent, averaging 25 percent. Porosity ranges from 0.4 to 19.3 percent, and permeability, from impermeable to 34 millidarcys.

Thin beds of coal are fairly common in the first 900 feet and between 2,300 and 2,500 feet. Good fernlike and grasslike leaf impressions occur in cores at 517–528 feet. Very rare yellowish to brownish-gray clay ironstone concretions also were found.

As a rule the beds are flat lying or dip as much as 5°, although ripple marks and crossbedding with dips as much as 20° are present. "Swirly" beds are present at 2,800 feet; slickensides are very rare. Shows of gas, faint petroliferous odors, and straw-colored cuts were obtained from several sandstone beds in the Grandstand formation.

The Topagoruk formation was penetrated between 2,825 and 4,860 feet in this test. The formation is fossiliferous and mostly clay shale with about 10

percent siltstone and sandstone. The porosity of the siltstone and sandstone sections ranges from 1 to 18 percent; permeability is less than 5 millidarcys; and the carbonate content ranges from 10 to 25 percent. The dip of the beds ranges from almost flat to 25°, with the average dip about 4°; the higher dips possibly reflect large-scale crossbedding or faults. A few partings of black bitumen are present. Pale cuts and faint oil odors were obtained in most of the cored sands. Gas found at 3,240–3,244 feet had a shut-in pressure of 1,350 pounds per square inch and a gas reading of 5.7 milliamperes on the Baroid gas detector.

The type section of the Oumalik formation is in this test well (Robinson, Rucker, and Bergquist, 1956). The Oumalik formation is 6,020 feet thick (4,860–10,880 feet) and is divisible into two parts—an upper shale unit between 4,860 and 9,270 feet and a lower sandy shale between 9,270 and 10,880 feet. (See p. 9.) The carbonate content of the sandstone and siltstone, measured quantitatively at selected points, ranges from 12.2 to 17.4 percent; the sandstone is impermeable to air, and the porosity ranges from 2.8 to 11.4 percent.

Several pronounced fracture zones with slickensides and sometimes with fault gouge were noted at 5,100 to 5,900 feet, 7,200 to 7,800 feet, and 8,400 to 8,700 feet. The repeated occurrence of slickensides throughout the shale section suggests local fracturing of incompetent beds.

Shows of gas were detected in the lower part of the Oumalik formation from 8,000 to 10,850 feet; faint to fair petroliferous odor was noted on fresh fractures, but no cuts were obtained.

The oldest rocks in Oumalik test well 1 are of Late Jurassic(?) and Lower Cretaceous(?) age, described on page 10. These beds are flat lying or dip as much as 10°, as indicated by two cores only. A few shows of gas were noted.

HEAVY-MINERAL STUDIES

Three heavy-mineral zones were recognized by R. H. Morris in Oumalik test well 1 (pl. 6). The glaucophane zone ranges from 434 feet to 2,954 feet. Glaucophane occurrences within this zone are sporadic. The zoned zircon zone ranges from 1,794 to 3,954 feet. The uppermost 1,000 feet of this zone extends into the lower part of the glaucophane zone. The stratigraphic section, 3,994 to 9,394 feet, is predominantly shale; therefore, no heavy-mineral samples were taken. The augite zone ranges from 9,454 feet to 10,654 feet.

DESCRIPTION OF CORES AND CUTTINGS

The following lithologic description was made by the author using cores, well cuttings, and to some extent the electric log. (See pl. 4.) Many of the well cuttings were badly contaminated with cement and a fine-grained white quartz sand. Some of the depths at which this contamination was particularly noted are 1,230–1,460 feet, 1,740–1,770 feet, 1,850–1,870 feet, 2,000–2,030 feet, 2,760–3,200 feet, and 8,000–8,150 feet. Depths are measured from the top of the kelly bushing.

Lithologic description

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

Core	Depth (feet)	Remarks
----	0–18	Height of derrick floor above ground level.
----	18–25	Tundra, ice, and silt.
----	25–30	Sand and gravel; gravel made up of polished subangular chert and a few quartz granules, primarily various shades of yellow and dark gray; a large amount of dark-yellowish-orange to light-brown angular clay-ironstone granules; also rare pieces of pale-yellowish-brown quartzite and other rocks. Sand is fine grained, made up primarily of subangular clear and white quartz, also some yellow quartz plus a few chert pebbles. Some suggestion of clay. Rare (Pleistocene or Recent?) white shell fragments. The base of the Gubik and top of the Grandstand formation is placed at 30 feet.
----	30–35	No samples received.
----	35–50	Clay shale, medium-olive-gray, and a large amount of grayish-black carbonaceous shale, very rare chips of coal, also some fine-grained sand; sand grains somewhat better rounded than at 25–30 ft.
----	50–60	No samples received.
----	60–70	Clay shale, dark- and light-gray, ironstone concretions, and considerable amount of vitreous black coal.
----	70–80	No samples received.
----	80–110	Siltstone, medium-gray, and medium-gray clay shale; ironstone concretions, small amount of coal, noncalcareous.
----	110–120	No samples received.
----	120–130	Siltstone, medium-dark-gray, slightly sandy, argillaceous, friable.
----	130–140	No samples received.
----	140–150	Clay shale and siltstone.
----	150–160	Clay shale with silty streaks.

Lithologic description—Continued

Core	Depth (feet)	Remarks
1	160–180	Recovered 15 ft: Cement. Took core from inside 22-in. casing to ascertain condition of cement. Not sent to Fairbanks.
----	180–250	No samples received in Fairbanks. Well geologist reports as follows: 180–189, sandstone, silty to very fine-grained, gray, moderately hard, argillaceous. 189–199, shale, gray, silty, micaceous, carbonaceous. 199–201, coal, lignite to subbituminous, broken. 201–210, sandstone and shale in thin beds. 210–244, clay shale, dark-gray, silty, carbonaceous streaks. 244–249, sandstone, very fine- to fine-grained, gray, slightly argillaceous, carbonaceous.
----	250–260	Silty clay shale, medium-light-gray, slightly calcareous, cement contamination.
----	260–270	Sandstone, medium-light-gray, very fine-grained, argillaceous, very slightly calcareous.
----	270–280	Sandstone and siltstone as above.
----	280–360	Clay shale, medium-light-gray to medium-gray, and slightly calcareous silt shale; rare clay ironstone at 310 ft, small amount of sandstone at 320 ft, and carbonaceous streaks at 350–360 ft.
----	360–370	No samples received.
----	370–440	Clay shale, medium-light-gray to medium-gray. At 390, 410, and 440 ft a small amount of medium-grained sandstone made up of medium-light-gray light-colored quartz, dark chert, rock fragments, and coal fragments; moderately calcareous.
	440–450	No samples received.
----	450–460	Sandstone, fine- to medium-grained, "salt and pepper" appearance, subangular white and clear quartz, dark chert; argillaceous, calcareous matrix, also some clay shale and clay ironstone concretions.
----	460–470	Coal, vitreous, black, and dark-gray carbonaceous clay shale; also some medium-light-gray shale.
----	470–517	Clay shale, medium-gray, carbonaceous streaks, micaceous, ironstone at 480 ft, possibly some silt.
2	517–528	Recovered 10 ft: Microfossils absent. 2 ft 5 in., siltstone, very fine, medium- to medium-dark-gray, hard, micaceous, very calcareous; bedding somewhat irregular, lenticular, but essentially at right angles to walls of core; fracture irregular but tends to parallel bedding. This section of the core is characterized by numerous dull and a few vitreous black carbonaceous plant impressions. *Elatides* sp. was identified. 2 ft, siltstone, very fine, as above, but with fewer plant remains. Grades into rock below. 3 ft 9 in., silty claystone, medium-gray, very calcareous, not fissile but tends to fracture roughly parallel to bedding; contains many black carbonaceous plant remains. *Ginkgo digitata* (Brongniart) Heer is present. 1 ft 10 in., limestone, medium-gray, dense, hard; much brown drusy siderite lining incipient fractures.
----	528–560	Clay shale, medium- to dark-gray, carbonaceous; also siltstone, a very little limestone at 550 ft.
----	560–570	Clay shale, and limestone, medium-gray; drusy siderite, some coal. Echinoid (?) spine.
----	570–680	Clay shale (and claystone) interbedded with siltstone, clay shale, medium-light- to medium-dark-gray, slightly calcareous, has carbonaceous streaks, black plant impressions, a little pyrite and coal; and siltstone, medium-gray, calcareous, contains carbonaceous particles. Very slight show of gas in ditch at 625 ft.
----	680–690	No samples received.
----	690–700	Limestone, medium-dark-gray, crystalline, also slightly to moderately calcareous claystone.
----	700–710	No samples received.
----	710–723	Clay shale and claystone, medium-light- to medium-dark-gray; rare clay ironstone concretions.
3	723–733	Recovered 10 ft: Microfossils common. 3 ft 5 in., clay shale, medium-dark- to dark-gray, noncalcareous, fissile; breaks in laminae 3 mm thick or less; a few small pyrite concretions. 7 in., siltstone, medium-gray, massive, hard, carbonaceous and micaceous flakes; grades in last 2 in. to silty claystone with carbonaceous plant remains; very calcareous. 8 in., clay shale, medium-dark- to dark-gray, noncalcareous, fissile;

Lithologic description—Continued

Core	Depth (feet)	Remarks
		breaks in laminae 3 mm thick or less; vitreous black carbonized plant remains.
		6 in., claystone, medium- to medium-dark-gray, silty, moderately calcareous; bedding indistinct but probably at right angles to walls of core; fracture irregular; many black carbonaceous plant impressions, light-brown discolorations frequently rimming plant remains. Grades into rocks below.
		2 ft 4 in., siltstone, very fine, medium-gray, massive, hard, moderately calcareous; irregular fracture; contains black carbonaceous plant impressions.
		4 in., clay shale, with carbonaceous fragments as above; noncalcareous.
		2 ft 2 in., siltstone, argillaceous, medium-gray, moderately calcareous; mostly massive but with slightly shaly structure at 732 ft; contains hard thin carbonaceous laminae and carbonaceous plant impressions.
----	733–830	Clay shale, siltstone, carbonaceous shale, and coal at 750 ft; some very fine- to fine-grained sandstone with calcareous cement and pale to yellowish-brown clay ironstone concretions, at 820 ft.
----	830–840	No sample received.
----	840–850	Sandstone, medium-light-gray, fine- to medium-grained, "salt and pepper"; and medium- to medium-dark-gray clay shale.
----	850–870	Clay shale with carbonaceous plant impressions. some pyrite; some coal and dark shale at 870 ft.
----	870–880	No sample received.
----	880–890	Coal, fine sand, and dark-gray clay shale.
----	890–900	No sample received.
----	900–911	Interbedded clay shale, medium-dark-gray, and medium-light-gray sandy siltstone, slightly calcareous.
4	911–921	Recovered 10 ft: Microfossils absent.
		3 ft 9 in., very argillaceous siltstone, medium-gray, moderately hard; calcareous in spots; cleavage irregular but tends to parallel bedding.
		4 ft 2 in., claystone or clay shale, medium- to medium-dark-gray, silty, slightly calcareous; fractures roughly parallel to the bedding in layers about 1 in. thick; lower foot more massive. Slickensides dip 30° at very base.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		9 in., sandstone, medium-light-gray, very fine- to fine-grained, calcareous matrix, fairly hard.
		3 in., claystone, as in above 4 ft 2 in. part of core; contains carbonaceous plant remains.
		1 ft 1 in., sandstone, medium-light-gray, between fine- and medium-grained, subrounded grains; primary mineral is quartz; numerous very thin micaceous and carbonaceous laminae. Very calcareous cement; by quantitative analysis the carbonate content at 921 ft is 22.1 percent by weight; cut at same depth was a very faint-straw color and had a very pale-yellow residue. At 921 ft effective porosity and air permeability parallel to bedding are 9.48 percent and less than 5 millidarcys respectively; and 8.55 percent and less than 5 millidarcys normal to the bedding.
----	921–940	No samples received.
----	940–950	Sandstone, medium-light-gray, "salt and pepper," fine- to medium-grained; moderately calcareous cement.
----	950–960	No samples received.
----	960–968	Clay shale, dark-gray, carbonaceous, and coal.
5	968–979	Recovered 6 in.: Microfossils absent.
		Siltstone and sandstone, light-gray, friable; silt to very fine sand, very calcareous, very faint oil stain, good odor, and light-straw-colored cut.
6	979–984	Recovered 6 in.: Microfossils absent.
		Sandstone, light-gray, moderately hard, very fine- to fine-grained, very calcareous; grains subrounded; rare thin black carbonaceous laminae; very faint oil stain, good odor, and light-straw-colored cut. Carbonate content 15.1 percent by weight. Effective porosity of one sample is 15.2 percent, and air permeability 34 millidarcys.
7	984–989	Recovered 2 ft 6 in.: Microfossils absent.
		Sandstone, light-gray, very fine-grained, very calcareous, hard but badly broken; fair odor, straw-colored cut from 988 ft.
8	989–994	Recovered 4 ft 6 in.: Microfossils absent.
		Sandstone, light-gray, very fine- to fine-grained, hard, massive, very calcareous; fair odor, very faint-yellowish cut from 991 ft. Effec-

Lithologic description—Continued

Core	Depth (feet)	Remarks
		tive porosity and air permeability of one sample parallel to bedding are 13.15 percent and 9.7 millidarcys respectively, and 13.43 percent and 5.6 millidarcys normal to bedding. Carbonate content 20.4 percent by weight.
9	994–999	Recovered 1 ft: Microfossils absent. Sandstone as above, also some interbedded siltstone; very calcareous; faint petroliferous odor.
10	991–1,004	Recovered 1 ft: Microfossils absent. Siltstone, grading from very fine-grained sandstone at top, medium-light-gray, with medium-dark-gray carbonaceous and micaceousp artings; hard; carbonaceous plant impressions; very calcareous; very faint petroliferous odor.
11	1,004–1,010	Recovered 2 ft 4 in. Microfossils absent. 1 ft, siltstone as above, dip 2°; grades into rock below. 1 ft 4 in., clay shale, medium-dark-gray, silty, hard, has black carbonaceous plant remains, rather hackly cleavage; slightly calcareous.
----	1,010–1,020	No samples received.
----	1,020–1,030	Clay shale and sandy siltstone.
----	1,030–1,033	Sandstone, medium-light-gray, very fine-grained to silty; well geologist reports dead tarlike oil at 1,028–1,033 ft; spotty fluorescence; no cut or odor.
12	1,033–1,038	Recovered 4 ft Microfossils absent. Clay shale, medium-dark- to dark-gray, rather hard, slightly to moderately calcareous; carbonaceous and micaceous partings; tends to have irregular fracture rather than good cleavage.
----	1,038–1,050	Silty sandstone and clay shale.
----	1,050–1,060	Clay shale and siltstone.
----	1,060–1,070	No sample received.
----	1,070–1,080	Silty sandstone, very fine, very calcareous and clay shale.
----	1,080–1,090	No sample received.
----	1,090–1,100	Clay shale.
----	1,100–1,110	Siltstone and very fine-grained sandstone, some clay shale.
----	1,110–1,150	Clay shale, medium-light- to medium-dark-gray; some dark-gray shale and coal at 1,130 ft and 1,150 ft.
----	1,150–1,160	No sample received.
----	1,160–1,170	Sandstone, fine- to medium-grained, moderately calcareous; subangular white quartz 60 percent, also rock and coal fragments; also dark shale, coal, and brownish lignite.
----	1,170–1,180	No sample received.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	1,180–1,190	Clay shale, light- and dark-gray, and coal.
----	1,190–1,195	Sandstone, light-colored shale, and a small amount of dark shale and coal.
13	1,195–1,205	Recovered 10 ft: Microfossils absent. Siltstone, medium-light-gray, hard; contains scattered very thin sandstone layers, some darker laminae which contain a larger proportion of carbonaceous material; silt contains mica; carbonate content at 1,201 ft is 28.3 percent by weight; dip approximately 3°. At 1,201 ft effective porosity and air permeability parallel to bedding 3.4 percent and less than 5 millidarcys, respectively, and 2.4 percent and less than 5 millidarcys normal to bedding.
14	1,205–1,210	Recovered 5 ft: Microfossils very rare. 6 in., siltstone as above but contains larger carbonaceous fragments and more common carbonaceous laminae. 4 ft 6 in., clay shale, medium-dark- to dark-gray, rather hard, very slightly calcareous in spots; has good shaly cleavage; numerous carbonaceous and micaceous partings.
15	1,210–1,215	Recovered 5 ft: Microfossils very rare. 8 in., siltstone, medium-gray, argillaceous, micaceous, carbonaceous, and slightly calcareous, hard; becomes more argillaceous in lowest 2 in.; dip approximately 5°; slickensides noted in last inch; dip 50°. 4 ft 4 in., silty clay shale or claystone, medium-dark- to dark-gray; rather hard; slightly calcareous; carbonaceous flecks and mica in partings; tends to have irregular fracture where carbon and mica partings are absent.
----	1,215–1,230	Siltstone and shaly clay, medium-light-gray.
----	1,230–1,410	Clay shale, medium-gray, slightly to moderately calcareous; some carbonaceous impressions. Samples contaminated with cement.
16	1,410–1,422	Recovered 3 ft 4 in: Microfossils rare. Clay shale and claystone, medium-dark-gray, moderately hard, slightly to moderately calcareous; has some good shaly cleavage but also tends to break irregularly along bedding planes in layers more than 1 in. thick; partings showing best shaly cleavage are silty and micaceous; numerous medium-dark-gray

Lithologic description—Continued

Core	Depth (feet)	Remarks
		silty lenses present; clayey layers bend over and around the silt; black carbonaceous plant remains and coaly flecks common throughout; a few small specimens of *Corbula?* sp. at about 1,417 ft.
----	1,422–1,450	No samples received.
----	1,450–1,490	Siltstone, medium-light-gray, argillaceous, some very fine sand, also clay shale. Well geologist reports very faint odor of kerosene at 1,470–1,480 ft. Top occurrence of *Ditrupa* sp. at 1,470 ft.
----	1,490–1,510	Clay shale, medium-gray.
----	1,510–1,604	Clay shale and siltstone; a small amount of very fine-grained sandstone.
17	1,604–1,609	Recovered 1 ft 10 in.: Microfossils absent.
		Sandstone, medium-light-gray, hard, very fine-grained, noncalcareous; grains mostly subangular; primary mineral quartz; grains coated and cemented by very fine powdery white silty material; thin, irregular, black coaly partings and flecks common; no shows. At 1,606 ft effective porosity 10.9 percent and air permeability 8.8 millidarcys parallel to bedding.
18	1,609–1,619	Recovered 8 ft 6 in.: Microfossils absent.
		Sandstone as above, bedding as indicated by carbonaceous-micaceous streaks shows dips ranging from essentially flat lying to 12° within a few inches; grain size as large as fine sand but cemented with much finer material. At 1,614 ft effective porosity and air permeability parallel to bedding 10.35 percent and less than 5 millidarcys respectively and 9.92 percent and less than 5 millidarcys normal to bedding.
19	1,619–1,626	Recovered 6 ft 4 in.: Microfossils absent.
		Sandstone as immediately above, very faint petroliferous odor, very faint cut and very pale-yellow residue from 1,622 ft. At 1,622 ft effective porosity and air permeability parallel to bedding 9.85 percent and less than 5 millidarcys and 9.45 percent and less than 5 millidarcys normal to bedding.
20	1,626–1,637	Recovered 11 ft: Microfossils absent.
		10 ft, sandstone as above, becomes silty toward base; noncalcareous; 5° average dip; no shows. At 1,634 ft effective porosity and air permeability parallel to bedding 7.92 percent and less than 5 millidarcys and 8.09 percent and less than 5 millidarcys normal to bedding.
		1 ft, siltstone and shale, interbedded. Siltstone, medium-light-gray, with carbonaceous streaks grades from sandstone above; shale, medium-dark-gray, silty, noncalcareous.
----	1,637–1,660	Clay shale, medium-gray; siltstone.
----	1,660–1,740	Sandstone, fine-grained, calcareous, primarily subangular white quartz; coaly particles; some coal and shaly clay.
----	1,740–1,780	Clay shale, medium-light- to medium-dark-gray; streaks of very fine sand.
----	1,780–1,790	Sandstone, fine- to medium-grained, slightly to moderately calcareous.
----	1,790–1,797	Clay shale, medium- to medium-dark-gray; coal.
21	1,797–1,803	Recovered 4 ft: Microfossils absent.
		Clay shale, dark-gray to grayish-black, fissile and brittle, noncalcareous, very carbonaceous; contains numerous black plant impressions and many laminae of coal; dip about 4°, but some of the thin coaly streaks dip as much as 25° through the shale. Coal, vitreous, black; has irregular fracture; shows a faint suggestion of bedding; occurs in laminae up to 2 cm thick but generally much thinner—1 mm or less; the thicker coal laminae are mostly in bottom foot.
----	1,803–1,850	Clay shale, medium-dark-gray; small amount of coal at 1,810–1,820 ft.
----	1,850–1,965	Sandstone, silty to fine-grained, medium-light-gray, slightly to moderately calcareous; and medium-light- to medium-dark-gray clay; streaks of coal from 1,850–1,860, 1,890–1,920, and 1,940–1,950 ft.
22	1,965–1,966	Recovered 9 in.: Microfossils absent.
		Siltstone, medium-gray, hard, massive, calcareous.
23	1,966–1,967	Recovered 9 in.: Microfossils absent.
		Siltstone as above; small calcite vein dips about 45° through core. Cross-bedding dipping as much as 20° is faintly visible. Both this core and one above show moderate but very slow reaction with 25 percent cold hydrochloric acid. A vigorous reaction takes place when the core is powdered. At 1,966 ft effective porosity and air permeability 0.42 percent and less than 5 millidarcys, respectively, parallel to bedding, and 0.36 percent and less than 5 millidarcys normal to bedding.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		Carbonate content at same depth 47 percent by weight.
----	1,967–1,990	Coal, vitreous, black, and medium-dark-gray shale, plus a small amount of medium-light-gray siltstone.
----	1,990–2,000	Sandstone, very fine-grained, and medium- to medium-dark-gray clay shale.
----	2,000–2,010	Clay shale, cement contamination.
----	2,010–2,030	Clay shale, medium-gray, and fine-grained very slightly calcareous silty sandstone.
----	2,030–2,050	Clay shale, dark-gray, and coal; small amount of siltstone toward base.
----	2,050–2,090	Sandstone, medium-light-gray, fine-grained, and medium-dark-gray clay shale; pyrite, a little coal at 2,070–2,080 ft.
----	2,090–2,140	Clay shale, cement, and sand (sand is contamination, possibly from cellar of well).
----	2,140–2,151	Sandstone, medium-light-gray, mostly subangular white quartz, with some gray chert, and clay shale; noncalcareous.
24	2,151–2,161	Recovered 8 ft: Microfossils common. 2 ft, interbedded siltstone and clay shale, about 33 percent shale and 66 percent silt. Siltstone, medium-light-gray, hard, noncalcareous; bedding and crossbedding as indicated by slight differences of grain size and color show local dips as high as 20°, general dip probably 3°–5°. Clay shale, medium-dark-gray, moderately hard. Contacts between shale and silt quite sharp; undulatory nature of some of contacts suggests ripple marks; estimated wave length 2 in., amplitude one-twelfth of an inch. Layer one-twelfth of an inch thick near bottom is siltstone containing thin flat fragments of shale as much as 1¼ in. in length—a sort of intraformational conglomerate. A few partings have vitreous, black flakes and fragments of coal. One 1¼-in. layer of fine-grained sandstone at 2,152 ft. 2 ft 4 in., sandstone and siltstone, very fine-grained, medium-light-gray, hard; throughout most of section bedding not pronounced except in center where micaceous and carbonaceous partings are present; dip 5°. Slight petroliferous odor. At 2,154 ft effective porosity and air permeability parallel to bedding 3.43 percent and less than 5 millidarcys, respectively, and 3.83 percent and less than 5 millidarcys normal to bedding. Carbonate content at same depth 8 percent by weight. 3 ft 8 in., interbedded siltstone and shale as above in this core, 25 percent siltstone, 75 percent shale.
25	2,161–2,171	Recovered 10 ft: Microfossils common. Interbedded siltstone, medium-light-gray, and medium-dark-gray shale as above. Siltstone, 20 percent, shale, 80 percent. Silty lenticles in the clay shale.
----	2,171–2,190	Sandstone, silty to fine-grained, medium-light-gray; and medium-dark-gray shale; some coal at 2,180–2,190 ft.
----	2,190–2,210	Clay shale and a small amount of sandstone.
----	2,210–2,220	Sandstone, silty to fine-grained, and some medium-dark-gray clay shale.
----	2,220–2,310	Clay shale, medium-gray to grayish-black; streaks of coal throughout, particularly at 2,240–2,250 and 2,280–2,290 ft; also streaks of silt.
----	2,310–2,330	Coal, vitreous black, irregular fracture, and medium-dark-gray clay shale.
----	2,330–2,340	Sandstone, medium-light-gray, very fine- to fine-grained, and medium-dark-gray clay; noncalcareous.
----	2,340–2,351	Clay shale, medium-dark- to dark-gray, moderately hard, coal streaks at 2,340–2,350 ft, slightly calcareous to noncalcareous.
26	2,351–2,356	Recovered 5 ft: Microfossils common. Interbedded siltstone, medium-light-gray, and medium-dark-gray clay shale; similar to core 25 except that shale is siltier, harder, and has less shaly cleavage. On the whole, distinction between siltstone and shale is not as great as above.
----	2,356–2,390	Clay shale, coal streaks at 2,370–2,390 ft.
----	2,390–2,420	Clay shale, medium-dark-gray, and very fine-grained sandstone.
----	2,420–2,430	Coal and dark-gray clay shale.
----	2,430–2,500	Clay shale, medium- to medium-dark-gray, and small amount of medium-light-gray siltstone; latter is slightly calcareous; a very little very fine sand; small amount of coal at 2,450–2,460 ft; pyrite present; clay ironstone at 2,440–2,450 ft.
----	2,500–2,520	Clay shale and siltstone, 1:1 ratio.
----	2,520–2,529	Clay shale, some siltstone, and a little coal.
27	2,529–2,539	Recovered 8 ft 6 in.: Microfossils absent. 2 ft 4 in., siltstone and shaly silt, medium-light-gray, noncalcareous fairly

