Test Wells Simpson Area Alaska

By FLORENCE M. ROBINSON

With a section on Core Analyses

By S. T. YUSTER

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

PART 5, SUBSURFACE GEOLOGY AND ENGINEERING DATA

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TEST WELLS, SIMPSON AREA, ALASKA

By Florence M. Robinson

ABSTRACT

Two test wells were drilled in the Cape Simpson area, northern Alaska, as a part of the exploration of Naval Petroleum Reserve No. 4. The first well, Simpson test well 1, was located and drilled in late 1947 and early 1948 on a deep seismic prospect near shallow core tests which had showed some signs of oil. The well was drilled to a depth of 7,002 feet, penetrating rocks of Cretaceous, Jurassic, Triassic, and pre-Mesozoic age. Fair shows of oil were found in the Cretaceous Grandstand formation, but they were not of commercial value, and the well was abandoned. The test however, furnished a great deal of stratigraphic information.

North Simpson test well 1 was drilled in the spring of 1950 to test another seismic anomaly. The well proved to be dry. North Simpson test well 1 penetrated Upper and Lower Cretaceous rocks to a total depth of 3,774 feet, but no sandstones or other suitable reservoir rocks were found.

INTRODUCTION

Largely because of the presence of seepages of oil along the north coast of Alaska, President Harding set aside Naval Petroleum Reserve No. 4 (see fig. 44) in 1923, as a possible future source of oil for the U. S. Navy. Under the stress of World War II, a program for the exploration of the Reserve was started by the Navy and carried out after the war by its prime contractor, Arctic Contractors. Exploration was carried on in the area near the Simpson seeps, approximately 50 miles southeast of Barrow, for several years.

In 1945 a magnetic survey covering the area was made by the U. S. Geological Survey in cooperation with the U. S. Navy, and gravity and seismic surveys

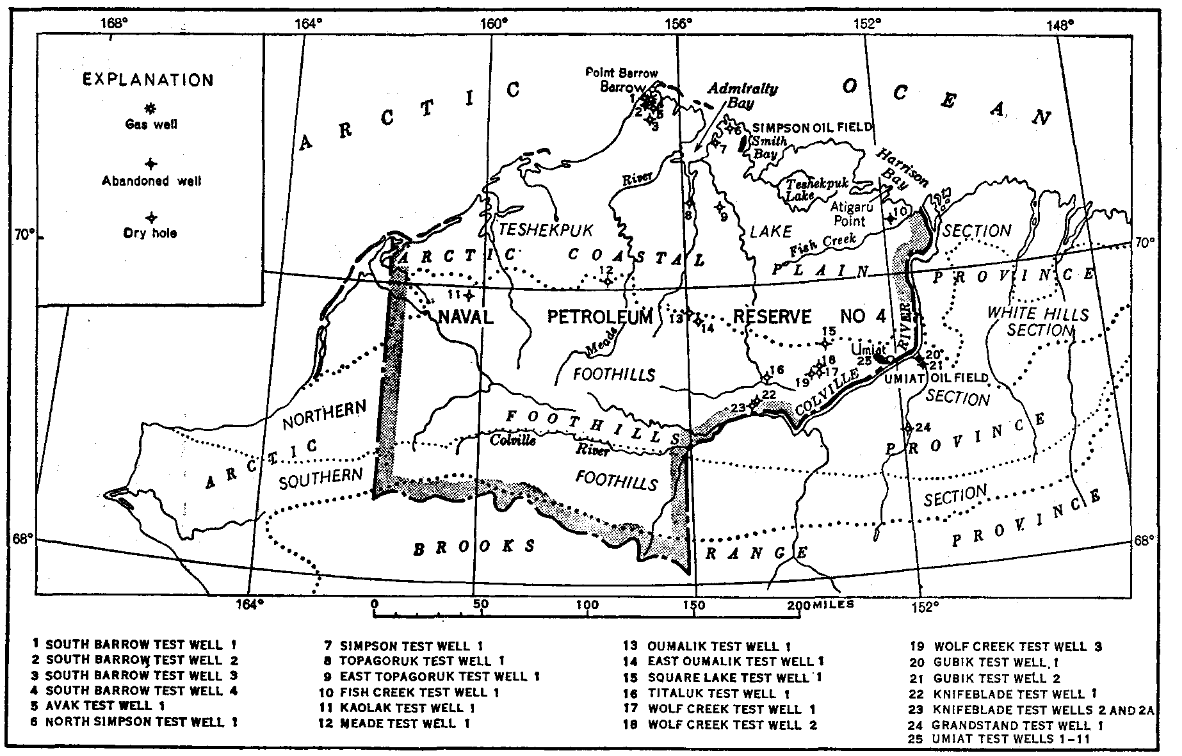


Figure 44.—Index map of northern Alaska showing Naval Petroleum Reserve No. 4 and the location of the test wells and oil fields.

were made later by United Geophysical Co. under subcontract to the Navy. On the west side of the Simpson peninsula in 1945, the Seabees drilled concurrently 12 shallow core tests for stratigraphic information. Simpson test well 1 was drilled in 1947 and early 1948, on a structural feature outlined by seismograph (fig. 45).

Although some oil shows were found in sandstones of Early Cretaceous age and the well was drilled to a total depth of 7,002 feet into pre-Mesozoic rocks, it was dry. Twenty-two more core holes that were drilled by Arctic Contractors from 1949 to 1951 in the seepage area near Cape Simpson on the east side of the peninsula resulted in the discovery and partial delineation of the shallow Simpson oil field. In the course of the examination of seismic profiles, an anomaly was noted on the north side of the peninsula. North Simpson test well 1 was drilled on this anomaly to a depth of 3,774 feet. This well was also dry, as the objective sandstones of the Grandstand formation are absent, probably having been removed by erosion before the Upper Cretaceous rocks were laid down.

The base map used in figure 45 is taken from the Barrow and the Teshekpuk quadrangles of the Alaska reconnaissance topographic series. The latitude and longitude of the well sites are adjusted to this base. The locations are all subject to change pending the publication of topographic maps.

Acknowledgments.—The information contained in this paper is taken from the daily, weekly, and completion reports of the Navy's prime contractor, Arctic Contractors; from the geophysical records of United Geophysical Co.; and from the records of the U. S. Geological Survey, which maintained a laboratory in Fairbanks, Alaska, for the description and analyses of well cores and cuttings. Unless otherwise indicated, the samples were described by the author. At the time of writing [1956] the core and cutting samples are stored at the U. S. Geological Survey's offices, 520 Illinois St., Fairbanks, Alaska.

Electric logs were run by Schlumberger Well Surveying Corp. A gas analysis was made by the National Bureau of Standards in Washington, D. C., and a water analysis was made by the U. S. Bureau of Mines.

Heavy minerals were identified by R. H. Morris, of the U. S. Geological Survey, as a part of a study of the heavy minerals of the whole Reserve, and microfossils were studied by H. R. Bergquist, also of the U. S. Geological Survey. Some of the microfossils from Simpson test well 1 are described by Helen Tappan Loeblich (Tappan, 1951, 1955, 1957). Upper Cretaceous megafossils were identified by George Gryc, of the Survey. Lower Cretaceous and Jurassic megafossils were identified and described (1955) by Ralph W. Imlay, of the Geological Survey, with the exception of the echinoderms which were identified by Arthur L. Bowsher, also of the Survey. Triassic megafossils were identified by Dr. Bernhard Kummel, of Harvard University. The fish from North Simpson test well 1 was identified by D. H. Dunkle, of the U. S. National Museum.

The help of the personnel connected with the above organization is gratefully acknowledged.

STRATIGRAPHY

Although both the Cape Simpson test wells were dry, they were of considerable interest stratigraphically. In a way, they complement each other. North Simpson test well 1 has the thickest section of Upper Cretaceous rocks found on the peninsula, and Simpson test well 1 penetrated older rocks including a part of the so-called basement, the age of which is undetermined. Figure 46 is a composite stratigraphic column representing the formations in the test wells and their relative thicknesses.

QUATERNARY DEPOSITS

GUBIK FORMATION

The Gubik formation of Pleistocene age, in North Simpson test well 1 is about 100 feet thick and is considerably thicker than in Simpson test well 1. It is made up primarily of sand and gravel. The gravel contains well-rounded pebbles and granules of black, gray, yellow, red, green, and white chert; yellow, grayish-green, and red quartzite and clear quartz; less well-rounded fragments of gray sandstone, limestone, calcareous clay shale; and other rocks. The constituents of the sand accompanying the gravel are the same. The sand grains are very fine and well rounded. The sand is commonly medium light yellowish gray. Samples of the Gubik formation from Simpson test well 1 contain a larger proportion of gravel than those from North Simpson. The samples from both wells included a small amount of light-olive-gray clay. The proportion of clay in the section may be substantially larger than is indicated by the samples; the process of washing to clean the cuttings of drilling mud may have removed much of this soft clay of the Gubik. The beds are probably entirely marine, which is indicated by the white mollusk shell fragments and microfossils found.

CRETACEOUS ROCKS

COLVILLE GROUP

SCHRADER BLUFF FORMATION

The Schrader Bluff formation of Late Cretaceous age, found in North Simpson test well 1 is 1,460 feet thick. It is rather uniform throughout and cannot be

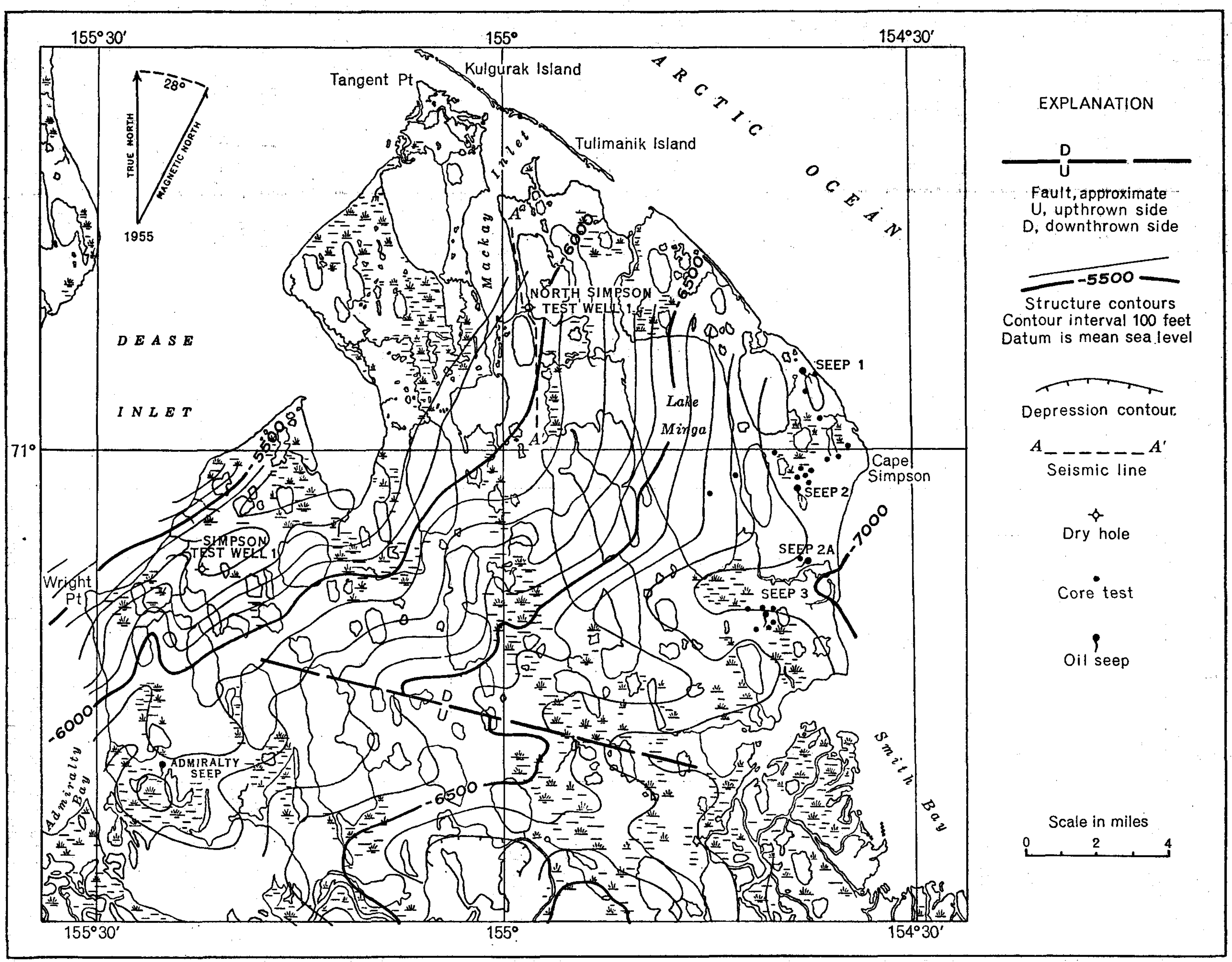


FIGURE 45.—Structure-contour map of the Cape Simpson area. Contoured by United Geophysical Co., Inc., on a phantom seismic horizon in Late Jurassic or Early Cretaceous rocks.

ERA SYSTEM, OR SERIES	GROUP	FORMATION
QUATERNARY		Gubik
UPPER CRETACEOUS	COLVILLE	Schrader Bluff
		Seabee
LOWER CRETACEOUS	NANUSHUK	Grandstand
		Topagoruk
		Oumalik
UPPER JURASSIC ? AND LOWER CRETACEOUS ?		Pebble shale
LOWER JURASSIC		No name
UPPER TRIASSIC		Shublik
PRE-MESOZOIC		No name

FIGURE 46.—Composite columnar section, North Simpson test well 1 and Simpson test well 1.

divided into the various members identified on the outcrop and in the subsurface to the south. However, the part of the Schrader Bluff formation present here is probably the lower two-thirds of the formation and may be approximately equivalent to the Barrow Trail and Rogers Creek members. (See a description of these members and a stratigraphic chart in Gryc and others, 1956.) The uppermost part, the Sentinel Hill member, has characteristic marine microfossils which are not found in North Simpson test well 1.

The formation is made up almost entirely of medium-light-gray clay shale. There are some light-gray and light-olive-gray beds as well. The clay shale is medium soft and has good to excellent cleavage or parting parallel to the bedding.

A negligible amount of light-gray siltstone and very fine-grained sandstone made up of subangular white and clear quartz is present. Rare silty partings contain abundant white volcanic shards, biotite and chlorite plates, carbonaceous flecks, and resinous amber particles. Characteristic of the whole section is the volcanic material, tuff and glass shards. All stages of alteration among the fluted shards were noted from clear glass to disintegrating particles. Most of the shards are opaque white.

The clay shale itself is noncalcareous, but very rare chips of white crystalline aragonite, light-gray limestone, calcareous siltstone, and sandstone were found in a few cutting samples within 500 feet of the base of the formation. One rounded and polished black chert pebble, three-fourths of an inch in diameter, was found in place in the clay shale 600 feet from the top of the Schrader Bluff formation. No other coarse material was associated with it.

The marine character of this formation is indicated by the abundant microfauna containing both Foraminifera and Radiolaria (H. R. Bergquist, personal communication). *Inoceramus* prisms and other pelecypod remains are also present.

The transition from the Seabee formation to the Schrader Bluff formation is arbitrary as deposition was continuous. The break is based on gradual lithologic and faunal changes. Above the contact glass shards are present; below they are essentially absent. The Schrader Bluff formation is less silty and less calcareous than the Seabee formation.

There were no shows of gas or oil in the Schrader Bluff formation.

SEABEE FORMATION

The Seabee formation of Late Cretaceous age is 1,220 feet thick in North Simpson test well 1. As in the Schrader Bluff formation, the clay shale which makes up about 95 percent of the Seabee formation is medium light gray and medium soft and has good cleavage. Some of the clay shale is a slightly lighter color or has a bluish cast and is waxy, probably containing some bentonite. The other 5 percent of the formation is composed of slightly silty or sandy beds and beds of limestone and calcareous siltstone. The hard limestone, which occurs in beds 1 foot thick or less, is variable—medium gray, medium dark gray, or light bluish gray; crystalline or dense, and lithographic or argillaceous. A small amount of white aragonite is also present. One chip of dull coal was found in a sample from near the middle of the formation. The lower half of the formation is the siltiest and sandiest part.

Microfossils are present but are not as abundant in either species or number as in the Schrader Bluff formation. However, *Inoceramus* prisms and fish fragments are common. A very small (1½ in. long) well-preserved fish, tentatively identified by D. H. Dunkle as *Leptolepis* sp., was found near the middle of the formation. The same core also contains *Borissiakoceras?* sp., a very small ammonite identified by George Gryc; it is characteristic of the Seabee formation.

The Seabee formation in North Simpson test well 1 is not as distinctive lithologically as it is where found structurally much higher in the nearby Simpson Seeps area. The base of the Seabee formation is also the base of the Colville group and is marked by a major unconformity and faunal change.

NANUSHUK GROUP

GRANDSTAND FORMATION

Simpson test well 1 penetrated the Grandstand formation of Early Cretaceous age immediately below the surface gravels. The formation here is 965 feet thick, but at one time it was even thicker because part of it has been removed by erosion. The lithology of the Grandstand formation in Simpson test well 1 is very accurately known as practically the entire section was cored. The formation is 68 percent of clay shale and 32 percent of sandstone and siltstone, which are of the most interest because they contain the oil and gas shows. At the outcrop of the type section (Detterman, 1956), 170 miles to the southeast, the formation is predominantly hard "dirty" sandstone and siltstone rather than clay shale, and it there interfingers with the nonmarine Killik tongue of the Chandler formation. In Simpson test well 1, however, the beds are entirely marine as indicated by the abundant megafauna and microfauna found in them (the *Verneuilinoides borealis* fauna similar to that found in the Topagoruk formation).

The clay shale in Simpson test well 1 is mostly light gray with some medium-gray or olive-gray streaks, is medium soft, and has poor to fair cleavage—sometimes hackly. It has rare micaceous partings and scattered silty laminae. In one place the light-olive-gray streaks are slightly sideritic.

The sandstone and siltstones are light to medium light gray. The coarser-grained sandstones are usually lighter in color than the siltstones. The rocks containing oil are stained light olive gray or olive gray. The sandstones are massive and rather soft and friable. The grains are angular to subrounded and range from very fine to fine, with rare medium grains. The sandstone is 80–90 percent of white and clear quartz, with some dark rock fragments and chert, carbonaceous particles, some white mica and biotite, as much as 5 percent of yellowish brown siderite, and rare chalky white (altered feldspar?) particles. The matrix is argillaceous.

The effective porosity of the sandstones from the Grandstand formation is quite high. The 30 samples tested ranged from 21.2 to 41.0 percent and averaged 33.1 percent out of 30 samples tested. The permeability of 20 of these samples ranged from 14.1 to 1,220 millidarcys. However, the values must be viewed with caution because the porosity and permeability tests were made on dry, extracted samples. The effect of moisture on the montmorillonite in the matrix is not taken into account. For a further discussion of these results see page 549.

One 6-inch bed of medium-light-gray hard dense argillaceous limestone with irregular fracture and containing rare minute calcite veins is 300 feet from the top of the formation in Simpson test well 1. Another foot of limestone and very calcareous siltstone is about 200 feet from the base of the formation. The limestone is pale yellowish brown, very hard and massive, and contains small dark-brown plant fragments. The limestone grades into very hard medium-light-gray siltstone. Elsewhere in the formation carbonate cementing material is very rare; some of it may be siderite. Grains of siderite are found in the sandstone, but very few clay ironstone concretions are present.

No coal was found, but carbonaceous partings and plant fragments are present rarely in both the clay shale and the sandstone.

The Grandstand formation is not found in North Simpson test well 1 as an unconformity is present in this part of the section.

TOPAGORUK FORMATION

The Topagoruk formation of Early Cretaceous age is differentiated from the overlying Grandstand formation on the basis of lithology alone. The Grandstand formation contains thick sandstone beds, and the Topagoruk does not, but the contact between the two formations is gradational. The base of the Grandstand is arbitrarily placed at the bottom of a series of thick sandstone beds. The lithologic characteristics of the Topagoruk formation in Simpson test well 1 and the equivalent section in

North Simpson test well 1 are identical, but in Simpson test well 1 the formation is 2,580 feet thick; and in North Simpson where the formation underlies an unconformity, only the lowest 820 feet are represented.

The formation consists of clay shale and siltstone very similar to that found in the Grandstand formation above. The clay shale, which is probably the predominant rock, is medium light to medium gray. It is soft to moderately hard, the hardness increasing with depth, and the cleavage is poor to fair, good in places. The clay shale has micaceous and carbonaceous partings. Pyrite nodules are very rare.

The siltstone is light to medium light gray and is soft and friable to medium hard; in most places the siltstone is a little softer than the clay shale. The siltstone ranges from thin bedded to massive, has poor to fair cleavage parallel to the bedding, and has irregular fracture. The grains composing the siltstone are mostly white and clear quartz. The siltstone is argillaceous or has scattered very fine sandy partings. It is mostly noncalcareous but does have a few slightly calcareous and moderately calcareous layers. In one place 6 inches of very calcareous and hard siltstone was recovered.

A few very thin beds of sandy siltstone or sandstone are near the top of the formation. The sandstone is light gray, thin bedded, and soft and friable. The grains are very fine and composed of 90 percent subangular to subrounded white and clear quartz. The remainder is carbonaceous material, rock fragments, and dark chert in an argillaceous matrix.

Beds of limestone are noted at 117, 318, and 1,363 feet from the top of the formation. The thickest is only 2 feet. The limestone is medium light gray, very hard, massive, finely crystalline, silty, and argillaceaus and tends to break at right angles to the core (along the bedding planes?). The sample at 318 feet from the top of the formation contains finely disseminated pyrite.

There is no coal and practically no carbonaceous material in the Topogoruk formation. Clay ironstone nodules are very rare, occurring only at two places in the section.

The formation is marine in origin. Fossils, microfossils in particular, are very abundant and diversified. The *Verneuilinoides borealis* fauna is present (H. R. Bergquist, personal communication). *Inoceramus* fragments and prisms and other pelecypod shell fragments are common. The worm tube *Ditrupa* sp. was found in many samples. Echinoid spines and crinoid ossicles were also found.

OUMALIK FORMATION

The contact between the Topagoruk and Oumalik formations in North Simpson test well 1 is marked by a sharp change in the electric log. The resistivity of the Oumalik formation of Early Cretaceous age is lower; there is a noticeable drop in the resistivity values at the contact. In this test the break could represent an unconformity. The dips change—the Topagoruk formation dips about 7° and the Oumalik only 2°.

Although the entire section is clay shale and the ditch samples show little change across the formation boundaries, probably because of contaminated cutting samples, the clay shale of the Oumalik formation in the cores in North Simpson test well 1 is slightly darker gray and contains less silt. The contact in Simpson test well 1 is less well defined, but here, too, there is a slight but gradual change in the characteristics of the electric log (slightly higher resistivity). Both wells are marked by the presence of pyritic *Lithocampe* sp., a diagnostic radiolarian from near the top of the Oumalik formation.

The North Simpson test had penetrated only 185 feet of the Oumalik formation at total depth, but Simpson test well 1 penetrated 1,710 feet of it—the complete section in this area.

The Oumalik formation is 90 percent of clay shale and about 10 percent of siltstone. In addition to the 10 percent of siltstone beds, thin silty beds are found throughout the clay shale. The clay shale is medium gray to medium dark gray with some medium-light-gray beds. The clay shale is medium hard and ranges from massive (claystone) to fissile. In general it has fairly good shaly cleavage, is noncalcareous, and has silty partings and laminae.

Thin beds of siltstone are distributed through the formation, but the most of them are in the lowest 650 feet. The siltstone is light gray and medium hard and has fair cleavage. A few streaks of sandstone are with the siltstone in the lower part of the Oumalik formation. The sandstone is light gray, medium hard, and fine grained. The grains are 90 percent of white and clear quartz. The remainder are mostly rock fragments with a little mica and yellowish quartz (?). The matrix is argillaceous or slightly calcareous.

The Oumalik formation is considered to be marine although the fauna is very limited. There is no indication of nonmarine beds. The base of the formation is marked by a lithologic break and faunal increase as indicated below.

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

The 340 feet of rocks underlying the Oumalik formation in Simpson test well 1 is very distinctive lithologically, and rocks of this type have been recognized in several of the northern wells. This rock is a dark clay shale containing scattered rounded grains of clear quartz and black chert. The occurrence of these quartz grains in the clay shale is unique among the rocks drilled on the Reserve and is always in the same position between the Oumalik formation and the Middle or lower Jurassic. This marine unit has been known informally to the geologists working in northern Alaska as the pebble shale.

More specifically, the clay shale of this unit is medium dark to dark gray (black to the casual glance, particularly when wet), is medium hard, and has poor to fair shaly cleavage. It characteristically contains floating (scattered at random) rounded grains of clear quartz ranging in size from very fine to medium. There are also very rare rounded grains of quartz and chert of several colors. In places the clay shale contains large isolated euhedral plates of biotite and patches and lines of pyrite.

In the few cores taken, there were very rare medium-light-gray laminae of pyritic siltstone, a ¼-inch layer of greenish-gray clay shale (possibly tuff?) containing finely disseminated biotite and pyrite, and a 6-inch layer of medium-dark-gray very hard lithographic and argillaceous limestone.

