Test Well Grandstand Area Alaska

By FLORENCE M. ROBINSON

With Micropaleontologic Study of Grandstand Test Well 1, Northern Alaska *By* HARLAN R. BERGQUIST

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 WELL, GRANDSTAND AREA, ALASKA

By FLORENCE M. ROBINSON

ABSTRACT

Grandstand test well 1 was the southernmost test drilled by Arctic Contractors during the exploration of Naval Petroleum Reserve No. 4 in northern Alaska. It was drilled in 1952 on the Grandstand anticline about 30 miles south of Umiat to test the sandstone beds of Early Cretaceous age for the presence of petroleum.

It was found that the objective sandstone present on the outcrop at Tuktu Bluff to the south grades to siltstone and clay shale at this location on the Grandstand anticline and that the thousand feet of shallower sandstone (Grandstand and Chandler formations) penetrated has very low porosity and permeability. No oil or gas was found.

This report includes stratigraphic, paleontologic, logistic, and engineering data obtained in the drilling of the test. Much of the information is presented on a graphic log.

INTRODUCTION

Location: Lat 68°57′58″ N., long 151°55′02″ W.
Elevation: Ground, 645 feet; kelly bushing, 660 feet.
Spudded: May 1, 1952.
Completed: August 8, 1952; Dry and abandoned.
Total depth: 3,939 feet.

Grandstand test well 1 was drilled by Arctic Contractors under contract to the U. S. Navy as a part of the exploratory program in Naval Petroleum Reserve No. 4 in northern Alaska. The test was on the Grandstand anticline about 30 miles south-southeast of Umiat (see fig. 18), within the northern foothills of the Brooks Range. The structure was so named because the eastern end overlooks "Racetrack syncline."

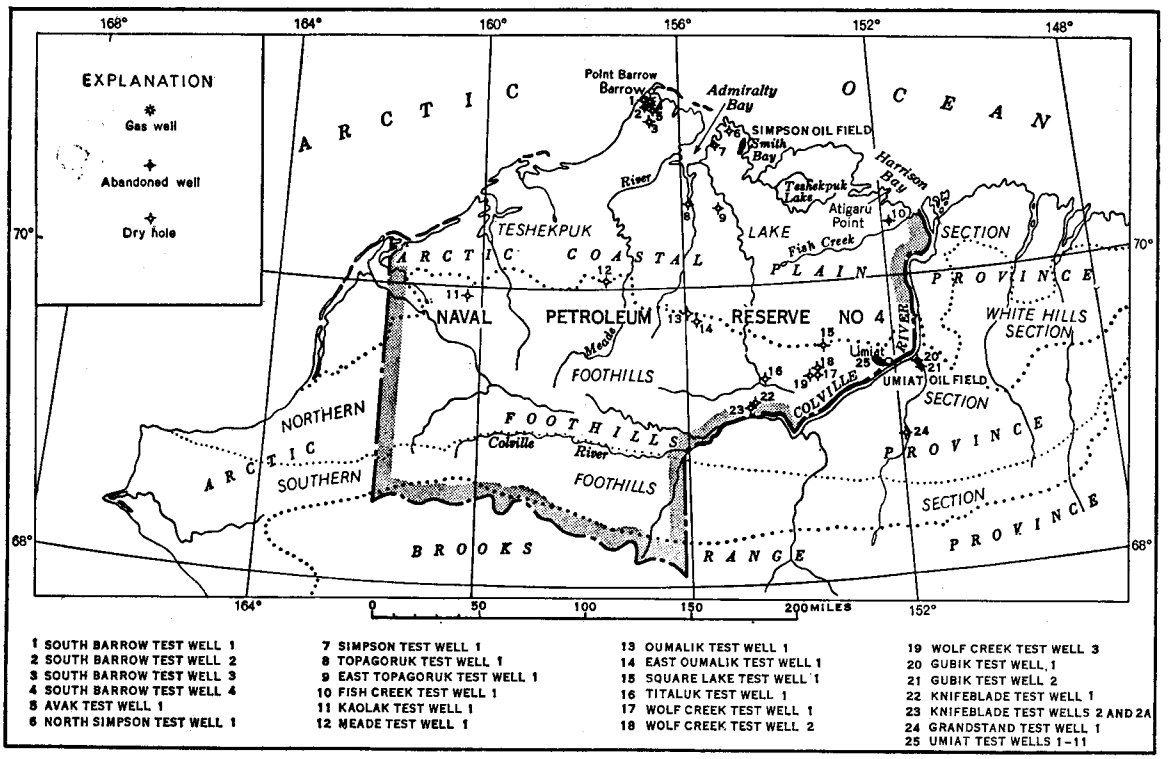

FIGURE 18.—Map of northern Alaska showing location of test wells and oil fields.

The drilling penetrated sandstone and shale of the Nanushuk group of Cretaceous age and was drilled to 3,939 feet and abandoned in shale of the Torok formation of Early Cretaceous age. No important shows of oil or gas were found in this well.

The latitude and longitude given for Grandstand test well 1 is subject to correction when final topographic surveys are completed.

ACKNOWLEDGMENTS

The engineering information contained herein is taken from Arctic Contractors' daily and final reports to the U. S. Navy. The Schlumberger Well Surveying Corp. ran the electric logs, and the U. S. Bureau of Mines made water and gas analyses. The author is grateful to the personnel of the above organizations for their cooperation and assistance.

Unless otherwise noted, the core and cutting analyses were made by the staff of the United States Geological Survey in Fairbanks, Alaska. Microfossil identifications and zonation were by Harlan R. Bergquist. The stratigraphic distribution of the microfossils in this and other test wells of northern Alaska will be presented by him in another chapter of this series. Megafossils were identified by Ralph W. Imlay, and heavy-mineral identifications were made by Robert H. Morris, both of the U. S. Geological Survey.

STRUCTURE

The Grandstand anticline was first recognized by a U. S. Geological Survey reconnaissance field party in the Chandler River area in 1945. The east end of this structural feature was seen by another Survey party on the Anaktuvuk River during the same summer. A detailed photogeologic study of the Grandstand anticline was made by the U. S. Geological Survey in late 1951, and the exploration department of Arctic Contractors examined the area briefly from the air. Grandstand test well 1 was authorized by the Navy, and drilling began in May 1952. During that summer, United Geophysical Co. party 144 ran a line (seismic line 4) across the anticline 4½ miles east of the Chandler River as a part of its regional north-south tie-in. Additional geological fieldwork was conducted in the vicinity of the well during the same summer. Robert L. Detterman has described the Grandstand anticline and nearby structual features (Detterman, written communication) based on detailed geological fieldwork.

The Grandstand anticline as mapped in the field by Detterman (written communication) and as shown on aerial photographs is about 52 miles long and about 5½ miles wide at the maximum. (See fig. 19.) The anticline exposes the Ninuluk formation, the Grandstand formation, the Killik tongue of the Chandler formation, the Grandstand and Chandler formations undifferentiated, and the Tuktu formation. Structurally, the highest part of the anticline is near the Chandler River, and another, but smaller, high is near the Anaktuvuk River. Total closure is probably in excess of 1,500 feet, of which 500 feet or more is on the high where the well was drilled. The rig site was on a low bench on the west side of the Chandler River at the base of a 600-foot-high east-trending ridge. (See pl. 20).

Evidence from outcrops (Detterman, written communication) suggests that the structure is complicated by high-angle reverse faults, low-angle thrust faults, and transverse faults. The seismic survey (line 4, party 144, see location of this line on fig. 19) showed that the beds 2,000–3,000 feet below the surface dip 10°–20° on the south flank and 10° on the north flank. In the test well, which is slightly north of the axis and about 7 miles west of the seismic line, the dip in the Grandstand and Chandler formations averages 6°, and in the Tuktu formation averages 5°. The dips in the Torok formation range from 5° to 35°. Slickensides were noted in some of the cores with steeper dips, and faults may be present.

PURPOSES OF THE TEST

The objectives of Grandstand test well 1 were as follows:

(1) To test for oil and gas in sandstones of the lower part of the Nanushuk group.

(2) To determine the reservoir characteristics of the sandstones of the Tuktu formation in the Grandstand area and to determine if there are shale beds that might serve as cap rock over such sands.

(3) To determine, by comparison with outcrop sections and the subsurface section at Umiat, the lateral extent of these sandstones, in order better to evaluate the other structures near the Grandstand anticline for the presence of petroleum.

(4) To determine more definitely the thickness of the lower part of the Nanushuk group and to determine if this part is within reach of the drill on other structural features in the area.

(5) To obtain paleontological data that would be helpful in correlating subsurface units in and near the Reserve.

The hole was dry. Sandstone was not well developed in the Tuktu formation, and reservoir rocks in the Grandstand formation which produced oil at Umiat (Collins, 1958) have very low permeability.

STRATIGRAPHY

Grandstand test well 1 penetrated alluvium from 20 to 110 feet, the Grandstand and Chandler formations

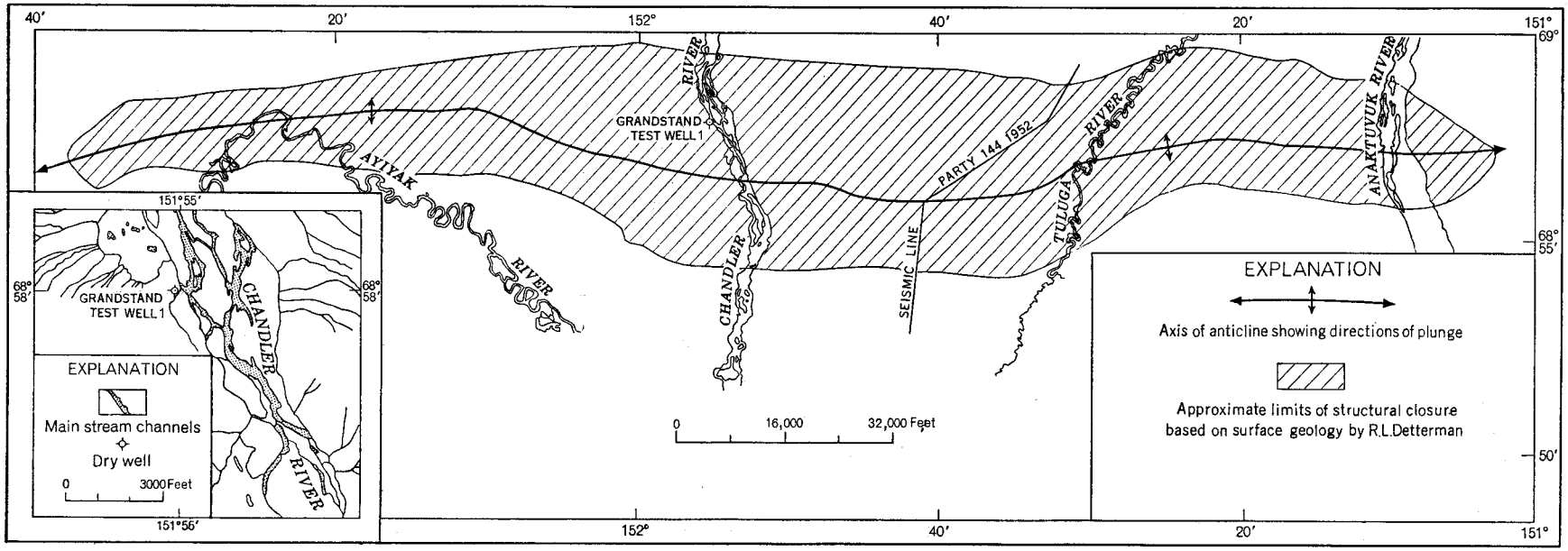

FIGURE 19.—Location of Grandstand test well 1 and its relation to closure on early Upper Cretaceous beds of the Grandstand anticline.

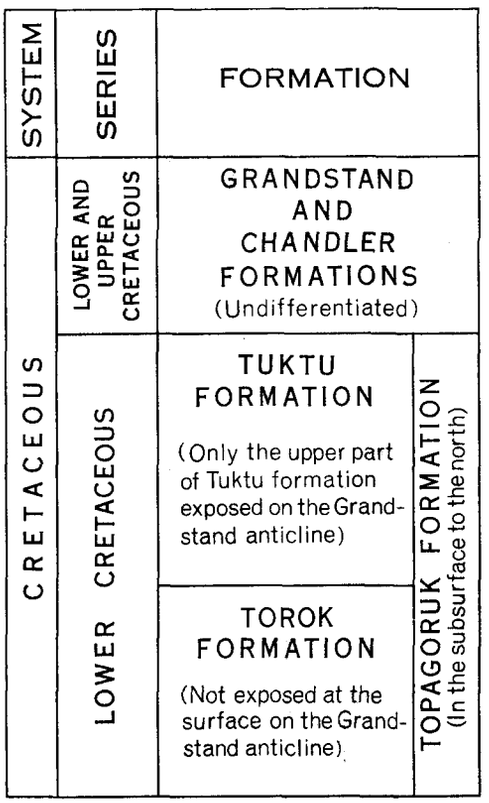

FIGURE 20.—Rocks of Cretaceous age penetrated by Grandstand test well 1.

undifferentiated from 110 to 1,070 feet, the Tuktu formation from 1,070 to 2,650 feet, and the Torok formation from 2,650 feet to the total depth at 3,939 feet (fig. 20).