Lithologic description—Continued

Core	Depth (feet)	Remarks
		hard; tends to have a shaly cleavage parallel to bedding; bedding and crossbedding visible owing to slight difference in color; dips as high as 20°; regional dip probably close to 3° or 4°; faint petroliferous odor, pale-straw-colored cut from 2,531 ft.
		6 ft 2 in., interbedded siltstone and clay shale. Siltstone as above. Clay shale medium- to dark-gray, moderately hard, noncalcareous. Lenticles of silt and "ripple marks" similar to those described in core 24 present.
----	2,539–2,570	Clay shale, plus small amounts of siltstone; clay ironstone concretion at 2,550–2,560 ft, a very little coal at 2,540–2,550 ft and 2,560–2,570 ft.
----	2,570–2,610	Clay shale, medium-dark- to dark-gray, and varying amounts of medium-light-gray silty sandstone and siltstone. Crinoid fragment at 2,590–2,600 feet.
----	2,610–2,620	Clay shale, medium-dark- to dark-gray, and very fine-grained medium-light-gray sandstone.
----	2,620–2,700	Clay shale, medium-dark-gray, moderately hard; streaks of sandy siltstone and coal at 2,660–2,700 ft (particularly in last 10 ft); clay ironstone at 2,620–2,630 ft. Crinoid fragment at 2,670–2,680 ft.
----	2,700–2,710	Sandstone, very fine-grained, and siltstone, clay shale, and a little coal.
----	2,710–2,730	Clay shale and siltstone.
----	2,730–2,740	Clay shale, medium-dark-gray, and medium-light-gray siltstone, about 50 percent of each. Also a small amount of very fine-grained sandstone and coal.
----	2,740–2,756	Clay shale, 50 percent, medium-dark-gray; and sandstone, 50 percent, medium-light-gray, very fine- to fine-grained; 70 percent white and clear quartz, matrix slightly calcareous.
28	2,756–2,757	Recovered 1 ft: Microfossils absent.
		3 in., siltstone, light- to medium-light-gray, hard; a few black carbonaceous plant impressions; moderate effervescence with cold 25 percent HCl. At 2,756 ft effective porosity 1.78 percent and air permeability less than 5 millidarcys parallel to bedding.
		6 in., sandstone, light- to medium-light-gray, hard; numerous vitreous and dull black coaly fragments and partings; fine-grained (some grains slightly coarser); primarily subangular clear, milky, and some gray quartz grains; has calcareous cement. No odor; no cut from 2,756½ ft. At 2,756½ ft effective porosity parallel to bedding 3.74 percent and carbonate content 7.88 percent by weight; sample unsuitable for permeability determination.
		3 in., clay shale or claystone, medium-dark-gray, hard, slightly calcareous; shaly cleavage not prominent, a few micaceous partings.
29	2,757–2,760	Recovered 3 ft: Microfossils absent.
		Clay shale or claystone, medium-dark-gray, hard; shaly cleavage not prominent; about 3 in. of medium-light-gray siltstone and very fine sandstone at 2,758 ft; sharp but wavy or "ripple-mark-like" contacts between silt and shale. Below 2,758 ft shale contains great deal of silt—therefore slightly lighter in color. Carbonaceous material, both finely disseminated and as larger fragments in certain laminae, is abundant. Siltstone is moderately calcareous.
----	2,760–2,767	Cement plus a small amount of clay shale (10¾-in. casing set at 2,762 ft).
30	2,767–2,777	Recovered 10 ft: Microfossils absent.
		5 ft, siltstone, medium- to medium-dark-gray, argillaceous, massive, fairly hard, very slightly calcareous; contains both biotite and muscovite, also a large amount of dull to shiny black carbonaceous or bituminous material.
		5 ft, claystone, medium-dark-gray, slightly shaly, micaceous, very slightly calcareous, contains finely disseminated carbonaceous material, few laminae of siltstone as above.
31	2,777–2,787	Recovered 10 ft: Microfossils very rare.
		2 ft 6 in., siltstone as described in core above, slight petroliferous odor on fresh fracture.
		4 ft, claystone as in core 30; very slightly calcareous, high-angle fracturing (about 80°) common; some slickensides; slight petroliferous odor on fresh fracture; grades into rocks below.
		3 ft 6 in., clay shale, medium-dark-gray, hard; not noticeably fractured, cleaves parallel to bedding (?); dip 4°.
32	2,787–2,792	Recovered 1 ft 3 in.: Microfossils very rare.
		Claystone or clay shale, medium-dark-gray, with lenses and laminae

Lithologic description—Continued

Core	Depth (feet)	Remarks
		of medium-gray very slightly calcareous siltstone; contacts between irregular but sharply defined; very small amount of fracturing indicated; one very thin lens of medium-light-gray very fine-grained sandstone.
33	2,792–2,799	Recovered 4 ft: Microfossils very rare. 1 ft 6 in., interbedded clay shale and siltstone as immediately above; siltstone fragments in the shale suggest partial consolidation and reworking at time of deposition, a sort of intraformational conglomerate. 2 ft, siltstone, medium-light-gray, hard, ranges from shale to very fine-grained sandstone; very slightly calcareous; slight petroliferous odor. 6 in., claystone, medium-dark-gray, fairly hard, noncalcareous; has irregular fracture.
34	2,799–2,809	Recovered 8 ft: Microfossils absent. 1 ft 4 in., broken zone containing fragments of siltstone, medium-gray, hard, carbonaceous, micaceous, very slightly calcareous; no fragments over 1½ in. in diameter. 3 ft 2 in., siltstone, medium-light-gray, with carbonaceous dark-gray hard laminae; concentric swirly structure indicated by small changes in texture and color, possibly a phenomenon of soft rock flowage. Grades into rock below. 3 ft 6 in., interbedded siltstone and clay shale.
35	2,809–2,819	Recovered 10 ft: Microfossils absent. Claystone and clay shale, medium-dark- to dark-gray, silty, hard, carbonaceous, micaceous, slightly calcareous; some shaly cleavage.
36	2,819–2,829	Recovered 2 ft 4 in.: Microfossils absent. Claystone as above; high-angle fractures and slickensides; slightly calcareous. Top of the Topagoruk formation is placed at 2,825 feet.
37	2,829–2,836	Recovered 6 ft 6 in.: Microfossils common. Clay shale, medium-dark-gray, with numerous lenses, laminae, and partings of medium-light-gray siltstone, carbonaceous, very slightly calcareous.
38	2,836–2,841	No recovery.
39	2,841–2,851	Recovered 8 ft 4 in.: Microfossils common. 4 ft 9 in., clay shale with silt laminae as in core 37.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		1 ft 3 in., clay shale as above but fractured; fractures small and irregular; very little displacement of beds. 2 ft 4 in., clay shale as in first part of core.
----	2,851–3,000	Clay shale or claystone, medium-dark-gray, essentially noncalcareous. Streaks of slightly calcareous medium-light-gray sandy siltstone, particularly at 2,900–2,910, 2,920–2,930, 2,960–2,970 ft; grains subangular, about 60 percent light quartz. Many ditch samples contaminated with very light-yellowish-gray sand-cement mixture (sand thought to come from well cellar).
----	3,000–3,022	Clay shale, medium-dark-gray. Siltstone at 3,010–3,020 ft. Much sand and cement contamination.
40	3,022–3,032	Recovered 3 ft: Microfossils common. Interbedded clay shale and siltstone as in core 37; noncalcareous.
----	3,032–3,090	Clay shale, medium-dark-gray.
----	3,090–3,100	Siltstone and clay shale in even proportion; carbonaceous particles very rare.
----	3,100–3,140	Clay shale, medium-dark-gray, noncalcareous; trace of siltstone.
----	3,140–3,180	Sand and cement contamination, clay shale.
----	3,180–3,222	Clay shale, medium-dark-gray, micaceous, also medium-gray siltstone at 3,180–3,190 ft; noncalcareous.
41	3,222–3,232	Recovered 8 ft 4 in.: Microfossils common. 4 ft 4 in., clay shale and claystone, medium-dark-gray, hard, fairly good cleavage, micaceous. 4 ft, clay shale as above, but softer and more fissile.
----	3,232–3,240	Clay shale.
----	3,240–3,244	Sandstone, medium-light-gray, fine- to medium-grained. Following determinations made on some fine-grained chips recovered from rig floor during heading of well on Sept. 30, 1949. No cut, very pale-yellow residue; effective porosity 18 percent; carbonate content 10.2 percent by weight.
42	3,244–3,254	Recovered 4 ft 6 in.: Microfossils very rare. 1 ft 8 in., clay shale, rather soft, as in last part of core above. 9 in., sandstone, medium-light-gray, massive, hard, fine-grained; grains primarily angular white quartz, a small amount of biotite and pyrite. Strong odor on fresh fracture. Effective porosity 1.59 percent and air permeability less than 3

Lithologic description—Continued

Core	Depth (feet)	Remarks
		millidarcys. Carbonate content 24.2 percent by weight.
		4 in., clay shale, soft as above.
		7 in., sandstone, as above, strong naphthalike odor on fresh fracture, pale-straw-colored cut, pale-yellow residue from 3,251 ft.
		1 ft 2 in., clay shale, as above, some sandstone interbedded.
43	3,254–3,262	Recovered 8 ft: Microfossils absent.
		1 ft 8 in., claystone, medium-light-gray, fairly soft, noncalcareous; darker laminae increase toward bottom and grade into rock below.
		2 ft 8 in., clay shale, medium-dark-gray, moderately hard, noncalcareous, with good cleavage.
		1 ft 7 in., sandstone, very fine, and medium-gray hard massive siltstone; angular white quartz is primary mineral; mica present; somewhat calcareous silty matrix. Faint odor; straw-colored cut and pale-yellow residue from 3,260 ft. At 3,260 ft effective porosity 9.2 percent and air permeability less than 4 millidarcys. Carbonate content 14.23 percent.
		9 in., clay shale, medium-dark-gray, micaceous.
		1 ft 4 in., siltstone and sandstone as above; faint odor.
44	3,262–3,272	No recovery.
45	3,272–3,282	Recovered 10 ft: Microfossils absent.
		3 ft, clay shale, medium-dark-gray, with laminae and irregular lenticles of medium-light-gray siltstone.
		7 ft, claystone and shale, medium-dark-gray, hard; poorly developed cleavage; dip of beds estimated 4°.
----	3,282–3,320	Sandy siltstone and sandstone, medium-light-gray, very fine-grained, slightly calcareous to noncalcareous; and medium-dark-gray clay shale. Small amount of coal at 3,280–3,290 ft.
----	3,320–3,400	Siltstone and shale.
----	3,400–3,455	Clay shale, medium-dark- to dark-gray, with silty streaks.
46	3,455–3,465	Recovered 5 ft: Microfossils common.
		Clay shale, medium-dark-gray, hard, carbonaceous, micaceous; interbedded with a few thin irregular laminae of medium-light-gray siltstone; noncalcareous; dips as much as 5°.
----	3,465–3,480	No samples received.
----	3,480–3,490	Sandy siltstone, medium-light-gray sandstone, and clay shale.