The rock is marine as two of the cores contained a very abundant marine microfauna. Chunks of *Inoceramus* (partly pyritized) were found in the cuttings, and one core contained shiny black carbonaceous plant remains as well as pyritized fishbone fragments.

Because of the poor quality of the cuttings and because no electric log was run from 5,400 to 5,956 feet, it is difficult to pick the lower contact of the unit. More common clear quartz grains and black chert granules at 5,620–5,630 feet (possibly representing coarser basal beds of the unit) and a lighter colored clay shale with a trace of medium-gray siltstone below it suggests that the contact may be near 5,630 feet. The core at 5,677–5,692 feet is Lower Jurassic. Rounded quartz grains and dark shale continue as contamination in the cuttings down as deep as 6,100 feet.

The age of this unit is not definitely established. The microfossils present have more in common with the overlying Oumalik formation than they have with the Jurassic rocks. Yet the lithology is identical with that found in the Upper Jurassic rocks of Topagoruk test well 1 which contains a different and distinct microfauna. It is possible that this pebble shale unit is partly Upper Jurassic and partly Lower Cretaceous, with the Lower Cretaceous represented in Simpson test well 1. In any event, the author does not believe that it can be considered a part of the overlying Oumalik formation as there is a pronounced lithologic change which may represent a major unconformity or change in the entire depositional regime.

LOWER JURASSIC ROCKS

An *Amaltheus* sp. indet., which is characteristic of the Pliensbachian, Lower Jurassic, was found at 5,680 feet in Simpson test well 1. This ammonite was identified by Ralph W. Imlay, and its occrrence in northern Alaska has been discussed by him (Imlay, 1955). The Lower Jurassic rock in this test is about 635 feet thick, with the top near 5,630 feet and the base at 6,265 feet. Undoubtedly there is an unconformity between these Lower Jurassic rocks and the overlying pebble shale as all of the Middle Jurassic as well as the latest Early Jurassic (Toarcian) is missing.

All but about the lowest 100 feet of the unit consists of claystone which is medium gray to medium dark gray. It is moderately hard or hard, has poor shaly cleavage and irregular fracture, and is silty and slightly micaceous. The bedding is obscure. The claystone characteristically contains numerous vermicular pyritic streaks about one thirty-second of an inch wide and pyritic aggregations up to 1 inch in diameter. There are traces of light- to medium-light-gray siltstone in the claystone, and some of the siltstone contains rare green glauconite pellets or grains. In the cutting samples, chips of clay shale (most of the "clay shale" described from the ditch samples is probably claystone as seen in the cores) containing glauconite pellets were noted, also chips of quartz grains embedded in a pyritic matrix. The claystone is noncalcareous, and the siltstone streaks are slightly calcareous.

The lowest 115 feet of the unit consists of sandstone and siltstone. The sandstone is light gray, hard, and massive and also has irregular fracture. It is very fine grained to silty, and the grains are angular to subangular but with rather high sphericity. The grains are composed of about 90 percent white and clear quartz and 5 percent of bluish-green glauconite, and the remainder of the material is rock and tiny carbonaceous fragments. The matrix is slightly calcareous to very calcareous.

The sandstone at 6,183–6,193 feet contains rounded masses (½ x 1 in.) of grayish-brown sandstone similar to the surrounding rock, but some of these masses are oil stained. The core was broken up by the time the author saw it, and she was not able to determine whether these were actual pebbles of sandstone in a sandstone matrix as they were earlier described by R. H. Chapman or simply lenticles of oil-stained sandstone. Some of the brownish "pebbles" were not actually oil-stained nor was there any show of oil in the "matrix." The average effective porosity of 6 samples from the interval 6,175–6,190 feet is 19.4 percent, but the average air permeability of the same samples is very low. The highest reading was less than 8 millidarcys. (See table 5.)

The core 20 feet from the base of the unit in Simpson test well 1 is made up of siltstone which ranges from light gray to dark greenish gray and is hard and massive. The light-gray siltstone is mottled with darker siltstone and some claystone. Vermicular markings and about 3 percent of greenish-blue glauconite is present. The darker phase of the siltstone contains abundant light- to dark-green soft glauconite particles which give the rock a speckled appearance.

Microfossils are abundant in the core where *Amaltheus* sp. indet. was found but are not so common in the coarser clastic beds. Helen Tappan (1955) has identified and described some of the Jurassic Foraminifera found in Simpson test well 1. The sandstone and siltstone cores contain pelecypods which have been identified by Ralph W. Imlay as *Oxytoma* sp. *Oxytoma* occurs in both the Lower Jurassic and the Lower Bajocian, lowest Middle Jurassic (Imlay, 1955) in northern Alaska. The occurrence of *Amaltheus* above *Oxytoma* in the well restricts the pelecypods here to the Lower Jurassic.

These Jurassic beds are undoubtedly a part of the Kingak shale as described by Payne and others (1951), but the term is too inclusive, and the author prefers to leave the section in this well unnamed until the Jurassic of northern Alaska is more completely described. More than one part of the Early Jurassic may be represented here.

UPPER TRIASSIC ROCKS

SHUBLIK FORMATION

At 6,265 feet in Simpson test well 1 there is a change in the electric log readings (see pl. 35) in which the average resistivity goes up, probably reflecting a high carbonate content of the rocks. The cores 40 feet below it contain Upper Triassic fossils of the Shublik formation. The Shublik here is 278 feet thick, with the base at 6,543 feet. The formation is composed of very argillaceous siltstone plus some silty claystone and some silty sandstone.

The color of the siltstone ranges from medium gray to medium dark gray, and the rock is commonly mottled, with the colors side-by-side. The mottling appears to be due to varying amounts of argillaceous material—the more clay the darker the color. Some medium-light-gray rock was seen in the cutting samples, and this lighter colored material might actually be silty limestone or very calcareous siltstone. The siltstone is hard and has irregular or vertical fracture. Most of the silt is quartz, but bright-bluish-green glauconite particles are abundant in some zones where the rock is grayish green. Finely disseminated pyrite and carbonaceous material were also found. The rock is moderately to very calcareous as the matrix is calcite. The siltstone grades in a few places to medium-light-gray silty limestone. Paper-thin light-colored calcite veinlets are in the limestone.

Scattered very fine subrounded to subangular grains of clear quartz are in the siltstone. These sand grains become more common with depth, and in the lowest 25 feet of the formation, the siltstone grades to a light-gray or medium-light-gray very calcareous sandstone. The sandstone is made up of 97 percent clear quartz grains which are subangular with a few subrounded. The remaining grains are rock fragments (schist?) and pyrite. The matrix is, of course, calcite. No porosity or permeability tests of this sandstone were made.

Some medium-dark-gray clay shale or claystone is found in the cutting samples. Glauconite grains are in the claystone as well as in the siltstone. Rare nodules and stringers of pyrite are found in the siltstone and claystone—similar to the occurrence of pyrite in the Jurassic rocks above.

The pelecypods *Halobia* sp. and *Monotis* sp. (or *Pseudomonotis?* sp.) are found abundantly throughout the Triassic section and in some places form a coquina. Impressions of these fossils were noted even on the chips in the cutting samples. Microfossils are abundant only in the upper, more argillaceous, part of the Triassic. These microfossils are described by Helen Tappan (Tappan, 1951).

The upper contact of the Triassic with the Jurassic rocks possibly represents a small unconformity, but the lower contact undoubtedly represents a break of major proportions.

PRE-MESOZOIC ROCKS

The rock underlying the Upper Triassic is argillite of undetermined age. The cutting sample in Simpson test well 1 from 6,535–6,545 feet contains a small amount of the argillite; so the contact must be a little above 6,545 feet. The author places it at 6,543 feet.

The argillite is predominantly light greenish gray rock but in places has grayish-red and purple bands. The banding is steeply inclined in the cores and is parallel to the bedding, which dips 75°–80° in Simpson test well 1. There is no textural difference between the color bands. The rock is hard, dense, and massive. It has numerous slickensided fracture planes dipping at angles up to 80°, and some of these are coated with pyrite and brown and white calcite. Very rare streaks in the argillite have a granular silty appearance. No fossils were found in this rock.

Although the drill penetrated these rocks from 6,543 to 7,002 feet, the total depth, the actual thickness of the beds is only 103 feet as computed using an average dip of 77°.

There has been much discussion of the degree of metamorphism and of the age of this rock. It is slightly siliceous but certainly is not markedly so. Beyond the introduction of a little silica and calcite, there is no evidence of metamorphism—no slaty cleavage, no micaceous or schistose bands, no secondary minerals indicative even of low-grade metamorphism are present. T. G. Payne (and others, 1951) compared these rocks at the bottom of Simpson test well 1 to the Neruokpuk formation which crops out in the Brooks Range and which is now considered to be of Late Devonian or older age.

STRUCTURE

In the summer of 1945 almost the entire Reserve was covered by an airborne magnetometer survey at an altitude of 1,000 feet on magnetic north-south lines with a 2-mile spacing. The Simpson area, which was the center of geophysical investigation at that time, was reflown on magnetic east-trending lines as well. The final magnetic map shows a decrease in intensity from east to west across the peninsula.

Of more interest was the gravity work which covered the entire peninsula in 1945. One small gravity high is centered about 4 miles north-east of Simpson test well 1. A seismograph party was also operating on the west side of the peninsula. The results of the 1945 gravity work were encouraging; so seismic coverage of the peninsula was completed in 1946 to check the gravity work. The seismic maps show a general southeasterly dip of all the Mesozoic rocks across the whole area with little seismic evidence in the Triassic and younger beds of the gravimetric high found in 1945. Along the seismic line through North Simpson test well 1 and across one of the gravity highs, there exists a rather poorly defined high in the pre-Triassic section which indicates that the gravity highs are probably related to the older rocks.

Simpson test well 1 was located on a small closure of 100 feet as contoured on a phantom seismic horizon in the extreme Lower Cretaceous? and Upper Jurassic? rocks (see fig. 45). This closure is elongated northeast and is a little over 2 miles long and a little less than 1 mile wide. The well is on the southwest end of the structural feature. A small amount of gas found below the bottom (5,954 feet) of the 7-inch casing (see formation tests 3 to 5, p. 555) possibly came from the sandstone of Jurassic age, with the top at 6,150 feet. An oil-stained pebble was found in the same standstone, although the sandstone itself showed no stain.

Seismic evidence indicates that a closure similar to that mentioned above is present on Triassic rocks.

The oil obtained in tests on Simpson test well 1 from the Grandstand formation (Lower Cretaceous, Nanushuk group) is probably partly trapped beneath an unconformity between the Colville (Seabee formation, clay shale) and Nanushuk groups. However, the quantity of oil trapped appears to be negligible. Possibly part of the oil has escaped at the surface as the impervious Colville group cover is not complete.

Compared with the structural features found in other parts of the Reserve, the one on which Simpson test well 1 was drilled was small. But there was great interest in the Cape Simpson area, and need for deep stratigraphic information was felt. At the time the well was drilled, the origin of the seeps at Cape Simpson, as well as that of Admiralty seep near the test well, was not understood.

North Simpson test well 1 was located on a rather unusual structural feature found on the reflection seismograph profiles. The test was based on an anomaly which suggested the presence of a lens-shaped structural feature (considered possibly limestone or sandstone) in Cretaceous rocks. The best idea of this feature can be obtained by examining the seismic profile (pl. 37).

An unconformity of considerable relief was shown to exist between the Colville group and the Topagoruk formation in the North Simpson area. Another unconformity of some magnitude but of lesser relief is present between the Topagoruk and older (Oumalik) formations. The striking unconformity can be seen on the seismic profile. The relief of the older one is not evident because it is in a shale upon shale sequence of beds, and no good reflectors are present; regional studies indicate its presence.

Drilling proved the section in the "hump" from 2,770 to 3,590 feet not to be a reef nor necessarily a bar but an erosional remnant of the Topagoruk formation under the upper unconformity. No reservoir beds were found; the section is entirely clay shale or silty clay shale.

Another interpretation of this structural feature is that it represents reworked Topagoruk sediments of earliest Colville age resting on the youngest of the two unconformities mentioned above. This does not seem likely however as the rocks themselves show no evidence of reworking. The part of the Topagoruk formation in North Simpson test well 1 is identical with the lowest part of the Topagoruk formation, both lithologically and paleontologically, in Simpson test well 1 and seems normal for the area.

A gap in the original seismic profile at shothole 361 was retained in plate 37 to show the reflectors in the pre-Mesozoic? below 6,800 feet. The reflectors between the bottom of North Simpson test well 1 and 6,800 feet represent the lowest Cretaceous, Jurassic, and Triassic sedimentary rocks.

SIMPSON TEST WELL 1

Location: Lat 70°57′12″ N., long 155°21′52″ W.
Elevation: Ground 15 feet, kelly bushing 29 feet.
Spudded: June 14, 1947.
Completed: June 9, 1948; dry and abandoned.
Total depth: 7,002 ft.

Simpson test well 1 is located on the flat Arctic Coastal Plain (see figs. 44 and 45) about 3½ miles northeast of Wright Point between Admiralty Bay and Dease Inlet.

The well was drilled with a rotary rig and penetrated the following:

	Feet
Gubik formation	17–25
Grandstand formation	25–990
Topagoruk formation	990–3, 580
Oumalik formation	3, 580–5, 290
Lower Cretaceous (?) and Upper Jurassic (?) rocks	5, 290–5, 630?
Lower Jurassic rocks	5, 630?–6, 265
Shublik formation	6, 265–6, 543
Pre-Mesozoic rocks	6, 543–7, 002

The ground in Arctic Alaska is permanently frozen, and along the north coast this permafrost attains great thickness. The deepest ice noted by the driller in Simpson test well 1 was a 2-inch streak in the core from 821–831 feet. The electric log (pl. 35) suggests that the base of the permafrost is at approximately 900 feet.

During the summer a few inches to a few feet of the surface soil thaws, particularly if the tundra is disturbed by man's activities; and the whole area becomes a virtual swamp. This is particularly true of the Simpson area, which is covered with lakes and ponds and is only a few feet above sea level in any place.

The stratigraphy of the formations found in Simpson test well is described on page 524. The dips in the Grandstand formation, which is the youngest Cretaceous formation penetrated beneath the Quaternary cover, are very low, averaging about 1½°–2°. These dips are also found in the Cretaceous down through the Oumalik formation. A few higher dips are probably the result of local crossbedding or foreset bedding.

Only a few dips were measured in cores from the rest of the Mesozoic rocks, but these seem to indicate a gradually increasing dip with depth from about 3° in the pebble shale to 5° in the Lower Jurassic and up to 10° in the Triassic rocks. Very steep dips averaging 75°–80° were measured in the alternating green and red beds of the pre-Mesozoic argillite.

Except in the pre-Mesozoic strata, at no place in the test is there any evidence of large-scale faulting, although a few local fractures in the cores were seen. The argillite cores contain numerous small calcite- and pyrite-coated or slickensided fracture planes which dip at a somewhat lesser angle than the bedding, but none of these have the appearance of a major fault.

Although shows of gas and oil were found in both the Cretaceous and Jurassic rocks, none were of commercial value and the well was completed dry and abandoned.

DESCRIPTION OF CORES AND CUTTINGS

The following lithologic description of core and cuttings was made by the author in 1954 at the Fairbanks laboratory of the U. S. Geological Survey. Earlier descriptions of this material, made in part by V. W. Schreiner and W. C. Fackler, of Arctic Contractors, and W. N. Lockwood, R. M. Chapman, and A. S. Keller, of the U. S Geological Survey, were consulted, particularly for oil shows.

Some of the cores, as indicated in the description, were badly contaminated with drilling mud. Contamination of the microfossil cuts from these cores is also likely. Many of the cutting samples were poor. This is partly the result of the washing process whereby a soft shale may wash away and leave only a sandy residue from the drilling mud. Where the cuttings were very poor, the description is based partly on the electric-log findings. The following notes were made by the author on the condition of the cutting samples in 1954: From 25 to 50 feet insufficient material was obtained to furnish both microfossil and lithology cuts; so microfossil cuts were made in preference to the lithology cuts. The lithology samples from 50 to 101 feet are made up only of the type of sediment ordinarily found in the Gubik formation, but the microfossil cuts starting as high as 25 feet contain Cretaceous microfossils (H. R. Bergquist, written communication). Therefore, the lithology samples must be highly contaminated with surface material. The Cretaceous rocks from this interval were probably soft clay shales and very fine-grained sandstones, which broke up and washed out when the lithology samples were being washed; 101–130 feet badly contaminated by surface material; 1,370–2,000 feet, some sand and pebbles of the Gubik formation; 2,000–2,300 feet, soft Cretaceous sand cavings; 3,060–3,900 feet, samples badly contaminated by loose Cretaceous sand—this sand actually persists down to about 5,500 feet; 5,650–5,900 feet, varying amounts of dark shale and rounded sand grains of the pebble shale; 5,940–6,090 feet, samples poorly washed, contain drilling mud, Cretaceous sand, and possibly even Cretaceous *Inoceramus* prisms; 6,150–6,220 feet, samples contaminated with everything from above including pipe scale and drill-bit filings, which rusted and turned the samples reddish; 6,220–6,495 feet, very poor, samples consist largely of loose sand and silt.

All material was described dry; colors were determined by comparison with the National Research Council rock color chart (Goddard and others, 1948). The term "trace" as used here is defined as less than 3 percent and in most places is less than 1 percent. Clay ironstone is a sideritic, dense, and rather hard mudstone that generally effervesces very slowly in cold dilute hydrochloric acid. The datum from which the depths are measured is the top of the rotary drive bushing.

Lithologic description

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

Core	Depth (in feet)	Remarks
----	0–14	Height of kelly bushing above ground level.
----	14–17	Cellar
----	17–50	Insufficient samples received in Fairbanks but described by Arctic Contractors well geologists as tundra, muck, sand and ice. Top of Grandstand formation placed at 25 ft on microfossil evidence.
----	50–61	Gravel, containing well-rounded pebbles and granules of black, gray, yellow, red, green, and white chert, also grayish-green and red quartzite, gray sandstone and limestone, clear quartz, and calcareous clay shale. A few rock fragments are angular. Material may be mostly contamination.
----	61–101	Gravel, sand, and clay. Gravel as above, better rounded pebbles are generally chert or quartzite, and poorly rounded ones sandstone. Sand is light gray, very fine to fine grained; grains subangular to rounded, made up largely of clear quartz, also dark chert and yellow quartz. Clay is light olive gray. White mollusk shell fragments and Gubik microfossils present. Material may be mostly surface contamination.
----	101–130	Clay shale, medium-light-gray, also sand and gravel contamination from Gubik formation.
1	130–133	Recovered 3 ft: Microfossils rare (?). Sandstone, light-olive-gray, fine-grained, noncalcareous, massive, very soft and friable; grains subangular to subrounded, made up of 90 percent white and clear quartz; remainder is mostly gray and black chert, carbonaceous particles and mica; loosely consolidated with argillaceous matrix; dip not determined; oil odor; free oil on microfossil wash water.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
2	133–141	Recovered 2 ft, 6 in.: Microfossils absent 1 ft sandstone, light-gray, fine-grained noncalcareous, soft and friable; 85 percent white and clear quartz; remainder is mica, rock fragments and small amount of carbonaceous material. 1 ft 6 in., clay shale, medium-light-gray, noncalcareous soft, with numerous silty laminae and partings, scattered sandy streaks, carbonaceous particles; dip undetermined but probably low.
3	141–146	Recovered 5 ft: Microfossils very rare. Clay shale, medium-light-gray, soft; poor to fair cleavage; grades to siltstone. Four inches of sandstone topping at 145 ft; sand is light gray and fine to medium grained, subangular to subrounded; 85 percent white and clear quartz; remainder is dark rock fragments, carbonaceous and micaceous material, scattered white grains—possibly feldspar; argillaceous matrix. A 1-in. dark-yellowish-gray-orange clay ironstone concretion at 144½ ft; whole interval is slightly calcareous; dip 1° (?).
4	146–156	Recovered 7 ft: Microfossils very rare. 4 ft siltstone, medium-light-gray, slightly calcareous, soft and friable; poor cleavage; very argillaceous rare clay ironstone nodules. 3 ft clay shale, medium-light-gray, soft, slightly calcareous; hackly cleavage, silty and sandy laminae; dip not determined.
5	156–166	Recovered 10 in.: Microfossils very rare. Clay shale, as immediately above, silty, slightly calcareous; no dip determined.
6	166–176	Recovered 5 ft: Microfossils common. Clay shale, medium-light-gray, medium soft, slightly calcareous; poor hackly cleavage; no dip determined.
7	176–181	Recovered 5 ft: Microfossils very rare. Clay shale as above, slightly calcareous in spots; fair cleavage; dip 1½°.
8	181–191	Recovered 5 ft: Microfossils common. Clay shale as immediately above, slightly silty, noncalcareous.
9	191–196	Recovered 5 ft: Microfossils rare. Clay shale, medium-light-gray, medium-soft, poor hackly cleavage; silty and with scattered light-gray siltstone laminae toward base. Slightly calcareous siltstone has good cleavage; dip 1½°.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
10	196–201	Recovered 5 ft: Microfossils common. Clay shale, medium-light-gray slightly silty, noncalcareous, medium-soft, fair cleavage; rare carbonaceous particles; dip 1½°.
11	201–206	Recovered 5 ft: Microfossils common. Clay shale as above, noncalcareous; rare streaks of siltstone.
12	206–211	Recovered 5 ft: Microfossils abundant. Clay shale as above, noncalcareous; fair cleavage; very rare micaceous partings; dip 1°.
13	211–216	Recovered 5 ft. Microfossils common. Clay shale, light- to medium-light-gray, noncalcareous, medium-soft; poor cleavage, very silty in lower 4 ft; one pale-yellowish-brown to moderate-yellowish-brown clay ironstone concretion at 215 ft; petroliferous odor; grades down into unit below.
14	216–221	Recovered 5 ft: Microfossils common. 2 ft siltstone, medium-light-to light-gray, soft; irregular fracture; very argillaceous in upper foot; becomes sandy toward base. 3 ft, sandstone, medium-light-gray to light-olive-gray, very fine to rare fine-grained, very silty, noncalcareous, very soft and friable; grains subangular; 85 percent white and clear quartz; remainder is dark chert, rock fragments and micaceous material; dip not determined; sand is oil stained and has strong petroliferous odor.
15	221–226	No recovery.
16	226–231	No recovery.
17	231–236	Recovered 6 in.: Not sampled for microfossils. Siltstone, light-gray, very argillaceous, noncalcareous, soft. *Ditrupa* sp.
18	236–241	Recovered 4 ft.: Microfossils rare. 2 ft, sandstone, light-gray, very fine-grained, medium-hard, slightly friable, massive; 90 percent white and clear quartz; remainder is carbonaceous and rock particles, micaceous material, and scattered yellowish grains (the latter effervesce slightly in cold HCl, sideritic). 2 ft, clay shale, medium-light-gray, noncalcareous, medium-soft; poor to good cleavage; rare silty laminae and partings; dip very low.
19	241–246	Recovered 6 ft: Microfossils common. Clay shale as above, fair cleavage; dip ½°.
20	246–251	Recovered 5 ft 6 in.: Microfossils common. Clay shale, medium-light-gray, noncalcareous, medium-soft, fair cleavage; rare silty or micaceous partings; dip not determined.
21	251–256	Recovered 5 ft: Microfossils common. Clay shale, exactly as above.
22	256–261	Recovered 2 ft, 6 in.: Microfossils very rare. 1 ft, 6 in. Clay shale as above; grades down into unit below. 1 ft, siltstone, light-gray, medium-soft, argillaceous, noncalcareous; fair to good cleavage; dip 2°.
23	261–266	Recovered 4 ft: Microfossils absent. Interbedded clay shale 50 percent, medium-light-gray, and 50 percent light-gray medium-soft siltstone; fair to good cleavage; noncalcareous; dip 1½°.
24	266–271	Recovered 5 ft: Not sampled for microfossils. Siltstone 70 percent and clay shale 30 percent, as above; siltstone is very argillaceous, with scattered carbonaceous and micaceous particles; dip 1½°.
25	271–276	Recovered 5 ft: Microfossils common. Clay shale, silty, grades to argillaceous siltstone, light- to medium-light-gray, medium-soft; fair cleavage; noncalcareous except very slightly calcareous at 272 ft; *Ditrupa* sp. at 273 ft.
26	[1] 273–278	Recovered 5 ft: Microfossils common. Clay shale, medium-light-gray, silty, medium-soft, poor to fair cleavage; some streaks of silt; very slightly calcareous in spots.
27	278–283	Recovered 5 ft: Microfossils rare. Clay shale as above, noncalcareous; some hackly cleavage; dip up to 3°.
28	283–288	Recovered 5 ft: Microfossils very rare. Clay shale as above, medium-light- to medium-gray, noncalcareous; dip 1°–2°.
29	288–293	Recovered 5 ft: Microfossils absent. Clay shale, medium-light-to medium-gray, medium-soft; fair cleavage, very little silt; slightly calcareous in spots; dip 1°.
30	293–298	Recovered 5 ft: Microfossils common. Clay shale as above, noncalcareous; dip 1°.
31	298–303	Recovered 5 ft: Microfossils common. Clay shale as above, scattered light-gray silty layers; inch-long crinoid (one-sixteenth of an inch wide) stem at 301 ft; slightly calcareous in silty layers.