DEPOSITS OF QUATERNARY AGE

ALLUVIUM

The uppermost 90 feet of material in the test well is unconsolidated sand and gravel, probably glacial deposits of Pleistocene age and river deposits of Recent age. The gravel is made up of subrounded black, brown, yellow, green, and red chert, white quartz granules and pebbles, angular chunks of very fine-grained to conglomeratic sandstone, and chunks of grayish-brown ironstone, medium-dark-gray and yellow quartzite, plus a few other rock fragments. Many of the sandstone pieces are yellowish gray, probably from surface weathering. Most of the sandstone chips are angular but may have been broken from larger rounded pebbles and boulders by the drilling.

In the sandy beds the grain size ranges from very fine sand to granules, but the sand is made up mostly of the larger sizes. It is composed of about 50 percent of white and clear quartz plus a large amount of variicolored chert, with black and brown chert predominant. No clay was noted in the well cuttings.

ROCKS OF CRETACEOUS AGE

GRANDSTAND AND CHANDLER FORMATIONS, UNDIFFERENTIATED

This well was drilled in an area where the marine Grandstand and nonmarine Chandler formations intertongue, but it is difficult to determine which part of the section is marine and which is not. In general, the rock from 120 to 1,070 feet resembles the Grandstand formation in the subsurface to the north but has a somewhat larger proportion of carbonaceous and coaly material at this location. Microfossils were found sparingly throughout the section except from 120 to 210 feet, which is barren and probably represents the nonmarine Chandler formation. The Grandstand formation was named by Robert L. Detterman from exposures found at the east end of Grandstand anticline near the Anaktuvuk River 18 miles east of the test well (Detterman, 1956).

About a third of the section between 120 and 1,070 feet is sandstone, and the remainder is clay shale containing sandy and silty beds. The sandstone is light gray, massive, medium soft to hard, and breaks easily parallel the bedding. The grains range in size from very fine to coarse and in shape are subangular to subrounded. They consist of 75–85 percent white and clear quartz; the rest is mostly rock fragments of dark chert, carbonaceous and clay ironstone particles, some white mica, a few rather soft white particles (weathered chert or feldspar?) and very rare pyrite.

The sandstone is noncalcareous and has an argillaceous matrix. As much as 5 percent of the matrix is sericite in the thin sandstone beds of the upper nonmarine part of the Grandstand and Chandler formations undifferentiated. The sandstones are relatively impermeable to air because of the argillaceous matrix and poor sorting. The highest reading obtained was 9.5 millidarcys, but this is questionable as the sample surface was irregular. (See table on pages 330–331.) Most of the plugs tested were impermeable or had a permeability of less than 1 millidarcy. The porosities of 112 samples tested range from 0.7 to 13.7 percent and average 4.2 percent.

The Grandstand and Chandler formations undifferentiated have only a small proportion of siltstone, but the clay shale contains many thin silty interbeds. The clay shale itself is medium light gray to medium dark gray and medium soft to medium hard and has fairly good bedding and fairly good cleavage parallel

to the bedding. It is silty in certain intervals and contains thin beds of hard light-gray siltstone. The clay shale in the upper 400 feet contains white mica or sericite.

Thin beds of coal and very dark-gray carbonaceous clay shale occur in minor amounts to a depth of about 800 feet. Some of these beds may be marginal marine as a few marine microfossils are associated with them, particularly below 600 feet. Scattered carbonaceous partings and plant fragments were noted in the clay shale. Clay ironstone nodules and laminae are present in both the shale and sandstone, but in general the carbonate content of the Grandstand and Chandler formations undifferentiated in this well is very low.

The base of the Grandstand and Chandler formations undifferentiated is placed at the bottom of the lowest thick sandstone beds.

TUKTU FORMATION

Detterman has traced the Tuktu formation from the type locality on the Chandler River at Tuktu Bluff, 16 miles south of the test well, to the Grandstand area, where it underlies the Grandstand and Chandler formations. The Tuktu formation at the type section as described by Detterman (1956, p. 235), however, consists almost entirely of sandstone and siltstone although the equivalent section from 1,070 to 2,650 feet in Grandstand test well 1 is about 75 percent clay shale and 25 percent sandstone and siltstone.

The clay shale in the test well is medium gray to medium dark gray and moderately hard, has poor cleavage, and is quite silty in part. Two inches of light-gray bentonitic clay shale was found in a core at 1,475 feet, and a few chips were found in a ditch sample from 1,490 feet.

The sandstone and siltstone are moderately hard and colored medium light gray to medium gray, mostly the latter. The grains range in size from silt to very fine sand, rarely fine. They are made up of about 80 percent white and clear quartz; the remainder is rock fragments, chert, rare carbonaceous particles, pyrite, and other minerals in an argillaceous matrix. There is some small-scale crossbedding. The rocks are impermeable to air, and the effective porosity averages 6 percent; they are essentially noncalcareous.

Coal and plant fossils are very rare. *Ditrupa* sp., a worm tube, *Inoceramus* sp. and other pelecypods, crinoid fragments, and abundant microfossils are present in the Tuktu formation.

The Tuktu formation in the subsurface on the Grandstand anticline corresponds to the upper part of the Topagoruk formation as identified farther north in the subsurface of Naval Petroleum Reserve No. 4. In the Grandstand well, the Tuktu formation, lithologically, more closely resembles the Topagoruk formation of the type section (Robinson, Rucker, and Bergquist, 1956, p. 229) than it does the Tuktu formation of the type section mentioned above. These rocks are designated Tuktu formation in this well only for continuity with the field geology.

TOROK FORMATION

The upper part of the Torok formation, which is equivalent to part of the Topagoruk formation of the subsurface to the north, was penetrated in this well from 2,650 to 3,939 feet, the total depth. Lithologically, there is no break between the Tuktu and Torok formations as found in this test well. The clay shale of the Torok formation is like that in the Tuktu above but has better cleavage. The microfossils, though rare and of few species, are of the same fauna as in the siltier Tuktu formation.

DESCRIPTION OF CORES AND CUTTINGS

The cores and cuttings were shipped from the test well to the Fairbanks laboratory where they were described. All cuttings were washed and dried, and all cores were allowed to dry at approximately room temperature before being described. Oil cuts were made and porosity-permeability plugs were taken before drying. The cutting samples were of good quality and relatively free from cavings. The term "trace" as used here is defined as less than 3 percent and mostly less than 1 percent. Clay ironstone is a sideritic, dense, and rather hard mudstone that generally effervesces very slowly in cold dilute hydrochloric acid. Colors were determined by comparison with the Rock color chart distributed by the National Research Council (Goddard and others, 1948). All depths were measured from the top of the kelly bushing.

DETAILED LITHOLOGIC DESCRIPTION

See plate 19 for a graphic representation of the lithology. Cuttings were not received for a few short intervals. In these places the lithology on plate 19 is based on the electric log.

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

Lithologic description

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

Core	Depth (feet)	Remarks
----	0–15	Height of kelly bushing above ground level.
----	15–19	Cellar.
----	19–30	Gravel and very fine to very coarse sand; contains fragments of subround black, brown, tan, yellow, green, and red chert granules and pebbles; numerous angular fragments of "tight" sandstone, most of which are medium to coarse grained and composed of about 60 percent white and clear quartz, remainder is dark-colored material; sandstone chunks are yellowish gray, probably from surficial weathering. Also present are chunks of grayish-brown ironstone, white quartz, and a few other rock fragments.
----	30–40	Sand, yellowish-gray, very fine-grained to granule-sized particles, noncalcareous; 50 percent white and clear quartz; remainder is varicolored chert but with black and brown most predominant, rare rock fragments.
----	40–50	No sample.
----	50–60	Sand, as above, very fine-grained to granule-sized particles but mostly very coarse sand and granule-sized particles; much brown and black chert, numerous pieces of sandstone.
----	60–110	Gravel and sand, contains chunks and pebbles of sandstone of various colors and composition. Sandstone is fine to very coarse grained (conglomeratic at 90–100 ft), light gray to medium gray and yellowish. Sandstone chips mostly angular but may have been broken from larger rounded pebbles or boulders. Gravel contains about 20 percent pebbles and granules of black, yellow, green, and white chert, also small amount of medium-dark-gray and yellow quartzite. Much loose sand present in all samples.
----	110–120	No sample. Top of Cretaceous rocks (Grandstand and Chandler formations undifferentiated) placed at 110 feet as based on the electric log.
----	120–140	Clay shale, medium-light-gray, rather sericitic; 20 percent light-gray siltstone in lower part.
----	140–150	Siltstone, light-gray.
----	150–160	Siltstone 50 percent, light-gray, and sandstone 40 percent, light-gray, fine- to medium-grained; composed of 70 percent white and clear quartz; remainder is dark minerals and coal particles; some coaly streaks; 10 percent medium-light-gray clay shale.
----	160–170	Clay shale, medium-gray.
----	170–180	Siltstone, medium-light-gray; trace of very fine sandstone.
----	180–220	Clay shale, medium- to medium-dark-gray; trace of carbonaceous material 180–190 ft. Silty at 210–220 ft.
----	220–227	No sample.
1	227–245	Recovered 17 ft: Microfossils common. Clay shale, medium- to medium-dark-gray, rather soft; has good cleavage; tends to break into small chips when dry; partings with dark-gray plant impressions and very rare thin coaly fragments; rare thin brownish-gray ironstone laminae. Shale contains irregular beds and laminae of medium-light-gray siltstone and very fine- to fine-grained sandstone; thickest sandstone layer, 1½ ft topping at 241 ft, is light gray, hard, "dirty," has irregular fracture, is composed of 65 percent of white and clear quartz, 30 percent of dark minerals, coal particles, and rock fragments, as much as 5 percent sericitic material, and some ironstone particles; noncalcareous; bedding irregular and dips variable probably because of crossbedding, but are generally 4°–6°. Effective porosity 2.5 percent, and air permeability 1.54 millidarcys at 242 ft.
----	245–320	Clay shale, medium- to medium-dark-gray; trace of coal and carbonaceous shale at 250–260 and 310–320 ft; trace of siltstone at 280–290 and 300–310 ft.
----	320–350	Clay shale and 10–30 percent light-gray siltstone; trace of coal at 340–350 ft.
----	350–364	Sandstone, light-gray, medium-grained, noncalcareous, rather soft; 85 percent white and clear quartz; remainder dark chert, carbonaceous particles and rock fragments; noncalcareous; trace of siltstone and clay shale.
2	364–369	Recovered 1 ft: Microfossils absent. Sandstone, light-gray, fine- to medium-grained, noncalcareous, hard, massive; grains subangular, 85 percent white and clear quartz; remainder mostly dark minerals, chert, rock and coal particles; trace of rather hard chalky white mineral—possibly feldspar or weathered chert; dip undetermined; no shows. In a sample from 364–369 ft, effective porosity 10.6 percent. Unable to cut permeability plug.
----	369–380	Sandstone as above, medium- to very rarely very coarse-grained.
----	380–410	Clay shale, medium-gray; some carbonaceous dark-gray at 400–410 ft; as much as 10 percent sandstone, as above.
----	410–413	No sample.