Lithologic description—Continued

Core	Depth (feet)	Remarks
47	3,490–3,500	Recovered 7 ft 3 in.: Microfossils absent.
		Siltstone, medium-light-gray, hard, with dark carbonaceous micaceous partings; very slightly calcareous; estimated 2° dip; very faint petroliferous odor on fresh fracture. At 3,494 ft effective porosity 14 percent and air permeability 4.9 millidarcys. At 3,495 ft effective porosity 14.3 percent; sample unsuitable for permeability determination.
48	3,500–3,510	Recovered 8 ft: Microfossils absent.
		2 ft, siltstone, medium-light-gray, hard; also a small amount of very fine-grained sandstone, micaceous, very slightly calcareous; grades at bottom into rock below.
		6 ft, clay shale and claystone, medium-dark-gray, hard, silty, micaceous, very slightly calcareous; contain carbonaceous flecks; interbedded with thin irregular laminae and lenses of medium-light-gray siltstone. Dips range from 4° to 25°—probably a reflection of large-scale crossbedding.
----	3,510–3,700	Clay shale and claystone, medium-dark- to dark-gray, moderately hard, micaceous, with streaks of medium-light- to medium-dark-gray siltstone—color darker because of abundance of carbonaceous particles; some partings of black bitumen present; noncalcareous.
49	3,700–3,710	No recovery.
50	3,710–3,712	Recovered 2 in.: Microfossils abundant.
		Clay shale, medium-dark-gray, hard, noncalcareous.
51	3,712–3,713	Recovered 6 in.: Microfossils abundant
		Clay shale as above; dip 10°.
----	3,713–3,740	No samples received.
----	3,740–3,752	Sandstone, medium-gray, very fine-grained, silty, slightly calcareous; made up of subangular quartz and carbonaceous particles, argillaceous matrix, thin streaks of bitumen. Some clay shale.
52	3,752–3,756	Recovered 3 ft 6 in.: Microfossils absent.
		Siltstone, medium-gray, moderately hard, micaceous, moderately calcareous to noncalcareous; grains primarily quartz, but siltstone is very argillaceous grading to silty claystone in places; small (up to 2 mm long) fragments of black carbonaceous material disseminated throughout; dips 3° or less; faint odor, pale-straw-colored cut and very pale residue from 3,752½ ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		At 3,752½ ft effective porosity 12.0 percent and permeability less than 1 millidarcy. Faint odor, no cut, greasy film from 3,755 ft. At 3,755 ft effective porosity 6.0 percent and air permeability 1 millidarcy.
----	3,756–3,802	Clay shale and siltstone, medium-gray, with carbonaceous flecks and streaks of bitumen; very fine-grained sandstone 3,770–3,800 ft; slightly calcareous in spots.
53	3,802–3,812	Recovered 8 ft 9 in.: Microfossils absent. Interbedded argillaceous siltstone and silty claystone, medium- to medium-dark-gray, noncalcareous; numerous black carbonaceous-micaceous partings; a few carbonaceous fragments; some shaly cleavage; very low to 20° dip (regional dip 3°); slight petroliferous odor in siltier parts. No cut; very pale-yellow residue at 3,805 ft.
54	3,812–3,817	Recovered 5 ft: Microfossils absent. Claystone, medium- to medium-dark-gray, hard, silty; scattered irregular laminae of medium-light-gray siltstone. One slickensided fracture dips 55° at 3,816 ft; beds nearly flat lying; essentially noncalcareous; no shows.
----	3,817–3,855	Clay shale, medium-dark-gray; siltstone; and some very fine sandstone.
----	NOTE:	Section from 3,855–9,278 ft is monotonous sequence of clay shale or claystone, medium-dark-gray, slightly micaceous and carbonaceous, slightly silty in part; section becomes siltier in last 1,000 ft. Gores and variations in this clay shale are described below.
55	3,995–4,005	Recovered 1 ft: Microfossils rare. Shaly clay, medium-gray, nonsilty, noncarbonaceous, nonmicaceous, noncalcareous; considerably softer in contrast to all shale described in cores above; somewhat waxy (kaolinitic?); fair shaly cleavage; beds essentially flat lying (?).
56	4,005–4,010	Recovered 5 ft: Microfossils common. Interbedded claystone and clay. Claystone, medium-dark-gray, fairly hard, silty; has minute micaceous and carbonaceous flecks, also has tiny fiberlike stringers of pyrite. The clay is softer, quite silty, and slightly lighter in color, kaolinitic, rarely has shaly cleavage; noncalcareous.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----		4,010–4,020 ft. Siltstone, medium-dark-gray, argillaceous, slightly calcareous; small amount.
----		4.030–4,040 ft. Siltstone, argillaceous.
----		4,040–4,070 ft. Siltstone, medium-light-gray; a little bitumen in the shale at 4,050–4,060 ft; trace.
----		4,140–4,160 ft. Siltstone, medium-light-gray.
57	4,200–4,210	Recovered 1 ft: Microfossils absent. Claystone, medium-gray, noncalcareous; shaly cleavage not well developed; moderately hard; very slightly waxy.
		4,250–4,260 ft. Trace of bitumens.
----		4,290–4,300 ft. Sandstone, medium-light-gray, very fine-grained, silty, slightly calcareous; small amount.
----		4,320–4,330 ft. Siltstone, medium-gray; trace.
		4,340–4,350 ft. Siltstone, medium-gray; bitumen; trace.
----		4,380–4,390 ft. Siltstone, medium-gray, slightly calcareous; trace.
58	4,420–4,440	Recovered 20 ft: Microfossils very abundant. Clay shale, medium- to medium-dark-gray, moderately hard; fairly good cleavage; only slightly silty in spots; noncalcareous; dip 5°.
----		4,444–4,450 ft. Siltstone, medium-gray; trace.
----		4,490–4,500 ft. Siltstone, medium-gray; trace.
----		4,540–4,550 ft. Siltstone, bitumen; trace.
----		4,650–4,670 ft. Siltstone, medium-gray, very slightly calcareous; trace.
59	4,670–4,690	Recovered 16 ft 6 in.: Microfossils rare. Clay shale, medium- to medium-dark-gray; essentially as in core above, hard, and siltier. Laminae up to half an inch thick of medium-light-gray siltstone scattered throughout section; estimated 90 percent shale, 10 percent siltstone. Some of the thicker of these silty laminae have slight petroliferous odor; noncalcareous; 7° dip.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----		4,730–4,740 ft. Siltstone; trace.
----		4,800–4,810 ft. Siltstone, medium-gray; trace.
----		4,830–4,840 ft. Siltstone, medium-gray; trace.
----		4,840–4,870 ft. Sandstone, medium-gray, slightly calcareous, very fine-grained; trace; almost entirely white and clear quartz, subangular to subrounded; also some siltstone. Top of the Oumalik formation is placed at 4,860 feet.
----		4,880–4,980 ft. Siltstone, medium-gray, slightly calcareous; trace.
60	4,900–4,920	No recovery.
61	4,920–4,940	Recovered 1 ft: Microfossils very rare. Shaly clay, medium-gray; moderately hard but softer than core 59; slightly waxy, noncalcareous. Similar in composition to cores 55 and 57. Entire recovery consists of broken chips as much as ½ x 2 x 3 in. in size. Chips flat along cleavage planes and irregular in other directions.
----		5,040–5,050 ft. Sandstone, medium-light-gray, very fine-grained, noncalcareous, very small amount.
----		5,100–5,130 ft. Sandstone, very fine-grained, small amount, made up of subangular white and clear quartz, cemented with argillaceous material, 60 percent sandstone in sample from 5,120 ft.
62	5,131–5,150	Recovered 4 ft: Microfossils very rare. Clay shale, medium- to medium-dark-gray, moderately hard, slightly silty, noncalcareous. One well-defined, high-angle slickensided fracture plane at top; with a thin white and very soft coating on this plane; another fracture 1 ft from bottom dips 45°. Polishing on bedding-cleavage surfaces suggests slight slippage along these planes. Also other minute irregularities on some of bedding surfaces suggest incipient fracturing. Dips as high as 18°; average about 10°.
----		5,210–5,220 ft. Siltstone, medium-light-gray; trace.
----		5,260–5,270 ft. Slickensides very rare.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----		5,290–5,300 ft. Siltstone, medium-light-gray; trace.
----		5,310–5,320 ft. Siltstone; trace.
----		5,350–5,360 ft. Siltstone; trace.
63	5,360–5,379	Recovered 17 ft: Microfossils rare. Claystone and clay shale, medium-dark-gray, moderately hard, noncalcareous; very uniform texture and color; contains much finely disseminated microscopic mica; shaly cleavage not particularly well developed; silty streaks very thin and very rare; dip 15°. Numerous highly polished and slickensided fracture surfaces, mostly parallel to bedding; greatest dip of these surfaces noted being 20°.
----		5,380–5,390 ft. Sandstone, very fine-grained, slightly calcareous; 5 percent of sample.
----		5,450–5,480 ft. Siltstone, slightly sandy, medium-light-gray; trace. Slickensides at 5,450–5,470 ft.
----		5,540–5,550 ft. Siltstone; trace.
----		5,570–5,590 ft. Sandstone and siltstone, medium-light-gray; trace. Slickensides with some fault gouge.
64	5,605–5,625	Recovered 16 ft 6 in.: Microfossils absent. Clay shale, medium-dark-gray; very rare and very thin laminae of medium-light-gray siltstone; noncalcareous. All but about 3 ft of recovery badly broken. Polished and slickensided fracture surfaces common throughout, extend at all angles through core. Some of these surfaces have a thin coat of soft white talclike material—possibly fault gouge; dip 7°.
----		5,625–5,630 ft. Siltstone; trace; slickensides with gouge.
----		5,660–5,670 ft. Slickensides.
----		5,670–5,680 ft. Siltstone, medium-light-gray; trace.
----		5,770–5,780 ft. Siltstone; trace.
----		5,840–5,845 ft. Slickensides.
65	5,845–5,865	No recovery.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----		5,865–5,870 ft. Siltstone; trace.
----		5,890–5,900 ft. Siltstone; trace.
----		5,920–5,930 ft. Siltstone; trace.
----		6,030–6,040 ft. Siltstone; trace.
66	6,041–6,056	Recovered 6 ft: Microfossils very rare. Clay shale, medium-dark-gray, hard; very rare medium-light-gray silty laminae; noncalcareous; slightly micaceous partings rare; fair shaly cleavage; dip 9°.
----		6,060–6,080 ft. Siltstone, medium-light-gray to medium-gray, noncalcareous; 10 percent.
----		6,090–6,100 ft. Siltstone; trace.
----		6,180–6,190 ft. Siltstone, medium-light- to medium-dark-gray, noncalcareous; 10 percent.
----		6,210–6,220 ft. Siltstone; trace.
67	6,285–6,293	Recovered 8 ft: Microfossils absent. Clay shale as in core 66, rare silty laminae, tiny offsets in beds suggest slippage at time of deposition; noncalcareous; dip 7°.
----		6,293–6,300 ft. Siltstone; trace.
----		6,320–6,360 ft. Siltstone, medium-light-gray to medium-gray; 5–10 percent.
----		6,380–6,390 ft. Siltstone; trace.
----		6,400–6,498 ft. Siltstone, medium-light-gray, micaceous, slightly carbonaceous, noncalcareous; trace to 15 percent.
68	6,498–6,506	Recovered 8 ft: Microfossils absent. Clay shale as in core 66; lowest foot badly shattered; dip 7°.
----		6,540–6,650 ft. Siltstone, medium-light-gray, sandy, slightly calcareous; trace to 20 percent.
69	6,669–6,675	Recovered 4 ft 6 in.: Microfossils absent. Clay shale, medium-dark-gray, hard; approximately 15 percent medium-light-gray, noncalcareous silty laminae; some partings have minute micaceous and carbonaceous flecks; dip 5°.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----		6,770–6,780 ft. Siltstone, sandy; trace.
----		6,810–6,820 ft.
----		6,850–6,860 ft. Siltstone, sandy, slightly calcareous; 10 percent
70	6,880–6,890	No recovery.
----		6,920–6,970 ft. Sandstone, silty to very fine-grained, and sandy siltstone; trace to 30 percent.
----		6,980–6,990 ft. Siltstone; trace.
71	7,078–7,092	No recovery.
----		7,100–7,120 ft. Siltstone, medium-light-gray; trace.
72	7,250–7,258	Recovered 6 ft: Microfossils absent. Clay shale, as in core 69; very little siltstone; noncalcareous; a few slickensided surfaces dip 45°; dip of beds 4°.
----		7,370–7380 ft. Siltstone; trace.
73	7,452–7,467	Recovered 9 ft: Microfossils absent. Clay shale as above, essentially no siltstone; noncalcareous. Core badly broken, has numerous polished slickensided surfaces at all angles, soft white gouge on some of these surfaces; dip of beds ranges from 3°–30°.
----		7,480–7,500 ft. Siltstone; trace.
----		7,500–7,540 ft. Slickensides very rare to common.
----		7,540–7,550 ft. Siltstone; trace.
----		7,590–7,660 ft. Slickensides rare to common. The driller's log reports "tight hole, heaving shale" between cores 73 and 74 (7,467–7,650 ft). It is possible that this "heaving shale" of the driller and the "slightly bentonitic shale" of the well geologist represents a softer, highly fractured shale zone with associated fault gouge.
74	7,650–7,665	No recovery.
----		7,660–7,780 ft. Siltstone, medium-light-gray to medium-gray, carbonaceous, micaceous; very slightly calcareous; trace. Slickensides rare, some gouge at 7,710–7,720, 7,730–7,750, and 7,770–7,780 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----		7,790–7,810 ft. Siltstone, medium-light-gray; trace to 10 percent.
----		7,810 ft. Top of contamination of loose yellowish-gray quartz sand identical to that noted from 2,760–4,120 ft.
----		7,910–7,940 ft. Siltstone, medium-light-gray to medium-gray; trace.
----		7,960–7,970 ft. Siltstone; trace.
----		7,990–8,030 ft. Siltstone, micaceous; carbonaceous, slightly calcareous; trace.
----		8,080–8,090 ft. Siltstone; trace.
75	8,090–8,094	Recovered 3 ft: Microfossils absent. Clay shale, medium- to medium-dark-gray, moderately hard, noncalcareous; has fair shaly cleavage. Approximately 7 percent of core made of irregular medium-light-gray silt laminae; dip 3°. Well geologist reports core bled gas.
----		8,094–8,110 ft. Siltstone, medium-gray; trace.
----		8,170–8,180 ft. Siltstone; trace.
----		8,220–8,240 ft. Slickensides very rare.
----		8,250–8,284 ft. Siltstone, medium-gray, and silty sandstone, slightly calcareous; trace.
76	8,284–8,294	Recovered 10 ft: Microfossils very rare. Clay shale, medium-dark-gray, moderately hard; good shaly cleavage; some partings coated with minute particles of pyrite; one pyrite concentration has a structure that suggests organic remains. Contains approximately 25 percent of medium-light-gray noncalcareous thin (up to 1 in. but usually ¼ in. or less) siltstone laminae and lenses; slightly harder than the shale. Siltstone has small ripple marks and very small amount of crossbedding; dip 3°. Very faint petroliferous odor.
----		8,330–8,350 ft. Siltstone, medium- to medium-light-gray; trace.
77	8,488–8,498	Recovered 10 ft: Microfossils absent. Clay shale and claystone, medium-dark-gray, moderately hard, noncalcareous; have poor shaly cleavage. No siltstone. About three-fourths of this core broken into pieces 1–2 in. in length; a few fractures at 40° are slickensided; beds dip 10°–25°. Well geologist reports core bled gas; strong gasoline odor noted in parts of core in laboratory.
----		8,640–8,691 ft. Clay shale, medium-dark-gray, slightly micaceous; also a trace to 25 percent of medium-light-gray to medium-gray sandstone and very fine- to fine-grained argillaceous sandy siltstone; grains are subangular to subround; primary mineral is clear quartz. Cuttings are very slightly calcareous.
78	8,691–8,701	Recovered 10 ft: Microfossils absent. Clay shale, medium-dark-gray, with about 15 percent silty laminae similar to core 76; one 60° slickensided surface at 8,692 ft; noncalcareous; flat lying to 2° dip. Well geologist reports core bled slight amount of gas.
----		8,760–8,770 ft. Sandstone, very fine, very slightly calcareous; 10 percent.
----		8,830–8,917 ft. Siltstone, sandy, medium-light-gray, trace to 15 percent, and very fine-grained sandstone.
79	8,917–8,927	Recovered 2 ft: Microfossils absent. Clay shale, medium-dark-gray, hard, fair shaly cleavage, micaceous, carbonaceous, noncalcareous; beds approximately flat lying (?) but with cleavage dipping as high as 20°.
----		8,930–8,940 ft. Sandstone, very fine- to fine-grained; trace.
----		8,990–9,040 ft. Sandstone, very fine-grained, and siltstone; noncalcareous; trace.
80	9,138–9,148	No recovery.
81	9,148–9,158	Recovered 1 ft: Microfossils absent. Clay shale, medium-dark-gray, hard, noncalcareous; has poor shaly cleavage, and contains irregular lenses and laminae of medium-light-gray siltstone; dip 10°.
----		9,180–9,230 ft. Siltstone, medium-light-gray, sandy; trace. Slickensides very rare at 9,190–9,200 ft.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----		9,230–9,240 ft. Slickensides very rare.
----		9,260–9,278 ft. Sandstone, very silty, noncalcareous; trace.
----	9,278–10,880	Section as indicated by ditch consists of slightly micaceous medium-dark-gray clay shale and varying amounts of sandstone and siltstone. Sandstone, medium-light-gray, fine-grained; very slightly calcareous to noncalcareous; grains subangular to subrounded, primarily white and clear quartz, cemented by argillaceous material; carbonaceous material or bitumen very rare. Almost every ditch sample has some sandstone or siltstone in it. Only the most abundant indicated below.
82	9,278–9,296	Recovered 7 ft: Microfossils absent. Sandstone, medium-light-gray, hard, silty to fine-grained, massive; irregular fracture; grains subangular to angular, estimated 50 percent white and clear quartz, 15 percent shiny black carbonaceous material or bitumen, occurring in partings and as flat pieces as much as one-fourth in. in diameter (plant remains?); small soft white mica fragments (altered feldspars?) and other minerals cemented by argillaceous material. When powdered, the rock effervesces slightly with cold HCl and moderately with warm acid, so it may contain some dolomite. In uppermost foot of recovered core effective porosity and air permeability parallel to bedding 6.67 percent and impermeable, respectively, and 9.82 percent and impermeable normal to bedding. Carbonate content 12.24 percent. In lower foot of recovered core effective porosity and air permeability parallel to bedding 5.92 percent and impermeable, respectively, and 11.47 percent and impermeable normal to bedding; carbonate content 12.34 percent by weight. This sandstone is "dirty," has no odor, no cut. Contains a few (5 percent of total core) laminae of medium-dark-gray shale, hard, but softer than sandstone; ripple marked near contacts with shale; irregular lenses of the sand found in the shale; one lens is crossbedded. In general, beds probably are flat lying or have very low dip.
----		9,350–9,360 ft. Slickensides, very rare.
----		9,380–9,390 ft. Bitumen, very rare streaks.
----		9,390–9,400 ft. Slickensides, very rare, some fault gouge.
----		9,450–9,480 ft. Sandstone, very fine-grained, 40–60 percent, and siltstone.
83	9,537–9,552	Recovered 15 ft: Microfossils very rare. Sandstone 70 percent, clay shale and closely interbedded sandstone, 30 percent. Sandstone, medium-light-gray, similar to that in core 82; very slightly calcareous (or dolomitic?). Clay shale similar to that in core 82; some partings contain more carbonaceous material. At 9,540 ft effective porosity and permeability parallel to bedding 4.2 percent and impermeable, normal to bedding 5.1 percent and impermeable, respectively; carbonate content 17.44 percent by weight. Beds flat lying but with very small amount of small-scale crossbedding; very faint petroliferous odor on fresh fracture.
----		9,552–9,560 ft. Siltstone, sandy, 60 percent.
----		9,610–9,620 ft. Bitumen very rare.
----		9,700–9,720 ft. Sandstone, very fine-grained, and siltstone; 30–40 percent.
----		9,770–9,780 ft. Sandstone, very fine-grained, and siltstone; 25 percent.
----		9,790–9,800 ft. Sandstone, very fine-grained, and siltstone; 35 percent.
84	9,824–9,841	Recovered 17 ft: Microfossils absent. Interbedded clay shale, siltstone, and a small amount of sandstone. Clay shale, medium-dark-gray, moderately hard; has good shaly cleavage; carbonaceous flecks present (plant fragments?); estimated one-third of total core. Siltstone, medium-light-gray, sandy, and grades to very fine-grained sandstone in spots; hard, dirty, argilaceous. At 9,830 ft effective porosity 2.9 percent, and the rock is impermeable to air; carbonate

Lithologic description—Continued

Core	Depth (feet)	Remarks
		content 12.89 percent by weight. Excellent small-scale crossbedding; crossbeds dip as high as 25°. True dip of beds approximately flat or very low. Very slight petroliferous odor on fresh fracture.
----		9,850–9,870 ft. Siltstone and very fine-grained sandstone; 30 percent.
----		9,880–9,900 ft. Siltstone and very fine-grained sandstone; 30–35 percent.
----		9,970–10,000 ft. Siltstone and very fine-grained sandstone; 25–40 percent.
85	10,009–10,029	Recovered 20 ft: Microfossils very rare. Siltstone, medium-light to medium-dark-gray, color depending on amount of argillaceous material present; grades into very silty clay shale on one hand and sandy siltstone on the other. Contacts not very sharp, as in core 84. Some soft-rock flowage indicated. Shaly streaks are micaceous and carbonaceous (small plant fragments); very slightly calcareous.
----		10,050–10,080 ft. Sandstone, medium-light-gray, fine-grained, very slightly calcareous to noncalcareous; 50–70 percent; grains subangular to subrounded and are 80 percent white and clear quartz; argillaceous matrix.
----		10,200–10,210 ft. Siltstone, sandy; 25 percent.
86	10,233–10,253	Recovered 15 ft: Microfossils rare. Interbedded siltstone, clay shale, and a very small amount of sandstone as in core 84. Clay shale, 30 percent, micaceous and carbonaceous. Siltstone very slightly calcareous; has many clay partings and excellent small-scale crossbedding; beds essentially flat lying. At 10,250 ft effective porosity 3.4 percent, and rock is impermeable; carbonate content 16.06 percent by weight.
----		10,280–10,300 ft. Siltstone, sandy; 25 percent.
----		10,310–10,340 ft. Siltstone, sandy; 20–30 percent.
----		10,360–10,380 ft. Siltstone, sandy; 25 percent.
----		10, 380–10,390 ft. Clay shale, medium-dark-gray; and 30–50 percent medium-light-gray silty very argillaceous very fine-grained sandstone; contains altered feldspar (?). A few chips of bluish-gray clay shale, kaolinitic or bentonitic (?). These chips occur very rarely in ditch samples down to 10,600 ft.
----		10,390–10,400 ft. Clay shale, medium-dark- to dark-gray. Shale is slightly darker below this point.
87	10,453–10,473	Recovered 2 ft 8 in.: Microfossils very rare. Siltstone, medium-light-gray to medium-gray, hard, sandy, argillaceous; made up primarily of white quartz and mica, chlorite, and other alteration products, also contains numerous soft black carbonaceous particles and plant remains; is interbedded with medium dark-gray to dark-gray micaceous carbonaceous clay shale (10 percent of total recovery) small amount of small-scale crossbedding. Clay shale not quite as hard as siltstone. Siltstone silghtly to moderately calcareous. Dip of beds 2°. Effective porosity 2.8 percent and air permeability 9 millidarcys (plug chipped); carbonate content 15.67 percent by weight.
----		10,500 ft. Between 10,500 and 10,870 ft the rock is mostly clay shale, medium-dark- to dark-gray, slightly micaceous; one chip of shale containing rounded grains of quartz, medium to coarse, in each sample from the following depths: 10,490–10,510, 10,630–10,640, and 10,860–10,870 ft. Very small amount of carbonaceous material or bitumen; also very rare pyrite. Siltstone is in some places medium-olive-gray and has a glassy glittering appearance. Very rare chips of siltstone or sandstone mottled with brown specks (iron oxide?). These slight differences in composition suggest a gradation from, or perhaps reworked, material from the *Aucella* zone below.
----		10,580–10,590 ft. Sandstone and siltstone, medium-light- to medium-dark-gray, very dirty; argillaceous matrix; 30 percent.
88	10,669–10,682	Recovered 8 ft: Microfossils very rare. Interbedded siltstone and clay shale,

Lithologic description—Continued

Core	Depth (feet)	Remarks
		about 60 percent clay shale and silty clay shale and 40 percent siltstone. Clay shale, silty, medium-dark-gray; numerous small shiny black carbonaceous flecks; fair shaly cleavage. Siltstone, medium-light-gray to medium-gray, hard, argillaceous; contains rare streaks of very fine sand and a few black carbonaceous plant impressions; probably has very low porosity and permeability. Some contacts between shale and siltstone are sharp, others gradational; dip 5°–20°; higher dips are probably crossbedding. Fair petroliferous odor in some of silty sections; no cut in CCl_4 from sample taken 4 ft from top.
----		10,840–10,850 ft. Siltstone, sandy; 20 percent.
----	10,880–11,872	Clay shale, medium-dark-gray to grayish-black, micaceous; contains well-rounded, slightly frosted, brownish-clear quartz grains up to very coarse embedded individually or in streaks in shale. Also traces of siltstone and very fine-grained sandstone, medium-light to medium-olive-gray, micaceous. Medium-olive-gray siltstone and sandstone are very tight and have glassy sheen in hand specimen. Pyrite rare to common. Cores and variations are described below.
		10,880–10,890 ft. Clay shale, grayish-black. Top of the Upper Jurassic(?) and Lower Cretaceous(?) is at 10,880 ft.
----		10,890–10,992 ft. Clay shale fragments containing glauconite (?), well-rounded quartz grains, and rare pyrite. Trace to 10 percent medium-gray sandstone and siltstone.
89	10,992–11,007	Recovered 4 ft 6 in.: Microfossils rare. Siltstone and clay shale interbedded in very thin laminae. Clay shale, 70 percent of recovery, silty, dark-gray to grayish-black, moderately hard; breaks irregularly parallel to bedding, plates of mica lying parallel to bedding are very prominent in hand specimens. Siltstone, 30 percent of recovery, medium-dark-olive-gray; 98 percent quartz, angular to subangular, some very fine sand grains; no megascopic carbonaceous material noted. Siltstone occurs as very thin laminae, irregular lenses, and nodules in clay shale. Slight change in lithology from core 88. The following features are noted: Clay shale in core 88 is lighter in color and lacks the prominent mica plates (although mica is present). Clay shale in core 88 is slightly harder than in 89. Sandy siltstone of core 88 is composed of subangular to subrounded quartz and dark mineral grains; quartz is clear, some slightly frosted, giving a milky appearance (hence, a lighter color to the whole sample). Siltstone of core 89 is finer grained, better sorted, almost all more angular quartz, and has a vitreous luster. Clay particles lodged in reentrants of quartz grains give grains a darker olive-brown cast and probably account for darker color of siltstone as a whole. Noncalcareous; no shows; beds essentially flat lying. Several casts of *Aucella sublaevis* Keyserling and other pelecypods were found 1 ft from bottom.
		11,010–11,140 ft. Glauconite (?), very rare; well-rounded quartz grains rare; large chips of pyrite rare to common.
		11,140–11,270 ft. Rounded quartz grains very rare. Pyrite rare to common.
		11,270–11,280 ft. Chert, one dark granule, one chip of sandstone with well-rounded grains of quartz containing some glauconite (?).
		11,280–11,320 ft. Pyrite abundant.
		11,320–11,330 ft. Sandstone with rounded grains and glauconite (?) very rare.
		11,330–11,510 ft. Rounded quartz grains very rare; traces of glassy-looking siltstone and very fine-grained sandstone. Pyrite abundant.
		11,510–11,520 ft. Rounded pebble of very dark-gray chert.
		11,520–11,530 ft. Clay shale fragment bearing *Aucella*-like rib impressions.

Lithologic description—Continued

Core	Depth (feet)	Remarks
		11,530–11,620 ft. Siltstone and very fine sandstone, medium- to medium-olive-gray, micaceous, glassy in part; trace. Rare to common rounded quartz grains up to very coarse size. Pyrite rare to common. 11,620–11,630 ft. Quartz, one granule. 11,630–11,680 ft. Siltstone, trace; rounded grains very rare. 11,680–11,690 ft. Clay shale, one chip, grayish-black, containing white vein-quartz grains. 11,690–11,852 ft. Siltstone and sandstone, trace, rounded grains, medium- to coarse-grained. Pyrite rare.
90	11,852–11,872	Recovered 3 ft 4 in.: Microfossils absent. Silty sandstone and siltstone 80 percent, and clay shale 20 percent of total recovery. Sandstone and siltstone, medium-olive-gray, very hard, tight, moderately calcareous; argillaceous and (or) calcareous matrix; rock sample has slight quartzitic glassy sheen, very fine grained and composed almost entirely of glassy, clear and brownish-clear subangular quartz. Mica plates scattered throughout: large pyrite nodule present. Bedding irregular and cut by a few minute faults with about ¼-in. displacement. Clay shale, grayish-black, irregularly interbedded with very thin laminae and lenses of siltstone; clay shale, moderately hard; contains abundant isolated plates of mica; clay shale and the sandstone and siltstone are identical with that in core 89; flat lying to 10° dip. Well geologist reports core bled slight amount of gas.

CORE ANALYSES

The porosities in the following table were determined by the Barnes (vacuum) method, and the air permeabilities were measured with a Hayward Permeameter in the U. S. Geological Survey laboratory.

Core analyses of Oumalik test well 1

Core	Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)	Carbonate content (percent by weight)
4	921 P [1]	8.55	<5	22.1.
	921 N [2]	9.48	<5	
6	979–984	15.25	34	15.1.
8	989–994 P	13.15	9.7	20.4.
	989–994 N	13.43	5.6	
13	1,201 P	3.42	<5	28.3.
	1,201 N	2.44	<5	
17	1,606 P	10.94	8.8	Not tested.
18	1,614 P	10.35	<5	Do.
	1,614 N	9.92	<5	
19	1,622 P	9.85	<5	Do.
	1,622 N	9.45	<5	
20	1,634 P	7.92	<5	Do.
	1,634 N	8.09	<5	
23	1,966 P	.42	<5	47.0.
	1,966 N	.36	<5	
24	2,154 P	3.43	<5	19.9.
	2,154 N	3.83	<5	
28	2,756 P	1.78	<5	Not tested.
	2,756½ P	3.74	(3)	7.8.
----	3,240–3,244	18.00	(3)	10.2.
42	3,250 P	1.59	<3	24.3.
43	3,260 P	9.20	<4	14.2.
47	3,494 P	14.05	4.9	Negligible.
	3,495 P	14.36	(3)	Not tested.
52	3,752½ P	12.02	<1	Do.
	3,755 P	6.08	1	Slightly calcareous.
82a	9,278–9,296 P	6.67	0	12.2.
	9,278–9,296 N	9.82	0	
82b	9,278–9,296 P	5.92	0	12.3.
	9,278–9,296 N	11.47	0	
83	9,540 P	4.20	0	17.4.
	9,540 N	5.14	0	
	9,550 P	5.10	0	13.8.
	9,550 N	10.10	0	
84	9,830 P	2.94	0	12.8.
86	10,250 P	3.47	0	16.0.
87	10,453–10,473 P	2.81	9	15.6.

[1] P, parallel to bedding.
[2] N, normal to bedding.
[3] Sample unsuitable.

Paul D. Krynine (written communication) made a preliminary appraisal of nine porosity and permeability specimens from Oumalik test well 1. He concluded that all the sandstones represent poor or inadequate reservoir rocks except the sample from 974–984 feet which could be classified as fair.

The reservoirs are poor because of the excessive amount of carbonate (calcite and particularly dolomite) cement present. Furthermore, in all but three samples,

the primary pore pattern is unfavorable, because well over 60 percent of the pore wall area is coated with clay. The three samples which have a fair primary precementation pore pattern are those from 921, 979–984, and possibly from 3,250 feet, all of which would have had a higher porosity were it not for the carbonate in the matrix. The following table gives the reservoir characteristics estimated by Krynine.

Estimated reservoir characteristics [1]

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)	Mode of sand grains (microns)	Matrix (percent)	Cement (percent)	Mode of visible pores (microns)	Visible pores (percent of rock volume)	Wall area clay coated (percent)	Type of reservoir
921	9.4	<5	14	<5	30	40	3	20	Inadequate.
979–984	15.2	34	15	5–10	10	45	4	50+	Fair.
989–994	13.1	9.7	10	15+	25	30	3	75	Very poor.
1,201	3.4	<5	6–7	10+	40	20	2−	70	Inadequate.
1,622	9.8	<5	9	15+	10–15	25	2+	65+	Inadequate.
1,966	.42	<5	6	?	65	0	0	50	Inadequate.
2,154	3.8	<5	11	10+	20+	15	----------	65	Inadequate.
3,250	1.5	<3	14	<5	15–20	30	----------	50+	Inadequate.
3,260	9.2	<4	8	10−	10−	15	3+	70	Inadequate.

[1] Possible error ±25 percent of each value.

Additional analyses shown in the following table were made by S. T. Yuster. He says (written communications, 1950)—

The top two samples from Oumalik test well No. 1, while containing some oil, are interbedded with shale and coal and no permeabilities or porosites could be run. With the exception of sample (core) 24 at 2,156 feet, the permeabilities were quite low. The high permeability of 580 is followed with a question mark since some slight cracks were noted in the sample. The oil saturation on the sands is quite low with the exception of the bottom three samples. These had very low water saturations and oil saturations around 30 percent. It is believed that the relatively low permeability would give poor productivity.