[1] Corrected measurement by drillers—276 ft of core 25 actually equals 273 ft of this core.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
32	303–308	Recovered 5 ft: Microfossils abundant. Interbedded clay shale 70 percent and siltstone 30 percent, light- to medium-light-gray, noncalcareous, medium-soft; fair cleavage; scattered very fine sand partings particularly in upper 6 in. of interval. Pelecypod fragments, *Ditrupa* sp., and abundant crinoid ossicles noted at 305 ft; slight petroliferous odor in upper foot of recovery; dip 1°–2°.
33	308–313	Recovered 5 ft: Microfossils abundant. 2 ft, clay shale, medium-light-gray, noncalcareous, medium-soft, fair cleavage. 1 ft, sandstone, light-olive-gray, very fine-grained to silty, soft, fair cleavage; grains subangular to subrounded; primarily white and clear quartz; some white mica, and few black carbonaceous (?) particles. At base is inch-thick dark-yellowish-orange, very hard and calcareous clay ironstone concretion; rest is noncalcareous; sand is slightly oil stained and has a slight petroliferous odor. 2 ft, clay shale, medium-light-gray, as above, slightly silty, noncalcareous; dip very low.
34	313–318	Recovered 5 ft: Microfossils abundant. 2 ft, siltstone, light- to medium-light-gray, medium-soft, very argillaceous; grades down into unit below. 3 ft, clay shale, medium-light-gray, slightly silty, medium-soft, fair cleavage; and light-olive-gray ironstone concretion at 317½ ft; noncalcareous; dip undetermined.
35	318–323	Recovered 5 ft: Microfossils absent. Clay shale, medium-light-gray, slightly silty, medium-soft; poor to fair cleavage. Topping at 1½ ft from base is about 6 in. of hard dense argillaceous, medium-light-gray limestone with a slight brownish cast; irregular fracture; contains rare minute calcite veins. Clay shale is noncalcareous except close to limestone layer; dip undetermined.
36	323–328	Recovered 4 ft: Microfossils absent. Clay shale as above, noncalcareous; dip undetermined.
37	328–333	Recovered 5 ft: Microfossils very rare. Clay shale, as above, noncalcareous; some beds with very pale-yellow cast.
38	333–338	Recovered 5 ft: Microfossils very rare. Clay shale as immediately above, 1 in. light-olive-gray clay ironstone concretion at 336 ft; except for concretion core is noncalcareous; dips probably very low (1° ?) but undetermined because of distortion caused by core barrel in soft sediments.
39	338–343	Recovered 5 ft: Microfossils common. Clay shale, medium-light-gray with olive cast, noncalcareous, soft; poor to fair cleavage; very little silt; dip undetermined.
40	343–348	Recovered 5 ft: Microfossils common. Clay shale as above; fair cleavage; slightly calcareous in spots; dips to 6°.
41	348–353	Recovered 5 ft: Microfossils abundant. Clay shale as above 75 percent and siltstone 25 percent, light-gray with yellowish cast, soft, very argillaceous, micaceous, poor cleavage, noncalcareous; *Ditrupa* sp. fragment at 357 ft; dip undetermined.
42	353–358	Recovered 5 ft: Microfossils abundant. Clay shale 90 percent, siltstone 10 percent as above, very rare carbonized plant remains; noncalcareous; dips up to 5° but mostly lower.
43	358–363	Recovered 5 ft: Microfossils common. Clay shale, medium-light-gray, with yellowish cast, noncalcareous, medium soft; fair to good cleavage; thin silty laminae, rare black carbonized plant remains; dip 2°.
44	363–368	Recovered 4 ft: Microfossils common. Clay shale as above, silty, noncalcareous; poor to fair cleavage; dip 1°.
45	368–373	Recovered 2 ft, 6 in.: Microfossils abundant. Clay shale as above; part of recovery appears to be drilling mud.
46	373–378	Recovered 4 ft: Microfossils abundant. Clay shale, medium-light-gray, noncalcareous, soft; poor cleavage; rare thin silt laminae; dip undetermined.
47	378–383	Recovered 5 ft: Microfossils very rare. Siltstone, light-olive-gray, noncalcareous, soft: poor to fair cleavage; very argillaceous but also slightly sandy in part; light-yellowish-brown clay ironstone concretion at 380 ft. Very rare carbonized wood fragments; very rare mollusk shell fragments; dip 2°.
48	383–388	Recovered 5 ft: Microfossils absent. Sandstone, olive-gray, very fine-grained, noncalcareous, very soft nearly unconsolidated; grains subangular to subrounded; 90 percent white and clear quartz; remainder is dark chert,

Lithologic description—Continued

Core	Depth (in feet)	Remarks
		rock fragments and carbonaceous material, numerous silty layers, argillaceous streaks; dip undetermined; strong petroliferous odor and stain.
49	388-393	Recovered 5 ft: Microfossils absent. Sandstone as above, light-olive to olive-gray, very fine- to fine-grained noncalcareous, soft, fair cleavage; abundant carbonaceous particles, also some mica, argillaceous matrix; dip 3°; strong petroliferous odor and stain.
50	393-398	Recovered 5 ft: Microfossils absent. Sandstone as immediately above, fair to good cleavage; 2 in. of hard light-olive gray ironstone concretion at 396½ ft; noncalcareous except for concretion which is very slightly calcareous; dip 2°; strong petroliferous odor and stain.
51	398-403	Recovered 5 ft: Microfossils absent. 4 ft sandstone, upper half is olive gray and lower half is light olive gray; noncalcareous, soft, very fine-grained to silty; grains subangular to subrounded; 90 percent white and clear quartz, also rock and carbonaceous fragments, micaceous material, small amount of chert and soft chalky white mineral; argillaceous matrix; dip 3°; strong petroliferous odor and stain. 1 ft shale, medium-dark-gray, slightly silty, noncalcareous, medium-soft; fair cleavage.
52	403-408	Recovered 5 ft: Microfossils absent. 1 ft, clay shale, medium-light-gray, noncalcareous, medium-soft; fair to good cleavage; few silty laminae. 2 ft, sandstone and siltstone, light-gray, noncalcareous, soft; components as in core above, also some pyrite present; strong petroliferous odor. 2 ft, clay shale as in upper interval of of core; noncalcareous; dip 3°.
53	408-413	Recovered 5 ft: Microfossils absent. Clay shale, medium-light-gray, medium-soft; fair cleavage; silty streaks; slightly calcareous in rare streaks; dip 3° in silty streaks which have a slight petroliferous odor.
54	413-418	Recovered 4 ft: Microfossils absent. 2 in. limestone, medium-gray, very hard, dense; brown calcite veins up to one-fourth inch thick. 3 ft, 10 in., clay shale, medium-light-gray, medium-soft; poor to fair cleavage; numerous light-gray silty laminae toward base; noncalcareous; dip as much as 5°.
55	418-423	Recovered 5 ft: Microfossils absent. 1 in., sandstone, medium-light-gray, very fine-grained, very hard; grains subangular; 75 percent white and clear quartz; remainder is rock fragments, micaceous and carbonaceous particles, and chert; trace pyrite; very calcareous matrix. 4 ft, 11 in., clay shale (large part of recovery appears to be drilling mud), light- to medium-light-gray slightly silty; noncalcareous, medium-soft to soft; poor cleavage; no dip determined.
56	423-428	Recovered 5 ft: Microfossils rare. Clay shale 80 percent and siltstone 20 percent (badly infiltrated by drilling mud), light- to medium-light-gray, medium-soft to soft; poor cleavage; very slightly calcareous in spots; dip not determined.
57	428-433	Recovered 5 ft: Microfossils rare. 3 ft, clay shale and siltstone as above; very little drilling mud. 2 ft, siltstone, light-gray, soft and friable argillaceous, noncalcareous; no cleavage; no dip determined.
58	433-438	Recovered 5 ft: Microfossils very abundant. Clay shale 90 percent, siltstone 10 percent, light- to medium-light-gray, medium-soft, noncalcareous, fair to good cleavage; rare micaceous partings; thin *Inoceramus* sp. shell fragment at 437 ft; dip 4°.
59	438-443	Recovered 5 ft: Microfossils very abundant. Interbedded clay shale 60 percent medium-light- to medium-gray, and 40 percent medium-light-gray medium-soft siltstone; poor to fair cleavage; noncalcareous; dip not determined.
60	443-448	Recovered 5 ft: Microfossils very rare. 6 in., sandstone, light-gray, very fine-grained, soft and friable; grains 90 percent white and clear quartz; also some yellow grains which effervesce slowly in cold acid—siderite (?), and a few dark minerals. 1 ft 6 in., clay shale, medium-light- to medium-gray, medium-soft; fair cleavage; thin interbeds of siltstone and sandstone. 3 ft, sandstone, light-gray, very fine- to fine-grained, noncalcareous, medium-soft and friable, massive; grains subangular to subrounded; 90 percent white and clear quartz; also some dark

Lithologic description—Continued

Core	Depth (in feet)	Remarks
		minerals, mica and yellow siderite; dip undetermined; no shows.
61	448–453	Recovered 4 ft: Microfossils absent. 9 in., sandstone as above, medium-hard, very calcareous; rare carbonaceous material. 3 ft 3 in., sandstone, light-gray, very fine-grained, slightly calcareous, medium-soft and friable, massive; grains angular to subrounded, primarily white and clear quartz, also yellow siderite grains; small amount of mica and dark minerals; dip not determined; no shows.
62	453–458	Recovered 5 ft: Microfossils absent. Sandstone, as above, very fine- to fine-grained, noncalcareous; some cleavage parallel to bedding; dip 1°; no shows.
63	458–463	Recovered 4 ft: Microfossils absent. Sandstone as in core immediately above; no dip determined; no shows.
64	463–468	Recovered 5 ft: Microfossils absent. Sandstone as above, very fine-grained; noncalcareous, massive; dip 1°; no shows.
65	468–473	Recovered 5 ft: Microfossils absent. Sandstone, as above, fairly good cleavage parallel to bedding, dip 1½°.
66	473–478	Recovered 5 ft: Microfossils very rare. Siltstone, light-gray, noncalcareous; poor to fair cleavage, largely white and clear quartz, but also a small amount of carbonaceous and micaceous material, also yellow siderite particles, sandy and soft at top becoming argillaceous and medium hard toward base; 1° dip; no shows.
67	478–483	Recovered 5 ft: Microfossils rare. 4 ft, siltstone as above. 1 ft, clay shale, medium-light-gray, noncalcareous, medium-soft; fair cleavage; rare carbonaceous partings; dip not determined.
68	483–488	Recovered 5 ft: Microfossils very rare. Clay shale as above, light- to medium-light-gray, fair to good cleavage; dip 2°.
69	488–493	Recovered 5 ft: Microfossils absent. 3 ft, clay shale, light- to medium-light-gray, noncalcareous, medium-soft; fair cleavage; dip 1°; grades into unit below. 2 ft, sandstone, light-gray, noncalcareous, medium-soft, friable; has fair cleavage parallel to bedding; grains mostly subangular; 95 percent white and clear quartz; some micaceous material, dark minerals and rare siderite grains; argillaceous matrix; no shows.
70	493–498	Recovered 5 ft: Microfossils rare. 1 ft, clay shale, light-gray to light-olive-gray, noncalcareous, medium-soft; fair cleavage parallel to bedding. 1 ft, sandstone as in core above, very fine-grained to silty; slightly larger amount of mica and siderite grains. 3 ft, clay shale, medium-light-gray, noncalcareous; thin laminae of siltstone; dip 1°.
71	498–503	Recovered 5 ft: Microfossils rare. Interbedded siltstone 75 percent and clay shale 25 percent. Siltstone is light gray, medium soft, and friable; fair cleavage; rare carbonaceous partings. Clay shale is light to medium light gray and noncalcareous; dip very low.
72	503–508	Recovered 5 ft: Microfossils rare. Interbedded clay shale 80 percent and siltstone 20 percent as above; dip 1½°.
73	508–513	Recovered 5 ft; Microfossils rare. Clay shale, light- to medium-light; gray, noncalcareous, medium-soft; numerous streaks of silt; poor to fair cleavage, *Ditrupa* sp. fragments at 509 ft; dip 1°.
74	513–518	Recovered 5 ft: Microfossils rare. Siltstone, light-gray, noncalcareous, medium-soft, friable; fair cleavage; argillaceous laminae, particularly toward base; rare carbonaceous partings; *Ditrupa* sp. fragments at 514 ft and 517 ft; dip 1½°.
75	518–523	Recovered 5 ft: Microfossils rare. Clay shale, light- to medium-light-gray, medium-soft; poor to fair cleavage; some light-olive-gray sideritic clay shale that is slightly calcareous; a few silty laminae, rare shell fragments; 1° dip.
76	523–528	Recovered 5 ft: Microfossils common. Clay shale as above, light-gray and light-olive-gray; light-olive-gray streaks are slightly calcareous; dip 1½°.
77	528–533	Recovered 5 ft: Microfossils common. Clay shale as above, noncalcareous; rare micaceous partings; fair cleavage; dip 1½°.
78	533–538	Recovered 5 ft: Microfossils common. Clay shale, light- to medium-light-gray; fair hackly fracture; rare silty laminae; slightly calcareous in spots; dip 1½°.
79	538–543	Recovered 5 ft: Microfossils common. Clay shale as above, noncalcareous; micaceous partings; very little silt; dip ½°.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
80	543–548	Recovered 5 ft: Microfossils abundant. Clay shale, light- to medium-light-gray, noncalcareous, medium-soft; fair cleavage; very little silt; dip 1°.
81	548–553	Recovered 1 ft 6 in.: Microfossils not sampled. Clay shale, medium-gray, medium-soft; poor to fair cleavage; dip low.
82	553–555	Recovered 2 ft 9 in.: Microfossils not sampled. (Probably includes part of above core). Clay shale, as above. Core diameter very small; large part of recovery consists of drilling mud.
83	555–565	Recovered 7 ft: Microfossils abundant. Clay shale, medium-light- to medium-gray; core badly infiltrated by drilling mud.
84	565–573	Recovered 5 ft: Microfossils common. Clay shale, medium-light- to medium-gray, noncalcareous, medium-soft, poor cleavage; scattered silty laminae; rare carbonaceous particles; dip not determined.
85	573–578	Recovered 5 ft: Microfossils common. Clay shale as above; badly infiltrated by drilling mud.
86	578–583	Recovered 4 ft: Microfossils common. Clay shale, medium-light-gray; recovery largely drilling mud.
87	583–588	Recovered 5 ft: Microfossils common. Clay shale, light-to medium-light-gray, medium-soft; poor cleavage; also streaks of light-gray siltstone; much drilling mud; silt is very slightly calcareous.
88	588–593	Recovered 2 ft 6 in.: Microfossils not sampled. Clay shale, light-to medium-light-gray, slightly calcareous, soft; poor to fair cleavage; dip undetermined.
89	593–598	Recovered 3 ft 6 in.: Microfossils not sampled. Clay shale as above.
90	598–603	Recovered 5 ft: Microfossils rare. Clay shale, light-gray, noncalcareous, medium-soft; fair to good cleavage; dip 1°.
91	603–608	Recovered 5 ft: Microfossils rare. Clay shale, light- to medium-light-gray, noncalcareous, medium-soft, good cleavage. A light-gray 3-in.-thick layer of siltstone at 606 ft, slightly softer than clay shale; dip 1°.
92	608–613	Recovered 4 ft 6 in.: Microfossils not sampled. 2 ft 3 in., clay shale as above with silty partings. 2 ft 3 in., siltstone, light-gray, medium-soft, and friable, finely micaceous, noncalcareous; fair cleavage; dip 1°.
93	613–623	Recovered 9 ft: Microfossils common. 2 ft, siltstone, light-gray, noncalcareous, medium-soft, friable; irregular fracture; pelecypod shell fragments at 615 ft. *Ditrupa* sp. fragments in microfossil cut; grades into unit below. 7 ft, interbedded light-gray siltstone and medium-light-gray clay shale, noncalcareous; fair cleavage.
94	623–633	Recovered 7 ft 6 in.: Microfossils common. 2 ft 6 in., clay shale, light- to medium-light-gray, noncalcareous, medium-soft, poor cleavage; numerous silty streaks; dip 1°; shell fragments near top. 3 ft, siltstone, light-gray, slightly micaceous, medium-soft, friable, massive; irregular fracture. 2 ft, interbedded siltstone and clay shale, noncalcareous; thin layers; large carbonaceous plant fragment at 631 ft; white shell fragments at 632 ft.
95	633–643	Recovered 8 ft 6 in.: Microfossils common. Interbedded siltstone and clay shale (about equal proportions), light- to medium-light-gray, noncalcareous, medium-soft; fair to good cleavage; dip 3°.
96	643–649	Recovered 2 ft 6 in.: Microfossils very rare. Clay shale, medium-light-gray, non-calcareous, medium-soft; dip 2°. Lower half badly infiltrated by drilling mud.
97	649–653½	Recovered 4 ft: Microfossils absent. 1 ft, clay shale as above. 3 ft, drilling mud.
98	653½–663	Recovered 2 ft: Microfossils rare. Clay shale as above.
99	663–668	Recovered 1 ft 9 in.: Microfossils common. Clay shale and some siltstone infiltrated by drilling mud.
100	668–673	Recovered 2 ft 6 in.: Microfossils common. Clay shale, medium-light-gray, noncalcareous, rather soft; poor cleavage; infiltrated by drilling mud.
101	673–683	Recovered 6 ft: Microfossils very abundant. 2 ft, clay shale as above; fair to good cleavage; micaceous partings. 4 ft, drilling mud, probably was clay shale.
102	683–693	Recovered 3 ft: Microfossils abundant. Clay shale, light- to medium-light-gray, medium-soft; slightly micaceous, non-

Lithologic description—Continued

Core	Depth (in feet)	Remarks
		calcareous; fair cleavage; lower half largely drilling mud.
103	693–703	Recovered 5 ft: Microfossils very rare. Siltstone, light-gray, noncalcareous, medium-soft, friable; fair to good cleavage; a few 1- to 3-in. layers of medium-dark-gray clay shale; rare very fine-grained sandstone streaks; dip 1½°; oil odor.
104	703–713	Recovered 4 ft: Microfossils common. 1 ft, clay shale, medium-light-gray, medium-soft. 3 ft, siltstone, light-gray; noncalcareous, medium soft; good cleavage; rare clay shale laminae; dip 4°.
105	713–723	Recovered 9 ft: Microfossils rare. Siltstone, light-gray, medium-soft, friable; slightly micaceous, noncalcareous, good cleavage; *Ditrupa* sp. at 715 ft; pale-yellowish-brown sideritic layer containing black carbonaceous flecks at 714½ ft; dip 2°–8°.
106	723–733	Recovered 8 ft 6 in.: Microfossils very abundant. 3 ft, 6 in., clay shale, medium-light-gray, noncalcareous, medium-soft; fair cleavage; *Ditrupa* sp. at 723½ ft; dip 4°. 5 ft, siltstone as in core above light-gray, layers up to 6 in. thick of clay shale.
107	733–743	Recovered 3 ft 9 in.: Microfossils abundant. Clay shale, medium-light-gray, noncalcareous, medium-soft; fair cleavage; about 1 ft 6 in. of total recovery is drilling mud.
108	743–753	Recovered 5 ft: Microfossils very abundant. Clay shale as above, all but about 1 ft of recovery is drilling mud.
109	753–763	Recovered 4 ft: Microfossils very rare. 1 ft 10 in., sandstone, medium-light-gray, very fine- to medium-grained (poorly sorted), medium-soft, friable; breaks parallel to bedding; angular to subrounded grains; 80 percent white and clear quartz; remainder is dark chert, carbonaceous particles, rock fragments, some mica, and possible feldspar. Sandstone is argillaceous, silty, and "dirty"; no shows. 2 ft 2 in., clay shale, medium-light-gray; infiltrated by drilling mud.
110	763–771½	Recovered 6 ft: Microfossils absent. Sandstone, light-gray, fine-grained, noncalcareous, medium-soft, friable; massive but tends to break roughly at right angles to core sides; "dirty"; composition same as in core above.
111	771½–781	Recovered 9 ft: Microfossils absent. 5 ft, sandstone as above, very fine-grained; slightly petroliferous odor. 3 ft 2 in., interbedded siltstone and clay shale, light- and medium-light-gray, rather soft; poor to fair cleavage. Three-inch-thick layer of very calcareous, medium-light-gray hard siltstone 6 in. from base; dip 3°. 1 in., sandstone as in first interval of core.
112	781–791	Recovered 10 ft: Microfossils absent. Sandstone, light- to medium-light-gray, fine-grained, noncalcareous, medium-soft, slightly friable, massive; tends to break approximately at right angles to core sides; grains subangular to subrounded; grains made up of 85 percent white and clear quartz; remainder is dark chert, carbonaceous particles, rock fragments, white mica, and rare chalky white particles, argillaceous matrix; slight petroliferous odor.
113	791–801	Recovered 9 ft 6 in.: Microfossils absent. Sandstone as in core 112 above.
114	801–811	Recovered 10 ft: Microfossils absent. Sandstone as above.
115	811–821	Recovered 10 ft: Microfossils absent. 6 ft, sandstone as above. 1 ft, limestone and very calcareous siltstone. Limestone is pale yellowish brown, very hard, massive and has vertical fracture and contains small dark-brown plant fragments. Limestone grades into medium-light-gray very hard siltstone that breaks with irregular fracture or parallel to bedding; very thin beds; black carbonaceous partings; dip 3°. 3 ft, sandstone as in upper interval of core, very fine- to fine-grained, noncalcareous; no petroliferous odor.
116	821–831	Recovered 9 ft: Microfossils absent. Sandstone, light-gray, very fine- to fine-grained, noncalcareous, medium-soft; irregular fracture; silty grains subangular to rarely subrounded; grains made up of 90 percent white and clear quartz; remainder is dark-gray chert, rock fragments, carbonaceous particles, white mica, biotite, and yellow siderite grains, argillaceous matrix.
117	831–841	Recovered 3 ft: Microfossils absent. Sandstone as in core above, noncalcareous except for ½-in. layer of very slightly calcareous, pale-yellowish-brown clay ironstone in about middle of recovery.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
118	841-851	Recovered 9 ft: Microfossils absent. Sandstone as above, fine-grained, noncalcareous, medium-soft to medium-hard.
119	851-857½	Recovered 4 ft 4 in.: Microfossils absent. Sandstone as above, very fine-grained; breaks at right angles to core sides.
120	857½-867	Recovered 5 ft 4 in.: Microfossils absent. Sandstone, light-gray, very fine- to fine-grained, medium-soft to very soft; composition of grains same as described in core 116 above but with smaller proportion of white and clear quartz; up to 5 percent opaque to clear brownish yellow siderite grains. Sandstone as a whole is noncalcareous, although siderite grains are very slightly so.
121	867-877	Recovered 3 ft: Microfossils absent. Sandstone as above, fine-grained, noncalcareous, medium-soft.
122	877-885	Recovered 4 ft: Microfossils absent. 2 ft 6 in., sandstone as above; grades from very fine-grained into unit below. 1 ft 6 in., siltstone, light-gray, medium-soft; contains some laminae of medium-light-gray clay shale. Bottom 2 in. is hard light-gray sandy siltstone.
123	885-895	Recovered 8 ft: Microfossils absent. 4 ft, sandstone 80 percent, light-gray, medium-hard, interbedded with siltstone and small amount of clay shale; slightly calcareous. 4 ft, sandstone, light-gray, noncalcareous, medium-hard, fine-grained; 85 percent white and clear quartz; remainder is dark chert, rock fragments, traces of mica, siderite, and opaque white particles.
124	895-900	Recovered 4 ft 6 in.: Microfossils absent. Sandstone as immediately above; 6 in. of clay shale topping at about 897 ft, medium-light-gray; fair cleavage.
125	900-910	Recovered 8 ft 6 in.: Microfossils common. 6 in. sandstone as above. 2 ft, clay shale, medium-light-gray, medium-soft; fair cleavage; dip 3°. 4 ft, sandstone as in core above. 2 ft, interbedded sandy siltstone and clay shale.
126	910-920	Recovered 8 ft: Microfossils common. 4 ft, clay shale, medium-light-gray, medium-soft; poor cleavage; numerous soft silty interbeds. 4 ft, interbedded sandstone 50 percent, siltstone 20 percent, and clay shale 30 percent.
127	920-930	Recovered 8 ft 6 in.: Microfossils very rare. Sandstone, medium-light-gray, very fined-grained, silty, noncalcareous, medium-soft, friable: breaks at right angles to core side; grains subangular to subrounded; grains 90 percent white and clear quartz; remainder is rock fragments, carbonaceous particles, some chert, and mica; argillaceous matrix.
128	930-940	Recovered 6 ft: Microfossils absent. Sandstone as above.
129	940-950	Recovered 5 ft: Microfossils absent. Sandstone as above; grades to siltstone; core is soft and crumbled.
130	950-960	Recovered 4 ft 6 in.: Microfossils absent. Siltstone, light-gray, argillaceous- noncalcareous; core soft and crumbled; poor cleavage; numerous medium light-gray clay shale laminae; shell fragment at 953 ft.
131	960-970	Recovered 4 ft 6 in.: Microfossils absent. Siltstone and clay shale as above; core not so badly broken; lower half of recovery contains numerous very fine-grained sandstone layers.
132	970-980	Recovered 7 ft 6 in.: Microfossils rare. Sandstone, light-gray, very fine-grained to silty, noncalcareous, medium-soft, friable; breaks approximately at right angles to core sides· grains subangular to subrounded; grains made up primarily of white and clear quartz, rare mica, chert, and rock fragments, about 5 percent yellowish brown siderite.
133	980-990	Recovered 2 ft 9 in.: Microfossils not sampled. Sandstone as above, very silty and argillaceous; grades toward base to siltstone.
134	990-1,000	Recovered 4 in.: Microfossils not sampled. Clay shale, medium-light-gray, noncalcareous, medium-soft; poor cleavage. Top of Topagoruk formation at 990 ft.
135	1,000-1,010	Recovered 3 ft: Microfossils common. Clay shale as above, soft; core badly infiltrated by drilling mud.
136	1,010-1,020	Recovered 4 ft: Microfossils very abundant. Clay shale, medium-light- to medium-gray, noncalcareous, soft; poor to fair cleavage; scattered thin laminae of soft siltstone infiltrated by drilling mud; *Inoceramus* shell fragments 1 ft from top and 1 ft from bottom.
137	1,020-1,030	Recovered 6 ft 9 in.: Microfossils very abundant. Clay shale, medium-light- to medium-gray, noncalcareous, medium-soft;