Lithologic description—Continued

Core	Depth (feet)	Remarks
3	413–429	Recovered 16 ft: Microfossils absent. 14 ft 6 in., interbedded siltstone (70 percent), and clay shale. Siltstone is medium light gray, hard, argillaceous, with poor or no cleavage, rather brittle; partings containing dark plant fragment impressions; rare coaly plant fragments; brownish-gray clay ironstone very rare; noncalcareous. Clay shale is medium-light to medium-gray. Some small-scale crossbedding in siltstone, general dip 4°–5°. 1 ft 6 in., sandstone as in core immediately below; some clay shale laminae and coaly partings.
4	429–448	Recovered 20 ft: Microfossils absent. 4 ft, sandstone, light-gray, fine-grained, hard massive; grains subangular to (rarely) subrounded; 80 percent white and clear quartz; remainder is rock fragments, coal particles and some dark chert and other minerals, small amount of sericite; noncalcareous. At 430 ft, effective porosity 0.7 percent, and sample is impermeable. 6 ft, clay shale, medium-light to medium-gray, grades to siltstone in some places; clay shale is medium soft thin-bedded brittle when dry; contains impressions of plant fragments; rare sandstone laminae. 2 ft 6 in., coal and very carbonaceous clay shale; dark-gray to black, shiny, soft, thin-bedded, very brittle; some clear yellow resinous material in coal. 7 ft 6 in., clay shale, medium- to medium-dark-gray, noncalcareous, thin-bedded, brittle, soft, silty; numerous dark-gray plant fragment impressions; dip 5°.
----	448–460	Sandstone 80 percent, light-gray, fine- to medium-grained; largely white and clear quartz; 20 percent medium-gray clay shale.
----	460–470	Clay shale, medium-gray; 5 percent light-gray siltstone.
----	470–480	Siltstone 50 percent light-gray, and 50 percent medium- to medium-dark-gray clay shale.
----	480–490	Clay shale 60 percent, siltstone 40 percent.
----	490–530	Clay shale, medium-gray; trace of slightly calcareous clay ironstone at 490–500 ft; trace of sandstone at 520–530 ft.
----	530–561	Sandstone, light-gray, fine- to medium-grained, noncalcareous; mostly white and white clear quartz; some dark minerals and coaly particles, sericite present; up to 40 percent medium-gray clay shale; some siltstone; trace of coal.
5	561–575	Recovered 7 ft: Microfossils absent. Interbedded clay shale 75 percent and sandstone and siltstone 25 percent; noncalcareous. Clay shale is medium gray, medium hard, with fair cleavage, noncalcareous. Sandstone and siltstone is light gray to medium light gray, hard, silty to fine grained; composed of 75 percent white and clear quartz; remainder is dark rock fragments, chert, carbonaceous and ironstone particles, white mica (sericite?) quite common; some lenticular beds of shale in the sandstone- numerous partings of black carbonaceous material; rare olive-gray clay ironstone laminae; very rare thin layers of coal; dip variable, 10°–16°.
----	575–580	No sample.
----	580–600	Clay shale, medium- to medium-dark-gray; trace of carbonaceous shale.
----	600–610	Sandstone 70 percent, light-gray, fine- to rarely medium-grained, noncalcareous; primarily white and clear quartz; some carbonaceous particles and dark minerals.
6	610–630	Recovered 19 ft: Microfossils very abundant. 14 ft, clay shale, medium-light- to medium-gray, noncalcareous, medium-hard, fair to good cleavage; contains numerous silty and a few sandy streaks; very small amount of swirly bedding; some crossbedding; dip varies between 4° and 11°; average dip about 6°. 5 ft, clay shale, medium-dark-gray, noncalcareous, moderately soft, thin-bedded, with good cleavage; a few small (as much as one-third inch in length) shell fragments found (*Lingula?* sp.).
----	630–730	Clay shale, medium-gray; trace of very fine-grained sandstone at 630–640, 680–690, and 700–720 ft; trace of light-gray siltstone at 630–640 and 710–730 ft; 5 percent, shiny black coal with blocky fracture at 640–650 ft; trace of coal and carbonaceous clay shale at 670–680, 690–700, and 720–730 ft.
----	730–733	No sample.
7	733–736	Recovered 3 ft: Microfossils very rare. Claystone, medium-dark-gray, hard, irregular fracturing; very small amount of siltstone.
----	736–770	Clay shale, medium- to dark-gray; these samples contaminated probably while setting casing at 730 ft.
----	770–791	Sandstone, light-gray, fine- to medium-grained; as in core below; up to 40 percent medium-gray clay shale.
8	791–809	Recovered 19 ft: Microfossils absent. Sandstone, medium-light-gray, fine

Lithologic description—Continued

Core	Depth (feet)	Remarks
		grained, hard, partly massive; grains subangular to subrounded; 75 percent white and clear quartz; remainder mostly rock particles, carbonaceous particles, dark chert, white mica, and pyrite; numerous beds as much as 3 in. thick of medium-dark-gray clay shale and some siltstone in upper 4 ft of recovery; very rare plant impressions and coal fragments, rare micaceous-carbonaceous partings; content of carbonate minerals 10.94 percent by weight at 808 ft, rest is essentially noncalcareous; dip 8°–11°; fleeting odor, very pale cut, and very pale-yellow residue from 803 ft and 805 ft. Of 13 samples tested from this core the average effective porosity was 4.22 percent, and air permeability was 0–<1 millidarcy.
9	809–824	Recovered 15 ft: Microfossils absent. Interbedded sandstone and siltstone 80 percent, and clay shale 20 percent. Sandstone and siltstone is medium light gray, hard, massive in part; some cleavage parallel bedding; silt to very fine grained; grains subangular to subrounded; mostly white and clear quartz. Clay shale is medium gray, medium hard, has fair cleavage, is gradational with siltstone; noncalcareous; dip 2°–7°. No odor, no cut, very pale yellow residue from 810 ft; no odor, no cut, and greasy stain from 820 ft. Of 3 samples tested, average effective porosity is 2.33 percent, and air permeability 0–<1 millidarcy (see p. 330).
10	824–843	Recovered 15 ft: Microfossils absent. 5 ft, interbedded medium-light-gray siltstone and medium-gray clay shale as in core immediately above, scattered sandy lenses. 10 ft, sandstone, light-gray, fine-grained, hard, massive, noncalcareous; cleaves approximately normal to sides of core; grains subangular to subrounded; 75 percent white and clear quartz; remainder is rock fragments, carbonaceous particles, brownish clay ironstone particles, some mica, and other minerals; rare silty streaks; two brownish-gray clay ironstone concretions less than one-half inch thick; very rare carbonaceous plant impressions with some pyrite; dip 8°. Fair oil odor, very pale cut, and very pale-yellow residue from 835 ft. Of 10 samples tested average effective porosity is

Lithologic description—Continued

Core	Depth (feet)	Remarks
		4.58 percent, and all samples are impermeable or have an air permeability of <1 millidarcy.
11	843–862	Recovered 15 ft: Microfossils absent. Sandstone, light-gray; massive as in lower interval of core 10 above; fine grained with scattered medium grains in lower half of core; noncalcareous. Two feet from bottom of recovery is 10-in. layer of hard medium-dark-brownish-gray clay ironstone which has a few low-angle slickensided surfaces; dip undetermined; fair odor, very pale-straw cut, pale-yellow residue from 844 ft; no odor, no cut, very pale-yellow residue from 857 ft. Of 13 samples tested average effective porosity is 3.26 percent, and all samples are impermeable.
12	862–882	Recovered 4 ft: Microfossils absent. Sandstone, light-gray, fine- to medium-grained, noncalcareous, medium-soft, salt-and-pepper; breaks easily approximately parallel to bedding; grains mostly subangular; 75–80 percent white and clear quartz; remainder is mostly dark-colored chert, rock fragments, some rather soft opaque white particles (weathered chert or feldspar?) and rarely other minerals; not very porous to drop test; dip difficult to determine—probably less than 5°; fair oil odor, straw-colored cut and pale-yellow residue from middle of recovery. Two plugs taken at 862–882 ft. Upper had effective porosity of 11.15 percent and air permeability of <1 millidarcy. Lower had 11.40 percent porosity and 9.5 millidarcys permeability. Latter permeability plug had irregular surface.
13	882–899	Recovered 11 ft: Microfossils absent. Sandstone as in core above, fine- to medium-grained, noncalcareous; rare coarse grains; lowest 2 ft of recovery fine grained and slightly harder than upper section; dip about 2°; fair oil odor, straw-colored cut; and pale-yellow residue from 885 ft. Effective porosity of samples from 883 and 884 ft is 13.70 and 12.54 percent, respectively. Samples unsuitable for air permeability test. Effective porosity at 898 ft is 8.22 percent, and the sample is impermeable.
14	899–919	Recovered 14 ft: Microfossils absent. Sandstone, light-gray to medium-light-gray, noncalcareous, hard, massive, with irregular fracture, fine grained with scattered medium grains, sub-

Lithologic description—Continued

Core	Depth (feet)	Remarks
		angular to subrounded; 75 percent white and clear quartz; remainder is dark chert, rock fragments, rare carbonaceous particles, and mica; dip 5° or less; fairly good oil odor, yellow cut, and yellow residue from 899 ft, no odor or cut but yellowish stain from 916 ft. Effective porosity of 14 samples from this core varies from 9.02 to 2.64 percent decreasing gradually from top to bottom. Samples impermeable except uppermost which was unsuitable to test.
15	919–939	Recovered 19 ft: Microfossils absent. Sandstone as in core 14 above, fine-grained, massive, hard; 80 percent white and clear quartz; rare yellowish-brown clay ironstone nodules; content of carbonate minerals 18.6 percent by weight at 923 ft and 20.62 percent at 929 ft; dip 3°–8°; no odor, no cut, yellowish stain in evaporating dish at 926 ft; faint oil odor; pale-straw-colored cut and pale-yellow residue at 932 ft. Of 20 samples tested for effective porosity, average is 3.55 percent, and all but one is impermeable. Sample at 920 ft has a permeability of 1 millidarcy.
16	939–958	Recovered 9 ft: Microfossils absent. Sandstone as above, very fine- to fine-grained, noncalcareous, hard, massive; 85 percent white and clear quartz, argillaceous matrix; grades to silty laminae; rare small ironstone nodules; rare carbonaceous and pyritic plant impressions; dip 6°; no odor, no cut, yellowish stain at 941 and 953 ft. Of 19 samples tested, average effective porosity is 2.55 percent; all samples impermeable.
	958–959	No sample.
17	959–979	Recovered 20 ft: Microfossils absent. 10 ft, interbedded fine- to very fine-grained sandstone and siltstone; light- to medium-light-gray, hard; some irregular fracture; scattered irregular clay partings; also rare carbonaceous and very rare coaly partings; rare brownish-gray clay ironstone laminae; noncalcareous; dip 4°; no cut, no odor, yellowish stain in evaporating dish from 962 ft. At 964 ft effective porosity is 5.66 percent; at 969 ft 5.65 percent. Both samples impermeable to air. 10 ft, interbedded siltstone and clay shale; siltstone is medium light gray and hard; contains a few streaks of