Supplementary core analyses, Oumalik test well 1

Core	Depth (feet)	Porosity (percent)	Oil saturation (percent)	Water saturation (percent)	Permeability (millidarcys)
24	2,152	15 [1]	32.4	16.2	--------
24	2,154	15 [1]	23.9	9.6	--------
24	2,156	9.5	15.0	32.5	580(?)
24	2,158	6.0	19.4	42.0	.08
28	2,756–2,757	5.9	None	33.3	.06
42	3,244–3,254	8.0	None	17.2	.08
42	3,244–3,254	16.3	5.2	29.0	.23
43	3,254–3,262	15.1	None	21.8	3.6
43	3,254–3,262	13.5	None	25.5	.67
47	3,490–3,500	15.0	None	25.9	1.14
47	3,490–3,500 (2.3 feet from core top).	15.4	31.5	5.7	.82
47	3,490–3,500 (3.2 feet from core bottom).	16.3	29.2	3.8	4.08
47	3,490–3,500 (2.2 feet from core bottom).	16.3	27.1	4.2	2.8

[1] Assumed.

OIL AND GAS

OIL AND GAS SHOWS

The following table presents the oil and gas shows as reported from the rig site by Arctic Contractors.

Oil and gas shows, Oumalik test well 1

Depth (feet)	Showing	Remarks [1]
960–1,000	Oil, slight	Formation test 1, 968–1,011 ft.
1,028–1,033	Oil, very slight	
1,603–1,637	Oil, very slight	Formation test 2, 1,607–1,637 ft.
1,670–1,740	Gas, very slight	
2,144–2,157	Odor, very slight	
2,740–2,757	Gas	45 psi casing pressure with blowout preventers closed at 2,756 ft.
2,762–2,767	Gas	Formation test 3, 2,762–2,767 ft.
2,762–2,851	Gas	Formation test 4, 2,762–2,851 ft.
3,240–3,263	Gas, good	1,375 psi casing pressure with blowout preventers.
2,762–3,498	Gas, good	Formation tests 5, 6, and 7, 2,762–3,498 ft.
3,484–3,503	Oil	
3,737–3,808	Oil	
10,791–10,829	Gas, very good	

[1] See list of formation tests, page 44, for additional information.

Cuts made in the U. S. Geological Survey Fairbanks laboratory from samples from Oumalik test well 1 are described in the following table.

Test for oil stain in CCl_4, Oumalik test well 1

Core	Depth (feet)	Cut	Residue
4	921	Very pale straw colored	Very pale yellowish.
5	968–979	Pale straw colored	
6	979–984	Pale straw colored	
7	988	Straw colored	Brownish yellow.
8	991	Very pale yellow	Yellow.
19	1,622	Very pale straw colored	Very pale yellow.

Test for oil stain in CCl_4, *Oumalik test well 1*—Continued

Core	Depth (feet)	Cut	Residue
27	2,531	Pale straw colored	Pale yellow.
28	2,756½	None	None.
---	3,240–3,244	None	Very pale yellow.
42	3,251	Pale straw colored	Pale yellow.
43	3,260	Straw colored	Pale yellow.
52	3,752½	Pale straw colored	Very pale yellow.
52	3,755	None	Greasy film.
53	3,805	None	Very pale yellow.
82	9,278–9,296	None	None.
88	10,669–10,689	None	Greasy film.

FORMATION TESTS

Test 1, 968–1,011 feet.—A Johnston formation tester was run on a 5½-inch drill pipe, dry, and a tapered packer was set on the shoulder (15½-in. hole to 968 ft and 8¾-in. hole at 968–1,011 ft) at 968 feet with perforated tail and pressure bomb to 992 feet. The valve was tripped, and the packer held. There was a weak blow of air for 4 minutes 20 seconds which decreased gradually and ceased after 17 minutes and 30 seconds. The tester was open 33 minutes. The tool was pulled, and a 3-foot rise in the drilling fluid was noted. The chart showed the valve was open, and the test satisfactory.

Test 2, 1,607–1,637 feet.—A Johnston formation tester was run on the 5½-inch drill pipe, and a tapered packer was set on the shoulder (13⅜-in. casing to 1,218 ft; 12¼-in. hole, 1,218–1,403 ft; 10⅝-in. hole, 1,403–1,604 ft; and 8¾-in. hole, 1,604–1,637 ft) at 1,604 feet and was worked down to 1,607 feet. The valve was tripped, and the packer held. There was a weak puff of air when the tool was opened, but the hole was dead for the remainder of the test. The tool was open 35 minutes. When the tool was pulled, 15 feet of drilling mud was recovered.

Test 3, 2,762–2,767 feet.—A water shutoff test on the shoe of the 10¾-inch casing proved dry. With the 10¾-inch casing cemented at 2,762 feet and the shoe drilled out with a 9⅝-inch bit to 2,767 feet, a Johnston formation tester was run on the 4½-inch drill pipe, dry. An Olympic-type casing packer was set in the 10¾-inch casing at 2,749 feet with a perforated tail and two pressure bombs to 2,761 feet. The valve was tripped satisfactorily, and a fair blow for 1 hour 40 minutes with gas to the surface in 35 minutes was recorded. The tool was closed for 20 minutes, and the recorder indicated a pressure build-up to 100 psi at the end of the period. On pulling the tool, 20 feet of drilling fluid was recovered. A sample of gas was taken 20 minutes after the gas reached the surface (55 minutes after the tool was opened).

Test 4, 2,762–2,851 feet.—The hole was cored with 8¾-inch core barrel from 2,767–2,851 feet and reamed with 9⅝-inch bit in the same interval. A Johnston formation tester with Olympic-type casing packer was run on the 4½-inch drill pipe, dry. The packer was set in the 10¾-inch casing at 2,756 feet with perforated tail and two pressure bombs to 2,768 feet. The valve was tripped satisfactorily, and a weak blow for 1 hour with gas to the surface in 55 minutes was recorded. The tool was closed in at the surface for 30 minutes, and the surface pressure increased slowly to 7.5 psi. The valves at the surface were opened for a second flow test in which there was a fair blow of gas for the duration of the 42 minute period. Two samples of gas at atmospheric pressure were taken. The tool was then closed for 1 hour 4 minutes, and the recorder indicated a pressure build-up to 1,700 psi. The tool was pulled, and 107 feet of gas-cut drilling fluid was recovered.

Test 5, 2,762–3,498 feet.—With a cement plug in the 9⅝-inch hole below 3,498 feet, the Johnston formation tester with an Olympic-type casing packer was run on the 4½-inch drill pipe, dry. The packer was set in the 10¾-inch casing at 2,551 feet with 452 feet of 2½-inch tubing tail with the bottom 21 inches perforated and two pressure recorders to 3,003 feet. The valve was tripped satisfactorily, but there was no blow at the well head. The tool was pulled and found plugged with sand and gravel and fragments of cement. The test was unsuccessful.

Test 6, 2,762–3,498 feet.—The mud was conditioned and tester run as before with the packer set at 2,525 feet. After setting the packer and tripping the valve, gas was noted working in the annulus between the 4½-inch drill pipe and the 10¾-inch casing. This gas was observed throughout the test. There was a weak blow for 1 hour 20 minutes, but the hole was dead for the remainder of the test. The valve was open 3 hours and 10 minutes. The tool was pulled, and a fluid rise of 2,434 feet was noted. One pressure recorder was lost in the hole. The test was considered unsuccessful. It was assumed the packer was not properly seated because of cement on the casing walls.

Test 7, 2,762–3,498 feet.—The walls of the 10¾-inch casing from 2,540–2,762 feet were cleaned with a 9⅝-inch bit. The Johnston formation tester was run as before but with one pressure recorder. The packer was set at 2,736 feet with 431 feet of 2½-inch tubing below and 21 feet of perforated pipe at the bottom. The valve was tripped satisfactorily, and the packer held. No gas was noted in the mud in the annulus between the 4½-inch drill pipe and the 10¾-inch casing. There was a fair blow for 2 hours decreasing during the third hour, and the hole was dead by the end of the

fourth hour. A wireline core barrel was run through the mud inside the drill pipe as a swab, and the mud was agitated for 7 hours. The valve remained open 17 hours. The packer was pulled loose and was started out of the hole. Gas expanding in the 4½-inch drill pipe made a head. Mud was circulated down through the tester for 3 hours, and the tool was pulled out of the hole. Gas volume from the formation was insufficient to clear the mud from the drill pipe.

GAS ANALYSES

The following table contains analyses of gas samples from Oumalik test well 1 made by several organizations.

Gas analyses (mol percent), Oumalik test well 1

Sample	Date collected	Depth from which obtained (feet)	Composition									Btu/cu ft
			Methane	Ethane	Propane	Butanes	Pentanes and heavier	CO_2	Argon	Helium	Others	
	1949											
1 [1]	Sept. 23	2,761	96.20	2.54	0.28	0.24	0.10	0.01	--------	0.21	0.42	1,025
2 [1]	Sept. 27	2,762–2,851	96.20	2.69	.36	.24	.19	--------	--------	--------	.32	1,031
3 [2]	Sept. 27	2,851	96.6	2.7	.4	0.3		Tr.	--------	--------	--------	--------
4 [2]	Oct. 3	2,762–3,240	95.8	3.1	.8	.3		Tr.	--------	--------	--------	--------
5 [1]	Oct. 3	3,240	95.40	3.20	.74	.29	.20	--------	--------	--------	.17	1,048
	1950											
6 [1]	Feb. 12	10,449	95.3	1.90	.28	.09	.07	1.68	--------	--------	.73	--------
7 [3]	?	Deep(?)	93.93	1.87	.29	--------	--------	1.73	0.03	.01	2.14	992

[1] Analyses by the National Bureau of Standards, Washington, D. C.
[2] Analyses by the U. S. Bureau of Mines, Amarillo, Tex.
[3] Analysis by the Smith-Emery Co., Los Angeles, Calif.

QUANTITY OF GAS

The gas pressure at Oumalik is high, but the sandstones are thin, with low porosity. As flow tests obtained on the sands in this well are inconclusive, the value of the field as a gas producer is questionable. It is believed that there is sufficient gas present in the sands above 2,760 feet to furnish fuel for a camp and a rig boiler, but commercial production is doubtful.

LOGISTICS

Transportation.—The bulk of the equipment used in drilling Oumalik test well 1 was moved from Barrow to the well site by Caterpillar-tractor-drawn train during January, February, and March of 1949. During the summer months it became necessary to transport heavy items, principally mud treating materials, by LVT caravan. In the fall of 1949 a 3,000-foot runway was prepared on a frozen swamp near the rig site and C–46 and C–47 aircraft were used. The total tonnage hauled in by "cat" and LVT train amounted to 4,288 tons; 100 tons were carried by airlift.

Housing.—The camp, located on the crest of a rise northwest of the rig, consisted of 5 quonset huts (3 sleeping quarters, 1 messhall and galley, 1 oilfield warehouse), 1 Jamesway sleeping hut, and 14 wanigans. Of these wanigans, 5 were used for sleeping, 1 latrine, 1 utility, 1 power house, 1 boiler, 1 for the petroleum engineer and geologist, 1 shop, 2 for mud storage, and 1 for the Schlumberger equipment. Quarters, galley, and warehouse were connected to the rig house by a boardwalk approximately 500 yards long.

Personnel.—While the hole was being drilled, a total of 30 men made up the permanent complement of the camp. This included, 1 drilling engineer, 1 petroleum engineer and 1 geologist as supervisory personnel; 2 drillers, 2 derrickmen, 6 floormen, 2 firemen, 2 heavy-duty-equipment mechanics, and 1 oiler as rig crews; and 2 cooks, 2 cook's helpers, 2 bulldozer operators, 1 bull cook, 1 combination storekeeper and first aid man, 1 warehouseman, 1 welder, 1 electrician, and 1 carpenter as camp maintenance crew.

During the construction period, rig builders, carpenters, crane operators, laborers, electricians, plumbers, and mechanics were present. During the drilling operations, an electric log operator, cementer and tester, extra carpenters, electricians, and laborers were sent out from Barrow as needed.

Vehicles and drilling equipment.—The vehicles used at the test site consisted of the following: 2 weasels, 1 LVT (landing vehicle, tracked), 1 D–8 Caterpillar with blade, 1 D–6 Caterpillar with blade, 1 TD–9 small crane (cherrypicker), and 1 Northwest crane.

The amounts of the major items used in drilling by Arctic Contractors were as follows:

1 ..... 136-foot Ideco derrick.
1 ..... 350-ton Ideco crown block, six 48-inch sheaves.
1 ..... 350-ton Ideco traveling block, five 48-inch sheaves.
1 ..... Byron-Jackson Super Triplex hook, ser. 4300.
1 ..... Wilson Super Titan drawworks.
3 ..... General Motors quad 6 diesel engines.
2 ..... C–350 National mud pumps.
2 ..... Link-Belt 48 x 60-inch mud shakers.
1 ..... Ideco rotary table, ser. HS–23–B.
1 ..... Ideal R–3 swivel.
1 ..... Cameron QRC blowout preventer.
1 ..... Hydril GK blowout preventer.
1 ..... Shaffer double-gate blowout preventer.
3 ..... 150-barrel mud tanks with ditches.
3 ..... 250-barrel storage tanks (1 water, 2 mud).
1 ..... 90-barrel "pill" tank.
1 ..... Kewanee boiler, 75 hp.
1 ..... Halliburton cementing unit.
1 ..... Schlumberger electric logging unit.

Fuel, water, and lubricant consumption.—The materials used while drilling the test were as follows: 330,361 gallons of diesel fuel, 5,743 gallons of gasoline, 1,926,943 gallons of water, 1,130 pounds of grease, 1,520 pounds of thread lubricant, 1,002 gallons of No. 9110 lubricant, SAE 10, 2,514 pounds of No. 9170 lubricant, SAE 20, and 403 pounds of No. 9500 lubricant, SAE 50.

DRILLING OPERATIONS

RIG FOUNDATION

The swampy surface at the site of Oumalik test well 1 presented numerous problems of foundation installation and necessitated unusual precautions to prevent thawing of the permafrost and subsequent settling of the rig. After detailed studies were made of permafrost reaction to heat transfer, steel piling was designed with a system to circulate a refrigerant to keep the ground frozen. Arctic Contractors (written communication, November 1950) described the installation as follows:

Analysis of the allowable substructure loads resulted in the selection of 8⅝-in. steel piling as the means of transferring the loads to the ground. In order to attain positive control over the frost zone the piling was designed to permit circulation of a refrigerating fluid (diesel oil). Insurance against radial thawing from the well hole was gained by inserting a galvanized steel heat-emissivity shield in the annulus between the 13⅜-in. and 22-in. casing. The shield, 18 in. in diameter, extended from the cellar to a depth of 219.19 ft and was landed on top of a packer set between the 22-in. and 13⅜-in. casing. A circulating joint in the 13⅜-in. casing was located immediately above the packer to permit the draining of fluids from the annulus between the 22-in. and the 13⅜-in. casings. A special manifolding ring for circulating refrigerant through the annulus between the 22-in. and the 13⅜-in. casing was fabricated at Barrow. Three refrigeration wells 4 inches in diameter were installed to a depth of 240 ft. at a distance of 5 feet from the well center line. Refrigerant was circulated through these wells to prevent thawing from the hole. As further insurance against possible delay caused by thawing, a beam fabricated from 10¾-in. casing was installed beneath the cellar floor. This beam was also refrigerated.

The subsurface temperatures were obtained by means of a system of thermocouples, and temperature readings were logged at three day intervals. The subsurface temperature showed a steady increase from June 10, 1949, when the rig was put into operation, and on Dec. 3, 1949, circulation was started through those areas which were considered critical. Circulation continued until April 29, 1950. Concurrent thermocouple readings indicated that the system was capable of maintaining the ground at the desired temperature. The rate of heat transfer ranged from 4 tons to 50 tons of refrigeration per day. Cooling of the refrigerating fluid was accomplished by pumping the oil through a fan-equipped radiator located outside the righouse. The amount of refrigeration available depended upon the ambient air temperature which varied during the period from a high of plus 20° F. to a minimum of minus 53° F. [See pl. 2.]

Although the original cost of labor and material was high, the operation was satisfactory as no settling was observed. By steaming, this type of pile can be recovered for future use.

DRILLING NOTES

The following table contains selected notes from the drilling records of the Arctic Contractors' petroleum engineer.

Notes from drill records

Depth (feet)	*Remarks*
0	Well spudded in on June 11, 1949.
5	Casing set; 28¾-in. outer diameter (28-in. inner diameter) shop-made, 3.8-in. roll plate with plain ends installed with cellar floor support truss. Flush with cellar floor at top and 5 ft long.
247.5	Casing set; 22¾-in. outer diameter (22-in. inner diameter) shop-made, ¾-in. rolled plate welded, slip joint casing with drive shoe on bottom. Cemented with 200 sacks Hi-Early cement treated with 2 percent $CaCl_2$. Found cement bridge in pipe at 128 ft. Drilled out with 21-in. bit, taking core 1, 160–180 ft; recovered 15 ft of cement.
1,215	Drill collar twisted off at 960 ft while reaming. Ran overshot and recovered fish. Drill collar had broken off below box.
1,221	Pulled bit minus two cones. Wore out three 9⅝-in. Globe baskets trying to recover cones and wore out two 9⅝-in. W7R bits milling on fish.
1,229	Had trouble running 13⅜-in. casing to bottom of hole. While opening hole, twisted another drill collar off at 525 ft. Recovered fish after 15 hr. Installed 18-in. emissivity shield from cellar floor to top of 22-in. packer at 219 ft. Set

Notes from drill records—Continued

Depth (feet)	Remarks
	casing at 1,218 ft; 13⅜-in. outer diameter (12.615-in. inner diameter), 54.4 lb, API seamless, grade J-55, range 2, 8 round thread, long T and C, with Baker guide shoe and Baker float collar. Cemented with 317 sacks of Oil Well Regular cement treated with 2 percent $CaCl_2$. Float collar at 1,185 ft; 22-in. packer and circulating joint at 219 ft. Circulating joint was later removed and replaced with die collar connection.
1,803	Threads on 5½-in. kelly-cock badly galled. Replaced 5½-in. kelly with 3½-in. kelly; 5½-in. kelly was repaired in Barrow shop.
2,024	Twisted off drill collar leaving sub and bit in hole. Recovered fish.
2,356	Weld between the 13⅜-in. casing and the Baash-Ross landing head broke. Removed blowout preventers and sent landing head to Barrow shop where it was rewelded.
2,529	Circulation broke between 13⅜-in. and 22¾-in. casings, mud returning to cellar inside of 22¾-in. casing. Removed blowout preventers. Cut away supports for flange on 13⅜-in. casing and casing dropped 10 in. Tried four times to close circulating joint but was unsuccessful.
2,760	Well started to blow gas. Treated and eventually raised mud weight to 113½ lb per cu ft to maintain positive control of the gas. Set cement plug at 303 ft. Pulled 13⅜-in. casing from 222 ft where it had parted in middle of circulating joint. Four joints of casing were in bad condition; one joint bent, rest had flattened ends. Bailed down to 237 ft. Ran 13⅜-in. casing with die nipple and wooden guide. Screwed into top of 13⅜-in. casing—withheld 40 tons test. Cemented with 100 sacks of cement treated with 2 percent $CaCl_2$. Welded Baash-Ross base to 22¾-in. casing and grouted it into cellar floor. Installed control gates. Found joint still leaking.
2,762	Set casing 10¾-in. outer diameter (9.76 inner diameter), 55.5 lb, API seamless, grade N-80, range 2, Hydril flush joint with square threads, with 282 sacks Oil Well Regular cement treated with 2 percent $CaCl_2$. Baker float shoe and Baker float collar at top of lower joint.
3,244	Well started to head. Closed blowout preventers and pressure built up to 1,350 psi. Mixed mud to 100 lbs per cu ft and bled pressure off through fill-up line. Circulation established with heavy mud and well killed. No test because of insufficient quantities of weight material.
7,793	Caving shale very troublesome; formations were successfully mudded off.

Notes from drill records—Continued

Depth (feet)	Remarks
8,426–10,838	While drilling and reaming this portion of hole, pump pressures indicated possible washouts. Pulled top 20 to 25 stands and located washed out tool joint boxes on eight different occasions.
10,838	Twisted off drill collar pin. Ran Bowen overshot and recovered fish. Returns from bottom severely gas cut. Increased mud weight to 101½ lbs per cu ft.
11,007	Drill pipe pulled into a key seat and stuck with bottom of core barrel at 3,512 ft. Washed over fish and ran Bowen overshot with jars and bumper sub. Jarred fish in two at top of core barrel, leaving top of fish at 3,491 ft. Washed over fish and fish dropped down hole. Recovered fish. Increased mud weight to 104 lbs per cu ft to limit quantity of gas in bottom returns after round trips. (See pl. 1.)
11,637	Inspected 10¾-in. casing and found top joints were damaged by continuous wear owing to misalinement. Set two cement plugs; backed off and pulled 10¾-in. casing from 302 ft. Reran 10 joints of new 10¾-in. casing and screwed into lower portion. Cleaned out plugs.
11,872	Completed drilling Apr. 6, 1950. Operations suspended Apr. 23, 1950. Completion status: All casing was left in hole. Prior to final testing from 2,752 to 3,498 ft, a cement plug was set at 3,400 to 3,600 ft, but top of plug was found at 3,498 ft. After testing, a cement plug was set at 2,543 to 2,815 ft, and no evidence of gas leaking through the plug was found. A thermistor cable was installed to 730 ft. From cellar floor upward the following equipment was installed: a Baash-Ross landing base, 20-in., Series 600; a spool, 20-in., Series 600, to 12-in., Series 900; a landing spool, 12-in., Series 900, to 10-in., Series 1500; a shop-made head consisting of a plate, 10 in., Series 1500, with two 2½-in. nipples and one 1-in. nipple with 1-in. Nordstrom plug valve; two 2½-in. nipples have packing glands through which thermistor cables run. Hole was left full of mud.
	Coldest outdoor temperature was minus 58°F. Derrick house and heating facilities proved to be sufficient even during coldest weather. Only time lost owing to weather was approximately 12 hr on February 1 and 2 when winds increased to gale force. While drilling in January the bearings on one crown sheave burned out. In enclosed derricks the crown blocks operate under very warm temperatures rather than under Arctic conditions, as the warm air is concentrated at top of derrick.

POWER PLANT

As the diesel engines did not always operate on full load, considerable difficulty was encountered with sticking valves and pistons, requiring frequent cleaning. This condition was aggravated by (1) the tendency of the governors to allow 1 engine to be pulled by the remaining 3, thereby causing that engine to run cold, (2) the comparatively low temperature of the intake air was causing precipitation of heavy ends of the diesel fuel on the scavenging cycle, (3) the low cetane rating of the fuels leaving unburned ends on the power stroke which turned to varnish on the rings and valves. These difficulties were alleviated by the use of additives and later by the use of a different type of diesel fuel and by the development of a new type rotating valve and single-weight governor; also, deeper drilling as the season progressed put more load on the engines.

HEAT TRANSFER CONTROL

Arctic Contractors' petroleum engineer made these further comments (see also p. 46) on heat transfer control—

Landed and cemented 22-inch ID shop-made casing at 247 feet in the normal manner. A special 13⅜-in. circulating joint with a 22-in. packer was constructed and run in the 13⅜-in. permafrost string with packer set at 219 feet in an effort to provide facilities to permit the fluid to be removed from the 13⅜ x 22-in. annulus by bailing fluid down in the 13⅜-in. casing and opening the circulation joint. The air space was intended to provide insulation to prevent the warm mud rising in the 13⅜-in. casing from thawing the frozen ground near the surface. As a further insurance against heat transfer across the air space, an 18 in.-diameter emissivity shield was installed in the 13⅜ x 22-in. annulus.

Special construction required to land the 13⅜-in. string gave considerable trouble with failures at welded points and by the time the hole was deepened to 2,760 ft., it became necessary to replace the circulating joint with a die collar and cement to effect a seal. As high-pressure gas was encountered at 2,760 ft., 10¾-in. casing was run to 2,762 ft. to insure safe operating conditions.