Lithologic description—Continued

Core	Depth (in feet)	Remarks
		poor hackly fracture; lower 2 ft badly infiltrated by drilling mud; *Inoceramus* shell fragments common; dip probably very low.
138	1, 030–1, 040	Recovered 2 ft 6 in.: Microfossils abundant. Clay shale as above; very rare silty micaceous partings; about one-half of recovery is drilling mud.
139	1, 040–1, 045	Recovered 2 ft 6 in.: Microfossils abundant. Clay shale as above, noncalcareous; about one-third of recovery is badly infiltrated by drilling mud, *Inoceramus* shell fragments.
140	1, 045–1, 050	Recovered 5 ft: Microfossils abundant. 4 ft 4 in., clay shale, medium-light-gray, medium-soft; poor cleavage; silty partings, *Inoceramus* shell fragments at 1,047 ft. 8 in., siltstone, light-gray, argillaceous, noncalcareous, soft; poor cleavage.
141	1, 050–1, 060	Recovered 7 ft 6 in.: Microfossils abundant. Interbedded clay shale 70 percent and siltstone 30 percent, noncalcareous, medium-soft; poor cleavage; scattered very fine sandy partings and laminae; rare *Inoceramus* shell fragments. Some infiltration of drilling mud in upper 2 ft.
142	1, 060–1, 070	Recovered 3 ft 6 in.: Microfossils abundant. Primarily drilling mud containing chips of clay shale and some siltstone; noncalcareous.
143	1, 070–1, 075	Recovered 4 ft: Microfossils abundant. 2 ft, clay shale, medium-light-gray, noncalcareous, medium-soft; poor cleavage; rare silty partings. 2 ft, drilling mud and broken clay shale.
144	1, 075–1, 080	Recovered 2 ft 6 in.: Microfossils abundant. Clay shale, medium-light-gray, noncalcareous, medium-soft; poor cleavage; rare silty partings; infiltrated by drilling mud.
145	[1] 1, 077–1, 087	Recovered 7 ft 9 in.: Microfossils abundant. 1 ft, 6 in., siltstone, light-gray, soft; fair cleavage; sandy partings. 6 ft, 3 in., clay shale, light- to medium-light-gray, noncalcareous, medium-soft; poor to good cleavage; rare silty partings; shell fragment at 1,080 ft; dip 1°.
146	1, 087–1, 097	Recovered 9 ft: Microfossils very rare. Interbedded claystone 60 percent and siltstone 40 percent; moderately calcareous; poor to fair cleavage, irregular fracture; echinoid spine present.
147	1, 097–1, 107	Recovered 6 ft: Microfossils absent. Siltstone, light-gray, argillaceous, soft, massive; irregular fracture. Scattered beds up to 3 in. thick of medium light-gray clay shale; whole interval is moderately calcareous; dip 3°.
148	1, 107–1, 117	Recovered 2 ft: Microfossils very rare. 1 ft 6 in., siltstone as above; clayey laminae; moderately calcareous. 6 in., limestone, medium-light-gray, silty, argillaceous, finely crystalline, very hard; irregular fracture.
149	1, 117–1, 127	Recovered 6 ft 6 in.: Microfossils very rare. Siltstone, very argillaceous, and very silty claystone; moderately calcareous; soft; a larger proportion of clay than silt.
150	1, 127–1, 137	Recovered 10 ft: Microfossils rare. 6 ft, clay shale, light- to medium-light-gray, moderately calcareous, medium-soft; fair to good cleavage; micaceous partings; dip 8°–10°. 3 ft, siltstone, light-gray, very argillaceous, slightly calcareous, medium-soft; fair cleavage; rare laminae of clay shale; streaks of very fine-grained sandstone. 1 ft, clay shale as in upper interval.
151	1, 137–1, 147	Recovered 2 ft 9 in.: Microfossils common. Interbedded clay shale and siltstone; about equal proportions; soft; poor to fair cleavage; rare *Inoceramus* fragments and prisms. Siltstone is slightly calcareous.
152	1, 147–1, 157	Recovered 2 ft 6 in.: Microfossils common. Clay shale, medium-light-gray with streaks of siltstone; white *Inoceramus* sp. shell fragment in middle, core badly infiltrated by drilling mud.
153	1, 157–1, 167	Recovered 10 ft: Microfossils abundant. Clay shale, medium-light-gray, medium-soft; poor to fair cleavage; layers of siltstone up to 3 in. thick fairly common. Siltstone is moderately calcareous; clay shale is noncalcareous or slightly calcareous; dip 2°.
154	1, 167–1, 177	Recovered 3 ft: Microfossils common. Siltstone, light-gray, slightly sandy, moderately calcareous, soft, friable; fair cleavage; contains a few thin clay shale beds.
155	1, 177–1, 187	Recovered 3 ft: Microfossils abundant. Clay shale, medium-light-gray, moderately calcareous, soft; fair cleavage; rare silty micaceous partings; *Inoceramus* prisms and shell fragments rela-

[1] Depth corrected by driller.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
		tively common; lower part of recovery infiltrated by drilling mud; dip about 2°.
156	1, 187–1, 197	Recovered 4 ft 6 in.: Microfossils abundant. Clay shale and siltstone, about equal proportions; *Inoceramus* sp., *Ditrupa* sp., Crinoid ossicles sp., an unidentified pelecypod, and an echinoid spine present. Core badly infiltrated by drilling mud.
157	1, 197–1, 207	Recovered 4 ft: Microfossils abundant. Interbedded light-gray siltstone 80 percent and medium-light-gray clay shale 20 percent, soft, slightly to noncalcareous; trace of sandstone; core infiltrated by drilling mud; *Inoceramus* sp. shell fragments.
158	1, 207–1, 217	Recovered 7 ft 6 in.: Microfossils rare. Interbedded siltstone and clay shale as in core above, about equal proportions; poor to fair cleavage. Siltstone is slightly calcareous; clay shale is noncalcareous. Dip about 1°.
159	1, 217–1, 227	Recovered 8 ft: Microfossils abundant. Interbedded siltstone 50 percent and clay shale 50 percent as above; poor cleavage.
160	1, 227–1, 237	Recovered 7 ft 6 in.: Microfossils abundant. Clay shale, medium-light-gray, very silty, noncalcareous, medium-soft; fair cleavage; contains numerous laminae of siltstone, rare micaceous partings, rare shell fragments, dip 1½°.
161	1, 237–1, 247	Recovered 9 ft 6 in.: Microfossils abundant. Clay shale as above, noncalcareous; smaller amount of siltstone; *Inoceramus* sp. shell fragment at 1,238 ft.
162	1, 247–1, 257	Recovered 8 ft 6 in.: Microfossils abundant. Clay shale, medium-light-gray, medium-hard; fair cleavage; scattered layers up to 3 in. thick of light-gray siltstone. Siltstone is slightly softer than clay shale. Both are noncalcareous; dip 1°.
163	1, 257–1, 267	Recovered 6 in.: Microfossils abundant. Clay shale as above, 1-in.-thick piece of very calcareous light-gray, hard argillaceous siltstone; irregular fracture.
164	1, 267–1, 277	Recovered 8 ft: Microfossils abundant. Clay shale, medium-light-gray, noncalcareous, medium-soft; poor cleavage; silty partings and laminae, infiltrated by drilling mud.
165	1, 277–1, 287	Recovered 10 ft: Microfossils rare. Clay shale with scattered silty laminae as above; moderate-yellowish-brown clay ironstone nodule at 1,283 ft; numerous *Inoceramus* sp. and other pelecypod fragments; *Ditrupa* sp. also common. Echinoid spine present. Noncalcareous.
166	1, 287–1, 297	Recovered 6 ft: Microfossils rare. 2 ft, interbedded clay shale and siltstone, soft streaks of sandstone. One yellowish-gray clay ironstone nodule one-half inch thick at 1,288 feet. 4 ft, interbedded siltstone 60 percent and sandstone 40 percent, light-gray, soft, friable; contains a few clay shale laminae. Sandstone is very fine grained; grains subangular to subrounded; 90 percent white and clear quartz; remainder is carbonaceous material, rock fragments, and dark chert; argillaceous matrix; trace of yellowish-gray clay ironstone. *Inoceramus* sp. shell fragments.
167	1, 297–1, 302	Recovered 5 ft 6 in.: Microfossils very rare. 2 ft, interbedded clay shale and siltstone, medium-light- and light-gray, noncalcareous. 1 ft 6 in., limestone, medium-light-gray, slightly argillaceous, very hard, massive, finely crystalline; breaks at right angles to core side; contains finely disseminated pyrite. 2 ft, interbedded clay shale and siltstone as in upper interval; siltstone is slightly calcareous.
168	1, 302–1, 312	Recovered 8 ft: Microfossils abundant. Interbedded clay shale and claystone 70 percent, siltstone 30 percent, medium-soft; poor to fair cleavage; one-half inch of yellowish-gray clay ironstone at 1,311 ft, *Inoceramus* sp. shell fragments at 1,304 ft; all but ironstone is noncalcareous; dip low.
169	1, 312–1, 322	Recovered 10 ft: Microfossils abundant. Clay shale 60 percent, siltstone 40 percent, as above. Siltstone slightly softer than clay shale; *Inoceramus* prisms at 1,318 ft. Whole interval is slightly to moderately calcareous; dip 2°.
170	1, 322–1, 330	Recovered 8 ft: Microfossils abundant. Clay shale, medium-light-gray, noncalcareous medium-hard; fair cleavage; silty partings and rare silty laminae; carbonaceous flecks and partings; *Ditrupa* sp. and shell fragments.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
171	1, 330–1, 340	Recovered 9 ft: Microfossils common. Clay shale as above; several siltstone laminae up to 3 in. thick; siltstone is slightly calcareous. *Ditrupa* sp. and shell fragments; dip 5°.
172	1, 340–1, 350	Recovered 9 ft: Microfossils common. Interbedded siltstone 60 percent and clay shale 40 percent; *Inoceramus* sp. shell fragment at 1,344 ft. Ophiuroid present. Siltier toward top.
173	1, 350–1, 360	Recovered 9 ft 6 in.: Microfossils common. Clay shale, medium-light-gray, noncalcareous medium-hard; fair cleavage: silty laminae, micaceous and carbonaceous partings; dip 3°.
174	1, 360–1, 370	Recovered 9 ft: Microfossils abundant. Interbedded clay shale 70 percent, and siltstone 30 percent, medium-light- and light-gray, rather soft; poor to fair cleavage; noncalcareous to moderately calcareous in silty streaks; rare carbonaceous partings; shell fragments.
----	1, 370–1, 380	Siltstone, light-gray, moderately calcareous, and medium-light-gray clay shale.
----	1, 380–1, 440	Siltstone 60–80 percent, light-gray (moderately calcareous at 1,400–1,410 ft), and clay shale, medium light gray. *Inoceramus* prisms and *Ditrupa* sp. fragments.
----	1, 440–1, 470	Clay shale, medium-light-gray, and light-gray siltstone, *Ditrupa* sp. fragments.
----	1, 470–1, 540	Clay shale, medium-light-gray; trace siltstone at 1,490–1,500 ft. *Ditrupa* sp. and *Inoceramus* sp. fragments.
----	1, 540–1, 560	Siltstone, light-gray, moderately calcareous.
----	1, 560–1, 570	Clay shale and siltstone.
175	1, 570–1, 580	Recovered 10 ft: Microfossils abundant. Clay shale, medium-light-gray, slightly calcareous to noncalcareous, medium hard; fair cleavage; rare silty partings and laminae; beds lie approximately flat.
----	1, 580–1, 650	Clay shale, medium-light-gray; a few pyrite nodules; 20 percent light-gray siltstone at 1,580–1,600 and 1,640–1,650 ft. *Ditrupa* sp. fragments.
----	1, 650–1, 660	Siltstone, light-gray, moderately calcareous.
----	1, 660–1, 680	Clay shale, medium-light-gray. *Ditrupa* sp. fragments.
----	1, 680–1, 690	Clay shale, medium-light-gray, silty.
----	1, 690–1, 758	Clay shale, medium-light-gray; trace siltstone at 1,740–1, 750 ft. *Inoceramus* sp. *Ditrupa* sp. fragments common. Crinoid ossicles at 1,740–1,750 ft.
176	1, 758–1, 768	Recovered 7 ft 6 in.: Microfossils common.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
		Practically all drilling mud. A few pieces of medium-light-gray, noncalcareous clay shale with fair cleavage; beds lie flat (?).
----	1, 768–1, 860	Clay shale, medium-light-gray; trace siltstone at 1,770–1,780, 1,810–1,820, and 1,840–1,850 ft. *Inoceramus* prisms and *Ditrupa* sp. fragments.
----	1, 860–1, 880	Clay shale 65 percent, medium-light-gray, and 35 percent light-gray moderately calcareous siltstone. *Inoceramus* and *Ditrupa* sp. common. Echinoid spine at 1,860–1,870 ft.
----	1, 880–1, 910	Siltstone, light-gray, and clay shale.
----	1, 910–1, 950	Siltstone, light-gray, and light-gray very fine-grained sandstone; mostly white quartz; moderately calcareous in part; also 10 percent clay shale at 1,930–1,940 ft.
----	1, 950–1, 967	Clay shale, medium-light- to light-gray, silty. *Inoceramus* and *Ditrupa* sp.
177	1, 967–1, 977	Recovered 9 ft: Microfossils abundant. Clay shale, medium-light-gray, noncalcareous, medium-hard; fair cleavage; dip 1°.
----	1, 977–1, 990	Clay shale, medium-light-gray, silty.
----	1, 990–2, 010	Clay shale, medium-light-gray. *Ditrupa* sp., *Inoceramus* sp., and crinoid ossicle.
----	2, 010–2, 024	Siltstone and clay shale.
178	2, 024–2, 026	Recovered 2 ft: Microfossils abundant. Clay shale, medium-light-gray, noncalcareous, medium-hard; fair cleavage; rare carbonaceous and micaceous partings; beds lie approximately flat.
----	2, 026–2, 090	Siltstone and clay shale, light- to medium-light-gray.
----	2, 090–2, 125	Clay shale and siltstone. A few *Inoceramus* prisms.
----	2, 125–2, 140	No samples received.
----	2, 140–2, 235	Clay shale, medium-light-gray; trace of siltstone 2,200–2,235 ft; pyrite present; a few *Inoceramus* prisms.
179	2, 235–2, 245	Recovered 6 ft: Microfossils abundant. Clay shale, medium-light-gray, noncalcareous, medium-hard; fair to good cleavage; rare scattered carbonaceous particles; beds lie approximately flat.
----	2, 245–2, 275	Clay shale, medium-light-gray.
180	2, 275–2, 285	Recovered 7 ft 6 in.: Microfossils abundant. Clay shale, medium-light-gray, slightly micaceous, noncalcareous, medium-hard; fair cleavage; contains a scattering of minute black carbonaceous particles; dip 3°.
----	2, 285–2, 343	Clay shale, medium-light-gray; 10 percent siltstone at 2,330–2,340 ft.
181	2, 343–2, 353	Recovered 10 ft: Microfossils rare. 9 ft, clay shale, medium-light-gray, noncalcareous, medium-hard; poor to fair