Lithologic description—Continued

Core	Depth (feet)	Remarks
		sandstone; cleavage fair where present. Clay shale is medium to medium dark gray, noncalcareous, moderately hard, and has poor cleavage and very rare slightly carbonaceous partings; dip 5°.
18	979–998	Recovered 20 ft: Microfossils common. Clay shale and claystone, medium- to medium-dark-gray, hard; poor cleavage where present; irregular fracture; grades to siltstone in places, micaceous; contains rare carbonaceous-coaly plant impressions, *Lingula* sp. and *Ditrupa* sp. at 979 ft; noncarcareous; dip 7°.
	998–1, 020	Clay shale 80–90 percent, medium-dark-gray; some medium-grained sandstone; *Ditrupa* sp. at 1,010–20 ft.
----	1, 020–1, 030	Sandstone, light-gray, fine-grained; very slightly calcareous; grains subangular; 85 percent white and clear quartz; remainder is coal particles and rock fragments; some white mica; 10 percent medium-dark-gray clay shale.
----	1, 030–1, 035	No sample.
19	1, 035–1, 055	Recovered 20 ft: Microfossils absent. 2 ft 8 in., siltstone, light-olive-gray, very calcareous, very hard, massive; has irregular fracture. Content of carbonate minerals 39.5 percent at 1,036 ft. 17 ft 4 in., sandstone, medium-light-gray, very fine- to fine-grained, hard; massive; subangular to rarely subrounded grains 85 percent white and clear quartz; remainder is mostly rock fragments and dark chert, fairly common white mica, rare silty laminae; dip 3°; no shows in laboratory but cores 19 and 20 had slight cuts at well site. Content of carbonate minerals 10.98 percent at 1,039 ft. Effective porosity of 4 samples tested at 1,039 ft. averages 3.71 percent. Samples impermeable.
20	1, 055–1, 075	Recovered 20 ft: Microfossils absent. Sandstone and siltstone, medium-light-gray, hard; massive for the most part: sandstone is very fine grained; constituents as in core above; gradational with the siltstone; very rare small brownish-gray clay ironstone nodules; rare carbonaceous and argillaceous partings; noncalcareous; dip 4°–6°; no shows. Of the 5 samples tested, average effective porosity is 4.00 percent, and all samples are impermeable. Top of Tuktu formation is placed at 1,070 ft, which is approximately the base of the sandstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
21	1,075–1,095	Recovered 19 ft: Microfossils absent. Interbedded siltstone (65 percent) and clay shale; small amount of sandstone; siltstone and sandstone are medium light gray to medium gray, argillaceous, hard and have irregular fractures and a very small amount of small-scale crossbedding. Clay shale is medium dark gray, noncalcareous micaceous, moderately hard and occurs in well-defined laminae or is gradational with the siltstone; a few steep-angled slickensides at 1,089 ft; dip 7°; no shows. At 1,076 ft effective porosity is 3.12 percent, and sample is impermeable.
----	1,095–1,103	Siltstone and very fine-grained sandstone, medium-gray; darker color than ordinarily found in these siltstones and sandstones comes from larger amounts of carbonaceous material; noncalcareous.
22	1,103–1,123	Recovered 20 ft: Microfossils absent. Clay shale, medium- to medium-dark-gray, very silty, hard; in some places grades to medium-light-gray siltstone; fair to poor cleavage; partings with small black carbonaceous plant impressions; noncalcareous; dip 3°.
----	1,123–1,269	Clay shale, medium- to medium-dark-gray, primarily the latter; trace of siltstone at 1,160–1,190 and 1,220–1,230 ft; trace of fine-grained sandstone at 1,138–1,145 ft. *Ditrupa* sp. 1,160–1,170 ft.
23	1,269–1,289	Recovered 19 ft: Microfossils common. Clay shale and claystone, medium-gray to medium-dark-gray, medium-hard; noncalcareous; quite silty in spots; has poor cleavage, streaks of siltstone, and some small pelecypods (*Psilomya?* sp., *Arctica?* sp., *Modiolus?* sp. and *Panope?* sp.) found throughout; dip 2°.
----	1,289–1,330	Clay shale, medium-dark-gray; trace of medium-light-gray siltstone; *Ditrupa* sp. at 1,290–1,300 ft.
----	1,330–1,337	No sample.
24	1,337–1,357	Recovered 18 ft: Microfossils rare. 9 ft, claystone and clay shale, medium- to medium-dark-gray moderately hard noncalcareous, very silty; some streaks of medium-light-gray siltstone; cleavage poor or absent; pelecypods found at 1,338 and 1,342 ft; crinoid stem ossicles at 1,340 ft; *Ditrupa* sp. present. 9 ft, sandstone and siltstone, light- to medium-light-gray, fine-grained, medium-hard; contains clayey intercalations; grains subangular to subrounded; 80 percent white and clear quartz; remainder is rock fragments, chert, rare carbonaceous particles, pyrite and other minerals; 1 yellowish-gray slightly calcareous sideritic layer at 1,350 ft; mostly noncalcareous; dip about 4°; small amount of crossbedding; no shows. At depth of 1,351 ft, effective porosity is 3.75 percent; sample impermeable.
25	1,357–1,378	Recovered 20 ft: Microfossils rare. Siltstone (with a few streaks of sandstone) 75 percent, and medium-hard clay shale, with poor cleavage in places. Siltstone is medium light gray, and clay shale is medium dark gray; all gradations of color and texture exist; 45° slickensides at 1,371 ft; layers 1/16 to 1/8 in. thick of shiny black coal at 1,358½ and 1,372½ ft; noncalcareous except for lower 3 ft, which is moderately calcareous; dip 4°; no shows.
26	1,378–1,398	Recovered 17 ft: Microfossils absent. Silty sandstone grading to sandy siltstone; finer material predominantly in lower part of core, medium light gray, hard and has fairly good cleavage parallel partings; a 1-in. clay ironstone layer at 1,387 ft; noncalcareous; dip 5°–10°; no shows. Average effective porosity of 3 samples tested is 6.08 percent; all samples impermeable.
----	1,398–1,408	Sandstone and siltstone as in core above.
27	1,408–1,422	Recovered 14 ft: Microfossils common. Clay shale, medium- to medium-dark-gray, noncalcareous, slightly silty, medium-hard; fair to poor cleavage; 45° slickensides at 1,409, 1,412, 1,413, and 1,417 ft; also some nearly horizontal slippage at 1,412 and 1,413 ft, white coatings on a few of the fault planes, very rare plant fragment impressions; *Ditrupa* sp. present; a pyrite-replaced *Inoceramus* at 1,417 ft; also *Entolium* sp. at 1,417 ft.
----	1,422–1,430	Clay shale, medium-gray, silty.
----	1,430–1,440	Siltstone, medium-light-gray; trace of very fine-grained sandstone; trace of clay shale.
----	1,440–1,460	Clay shale, medium-gray, 30 percent of very fine-grained, medium-light-gray sandstone and siltstone.
	1,460–1,469	No sample.
28	1,469–1,487	Recovered 17 ft: Microfossils common. Clay shale and claystone, medium- to medium-dark-gray, slightly silty; moderately hard but slightly softer than core 28; poor or no cleavage; irregular fracture. At 1,475½ ft is a little more than 2 in. of soft, waxy, light-gray

Lithologic description—Continued

Core	Depth (feet)	Remarks
		bentonitic shale; 2 inches below bentonitic shale is slickensided plane coated with white aragonite; essentially horizontal slickensides at 1,479, 1,481, and 1,482 ft; *Thracia*? sp. at 1,475 ft; slightly to moderately calcareous in the upper 7 ft of recovery; noncalcareous elsewhere; dip 4°–12°.
----	1, 487–1, 490	Siltstone 60 percent, medium-light-gray; trace of sandstone; trace of medium-dark-gray clay shale.
----	1, 490–1, 540	Clay shale, medium-dark-gray; trace of light-gray bentonitic shale 1,490–1,500 ft; *Inoceramus* sp. 1,500–1,510 and 1,530–1,540 ft, *Ditrupa* sp. 1,530–1,540 ft.
----	1, 540–1, 560	Siltstone 50–80 percent, medium-light-gray, also medium-dark-gray clay shale and trace of very fine-grained sandstone.
----	1, 560–1, 600	Clay shale, medium-dark-gray; trace to 25 percent siltstone; *Ditrupa* sp. at 1,570–1,580 ft.
29	1, 600–1, 620	Recovered 20 ft: Microfossils common. Clay shale, medium-dark-gray, medium-hard, silty and slightly sandy in some places; has poor cleavage. Fifteen percent is medium-light-gray medium-hard siltstone, with fair to good cleavage; shows small amount of crossbedding, *Thracia kissoumi* McLearn and *Psilomya*? sp. at 1,606 ft, *Inoceramus* sp. at 1,607 ft, and fragment of ammonite *Cleoniceras*? sp. at 1,600 ft; mostly noncalcareous; some of siltstone near base is slightly calcareous; dip 5°–8°. *Ditrupa* sp. in microfossil cut.
----	1, 620–1, 630	Clay shale, medium-gray, silty.
----	1, 630–1, 640	No sample.
----	1, 640–1, 740	Clay shale, medium- to medium-dark-gray, primarily the latter; trace of siltstone at 1,660–1,670 ft; *Inoceramus* sp. and *Ditrupa* sp. at 1,660–1,670 ft.
----	1, 740–1, 751	Sandstone, medium-light-gray, very fine- to fine-grained, slightly calcareous; grains subangular to subrounded, mostly white and clear quartz, also carbonaceous particles, rock fragments.
30	1, 751–1, 767	Recovered 16 ft: Microfossils common. Clay shale and claystone, medium- to medium-dark-gray, silty noncalcareous, moderately hard; poor or no cleavage; grades in places to siltstone, a few slickensides nearly parallel bedding at 1,761 ft have white aragonitic coating; *Ditrupa* sp. and a pelecypod found at 1,752 ft. Echinoid spines in microfossil cut.
----	1, 767–1, 780	Clay shale 60 percent, medium-gray, and 40 percent medium-light-gray siltstone.
----	1, 780–1, 790	Clay shale, medium-gray, very silty.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	1, 790–1, 810	Clay shale, medium-gray; medium-ligh gray siltstone; and a little very fine-grained sandstone.
----	1, 810–1, 820	Clay shale, medium- to medium-dark-gray; slickensides on one chip; also 10 percent medium-light-gray stiltstone.
----	1, 820–1, 830	Clay shale, medium- to medium-dark-gray; trace of very fine-grained sandstone.
----	1, 830–1, 835	Sandstone, medium-light-gray, very fine- to fine-grained (as in core below), noncalcareous; 10 percent medium-dark-gray clay shale.
31	1, 835–1, 855	Recovered 10 ft: microfossils common. 3 ft 10 in., siltstone and sandstone, medium-light-gray to medium-gray, noncalcareous to very slightly calcareous, silt to very fine sand, hard; 85 percent white and clear quartz; remainder is rock fragments, dark chert and pyrite; argillaceous intercalations; dips low, some up to 10°, which may be crossbedding; no shows. At 1,836 ft effective porosity is 7.68 percent, and sample is impermeable. 6 ft 2 in., claystone, medium-gray, very silty, noncalcareous, no cleavage; some vertical fracture; *Ditrupa* sp. present.
----	1, 855–1, 860	Clay shale, medium-dark-gray, 30 percent of siltstone and very fine-grained sandstone.
----	1, 860–1, 880	Siltstone, medium-light-gray; trace of very fine-grained sandstone, also medium-dark-gray clay shale.
----	1, 880–1, 890	Clay shale, grading through siltstone to very fine-grained sandstone, medium-light- to medium-dark-gray.
----	1, 890 1, 900	Siltstone 80 percent, grading to sandstone and clay shale, medium light gray to medium dark gray.
----	1, 900–1, 910	Clay shale, medium-dark-gray, and medium-light-gray siltstone. *Ditrupa* sp.
----	1, 910–1, 923	Siltstone 90 percent; trace of very fine-grained sandstone and clay shale.
32	1, 923–1, 941	Recovered 17 ft: Microfossils common. 7 ft clay shale, medium-dark-gray; poor to fair cleavage; scattered medium-light- to medium-gray streaks of siltstone; one pyrite nodule; *Solecurtus* n. sp. at 1,926 ft. 10 ft siltstone, medium-light- to medium-gray, hard, noncalcareous; cleavage good where present; interbedded with about 15 percent of medium-dark-gray clay shale as above; noncalcareous; pelecypod impression at 1,926 ft; dip 4°; no shows in laboratory but well geologist reports very pale cuts in