Subsequent experience, as the hole was deepened to 11,872 feet, indicated that such elaborate preparations to prevent thawing of the upper portions of the permafrost were unnecessary. Thermocouple readings immediately adjacent to the casing reflected changes due to warm fluids, but readings obtained a few feet from the hole gave little evidence of temperature variation.

DRILL AND CORE BITS

One hundred and twenty-two drill bits were used at Oumalik test well 1. Some of these, used to drill only short distances, were not worn out and were returned to the warehouse. Hole openers, which were assigned a bit number, were used to set the 13¾-inch and 10¾-inch casings. Drill bits were used for reaming through the smaller sized core hole, although this was not indicated on the graphic logs (pls. 4 and 5) of Oumalik test well 1 and East Oumalik test well 1. Nine sizes of bits and hole openers were used, ranging from 26 to 7⅝ inches. In general, the cutting teeth of most of the bits showed little wear, but worn bearings necessitated retiring the bits.

Reed core barrels were used to do all the coring. Both the drag and rock-type heads were used on two sizes of wire-line barrels, 8¾ and 7⅝ inches. A Kor-King conventional type barrel was also used to take many of the cores. Total footage cored was 920 feet or 7.83 percent of the total of the hole, and the total amount recovered was 549.58 feet or 59.73 percent of the cored footage.

See plate 4 for a graphic summary of both drill and core bits. Drill bits Nos. 9, 12, 13, 21, 22, 34, 35, and 36 were omitted from the plate because they reamed or cleaned out parts of the hole, already penetrated by larger bits.

DRILLING MUD

Rather large amounts of treating material had to be used in the drilling of Oumalik test well 1. Mud treatment presented some problems, and high gas pressures necessitated carrying high mud weights. While drilling the surface hole, fluid returns were not recoverable when circulation thawed an area under the cement mat. The following approximate amounts of mud-treating materials were used:

Baroid	sacks	9, 382
Aquagel	do	462
Quebracho	pounds	8, 675
Sodium tetrapyrophosphate	do	5, 590
Acid pyrophosphate	do	5, 690
Stabilite-8	do	2, 100
Quadrafos	do	2, 253
Sodium bicarbonate	do	2, 830

Appropriate amounts of materials used and depths at which used are contained in the following table.

Drilling mud characteristics and additives

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec. API)	Filtration loss (cu cm per 30 min)	Drilling fluid temperature (degrees F)	Remarks
0–249					Mixed 76 sacks of Aquagel to drill surface hole, added 27 more when circulation broke around mat.
515	72.5	36	17.5	55	Added 2½ sacks quebracho, 2 sacks of sodium tetrapyrophosphate.
540	75	36	17.5	61	
625	75	38	17.5	66	
680	79	39	17	62.5	
735	80	36	15	70	
805	83	43	14.5	64	
850	78	33	13	60	
905	84	39	9.5	60	
935	83	38	9	57	

Drilling mud characteristics and additives—Continued

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec. API)	Filtration loss (cu cm per 30 min)	Drilling fluid temperature (degrees F)	Remarks
957	82	37	11	67	Added 501 lb sodium tetrapyrophosphate, 20 lb Driscose, 16 sacks Aquagel, and 5 sacks Baroid. Hole taking mud, added water at 1,000 ft.
1,005	77	34	11	63	
1,010	73	35.5	16	46	
1,030	74	47	17.5	47	
1,075	74	33	17.5	55	
1,205	73	33	17.5	52	
1,215	79	39	9.5	60	
1,220	82	40	8.5	61	Set 13⅜-in. casing. Added 45 lb Driscose, 50 lb sodium tetrapyrophosphate, and 22 sacks of Aquagel.
1,230	84	43	5.5	72	
1,280	73	36	15	62	Added 100 lb acid pyrophosphate, 50 lb Driscose, 150 lb quebracho, and 10 lb sodium tetrapyrophosphate.
1,390	74	38	15	60	
1,410	76	41	15	55	
1,420	73	39	15.5	60	
1,515	74	35	16.5	64	
1,610	72	35	17	66	
1,635	73	33	15	65	
1,730	72	33	15	63	
1,800	77	33	16	68	
1,880	79	32	15	66	Added 20 lb sodium tetrapyrophosphate and 20 lb quebracho. Twist off fishing at 2,010 ft. Shut down 6 days at 2,350 ft.
1,955	82	36	13.5	73	
2,010	84	----------	14	68	
2,090	85	38	12	68	
2,150	84	39	13	72	
2,170	84	41	13	77	
2,230	82	39	12.5	77	
2,290	84	39	10.5	77	
2,350	85	38	10.5	83	
2,420	84	37.5	9.5	64	Added 10 lb quebracho.
2,490	84	38	9.5	64	
2,530	85	38	7.5	67	
2,590	86	37	7	71	Added 1,525 sacks of Baroid, 9 sacks of Aquagel, and 30 lb of sodium bicarbonate.
2,620	86	40	7.5	70	
2,670	87	38	6.5	73	
2,725	89	39	6	74	
2,760	94	52	55	63	
2,762	----------	----------	----------	----------	Ran casing, well making gas. Added 100 sacks Baroid to replace mud lost testing for leak in casing. Later added 560 sacks Baroid, 9 sacks Aquagel, and 200 lb sodium bicarbonate.
2,790	101	44	4.5	60	Added 85 sacks of Baroid and 750 lb of sodium bicarbonate.
2,830	102	41	4.5	62.5	Added 275 sacks Baroid and 46 sacks Aquagel. Well heading gas at 3,240 ft, killed.
2,870	105	43	4.5	62	
2,920	105	42	4	71	
2,970	105	43	4	70	
3,030	105	46	6	66	
3,085	106	43	6	70	
3,135	107	45	5.5	73	
3,185	103	40	6	73	
3,220	92	38	----------	63	
3,240	88	36	5.5	67	
3,260	98	38	5.5	58	Added 8 sacks Aquagel and 685 sacks Baroid.
3,285	99	39	5.5	61	
3,340	99	38	5	67	
3,400	100	41	5	68	
3,450	100	39	4.5	69	
3,505	100	42	4	65	
3,540	100	42	3.5	65	
3,610	101	43	4	70	
3,655	101	44	4.5	68	
3,700	101	43	4	72	

Drilling mud characteristics and additives—Continued

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec. API)	Filtration loss (cu cm per 30 min)	Drilling fluid temperature (degrees F)	Remarks
3,750	101	46	3.5	63	
3,800	101	44	3	64	
3,860	102	41	3	68	
3,930	102	44	3	72	Added 85 sacks Baroid and 100 lb sodium tetrapyrophosphate.
3,995	102	54	3.5	70	
4,065	102	57	4	69	
4,120	102	49	4	78	
4,180	102	53	3.5	73	
4,280	102	55	3.5	73	
4,385	101	49	3.5	83	
4,430	102	54	3	80	52 sacks Baroid and 50 lb sodium tetrapyrophosphate.
4,610	101	55	3.5	78	
4,670	100	65	4	82	
4,820	101	59	3	81	
4,900	102	56	3.5	82	
4,940	102	69	4	79	
5,030	101	57	3.5	83	
5,140	100	69	3	78	
5,275	100	59	3	84	
5,360	101	69	3.5	83	Added 135 sacks Baroid, 2 sacks quebracho, 1 sack sodium tetrapyrophosphate.
5,395	101	69	3	75	
5,525	101	58	3	84	
5,605	100	60	3	84	
5,765	100	62	3.5	86	
5,850	99	63	3	82	
5,950	99	57	3.5	82	
6,055	99	55	3	86	
6,125	101	48	3	86	
6,205	102	50	3	94	
6,295	101	58	3	93	Added 105 sacks Baroid.
6,370	101	58	3.5	93	
6,500	101	55	3	95	
6,570	102	67	3	92	
6,635	100	66	3	93	
6,670	102	----------	3	86	Added 160 sacks Baroid.
6,745	101	66	3	92	
6,790	100	68	3.5	95	
6,835	101	69	3.5	95	
6,880	99	66	3.5	95	
6,920	98	66	3	92	
6,970	98	60	3.5	93	
7,005	98	66	3.5	93	
7,055	98	64	3	93	
7,080	98	58	3	95	
7,145	98	62	3.5	91	Added 250 sacks Baroid, 400 lb sodium tetrapyrophosphate, and 4 sacks Aquagel.
7,215	98	60	3	94	
7,250	97	58	3	95	
7,315	97	65	3	95	
7,380	98	60	3	93	
7,420	99	68	3	97	
7,455	99	63	3	99	
7,530	97	69	3.5	93	
7,610	99	62	3	97	
7,650	98	65	3	97	
7,680	100	----------	3	91	Added 564 sacks Baroid, 35 sacks Aquagel, 800 lbs of quebracho, 1,050 lb Quadrafos.
7,725	99	60	3	97	
7,770	100	65	3.5	99	
7,790	100	70	4	99	
7,815	98	48	4	90	
7,850	99	47	4	97	Added 54 sacks Baroid, 5½ sacks Quadrafos, 6 sacks quebracho, and 200 lb sodium tetrapyrophosphate.
7,875	98	49	4	100	
7,920	99	46	4	98	
7,990	98	46	4	101	
8,030	99	46	4	98	
8,070	99	45	4	99	
8,090	98	44	4	100	

Drilling mud characteristics and additives—Continued

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec. API)	Filtration loss (cu cm per 30 min)	Drilling fluid temperature (degrees F)	Remarks
8,130	99	46	3.5	97	Added 40 sacks Baroid, 100 lb Dricose, 275 lb Quadrafos, 250 lb quebracho, 5 sacks Aquagel.
8,185	99	46	4	102	
8,230	99	40	4.5	102	
8,285	98	44	4.5	105	
8,325	98	40	4.5	100	
8,375	99	41	4	104	
8,425	99	55	4	107	
8,465	99	46	4	105	Added 40 sacks Baroid, 485 lb sodium tetrapyrophosphate, and 250 lb quebracho.
8,500	99	52	4	100	
8,535	99	47	4	107	
8,590	98	52	4	98	
8,675	99	49	4	110	
8,700	98.5	48	4	109	
8,735	98.5	45	4	106	
8,780	98.5	47	4	110	
8,845	98.5	48	4	110	Added 90 sacks Baroid, 6½ sacks sodium tetrapyrophosphate, 5 sacks quebracho, and 60 lb Stabilite-8.
8,900	98.5	46	4	110	
8,965	98.5	45	3.5	108	
9,015	98.5	48	4	112	
9,035	98.5	49	4	116	
9,075	98.5	47	4	114	
9,110	98.5	48	3.5	115	
9,145	98.5	62	3.5	105	
9,215	98.5	46	3.5	110	
9,260	98	46	4	112	Added 60 sacks of Baroid, 1 sack sodium tetrapyrophosphate, 5 sacks Stabilite-8, and 6 sacks Aeroseal-Q.
9,300	98	58	4	105	
9,390	98	43	4	109	
9,420	98	45	3.5	112	
9,510	98	42	3.5	118	
9,550	98	68	3.5	108	
9,600	98	46	3.5	114	Added 85 sacks Baroid, 180 lb Stabilite-8, 175 lb sodium tetrapyrophosphate, and 300 lb quebracho.
9,640	98	46	4	116	
9,675	98.5	46	3.5	101	
9,720	99	48	3.5	110	
9,745	98.5	45	3	108	
9,790	99	46	3.5	106	
9,825	99	46	3.5	110	
9,895	99.5	50	3.5	111	
9,940	99	48	3.5	102	Added 87 sacks Baroid, 180 lb sodium tetrapyrophosphate, 180 lb quebracho, and 170 lb Stabilite-8.
10,010	99.5	47	3.5	114	
10,035	99.5	48	4	96	
10,090	99.5	48	5.5	110	
10,160	99.5	47	3.5	104	
10,235	99.5	48	3.5	109	
10,310	99	48	3.5	112	
10,360	99	48	3.5	111	Added 75 sacks Baroid, 375 lb Aeroseal-Q, and 625 lb sodium tetrapyrophosphate.
10,400	99	52	3.5	104	
10,455	99	51	3.5	109	
10,485	99.5	50	3	101	
10,560	99.5	50	3	116	
10,595	99.5	49	3	105	
10,670	99.5	46	3	112	
10,700	99.5	53	3	101	
10,770	99.5	47	3	113	Added 360 sacks Baroid, 6½ sacks quebracho, and 6 sacks sodium tetrapyrophosphate.
10,840	99.5	46	3.5	114	
10,895	100	55	4	114	
10,940	102	64	4	118	
10,990	102.5	49	3.5	116	Added 199 sacks Baroid, 770 lb sodium tetrapyrophosphate, 325 lb quebracho.
11,010	103	52	3.5	108	Added 346 sacks Baroid, 575 lb sodium tetrapyrophosphate, 745 lb of acid pyrophosphate, 1,010 lb of quebracho.
11,035	103	55	3.5	102	
11,070	103	57	3.5	106	
11,100	103	59	4	109	
11,140	103	59	3.5	110	
11,175	103	55	4	110	
11,220	104	53	4	110	Added 130 sacks Baroid, 545 lb acid pyrophosphate, 520 lb quebracho, 480 lb Stabilite-8.
11,265	104	55	4	108	
11,325	104	65	4	98	
11,375	104	65	4	104	
11,415	104	55	4	109	

Drilling mud characteristics and additives—Continued

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec. API)	Filtration loss (cu cm 30 min)	Drilling fluid temperature (degrees F)	Remarks
11,460	104	56	3.5	104	Added 140 sacks Baroid, 715 lb quebracho, 150 lb sodium tetrapyrophosphate, 420 lb Stabilite-8, and 200 lb of acid pyrophosphate.
11,510	104	56	3.5	104	
11,560	104	50	3.5	110	
11,610	104	57	3.5	110	
11,640	104	58	3.5	116	Repaired 10¾-in. casing; mud contaminated by cement and some discarded. Added 345 sacks of Baroid, 100 lb of quebracho, and 350 lb of acid pyrophosphate.
11,675	102	61	6	106	Mud badly gas cut. Added 710 sacks Baroid, 650 lb quebracho, 450 lb. sodium tetrapyrophosphate, and 1,600 lb acid pyrophosphate.
11,710	102	58	5	87	
11,740	104	62	4.5	97	
11,800	103	67	4.5	100	Added 250 sacks of Baroid, 325 lb quebracho, 700 lb sodium tetrapyrophosphate, 725 lb acid pyrophosphate, 100 lb Stabilite-8 and 150 lbs Driscose.
11,850	104	66	4.5	100	Added 500 lb Baroid, 675 lb quebracho, 875 lbs acid pyrophosphate, 10 lb Aquagel. Later 145 lb Baroid, 350 lb quebracho, and 250 lb sodium tetrapyrophosphate were added to condition mud for formation tests.
11,872	104	64	4.5	102	

HOLE-DEVIATION RECORD

From the surface to 2,710 feet, the deviation did not exceed 1°30′. From 2,930 to 4,350 feet, the deviation ranged between 2°00′ and 2°30′. From 4,550 to 11,100 feet, the deviation did not reach 2°00′ and was generally less than 1°00′. (See pl. 4.)

KEY SEATS

Concerning the key seats which developed while drilling, Arctic Contractors' petroleum engineer (written communication, November 1950), writes that—

Though Totco readings indicated the hole was relatively straight with maximum deviation equaling 2°15′, considerable trouble was derived from the development of key seats in the section of the hole from the shoe of the 10¾-in. casing at 2,762 to approximately 3,850 feet. This interval contains nearly all the relatively thin sandy strata as indicated by the electric log. It is recognized that fine-grained sand beds tend to cave less than the intervening shale beds, leaving sections where the hole remains nearly to gauge and therefore subject to grooving by pipe and tool joint wear. By exerting considerable caution, the drillers managed to make many trips through the section where key seats were known to exist.

In addition to the time lost on the fishing job at 11,007 feet, the key seats caused severe wear on many tool joints.

ELECTRIC LOGGING AND TEMPERATURE SURVEY

The electric log and temperature surveys run by the Schlumberger Well Surveying Corp. are shown in the following table. No electrical temperature survey was made at the final depth, but maximum temperature readings taken at the bottom of the hole when the various runs were made indicate a temperature gradient of 1.25°F per 100 feet of depth and a bottom hole temperature of 175°F at the final depth.

Electric log runs and temperature surveys

Run	Date	Depth (feet)	Maximum temperature
	1949		
1	June 28	248–1, 013	No reading.
2	July 4	1, 013–1, 221	No reading.
3	Aug. 7	1, 221–2, 541	62°F.
4	Sept. 16	2, 541–2, 764	No reading.
5	Oct. 9	2, 764–3, 699	74°F.
Discarded	Oct. 22	3, 699–5, 131	Short in cable.
6	Oct. 24	3, 699–5, 365	96°F.
7	Dec. 2	5, 365–8, 024	130°F.
8	Dec. 12	8, 024–8, 420	130°F.
	1950		
9	Mar. 4	8, 420–11, 475	175°F.
10	Apr. 6	11, 475–11, 754	175°F.

VELOCITY SURVEY

Seismograph velocity surveys were made on the hole at depths of 5,605 and 11,872 feet in an attempt to obtain a high-velocity break which probably would have been indicative of the limestone of the Lisburne group (Mississippian). However, the highest velocities obtained were on the order of 13,000 feet per second and probably originated in a sandstone-shale sequence. These surveys were made by the United Geophysical Co., Inc.

SUMMARY OF THERMAL INVESTIGATIONS

By Max C. Brewer

A thermal cable, containing 28 thermistors spaced for different depths, was installed in Oumalik test well 1 to a depth of 735 feet on Apr. 22, 1950. The highly viscous mud kept the cable from penetrating to the planned depth of 1,248 feet even though the cable had heavy weights attached just below the bottom thermistor.

The readings taken on Apr. 23, 1950, gave temperatures that ranged from 3.4°C at 227 feet to 11.1°C at 687 feet. The temperatures above 227 feet averaged 4.3°C.

When the site was visited on Aug. 9, 1950, it was found that all the conductors in the cable showed open circuits, indicating that the conductors were broken. The one set of thermal measurements from this well, taken so soon after the completion of the drilling, do not allow for any particularly significant interpretation.

The cable above the ground surface showed no evidence of damage, and it was therefore assumed that the break occurred at some depth below the surface. It was first believed that the well casing collapsed, because the fluid surrounding the casing froze and severed the thermistor cable in the process. This supposition was strengthened by the observation of constriction, near 670 feet in depth, in the tubing recovered from another well, South Barrow test well 2.

More recent evidence has indicated that casing collapse is probably not nearly as frequent as it was assumed to be in 1950. Four sets of cables have been lost under similar conditions since that time. In three sets it was proved that the cables failed because the metal conductors (1) were designed for strength, (2) were brittle as a result of the alloying, and (3) lacked the ductility necessary to stretch as the ice in the casing expanded. In none of these was there casing collapse. No clear cut evidence is available to indicate the presence or absence of casing collapse in the fourth cable loss.

EAST OUMALIK TEST WELL 1

Location: Lat 69°47′29″ N., long 155°32′39″ W.
Elevation: Ground, 277 feet; kelly bushing, 293 feet.
Spudded: Oct. 23, 1950.
Completed: Jan. 7, 1951, dry and abandoned.
Total depth: 6,035 feet.

East Oumalik test well 1 is located on a high ridge above an unnamed creek that flows into the Oumalik River (fig. 4). Topographic relief in the area is about 100 feet; streams are incised.

The exact thickness of the permafrost in this well is not known. Numerous lenses of ice were drilled in both the Gubik formation and the Killik tongue of the Chandler formation. The deepest ice noted by the well geologist in the hole was between 740 and 750 feet. Temperature readings obtained from thermistors, installed in the hole after completion of drilling, are inconclusive.

The following is a list of depths at which the various stratigraphic units are found in East Oumalik test well 1:

Depth (feet)	
16–50	Recent and (or) Gubik formation.
50–730	Chandler formation (Killik tongue).
730–3,050	Grandstand formation.
3,050–5,200	Topagoruk formation.
5,200–6,035 (total depth)	Oumalik formation.

The first 34 feet penetrated by the drill consists of relatively unconsolidated fine sand, silt, and clay of Pleistocene and possibly Recent age. (See pl. 5.) Ostracodes and white shell fragments were found in the well cuttings. Underlying the surficial mantle are 680 feet (50–730 ft) of the nonmarine Killik tongue of the Chandler formation. (See p. 8.) It is predominantly clay shale and coal interbedded with a total of about 80 feet of sandstone and 75 feet of siltstone.

The Grandstand formation, part of the lower marine section of the Nanushuk group, is present between 730 and 3,050 feet. It is differentiated from the Killik tongue of the Chandler formation by the presence of an abundant marine fauna. The highest occurrence of this fauna marks the approximate top of the thickest sandstone section in the Oumalik area. About 600 feet of the total thickness of the Grandstand is made up of sandstone and siltstone. The rest is mostly clay shale. Argillaceous limestone occurs in thin beds between 1,150 and 1,450 feet. Some of this calcareous section may be dolomitic or sideritic, as it reacts slowly with cold dilute hydrochloric acid. A few clay ironstone concretions were noted.

The abundant and varied *Verneuilinoides borealis* microfauna is present throughout, as well as a number of associated megafossils. Although the sandstone beds of the Grandstand formation are the major oil-producing Cretaceous unit in Naval Petroleum Reserve No. 4, they were essentially dry in this test.

The 2,150-foot marine sequence from 3,050 feet to approximately 5,200 feet in East Oumalik test well 1 is correlated with the Topagoruk formation. In this well the formation consists of 95 percent silty clay shale and clay shale and only about 5 percent sandstone. The top of the formation is placed at the base of the predominantly sandy section of the overlying Grandstand formation. The Topagoruk formation also contains an excellent *Verneuilinoides borealis* microfauna.

East Oumalik test well 1 penetrated 835 feet of the Oumalik formation from 5,200 feet to the bottom of the hole at 6,035 feet. It is a medium-gray to medium-dark-gray clay shale, with the latter color predominating. No sandstone and only rare siltstone is present. Pyritic specimens of *Lithocampe*? sp., a radiolarian distinctive of the Oumalik formation, occur below 5,705 feet.

The contact between the Oumalik and Topagoruk formations is placed somewhat arbitrarily at 5,200 feet in the shale section. In general the shale above 5,200 feet is more silty, lighter colored, and contains the *Verneuilinoides borealis* microfauna characteristic of the Topagoruk formation. The angular uncomformity and lithologic break present between the two formations in test holes in the northern part of the Reserve are absent here in the deepest part of the Cretaceous depositional basin where Early Cretaceous sedimentation probably was continuous.

HEAVY-MINERAL STUDIES

Two heavy-mineral zones are recognized by Robert H. Morris in East Oumalik test well 1 (pl. 6), the glaucophane zone and the zoned zircon zone. The glaucophane zone is represented by one sample at 526 feet. Other minerals of the sample from 915 feet have the general characteristics of the glaucophane zone, but glaucophane is absent. The zoned zircon zone is recognized (in four samples) from 1,693 to 3,869 feet.

DESCRIPTION OF CORES AND CUTTINGS

The well cuttings from which the following record was made were of good quality. See plate 5 for a summary of the lithologic material and engineering data. Depths are measured from the top of the kelly bushing.