Lithologic description—Continued

Core	Depth (in feet)	Remarks
		cleavage. One 1½-in.-thick hard light-olive-gray clay ironstone nodule at 2,349 ft; dip low. 1 ft, siltstone, light-gray, argillaceous, noncalcareous, soft; infiltrated by drilling mud; grains mostly white and clear quartz.
182	2, 353–2, 363	Recovered 3 ft: Microfossils absent. 2 ft, limestone, medium-light-gray, silty, argillaceous, hard, massive; tends to break at right angles to core side; contains dark mica flecks; grades into unit below. 1 ft, clay shale, medium-light-gray, silty, noncalcareous.
----	2, 363–2, 370	Siltstone, light-gray; some very fine-grained sandstone.
----	2, 370–2, 434	Clay shale and siltstone; rare pyrite at 2,390–2,410 ft; crinoid ossicle at 2,420–2,430 ft.
183	2, 434–2, 440	No recovery.
----	2, 440–2, 444	No sample received.
184	2, 444–2, 447	No recovery.
----	2, 447–2, 490	Clay shale, medium-light-gray; also 10–20 percent siltstone.
----	2, 490–2, 500	Siltstone 60 percent, light-gray, and clay shale 40 percent.
----	2, 500–2, 510	Clay shale 80 percent, and siltstone 20 percent.
----	2, 510–2, 530	Siltstone, light-gray; trace to 20 percent clay shale.
185	2, 530–2, 535	Recovered 3 ft: Microfossils abundant. Clay shale, medium-light-gray, medium-hard: fair to poor cleavage; badly infiltrated by drilling mud; low dip.
186	2, 535–2, 540	Recovered 4 ft: Microfossils abundant. Clay shale as above, some medium-gray very rare minute carbonaceous particles; noncalcareous.
----	2, 540–2, 590	Clay shale, medium-light-gray; trace to 30 percent siltstone.
----	2, 590–2, 600	Siltstone 80 percent, light-gray; 20 percent medium-light-gray clay shale.
----	2, 600–2, 739	Clay shale, medium-light-gray; trace siltstone.
187	2, 739–2, 749	Recovered 9 ft: Microfossils very abundant. Clay shale, medium-light- to medium-gray, medium-hard; fair cleavage; rare dark carbonaceous partings; scattered light-gray silty laminae which are slightly softer than clay shale; dip low.
----	2, 749–2, 790	Clay shale, medium-light-gray.
----	2, 790–2, 860	Siltstone up to 80 percent, light-gray, and clay shale.
----	2, 860–2, 939	Clay shale, medium-light-gray; trace siltstone.
188	2, 939–2, 949	Recovered 10 ft: Microfossils abundant. Clay shale, medium-light- to medium-gray, noncalcareous, medium-hard; good cleavage; rare thin silty laminae; dip 10°.
----	2, 949–3, 000	Clay shale, medium-light-gray.
189	3, 000–3, 003	Recovered 3 ft: Microfossils absent. Clay shale, medium-light- to medium-gray, noncalcareous, medium-hard; good cleavage; rare thin silty laminae and partings; dip 3°.
----	3, 003–3, 175	Clay shale, medium-light-gray; trace of light-gray siltstone.
190–191	3, 175–3, 190	Recovered 11 ft: Microfossils absent. Clay shale, medium-gray, slightly silty, noncalcareous, moderately hard; rare medium-light-gray silty partings and laminae; good cleavage, dip 1°–3°.
----	3, 190–3, 365	Clay shale, medium-light-gray; trace siltstone.
192	3, 365–3, 370	Recovered 3 ft: Microfossils not sampled. Clay shale as in core above; dip 1°.
----	3, 370–3, 580	Clay shale, medium-light-gray.
193	3, 580–3, 585	Recovered 5 ft. Clay shale, medium-gray, slightly micaceous, noncalcareous, medium-hard; fair cleavage; beds lie approximately flat. Top of Oumalik formation at 3,580 ft.
----	3, 585–3, 781	Clay shale, medium-light- to medium-gray, slightly silty.
194	3, 781–3, 786	Recovered 2 ft: Microfossils absent. Clay shale as in core above, but slightly softer.
195	3, 786–3, 791	No recovery.
196	3, 791–3, 796	Recovered 2 ft. Recovery consists entirely of broken chips up to an inch in diameter of medium-gray medium-hard slightly silty clay shale.
197	3, 796–3, 801	No recovery.
198	3, 801–3, 805½	Recovered 1 ft. Mostly drilling mud. A few chips of medium-gray silty clay shale and a few chips of medium-dark-gray clay shale.
199	3, 805½–3, 811	Recovered 1 ft 6 in. Chips of medium-light-gray to medium-gray fissile noncalcareous clay shale.
200	3, 811–3, 816	Recovered 3 ft. Chips exactly as above; one chip of light-gray siltstone.
201	3, 816–3, 819	Recovered 3 ft. Chips of medium-gray clay shale plus a few chips of light-gray slightly calcareous siltstone.
202	3, 819–3, 824	No recovery.
203	3, 824–3, 829	Recovered 1 ft 6 in. Clay shale, medium-gray, a few chips.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
204	3, 829–3, 830	Recovered 1 ft. Clay shale, medium-gray, noncalcareous, medium-hard: fair cleavage; mostly drilling mud.
----	3, 830–3, 981	Clay shale, medium-light- to medium-gray, silty, noncalcareous.
205	3, 981–3, 986	No recovery.
206	3, 986–3, 991	Recovered 5 ft. Clay shale or claystone, medium-light- to medium-gray, silty, slightly micaceous, noncalcareous, medium-hard; poor cleavage, irregular fracture: rare medium-light-gray siltstone laminae.
207	3, 991–3, 996	Recovered 4 ft. Clay shale as above; recovery is mostly drilling mud.
208	3, 996–4, 006	Recovered 5 ft. Claystone and clay shale, medium-gray, noncalcareous, medium-hard: poor cleavage; a few fractures at 30° but mostly irregular; dip undetermined.
----	4, 006–4, 120	Clay shale, medium-gray.
209	4, 120–4, 130	No recovery.
210	4, 130–4, 135	Recovered 4 ft. Claystone and clay shale as in core 208 above, noncalcareous.
----	4, 135–4, 201	Clay shale, medium-gray, slightly silty.
211	4, 201–4, 206	Recovered 6 in.: Microfossils absent. Clay shale and claystone as above; mostly drilling mud.
212	4, 206–4, 211	Recovered 2 ft: Microfossils absent. Clay shale and claystone as above: core is fractured at an angle of 30°.
213	4, 211–4, 221	Recovered 9 in: Microfossils absent. Claystone, medium-gray, medium-hard; irregular fracture; noncalcareous.
----	4, 221–4, 250	Clay shale, medium-gray.
214	4, 250–4, 255	No recovery.
215	4, 255–4, 260	Recovered 3 ft: Microfossils absent. Clay shale, medium-gray, noncalcareous, medium-hard; fair to good cleavage; dip 3°.
----	4, 260–4, 330	Clay shale, medium-gray; slightly silty near bottom.
216	4, 330–4, 335	Recovered 2 ft 6 in.: Microfossils absent. Clay shale, medium-gray, noncalcareous, medium-hard; good cleavage; scattered very thin light-gray silty laminae and partings.
----	4, 335–4, 501	Clay shale, medium-gray; trace of siltstone.
217	4, 501–4, 511	Recovered 1 ft. Clay shale, medium-gray, noncalcareous; also a few light-gray silty laminae; dip 3° (?).
----	4, 511–4, 698	Clay shale, medium-gray; some light-gray siltstone at 4,660–4,698 ft.
218	4, 698–4, 708	Recovered 7 ft: Microfossils absent. Interbedded clay shale, claystone 60 percent and siltstone 40 percent; poor to good cleavage. Clay shale is medium hard; poor to excellent cleavage. Siltstone is light-gray, medium-hard, and alternates in thin beds with clay shale. Rare thin beds of sandstone up to 4 in. thick, light-gray, medium-hard, fine grained; grains are subangular to subrounded; 90 percent white and clear quartz: remainder is rock fragments, yellowish quartz, and mica: matrix is calcareous. Clay shale and siltstone are noncalcareous. Dip 1½°.
----	4, 708–4, 850	Clay shale, medium-gray; trace to 50 percent light-gray noncalcareous siltstone.
----	4, 850–4, 873	Siltstone, light-gray: some clay shale; trace of sandstone.
219	4, 873–4, 878	Recovered 3 in.: Microfossils absent. Clay shale, medium-gray, noncalcareous, medium-hard; good cleavage; silty and micaceous partings.
220	4, 878–4, 883	Recovered 6 ft. Interbedded siltstone and sandstone 70 percent and clay shale 30 percent. Siltstone is light gray, medium hard; fair cleavage. Sandstone is light gray, vertical fracture, fine grained; grains subangular to subrounded, "dirty"; contains quite a few rock fragments in addition to white and clear quartz, argillaceous matrix; noncalcareous. Clay shale is medium gray as above. Dip 2°.
----	4, 883–4, 890	Siltstone, medium-gray, and medium-dark-gray clay shale.
----	4, 890–4, 930	Clay shale, medium-dark-gray.
----	4, 930–4, 940	Siltstone, and clay shale, medium-gray.
----	4, 940–4, 980	Clay shale, medium-gray.
----	4, 980–5, 000	Siltstone, light-gray, and clay shale.
----	5, 000–5, 074	Clay shale, medium-gray; trace siltstone.
221	5, 074–5, 079	Recovered 1 ft: Microfossils absent. Mostly drilling mud. A few chips of clay shale.
222	5, 079–5, 084	Recovered 1 ft: Microfossils absent. Clay shale, medium-gray, noncalcareous, medium-hard, fair cleavage; dip not determined.
223	5, 084–5, 087	Recovered 3 ft 6 in.: Microfossils absent. Clay shale as above, poor cleavage.
----	5, 087–5, 277	Clay shale, medium-gray to medium-dark-gray, and trace to 10 percent siltstone; noncalcareous.
224	5, 277–5, 281	No recovery.
225	5, 281–5, 287	Recovered 1 ft: Microfossils not sampled. Chips of clay shale embedded in drilling mud, medium-gray, medium-soft.
226	5, 287–5, 294	No recovery. Top of Upper Jurassic(?) and Lower Cretaceous(?) rocks at 5,290 ft—partly on electric-log evidence.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
227	5, 294–5, 297	No recovery.
228	5, 297–5, 303	Recovered 1 ft 6 in.: Microfossils abundant. Clay shale, medium-dark to dark-gray, medium-hard; poor to fair cleavage. Clay shale contains "floating" (scattered at random) rounded very fine to medium sand grains of clear quartz, and very rare rounded grains of chert and varicolored quartz. Clay shale also contains large isolated euhedral plates of biotite and patches and lines of pyrite. Very rare medium-light-gray laminae of pyritic siltstone. Noncalcareous; dip not determined but probably low.
229	5, 303–5, 308	Recovered 4 ft 6 in.: Microfossils very abundant. Clay shale, with "floating" quartz grains exactly as above; no siltstone. One ¼-in.-thick layer of greenish-gray clay shale (possibly tuff) near top of the interval—softer and disintegrates more readily in water than the dark clay shale; this green clay shale contains finely disseminated biotite and pyrite. Noncalcareous, dip 4°.
----	5, 308–5, 464	Clay shale, medium-dark to dark-gray; rare rounded very coarse clear quartz sand grains; chunks of *Inoceramus* prisms.
230	5, 464–5, 484	Recovered 16 ft.: Microfossils absent. Clay shale, medium-dark-gray, medium-hard; fair cleavage; irregular fracture; rare "floating" rounded clear quartz sand grains and very rare black chert granules. Six inches of medium-dark-gray very hard lithographic argillaceous limestone in about middle of recovered interval. Clay shale contains shiny black carbonaceous plant remains and pyritized fishbone fragments. Clay shale is noncalcareous; dip 3°.
----	5, 484–5, 630	Clay shale, medium-dark to dark-gray; medium to coarse rounded quartz sand grains common; rounded black chert granules at 5,490–5,500, 5,550–5,560, and 5,620–5,640 ft; trace medium-dark-gray siltstone.
----	5, 630–5, 677	Clay shale, medium-gray (some darker colored), silty; also trace of medium-gray siltstone. Top of Lower Jurassic probably at about 5,630 ft.
231	5, 677–5, 692	Recovered 14 ft: Microfossils abundant. Claystone, medium-gray, silty, slightly micaceous noncalcareous, hard; irregular fracture; vermicular pyritic streaks and aggregations up to 1 in. diameter; ammonite impressions at 5,677, 5,680, and 5,685 ft. Ammonite at 5,680 ft identified by R. W. Imlay as *Amaltheus* sp. indet. Bedding obscure but dip seems low.
----	5, 692–5, 866	Clay shale, medium-gray to medium-dark-gray; trace of light- to medium-light-gray siltstone, at 5,730–5,750, 5,820–5,830 (one chip with glauconite), and 5,860–5,866 ft; trace of light-gray very fine-grained sandstone at 5,850–5,860 ft.
232	5, 866–5, 874	Recovered 6 ft: Microfossils common. Claystone as above; slightly less silty; leaf impression at 5,873 ft.
----	5, 874–5, 910	Clay shale, medium-gray to medium-dark-gray; trace to 5 percent medium-light-gray hard siltstone; 1 piece with glauconite; trace pyrite; 1 chip of dark-yellowish-brown ironstone (?) with glauconite pellets and rounded quartz grains.
----	5, 910–5, 940	Clay shale, medium-gray to medium-dark-gray; 5–10 percent medium-gray slightly calcareous siltstone; trace very fine-grained sandstone.
----	5, 940–6,067	Clay shale, medium- to dark-gray; trace medium-light-gray siltstone.
233	6, 067–6, 077	Recovered 10 ft. Claystone 60 percent and siltstone 40 percent, medium-gray to medium-dark-gray, finely micaceous, noncalcareous, hard; closely and irregularly interbedded with all gradations of each, numerous vermicular pyritic streaks, about one thirty-second of an inch wide.
----	6, 077–6, 150	Clay shale, medium-gray to medium-dark-gray, silty; trace of light-gray siltstone. One chip of clay shale contains glauconite pellets, another of quartz sand grains (medium size) in pyritic matrix.
----	6, 150–6, 173	Clay shale, medium-gray, silty, and sandstone as in cores below.
234	6, 173–6, 183	Recovered 9 ft. 1 ft, drilling mud. 8 ft, sandstone, light-gray, very fine-grained to silty, hard, massive; irregular fracture; grains angular to subangular but with rather high sphericity; about 90 percent white and clear quartz and 5 percent bluish green mineral (glauconite?); remainder is rock fragments; calcareous matrix-slightly to very calcareous; abundant tiny carbonaceous fragments; several layers 2–3 in. thick of whole and fragmental pelecypods (*Oxytoma* sp.); dip not determined but probably low as suggested by orientation of carbonaceous particles.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
235	6, 183–6, 193	Recovered 8 ft. Sandstone as above; color varies with carbonate content; the lighter the color the more calcareous the section. About 1 ft of very calcareous sandstone topping at 6,185½ ft contains abundant small pelecypods (*Oxytoma* sp.). Lenticular and rounded masses up to ½ by 1 in. of grayish-brown sandstone—same type as above but with brownish stain. These were called "pebbles" in an earlier description. One highly petroliferous brown sandstone "pebble" shows fluorescence under ultraviolet light; oil extracted with carbon tetrachloride; other brownish "pebbles" did not show these characteristics. No show of oil in the "matrix." Dip not determined but may be between 3°–5°.
----	6, 193–6, 220	Sandstone like that in core above, light-gray, fine-grained.
----	6, 220–6, 237	Siltstone, light-gray, and medium-gray clay shale. A few siltstone chips mottled with green glauconite.
236	6, 237–6, 247	Recovered 10 ft: Microfossils absent. 1 ft 9 in., siltstone, light-gray, hard, massive; irregular fracture; mottled with medium-gray siltstone and claystone; grains mostly white and clear quartz plus about 3 percent greenish-blue glauconite; some very fine sand; slightly to moderately calcareous; dark-colored fossil plants (?); vermicular markings; pelecypod impressions; calcite casts; grades into unit below. 5 ft, 6 in., siltstone, dark-greenish-gray, mottled dark-gray, noncalcareous, hard, massive, irregular fracture; abundant light- to dark-green soft claylike particles (glauconite?) gives rock a speckled appearance. Pelecypod and fragmental shell remains common. 2 ft 9 in., as in upper interval.
----	6, 247–6, 304	Loose very fine sand and silt. Top of Upper Triassic placed at 6,265 ft partly on electric-log evidence.
237	6, 304–6, 314	Recovered 8 ft 6 in.: Microfossils abundant. Siltstone and claystone, gradational, medium gray, moderately to very calcareous, hard; irregular fracture; finely disseminated pyrite; abundant pelecypod remains throughout. Echinoid spine.
----	6, 314–6, 316	No sample.
238	6, 316–6, 334	Recovered 6 ft: Microfossils common. Siltstone or very silty limestone, mottled medium-gray to medium-dark-gray; mottling appears to be due to varying amounts of argillaceous material; very calcareous throughout, hard; irregular and vertical fracture; bright-bluish-green glauconite (?) grains abundant. About 10 percent very fine sand; clear quartz with a brownish cast; grains subrounded. Paper-thin light-colored calcite veinlets, also abundant shiny gray, pelecypod shell fragments, and rare small (½-in. diameter) silty pebble-like masses. Dip 4°.
239	6, 334–6, 337	Recovered 1 ft 4 in.: Siltstone as above, very calcareous.
----	6, 337–6, 346	Clay shale, medium-dark-gray; trace siltstone.
240	6, 346–6, 356	Recovered 8 ft 6 in.: Microfossils abundant. Siltstone, mottled medium-gray to medium-dark-gray, hard; slightly darker, slightly more argillaceous, and slightly less calcareous than cores above. Scattered pelecypod remains. Finely disseminated pyrite; rare carbonaceous fragments.
----	6, 356–6, 375	Clay shale 40–50 percent, medium-dark-gray; remainder medium-gray siltstone; moderately calcareous.
241	6, 375–6, 385	Recovered 9 ft 6 in.: Microfossils absent. 3 ft 6 in., siltstone, medium-gray, very argillaceous, noncalcareous, hard; vermicular pyritic stringers; vertical fracture. 6 ft, siltstone, grayish-green, hard; vertical fracture; most silt grains are quartz, light-blue-green soft glauconite (?), finely disseminated pyrite, and some very fine sand grains. Siltstone is mottled with patches of medium-gray argillaceous siltstone. Slightly calcareous. Beds lie approximately flat.
----	6, 385–6, 410	Siltstone and very fine-grained sandstone, medium-light-gray, moderately calcareous; glauconite common. Sand grains mostly clear quartz, also rock fragments, glauconite, and biotite or carbonaceous material (?); trace medium-dark-gray clay shale.
----	6, 410–6, 435	Clay shale 90 percent, medium-dark-gray, and medium-light-gray siltstone. Some glauconite in both. Megafossil impression in clay shale.
----	6, 435–6, 455	Siltstone, medium-gray, very calcareous; trace very fine sand; some glauconite; pelecypod impressions.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
242	6, 455–6, 465	Recovered 8 ft: Microfossils absent. Siltstone, medium-gray, hard; vertical fracture; siltstone contains primarily quartz plus finely disseminated pyrite, scattered grains of glauconite (?) and carbonaceous material, rare very fine quartz sand; subrounded to subangular clear; very calcareous matrix; rare pyrite nodules up to one-half an inch in diameter; numerous pelecypod shell fragments; dip 7°.
----	6, 465–6, 485	Siltstone, medium-gray, very calcareous; trace medium-gray hard silty limestone at 6,465–6,470 ft.
243	6, 485–6, 495	Recovered 10 ft: Microfossils absent. Siltstone, mottled medium-gray to medium-dark-gray, very calcareous, hard; possibly grades to medium-light-gray silty limestone; argillaceous laminae. Siltstone contains small amount of glauconite (?), pyrite, and carbonaceous material as in core above. Contains clear fine quartz sand as above. Pelecypod shells fragments; dip 10°.
----	6, 495–6, 520	Siltstone, medium-light to medium-gray, slightly sandy, very calcareous (crystalline calcite in matrix); possibly grades to silty limestone at 6,510–6,515 ft; also pelecypod impressions at 6,510–6,515 ft; traces of noncalcareous medium-dark-gray clay shale; some sandstone at 6,515–6,520 ft.
----	6, 520–6, 535	Sandstone, light- to medium-light-gray, very calcareous; fine grained; made up of 97 percent clear quartz grains which are subangular and a few subrounded; remainder is rock fragments (schist?) and pyrite. Matrix is calcite.
----	6, 535–6, 543	Siltstone, medium-gray, very calcareous, and some medium-dark-gray noncalcareous silty clay shale.
----	6, 543–6, 545	Three percent greenish-gray argillite as below. Top of the pre-Mesozoic rocks placed at 6,543 ft.
244	6, 545–6, 557	Recovered 10 ft: Microfossils absent. Argillite, greenish-gray, very hard; contains minute pyrite crystals; laminated color banding probably represents bedding dip of 80°. Thin films of pyrite and brown calcite coat joints or slickensided fracture planes. Fracture planes dip 25°–80°.
----	6, 557–6, 615	Argillite, light-greenish-gray to greenish-gray (5G 6/1, Goddard and others, 1948), hard; contains finely disseminated pyrite and rare calcite coatings on fracture surfaces. Very rare thin streaks in the argillite have granular silty appearance and may be silicified siltstone.
245	6, 615–6, 619	Recovered 1 ft 10 in.: Microfossils absent. Argillite as above but with grayish-red banding parallel to bedding. Bedding dips 80°; fractures dip 60°.
----	6, 619–6, 653	Argillite, greenish-gray. Pyrite is slightly more common than above. White calcite veinlets.
246	6, 653–6, 673	Recovered 7 ft 6 in.: Microfossils absent. Argillite, mostly greenish-gray; about 2 ft contains grayish-red bedding bands; dip of beds 80°; fracture dips 45°.
----	6, 673–6, 780	Argillite as above; traces of grayish-red argillite (5R 4/2, Goddard and others, 1948) below 6,755 ft.
247	6, 780–6, 796	Recovered 12 ft: Microfossils absent. Argillite as above; no red bands; numerous slickensided fracture planes at angles up to 80°; calcite veinlets present particularly along fractures. Dip of beds 75°–80°.
----	6, 796–6, 896	Argillite as in core above; trace to 10 percent grayish-red.
248	6, 896–6, 916	Recovered 18 ft 6 in.: Microfossils not sampled. Argillite; banded gray green and grayish red in upper 10 ft and primarily gray green in lower part; fracture planes coated with calcite and some pyrite dipping 30°–70°; dip of beds 75°.
----	6, 916–6, 982	Argillite as above, 20–30 percent grayish-red.
249	6, 982–7, 002	Recovered 16 ft: Microfossils not sampled. Argillite as above, hard; faintly banded red and green.

CORE ANALYSES

By S. T. Yuster

A total of fifteen core samples was received from Simpson test well 1. In practically all samples, the core material was extremely friable and very difficult to handle for testing. Special precautions had to be taken to maintain the material in a consolidated condition during the test. As no adequate consolidated sample was available for core sample 1, taken in the interval 218–220 feet, the porosity and permeability tests were performed on the unconsolidated material packed in a tube fitted with end screens.

The routine tests performed on these samples are as follows: Porosity, air and Klinkenberg permeability, oil saturation, connate water saturation, chloride content of connate water, special permeabilities to brine and fresh water, and density of the extracted crude. The results of these tests are summarized in table 1 and figure 47.

GENERAL CHARACTER OF THE SAND

The formation tested was an extremely friable poorly consolidated fine-grained graywacke that contained variable quantities of material derived from volcanic ash. According to P. D. Krynine, this material contains variable quantities of the clay mineral montmorillonite. Evidence for the existence of this material was obtained in some of the core analysis tests and will be cited under the discussion of the tests. A summary of the analyses is presented in the following table.

TABLE 1.—*Summary of analyses of cores from Simpson test well 1*

Core	Depth (ft)	Water saturation (percent)	Oil saturation (percent)	Chloride content (parts per million)	Klinkenberg permeability (millidarcys)	Air permeability at 1 atm. mean pressure (millidarcys)	Porosity (percent)	Oil content (bbl per acre ft)	Density of oil extract
1	218–220	46.33	11.59	5,390	486	[1] 558	36.62	329.4	0.8893
2	309–310	92.09	9.04	5,480	98	109	29.61	207.7	.8967
3	383–384	46.67	53.54	10,370	735	870	34.60	1,437.5	.9016
4	385–386	37.87	57.03	7,900	725	850	35.57	1,541.5	.9169
5	387–388	41.54	59.24	9,900	430	472	38.71	1,779.5	.8997
6	388–389	57.40	45.72	7,510	11.3	14.1	21.23	753.0	.9120
7	390–391	50.74	30.53	9,960	870	1,120	33.63	796.8	.9062
8	392–393	40.42	33.91	9,870	282	340	35.56	935.6	.9116
9	393–394	38.96	36.77	7,871	1,130	1,220	39.06	1,114.0	.8981
10	395–396	49.63	33.83	6,200	682	705	35.18	923.6	.9056
11	397–398	38.25	27.64	9,950	562	610	40.98	878.9	.9054
12	398–399	57.08	29.63	6,356	910	1,035	37.02	851.3	.9067
13	400–401	63.01	17.20	5,330	325	362	40.98	546.9	.8874
14	402–402.5	58.74	8.90	3,678	849	865	37.11	256.3	.9201
15	405	31.71	6.59	11,247	407	434	38.89	119.9	.9077

[1] Unconsolidated sand.

POROSITY

The volume of pore space in the samples was determined on the same material that was used to measure the fluid saturation. The extracted samples were evacuated and impregnated with butanol, and the increase in weight was calculated in relation to pore volume. The bulk volume was measured by immersion of the impregnated sample in a graduate partly filled with butanol and noting the increase in volume. The samples had to be handled with extreme care during these operations because of their friability.

The porosity of the formation tested in this well is very uniform and averages about 36 percent; however, this and the individual values must be taken with some caution, for the formation contains the clay mineral montmorillonite, which swells greatly in certain types of water. The porosity tests were made on completely extracted, dry samples. The volume of the clay is at a minimum under such conditions, and therefore the porosity would be at a maximum. To obtain an idea as to the magnitude of the possible error in porosity, a composite sample of unconsolidated material was taken from individual samples and packed into a graduated cylinder. The bulk volume was measured, and sufficient distilled water was added to make a slurry. After shaking, the material was allowed to settle, and the bulk volume of the solids was measured again. A 5-percent increase in volume was noted. If it is assumed that the packing of the solid material was the same in the wet and dry condition, and if it is further assumed that any swelling in the actual formation manifests itself as a change in pore volume but no change in bulk volume, then all porosities should be decreased by 5-percent. It is believed that this is probably a minimum value and that 5-percent is too low. No study was made on the effect of brine concentration on the swelling, but it would tend to repress the effect.

In summary, the tests indicate that the formation has a high porosity because the formation is poorly consolidated and that the determined values may be higher than those in the formation by an absolute value of the order of 5 percent. It should be pointed out that the swelling test is only approximate and indicates the possible magnitude of the effect. No adequate test is available at the present for determining porosity in a formation where swelling occurs.

PERMEABILITY

Routine permeabilities were determined using the Klinkenberg technique. A minimum of four different air permeability tests were run on each sample at different mean pressures. The results were plotted with the permeability along the ordinate and the reciprocal of the mean pressure along the abscissa. A linear relationship is obtained which is extrapolated to an infinite mean pressure. The value of the permeability at this extrapolated point is the theoretical liquid permeability, and this is the quantity plotted on the core graph (fig. 47). For comparison, the air permeability at 1 atmosphere mean pressure is given in the preceding table.

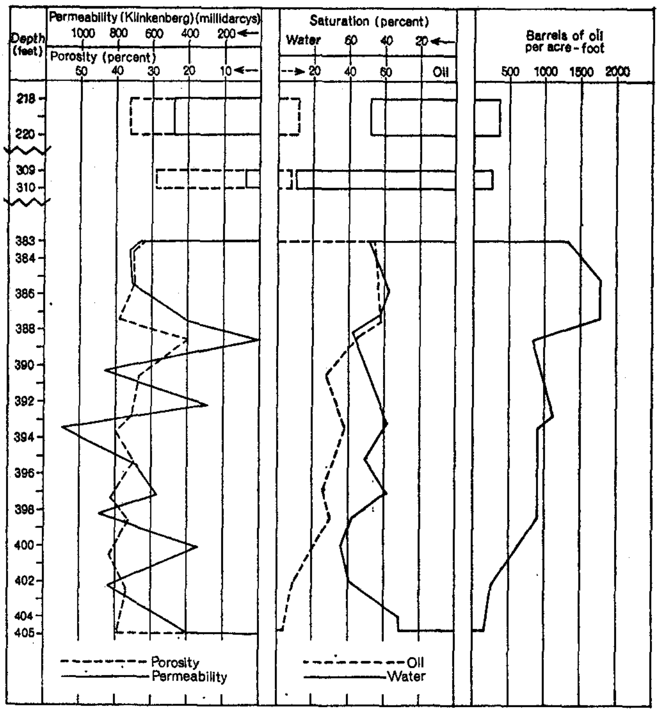


FIGURE 47.—Graph showing results of core tests on samples from Simpson test well 1.

As the cores were very friable, it was not possible to prepare them as cylinders and place them in a tapered-stopper permeability holder. The cores were carefully cut to a rectangular cross section on the diamond saw, dried in an oven, and mounted in sealing wax retained by a metal ring.

The permeability of the formation in the section studied was very heterogeneous, ranging from 11.3 to 1,130 millidarcys, a ratio of 100 to 1. The average is about 700 millidarcys. Just as in the porosity tests, the determination was made on a completely extracted and dry core. In the absence of water, the clay minerals such as montmorillonite occupy a minimum volume. This is an artificial condition and not comparable to those in the formation. The effect of clay swelling on permeability would be considerably more marked than on porosity as, according to Poiseuille's law, the rate of fluid flow through a capillary varies directly as the fourth power of the radius. The effect on permeability may be further aggravated by a concentration of the swelling minerals at constrictions in the pores.

To obtain some data on the effect of the clay swelling on permeability, a brine permeability test was run after the air permeability determination was made. A synthetic brine was used in which the solute was sodium chloride made up to a concentration of 10,000 ppm (parts per million) of chloride ion. This is fairly close to the maximum concentration found in the connate water of the cores (see table 1). In one of the cores the brine permeability test was followed by a fresh-water permeability test, which cause maximum of swelling and therefore minimum permeability. The results of these liquid permeability tests are summarized in table 2.

TABLE 2.—*Effect of aqueous liquids on permeability*

Sample	Theoretical liquid permeability (Klinkenberg) (millidarcys)	Brine permeability (millidarcys)	Percent reduction	Fresh-water permeability	Percent reduction
8	282	118	50		
10	682	205	70	18	97.5
11	562	446	20.6		

It can be seen that there is a very marked reduction in permeability if the core is in contact with aqueous liquids. With the few cores studied, a maximum permeability reduction of 70 percent was obtained when brine was used, and a reduction of 97.5 percent was obtained when distilled water was used. The distilled water permeability tended to decrease slowly with time, indicating that the final reduction is obtained rather slowly and would be lower than that indicated. These results give a qualitative indication of the factors which must be applied to the air permeabilities if the liquids indicated are flowing through sand.

Because the production of oil is the purpose of this investigation, it would be fitting to consider the effective permeability of the sand to this fluid. No direct oil test was made, but an approximation can be made based upon relative permeability and saturation data obtained in studies of other sands. If production of oil is at all possible, it will come from the upper part of the section analyzed. The average oil saturation there is about 50 percent of the pore space. With such an oil saturation, the relative permeability to oil will be about 0.25 or about 25 percent of the single-phase permeability.

Another point must be stressed in discussing permeability. In view of the adverse effect of fresh water on the sand, it would appear to be advisable to use either oil-base or salt-water-base muds in drilling wells in this area. The production after using such drilling fluids would be a better indication of the productivity of the formation than after using fresh-water mud.

Because the sand is poorly consolidated, it is very possible that there may be a migration of silt within the sand during production, resulting in a gradual plugging of pores. How serious this might be is not known as it would require extensive experimentation to determine the effect.

CONNATE-WATER SATURATION

The oil and water saturations of the samples were obtained by an extraction and distillation process in which a special heptane fraction was used as a solvent. The result of any saturation determination is open to question as adequate sampling is probably the biggest problem in core analysis. Penetration of drilling fluid and a flushing of the fluid content of the core is a possible action which may result in a decrease in oil saturation and an increase in water saturation. With live crude oil it is also possible that oil may be flushed from the core by internal gas drive as it is brought to the surface. This is not likely in the samples tested as the extracted crude had a high density, indicating very little gas. Because the formation studied is in the permafrost zone, the water saturation would be solid for at least a short time after the bit contacted a given section of sand. This would tend to minimize penetration of drilling fluid and thereby reduce flushing. Evidence in support of this is found in the high oil saturation (about 60 percent) in the depth range from 383 to 388 feet. The oil saturation would not be that high if flushing had occurred. All other factors being equal, the extent of any flushing action would be some inverse function of the rate of bit penetration. The formation is soft, drilling should preceed fairly rapidly with a minimum of fluid penetration.

The fluid saturations are given in terms of percent of the total spore space (extracted, dry core). The oil saturation is plotted from left to right, on figure 47, and the connate-water saturation is plotted from right to left. The space between the two liquid saturations represents unfilled pore space in the samples.

The connate-water saturation averages about 50 percent, the lower part of the sand having a slightly higher value than the upper. A small fraction of this may be drilling water. Some of the water may not be present as free connate water in the sand as a part of it is associated in physical and chemical complexes with the swollen clay minerals. It was indicated previously that the bulk volume of some of the unconsolidated sand increased about 5 percent when in contact with fresh water. As a first approximation, it may be assumed that 5 percent can be subtracted from the absolute values of the water saturations for imbibed water, the remainder being the active connate-water saturation.