Lithologic description—Continued

Core	Depth (feet)	Remarks
		cores 32 and 33. *Ditrupa* sp. in microfossil cut.
33	1, 941–1, 957	Recovered 16 ft: Microfossils rare. Interbedded siltstone 70 percent and clay shale 30 percent; all gradations of each; medium-light- to medium-dark-gray, noncalcareous, moderately hard, with fair cleavage and small amount of crossbedding; dip 4°; no shows. *Ditrupa* sp. in microfossil cut.
34	1, 957–1, 971	Recovered 7 ft: Microfossils common. Clay shale and claystone, medium- to medium-dark-gray, noncalcareous, hard, with poor cleavage, numerous silty streaks, rare dark carbonaceous plant impressions, some very small scale crossbedding in silty streaks; dip 4°.
----	1, 971–1, 990	Siltstone, medium-light- to medium-gray, very argillaceous; trace of very fine-grained sandstone.
----	1, 990–2, 000	Sandstone and siltstone 80 percent, very fine-grained with one fine-grained chip, noncalcareous; sand is almost entirely white and clear quartz.
35	2, 000–2, 017	Recovered 17 ft: Microfossils rare. 4 ft, siltstone, medium-light-gray, noncalcareous; fair to good cleavage; dip 4°. Effective porosity at 2,000 ft is 6.23 percent, and sample is impermeable. 13 ft, clay shale, medium- to medium-dark-gray, noncalcareous, moderately hard; numerous silty streaks, a few "worm tubes"—flattened tubelike objects ⅛–1/16 in. in diameter which extend through core; seem to be lined with lighter-colored silty material. These tubelike impressions have also been noted in cores above. They somewhat resemble *Ditrupa* in cross-section; however, they are generally larger, have walls made of different materials and are simpler structurally. *Thracia kissoumi* McLearn found at 2,017 ft.
----	2, 017–2, 030	Clay shale, medium-dark-gray; 30 percent medium-light-gray siltstone; one chip with slickensides; trace of pyrite.
----	2, 030–2, 080	Clay shale, medium-dark-gray; trace of siltstone at 2,040–2,050 and 2,060–2,070 ft; *Ditrupa* sp. at 2,030–2,080 ft.
----	2, 080–2, 090	Clay shale 50 percent, medium- to medium-dark-gray, and 50 percent medium-light-gray noncalcareous siltstone; *Ditrupa* sp.
----	2, 090–2, 100	Siltstone 80 percent, medium-light-gray; and medium-gray clay shale.
----	2, 100–2, 110	Clay shale, medium-gray; 10 percent siltstone.
----	2, 110–2, 120	No sample.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	2, 120–2, 150	Clay shale, medium- to medium-dark-gray; trace to 10 percent siltstone.
36	2, 150–2, 170,	Recovered 12 ft: Microfossils absent. 8 ft, sandstone, light- to medium-light-gray, very silty, noncalcareous; good cleavage parallel bedding or no cleavage; grain size, silty to very fine grained, fine grained in part; grains subangular to subrounded, 85 percent white and clear quartz; remainder is rock fragments and dark chert; dip 4°–8°; no shows in laboratory but well geologist reported very pale cuts in cores 35 and 36. At 2,155 ft, effective porosity is 9.08 percent, and rock is impermeable. 4 ft, siltstone, medium-light-gray, hard; good cleavage; carbonaceous and micaceous partings; rare clay shale laminae; very small amount of small-scale crossbedding; dip 4°–8°.
----	2, 170–2, 190	Sandstone and siltstone 80 percent, light-gray, as in core above, also medium-dark- to dark-gray clay shale.
----	2, 190–2, 203	Siltstone, medium-light- to medium-gray, very argillaceous; 10 percent clay shale.
37	2, 203–2, 215	Recovered 10 ft: Microfossils common. Siltstone and silty shale, medium-light-gray and medium-gray, noncalcareous, moderately hard; poor to good cleavage; numerous thin layers of medium-dark-gray clay shale; small amount of crossbedding; *Inoceramus* sp. at 2,210 ft; dip 2°; no shows, well geologist reports very slight fluorescence.
----	2, 215–2, 220	Sandstone, light-gray, hard, very fine-grained, noncalcareous, "dirty"; grains subangular to subrounded; 80 percent white and clear quartz, also carbonaceous particles, rock fragments, some mica; some siltstone and medium-dark-gray clay shale.
----	2, 220–2, 240	Siltstone, light- to medium-light-gray; trace of very fine-grained sandstone; some silty clay shale.
----	2, 240–2, 280	Clay shale 50–70 percent, medium- to medium-dark-gray; trace of siltstone and sandstone.
----	2, 280–2, 290	Sandstone, light-gray, very fine-grained; grains subangular and some subround; 80 percent white and clear quartz, also rock fragments, carbonaceous particles, argillaceous cement; 5 percent medium-dark-gray clay shale.
----	2, 290–2, 310	Siltstone 50–90 percent, medium-light- to medium-gray; and medium-dark-gray clay shale.
----	2, 310–2, 350	Clay shale 70–90 percent, medium- to medium-dark-gray; and medium-light-gray siltstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	2, 350–2, 360	Siltstone, light- to medium-light-gray; 10 percent medium-dark-gray clay shale.
----	2, 360–2, 373	Clay shale, medium- to dark-gray; silty in part.
38	2, 373–2, 386	No recovery.
----	2, 386–2, 408	Clay shale, medium-dark-gray; 10–15 percent medium-light-gray siltstone at 2,386–2, 400 ft; 5 percent very fine-grained light-gray noncalcareous sandstone.
39	2, 408–2, 413	No recovery.
40	2, 413–2, 424	Recovered 10 ft: Microfossils rare. Clay shale, medium-dark-gray, noncalcareous, moderately hard, slightly micaceous, with fair cleavage, rare carbonaceous plant fragments, very rare slightly silty streaks; *Yoldia kissoumi* McLearn was found at 2,413 ft and *Thracia*? sp. at 2,420 ft; tiny crinoid ossicles present; dip 5°.
----	2, 424–2, 429	No sample.
----	2, 429–2, 450	Clay shale, medium-gray; trace of very fine-grained sandstone and siltstone.
----	2, 450–2, 460	Clay shale 60 percent, medium- to medium-dark-gray; 40 percent siltstone and light- to medium-light-gray noncalcareous very fine-grained sandstone.
----	2, 460–2, 467	No sample.
41	2, 467–2, 480	Recovered 9 ft: Microfossils absent. Siltsone and very fine-grained sandstone, medium-light-gray, slightly soft and friable to very hard, excellent cleavage where present; sand is largely white and clear quartz, also rock particles, coaly particles, and micaceous material present; upper 6 ft noncalcareous, but lower 3 ft moderately calcareous, harder, and have an olive cast—possibly because of sideritic cement. One light-olive-gray clay ironstone lens at 2,478 ft; dip 5°; no shows. At 2,471 ft effective porosity is 7.3 percent, and rock is impermeable.
42	2, 480–2, 494	Recovered 14 ft: Microfossils very rare. Siltstone, medium-light-gray, hard, with poor cleavage parallel bedding where present; some very fine-grained sandstone streaks, numerous shaly intercalations; upper 2 ft moderately calcareous, and remainder noncalcareous; dip 2°–3°; no shows. At 2,484 ft effective porosity is 5.02 percent, and rock is impermeable.
43	2, 494–2, 513	Recovered 10 ft: Microfossils very rare. Siltstone, as above, with poor to excellent cleavage, rare carbonaceous partings; noncalcareous except moderately calcareous in upper 1½ ft; dip 5°; no shows. At 2,512 ft effective porosity is 3.55 percent, and air permeability

Lithologic description—Continued

Core	Depth (feet)	Remarks
		approximately 15 millidarcys. However, the plug was cracked, and the permeability measurement is probably too high.
----	2, 513–2, 520	Siltstone 60 percent, medium-light-gray; and 20 percent light-gray very fine-grained noncalcareous sandstone; 10 percent medium-dark-gray clay shale.
----	2, 520–2, 530	Sandstone, light-gray, very fine-grained, noncalcareous, "dirty"; subangular to subrounded grains; 80 percent white and clear quartz; remainder mostly rock fragments, dark chert, and carbonaceous particles; trace of pyrite; argillaceous matrix, 5 percent medium-dark-gray clay shale.
----	2, 530–2, 540	Sandstone and siltstone, light- to medium-light-gray; 20 percent medium-dark-gray clay shale.
----	2, 540–2, 560	Siltstone, trace of sandstone, 20–30 percent medium-gray clay shale, trace of light-gray bentonitic shale 2,540–2,550 ft.
----	2, 560–2, 580	Clay shale 60–90 percent, medium- to medium-dark-gray; remainder is sandy siltstone.
----	2, 580–2, 590	Sandstone 60 percent, light-gray, very fine-grained; grades to siltstone; 40 percent medium-dark-gray clay shale.
----	2, 590–2, 620	Clay shale, medium-dark-gray; 10 percent siltstone.
----	2, 620–2, 680	Siltstone, light- to medium-light-gray; up to 50 percent medium-dark-gray clay shale; trace of sandstone at 2,620–2,640 ft. Top of Torok formation placed at 2,650 ft—there is no appreciable lithologic break between the Tuktu and Torok formations.
----	2, 680–2, 690	Clay shale, medium-dark-gray; 10 percent siltstone.
----	2, 690–2, 694	No sample.
44	2, 694–2, 712	Recovered 18 ft: Microfossils rare. Clay shale and claystone, medium-gray, very slightly silty, moderately hard; poor cleavage; very rare irregular silty laminae; very rare small light-olive-gray clay ironstone nodules; noncalcareous except for ironstone nodules which are moderately calcareous; dip 5°–8°.
----	2, 712–2, 760	Clay shale, medium- to medium-dark-gray; trace of siltstone.
----	2, 760–2, 780	Clay shale, medium-dark-gray; 20–40 percent light-gray siltstone; trace of sandstone, slightly to moderately calcareous.
----	2, 780–2, 790	Clay shale, medium- to medium-dark-gray; 5 percent siltstone.
----	2, 790–2, 850	Clay shale, medium- to medium-dark-gray; 5–30 percent medium-light-gray noncalcareous siltstone.

Lithologic description—Continued

Core	Depth (feet)	Remarks
----	2, 850–2, 870	Clay shale, medium- to medium-dark-gray; trace of siltstone.
----	2, 870–2, 880	Clay shale, 5 percent medium light gray siltstone and very fine-grained sandstone.
----	2, 880–2, 926	Clay shale, medium- to medium-light-gray; trace of siltstone; one chip with slickensides at 2,900–2,910 ft.
45	2, 926–2, 946	Recovered 20 ft: Microfossils rare. Clay shale, medium-gray, noncalcareous, medium-hard; good cleavage; numerous medium-light-gray silty partings but no thick beds; a few low-angle slickenside surfaces at 2,940 ft; dip 20°–28°.
----	2, 946–3, 170	Clay shale, medium- to medium-dark-gray (mostly the latter); traces of medium-light-gray siltstone throughout; trace of very fine-grained sandstone 3,010–3,020, 3,120–3,130, and 3,140–3,150 ft; one chip with slickensides in each of the following samples: 2,980–2,990, 3,000–3,010, and 3,060–3,070 ft.
46	3, 170–3, 190	Recovered 19 ft 6 in.: Microfossils absent. Clay shale, medium-gray, noncalcareous, medium-hard; good to excellent cleavage; rock tends to fracture at 75° angle. Medium-light-gray silty partings and laminae; also numerous tiny (up to one-half inch long, one thirty-second inch wide) vermicular clay shale inclusions in upper 5 ft; dip 8°.
----	3, 190–3, 360	Clay shale, medium- to medium-dark-gray (mostly the latter); some dark-gray clay shale 3,340–3,350 ft; traces of medium-light-gray siltstone and a very fine-grained sandstone.
----	3, 360–3, 364	No sample.
47	3, 364–3, 377	Recovered 13 ft: Microfossils very rare. Clay shale, medium- to medium-dark-gray, noncalcareous, medium hard; good to very good cleavage; very little silt present; dip 15°.
----	3, 377–3, 502	Clay shale, medium- to medium-dark-gray; some traces of siltstone at 3,410–3,420 ft.
48	3, 502–3, 510	Recovered 7 ft: Microfossils very rare. Clay shale, medium-dark-gray, noncalcareous, medium-hard; excellent cleavage; no silt; dip 5°.
----	3, 510–3, 730	Clay shale, medium- to medium-dark-gray; 10 percent medium-light-gray siltstone at 3,560–3,570 ft; trace of medium-light-gray to medium-gray siltstone at 3,530–3,540, 3,550–3,560, 3,570–3,590, 3,720–3,730 ft; trace of light-gray very fine-grained sandstone at 3,590–3,620 ft; one chip with slickensides 3,720–3,730 ft.
49	3, 730–3, 742	Recovered 12 ft: Microfossils very rare. Clay shale, medium-gray, noncalcareous, moderately hard, with good cleavage, negligible amount of silt. Slickensided surfaces approximately parallel bedding in at least six places; dip 35°.
----	3, 742–3, 902	Clay shale, medium- to medium-dark-gray; trace of medium-gray siltstone at 3,742–3,750, 3,760–3,770, 3,800–3,810, and 3,840–3,850 ft; trace of medium-light-gray to medium-gray siltstone 3,810–3,840, 3,870–3,880, and 3,890–3,900 ft; one chip with slickensides at 3,870–3,880. ft.
50	3, 902–3, 910	Recovered 8 ft: Microfossils very rare. Clay shale, medium- to medium-dark-gray, noncalcareous, moderately hard; good cleavage; rare small pyrite nodules; near-vertical slickensides present—surfaces partly coated with white material; dip 23°.
51	3, 910–3, 930	Recovered 3 ft: Microfossils very rare. Clay shale, as above, moderately hard except for lowest 6 in. which is rather soft; nearly vertical slickensides present; dip 23°.
52	3, 930–3, 939	Recovered 9 ft: Microfossils very rare. Clay shale, medium- to medium-dark-gray, noncalcareous, moderately hard; good to excellent cleavage; no slickensides noted; dip 20°–23°.

CORE ANALYSES

The core analyses in the following table were made in the Fairbanks laboratory of the U. S. Geological Survey. Porosities were determined by the Barnes (vacuum) method, and the permeabilities, by a permeameter whose general requirements are detailed in API Code No. 27, Second Edition, April 1942.

Analyses of core samples, Grandstand test well 1

Core	Depth [1] (feet)	Effective porosity (percent)	Air permeability (millidarcys)
1	242	2.50	1.54.
2	364-369	10.60	Unable to cut plug.
4	430	0.70	0.
8	796	3.97	<1.
	797	2.90	<1.
	798	4.12	0.
	799	3.56	<1.
	800	4.78	<1.
	801	5.56	<1.
	802	5.33	<1.
	803	5.47	<1.
	804	4.86	<1.
	805	5.12	<1.
	806	3.85	0.
	807	3.85	<1.
	808	1.57	0.
	810N	2.65	<1.
9	814	2.35	<1.
	820	1.99	0.
	828N	2.26	<1.
10	830	6.16	0.
	831	5.56	0.
	832	4.00	<1.
	833	4.79	0.
	834	4.59	0.
	835	4.80	0.
	836	3.30	0.
	838	3.30	0.
	839	4.10	0.