Lithologic description

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

Core	Depth (feet)	Description
----	0–16	Kelly bushing to ground level.
----	16–30	No samples received.
----	30–50	Ice (reported by well geologist), sand, silt, and clay. Sand, moderate-yellowish-brown, very fine- to medium-grained. Grains subrounded to rounded; 80 percent yellow and yellowish-orange quartz and clear quartz with yellowish cast; 10 percent white and clear quartz, 5 percent black chert and coal; also yellow chert and rare chert of other colors. Some yellowish-gray clay. Rare, white shell fragments and ostracodes.
----	50–90	Clay, yellowish-gray to medium-light-gray, and sand as above. Rare rock fragments, clay ironstone. The top of the Chandler formation is placed at 50 feet.
----	90–106	No samples received.
----	106–126	Sandstone, siltstone, limestone, and clay shale. Sandstone and siltstone, medium-light-gray, very fine- to fine-grained; grains subangular to rare subrounded; 95 percent white and clear quartz, also carbonaceous particles. Clay shale, light-gray; contains carbonaceous particles. Limestone, medium- to medium-dark-gray, argillaceous, lithographic, with veinlets of white crystalline calcite.

Lithologic description—Continued

Core	Depth (feet)	Description
----	126–146	Clay shale, light- and medium-gray with brownish cast. Some sandstone, stiltstone, and vitreous black coal chips.
----	146–156	Sandstone, light-gray, medium-grained, subangular to subrounded; largely white and clear quartz; also carbonaceous particles, some grains of glauconite and yellow quartz.
1	156–166	Recovered 1 ft: Microfossils rare. Material recovered consists primarily of drilling mud containing chips of shale and coal. Clay shale or claystone (?), medium-light-gray to medium-gray, medium-soft; thin laminae (to ¼ in.) of black coal. Rare light-gray sandy to silty shale chips, slightly calcareous. Minutely shattered coal particles; appears to be coal ground up and repacked while drilling. Dip undetermined.
----	166–190	Clay shale, light-gray, also hard dark-gray clay shale that resembles limestone but is only slightly calcareous. Rare vitreous black coal chips. Clay ironstone, light-olive-gray and yellowish-brown, has carbonaceous fragments.
----	190–220	Sandstone grading to siltstone below 200 ft. Sandstone, light-gray, very fine-grained with very fine coaly streaks and carbonaceous partings. Brownish-yellow clay ironstone, plant impressions. Very rare chips of coal.
----	220–240	Clay shale, light-gray, also yellowish-gray silty clay ironstone.
----	240–250	Sandstone, light-gray, very fine- to fine-grained; some grayish-orange clay ironstone.
----	250–270	Sandstone, siltstone, and clay shale, dark carbonaceous partings, noncalcareous.
----	270–280	Clay shale, light-gray and medium-dark-gray.
----	280–310	Sandstone, light-gray, fine- to medium-grained; subangular, 90 percent white and clear quartz, remainder of grains mostly carbonaceous particles; white powdery matrix; numerous carbonaceous partings; noncalcareous, moderately porous to drop test.
2	310–320	Recovered 2 ft 5 in.: Microfossils absent. Siltstone, light-gray, medium-soft and friable, sandy, very argillaceous, "dirty." Some streaks of fine- to medium-grained sandstone; subangular grains, mostly white and clear quartz; very light-gray clayey cementing material. A few laminae of medium-gray clay shale. Rare thin black layers and fragments of coal; noncalcareous; dips probably low; core slightly broken up.
----	320–330	No sample.
----	330–350	Clay shale, light-gray, and some sandstone; thin layers of coal.
----	350–370	Sandstone, fine-grained, siltstone, and clay shale. Some clay shale is dark gray; numerous carbonaceous particles in the sandstone.
----	370–380	Clay shale, light-gray, and much carbonaceous dark-gray shale. Light-gray siltstone. Calcareous shell fragments of pelecypods.
----	380–400	Sandstone, light-gray, fine-grained; quartz with carbonaceous and ironstone particles; plant fragments in partings; slightly calcareous. A small amount of light-gray clay shale.
----	400–410	Clay shale, medium-light-gray, rare coaly particles.
----	410–420	Siltstone, light-gray; black carbonaceous plant fragments.
----	420–430	Clay shale and siltstone; plant fragments.
----	430–460	Siltstone, light- and medium-light-gray, slightly sandy; yellowish-gray clay ironstone chunks. Small amount of grayish-black carbonaceous shale.
----	460–470	Clay shale, medium-light- and medium-gray; rare shiny black coal chips.
----	470–480	Siltstone, clay shale, light-gray and very dark-gray; also coal chips.
----	480–490	Coal (half the sample), dull to vitreous, black. Clay shale, medium-light-gray.
----	490–500	Clay shale, medium-gray, and siltstone; carbonaceous particles.
----	500–517	Coal 60 percent of sample, grayish-black and black, dull to shiny; clay shale, light-olive-gray. Clay ironstone, grayish-yellow.
3	517–527	Recovered 10 ft: Microfossils absent. 5 ft 7 in., clay shale, medium-light- to medium-dark-gray, soft and slightly fissile; tends to break into little chips when dried out, moderate amount of very thin black coaly streaks and carbonaceous fragments. Grayish-yellow clay ironstone concretion (½-in. diameter) from 517½ ft; noncalcareous to slightly calcareous toward base. 4 ft 5 in., sandstone, siltstone, and clay shale, thinly interbedded, becoming progressively sandier toward the bottom of core, medium hard.

Lithologic description—Continued

Core	Depth (feet)	Description
		Clay shale, medium-gray. Siltstone, light-gray. Sandstone, light-gray, fine-grained, subangular, primarily quartz, some coal particles and mica. Partings of carbonaceous and coaly material; some black fragmental carbonaceous plant remains. Two-in. bed of very hard yellowish-gray clay ironstone at base. At 526 ft effective porosity 11.5 percent; impermeable; carbonate content 13.3 percent by weight. Bedding well defined because of changes in composition and color; range of dips (to 15°) suggest crossbedding, dip generally about 5°; sandstone and siltstone slightly calcareous; no oil or gas shows.
----	527–530	Sandstone, light-gray, fine-grained, subangular; white quartz and dark carbonaceous particles, plant impressions, and carbonaceous partings.
----	530–550	Clay shale, medium-light-gray; rare plant impressions; some ironstone; very small amount of coal chips.
----	550–560	Sandstone, light-gray, very fine- to fine-grained. Clay shale, clay ironstone carbonaceous partings.
----	560–570	Limestone and calcareous siltstone, medium-dark-gray, hard. Veinlet of white calcite. Clay shale, medium-light-gray.
----	570–600	Clay shale, medium-light-gray and dark-olive-gray; some dull coaly chips yellowish-gray clay ironstone.
----	600–610	Coal and carbonaceous shale, grayish-black to black, 50 percent. Clay shale, medium-light-gray, clay ironstone.
----	610–620	Clay shale, black and medium-light-gray. Rare coal chips, clay ironstone.
----	620–640	Sandstone, light-gray, fine-grained, subangular to subrounded grains, mostly white and clear quartz; coaly; sideritic; micaceous particles common; carbonaceous partings; slightly to moderately calcareous (possibly dolomitic—reacts slowly but steadily with cold dilute acid.). Some medium-dark-gray siltstone near base.
----	640–650	Siltstone, light-gray, sandy.
----	650–660	Sandstone, siltstone, and clay shale.
----	660–670	Clay shale 60 percent, grayish-black; rare shiny black coal chips; also medium-light-gray clay shale; clay ironstone.
----	670–690	Coal and black shale 40–70 percent, clay shale and clay ironstone, minor fine-grained sandstone.

Lithologic description—Continued

Core	Depth (feet)	Description
----	690–700	Sandstone, very fine-grained, and siltstone; very rare coal chips.
----	700–710	Siltstone 50 percent, light-gray, and medium-light-gray clay shale.
----	710–720	Clay shale 80 percent, and fine-grained sandstone.
----	720–730	Sandstone, light-gray, very fine- to fine-grained, slightly to moderately calcareous. Clay shale, carbonaceous partings.
----	730–740	Clay shale, medium-light-gray. The top of the Grandstand formation is placed at 730 feet.
4	740–750	No recovery.
5	750–755	Recovered 5 ft: Microfossils very abundant.
		Clay shale, medium-dark-gray, very silty, hard; fair cleavage parallel to bedding, light-colored paper-thin layers of siltstone common, particularly in lower third of core; grayish-yellow clay ironstone concretions or lenses at 751 and 752 ft; irregular pyrite nodule at 751½ ft; scattered carbonaceous plant fragments in partings. Siltstone is slightly calcareous; beds are flat lying.
----	755–765	Siltstone and sandstone, light- to medium-light-gray, slightly calcareous.
----	765–775	Clay shale and sandstone.
----	775–795	Sandstone, light-gray, fine-grained, subangular; 75 percent white and clear quartz grains; 10 percent carbonaceous particles; also mica and some yellowish quartz grains; very slightly calcareous; carbonaceous coaly partings.
----	795–805	Siltstone, medium-light-gray, carbonaceous partings.
----	805–865	Clay shale, medium-light-gray, carbonaceous partings and plant impressions. Argillaceous siltstone at 825–835 ft. Chips of coal at 855–865 ft.
----	865–875	Coal, dull to vitreous, black, irregular fracture; 50 percent of sample. Clay shale, medium-light-gray; some pyrite.
----	875–895	Sandy siltstone and clay shale, medium-light-gray; very small amount of coal.
----	895–950	Sandstone, light-gray, fine- to medium-grained (mostly fine), subangular grains, 85 percent white and clear quartz; carbonaceous particles and mica common.
6	950–956	Recovered 6 ft: Microfossils absent.
		Siltstone and clay shale, interbedded. Clay shale, medium-light- to medium-gray, hard; good cleavage paral-

Lithologic description—Continued

Core	Depth (feet)	Description
		lel to bedding. Siltstone, light-gray, hard, grades very rarely into very fine-grained sandstone; slightly calcareous. Excellent small-scale crossbedding (laminae to one-quarter of an inch) at 951 ft, "swirly" bedding at 951½ ft. Lenses and irregular beds with dips to 20° (large-scale crossbedding) at 953 ft; dip generally about 4°.
----	956–960	No sample.
----	960–980	Clay shale, medium-light-gray, and sandstone; carbonaceous partings; grayish-yellow clay ironstone.
----	980–1,040	Sandstone, light-gray, very fine- to fine-grained, and clay shale.
----	1,040–1,050	No sample.
----	1,050–1,080	Clay shale and sandstone, slightly calcareous.
----	1,080–1,100	Coal, 40–80 percent of samples, vitreous, black, and clay shale, medium-light-gray. *Inoceramus* prisms.
----	1,100–1,110	Siltstone, medium-light-gray; contaminated by cement.
----	1,110–1,140	Clay shale, medium-light- to medium-gray, moderately calcareous; rare plant impressions; brownish-gray clay ironstone 1,130–1,140 ft.
----	1,140–1,150	Clay shale, very fine-grained sandstone, and trace of siltstone; plant impressions.
7	1,150–1,156	Recovered 6 ft: Microfossils absent. Claystone, medium-light- to medium-dark-gray, hard; irregular fracture roughly parallel to bedding; good shaly cleavage rare; small black carbonaceous plant fragments in some partings; scattered slightly lighter colored silty streaks; moderately to very calcareous; grades to argillaceous (and dolomitic?) limestone at 1,155 ft; tiny white calcareous veinlets at this depth nearly vertical through core. Beds approximately flat lying; rare steeper dipping crossbeds.
----	1,156–1,185	Clay shale, medium-light- to medium-gray; some dark-gray, moderately calcareous; plant impressions rare; clay ironstone 1,175–1,185 ft.
----	1,185–1,205	Clay shale, medium-light- to medium-dark-gray; coaly partings; some pyrite. Also small amount of very fine-grained light-gray moderately calcareous sandstone.
----	1,205–1,225	Clay shale, medium-light-gray, and very argillaceous medium-dark-gray limestone; small amount of light-gray, very "dirty" and very fine-grained sandstone; plant impressions; brownish-gray clay ironstone.
----	1,225–1,235	Clay shale, medium-light- to light-gray; pyrite.
----	1,235–1,245	Sandstone 40 percent, light-gray; white quartz grains and many carbonaceous particles; moderately calcareous. Also medium-light-gray clay shale and dark-gray carbonaceous shale.
----	1,245–1,275	Clay shale, medium-light-gray; minor amount of light-gray sandy siltstone.
----	1,275–1,295	Clay shale, medium-light- to medium-gray.
----	1,295–1,315	Clay shale, medium-light- to medium-dark-gray; trace of light-gray moderately calcareous siltstone.
----	1,315–1,325	Sandstone and siltstone 60 percent; medium-light-gray clay shale.
----	1,325–1,335	Limestone 30 percent, medium-dark-gray, very argillaceous and silty, hard. Also clay shale.
----	1,335–1,345	Clay shale, medium-light-gray; plant impressions; pyrite; clay ironstone.
----	1,345–1,350	No sample.
8	1,350–1,360	Recovered 10 ft: Microfossils very abundant. 6 ft 7 in., clay shale, medium- to medium-dark-gray, medium-hard, fair shaly cleavage, conchoidal fracture; rare thin laminae of medium-gray siltstone. Quarter-inch brownish-gray clay ironstone layers at approximately 1,351 ft and 1,352 ft, pelecypods found between 1,354 and 1,356 ft were identified as *Anomia* sp., *Psilomya?* sp., and *Arctica?* sp. 3 ft 5 in., clay shale and siltstone, similar to upper part of core but with larger proportion of silt. Siltstone, medium-gray, argillaceous; has irregular fracture roughly parallel to bedding; contains fairly numerous black carbonaceous plant fragments; moderately calcareous; beds approximately flat lying.
----	1,360–1,410	Clay shale, medium-light- and medium-dark-gray; trace of siltstone and very fine-grained, light-gray sandstone.
----	1,410–1,420	Limestone, medium-gray, very silty; grades into very calcareous siltstone.
----	1,420–1,440	Sandstone, light-gray, fine-grained, hard, tight; mostly subangular, white and clear quartz grains; carbonaceous particles abundant; black plant impressions; white vein calcite very rare. Also siltstone and clay shale toward base.

Lithologic description—Continued

Core	Depth (feet)	Description
----	1,440–1,480	Clay shale, medium-light- to medium-dark-gray; yellowish-gray clay ironstone 1,440–1,450 ft, 1,460–1,470 ft; coal partings 1,470–1,480 ft; pyrite.
----	1,480–1,500	Clay shale, medium-light- to medium-gray; minor amount siltstone and fine-grained sandstone; pyrite.
----	1,500–1,530	Clay shale, medium-light-gray; shiny black coal chips rare; pyrite.
----	1,530–1,540	Clay shale, medium-light- to medium-gray; sandy siltstone; pyrite common; one chip of coal.
----	1,540–1,550	Clay shale, medium-light-gray, slightly calcareous; small amount of clay ironstone.
9	1,550–1,560	Recovered 7 ft 6 in.: Microfossils abundant. Clay shale, medium-dark-gray, medium-hard, brittle, fissile; conchoidal fracture; brown-shelled pelecypod (unidentified) at 1,560 ft; noncalcareous; beds flat lying.
----	1,560–1,570	Clay shale, medium-light- to medium-gray.
----	1,570–1,590	Clay shale, medium- to medium-dark-gray, and small amount of very fine-grained very calcareous sandstone; trace of siltstone.
----	1,590–1,630	Clay shale, medium-light- to medium-dark-gray; brownish clay ironstone; carbonaceous partings and plant impressions; pyrite chunks.
----	1,630–1,660	Sandstone, medium-light-gray, fine- to medium-grained; largely white and clear quartz grains; some mica; about 10 percent carbonaceous particles; slightly calcareous. Clay shale, dark-gray; rare shiny black coal chips 1,630–1,640 ft.
----	1,660–1,692	Sandstone as above, very fine- to fine-grained; almost entirely quartz grains; moderately calcareous; some medium-dark-gray very calcareous clay shale or argillaceous limestone 1,680–1,690 ft.
10	1,692–1,702	Recovered 10 ft: Microfossils very rare. Sandstone, light-gray, hard, massive, very fine- to fine-grained with scattered medium-sized grains; 85 percent subangular white and clear quartz grains; calcareous cement; very rare isolated medium-dark-gray shale chips ½ in. in diameter in the sandstone; chips lie flat parallel to bedding. One inch of medium-gray clay shale 2 in. from top of core. At 1,693 ft effective porosity 11.6 percent; air permeability less than 1 millidarcy, and carbonate content 18.23 percent by weight. Spotty stain and oil odor, light-straw-colored cut, yellow residue at 1,700 ft; beds flat lying. *Inoceramus* prisms in microfossil cut.
----	1,702–1,760	Sandstone as in core above, fine-grained becoming very fine with depth; also medium- to medium-dark-gray clay shale, quantity increasing with depth. *Inoceramus* prisms 1,740–1,750 ft.
----	1,760–1,790	Clay shale, medium- to medium-dark-gray; 50 percent siltstone 1,770–1,780 ft.
----	1,790–1,810	Sandstone 50 percent, light-gray, very fine- to fine-grained, and clay shale 50 percent.
----	1,810–1,820	Sandstone, light-gray, very fine- to medium-grained, (latter rare), mostly white and clear quartz grains and carbonaceous particles; 10 percent clay shale. *Inoceramus* prisms.
----	1,820–1,830	Sandstone, siltstone, and clay shale.
----	1,830–1,840	Clay shale, medium-gray, slightly calcareous; rare plant impressions; 10 percent sandstone.
----	1,840–1,900	Clay shale, medium- to medium-dark-gray.
----	1,900–1,920	Clay shale and small amount of soft light-gray very fine-grained sandstone; pyrite.
----	1,920–1,940	Sandstone, light-gray, very fine-grained to silty, rather soft; 20 percent clay shale, medium-light- to medium-gray.
----	1,940–1,950	Siltstone and clay shale; pyrite.
----	1,950–1,968	Sandstone, very fine-grained to silty; 50 percent clay shale, medium-light- to medium-dark-gray; pyrite.
11	1,968–1,974	Recovered 6 ft 8 in.: Microfossils absent. Interbedded siltstone, two-thirds, and clay shale, one-third. Siltstone, light-gray, hard; 95 percent white and clear quartz grains, with coaly grains and subangular, very rare, very fine sand grains; carbonaceous-micaceous partings; noncalcareous to very slightly calcareous. Clay shale, medium-gray, hard; contains minute micaceous partings, noncalcareous. Siltstone has excellent small-scale crossbedding with dips to 15°, ripple marks noted on breaks between silt and shale, amplitude ⅜ in. and length about 1¾ in.; dip 1°; no shows.
----	1,974–1,980	Clay shale.
----	1,980–1,990	Sandstone, light-gray, very fine-grained, and siltstone 70 percent; clay shale 30 percent, slightly calcareous.
----	1,990–2,020	Clay shale, medium-light- to medium-dark-gray. Sandy siltstone 10–35 percent.

Lithologic description—Continued

Core	Depth (feet)	Description
----	2,020–2,050	Clay shale, medium-light- to medium-dark-gray; pyrite; *Inoceramus* prisms 2,020–2,030 ft.
----	2,050–2,060	Clay shale; trace siltstone.
----	2,060–2,080	Siltstone, light-gray, moderately calcareous, 70 percent; clay shale; pyrite.
----	2,080–2,100	Sandy siltstone 60 percent; clay shale; pyrite common. Clay ironstone 2,090–2,100 ft.
----	2,100–2,140	Clay shale, medium-light to medium-dark-gray, small amount dark-gray; pyrite.
----	2,140–2,150	Clay shale; some medium-gray siltstone.
----	2,150–2,190	Clay shale, medium-light- to medium-gray; pyrite; slightly silty 2,160–2,170 ft. *Inoceramus* prisms 2,150–2,160 ft.
----	2,190–2,210	Sandstone, light-gray, fine-grained to silty, tight; mostly white and clear quartz grains; slightly to moderately calcareous. Clay shale 20 percent; some pyrite.
----	2,210–2,220	Clay shale, medium- to medium-dark-gray; 20 percent silty sandstone.
----	2,220–2,237	Sandstone, light-gray, silty to medium-grained (latter very rare), slightly calcareous, 50–70 percent. Clay shale.
12	2,237–2,246	Recovered 9 ft: Microfossils absent. Sandstone, light-gray, hard, fine-grained; massive in part; breaks roughly parallel to bedding; subangular to subrounded grains (mostly subangular); contains scattered partings of black carbonaceous material; excellent small-scale cross-bedding; also small amount of irregular bedding that suggests agitation contemporaneous with deposition; small nodule of brownish-gray clay ironstone at 2,245 ft; at a depth of 2,239 ft effective porosity 11.9 percent; air permeability less than 1 millidarcy; and carbonate content 9.4 percent by weight; dip 1°; faint spotty oil stain throughout core, poor to fair odor, yellow cut and brownish-yellow residue from 2,244 ft.
----	2,246–2,260	Sandstone, as in core above, fine- to medium-grained (latter very rare), moderately calcareous. Clay shale 20–25 percent.
----	2,260–2,290	Clay shale, medium- to medium-dark-gray; pyrite quite common; very rare coal chips 2,260–2,270 ft. *Ditrupa* sp. fragment 2,270–2,280 ft.
----	2,290–2,310	Clay shale 60 percent; sandstone and siltstone, light-gray, 40 percent.

Lithologic description—Continued

Core	Depth (feet)	Description
----	2,310–2,330	Sandstone, light-gray, fine- to medium-grained, 60 percent. Clay shale, medium-gray.
----	2,330–2,350	Clay shale, medium-gray to dark-gray.
----	2,350–2,370	Clay shale with sandstone, fine-grained, 25–40 percent, slightly calcareous.
----	2,370–2,420	Clay shale, medium-light-gray to medium-dark-gray, mostly medium-gray; small amount of clay ironstone 2,370–2,380 ft, trace siltstone 2,390–2,400 ft.
----	2,420–2,436	Sandstone, light-gray, fine-grained; mostly white and clear quartz grains; slightly to moderately calcareous; 15 percent clay shale, medium-dark-gray.
13	2,436–2,444	Recovered 8 ft 3 in.: Microfossils absent. Sandstone, light-gray, hard, very fine-grained, silty, massive in part, otherwise fair cleavage parallel to bedding; 85 percent white and clear quartz, 5 percent yellow quartz grains, remainder of dark minerals and pyrite; calcareous cement; some partings with dark carbonaceous particles. Contains very rare, isolated fragments of medium-dark-gray clay shale (to 1½ in. in diameter) lying parallel to bedding; 6 in. of clay shale at about 2,443 ft; shale contains a nodule of pyrite and fragments of medium-gray siltstone; some cross-bedding; *Placunopsis* sp., a pelecypod, was found at 2,442 ft. At 2,439 ft effective porosity 7.52 percent; sandstone impermeable; carbonate content 16.88 percent by weight.
----	2,444–2,460	Clay shale and sandstone.
----	2,460–2,510	Sandstone, light- to medium-light-gray, fine- to medium-grained; subangular primarily white and clear quartz grains; some dark chert, carbonaceous particles and mica; slightly to moderately calcareous; 10 percent clay shale, medium- to medium-dark-gray.
----	2,510–2,550	Clay shale, medium- to medium-dark-gray; 15 percent sandstone.
----	2,550–2,560	Clay shale 60 percent; sandstone 40 percent. Trace of bentonite in circulation sample.
----	2,560–2,620	Sandstone, light- to medium-light-gray, medium-grained, becoming fine grained toward base; similar to sand 2,460–2,510 ft but has larger proportion of dark minerals and rock fragments (?); nearly white calcareous cement; some clay shale, medium- to medium-dark-gray. *Inoceramus* sp. at 2,610–2,620 ft.