As the stratum under study is in the permafrost, the connate water will be frozen even with the chloride concentration indicated. (See table 1.) It would, therefore, be correct to speak of ice saturation. Ice occupies approximately 10 percent more volume than the water from which it was derived. To calculate ice saturation from water saturation it is necessary to multiply by the factor 1.1.

CHLORIDE ION CONTENT OF CONNATE WATER

To obtain evidence on the flushing action of the drilling fluid and additional information which could be used in area studies, the chloride ion content of the water extract of the core samples was determined. A dried, weighed, but unextracted core sample was crushed in a beaker and extracted with a known quantity of distilled water. The material was filtered, and an aliquot of the filtrate analyzed for chloride ion by the Mohr method. The extract was titrated with silver nitrate, using potassium chromate as an indicator. The results are given in table 1.

There is no regular variation in the chloride ion concentration with either depth or permeability; the range is from 3,678 to 11,247 ppm. If flushing had taken place, it might be expected that it would be some direct function of the permeability, and the chloride ion concentration would be reduced accordingly (providing a fresh-water mud was used). Such a trend is not indicated.

The chloride ion concentration in the connate water of the core samples appears to be unusually low. Concentrations which are greater by a factor of four, and even more, are the usual values for other sands. An explanation for this is not now apparent. It may be that considerable ion exchange (both cationic and anionic) took place as the connate water migrated through the formation over geologic time and came in contact with some of the complex minerals such as the clays.

OIL SATURATION

The oil saturation was computed by two methods which yielded similar results. The first involved weighing the extracted crude oil in the extraction flask after the solvent had been driven off, determining density with a micropycnometer (see table 1), and computing the volume, assuming no loss of light ends. A similar set of calculations was made using the weight of the charged samples, the extracted weight, the volume (and therefore the weight) of water extracted, and obtaining the weight of oil in the sample by difference. The results of the first method are given in table 1 and figure 47. The assumption of no evaporation is valid, as indicated by the 100 percent liquid saturations in the upper part of the sand. With evaporation the total liquid saturation should be less than 100 percent.

As part of the program to determine wax saturations of the core, the crude oil from Umiat test well 1 was subjected to a density versus loss test. In this test a series of densities of the crude oil is determined continuously as it is slowly evaporated. A plot is made of density versus percent volume loss. Assuming that the crude oil sample has the same makeup as the oil in the sand and given the density and volume of the extract, it is possible to calculate the volume of live oil in the sand from the extracted oil. A few such computations were made, but the fantastic total liquid saturation values of 160 percent obtained show lack of validity of the method in this test. The reason for this is that the crude from Umiat test well 1 is different from that in Simpson test well 1. This does not mean that the chemical makeup of the same fractions in the two crudes may not be the same, but it would appear that if the crude from Simpson test well 1 were originally the same as from Umiat test well 1, a very large amount of the light fractions have been lost from the crude from Simpson test well 1 during geologic time. Using the technique described above, an average loss of 60 percent was found on the 12 extracts studied. This is considerable and cannot be rationalized with the data available.

The oil saturation differs quite continuously from the bottom to the top of the sand, ranging from 6.59 percent to about 60 percent of the pore space, an almost tenfold factor of variation. The trend appears to be a normal oil and water saturation distribution in a reservoir containing bottom water. It will be noted from figure 47 that the upper part of the formation is completely saturated with fluid. This is to be expected with the dead crude (note high density of extract from the cores in table 1) present in the sand, and lack of gas-expansion drive as the core is brought to the surface. However, the remainder of the sand shows a gas saturation which is difficult to explain. Certainly the formation is fairly close to 100 percent liquid saturation. A small gas saturation can be explained by the difference in volume of water and ice. Even if the core could be brought to the surface before all the contained ice had melted, subsequent melting in the core cans would create a deficiency in total liquid saturation. If the ice melted before coming to the surface, the core may imbibe sufficient drilling water to correct for the volume change. One other possibility is evaporation of water from the cores after they were brought to the surface and before the samples were sealed in cans. This would depend on the time interval between sampling and sealing.

The oil content in barrels per acre foot is also given in table 1 and figure 47. The average is about 850 barrels per acre foot, which is quite high. When viewed from a percent saturation basis, it is not quite so favorable. The latter criterion is the more important in judging possible recoveries.

WAX SATURATION

In view of the low formation temperatures in the area being tested, it was deemed advisable to test the core samples for wax saturation. This is necessary because the ordinary oil saturation determination measures the total hydrocarbon content and does not differentiate between solid and liquid hydrocarbon. Obviously, only liquid hydrocarbon can be produced from the formation, and the presence of a solid hydrocarbon such as wax may immobilize a part and at times all the liquid hydrocarbon present.

An attempt was made to determine the wax saturation in the core samples from the Simpson well. This was not possible as it was found that the crude from Umiat test well 1 was not comparable to the crude in the core samples from Simpson test well 1. However, other tests were made to ascertain whether soild hydrocarbons were present in the formation. With ideal pure liquids, the logarithm of the absolute viscosity is a linear function of the reciprocal of the absolute temperature. If a series of viscosities are measured at gradually reduced temperatures, the above relationship should hold. When a solid phase begins to separate owing to cooling, the apparent viscosity should suddenly increase. A break in the viscosity-temperature curve will indicate the wax separation temperature. If there is a wax saturation in the formation, this break temperature should be equal to formation temperature, because the crude was saturated with respect to the formation wax at the formation temperature. The sample of crude used for the test must not be cooled below the formation temperature before placing in the sample bottle or can because wax will separate and give a false result in the subsequent testing.

Such data were obtained on the crude from Umiat test well 1. This is summarized in table 3. The break point was found to be at 23.5° F. If the sample of crude was properly taken at the well and there is a wax saturation in Umiat test well 1, the above break temperature should be very close to the formation temperature. Unfortunately, the Umiat crude sample has different properties than the crude in the cores from Simpson test well 1, and the data cannot be applied to this core analysis.

A cloud point was run on a composite of the oil extracts obtained from the cores from Simpson well test 1. This test should also give the maximum temperature for the initiation of wax separation, but not quite as accurately as the temperature-viscosity data. The cloud point for the composite extract was found to be in the range 22°–24° F. This checks the paraffin point of the Umiat 1 crude, which is rather surprising in view of the different character of the two oils. It may indicate a common origin of the oils or possibly continuity of formation between the two wells.

TABLE 3.—*Effect of temperature on viscosity of crude oil from Umiat test well 1*

Temperature (°F)	Viscosity (centipoises)	Density (gms per ml)
82	2. 734	0. 8350
70	3. 204	. 8401
64	3. 428	. 8415
51	4. 188	. 8470
40.5	5. 005	. 8505
32	5. 696	. 8533
24	7. 189	. 8590
23	7. 300	. 8590
22	8. 890	. 8600
18	16. 473	. 8630

If the formation temperature is below about 23° F, a wax saturation will be present, but will be absent if the formation tmperature is above this. The results of the temperature survey were not available for a check.

OIL PRODUCTION

The possibility of producing oil from Simpson test well 1 does not appear to be too favorable. Only the upper six feet of sand in the interval 383–389 feet appears to have sufficient oil saturation for production considerations. Even this small interval will not produce its oil naturally because of the almost complete absence of dissolved gas. Production by gravity drainage would be at a minimum because of the high viscosity of the oil, the high ice saturation, and the relatively low effective oil permeability. Increasing the effective well radius by acidizing and shooting in order to increase the drainage rate is unfeasible because the formation will not respond to these treatments.

Secondary recovery methods present possibilities, but the difficulties may be too great in applying them. Water flooding with brines (sea water for example) may be successful, but the formation temperature must be above the freezing point of the brine. If this method can be used, it will result in maximum oil recovery. Secondary recovery by gas drive may be used, but it would be inefficient because of the high oil viscosity. This would result in high gas-oil ratios.

ADDITIONAL CORE ANALYSES

POROSITY AND PERMEABILITY ANALYSES

In addition to the preceding report made in 1948, a few analyses were made later by S. T. Yuster (see table 4); P. D. Krynine made special porosity checks on friable samples not suitable for testing by the Washburn Bunting method.

Tables 1–4 represent samples from the Cretaceous Grandstand formation. The U. S. Geological Survey laboratory personnel in Fairbanks tested a few samples from the deep Jurassic sandstones for porosity and permeability. (See table 5.) In these tests the Washburn-Bunting method was used to determine porosity, and a Hayward permeameter was used to determine permeability.

TABLE 4.—*Core analyses, Simpson test well 1*

Depth (feet)	Porosity (percent)	Average grain density (gms per cc)	Klinkenberg permeability before liquid flow (millidarcys)	Brine permeability (millidarcys)	Fresh-water permeability (millidarcys)	Klinkenberg permeability after liquid flow (millidarcys)
133	[1] 32.0	[2] 2.58				
310	32.3	2.66	168	74.0	30.0	220
390	30.1	2.61	158	94.3	50.0	193
399	30.3	2.59	320	211.0	78.0	372
454	[1] 31.4	[2] 2.68				
471	[1] 30.0	[2] 2.71				
768	[1] 30.4	[2] 2.67				
786	[1] 29.0	[2] 2.61				
829	[1] 28.8	[2] 2.66				
842	31.1	2.67	392	295.0	95.0	352
842	[1] 31.1	[2] 2.67				
888	[1] 30.7	[2] 2.69				
936	30.5	2.66	338	206.0	33.0	272
936	[1] 30.7	[2] 2.68				
979	[1] 30.3	[2] 2.70				

[1] Effective porosity (percent) analyzed by P. D. Krynine.
[2] Effective grain density (gms per cc) analyzed by P. D. Krynine.

TABLE 5.—*Core analyses, Jurassic rocks, Simpson test well 1*

Depth (feet)	Effective porosity (percent)	Air permeability (millidarcys)
6,175	23. 3	<8
6,178	16. 8	
6,181	22. 4	<6
6,184	18. 5	<5
6,188	16. 7	
6,190	18. 7	<5

SIEVE ANALYSES

The two tables following show the results of a few sieve analyses that were made of some other sandstones at the Fairbanks laboratory.

Sieve analyses of sandstone samples of the Grandstand formation from Simpson test well 1 made with American Society for Testing Materials sieves

Depth (feet)	Sand grains size (percent) [1]				
	60 mesh	120 mesh	230 mesh	<230 mesh	Total
133	0.4	54.5	27.0	18.2	100.1
768		10.5	45.5	43.9	99.9
800		7.9	60.8	31.2	99.9
842	0.8	12.7	62.1	24.4	100.0
888		8.3	56.2	35.5	100.0
936		10.5	59.9	30.0	100.0

[1] The 20- and 40-mesh screens were also used, but no grains were retained on them.

Sieve analyses of Jurassic sandstone samples from Simpson test well 1 using American Society for Testing Materials sieves approximating the Wentworth grade scale

Depth (feet)	Grain size (percent) [1]				
	120 mesh (fine sand)	230 mesh (very fine sand)	325 mesh (silt)	<325 mesh (clay)	Total
6,175	trace	46.5	9.4	44.1	100.0
6,184	1.3	51.1	6.4	41.3	100.1

[1] The 18-, and 35-, and 60-mesh screens were also used, but no grains were retained on them.

SPECIFIC GRAVITY

Because Simpson test well 1 penetrated different formations, specific gravity determinations were made of samples at intervals throughout the hole. (See table following.)

Specific gravity of selected samples, Simpson test well 1

Depth (feet)	Specific gravity	Lithology
166	1.99	Clay shale.
202	2.02	Siltstone.
358	2.19	Clay shale.
428	2.07	Silty clay shale.
448	2.09	Argillaceous sandstone.
488	2.16	Clay shale.
498	2.15	Clay shale.
543	2.10	Clay shale.
603	2.16	Clay shale.
713	2.09	Soft siltstone.
900	2.25	Silty clay shale.
1,020	2.04	Soft siltstone.
1,207	1.82	Soft siltstone.
1,330	2.19	Clay shale.
1,570	2.20	Clay shale.
1,758	2.04	Clay shale.
1,967	2.24	Clay shale.
2,343	2.08	Siltstone.
2,739	2.36	Clay shale.
3,000	2.44	Clay shale.
3,190	2.46	Clay shale.
3,580	2.42	Clay shale.
3,824	2.49	Medium-hard clay shale.
3,996	2.49	Medium-hard clay shale.
4,255	2.47	Medium-hard clay shale.
4,698	2.53	Hard clay shale.
5,084	2.53	Hard clay shale.
5,465	2.51	Hard clay shale.
5,677	2.51	Silty claystone.
6,072	2.48	Siltstone.
6,177	2.25	Glauconitic calcareous sandstone.
6,242	2.58	Argillaceous glauconitic siltstone.
6,321	2.65	Argillaceous calcareous siltstone or limestone.
6,460	2.57	Calcareous siltstone.
6,550	2.62	Argillite.
6,790	2.64	Argillite.

HEAVY MINERALS

A study of the heavy minerals found both on the surface and in the subsurface of Naval Petroleum Reserve No. 4 was made by R. M. Morris (Morris and Lathram, 1951). He recognizes three heavy-mineral zones in Simpson test well 1. The glaucophane zone ranges from 130 feet to 1,300 feet. The zoned zircon zone is represented by 1 sample at 2,748 feet. The prismatic tourmaline zone is represented by the sample at 6,173 feet. (See fig. 48.)

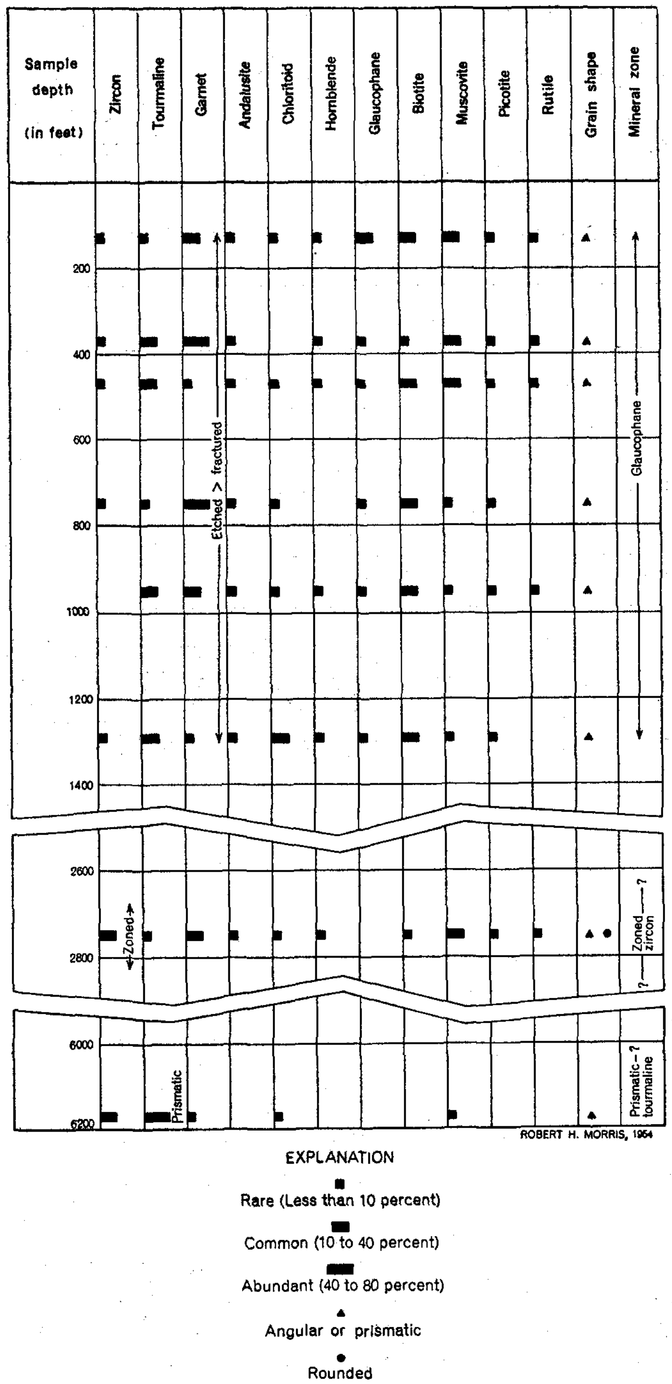


FIGURE 48.—Relative abundance of heavy minerals, Simpson test well 1.

OIL AND GAS

OIL AND GAS SHOWS

The following table gives the oil and gas shows recorded by Arctic Contractors' geologist at the well site when the hole was drilled. A few shows were present near 413 feet, but no well geologist's report is available for this depth.

Oil and gas shows, Simpson test well 1, as reported by Arctic Contractors

Depth (feet)	Show
468–473 [1]	A few gas bubbles on mud sheath, no odor, no cut.
608–613	Fleeting petroleum odor on fresh break.
703–713	Weak odor; fluorescence; light-straw-colored cut; core bled light-green free oil in spots.
713–723	Very weak odor; fluorescence; core bled a few drops of oil.
723–733	Fleeting odor; poor fluorescence.
753–763	Very weak petroleum odor; bled tiny drops of oil.
763–771½	Fleeting petroleum odor.
851–857½	Weak petroleum odor; poor oil stain.
857½–867	Weak petroleum odor; spotty fluorescence; core bled some oil.
867–877	Gas bubbles on mud sheath.
885–895	Gas bubbles on mud sheath.
910–920	Gas bubbles on mud sheath.
920–930	Gas bubbles on mud sheath; no oil.
960–970	Gas bubbles on mud sheath; no odor.
1,030–1,040	Gas bubbles on mud sheath; no oil odor.
1,077–1,087	Fairly strong petroleum odor; fluorescence.
1,097–1,107	Weak petroleum odor in streaks.
1,107–1,117	Fleeting petroleum odor.
1,127–1,137	Fair petroleum odor.
1,157–1,167	Weak petroleum odor; spotty fluorescence.
1,187–1,197	Fleeting gas odor.
6,183–6,193	Fair oil stain in pebbles.

[1] The oil-stained sand between 413 and 1,080 ft was much less saturated than the sandstone at 218–238 ft and 383–403 ft which was tested and proved nonproductive.

The following table gives the shows noted in the Fairbanks laboratory after the cores had been shipped down from the Arctic.

Oil and gas shows, Simpson test well 1, as reported by U. S. Geological Survey

Depth (feet)	Show
130–133	Oil odor; free oil on water in microfossil separation.
211–216	Petroleum odor.
216–221	Oil stain, marked.
303–308	Slight petroleum odor in upper foot.
308–313	Slight oil stain and slight petroleum odor.
383–388	Strong petroleum odor and stain.
388–393	Strong petroleum odor and stain.
393–398	Strong petroleum odor and stain.
398–403	Strong petroleum odor and stain.
403–408	Strong petroleum odor.
408–413	Slight petroleum odor.
693–703	Oil odor.
771½–781	Slight petroleum odor.
781–791	Slight petroleum odor.
791–801	Slight petroleum odor.
801–811	Slight petroleum odor.
6, 183–6, 193	Fluorescent pebble, oil cut.

FORMATION TESTS

Test 1, 115–308 feet.—With a total depth of 308 feet and with the 16-inch casing set at 115 feet, the hole was bailed dry. An estimated 1–2 quarts of oil and very little gas came in.

Test 2, 115–413 feet.—At a total depth of 413 feet, the hole was bailed dry and allowed to stand for 2 hours. The hole was bailed several times again, and about 1 gallon of oil was recovered.

Test 3, 5,594–7,002 feet.—With the hole cased to 5,954 feet, a Johnston formation tester was run with a packer set at 5,905 feet and with perforated pipe at 6,060–6,090 feet. With a five-eighths-inch bean the tool was open for 1 hour and 25 minutes, during which time there was a light but steady flow of air. The valve was then closed for 27 minutes. The recovery was 4,030 feet of mud, of which the bottom half was gas cut. The closed-in pressure was 2,120 to 2,375 pounds per square inch.

Test 4, 5,954–7,002 feet.—A Johnston formation tester was run with a packer set in the 7-inch casing at 5,901 feet and with perforations from 5,974–5,994 feet. The pressure gauge was set at 5,996 feet. The tool was open 12 hours 6 minutes, but the well did not flow. The fluid rose 5,471 feet to within 6 stands of the top of the hole. The tool was pulled, and the bottom 2,000 feet of fluid was cut with gas and showed a trace of salt. While the valve was open, the pressure increased from 1,050 psi to 3,050 psi.

Attempts were made to set the packer at 6,106, 6,097, 6,120, 6,159, and 6,181 feet. All attempts failed.

Test 5, 5,954–7,002 feet.—A swabbing test was made by running a Guiberson tubing swab inside of the 2½-inch tubing. The tubing was run to 6,136 feet with perforations in the bottom 30 feet. A Guiberson casing packer was run on the tubing string and set at 5,917 feet. The well tested 20 barrels per hour salt water with a small volume of gas on each run of the swab. No oil was found. The gas volume was estimated at 1,000 to 3,000 cubic feet per day. It was not possible to lower the fluid level below 1,200 feet by continuous swabbing.

GAS AND WATER ANALYSES

The gas analyses in the following table were made by the Mass Spectrometry Section of the National Bureau of Standards in Washington, D. C., and are reported on an air-free basis.

Gas analyses (in Mol percent), Simpson test well 1

[Analysis by Natl. Bur. Standards]

Component	Sample at 160 feet	Sample at 221 feet	Sample at 6,153 feet
Methane	99.8	95.1	98.4
Ethane		[1].01	1.0
Propane		[1].01	.2
Butane		[1].01	.1
Nitrogen		4.6	
Carbon dioxide	.2	.2	.3
Argon		.1	

[1] Calculated by removing the noncondensable components at liquid air temperature and obtaining the mass spectrum of the resulting concentrates.

The U. S. Bureau of Mines made one analysis of the water. (See table following.)

Analysis of water sample[1] from 6,153-7,002 feet, Simpson test well 1

[Analysis by U. S. Bur. Mines]

Radical	Parts per million (= milligrams per liter)	Reacting values in percentages (Palmer)
Calcium (Ca)	241	1. 75
Magnesium (Mg)	42	. 50
Sodium (Na)	7, 571	47. 75
Bicarbonate (HCO_3)	1, 135	2. 70
Sulfate (SO_4)	53	. 16
Chloride (Cl)	11, 524	47. 14
Total	20, 566	100. 00

[1] Specific gravity at 15.6° C (= 60°F), 1.015.

SUMMARY OF OIL AND GAS

The oil found in Simpson test well 1 is of minor significance. The following comments on the gas shows were made by Arctic Contractors (written communication, September 1948):

Gas from these zones (that is, near 218 and 383 ft), when later cased off, was bled off between the 11¾-inch and 16-inch casings and piped to the boiler for fuel. For a few weeeks there was sufficient gas to build a 90-pound head of steam in the boiler as long as there was no withdrawal of steam. The gas was drowned out as drilling continued, but showed up again between casings after the 7-inch casing had been set. Gas was found in the drilling mud below the shoe of the 7-inch casing during the tests of fluid rise made while the well was standing idle in February and March, and again in the formation tests made after suspension of drilling. None of these, however, gave indication of sufficient volume to be of commercial value.

LOGISTICS

Transportation.—Winter freighting by tractor train from Barrow to the Simpson test well site was started in the middle of February 1947, when the thickness over the freighting route of fresh-water ice measured 54 inches and the salt-water ice 41 inches. All freighting that supported the Simpson exploration program was completed in April. Additional trips were made to supply the camp in the winter of 1947-48. A total of about 2,057 tons of material were hauled.

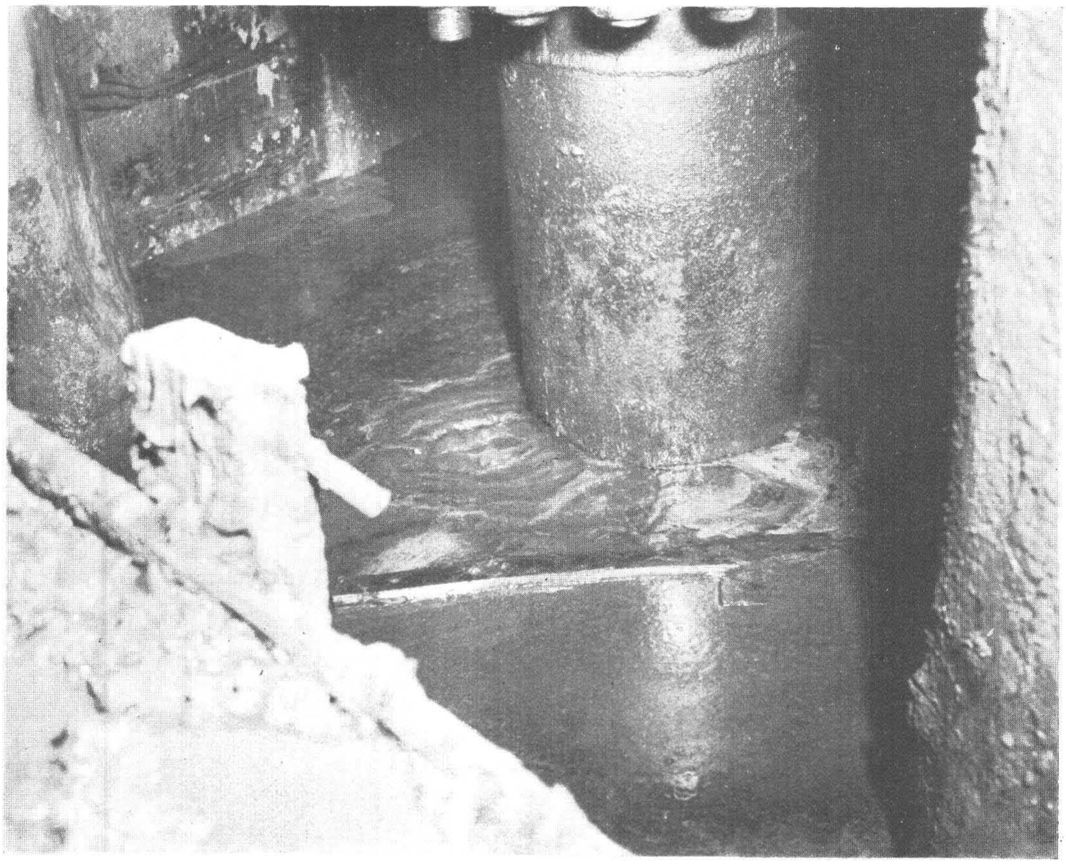
Housing.—There was no gravel or rock in the camp area. The location was bulldozed free of snow, and all the huts were placed on 12- by 12-inch timbers with 3- by 12-inch subfloor to raise them 1 foot above the tundra. No roads were built. The ground remained frozen most of the year, although it thawed from 1 to 3 feet during late summer, when the mud made transportation difficult.