Analyses of core samples, Grandstand test well 1—Continued

Core	Depth [1] (feet)	Effective porosity (percent)	Air permeability (millidarcys)
	843	4.86	0.
	844	4.10	0.
	845	3.33	0.
	846	2.61	0.
	847	3.34	0.
	848	3.27	0.
11	849	2.50	0.
	850	3.61	0.
	851	3.53	0.
	854	2.44	0.
	855	2.62	0.
	856	2.28	0.
	857	3.89	0.
12	(upper) 862–882	11.15	<1.
	(lower) 862–882	11.40	9.5 (irregular surfaces).
	883	13.70	Unsuitable.
13	884	12.54	Do.
	898	8.22	0.
	905	9.02	Unsuitable.
	906	6.40	0.
	907	4.18	0.
	908	5.78	0.
	910	6.32	0.
	911	6.98	0.
	912	6.51	0.
14	913	5.43	0.
	914	4.87	0.
	915	5.20	0.
	916	4.31	0.
	917	3.64	0.
	918	2.64	0.
	919	2.83	0.
	920	3.49	<1.
	921	4.93	0.
	922	4.82	0.
	923	0.83	0.
	924	1.97	0.
	925	2.72	0.
	926	3.65	0.
	927	4.47	0.
	928	3.68	0.
	929	3.52	0.
15	930	3.91	0.
	931	4.28	0.
	932	5.12	0.
	933	3.18	0.
	934	3.97	0.
	935	4.63	0.
	936	3.21	0.
	937	3.51	0.
	938	3.50	0.
	939	1.63	0.
	940	3.79	0.
	941	3.39	0.
	942	3.71	0.
	943	1.39	0.
	944	2.24	0.
	945	2.81	0.
	946	1.66	0.
	947	3.45	0.
	948	2.95	0.
16	949	2.89	0.
	950	2.92	0.
	951	1.50	0.
	952	2.73	0.
	953	2.98	0.
	954	1.37	0.
	955	1.36	0.
	956	1.85	0.
	957	2.39	0.
	958	3.01	0.
	964	5.66	0.
17	989	5.65	0.
	1,039	3.79	0.
	1,044	4.10	0.
19	1,047	3.36	0.
	1,051	3.61	0.
	1,057	4.12	0.
	1,059	4.86	0.
	1,061	4.95	0.
	1,064	(cracked) 8.65	0.
20	1,067	4.30	0.
	1,069N	5.74	0.
	1,071	4.88	0.
	1,074	7.72	0.
21	1,076	3.12	0.
24	1,351	3.75	0.
	1,384	5.33	0.
26	1,387	7.76	0.
	1,390	5.16	0.
31	1,836	7.68	0.
35	2,000	6.23	0.
36	2,155	9.08	0.
41	2,471	7.30	0.
42	2,484	5.02	0.
43	2,512	3.55	15 [2] (approx.).

[1] N indicates plugs cut normal to the bedding. All others were cut parallel to the bedding.
[2] Plug was cracked from top to bottom.

A few samples, given in the following table, were tested for content of carbonate minerals.

Content of carbonate minerals of core samples, Grandstand test well 1

Core	Depth (feet)	Content of carbonate minerals (percent by weight)
15	923	18.60
	929	20.62
19	1,036	39.50
	1,039	10.98

HEAVY-MINERAL STUDIES

Robert H. Morris has made an analysis of the heavy minerals of the Cretaceous rocks in northern Alaska (Morris and Lathram, 1951). In a study of 23 heavy-mineral samples from this test well, he found that the zoned zircon zone is well developed and is represented from 240 to 2,500 feet. (See fig. 21.)

OIL AND GAS

OIL AND GAS SHOWS

Shows of oil and gas in Grandstand test well 1 were very poor. The shows in the following table were recorded by R. D. Rutledge, Arctic Contractors' well geologist, and another table presents the cut made with carbon tetrachloride in the Fairbanks laboratory.

Oil and gas shows, Grandstand test well 1 based on Arctic Contractors' records

Formation test [1]	Depth (feet)	Showing
	90	Gas bubbles in mud.
	791	Fleeting petroleum odor.
2	899	Slight fluorescence and pale cut in streaks.
	919	Slight fluorescence and pale cut in streaks.
	959	Very slight fluorescence.
	1,035	Very slight fluorescence.
	1,923	Slight odor and fluorescence; few gas bubbles.
3	1,941	Slight fluorescence.
	2,000	Very slight fluorescence; few gas bubbles.
	2,203	Very slight fluorescence and odor.
4, 5, and 6	3,902	Gas in ditch.

[1] For complete information on formation tests, see page 332.

Oil cuts, Grandstand test well 1, based on U. S. G. S. records

Core	Depth (feet)	Cut	Residue
8	803	Very pale	Very pale yellow.
	805	Very pale	Very pale yellow.
9	810	None	Very pale yellow.
	820	None	Greasy stain.
10	835	Very pale	Very pale yellow.
11	844	Very pale straw colored	Pale yellow.
	857	None	Very pale yellow.
12	862–882	Straw colored	Pale yellow.
13	885	Straw colored	Pale yellow.
14	899	Yellow	Yellow.
	916	None	Yellowish stain.
15	926	None	Yellowish stain.
	932	Pale straw colored	Pale yellow.
16	941	None	Yellowish stain.
	953	None	Yellowish stain.
17	962	None	Yellowish stain.

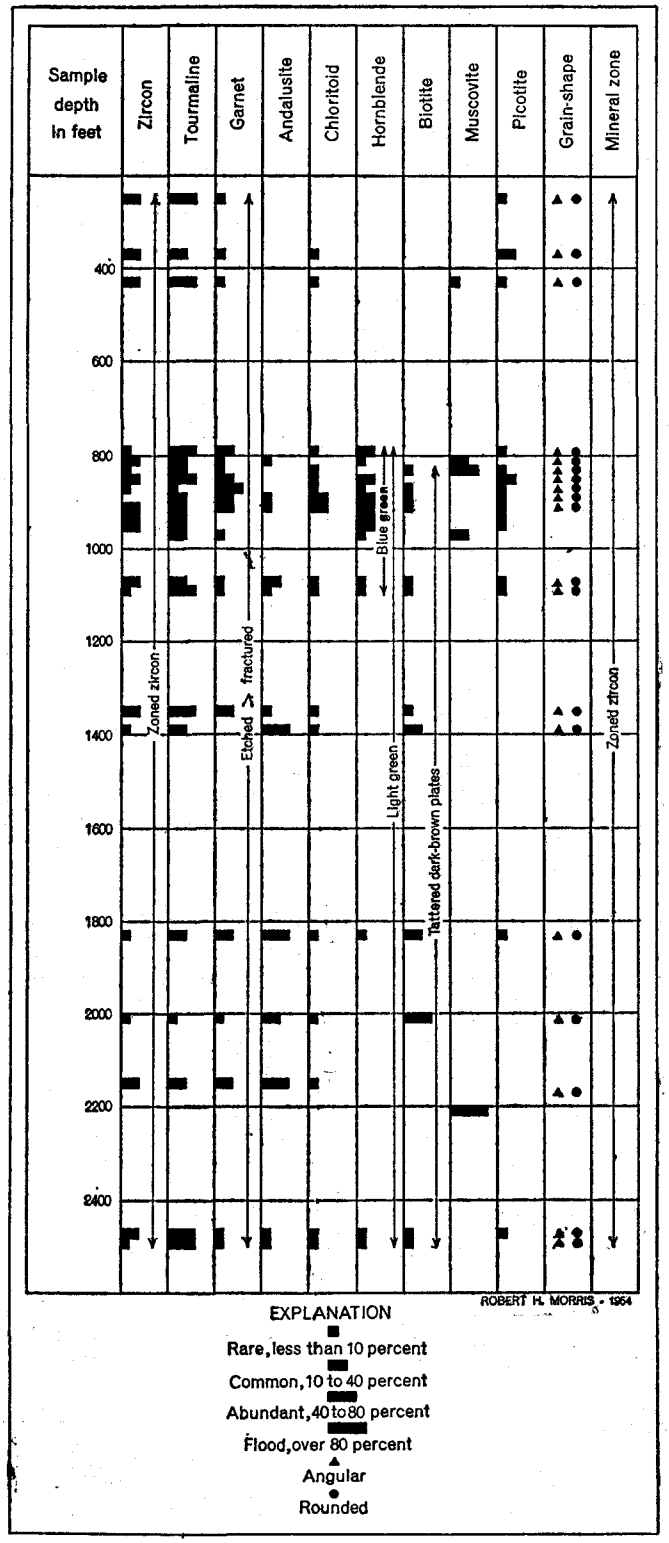

FIGURE 21.—Relative abundance of heavy minerals, Grandstand test well 1.

FORMATION TESTS

Test 1, 833–862 feet.—A Johnston formation tester was run with a 7¼-inch packer set at 833 feet, using a three-eighth-inch bean. The tool was open 2 hours. There was a very weak blow of air but no odor and no gas came to the surface. The tool was closed 10 minutes. Ninety feet of drilling fluid, slightly cut by drilling fluid filtrate, was recovered. The bottom-hole pressure was 50 pounds per square inch (psi). The salinity of the drilling fluid and the salinity of the recovered fluid were both 540 parts per million (ppm.).

Test 2, 865–899 feet.—A tester was run with a 7¼-inch packer set at 865 feet, using a three-fourths-inch bean. The tool was open 3 hours, and there was a very weak blow of air, which gradually diminished. The flowing pressure was 125 psi. The recovery consisted of 352 feet of slightly gas cut water. The packer leaked; so, no bottom-hole pressure was recorded. The salinity of the drilling fluid was 550 ppm and that of the recovered fluid, 800 ppm.

Test 3, 1,938–1,951 feet.—A tester was run with a 7¼-inch packer set at 1,938 feet, using a five-sixteenth-inch bean. The tool was open 1 hour. There was a slight puff and a very light blow of air for 5 minutes. The tool was closed 15 minutes, and 15 feet of uncut mud was recovered. The flowing pressure and the bottom-hole pressure were zero. The salinity of the drilling fluid was 750 ppm, and the salinity of the recovered fluid was 800 ppm.

Test 4, 3,908–3,939 feet.—A tester was run with a 7¼-inch packer set at 3,908 feet, using a five-sixteenths-inch bean. The tool was open 20 minutes, but no odor or gas came to the surface. The tool was closed 15 minutes. Fifty feet of uncut mud was recovered. The flowing pressure and the bottom-hole pressure were zero. The salinity of the drilling fluid was 900 ppm, and the salinity of the recovered fluid was 1,000 ppm.

Test 5, 3,864–3,939 feet.—A tester was run with an 8⅝-inch packer at 3,864 feet. The tester was opened, and there was a light blow for 4 minutes after which the valve became plugged. The test was unsuccessful.

Test 6, 3,834–3,939 feet.—A tester was run with an 8⅝-inch packer at 3,834 feet. No bean was used. The tool was open 45 minutes, and a strong initial puff diminished to a faint blow in 6 minutes. Then there were a few intermittent weak puffs during the rest of the test. The tool was closed for 10 minutes. No record of the pressures was obtained because the pressure recorder failed.

WATER AND GAS ANALYSES

The following table of water analysis was made by the U. S. Bureau of Mines from a sample collected from 865–899 feet during formation test 2. A mass-spectrometer analysis (shown in a following table) was made by the U. S. Bureau of Mines at Amarillo, Tex., on the only gas sample collected from the test well.

GRANDSTAND TEST WELL 1 AND CAMP

View looking from the Chandler River toward the 600-foot ridge to the southwest. End of April 1952.

Water analysis of sample from 865–899 feet, Grandstand test well 1

[Analysis by U. S. Bur. Mines. Specific gravity at 15.6°C (60°F) is 1.002. No H_2S detected. Ba, not determined]

Radical	Parts per million (milligrams per liter)
Calcium (Ca)	56
Magnesium (Mg)	35
Sodium (Na)	[1] 244
Carbonate (CO_3)	----
Bicarbonate (HCO_3)	----
Sulfate (SO_4)	177
Chloride	446

[1] Calculated by difference, neglecting carbonate and bicarbonate values. Sample was largely drilling mud, and a sample suitable for HCO_3 analysis could not be separated. Other determinations may be somewhat in error because the mud could not be completely separated from the sample.

Analysis of gas sample from 3,834–3,939 feet, Grandstand test well 1

[Analysis by U. S. Bur. Mines. Gross Btu per cu ft calculated dry at 60°F and 30 in. of mercury is 1,001]

Components	Mol percent
Methane	89. 7
Ethane	2. 8
Propane	1. 0
Normal butane	0. 2
Isobutane	0. 0
Normal Pentane	0. 1
Isopentane	trace
Cyclopentane	trace
Hexanes plus	0. 1
Nitrogen	5. 9
Oxygen	trace
Argon	0. 1
Helium	0. 0
Hydrogen	0. 1
CO_2	0. 0
H_2S	0. 0
	100. 0

SIGNIFICANCE OF SHOWS

The few bubbles of gas noted in the ditch at approximately 90 feet were probably from gas formed by decaying vegetal matter near the surface; the gas could possibly have come from near-surface sandstones, although this is unlikely as there were no other shows from these sandstone.

Arctic Contractors' Chief of Exploration C. L. Mohr made the following comments about the gas sample obtained from approximately 3,900 feet (written communication, 1952):

As a result of these three (formation) tests and the behavior of the gas when the hole was standing idle, it was concluded that the gas had no important volume but had shut-in pressure about 50 percent higher than normal hydrostatic pressure for the corresponding depth. The gas had a foul odor not typical of hydrogen sulphide nor gasoline, but it was readily ignited. Although the gas bubbled steadily through 98-pound mud at the top of the casing it did not threaten to blow out. Its behavior was like that of high-pressure gas often encountered in crevices in shale in cable-tool holes in that there seemed to be no important volume. Probably it would quickly exhaust if allowed to flow freely without the back pressure of a column of mud.