Lithologic description—Continued

Core	Depth (feet)	Description
----	2,620–2,635	Clay shale, 70 percent, and very fine-grained sandstone.
14	2,635–2,643	Recovered 8 ft 6 in.: Microfossils rare. Interbedded clay shale, 70 percent; and siltstone, 30 percent. Clay shale, medium- to medium-dark-gray, medium-hard; fair cleavage; very rare micaceous partings. Siltstone, light- to medium-light-gray, hard; some very fine- to fine-grained sandy laminae; some crossbedding. Small unidentified mollusk fragment at 2,636 ft, replaced partly by calcite and partly by pyrite; sandy-silty layers moderately calcareous; dip about 5°.
----	2,643–2,660	Clay shale, medium- to medium-dark-gray; pyrite. *Ditrupa* sp. at 2,640–2,650 ft. Trace sandstone.
----	2,660–2,680	Sandstone, medium-light-gray; very fine subangular grains, mostly white quartz; also slightly calcareous siltstone.
----	2,680–2,700	Clay shale, medium- to medium-dark-gray; some sandstone.
----	2,700–2,730	Sandstone, medium-light-gray, very fine- to fine-grained; some siltstone and clay shale.
----	2,730–2,750	Clay shale, medium-light- to medium-dark-gray; trace siltstone and sandstone.
----	2,750–2,780	Sandstone and siltstone, 50 percent, very fine- to fine-grained, and 50 percent clay shale.
----	2,780–2,835	Clay shale, medium- to medium-dark-gray; trace siltstone and sandstone.
15	2,835–2,840	Recovered 5 ft: Microfossils common. Clay shale and claystone, medium-gray; shale, rather soft, thin bedded; claystone, hard and massive. Some infiltrated drilling mud in softer shaly portions of core; small nodules of pyrite; noncalcareous; dip 7°.
----	2,840–2,860	Clay shale, medium- to medium-dark-gray; a few small coal chips; pyrite.
----	2,860–2,880	Clay shale; trace to 15 percent siltstone.
----	2,880–2,910	Clay shale, medium-light- to medium-dark-gray.
----	2,910–2,920	Clay shale; trace sandstone and siltstone; small amount of yellowish-gray clay ironstone.
----	2,920–2,940	Sandstone, 70–90 percent, light- to medium-light-gray, fine- to medium-grained; subangular to subrounded primarily white and clear quartz grains; carbonaceous particles; dark minerals; some mica; calcareous cement; clay shale in small quantity.
----	2,940–2,950	Clay shale, 60 percent; silty sandstone, 40 percent.

Lithologic description—Continued

Core	Depth (feet)	Description
----	2,950–3,000	Clay, shale, medium- to medium-dark-gray.
----	3,000–3,010	Clay shale, 70 percent; sandstone, very fine- to fine-grained, and siltstone, medium-light-gray, 30 percent.
----	3,010–3,040	Clay shale, medium- to medium-dark-gray; trace siltstone and very fine-grained sandstone.
16	3,040–3,045	Recovered 5 ft: Microfossils very rare. Claystone, medium-dark-gray, hard; irregular fracture; rare shaly cleavage; slightly micaceous; noncalcareous; dip undetermined; well geologist reports core bled slight amount of gas.
----	3,045–3,140	Clay shale, medium- to dark-gray; trace siltstone 3,045–3,050 ft, 3,080–3,090 ft, 3,100–3,110 ft, some pyrite. *Inoceramus* prisms, 3,060–3,070 ft; *Ditrupa* sp. fragment, 3,100–3,110 ft. The top of the Topagoruk formation is placed at 3,050 feet.
----	3,140–3,268	Clay shale, medium- to medium-dark-gray, some dark-gray; trace of medium-light-gray very slightly calcareous siltstone at 3,160–3,170 ft, 3,220–3,230 ft; small amount of grayish-brown clay ironstone 3,250–3,260 ft; one chip of coal 3,260–3,268 ft.
17	3,268–3,275	Recovered 7 ft 3 in.: Microfossils abundant. Interbedded clay shale, 60 percent, and siltstone, 40 percent. Clay shale, medium- to medium-dark-gray, medium-hard, slightly micaceous; fair cleavage parallel to bedding. Siltstone, light- to medium-light-gray, good cleavage along carbonaceous-micaceous partings; most beds an inch or thinner, one bed 6 in. thick. Small amount of small-scale crossbedding. A few irregular masses of siltstone included in the clay shale, suggesting contemporaneous deformation because shale is bent over, under, and around the silt; noncalcareous; dip 3°–4°.
----	3,275–3,470	Clay shale, medium- to medium-dark-gray, rare dark-gray; trace of medium-light-gray siltstone or silty sandstone at 3,275–3,290 ft, 3,320–3,340 ft, 3,370–3,380 ft. Crinoid ossicle 3,460–3,470 ft.
18	3,470–3,480	Recovered 10 ft: Microfossils common. Claystone and clay shale, medium-gray, hard; irregular fracture roughly parallel to bedding; slightly silty; few irregular medium-light-gray siltstone laminae; noncalcareous; dips variable but mostly 2°–5°.

Lithologic description—Continued

Core	Depth (feet)	Description
----	3,480–3,600	Clay shale, medium- to medium-dark-gray; trace medium-light- to medium-gray sandy siltstone at 3,480–3,500 ft, 3,520–3,570 ft; 10–15 percent silty sandstone at 3,580–3,600 ft, moderately calcareous.
----	3,600–3,610	Sandstone, 50 percent, light- to medium-light-gray, fine-grained; subangular to subrounded largely white and clear quartz grains; also some dark chert and carbonaceous particles; light-colored moderately calcareous cement. Also clay shale, medium- to medium-dark-gray.
----	3,610–3,670	Clay shale, medium- to medium-dark-gray; trace of medium-light- to medium-gray siltstone throughout.
19	3,670–3,675	Recovered 5 ft: Microfossils common. Clay shale and claystone, medium-gray, hard; cleavage fair to poor; slightly micaceous; about 5 percent of total recovery is irregular lenses of medium-light-gray siltstone; some crossbedding, noncalcareous; dip 3°.
	3,675–3,760	Clay shale, medium- to medium-dark-gray; trace medium-light-gray siltstone at 3,675–3,680 ft, 3,690–3,700 ft, 3,740–3,760 ft; rare carbonaceous plant impressions at 3,690–3,700 ft.
	3,760–3,780	Sandstone, 60 percent, light- to medium-light-gray, very fine- to fine-grained; subangular to subrounded grains, 80 percent white and clear quartz; dark chert and rock fragments; rare biotite; moderately calcareous cement; also clay shale, medium-dark- to dark-gray.
	3,780–3,820	Clay shale, 85 percent; very fine-grained sandstone and siltstone, 15 percent.
	3,820–3,864	Sandstone, as much as 70 percent, light-gray, moderately calcareous; also clay, shale, medium- to dark-gray.
20	3,864–3,873	Recovered 9 ft: Microfossils very rare. Sandstone and siltstone, 60 percent, and clay shale, 40 percent. Sandstone, light-gray, medium-hard, silty; good cleavage parallel to bedding along micaceous-carbonaceous partings, fine-grained; 85 percent subangular white and clear quartz grains; rest is dark minerals, coal, and mica. Small-scale crossbedding and ripple marks. Clay shale, medium-gray, medium-hard; contains silty laminae; very slightly calcareous; dip 1°. Well geologist noted that core bled gas. At 3,869 ft effective porosity 13.35 percent; sandstone impermeable; carbonate content 14.41 percent by weight.

Lithologic description—Continued

Core	Depth (feet)	Description
21	3,873–3,883	Recovered 10 ft: Microfossils very rare. Interbedded clay shale, 60 percent, and siltstone, 40 percent; clay shale, medium-gray, medium-hard, slightly micaceous; fair cleavage. Siltstone, light-gray, has dark carbonaceous-micaceous partings; good small-scale crossbedding; some very thin laminae of sandstone; irregular fragments of siltstone in the clay shale; noncalcareous; dips differ because of crossbedding, average dip 3°–6°.
	3,883–3,890	Sandstone, 50 percent; clay shale, 50 percent.
	3,890–3,930	Clay shale, 70–90 percent; siltstone and sandstone.
	3,930–3,940	Sandstone, 60 percent, fine-grained, slightly to moderately calcareous. Clay shale, medium- to medium-dark-gray.
	3,940–3,950	Clay shale.
	3,950–3,960	Clay shale, 60 percent; and light-gray slightly calcareous sandstone, 40 percent.
	3,960–4,010	Clay shale, medium- to medium-dark-gray; trace of siltstone.
	4,010–4,020	Clay shale, 60 percent; and light-gray slightly calcareous sandstone, 40 percent.
	4,020–4,100	Clay shale, medium- to medium-dark-gray; some dark-gray chips; trace of siltstone; very slightly calcareous.
22	4,100–4,110	Recovered 10 ft: Microfossils abundant. Interbedded clay shale, 85 percent; and siltstone, 15 percent as above; noncalcareous; dip 5°–7°.
	4,110–4,210	Clay shale, medium- to medium-dark-gray. Trace of siltstone, medium-light-gray, 4,110–4,140 ft, 4,160–4,210 ft.
	4,210–4,240	Clay shale, 5–10 percent; medium-light-gray, sandy siltstone.
	4,240–4,405	Clay shale, medium- to medium-dark-gray. Trace of siltstone at 4,240–4,250 ft, 4,310–4,340 ft, 4,350–4,360 ft, 4,390–4,405 ft.
23	4,405–4,415	Recovered 10 ft: Microfossils very rare. Clay shale, medium- to medium-dark-gray, moderately hard; fair to good cleavage; core fractured; many slickensided surfaces at differing angles, particularly in upper half of core; very rare medium-light-gray silty partings; noncalcareous; dip 8°.
----	4,415–4,540	Clay shale, medium- to medium-dark-gray. Trace of siltstone, medium-light- to medium-gray 4,450–4,460 ft, 4,490–4,510 ft, 4,530-4,540 ft.

Lithologic description—Continued

Core	Depth (feet)	Description
----	4,540–4,690	Clay shale, medium- to dark-gray. Trace siltstone, medium-light- to medium-gray, 4,540–4,550 ft, 4,600–4,610 ft, 4,670–4,680 ft.
----	4,690–4,710	Clay shale; 5–10 percent siltstone, medium-light-gray, noncalcareous.
24	4,710–4,717	Recovered 5 ft: Microfossils rare. Clay shale, medium- to medium-dark-gray, moderately hard; good cleavage; locally grades into medium-light-gray siltstone; some silty partings and laminae; noncalcareous; dip 7°–9°.
----	4,717–4,780	Clay shale, medium- to medium-dark-gray. Trace siltstone; noncalcareous.
----	4,780–4,790	Clay shale and a small amount of sandstone, medium-light-gray, fine-grained; 80 percent white and clear quartz grains; also dark chert; rock fragments; very calcareous cement.
----	4,790–5,077	Clay shale, medium- to medium-dark-gray.
25	5,077–5,085	Recovered 8 ft: Microfossils abundant. Clay shale and claystone, medium- to medium-dark-gray, moderately hard; poor to good cleavage; in part bedding indistinct; rare lighter gray silty partings; very slightly micaceous; noncalcareous; dip 9°.
----	5,085–5,428	Clay shale, medium- to medium-dark-gray; rare dark-gray chips. Small amount of siltstone (locally sandy), medium-light to medium-gray, 5,085–5,090 ft, 5,120–5,140 ft, 5,160–5,200 ft, 5,330–5,340 ft, 5,350–5,360 ft, 5,410–5,420 ft. The top of the Oumalik formation is placed at 5,200 feet.
26	5,428–5,435	Recovered 5 ft 5 in.: Microfossils very rare. Clay shale, medium-dark-gray, moderately hard; excellent cleavage parallel to bedding; very slightly micaceous; rare silty partings; noncalcareous; dip 8°.
----	5,435–5,727	Clay shale, medium- to medium-dark-gray, mostly the latter. Trace of medium-light- to medium-gray siltstone at 5,460–5,470 ft and 5,490–5,500 ft.
27	5,727–5,736	Recovered 4 ft: Microfossils absent. Clay shale, medium- to medium-dark-gray, moderately hard; excellent cleavage; scattered siltstone partings and laminae mostly less than one-half of an inch thick; very small amount of crossbedding in the laminae; a few silty laminae displaced one-fourth inch or less; noncalcareous; dip 9°.

Lithologic description—Continued

Core	Depth (feet)	Description
----	5,736–5,830	Clay shale, medium- to medium-dark-gray.
----	5,830–5,920	Clay shale, medium-dark-gray; trace of medium-gray siltstone, 5,840–5,850 ft.
----	5,920–6,020	Clay shale, medium- to medium-dark-gray (primarily medium-dark-gray). Trace of siltstone, medium-light- to medium-gray, 5,920–5,930 ft, 5,940–5,980 ft, and 6,000–6,020 ft.
28	6,020–6,030	Recovered 10 ft: Microfossils very rare. Claystone, medium- to medium-dark-gray, moderately hard; tends to break irregularly parallel to bedding but has no good cleavage; essentially no silt; noncalcareous; dip 4°–9°.
----	6,030–6,035	No samples received. Total depth 6,035 feet.

HOMCO SIDE-WALL CORING RESULTS

The following is a description of the side-wall cores by Marvin Heany, Arctic Contractors' well geologist (written communication, Jan. 7, 1951) at East Oumalik test well 1.

The Homco side-wall core barrel was used to obtain samples from sands occurring at depths of 1,630–1,655, 1,660–1,685, and 1,710–1,735 feet. Cores were taken at approximately 5-foot intervals within these zones. Owing to the hardness of the formation, the recovered cores were badly ground up and compressed in the core barrel, but no evidence was encountered at the well to indicate the presence of oil or gas. Following is a list of the cores taken.

1,630 ft	Shale and drilling mud.
1,735 ft	Sand, whitish-gray, very silty, fine-grained. Hard core of sandstone in center, but remainder ground up by barrel. Very low porosity, permeability. No shows.
1,640 ft	Sand, as above, badly ground up by core barrel and contaminated with drilling mud.
1,645 ft	Sand, as above, hard center, very silty, fine, tight.
1,648 ft	Sand, as above.
1,653 ft	Sand and drilling mud.
1,663 ft	Sand, ground up and compressed by core barrel, very fine grained, tight.
1,668 ft	Sand, as above with hard fragments sandstone in core.
1,673 ft	Sand, as above.
1,678 ft	Sand, as above.
1,683 ft	Sand, as above.
1,712 ft	Sand, as above.
1,718 ft	Sand, as above.
1,723 ft	Sand, as above.
1,728 ft	Sand, as above.
1,733 ft	Sand, but contaminated with grease from barrel.

CORE ANALYSES

Core analyses were run on sandstone drill cores, and determinations of effective porosity, air permeability, and carbonate content are contained in the following table. The Barnes (vacuum) method was used to obtain the porosity values. A permeameter, whose general requirements are detailed in API Code No. 27, Second Edition, April 1942, was used to determine the permeability.

Core analyses, East Oumalik test well 1

Core	Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)	Carbonate content (percent by weight)
3	526	11.5	0	13.32
10	1,693	11.6	<1	18.33
12	2,239	11.9	<1	9.40
13	2,439	7.5	0	16.88
20	3,869	13.3	0	14.41

OIL AND GAS

Oil and gas shows in East Oumalik test well 1 were poor. The hole was bailed down to 1,000 feet before running thermistor cables. When the hydrostatic head was reduced, gas appeared at the casing head. Some surging was noted during bailing. The volume of gas flowing was not measured. All cuts listed below were made with carbon tetrachloride.

Core	Depth (in feet)	Remarks
10	1,692–1,702	Spotty stain and oil odor; light-straw-colored cut; yellow residue at 1,700 ft.
12	2,237–2,246	Spotty stain throughout core, poor to fair odor, yellow cut, and brownish-yellow residue from 2,244 ft.

The well geologist, Marvin Heany, reported that cores 8, 9, 10, 16, and 18–28 bled a slight amount of gas. The following shows were also reported by Heany:

Slight shows of gas in sands at 2,310–2,320 feet, 2,470–2,490 feet by gas detector, but no evidence in the ditch. Light scum of oil appeared in ditch from sand at 2,314–2,319 feet. Very slight show of gas in ditch at 3,500–3,550 feet. No indication of oil. Slight show of gas in ditch from 4,870 feet to 5,100 feet.

LOGISTICS

Personnel.—The supervisory staff consisted of 1 tool pusher, 1 petroleum engineer, and 1 geologist. The rig crew was made up of 2 drillers, 2 derrickmen, 6 floormen, 2 firemen, 2 heavy-duty-equipment mechanics, and 1 oiler. Also employed were 2 cooks and 1 cook's helper, 1 bull cook, 2 bulldozer operators, 1 electrician, 1 carpenter, 1 warehouseman (first aid man and storekeeper), and 1 extra floorman.

During camp and rig construction periods, extra carpenters, rig builders, and laborers were employed. Six carpenters were sent from Point Barrow to repair the righouse after it was damaged by high winds. Schlumberger operators and cementers were sent as needed.

Housing.—Of 5 quonset huts at the drilling site, 1 was used as a mess hall and galley, 2 for sleeping quarters, 1 for recreation, and 1 as a warehouse. One Jamesway hut was used, and of the 11 wanigans used one each was for boiler, generator, office, shop, carpenter shop, latrine, mess storage, water, and 3 for sleeping quarters.

Vehicles and drilling equipment.—The total tonnage hauled to the test well site was 2,000 tons by Caterpillar tractor-drawn train and 2,000 tons by airlift. For local use, 3 weasels (military, fully-tracked vehicle), 1 LVT (landing vehicle, tracked), 1 D–8 Caterpillar bulldozer, and 1 D–6 Caterpillar tractor were used. Other heavy equipment consisted of 1 forklift, 1 Northwest crane, and 1 small mobile crane (cherrypicker). The major drilling equipment used by Arctic Contractors was as follows:

1 ---------- 136-foot Ideco derrick.
1 ---------- 350-ton Ideco crown block, six 48-inch sheaves.
1 ---------- 350-ton Ideco traveling block, five 48-inch sheaves.
1 ---------- Wilson Super Titan drawworks.
3 ---------- General Motors quad 6 diesel engines.
1 ---------- Byron-Jackson Super Triplex hook, ser. 4300.
2 ---------- C–350 National mud pumps.
2 ---------- Link-Belt 48 x 60 mud shakers.
1 ---------- Ideco rotary table, ser. HS–23–B.
1 ---------- Ideal R–3 swivel.
3 ---------- 150-barrel mud tanks with ditches.
3 ---------- 250-barrel storage tanks (1 water, 2 mud).
1 ---------- 90-barrel "pill" tank.
1 ---------- Cameron QRC blowout preventer.
1 ---------- Hydril GK blowout preventer.
1 ---------- Shaffer double-gate blowout preventer.
1 ---------- Kewanee boiler, 75 hp.
1 ---------- Halliburton cementing unit.
1 ---------- Schlumberger electric logging unit.

Fuel, water, and lubricant consumption.—The following materials were used in drilling this test: 91,035 gallons diesel fuel, 1,429 gallons gasoline, 718,500 gallons water, 320 pounds grease, 450 pounds thread lubricant, 524 gallons No. 9170 lubricant, 159 gallons No. 5190 lubricant, 212 gallons No. 9500 lubricant, and 106 gallons No. 9100 lubricant.

DRILLING OPERATIONS

RIG FOUNDATION

The following discussion of the rig foundation was supplied by Arctic Contractors' petroleum engineer (written communication, June 1951).

The Wilson Super Titan rig, equipped with a steel substructure, was set on a foundation of 12 by 12 timbers. The refrigeration circulation system consisted of a 1-inch pipe cleated to the under side of each timber. The pipes were hose-connected and manifolded into 9 separate circuits off the main headers. Diesel oil, cooled by three mechanical refrigeration units, each of 0.42-ton capacity, was circulated through the refrigeration system. Oil and ground temperatures were obtained from thermometers and thermocouples.

Construction of the foundation was not completed until late spring. The ambient air temperature at that time was well above freezing, requiring that the muck be frozen back by the refrigeration system. This proved to be a slow process since the plant was of insufficient capacity to rapidly extract large quantities of heat from the ground.

During the drilling operation, the ground under the mud pits thawed below the timber sills, requiring shimming under these sections. Part of the excessive thawing was due to drainage of waste water from the derrick through these areas.

DRILLING NOTES

The following table is composed of selected notes from the drilling records of the Arctic Contractors' petroleum engineer.

Notes from drill records

Depth (feet)	
0	Well spudded in at 2 p. m., Oct. 23, 1950, with 15-in. bit.
106	Casing set. 16⅝-in. outer diameter, 42 lb, welded slip joint, Western Pipe and Steel, welded plate casing with Baker casing shoe. Cemented with 65 sacks of Cal-Seal. Cemented around top through 1-in. pipe to 40 ft with 59 sacks of Cal-Seal. Top 55 ft were jacketed with 22-in. welded slip joint casing.
1,100	Casing set. 11¾-in. outer diameter seamless 47 lb (thread and coupling) grade J–55, 8 round thread, API casing with Baker Tubing Float Collar. Cemented with 550 sacks of cement. First and last 100 sacks were treated with calcium chloride.
	Both casing cement operations were conducted without incident. Though the 16-inch casing cement job was apparently satisfactory at the completion of the job, subsequent circulation of warm fluid caused the circulation to channel by and returns appeared in the cellar. Efforts to overcome the condition were not entirely satisfactory and hole was made to 1,103 feet and reamed to 15½ inches with partial or complete returns appearing in the cellar. Mud was circulated from the cellar and drilling continued.
1,702	Winds of gale force demolished rig house. Shut down 12 hours (Nov. 10, 1950).
3,298	Shut down 17½ hours owing to high winds (Nov. 27, 1950).

Notes from drill records—Continued

Depth (feet)	
6,030	Ran Homco side-wall core barrel; obtained cores at 5-ft intervals from sands at 1,630–1,655, 1,660–1,685, and 1,710–1,735 ft.
6,035	Mud bailed down to a level of approximately 1,000 ft. Five thermistor cables and the following equipment were installed: Landing base (11¾ x 12 in., series 900) top 19 in. above cellar floor with plate welded on top and 10¾ x 5 in. nipple welded on plate.
	No drill stem or other tests of fluid productivity were made. This well was drilled without mechanical failure in machinery. Failures in drill pipe were numerous, but all were detected by decreased pump pressure, indicative of a washout. Fifteen such washouts were detected, but pipe was pulled and singles exchanged without necessitating fishing. The failures were similar and occurred at similar places in the joints: cracks developed about 3 in. from the end of the upset where boxes are screwed on. The fluid passed through the break, down the threaded section of the drill pipe and tool joint box, then left the drill stem at the bottom of the box.

DRILL AND CORE BITS

Three 15-inch and forty 10⅝-inch bits were used to drill East Oumalik test well 1. Bearing wear rather than dulled teeth necessitated retiring most of the bits. The surface hole was drilled to 106 feet, using a 15-inch bit, and was opened to 26 inches with a Reed hole opener. Below 106 feet a 10⅝-inch hole was drilled to 1,103 feet and opened to 15 inches using 15-inch bits and a reamer. Below 1,103 feet the hole was drilled to 6,035 feet (total depth) using 10⅝-inch bits to drill and to ream the 8¾-inch cored intervals.

A Reed wire-line core barrel and five 8¾-inch rock bits were used to core a total of 230 feet.

DRILLING MUD

Mud control presented only minor problems. Most of the rocks penetrated produced heavy mud (90 lb per cu ft) of very low viscosity. Practically no treating material or agents were used. A rather large amount of natural mud was eliminated from time to time. As gel strength was very low, 9 sacks of Aquagel were added to the system after drilling to 5,300 feet. Hole condition was excellent at all times.

About the following amounts of mud materials were used in drilling this well:

Aquagel	33 sacks
Pyrophosphates	1½ sacks
Quebracho	6¼ sacks
Driscose	3 sacks (150 pounds)
Gel flake	6 sacks

Data on drilling mud and additives are contained in the following table.