The camp, excluding the rig, was made up of the following units: 10 jamesway huts to house 4 men each, 1 jamesway galley with 2 wanigans on steel runners placed at the rear for galley stores, 1 quonset for warehouse, office, store, and hospital, 1 wanigan on pipe runners for light plant, 2 wanigans on wood runners for utility warehouse and latrine, 1 water wanigan with a 28-barrel pontoon tank mounted on a go-devil sled, 1 wanigan used as store room for pump parts, and 1 canvas-covered sled on steel runners for housing the Schlumberger unit.

Personnel.—The number of permanent employees at the test site was 26. The supervisory personnel consisted of a drilling foreman, a petroleum engineer and a geologist. Two rig crews were made up of 2 drillers, 2 derrickmen, 6 floormen, a heavy-duty-equipment mechanic, and 1 welder-mechanic. In addition there was 1 tractor operator, 1 tractor operator's helper, 1 electrician, 1 bull cook and laborer, 1 oiler, and 1 timekeeper-clerk-warehouseman. Two cooks and one cook's helper were in the galley. In addition, a total of 20 other people were present at various times during the operation, including 4 rig builders, 5 carpenters, a Schlumberger engineer, a Schlumberger technician, the chief petroleum engineer, a tractor operator, a tractor operator's helper, and 6 men from the velocity survey crew.

Vehicles and drilling equipment.—The following items of equipment were used by Arctic Contractors while setting up camp and drilling Simpson test well 1. Vehicles that were kept at the well site were a D8 Caterpillar tractor, 2 weasels, 1 T-9 crane (cherrypicker), and 1 Northwest 25 crane. A D6 Caterpillar tractor, 2 weasels, and an Athey wagon were also used during operations. The major items of drilling equipment were—

1	National 50 drawworks.
1	7¼- by 14-in. Gardner-Denver pump.
2	7¼- by 10-in. Gardner-Denver pumps.
1	C-250 National 7¼- by 15-in. pump.
1	122-ft Ideco derrick.
1	9-ft Ideco derrick substructure.
1	200-ton Ideco crown block.
1	NC-36-4 Emsco traveling block with sheaves grooved for 1-in. line and later replaced with sheaves grooved for 1⅛-in. line.
1	Emsco AE-6 swivel.
1	Ideal Type-D swivel.
1	17½-in. Ideal rotary table.
1	125-ton Byron-Jackson hook.
1	75 hp Broderick boiler with 6- by 4- by 6-in. Oil Well boiler feed pump.
1	48- by 60-in. Link Belt mud screen.
1	4½- by 41-in. forged-steel square kelly.
1	General Motors, 30-kva generator.
1	Kohler, 5-kva generator, used as spare.
1	General Motors, 30-kva generator, used as alternate.



GAS SHOW, SIMPSON TEST WELL 1

Natural gas bubbling up outside the 16-inch casing in the cellar, July 7, 1947

1..... Scramm air compressor, 210 cu ft per min.
1..... 250-bbl Malone bolted-steel tank.
2..... 1,500 gal welded-steel tanks mounted on steel runners.
1..... 11¾-in. Shaffer double-cellar control gate with type 39 rams.
2..... 18⅝-in. Shaffer single type-34 gate, blowout preventer, one used with blank rams, the other with drill pipe rams.
1..... Howco cementing unit.
1..... Schlumberger hand-recording electric-logging unit.
1..... Wilson winch super model, single drum with manual control with model K-428 Buda engine.

Water, fuel, and lubricant consumption.—During the summer (June 25 to Sept. 1, 1947) sufficient water was obtained by hauling and by pumping from a 2½-inch line from a pond three-fourths of a mile from the camp. Eventually the pond froze solid (5 feet of ice) and water was hauled with a water wanigan and D8 tractor from a lake 3½ miles south. At times water was in short supply during the winter. No record was kept of the amount of water used in July, August, and September 1947, but 1,137,800 gallons was used between September 30, 1947 and June 14, 1948.

The following were also used: 196,519 gallons of diesel oil, 47,010 gallons of gasoline and 5,283 gallons of lubricating oil.

DRILLING OPERATIONS

DERRICK HOUSE AND RIG FOUNDATION

The derrick was covered from the top of the gin pole down to the first girt by insulated double canvas. The righouse from the first girt down was constructed out of ½-inch waterproof plywood attached to 2- by 4-inch framing. Steel rollers and iron tracks were used for swinging the door.

The foundation was constructed of piling with 12- by 12-inch timber caps. The holes for the piling were thawed out of the frozen silt, clay and ice with steam points, and the piling was driven by the big crane converted into a pile driver. The average depth of the piling was 15 feet, and the average dimensions were 16 inches on the butt and 10 inches on the small end.

Arctic Contractors report (written communication, September 1948) that—

In order to insulate the piling and prevent thawing due to heat from the rig and to collect mud and water which runs under the rig floor during drilling, a concrete mat (26 by 26 ft.) was laid under the rig floor a few inches above ground level. Tundra was hauled in and laid 4–6 inches thick on top of the tundra that was in place. Above this was placed a layer of ¾-inch Celotex as extra insulation. A layer of Marston steel mat was laid as reinforcing. Approximately 4 inches of concrete was poured for mat with a slight slope toward the cellar. The concrete in the cellar bottom was poured 1 foot thick. In addition to the derrick foundation, piling with 12- by 12-inch timber caps was used for the engine and pump foundation and for the pipe racks.

With this type of insulation and rig covering representative temperatures were recorded. (See table following.) Although canvas was draped over the open door when the 7-inch casing was being run in December, it was impossible to keep the temperature on the rig floor above freezing.

Representative inside and outside temperatures, Simpson test well 1

Date	Inside—rig floor level (°F)	Outside—open atmosphere (°F)
January 1948	50	−30
	45	−38
	38	−15
	55	−20
April 1948	50	4
	50	10
	55	24
	55	0
	35	10

DRILLING NOTES

The following drilling operations were reported by the petroleum engineer at the rig site.

Notes from drilling records

Depth (feet)	Remarks
0	Well spudded in on June 14, 1947.
25	Ran 18 ft of 24-in. conductor pipe and cemented with 15 sacks of cement.
115	Set casing—16-in. inner diameter, 60-lb Western Pipe and Steel Co. welded steel; slip-joint casing cemented at 115 ft with 150 sacks of portland cement treated with 200 lb of calcium chloride.
221	Gas started to blow mud out of drill pipe. Increased weight of mud.
300	Rotary clutch broke down. Repaired. Gas bubbled up around 16-in. casing in cellar. (See pl. 38.)
1,078	Set casing—cemented 11¾-in. 43- and 47-lb API seamless 8 thread, grade H-40 and J-55, range 2 casing at 1,028 ft with 300 sacks of portland cement, treating the last 50 sacks with calcium chloride.
2,486	Hole crooked. (See Deviation survey on pl. 38.) Reamed and reduced weight on drilling bit.
2,600	Started to have trouble with pipe hanging up while pulling out of hole.
4,708	Mud pit 2 sprang a leak and about half of the mud from the pits was lost. Main drive chain broke. High winds lifted roof of righouse every time door was opened.
5,725	Shut down 1 week for repairs on drawworks.
5,800	Hole caved badly. Treated mud with Stabilite 8 and quebracho.
6,094	Stuck pipe in key seat at about 2,800 ft when coming out of hole. Pipe parted at 2,561 ft. Cut and recovered pipe down to 2,794 ft leaving core barrel and a part of one single in hole. Shut down from Nov. 11 to Dec. 14, 1947 for fishing but were unable to recover fish, which extended from 2,794 to 2,832 ft. Drilled alongside fish and cased it off by setting 7-in. 23 lb 8-thread grade J-55, range 2 casing at 5,954 ft cemented with 105 sacks of portland

Notes from drilling records

Depth (feet)	Remarks
	cement. Had to steam out every joint because they were full of snow, ice, gravel, and sticks. Cleaned out mud pits. Short of water. Auxiliary heater broke down and shale-shaker motor burned out while drilling out cement. Repaired.
6,171	Pipe stuck on bottom. After several attempts, backed off at top of float collar at 6,076 ft. Eventually washed over to 6,160 ft and took hold of fish and pulled out. Changed from 4½- to 3½-in. drill pipe, at about 6,170 ft. Were shut down from Jan. 8 to Feb. 2, 1948.
6,314	Bailed down to 926 ft and checked fluid rise periodically. Installed heavier duty mud pump.
6,455	Installed new sheaves in travelling block and strung up new 1⅛-in. drilling line.
7,002	Reached total depth May 12, 1948. Gas was coming in about 3 feet below top of 7 in. casing. Repaired hole worn by kelly at and just below landing slips. Ran formation tests. Cement plugs set at 6,387 and 5,520 ft. Fluid in 7-in. casing bailed down to 1,185 ft. Shaffer landing head was left on hole capped with a 3-in. hammer plug valve. The valve was left open to receive a thermistor cable, which was lowered to 1,000 ft. An oil drum was placed over the valve to prevent junk from falling in hole. Completed June 9, 1948.

Simpson test well 1 was the first deep test in the Reserve drilled continually through the winter. The hole afforded Arctic Contractors much valuable experience in drilling under arctic conditions, and suggestions made by the engineers for improving efficiency of camp layout and drilling methods were applied to future holes drilled. There were difficulties in drilling Simpson test well 1 because new equipment and pipe was not available for the project in 1946. The drilling rig had been used in Naval Petroleum Reserve No. 1 during World War II and showed a considerable amount of wear.

DRILL AND CORE BITS

A total of 74 drilling bits, in 6 sizes, ranging from 6⅛ to 30 inches, was used. The type of bit and the interval through which they drilled are shown on plate 35. In these formations the bearings of the bits wore out faster than the cutting teeth.

Forty-three core bits, in 3 sizes, were utilized. The first core was taken using a conventional barrel, but it was damaged when being pulled from the hole. The rest of the cores down to 5,308 feet and 2 cores between 6,067 and 6,094 feet were taken with a wire-line barrel. The remainder of the coring was done with a conventional barrel. Two hundred and forty-nine cores were taken, with a recovery of a little over 1,273 feet or about 70 percent of the total footage cored.

DRILLING MUD

With the occasional addition of small quantities of Aquagel in drilling to 5,000 feet, little difficulty was had in keeping the mud in condition as the hole made fairly good mud and required little else but water. Caving shale caused increasing difficulty, and it was necessary to use chemicals below 5,800 feet and later Baroid to increase the weight. The approximate amounts of drilling-mud materials used were as follows:

Aquagel	184 sacks
Baroid	975 sacks
Fibertex	4 sacks
Smentox	6 sacks
Sodium bicarbonate	272 lb
Stabilite-8	442 lb
Quebracho	353 lb
Quadrafos	571 lb
Sodium acid pyrophosphate	907 lb

The approximate amount of chemicals used and the characteristics of the mud were as given 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 (°F)	Additives
120					17 sacks Aquagel, 47 sacks Baroid, 4 sacks Fibrotex.
205	70.5	33.5		36	22 sacks Aquagel, 90 sacks Baroid.
220	78.5	38.5			
240	80.0	36.5			
295	80.0	36.5			
307	79.0	35.0			4 sacks Aquagel.
325	76.0	35.0			
410	77.0	36.0			
433	75.5	35.5			
500	74.0	33.0		45	
565	74.0	34.5		42	
645	77.0	36.0		40	5 sacks Aquagel.
740	74.0	33.0		39	
840	75.0	33.5		38	
1,020	76.0	33.5		38	
1,080	77.0	35.0	90	39	
1,083	77.5	37.5			3 sacks Aquagel.
1,265	79.0	38.0		44	
1,370	88.0		45		
1,750	81.0	33.5	95	51	
2,010	77.5	31.0	95	53	
2,060	79.5	33.0	75	54	
2,100	82.5	35.5	73	52	
2,245	84.0	37.0	60	53	12 sacks Aquagel.
2,427	82.0	35.5	65	54	
2,485	83.5	37.5	60	58	
2,530	87.0	37.5	53	61	
2,547	85.5	37.5	63	59	
2,570	87.0	38.0	60	62	
2,577	85.0	36.5	67	61	
2,605	86.0	38.0	60	64	
2,625	85.5	35.5	70	64	
2,633	87.0	36.5	73	67	
2,660	86.5	36.5	63	62	
2,693	86.5	36.5	65	64	
2,723	86.5	37.5	67	65	No additives.
2,763	86.5	36.0	63	66	
2,850	87.0	37.5	60	66	
2,930	86.0	38.0	65	62	
2,983	88.0	36.0	60	66	
3,033	88.0	36.0	60	58	
3,175	87.0	36.0	63	63	
3,190	89.0	37.5	67	64	
3,223	87.5	36.5	67		
3,257	85.0	35.0	73	68	

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 (°F)	Additives
3,307	86.5	36.5	63	70	
3,350	88.0	37.0	65	72	
3,380	86.0	36.0	70	69	
3,463	87.0	38.0	60	73	
3,553	87.5	38.0	67	74	5 sacks Aquagel.
3,590	86.0	38.0	67	64	
3,675	86.5	38.5	63	--------	
3,760	86.0	36.5	60	74	
3,812	86.5	39.5	50	69	
3,840	89.0	42.0	50	69	
3,935	88.0	40.0	55	74	
3,990	88.0	41.0	--------	71	
4,025	88.0	39.5	--------	74	
4,090	89.5	41.5	50	78	
4,130	--------	42.5	45	73	
4,190	87.5	39.5	57	76	
4,255	88.0	39.5	--------	76	
4,290	92.0	42.0	75	81	No additives.
4,325	86.5	36.5	63	--------	
4,360	82.0	33.5	35	69	
4,430	88.0	38.5	57	76	
4,495	89.0	41.0	55	79	
4,520	89.0	38.5	55	66	
4,550	89.0	37.0	65	73	
4,650	89.0	37.0	55	83	
4,700	--------	41.5	53	--------	
4,707	88.0	36.5	60	67	
4,715	88.5	38.0	65	68	
4,760	88.0	37.0	60	74	
4,795	85.0	35.0	70	75	
4,870	87.5	37.0	70	77	14 sacks Aquagel.
4,885	88.0	40.0	65	70	
4,940	86.5	36.0	75	78	
4,990	87.0	36.0	65	77	
5,015	88.0	37.0	70	78	
5,085	86.5	39.5	70	72	
5,125	87 0	36.5	73	76	
5,190	87.0	36.5	73	79	
5,235	86.5	36.0	80	78	
5,280	89.0	41.0	63	80	
5,305	87.5	38.5	70	78	
5,310	86.5	35.5	73	81	
5,345	89.0	41.0	60	79	
5,395	88.0	37.5	67	85	No additives.
5,420	87.5	36.5	73	79	
5,440	88.5	38.5	63	82	
5,460	87.0	37.5	70	78	
5,473	87.0	36.0	63	80	
5,490	86.5	35.5	75	82	
5,535	86.0	36.5	80	85	
5,553	87.5	38.5	75	85	
5,590	89.0	39.0	67	88	
5,607	88.5	39.0	67	86	
5,650	87.0	38 0	70	88	
5,687	87.5	39.0	65	83	
5,693	88.5	39.0	67	86	
5,717	88.5	38.5	65	88	*14 sacks Aquagel.*
5,725	88.0	43.0	63	74	
5,787	86.0	44.5	67	85	
5,800	86.5	50.0	70	76	17 lb Stabilite-8, 7 lb quebracho.
5,820	87.0	42.5	67	76	
5,863	90.0	46.0	73	88	
5,867	90.0	42.5	65	87	
5,873	90.5	42.5	63	84	
5,900	92.0	44.5	60	86	35 lb quebracho, 73 lb Stabilite-8.
5,920	92.0	45.0	63	82	
5,955	94.0	46.0	60	83	
5,980	94.0	44.0	55	83	
6,007	93.0	43.5	53	85	10 sacks Aquagel, 87 lb Quadrafos, 94 lb sodium acid pyrophosphate, 176 lb Stabilite-8.
6,027	93.0	43.0	53	86	
6,053	93.5	44.5	53	85	
6,070	93.5	43.0	53	86	
6,093	94.0	45.5	30	86	
6,153	77.0	37.0	130	76	66 sacks Aquagel, 230 sacks Baroid, 120 lb Quadrafos, 6 sacks Smentox, 74 lb sodium bicarbonate, 24 lb Stabilite-8.
6,155	82.0	45.0	103	77	
6,167	89.5	50.5	63	75	
6,175	90.0	53.0	60	71	324 sacks Baroid, 120 lb sodium acid pyrophosphate, 54 lb Stabilite-8.
6,207	89.5	55.5	63	84	6 sacks Aquagel, 30 sacks Baroid, 160 lb Quadrafos, 15 lb sodium acid pyrophosphate, 88 lb Stabilite-8.
6,272	85.5	--------	85	82	
6,300	85.5	--------	85	86	
6,305	82.0	--------	93	76	
6,315	79.0	35.0	103	77	
6,347	83.0	39.0	83	77	
6,357	83.0	40.0	87	79	9 sacks Aquagel, 89 sacks Baroid, 80 lb sodium acid pyrophosphate.
6,365	82.5	40.5	87	77	
6,385	83.0	41.0	93	80	
6,410	82.0	42.0	93	82	
6,435	80.5	45.5	110	83	

Drilling-mud characteristics and activities—Continued

Depth (feet)	Weight (lb per cu ft)	Viscosity (sec. API)	Filtration loss (cu cm per 20 min)	Drilling fluid temperature (°F)	Additives
6,463	79.5	41.5	137	85	
6,485	79.0	47.5	140	87	
6,490	79.0	51.5	133	82	
6,510	80.0	40.5	110	88	165 lb sodium acid pyrophosphate.
6,540	80.0	43.0	120	91	
6,545	80.0	41.0	110	92	
6,557	80.5	47.0	120	80	
6,577	80.5	41.0	120	90	
6,620	82.5	43.0	105	87	4 lb quebracho, 188 lb sodium acid pyrophosphate.
6,640	82.5	44.0	103	93	
6,657	82.5	46.0	110	93	
6,673	81.0	44.5	130	94	
6,697	80.5	45.0	113	97	6 sacks Aquagel, 7½ lb quebracho, 6½ lb sodium acid pyrophosphate.
6,723	81.0	52.0	107	93	
6,757	80.5	47.5	97	92	
6,795	79.0	43.0	127	86	
6,817	78.0	38.5	127	93	
6,850	80.0	44.5	120	96	7 lb quebracho, 7 lb sodium acid pyrophosphate.
6,865	79.0	42.0	133	92	
6,895	80.0	41.0	97	96	
6,915	80.0	40.5	133	92	
6,937	81.0	41.5	113	89	
6,953	81.5	44.5	103	90	6 lb quebracho, 6 lb sodium acid pyrophosphate.
6,980	82.0	43.0	115	94	
6,990	82.0	43.5	125	92	

HOLE DEVIATION

Figures on the inclination of the hole may be found on the graphic log (pl. 35). The hole was checked about every 200 feet down to 5,875 feet, using a Technical Oil Tool Corporation instrument. Inclination ranged from zero to 1°40′ down to 2,350 feet. When 3°30′ was reached, at 2,525 feet, the hole was straightened by reducing weight on the bit. After the hole was straightened, a series of directional shots were made with an Eastman instrument, taken in the open hole. From 2,625 to 3,275 feet the readings ranged from 40′ to 2°00′ and from 3,275 to 5,875 feet the deviation was 35′ or less, except for one reading of 1°05′ at 3,825 feet. No inclination survey shots were made below 5,875 feet because of the caving condition of the hole—with the exception of a reading of 2°45′ taken at 6,945 feet after drilling was completed.

ELECTRIC LOGGING

The electric logs were run using sled-mounted Schlumberger equipment with a three-conductor cable and hand recorders which had been at Cape Simpson for about two years. The curves run consisted of a self potential and long and short normals. (See pl. 35.) A lateral curve was made on runs 1, 3, 4, 5, 6, and 8. On run 2 the batteries faded too rapidly to give sufficient current to make the lateral curve; on run 7 cavings from the walls of the hole almost struck the surveying device near the bottom while making the first recording, and the lateral run was postponed. The lateral curve was not included on plate 35 because it adds nothing of significance.

On run 7 the Schlumberger engineer commented (written communication, April 12, 1948) that the "low apparent resistivity of the sandstone zones as shown by the resistivity curves on the electric log may be due in part to the poor insulation of the electrical-logging cable, but it is believed that the resistivity measurements afford fairly reliable evidence of the character of the formations." After this run the cable was returned to Barrow and repaired. However, run 8 made in May 1948 (shown on pl. 35) also shows low resistivity in the sandstones between 6,153 and 6,269 feet; so the formation water is probably saline in this interval.

No electric log was made between 5,400 and 5,954 feet before cementing the 7-inch casing. The presence in the hole of a lost core barrel made the running of an electric survey hazardous.

TEMPERATURE SURVEY

A temperature survey was made immediately following the last electrical survey to find the source of the gas being produced from between the conductor pipe and surface pipe. Conditions were not very good, so the survey was run as an experiment. Circulation had been stopped, the pipe had been out of the hole for about 6 hours, and the mud had been disturbed by several trips to the bottom by the Schlumberger sonde and cable. Apparently the temperature had not had time to equalize properly in the mud as no good indication of the source of gas was found. The temperature varied between 52°F and 54°F down to 975 feet. From 975 to 1,050 feet it increased rapidly to 58°F. From 1,050 feet down it increased gradually to about 67° at total depth. The break in gradient between 975 and 1,050 feet probably represents the base of the permafrost.

Three thermistor cables were installed in the hole after the completion of drilling. One was about 50 feet long, the second was about 100 feet long, and the third about 1,000 feet long. Thermoresistance elements were set about every 10 feet between the surface and 100 feet and at every 100 feet between 600 and 1,000 feet. Temperature readings were taken until September 4, 1948, by J. H. Swartz and G. R. MacCarthy, of the U. S. Geological Survey, who supplied the following data (written communication, G. R. MacCarthy, January 1951): The hole was bridged, presumably by ice, at a depth of 194 feet with the 1,000-foot cable frozen in the hole. The temperatures measured ranged from plus 1.5°C at 5 feet to a minimum of minus 4.8°C at 60 feet. The temperature at 900 feet was minus 0.9°C and at 1,000 feet plus 1.9°C. The temperatures in the hole probably had not reached equilibrium. Experience has shown that it may take over a year for a deep test to reach thermal equilibrium. Shortly after these readings were taken, the cable terminals were accidentally destroyed, and the cables are inoperative.

VELOCITY SURVEY

A velocity survey was run by United Geophysical Co. on Simpson test well 1 on February 21, 1948, when the hole was at 6,314 feet. Three shotholes were drilled 100 feet apart and in an arc 1,000 feet southwest of the test-well site. Only two of the shotholes (uncased) were actually used.

The average velocity decreases from 8,396 feet per second at 500 feet to 8,016 feet per second at 1,700 feet. Below this the average velocity increases to 9,508 feet per second at the depth of 6,314 feet, with a few minor breaks.

An interesting sidelight to the drilling of the shotholes was the testing of these holes for water. The engineers wanted to know if enough water was present in the shotholes to furnish water for winter drilling with a big rig. Sufficient water was not found.

NORTH SIMPSON TEST WELL 1

Location: Lat 71°03′23″ N., long 154°58′06″ W.
Elevation: Ground, 15.5 feet; kelly bushing, 30.5 feet.
Spudded: May 6, 1950.
Completed: June 3, 1950; dry and abandoned.
Total depth: 3,774 feet.

North Simpson test well 1 was located between Dease Inlet and Smith Bay approximately 11 miles northeast of and on the same peninsula as Simpson test well 1. It, too, is on the flat and swampy coastal plain only a few miles from the Arctic Ocean.

This test hole started much higher in the section than Simpson test well 1, and a part of the Upper Cretaceous is present. The formations penetrated in this test consist of the following:

	Feet
Gubik	15 -90?
Schrader Bluff	90?-1, 550?
Seabee	1, 550?-2, 770
Topagoruk	2, 770 -3, 590
Oumalik	3, 590 -3, 774

The thickness of the permafrost in North Simpson test well 1 was not recorded by the driller, but an examination of the electric log (see pl. 36) shows that something with high resistivity, probably fresh water or ice, is present in the hole down to a depth of about 500 feet.