The various sandstone beds from which the rather poor cuts of oil were obtained could not be expected to produce oil because of their low permeability.

LOGISTICS

Transportation.—A total of 1,291 tons of equipment and supplies was carried to Grandstand test well 1 by Caterpillar tractor train in 6 trips from Barrow from March 10 to May 15, 1952. The drilling rig was hauled from the site of Avak test well 1, near Barrow, where it had been used the previous year. An airstrip for multiengined aircraft was constructed on a river bar near the Grandstand well site, but no heavy equipment was transported by air. During drilling operations, when weather conditions prevented air travel, an LVT (landing vehicle, tracked) was used to get to Umiat in emergencies.

Housing.—The camp (see pl. 20) was set up adjacent to the test site and consisted of 19 wanigans (1-room building without a foundation—usually on skids or runners to facilitate moving) and 1 quonset. Four of the wanigans served as sleeping quarters for the crew, one each as galley, messhall, radio shack, food warehouse, boiler room, geological and engineering office, machine shop, power room, cement bulker, cement pumper, utility room, latrine, and water, electric logging, and chemical storage warehouses. The quonset was used as an oilfield-equipment warehouse and store.

Personnel.—A drilling foreman and 2 geologists (1 acting as petroleum engineer) were in charge of 2 drillers, 2 derrickmen, 6 floormen, 2 firemen, 2 heavy-duty-equipment mechanics, 1 oiler, 1 oil-field warehouseman-timekeeper-storekeeper, 2 cooks, 1 janitor, 2 tractor operators, and 1 roustabout. Carpenters, electricians, radio repairman, oil-well cementer, Schlumberger operator, and plumber were sent out from Umiat as needed.

Vehicles and drilling equipment.—For use around the rig site were weasels, 1 Caterpillar D–8 tractor, 1 heavy-duty dirt mover (carryall), 1 Northwest crane, 1 small crane (cherry picker, TD9), and 1 Dodge truck (flat bed, 6 x 6 ft, 2½ tons). Five Caterpillar tractors left from the "cat" train were overhauled and used occasionally.

The major drilling equipment used by Arctic Contractors consisted of the following:

1 ---------- 87-ft Ideco derrick, 24-ft base.
1 ---------- Cardwell Model "H" drawworks with Foster Hi-Speed cathead and rotary drive.
1 ---------- Ideal rotary table, 17½ x 44 in.

1	Caterpillar engine, Model D–8800, on drawworks.
1	Ideal crown block, Model D–12, with 34-in. sheaves grooved for 1-in. line.
1	Ideal traveling block, Model D, with 34-in. sheaves grooved for 1-in. line.
1	Ideal swivel, Model D.
1	Byron Jackson Triplex hook, 125-ton capacity.
2	Gardner-Denver circulating pumps, FXO, 7¼- x 10-in. size.
2	Caterpillar engines, Model D–13000, for circulating pumps.
1	Marlowe cellar pump, Model 445, powered by 5-hp U. S. electric motor.
1	Mud tank with dividing partition.
1	Kewanee boiler, 35-hp, 110 psi steam pressure.
1	Shaffer blowout preventer, Type 34.
1	Shaffer blowout preventer, Type 45.

Fuel, water, and lubricant consumption.—A total of 605,600 gallons of water, 64,841 gallons of diesel oil, 1,378 gallons of gasoline, 1,325 gallons of lubricating oil, and 1,380 pounds of thread lubricating grease were used.

DRILLING OPERATIONS

RIG FOUNDATION

The derrick and drawworks were mounted on a steel substructure, which was mounted on heavy steel runners to provide mobility over the frozen terrain. The pump house was mounted on four Athey tracks.

DRILLING NOTES

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

Notes from drill records

Depth (feet)	*Remarks*
0	Spudded in at 5:30 p.m. May 1, 1952.
98.5	Ran 16⅝-in. 54-lb range 2 seamless casing to 98.5 ft, jacketed with 23⅝-in. casing from 19 to 35.5 ft and from 39.5 to 65.5 ft. Cemented with 150 sacks of Cal-Seal (double the usual amount because of hole caving), plus 60 additional sacks, into annulus through 2-in. pipe at 20 ft. Used a top and bottom cementing plug. Tested cement with 500 psi before drilling out shoe.
413	Circulation broke out around conductor casing. Ran in with open-end drill pipe to 101 ft, and pumped in 15 sacks of Cal-Seal. Tested after 6 hr, and found circulation still open behind casing. Ran open-end drill pipe to 101 ft, and pumped in 50 sacks of Hi-Early cement treated with 2 percent calcium chloride. Tested after 18 hr, and found job satisfactory.
731	Ran 18 joints of 11¾-in. 47-lb J–55 range 3, 8-round thread coupled seamless casing to 730 ft. Cemented with 372 sacks Hi-Early cement using float shoe and top plug. Tested plug before drilling out with 800 psi, and had no pressure drop in 15 min. Tested formation after drilling out shoe with 800 psi, and pressure slowly dropped to 700 psi, then remained constant for 15 min.
2,408	Jack-shaft on rotary clutch bent while making a connection. Removed shaft and sent it to Barrow for repair. Reinstalled after about 36 hr lost.
3,910	Hole bubbling considerable gas. Raised mud weight from 90 to 99 lb.
3,939	Total depth. The hole was left full of heavy mud, and cement plugs were set at 3,619–3,690 ft and 688–742 ft. The 11¾-in. casing was cut off 6 in. above cellar floor, and a ⅜-in. thick plate was welded on top. A 6-ft length of 4-in. line pipe was welded on top of this as a marker. Elevation of top of marker is 652.75 ft.

DRILL AND CORE BITS

A total of 48 drilling bits was used. The types and the depths drilled are indicated on plate 19. All cores were taken with a conventional core barrel using Reed hard- and soft-formation conventional core bits. A total of 49 bits was used to core 876 feet or 22.2 percent of the total footage of the test. Core recovery amounts to 691 feet or 80 percent of the total footage cored.

DRILLING MUD

The hole was spudded with Aquagel-Baroid mud weighing 85 pounds per cubic foot. The weight was raised to 95 pounds to combat hole-caving conditions at about 105 feet. Below this it was reduced and was maintained at approximately 88 pounds until a depth of 3,900 ft. was reached. Near 3,900 feet, gas entered the hole, necessitating an increase of mud weight to 99 pounds.

Aquagel and Driscose were added periodically to keep the average water loss down to 4.2 cc per 30 minutes, and quebracho and acid pyrophosphate were used when needed to keep viscosity at about 55 Marsh funnel seconds. The well-cake thickness was one-sixteenth-inch, the pH 9.5, and the sand content 3 percent. The following are the total amounts of materials used in treating the mud:

Baroid	868 sacks.
Aquagel	191 sacks.
Quebracho	1,060 lb.
Acid pyrophosphate	470 lb.
Driscose	875 lb.
Quadrafos	90 lb.
Fibertex	640 lb.
Aeroseal	50 lb.
Sodium bicarbonate	535 lb.

The drilling-mud characteristics and the approximate amounts of materials added to the various depths are given in the following table:

Drilling-mud characteristics and additives

Depth (ft)	Weight (lb/cu ft)	Viscosity (Marsh funnel sec)	Filtration loss (cc/30 min)	Drilling fluid temperature (° F)	Remarks
19–115					85 sacks Aquagel. 234 sacks Baroid.
115–200					15 sacks Aquagel. 55 sacks Baroid. 75 lb Driscose. 65 lb acid pyrophosphate.
200	82.5	52		50	
300	83.0	51	7.5	50	39 sacks Aquagel, 18 sacks Baroid, 200 lb quebracho, 155 lb acid pyrophosphate, 50 lb Aeroseal, 500 lb sodium bicarbonate, 600 lb Fibertex.
370	86.0	64	7.5	50	
415	86.0	62	6.0	50	
445	77.5	45	10.0	60	
510	76.0	54	9.0	58	
575	77.0	61	8.0	60	
690	75.0	49	8.5	60	3 sacks Aquagel, 105 lb acid pyrophosphate.
735	77.5	49	8.5	60	
810	77.5	49	5.0	60	20 sacks Aquagel, 180 sacks Baroid, 110 lb Driscose, 165 lb quebracho, 10 lb acid pyrophosphate, 35 lb sodium bicarbonate.
843	80.0	49	5.0	74	
860	85.0	48	6.0	75	
890	85.0	49	5.5	75	
900	85.0	50	5.5	72	
950	85.0	58	5.0	74	
970	85.0	60	5.0	70	
1,000	83.0	80	5.0	73	12 sacks Aquagel, 140 lb Driscose, 80 lb quebracho, 10 lb acid pyrophosphate, 40 lb Fibertex.
1,060	82.5	70	4.5	73	
1,100	82.5	62	5.0	74	
1,150	82.5	56	4.0	74	
1,195	82.5	56	4.5	74	
1,250	82.5	57	5.0	77	2 sacks Aquagel, 200 lb Driscose, 140 lb quebracho, 25 lb acid pyrophosphate.
1,330	82.5	59	5.5	77	
1,405	83.0	55	5.5	77	
1,450	83.0	54	5.5	74	
1,480	83.0	53	6.0	78	
1,520	83.5	52	5.0	78	
1,575	85.0	61	4.0	78	1 sack Aquagel, 80 lb Driscose, 50 lb quebracho.
1,615	86.0	54	4.5	78	
1,650	86.0	56	4.5	80	
1,700	86.0	58	4.5	76	
1,750	87.5	58	4.0	74	
1,795	87.5	54	4.0	74	
1,845	87.5	60	4.5	73	
1,900	87.5	56	4.5	74	3 sacks Aquagel, 80 lb Driscose, 20 lb acid pyrophosphate.
1,960	87.5	57	5.0	74	
2,015	87.5	55	5.0	76	
2,100	87.5	55	4.5	74	
2,160	87.5	54	4.5	74	

Drilling-mud characteristics and additives—Continued

Depth (ft)	Weight (lb/cu ft)	Viscosity (Marsh funnel sec)	Filtration loss (cc/30 min)	Drilling fluid temperature (° F)	Remarks
2,205	87.5	54	4.0	74	20 lb Driscose, 75 lb quebracho, 40 lb acid pyrophosphate.
2,270	87.5	54	5.0	70	
2,330	87.5	56	4.0	68	
2,385	87.5	55	4.0	69	
2,410	87.5	56	4.0	68	4 sacks Aquagel, 70 lb Driscose, 95 lb quebracho, 40 lb acid pyrophosphate.
2,430	88.5	55	4.0	61	
2,500	90.0	54	4.5	62	
2,530	90.0	56	4.5	58	
2,600	90.0	54	5.5	60	
2,620	90.0	55	4.5	60	
2,685	90.0	54	4.5	62	
2,730	90.0	55	4.0	62	40 lb Driscose, 115 lb quebracho, 10 lb acid pyrophosphate, 30 lb Quadrafos.
2,805	90.0	54	4.5	63	
2,900	90.0	56	4.0	64	
2,975	90.0	56	3.5	64	
3,040	90.0	55	4.0	64	
3,100	90.0	53	4.0	64	
3,175	90.0	53	4.0	64	
3,230	90.0	53	4.0	64	
3,300	90.0	54	4.0	64	2 sacks Aquagel, 60 lb Driscose, 140 lb quebracho, 60 lb Quadrafos.
3,365	90.0	53	4.5	63	
3,375	90.0	49	4.5	63	
3,395	90.0	49	5.0	63	
3,470	90.0	49	4.5	63	
3,510	90.0	50	4.0	63	
3,600	90.0	50	4.5	62	
3,675	90.0	52	4.0	60	
3,740	90.0	46	4.0	60	
3,800	90.0	50	4.0	61	5 sacks Aquagel, 327 sacks Baroid.
3,860	90.0	49	4.0	62	
3,900	90.0	50	4.0	61	
3,910	93.0	45	6.0	62	
3,930	93.0	41	4.0	60	
3,939	99.0	53	4.0	60	

HOLE DEVIATION

Between 100 and 780 feet the hole deviation was less than 2°00′. From 780 to 1,920 feet the deviation was mostly 2°00′ or more, the highest being 2°50′ at 1,548 feet. Below 1,920 feet at only three depths—2,465, 3,070, and 3,840 feet—did the deviation exceed 1°50′. (See pl. 19 for a complete record of the deviation.)