Drilling mud characteristics and additives, East Oumalik test well 1

[Values for drilling mud characteristics are based on daily averages]

Depth (feet)	Weight (lb per cu ft)	Viscosity (Marsh funnel sec)	Filtration loss (cu cm per 30 min)	Remarks
0	----------	----------	----------	Mixed 20 sacks Aquagel to spud, 20 more to drill out after cementing.
120	72	35	----------	
295	72	35	----------	
520	73	37	----------	
740	73	36	----------	
920	73.5	37	----------	
956	----------	----------	----------	Circulation broke through around surface pipe. Added 12 sacks Aquagel and 6 sacks Gel flake.
1,100	73	42	----------	
1,103	----------	----------	----------	Dumped cement cut mud after cementing casing.
1,150	72	60	----------	
1,350	75	32	----------	
1,450	75	30	----------	Added 35 lb Driscose.
1,550	75	35	----------	Added 10 lb Driscose.
1,675	80	37	11	Added 5 lb Driscose.
1,760	80	37	----------	
1,825	80	37	9	Added 40 lb quebracho, 50 lb pyrophosphate.
1,905	79	36	----------	
1,960	82	36	7	
2,030	80	36	7	Added 50 lb Driscose.
2,090	85	35	5	Added 20 lb quebracho.
2,145	83	36	6	
2,210	84	35	5	
2,285	85	35	4.5	
2,350	86.5	35	4	
2,440	89	38	4	Added 40 lb Driscose.
2,560	87	34	3.5	
2,645	87	36	3.5	
2,770	88	37	3	Added 25 lb pyrophosphate and 25 lb quebracho.
2,845	89	36	3.5	
2,955	88.5	37	4	
3,045	91	37	4	Added 20 lb Driscose.
3,150	90	37	4.5	
3,260	91	38	4	
3,345	91	40	4	Added 20 lb pyrophosphate.
3,450	91	37	4	
3,540	91.5	42	3.5	Added 50 lb quebracho.
3,655	91.5	37	3	Added 30 lb quebracho, 25 lb pyrophosphate.
3,720	92	39.5	3	Added 25 lb quebracho.
3,805	91	38	3	Added 30 lb quebracho.
3,860	92	37.5	3	Added 30 lb quebracho.
3,925	90	37	3.5	Added 20 lb quebracho, 20 lb pyrophosphate.
4,005	92	39	3	Added 30 lb quebracho.
4,105	91.5	38	3	Added 30 lb quebracho.
4,195	91.5	38	4	Added 35 lb quebracho.
4,280	91	37	4	Added 30 lb quebracho.
4,360	91.5	38	3.5	Added 30 lb quebracho.
4,420	91.5	37	3	Added 30 lb quebracho.
4,510	90	36.5	3	Added 30 lb quebracho, 12 sacks Aquagel.
4,645	91	36.5	3	Added 45 lb quebracho.
4,705	91	37.5	3	
4,785	90	37	3	
4,860	90	37	3	Added 30 lb quebracho.
4,920	90	37	3.5	Added 25 lb quebracho.
5,015	90	37	3.5	
5,105	90.5	38	3	
5,190	90.5	37	3	
5,255	91	39	3	Added 9 sacks Aquagel.
5,360	91.5	43	4	Added 30 lb quebracho.
5,460	92	43	3	
5,575	91	42	3.5	
5,665	90.5	43	3.5	
5,740	91	43	3.5	
5,840	91	45	4	
5,940	91	43	3.5	
6,020	91.5	44	3.5	

HOLE DEVIATION

Hole-deviation readings were made with a Totco Recorder in the drill pipe. Deviation from 510 feet (first reading) to 5,200 feet was less than 1°. From 5,595 feet to 5,995 feet (last reading) the deviation was 1° or slightly greater. (See pl. 5.)

ELECTRIC LOGGING

The electric logs, gamma-ray log, and microlog were run by the Schlumberger Well Surveying Corp. The gamma ray and micrologs are not included in plate 5 because they showed little of significance. The following table indicates the depths tested.

Depths tested by electric and gamma ray logging

Type of log	Run number	Depth (feet)
Electric	[1] 1	1,104–108
Electric	2	2,337–1,105
Electric	3	3,985–2,337
Electric	4	5,220–3,985
Electric	[1] Special	5,220–1,105
Electric	[1] 5	6,030–5,220
Gamma ray	1	6,027–Surface
Micro	1	6,034–1,105

[1] Runs shown on plate 3.

SUMMARY OF THERMAL INVESTIGATIONS

By Max C. Brewer

Because the cable in Oumalik 1 failed before any significant temperature reading was obtained, it was considered very desirable to obtain temperatures to and below the base of permafrost at East Oumalik, especially since at that time the only other temperature measurements available in the foothills area were at Umiat where there was a possibility that the permafrost temperatures might be greatly affected by topography and the Colville River. To this end 2 multiunit thermistor cables and 3 Humble or resistance coil type cables were installed on Jan. 7, 1951. (See table below.)

Daily readings were taken starting on the day of installation and running through January 16. On February 3, readings were obtained from the Humble cables, but satisfactory readings from the two thermistor cables could not be obtained.

During early January, no evidence of subsurface freezing was found, although on January 16 the freezing point of fresh water had been reached at the cellar surface, at 10 feet, and between 90 and 135 feet. On February 3 the well was frozen from a point between 55 and 80 feet to below the bottom of the Humble cable at 205 feet. Above this top limit of freezing, the

only definitely known frozen zone was between the surface and 5 feet.

The readings obtained from the thermistor cables on January 16, the last day of satisfactory readings, were approximately from 4°C at 725 feet to 10°C at 1,500 feet. On Feb. 3, 1951, these cables gave such unsatisfactory results that they can be considered inoperative as of that date. Various tests showed that many of the conductor leads were short circuited together, some by very low resistance shorts; and all but 1 of the 40 individual leads were short circuited to the well casing, although they did not make exceptionally good contact. Test indicated that at least one and probably both cables were severely damaged between the 234- and 750-foot depths.

It is believed that these cables failed because of ice expansion or ice movement within the well casing. This would necessitate assuming that the well refilled with water after bailing to 1,000 feet. The expansion could also be explained by the presence of ice plugs formed by gas-carried water vapor condensing at various depths. In order to rupture the cables, these ice plugs would necessarily have been forced apart by either the freezing of additional fluid between the plugs or gas pressure forcing the upper plug farther up the well casing while the lower plug essentially remained stationary.

Casing collapse could also have been caused by an inward pressure brought about by the freezing of the fluids in the space behind the casing. However, evidence for this phenomenon is meager, occurs only in South Barrow test well 2, and is not thought to be operative at East Oumalik.

The three short Humble cables were removed in March 1951 because transportation difficulties would not warrant making trips to read these cables.

Depths at which temperatures were measured by thermistor cables, East Oumalik test well 1

Cable no.	Length of cable (feet)	Depth measured (feet)
Humble or resistance-type coil:		
11	120	5–120
17	135	10–135
7	205	15–205
Multiunit thermistor cable:		
143	1, 000	725–1, 000
134	1, 500	1, 010–1, 500

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PALEONTOLOGY OF TEST WELLS AND CORE TESTS IN THE OUMALIK AREA, ALASKA

By Harlan R. Bergquist

SOURCE OF SAMPLES

During the drilling of wells on the Oumalik anticline in connection with the exploration of Naval Petroleum Reserve No. 4, northern Alaska, samples from cores and cuttings from 2 deep test wells and 3 core tests were prepared for paleontologic study in the U. S. Geological Survey laboratory at Fairbanks, Alaska. The samples were washed and picked under the author's supervision; a total of 947 samples were examined for microfossils, of which 624 samples were from Oumalik test well 1; 190 were from East Oumalik test well 1; and 133 were from Oumalik core tests 1, 2, 11, and 12 and Ikpikpuk core test 1. No samples were available from the other core tests.

A number of the species in these wells are new and have been described by Mrs. Helen Tappan Loeblich (Tappan, 1951, 1956).

OUMALIK TEST WELL 1

All core samples and ditch samples from every 10- or 20-foot interval in Oumalik test well 1 were examined for microfossils. Approximately 920 feet of cores were taken, but microfossils were recovered from only 29 of the 90 cores. Most of the cores below the one at 4,420–4,440 feet were barren. Some of the cores contained 1 or 2 specimens, but a few cores had common to abundant specimens of certain species.

Only a few more than 1,000 specimens of Foraminifera, representing 18 arenaceous species and 4 calcareous species, were found in ditch and core samples from the 2,800 feet of the Grandstand formation penetrated in drilling this test hole. These species are typically associated with *Verneuilinoides borealis* Tappan, an arenaceous foraminifer which is the dominant species in the shallow-water marine fauna of the Grandstand–Topagoruk formations, and whose name is therefore used to designate the faunal zone. In the Grandstand formation in this test hole, *V. borealis* occurs in most of the ditch samples and in some of the cores, and constitutes 60 percent of the fauna. It is most numerous in ditch samples, but its abundance is confined to intervals above the 1,150-foot depth. The next most abundant (7 percent) species is *Haplophragmoides topagorukensis* Tappan. A few other species make up 5 or 6 percent each, but most species found in the Grandstand formation in this test well constitute only 1 or 2 percent of the total specimens collected from the formation.

GRANDSTAND FORMATION (30–2,825 FEET)

Only a few Foraminifera occurred in samples in the upper few hundred feet of beds of the Grandstand formation penetrated in drilling this test well. Of the few found, *Verneuilinoides borealis* was common to abundant at 130 feet and at 160 feet. A core from 517–528 feet was barren of microfossils, but carbonized plant remains of Cretaceous age were in it. A few charophyte oogonia were in ditch samples below this core. About 60 percent of the cores from the Grandstand formation were barren, but a core from 723–733 feet carried 35 percent of all specimens recovered from cores. In this core *V. borealis* and *Gaudryinella irregularis* Tappan were common, and there were a few specimens each of *Ammobaculites tyrrelli* Nauss, *Miliammina manitobensis* Wickenden, and *Inoceramus* prisms.

Inoceramus prisms occurred in cores at 1,410–1,422 and 1,626–1,637 feet, and intermittently in ditch samples through 2,590 feet. A shell fragment of *Ditrupa* sp.[3] was found at 1,470–1,480 feet. In the test holes drilled in the Umiat field, the Grandstand anticline, and the Topagoruk River and Simpson peninsula areas, the fragmentary shells of *Inoceramus* and *Ditrupa* constitute a subzone of the *Verneuilinoides borealis* faunal zone and range through most of the Grandstand formation and a part of the underlying Topagoruk formation.

In a core at 2,351–2,361 feet in the lower part of the Grandstand formation, only fragments of *Bathysiphon vitta* Nauss were common and mark the first occurrence of this species in any abundance in this test hole. Other species were rare, but among them were two small specimens of *Gaudryina nanushukensis* Tappan.

TOPAGORUK FORMATION (2,825–4,860 FEET)

A greater number of species and specimens of Foraminifera of the *Verneuilinoides borealis* faunal zone were recovered from the Topagoruk formation than from the Grandstand formation, and these came from 11 of the 19 recovered cores.

[3] Curved tubular shells from the Cretaceous beds of northern Alaska were formerly referred to *Laevidentalium* sp. or *Dentalium* sp. Determinations by Ralph W. Imlay show that these shells are not scaphopods but are worm tubes of the genus *Ditrupa*.

Twenty-four arenaceous species and six calcareous species were identified in 515 specimens picked from core samples, and 706 specimens were identified from ditch samples. In the core samples *Haplophragmoides topagorukensis* numerically leads all species with 47 percent of the total number of specimens; *Textularia topagorukensis* Tappan comprises 13 percent of the total, and *Bathysiphon vitta*, 11 percent. The remaining species range downward from 5 specimens for *Verneuilinoides borealis* to 1 specimen for *Gaudryinella irregularis*.

A fauna of 10 species was picked from a core sample near the top of the formation (2,841–2,851 feet) where *Haplophragmoides topagorukensis* and *Tritaxia manitobensis* Wickenden were common and *Textularia topagorukensis* was abundant.

OUMALIK FORMATION (4,860–10,880 FEET)

Of the 23 cores taken in this formation 18 were barren, whereas the ditch samples, though fossiliferous, are contaminated by the *V. borealis* fauna from the overlying beds.

About 20 specimens of 6 long-ranging species (common to the Nanushuk group) occurred in the 4 or 5 fossiliferous cores in the Oumalik formation. *Dorothia chandlerensis* Tappan, a species found in the lower part of the Torok formation, was found in the Oumalik formation in this test hole and was used to mark the top of the formation. Three other specimens of *D. chandlerensis* were found in three ditch samples (8,130 feet, 8,310 feet, and 9,310 feet). Eight pyritic casts of a radiolarian, *Dictyomitra?* sp. came from a core sample from 10,233–10,240 feet. Pyritic casts of another radiolarian, *Lithocampe?* sp., were found in ditch samples (8,050–8,060 feet and 10,210–10,220 feet) and in cores from 10,233–10,240 feet and from 10,669–10,682 feet. Pyritic casts of the latter radiolarian are also characteristic of the lower part of the Torok formation.

UPPER JURASSIC(?) AND LOWER CRETACEOUS(?) ROCKS UNDIFFERENTIATED (10,880–11,872 FEET, TOTAL DEPTH)

The only Foraminifera found in cores from the beds below the Oumalik formation in this test hole came from a sample at 10,992–11,007 feet in which were also molluscan casts which R. W. Imlay has identified as *Aucella sublaevis* Keyserling, of Early Cretaceous (middle Valanginian) age; this species is limited to the lower 200 feet of the Okpikruak formation in northern Alaska. The associated Foraminifera are specimens of *Haplophragmoides* which are more like *H. canui* Tappan of Late Jurassic age (Oxfordian) than any other species. Other specimens of *H.* cf. *H. canui* were scattered through many of the ditch samples but were most numerous in the upper 150 feet of the unit.

In some of the ditch samples there are Foraminifera that are contamination from higher beds and a few that are suggestive of Late Jurassic (Oxfordian or lower Kimmeridgian) species that have been found in Topagoruk test well 1 and in some outcrop samples. Fossils from these rocks have been described by Mrs. Helen Tappan Loeblich (Tappan, 1955). Two specimens of questionable *Gaudryina topagorukensis* Tappan, a small species whose chambers have greater width than height, were found in samples from 10,920–10,930 feet and 11,360–11,370 feet and compare quite favorably to specimens of *G. topagorukensis* from Topagoruk test well 1. A few coarse-grained arenaceous planispiral specimens (11,140–11,150 feet, 11,180–11,190 feet, and 11,690–11,700 feet) resemble an unnamed species of *Haplophragmoides* found in samples from the lower part of the Tiglukpuk formation on the East Fork of the Nanushuk River and along Welcome Creek (tributary to Kanayut Creek) in the Siksikpuk–Nanushuk Rivers area, Alaska. Within the interval from 11,400 to 11,550 feet five calcite-filled specimens of a small *Globulina* (*G. topagorukensis?* Tappan) were found. The similarity of these Foraminifera to species of Jurassic age presents the possibility of a Late Jurassic age for most of the beds below the Oumalik formation in this test hole.

EAST OUMALIK TEST WELL 1

PLEISTOCENE-RECENT(?) DEPOSITS

A few broken smooth-valved ostracodes in a ditch sample at 30–40 feet resemble the valves of a present-day species found along the Arctic coast. No species characteristic of the Gubik formation were noted.

KILLIK TONGUE OF THE CHANDLER FORMATION (50–730 FEET)

Except for scattered occurrences of *Verneuilinoides borealis* Tappan and a few specimens of *Miliammina awunensis* Tappan in this well, the Killik tongue of the Chandler formation is essentially barren.

GRANDSTAND FORMATION (730–3,050 FEET)

The top of the Grandstand formation was placed at the top (730 feet) of the *Verneuilinoides borealis* faunal zone, where very abundant specimens of *Verneuilinoides borealis* and *Trochammina rutherfordi* Stelck and Wall appear in association with common specimens of *Miliammina awunensis* and a few specimens of *Gaudryinella irregularis* Tappan, *Textularia topagorukensis?* Tappan, and *Siphotextularia? rayi* Tappan. Through the succeeding 350 feet of section *Verneuilinoides borealis* is common to abundant in ditch samples, whereas other species are only sparingly present. Cores from 950–956 feet and from 1,150–1,156 feet

were barren. In core 8 from 1,350–1,360 feet *Verneuilinoides borealis* was very abundant, and fragments of *Ammobaculites humei?* Nauss were found in the same sample along with specimens of ostracodes and charophyte oogonia. Specimens of *Verneuilinoides borealis*, *Haplophragmoides topagorukensis* Tappan, and *Psamminopelta bowsheri* Tappan were abundant in core 9 from 1,550–1,560 feet. Most of the succeeding cores through 2,446 feet were barren, but *Verneuilinoides borealis* was fairly persistent in the ditch samples through that part of the section.

Along with Foraminifera, fragments of the worm tube *Ditrupa* sp. were found in a ditch sample at 1,850 feet and in core 14 from 2,635–2,645 feet. *Inoceramus* prisms appeared first in core 10 from 1,692–1,702 feet and also occurred in core 14.

The *Verneuilinoides borealis* fauna persists in ditch samples through the lower part (about 2,446–3,250 feet) of the Grandstand formation, but relatively few species and specimens were found in the cores. Only *Haglophragmoides topagorukensis* was common in one core (2,835–2,840 feet), where the highest fragments of *Bathysiphon vitta* Nauss also occurred.

Calcareous Foraminifera were very scarce in the Grandstand formation; the first one, *Pallaimorphina ruckerae* Tappan, appeared low in the section in a ditch sample from 2,080–2,090 feet. Three specimens of *Eponides morani* Tappan were found in the core from 2,635–2,640 feet; a specimen of *Gavelinella stictata* (Tappan) and one of *Pallaimorphina ruckerae* were found in the core from 2,835–2,840 feet.

A specimen of *Gaudryina nanushukensis* Tappan was found in a ditch sample from 2,950–2,960 feet; scattered specimens occurred in ditch samples from 3,150 feet through 5,710 feet.

TOPAGORUK FORMATION (3,050–5,200 FEET)

The best development of the *Verneuilinoides borealis* faunal zone in this well is in the upper 500 to 600 feet of the Topagoruk formation. Core 17 from 3,268–3,275 feet furnished the largest fauna of the well, having 13 species, with *Haplophragmoides topagorukensis*, *Verneuilinoides borealis*, and *Eurycheilostoma robinsonae* Tappan of common occurrence, and a few specimens of *Bathysiphon brosgei* Tappan, *Pelosina complanata* Franke, *Psamminopelta bowsheri*, *Miliammina awunensis*, *Gaudryina hectori* Nauss, *Tritaxia manitobensis* Wickenden, *Lenticulina macrodisca* (Reuss), *Valvulineria loetterlei* (Tappan), *Pallaimorphina ruckerae*, and *Gavelinella stictata*. In a core from 3,670–3,675 feet nine species occurred, but only *Haplophragmoides topagorukensis* and *Verneuilinoides borealis* were common.

Although never common, *Ammobaculites humei* Nauss occurred low in the Grandstand formation, and in the upper part of the Topagoruk formation in ditch samples and in the cores from 3,470–3,480 feet and 3,670–3,675 feet. It is probably not found in the lower part of the Topagoruk formation of this test, though a few specimens occurred in ditch samples. Specimens of *Ammobaculites tyrrelli* Nauss were rare and were identified in only a few samples.

Gaudryina nanushukensis was found sparingly from 3,150 feet to 5,710 feet, but its rare occurences were in the upper part of the Topagoruk formation. It was not found in the Grandstand formation of this test, although it does occur in that formation in Oumalik test well 1.

The fauna apparently fades gradually with depth, as in core 22 (from 4,100–4,110 feet) the only species is *Haplophragmoides topagorukensis*, but it occurs in abundance. In the lower beds of the Topagoruk formation, the ditch samples contain a fairly constant fauna, which may be contamination, because in the cores below 4,400 feet the species typical of the *Verneuilinoides borealis* faunal zone were almost completely absent. In a core from 5,077–5,085 feet *Textularia topagorukensis?* was abundant. This species was sparingly present throughout the *Verneuilinoides borealis* faunal zone in this well, but in Oumalik test well 1 it was common in some cores in the upper part of the Topagoruk formation.

OUMALIK FORMATION (5,200–6,035 FEET)

All except the last core taken from the Oumalik formation in this well were barren. The exception, the bottom-hole core, contained a few specimens, but these were so poorly preserved that positive identifications could not be made. Pyritic specimens of the Radiolaria, *Lithocampe?* sp., and *Dictyomitra?* sp. appeared in ditch samples from 5,710–5,720, 5,810–5,820, and 5,890–5,900 feet. The pyritic *Lithocampe?* marks the Oumalik formation in its type section, Oumalik test well 1.

IKPIKPUK AND OUMALIK CORE TESTS

Samples from Ikpikpuk core test 1 and Oumalik core tests 1, 2, 11, and 12 were studied in the laboratory at Fairbanks. Samples from Oumalik core (foundation) tests 1–10 were never received at the laboratory.

Ikpikpuk core test 1 and Oumalik core test 1.—Very little paleontologic information came from these two core tests because of the shallow depth of the holes and the poor quality of the samples. Two cores were taken in the Ikpikpuk core test, but these and all ditch samples were badly contaminated with surficial material, making them valueless for age determinations. Common

to all the samples were specimens of a smooth-walled species of nonmarine ostracode *Candona* cf. *C. candida* (Muller), which is apparently indigenous to beds of Pleistocene and Recent age in the uppermost part of the hole. In Oumalik core test 1 all the ditch samples and three of the cores (down to 209 feet) are contaminated with the same species of Pleistocene and Recent ostracode. A solitary specimen of *Pelosina complanata* Franke in a sample from 210–220 feet and *Inoceramus* prisms in a ditch sample from 330–340 feet provide meager evidence of marine beds of Cretaceous age in Oumalik core test 1, but these fossils offer no clue as to which formations were penetrated.

Oumalik core test 2.—About 40 feet of possible Gubik formation covered the Cretaceous rocks in this core test. In the upper 10 feet were ostracode valves that F. M. Swain has identified as *Ilyocypris* cf. *I. bradyi* Sars, a lacustrine species.

The fossiliferous Grandstand formation (Lower and Upper Cretaceous) occurs from 70 feet to the total depth, below beds defined as the Chandler formation by Miss Robinson. Only a charophyte oogonium was found in samples from the Chandler, but there were light-brown, somewhat compressed tests of *Verneuilinoides borealis* Tappan in most of the samples from the Grandstand formation. This species was very abundant in the lowest 40 feet of samples. In a few of the samples, particularly from the lowest 30 feet, were a few specimens of *Miliammina awunensis* Tappan, *Gaudryina hectori* Nauss, and *Trochammina rutherfordi* Stelck and Wall. Two specimens of charophyte oogonia, which are the same as the specimen found in the Chandler and suggest some contamination during drilling, were in two samples.

Oumalik core test 11.—The Grandstand formation was penetrated at 14 feet in this core test beneath a thin mantle of Pleistocene strata. In the first sample (14–24 feet) were common numbers of compressed tests of *Miliammina awunensis* and *Trochammina rutherfordi*, and a great abundance of *Verneuilinoides borealis*. These fossils, with the addition of a few others, continue through 137 feet of the core test but are relatively inconspicuous in the remainder of the samples. The most fossiliferous core was from 127–137 feet, where *V. borealis* was very abundant, *Psamminopelta subcircularis* Tappan and *Trochammina rutherfordi* were abundant, and there were a few specimens of each of three other species.

Oumalik core test 12.—Foraminifera of the *Verneuilinoides borealis* faunal zone appeared abruptly in the core at 17 to 27 feet and were irregularly distributed throughout the lower samples from the hole. The most numerous were *Verneuilinoides borealis* and *Trochammina rutherfordi*, each being common to abundant in 6 samples. *Gaudryinella irregularis* Tappan was abundant in 3 samples; *Psamminopelta subcircularis* was abundant to common in 4 samples; and *Pelosina complanata*, *Psamminopelta bowsheri*, and *Gaudryina hectori* each had one common to abundant occurrence. A few specimens of *Miliammina awunensis* occurred in 5 samples.

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