The dips in the Colville group, which was deposited over an unconformity of considerable relief (see pl. 37), average 5° and are probably toward the north. A dip of 6° or 7° was determined from cores in the Topagoruk formation; the dip is either an initial dip over a small erosional high in the Oumalik formation or represents a local irregularity in deposition. The bottom-hole core in the Oumalik formation shows a dip of 2°. This is probably a part of the regional southeasterly dip as shown in seismic sections and is in accordance with the dips recorded for the Oumalik formation of Simpson test well 1.

Rare slickensided fracture surfaces were found in the core from 1,790–1,800 ft (Seabee formation), and an irregular fracture was noted in core from 3,160–3,170 ft (Topagoruk formation). Both of these occurrences are very minor features of structure.

This test well was completed, found dry, and abandoned as there were no shows of oil or gas and no reservoir rocks were found.

DESCRIPTION OF CORES AND CUTTINGS

North Simpson test well 1 was described by the author from the cores and cutting samples under the same conditions described for Simpson test well 1 except that these samples were "fresh" and had not been in storage for several years. As there were no sandstones, no tests other than for specific gravity were run.

The uppermost sample received in the laboratory, labeled "0–110 ft," consisted entirely of sand similar to that of the Gubik formation, a little clay, and cement contamination. This sample must have been dipped out of the mud pit after the cement for the surface casing was set. The base of the Gubik formation is placed arbitrarily at 90 feet, based on the proportion of sand to clay. The samples down to 180 feet consisted of little but cement.

It will be noted that most of the core material is described as "clay shale," whereas the intervening cutting samples are described as "clay." No discrepancy is meant here. The Upper Cretaceous shales are so soft that much of the material disintegrated as it was washed and cleaned in preparation for examination. A factor contributing to poor samples was the absence of a shale shaker on the drilling rig. The author believes that all samples described as "clay" below the base of the Gubik formation are really clay shale.

The cuttings samples across the contact of the Topagoruk and Oumalik formations (3,590 ft) show little change, although there is a definite electric-log break at this point. This is probably partly because of contamination from above and partly because there actually is little change in the clay shales, which can be seen by the naked eye. A change in color shows up gradually in the cuttings.

Lithologic description

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

Core	Depth (in feet)	Remarks
----	0–15	Height of kelly bushing above ground.
----	15–19	Cellar.
----	19–110	Whole interval represented by one ditch sample which contains medium-light-yellowish-gray fine, subangular to rounded sand grains that are clear, milky, yellow quartz, gray and black chert. Well-rounded granules and pebbles of dark chert and yellow quartzite. Also a very small amount of clay. Top of Schrader Bluff formation probably near 90 ft.
----	110–120	No samples received.
----	120–180	Cutting samples are predominantly cement (Cal-Seal); some clay.
----	180–290	Clay, light-olive gray; some medium-light-gray silt, possibly a very small amount of fine subangular white quartz sand; rare volcanic glass shards at 260–270 ft. *Inoceramus* prisms at 240–260 ft and 270–280 ft.
1	290–300	Recovered 4 ft: Microfossils rare. 2 ft, drilling mud mixed with a few soft chips of rock as described below. 2 ft, clay or clay shale, light-gray to medium-light-gray, slightly silty; fair cleavage; contains streaks up to 1 in. thick of very fine claylike noncalcareous white material. Embedded in this white material are quartz silt grains, rare plates of biotite, and carbonaceous flecks. White matrix is probably tuffaceous material; noncalcareous; dip 3°–6°.
----	300–380	Clay, slightly silty.
----	380–455	Clay, light-olive-gray; very small amount of medium-light-gray fine-grained subangular, white and clear quartz silt and sand grains; opaque white volcanic glass shards common.
----	455–490	Clay; shards rare.
2	490–498	Recovered 8 ft: Microfossils abundant. Clay shale, medium light gray, tuffaceous, noncalcareous, fairly soft; fair to good cleavage which parallels bedding; numerous very light-gray silty partings and thin laminae which contain abundant white claylike specks, biotite and chlorite (?) plates, carbonaceous flecks, and rare resinous, amberlike particles. The washed microfossil residue from this core indicates that white material is altered volcanic glass (and ash?). Most fluted shards are opaque white, although all stages of alteration from clear glass to disintegrated particles were noted; dip 3°. One fragment of a pelecypod (?).

Lithologic description—Continued

Core	Depth (in feet)	Remarks
----	498–500	No sample.
----	500–690	Clay, medium-light-gray; some silt; shards very rare to rare.
3	690–700	Recovered 10 ft: Microfossils rare. Clay shale as in core 2 above, tuffaceous, noncalcareous. One ¾-in. diameter rounded and polished black chert pebble at 690 ft. This pebble is undoubtedly in place, embedded in clay, no other coarse material associated with it; dip 3°.
----	700–810	Clay, medium-light-gray; some silty laminae; volcanic shards very rare.
----	810–890	Clay as above, also silt and small amount of sand; 1 rounded black chert pebble at 820–830 ft; shards rare to fairly common.
4	890–900	Recovered 10 ft: Microfossils rare. Clay shale as above, very light-gray to medium-light-gray, tuffaceous, noncalcareous; very good cleavage; abundant thin laminae and partings of tuffaceous material. Rare angular to subangular fine-grained quartz sand grains are embedded in lighter streaks; dip 6°–7°.
----	900–1, 010	Clay, medium-light-gray, slightly silty; shards very rare.
----	1, 010–1, 190	Clay; shards rare to fairly common; small amount of white crystalline calcite at 1,050–1,060 ft.
5	1, 190–1, 200	Recovery 10 ft: Microfossils very rare. 8 in., siltstone, very calcareous; and finely crystalline light-gray limestone; contains carbonaceous and micaceous flecks. 9 ft 4 in., clay shale as in core above, tuffaceous, noncalcareous; streaks of fine-grained, subangular quartz in tuffaceous material; very good cleavage parallel to bedding; dip 6°.
----	1, 200–1, 270	Clay, medium-light-gray; some silt and very fine quartz sand; subangular white and clear quartz, shards very rare. *Inoceramus* prisms 1,200–1,210 ft.
----	1, 270–1, 489	Clay, medium-light-gray; some silt and sand; small amount of white crystalline aragonite at 1,330–1,340 ft. Shards very rare to absent. Arctic Contractors well geologist reports very thin hard layers—calcareous siltstone and limestone—at 1,270–1,489 ft. *Inoceramus* prisms at 1,270–1,280 ft and 1,400–1,410 ft. Fish fragment at 1,410–20 ft.
6	1, 489–1, 499	Recovered 10 ft: Microfossils very rare. Clay shale, medium-light-gray, noncalcareous; decided decrease in amount of volcanic material compared with cores above; tuffaceous laminae rare; glass shards present in washed residue but not abundant. Silty and slightly sandy laminae and partings; good cleavage; dip ranges from 6° to 12°, primarily about 6°. One minute unidentified pelecypod at 1,493 ft.
----	1, 499–1, 500	No sample.
----	1, 500–1, 660	Clay, medium - light - gray, very fine - grained; scattered chips of sideritic and calcareous cemented sandstone. *Inoceramus* prisms 1,630–1,640 ft. Top of Seabee formation is probably near 1,550 ft.
----	1, 660–1, 790	Clay, medium-light-gray; also first rare occurrence of light-gray clay; chips of very calcareous argillaceous siltstone. *Inoceramus* prisms at 1,670–1,680 ft, 1,730–1,740 ft, and 1,770–1,780 ft.
7	1, 790–1, 800	Recovered 10 ft: Microfossils rare. Clay shale, medium-light-gray, noncalcareous, moderately hard; silty partings; *Inoceramus* prisms, fish fragments. Rare slickensided fracture surfaces at 1,792 ft. Several fractures dipping 30°–40° in first 5 ft of interval. Bedding dips 5°–15°, somewhat irregular in vicinity of fractures; dips are 5°–8° for the most part.
----	1, 800–1, 930	Clay, light- to medium-light-gray. *Inoceramus* prisms at 1,860–1,870 ft.
----	1, 930–2, 020	Clay as above, quite silty; some fine sand at 1,970–1,980 ft.
----	2, 020–2, 090	Clay, light- to medium-light-gray; some very fine white and clear quartz sand. *Inoceramus* prisms at 2,020–2,030 ft. Fish fragments at 2,060–2,090 ft.
8	2, 090–2, 100	Recovered 4 ft: Microfossils very rare. Clay shale, medium-light-gray; silty partings; some with finely disseminated pyrite noted; also a few partings of very light-gray volcanic material; excellent cleavage parallel to bedding; some partings are slightly calcareous; dip 9°–11°; well-preserved skeleton (1½ in. long) of a fish (cf. *Leptolepis* sp.) 1 ft from bottom. Very small specimen of the ammonite *Borissiakoceras*? sp.
----	2, 100–2, 220	Clay, light- to medium-light-gray; very rare pyrite at 2,110–2,140 ft; very rare white aragonite at 2,160–2,170 ft; one small chip of dull black coal at 2,200–2,210 ft. *Inoceramus* prisms at 2,210–2,220 ft. Fish fragment at 2,150–2,160 ft.
----	2, 220–2, 390	Clay; small amount of calcareous siltstone, *Inoceramus* prisms at 2,270–2,280 ft.
9	2, 390–2, 400	No recovery.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
10	2,400–2,410	Recovered 9 ft: Microfossils absent. 7 ft 11 in., clay shale, light-gray, with slight bluish cast, nonsilty, noncalcareous, medium-soft, very uniform of texture; fair to good cleavage parallel to bedding; dip 2°. 1 ft 1 in.; limestone, light-gray, with slight bluish cast, argillaceous (?), hard, very dense, lithographic; irregular fracture. *Inoceramus* prisms.
----	2,410–2,540	Clay, light-to medium-gray; very small amount of very fine to fine white and clear quartz sand. *Inoceramus* prisms at 2,420–2,430 ft and 2,520–2,530 ft.
----	2,540–2,690	Clay, medium-light- to medium-gray; very small amount of medium-light-gray siltstone at 2,610–2,620 ft; trace of medium-dark-gray crystalline limestone at 2,540–2,550 ft; trace medium-gray limestone at 2,630–2,640 ft; very small amount of light-gray fine-grained sand at 2,680–2,690 ft, *Inoceramus* prisms at 2,620–2,630 ft and 2,680–2,690 ft.
11	2,690–2,700	No recovery.
12	2,700–2,710	Recovered 7 ft: Microfossils absent. Clay shale, medium-light-gray, noncalcareous, medium-soft, slightly waxy, good cleavage; dip 6°. *Inoceramus* sp. fragment from 2,708 ft.
----	2,710–2,890	Clay, light- to medium-gray. *Inoceramus* prisms at 2,780–2,790 and 2,880 ft. Top of Topagoruk formation placed at 2,770 ft.
----	2,890–2,990	Clay, medium-light- to medium-gray.
13	2,990–2,998	Recovered 8 ft: Microfossils rare. Clay shale, medium-light- to medium-gray, medium-soft; fairly common partings and laminae (up to 1½ in. thick) of slightly sandy light-gray siltstone; fair cleavage: Siltstone contains quartz, plus some mica and carbonaceous flecks, and is moderately calcareous. Clay shale is noncalcareous. Dip 8°.
----	2,998–3,000	No sample.
----	3,000–3,150	Clay, medium-light- to medium-gray; scattered thin streaks of medium-light-gray noncalcareous siltstone. *Inoceramus* prisms at 3,010–3,020 ft. and 3,140–3,150 ft.
14	3,150–3,160	Recovered 10 ft: Microfossils very rare. Clay shale, medium-light- to medium-gray, good cleavage parallel to bedding, generally along planes of silty partings. Partings contain flecks of mica and carbonaceous material. Very rare light-gray silty laminae which are slightly calcareous; dip 3°.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
15	3,160–3,170	Recovered 10 ft: Microfossils rare. Clay shale as above, with silty partings; small amount of irregular fracture; dips 8°–17°.
16	3,170–3,180	Recovered 9 ft: Microfossils rare. Clay shale with silty partings but no silty laminae; noncalcareous; dip 10°.
17	3,180–3,190	Recovered 1 ft: Microfossils rare. Clay shale, medium-light- to medium-gray, noncalcareous; fair cleavage; recovery consists mostly of broken pieces.
18	3,190–3,200	Recovered 6 in.: Microfossils very rare. Clay shale or claystone, medium-light- to medium-gray, silty, slightly calcareous.
19	3,200–3,204	Recovered 3 ft 3 in.: Microfossils very rare. 3 in., clay shale, or claystone, medium-light- to medium-gray, silty, slightly calcareous. 3 ft, clay shale, medium-light- to medium-gray, fair cleavage; some silty laminae which are calcareous; dip 3°.
20	3,204–3,209	Recovered 1 ft: Microfossils very rare. Clay shale as above; dip undetermined.
21	3,209–3,214	Recovered 5 ft: Microfossils very rare. Clay shale, medium-gray, noncalcareous, moderately hard; good cleavage parallel to bedding; silty partings with plates of mica and flecks of carbonaceous material parallel bedding; dip 6°.
22	3,214–3,224	Recovered 7 ft: Microfossils absent. Clay shale, medium-gray, noncalcareous, moderately hard; good cleavage parallel to bedding; silty partings with plates of mica and flecks of carbonaceous material parallel bedding; dip 4°.
23	3,224–3,234	Recovered 10 ft: Microfossils absent. Clay shale or claystone, medium-gray, moderately hard, good to poor cleavage; somewhat fractured in lower half; slightly calcareous in spots. Four inches of medium-light-gray, rather hard argillaceous, very calcareous siltstone at approximately 3,225 ft. Bedding in this siltstone is rather irregular; dip 6°–12°.
24	3,234–3,244	Recovered 8 ft: Microfossils very rare. Clay shale, medium-gray; poor to good cleavage; silty partings: Approximately one-third of this core, mostly in lower section, is made up of soft friable siltstone that is light gray, argillaceous, very calcareous, mostly white quartz, micaceous, very slightly carbonaceous; dip 3°–6°; 1 small *Inoceramus* sp. fragment noted at 3,236 ft.

Lithologic description—Continued

Core	Depth (in feet)	Remarks
25	3, 244-3, 254	Recovered 10 ft: Microfossils very rare. Clay shale, medium-gray with a few light-gray calcareous silty laminae and partings; fair cleavage; dip 3°.
26	3, 254-3, 264	Recovered 5 ft: Microfossils very rare. Clay shale, medium-gray, micaceous, slightly calcareous; slightly carbonaceous silty partings; fair cleavage; dip 2°.
27	3, 264-3, 274	Recovered 10 ft: Microfossils absent. Clay shale, medium-gray, micaceous, slightly calcareous; slightly carbonaceous silty partings; fair cleavage; dip 6°.
28	3, 274-3, 280	Recovered 4 ft: Microfossils rare. Clay shale, medium-gray, very slightly calcareous; silty micaceous partings; good poker chip cleavage; dip 2°.
29	3, 280-3, 290	Recovered 10 ft: Microfossils rare. Clay shale, medium-gray, moderately hard; fair to good cleavage; silty micaceous partings; noncalcareous except in partings; dip 4°.
30	3, 290-3, 300	Recovered 10 ft: Microfossils very rare. Clay shale as immediately above.
31	3, 300-3, 310	Recovered 10 ft: Microfossils rare. Clay shale, medium-gray; excellent poker chip cleavage. Light-gray rather soft very calcareous silty laminae and partings; dip 4°-10°, average 7°.
32	3, 310-3, 320	Recovered 10 ft: Microfossils very rare. Clay shale as above; good cleavage; dip 8°.
33	3, 320-3, 330	Recovered 10 ft: Microfossils common. Clay shale as above. Dip 7°.
34	3, 330-3, 340	Recovered 10 ft: Microfossils common. Clay shale as above; silty partings common, but silty laminae rare; dip 7°.
35	3, 340-3, 350	Recovered 10 ft: Microfossils very rare. Clay shale, medium-gray, excellent poker chip cleavage; carbonaceous silty partings and rare slightly calcareous silty laminae.
----	3, 350-3, 530	Clay, medium-light to medium-gray; *Inoceramus* prisms at 3,360-3,370 ft, 3,380-3,390 ft, 3,400-3,450 ft, 3,470-3,480 ft, and 3,520-3,530 ft.
----	3, 530-3, 760	Clay, light to medium-gray; nearly every ditch sample through this interval contains 1 or 2 chips of medium-light-gray siltstone. *Inoceramus* prisms at 3,540-3,550 ft, 3,560-3,570 ft, and 3,620-3,760 ft. Top of Oumalik formation placed at 3,590 ft.
36	3, 760-3, 774	Recovered 14 ft: Microfossils abundant. Clay shale, medium-gray; good cleavage, but few silty partings and laminae. *Inoceramus* sp. fragments noted at 3,762 ft; dip 2°.

CORE ANALYSES

No sandstone was cored in this well. No tests for porosity, permeability, carbonate content, or cuts for oil were made. However, specific gravity determinations were made on clay shale samples from the Colville group. (See table following.) Unfortunately, no determinations were made in the Topagoruk formation below the unconformity where compaction might have given slightly higher readings.

Specific gravity determinations of clay shale samples, North Simpson test well 1

Core	Depth (feet)	Specific gravity
1	290-300	1. 89
2	490-498	1. 90
3	690-700	1. 89
4	890-900	1. 96
5	1, 190-1, 200	2. 00
6	1, 489-1, 497	2. 14
7	1, 790-1, 800	2. 13
8	2, 090-2, 100	2. 21
10	2, 400-2, 410	2. 15
12	2, 700-2, 710	2. 16

LOGISTICS

Transportation.—Approximately 1,100 tons of equipment and supplies were hauled to the North Simpson test well site by winter tractor train. During the summer the site was accessible by float-equipped aircraft using a nearby lake for landing purposes.

Housing and personnel.—The camp consisted of 19 wanigans utilized as follows: A geological and engineering office, a boiler house, a shop, a generator room, a messhall, a kitchen, 4 sleeping rooms, 2 utility rooms, a cement-mixing room, a cement storage room, an electric-logging room, an electrical-equipment room, an oil-field warehouse, a food warehouse, and a store.

One drilling foreman, a petroleum engineer, and a geologist constituted the supervisory personnel; 2 drillers, 2 derrickmen, 6 floormen, 2 firemen, 2 heavy-duty-equipment mechanics, and 1 oiler made up the rig crew. Camp personnel comprised 2 cooks, 1 cook's helper, 2 bulldozer operators, and 1 warehouseman and storekeeper. Carpenters, laborers, electricians, a cementer, and an electric-log operator constituted the temporary personnel sent out from Barrow camp as needed.

Vehicles and drilling equipment.—While the well was being drilled, 2 weasels, 1 swing crane, 1 small crane (cherry picker), and 2 bulldozers (D8 Caterpillar) were used.

The following equipment was used in drilling the hole by Arctic Contractors:

1	87-ft Ideco derrick with crown block, racking platform and finger.
1	Cardwell drawworks Model H skid mounted with controls, cathead and rotary drive assembly.
1	Caterpillar D-8800 power unit for drawworks.
1	Ideal rotary table, 17½- by 44-in.
2	Gardner-Denver FXO-FO mud pump, 7½- by 10-in.
2	Caterpillar D-13000 power unit for pump.
2	4-in. Marlow pump with Briggs-Stratton engine Model ZZR-6.
1	Mud tank, shop made, 125-bbl capacity.
1	Baash-Ross 100-ton traveling block with three 30-in. sheaves, grooved for 1-in. line.
1	Emsco Type AB-4 swivel.
1	Web Wilson 100-ton connector.
1	Kewanee No. 578 boiler, 32 hp.
1	Worthington 3- by 2-in. BF pump.

Fuel, water, and lubricant consumption.—Reports on the fuel, water, and lubricant consumption are incomplete. The following figures represent approximate totals only: 355½ barrels of diesel oil, 718 gallons of gasoline, 132,000 gallons of water, 114 pounds of grease, 125 pounds of thread lubricant, and 302 gallons of other lubricant.

DRILLING OPERATIONS

RIG FOUNDATION

The derrick and drawworks at North Simpson test well 1 were mounted on a steel substructure which was in turn set on a heavy sled having four runners, making the installation entirely portable as long as the ground was frozen. The pump platform, including the mud and water tanks, mud pumps and engines, was also portable, having four other tracks supporting its substructure.

DRILLING NOTES

The following drilling operations were reported by the petroleum engineer at the rig site.

Notes from drilling records

Depth (feet)	*Remarks*
0	Well spudded in on May 6, 1950.
109	Set casing: 13⅜-in. O. D. 54.5-lb seamless casing with 2 top joints (20 ft and 80 ft) jacketed with 16½-in., 42-lb welded slip-joint casing. Cemented at 109 ft with 80 sacks of Cal-Seal.
3,774	Hole abandoned June 3, 1950; full of drilling mud. 4-in. nipple welded on top of 13⅜-in. casing in celler. Opening through plate. Top of 4-in. nipple 1 ft above ground level. Although hole was left in condition to put in thermal cable, none was installed. During period of drilling, maximum outside temperature was 55° F on 22d of May, and minimum was 13° F on 10th of May.

DRILL AND CORE BITS

A total of 13 drilling bits (see pl. 36) was used in the drilling of North Simpson test well 1, including 5 sizes from 9⅝ inches to 22 inches in diameter. After reaming the 15½-inch hole to 17¼ inches for the surface conductor pipe, it was decided to further enlarge the hole to 22 inches. Below 110 feet only two drilling bit sizes were used—12¼-inch to 2,090 feet and 9⅝-inch to 3,760 feet. The bits gave good performance in these relatively soft formations. The teeth were worn down to a noticeable extent on one bit only. On the others, worn-out bearings necessitated replacement of the bits.

Six hard-formation core bits were used to core 338 feet. Total recovery was 276.5 feet or approximately 81.2 percent. All cores except the last were taken with a wire-line core barrel; the last was a conventional core.

DRILLING MUD

The well engineer, Gordon H. Oosting, reported (written communication) that—

mud control was relatively easy in drilling this hole, and no problems of any significance were encountered. A small amount of cement-cut mud, resulting from drilling out the surface conductor pipe, was dumped. Occasionally it was necessary to dump excess mud made by the formation penetrated. The natural clays from the formation did not impart adequate gel strength to the mud, so that Aquagel was added from time to time. The viscosity rose occasionally as the formation made mud, and this was controlled with pyro and quebracho.

The mud weight varied from 70 to 79 pounds per cubic foot and the viscosity from 35 to 53 Marsh funnel seconds. An attempt was made to keep the mud temperature as low as possible to prevent thawing of the permafrost, and the temperature ranged from 51°F at the top of the hole to 74°F at the final depth of 3,774 feet.

The mud [shale] shaker used previously with the Cardwell rig on South Barrow test well 4 was not used in drilling this hole. Though this caused occasional shut-downs for the purpose of cleaning the mud pits, the saving in time and difficulties eliminated by setting the derrick at a lower elevation more than compensated for the time lost in shut-downs.

The following table gives the drilling mud character-

Drilling-mud characteristics and additives, North Simpson test well 1

Depth (feet)	Weight (lb per cu ft)	Viscosity (Marsh funnel sec)	Filtration loss (cu cm per 30 min)	Drilling fluid temperature (°F)	Additives
0	----------	----------	----------	----------	11 sacks Aquagel used to spud.
125	71	35	----------	----------	65 lb tetrasodium pyrophosphate, 15 lb quebracho, 7 sacks Aquagel.
400	73	40	----------	----------	
530	70	53	83	54	
750	75	41	40	62	
1,000	76	48	30	68	
1,393	77	48	28	56	80 lb tetrasodium pyrophosphate, 80 lb quebracho, 24 sacks Aquagel.
1,590	75	45	30	54	
1,860	76	45	30	51	
2,070	76	47	35	56	
2,270	75	43	35	54	
2,490	75	50	30	60	
2,665	75	47	30	61	
2,800	76	47	25	65	2 sacks Baroid, 7 sacks Aquagel.
2,810	77	48	25	58	
2,987	78	47	20	57	
3,100	77	47	30	65	
3,250	78	45	30	65	
3,305	79	46	25	64	
3,365	78	40	20	69	No additives.
3,410	79	43	30	70	
3,450	79	45	30	70	
3,575	78	43	30	74	
3,720	78	43	30	74	
3,860	79	45	35	74	
3,875	80	45	35	74	

istics and additives. The total quantity of additives used is as follows: 49 sacks of Aquagel, 2 sacks of Baroid, 145 pounds of tetrasodium pyrophosphate, and 95 pounds of quebracho.

HOLE DEVIATION

Detailed record of the hole deviation may be found on plate 36. Two checks were made at 110 feet. The first was run in the 17½-inch hole; another was made when the hole was straightened and reamed to 22 inches. The deviation in North Simpson test well 1 was less than 1° above 2,300 feet. From there to 2,700 feet, it increased to 2°. Below 2,700 feet it decreased again to less than 1° at the total depth.

ELECTRIC LOGGING

Two Schlumberger electric logs were made. (See pl. 36.) Run 1 was made from 108 to 2,430 feet, and run 2 was made from 2,350 to 3,774 feet.

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