ELECTRIC LOGGING

The tabulation below shows the runs made by the Schlumberger Well Surveying Corp. A 2-inch normal, a 5-inch normal, a 5-inch lateral, and a 5-inch microlog were recorded on each electric-log run. The 2-inch normal log is shown on plate 19. The microlog is used only to study porosity, and little information is to be derived from the shaly zones between the porous zones. A porous zone with porosity ranging from 10 to 15

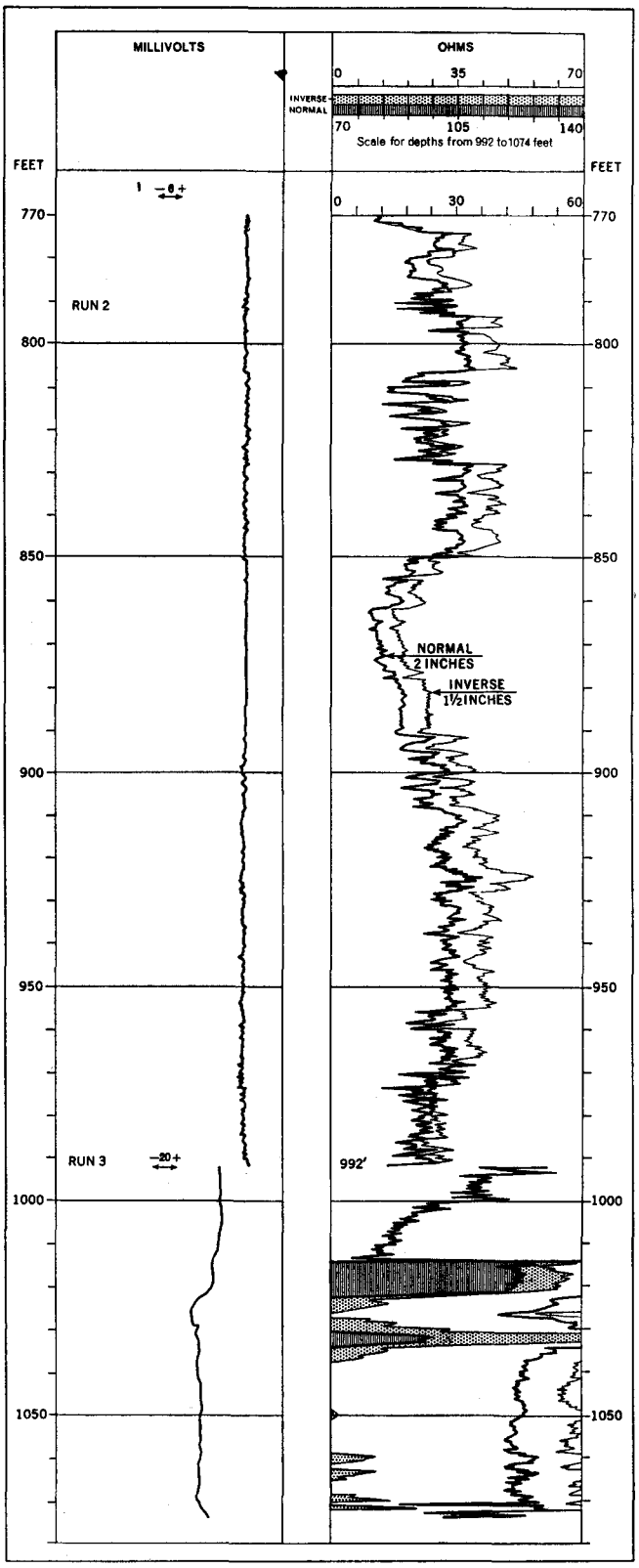

FIGURE 22.—Selected section of the microlog, Grandstand test well 1.

percent (as interpreted from the microlog) was indicated in the sandstone from 350 to 378 feet. Figure 22 is the microlog of the most important sandstone beds of the Grandstand and Chandler formations undifferentiated from 770 to 1,070 feet.

Intervals in rock (in feet) tested by electric logging methods

Run	
1	99– 733
2	728– 995
3	995–1, 954
4	1, 969–3, 075
5	3, 075–3, 939 (total depth)

DIPMETER AND MAGNETIC ORIENTATION SURVEYS

Plans were made to make a dipmeter survey of the Grandstand hole to determine the direction of the dip at various depths. It was decided, however, that the equipment probably would not function in northern Alaska, owing to the high inclination of the earth's magnetic field, and plans for the survey were canceled.

Cores were sent to Sperry-Sun Well Surveying Co. for magnetic orientation. The results of these tests were reasonably consistent, but additional magnetic orientation tests would have to have been made on cores or outcrop specimens of the equivalent formation elsewhere in northern Alaska before the final significance of the magnetic core tests could be determined. Further studies were not completed because the exploration of Naval Petroleum Reserve No. 4 was terminated shortly after the drilling of Grandstand test well 1.

LITERATURE CITED

Collins, F. R., 1958, Test wells, Umiat area, northern Alaska: U. S. Geol. Survey Prof. Paper 305–B.

Detterman, R. L., 1956, New and redefined nomenclature of Nanushuk group, *in* Gryc, George, and others, 1956, Mesozoic sequence in Colville River region, northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 2, p. 233–244.

Goddard, E. N., and others, 1948, Rock color chart: Natl. Research Council, Washington, D. C.

Gryc, George, and others, 1956, Mesozoic sequence in Colville River region, northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 2, p. 209–254.

Morris, R. H., and Lathram, E. H., 1951, Heavy mineral studies, *in* Payne, T. G., and others, 1951, Geology of the Arctic Slope of Alaska: U. S. Geol. Survey Oil and Gas Invs., Map OM 126.

Payne, T. G., and others, 1951, Geology of the Arctic Slope of Alaska: U. S. Geol. Survey Oil and Gas Invs., Map OM 126.

Robinson, F. M., Rucker, F. P., and Bergquist, H. R., 1956, Two subsurface formations of Early Cretaceous age, *in* Gryc, George, and others, 1956, Mesozoic sequence in Colville River region, northern Alaska: Am. Assoc. Petroleum Geologists Bull., v. 40, no. 2, p. 223–233.

MICROPALEONTOLOGIC STUDY OF GRANDSTAND TEST WELL 1, NORTHERN ALASKA

By Harlan R. Bergquist

In Grandstand test well 1 the first 227 feet of section is considered by F. M. Robinson to be in part alluvium of Quaternary age and in part the nonmarine Killik tongue of the Chandler formation. The ditch samples from the uppermost 210 feet of beds were unfossiliferous; no sample was received of the rocks from 210 to 227 feet. Below 227 feet the beds are fossiliferous and all a part of the *Verneuilinoides borealis* faunal zone of Albian age.

The *Verneuilinoides borealis* faunal zone extends throughout the Grandstand formation, the Tuktu formation and the upper part of the Torok formation, as well as their subsurface equivalent to the north. The zone can be recognized throughout northern Alaska and is named for the dominant foraminifer. Most of the Foraminifera are arenaceous, but calcareous species are important locally. Several species are the same as Albian forms described from Lower Cretaceous rocks of Europe; a few are the same as species found in Lower Cretaceous strata in western Canada.

About 60 species of Foraminifera and a few Radiolaria are known in the *Verneuilinoides borealis* faunal zone, but the full complement occurs only in the coastal wells. In the Grandstand test well, 26 species of Foraminifera and 2 species of Radiolaria were found in the zone. About half the species occur in the Grandstand formation, but none are very abundant. Additional species occur in the shale beds below the Grandstand formation. Most abundant Foraminifera in the zone were *Verneuilinoides borealis* Tappan, *Haplophragmoides topagorukensis* Tappan, *Ammobaculites wenonahae* Tappan, and *Gaudryina nanushukensis* Tappan. The latter two occurred only in the shale beds below the Grandstand formation.

VERNEUILINOIDES BOREALIS FAUNAL ZONE

The first fossiliferous core (227–245 ft) carried common specimens of *Verneuilinoides borealis* Tappan (Tappan, 1957) and *Psamminopelta subcircularis* Tappan, and a few specimens of *Gaudryina canadensis* Cushman (Cushman, 1943), *Trochammina rutherfordi* Stelck and Wall (Stelck and Wall, 1955), and *Miliammina awunensis* Tappan. This is the first appearance of the *Verneuilinoides borealis* faunal zone, but the fauna is sparse in the sandy section (227–1,070 ft). Many of the ditch samples and most of the cores were barren.

The largest assemblage of Foraminifera found in the upper beds in this well was in a core sample from 619–629 feet, where *Verneuilinoides borealis* and *Haplophragmoides topagorukensis* Tappan were abundant and *Gaudryina canadensis*, *Miliammina awunensis*, and *Zonodiscus* sp. C (pyritic casts of a radiolarian) were common. Some of these species were also found in ditch samples in the succeeding 100 feet. A continuously cored section from 791–979 feet was entirely unfossiliferous, but in the succeeding 19 feet (979–998 ft) were common specimens of *Verneuilinoides borealis*, a few specimens of *Haplophragmoides topagorukensis*, and a few calcareous Foraminifera, plus fragments of the tubes of *Ditrupa* sp.[1] Specimens of *Trochammina rutherfordi* were common in a ditch sample from 1,020–1,030 feet. Cores were barren from 1,035 feet to the base of the sandy section at 1,070 feet.

The predominantly shale section from 1,070 feet to the bottom of the hole is probably equivalent to outcropping beds of the upper part of the Torok formation. This shale section is much more fossiliferous than the overlying beds, and fossils were found throughout most of the section and in the bottom-hole core. Some of the Foraminifera are the same as those occurring in the overlying beds above 1,070 feet but there are additional species. All species are part of the *Verneuilinoides borealis* fauna, and formations probably cannot be distinguished faunally.

The sample from 1,160–1,170 feet yielded a fragment of *Ditrupa* sp., which marked the highest occurrence of fossils in this part of the section. A few arenaceous Foraminifera occurred in a sample from 1,180–1,190 feet. Below this depth, Foraminifera were found in most of the core samples and in all the ditch samples. Even in the lowest cores (3,902–3,920 ft and 3,930–3,939 ft), there were a few specimens of *Bathysiphon brosgei*

[1] Curved tubular shells formerly referred to *Laevidentalium* sp. or *Dentalium* sp. in the beds of the *Verneuilinoides borealis* faunal zone of the Cretaceous of northern Alaska are now known to be worm tubes of the genus *Ditrupa* sp. (Determinations by Ralph W. Imlay in 1956.)

Tappan, *Verneuilinoides borealis, Saccammina lathrami* Tappan, *Textularia topagorukensis* Tappan, *Siphotextularia? rayi* Tappan, and common specimens of *Trochammina rutherfordi*? Stelck and Wall. *Ditrupa* tubes occurred in several cores, the lowest being from 1,941–1,949 feet.

Verneuilinoides borealis and *Haplophragmoides topagorukensis* were common to abundant in many of the samples and were the most frequently occurring species, being found in 113 of the 135 samples taken from the predominantly shale section. *Ammobaculites wenonahae* Tappan is next most frequent in occurrence, but it was common only in a core sample from 1,751–1,767 feet and in another from 1,957–1,971 feet, although the species occurred much lower in a core sample from 2,926–2,946 feet and in ditch samples near the bottom of the hole. *Gaudryina canadensis, Trochammina rutherfordi, Miliammina awunensis,* and *M. manitobensis* Wickenden (Wickenden, 1932) occurred in core and ditch samples through much of the section between 1,180 feet and the bottom of the hole. There were occasional specimens of *Bathysiphon brosgei* and *B. vitta* Nauss (Nauss, 1947) in some of the samples. The most distinctive species, however, is *Gaudryina nanushukensis* Tappan which was found in a ditch sample from 1,570–1,580 feet and occurred in ditch and core samples down to a core sample from 3,364–3,377 feet.

A few calcareous Foraminifera such as *Eurycheilostoma grandstandensis* Tappan, *Nanushukella umiatensis* Tappan, *Globorotalites alaskensis* Tappan, and *Lenticulina macrodisca* (Reuss) were found in samples from 1,200 through 2,140 feet, but none were found in cores below 1,971 feet.

BIBLIOGRAPHY OF THE MICROPALEONTOLOGIC STUDY

Cushman, Joseph A., 1943, *Gaudryina canadensis,* new name: Cushman Lab. Foram. Research Contr., v. 19, pt. 2, p. 27–28.

Nauss, A. W., 1947, Cretaceous microfossils of Alberta: Jour. Paleontology v. 21, no. 4, p. 329–434.

Stelck, C. R., and Wall, J. H., 1955, Foraminifera of the Cenomanian *Dunveganoceras* zone from Peace River area of western Canada: Alberta Research Council Rept. 70.

Tappan, Helen, 1951, Northern Alaska index Foraminifera: Cushman Found. Foram. Research Contr., v. 2, pt. 1. p. 1–8.

——— 1957, New Cretaceous index Foraminifera from northern Alaska: U. S. Natl. Mus. Bull. 215, p. 201–222.

Wickenden, R. T. D., 1932, New species of Foraminifera from the Upper Cretaceous of the prairie provinces: Royal Soc. Canada Proc. and Trans. 3d ser., v. 26, sec. 4.

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