

GEOLOGICAL SURVEY CIRCULAR 298



THE CORED SECTION IN
GEORGE VASEN'S FEE
WELL 1, STONE COUNTY
MISSISSIPPI

UNITED STATES DEPARTMENT OF THE INTERIOR

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By Paul L. Applin and Esther R. Applin

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INTRODUCTION

George Vasen's Fee well 1 (sec. 9, T. 2 S., R. 11 W.), about 3 miles northeast of Wiggins, Stone County, Miss. (fig. 1), in June 1951 reached a total depth of 20,450 feet in rock salt of pre-Smackover (Jurassic) age. The Vasen Fee well 1 is the deepest test in the Gulf Coast and, at its total depth, lacks 71 feet of equaling the record of 20,521 feet attained in 1949 by the Superior Oil Co. Unit 1 well, Sublette County, Wyo. Not only does this interesting and important test rank second in depth among the world's borings, but a gas showing at about 20,300 feet is the deepest on record. The information obtained from nearly 5,500 feet of consecutive cores of unmetamorphosed Jurassic strata in the lower part of the Vasen test provides data on the stratigraphy of the Jurassic rocks of the Gulf Coastal Plain. Situated less than 50 miles north of the Gulf of Mexico on the regional subsurface structure commonly called the Wiggins anticline, the Vasen test penetrated Jurassic rocks at the farthest down-dip location in the central Gulf Coast. Showings of oil and gas were found in the limestone and dolomite of the Smackover(?) formation.

Previous work

The well was started in August 1946 by Tom McKinney who drilled to 11,209 feet. George Vasen continued the well to its total depth. In December 1947, the test reached the depth of 14,038 feet where an electric log was made and 7-inch casing set. In January 1950, diamond-bit coring began at 14,670 feet, and subsequently 197 consecutive cores penetrated 5,771 feet of sedimentary strata to the depth of 20,441 feet. Milling and fishing for lost parts of the diamond-bit added 9 feet, bringing the final depth of the well to 20,450 feet. A core composed of 1 foot of anhydrite and 1 foot of rock salt was recovered in a basket core barrel from the 9-foot interval. No electric log was made of the cored section. Bottom-hole temperature of 389 F was recorded by engineers of Halliburton Oil Well Cementing Co.

Acknowledgments

George Vasen and members of his staff at Wiggins, Miss., were most cooperative in facilitating the core study. Representatives of Core Laboratories,

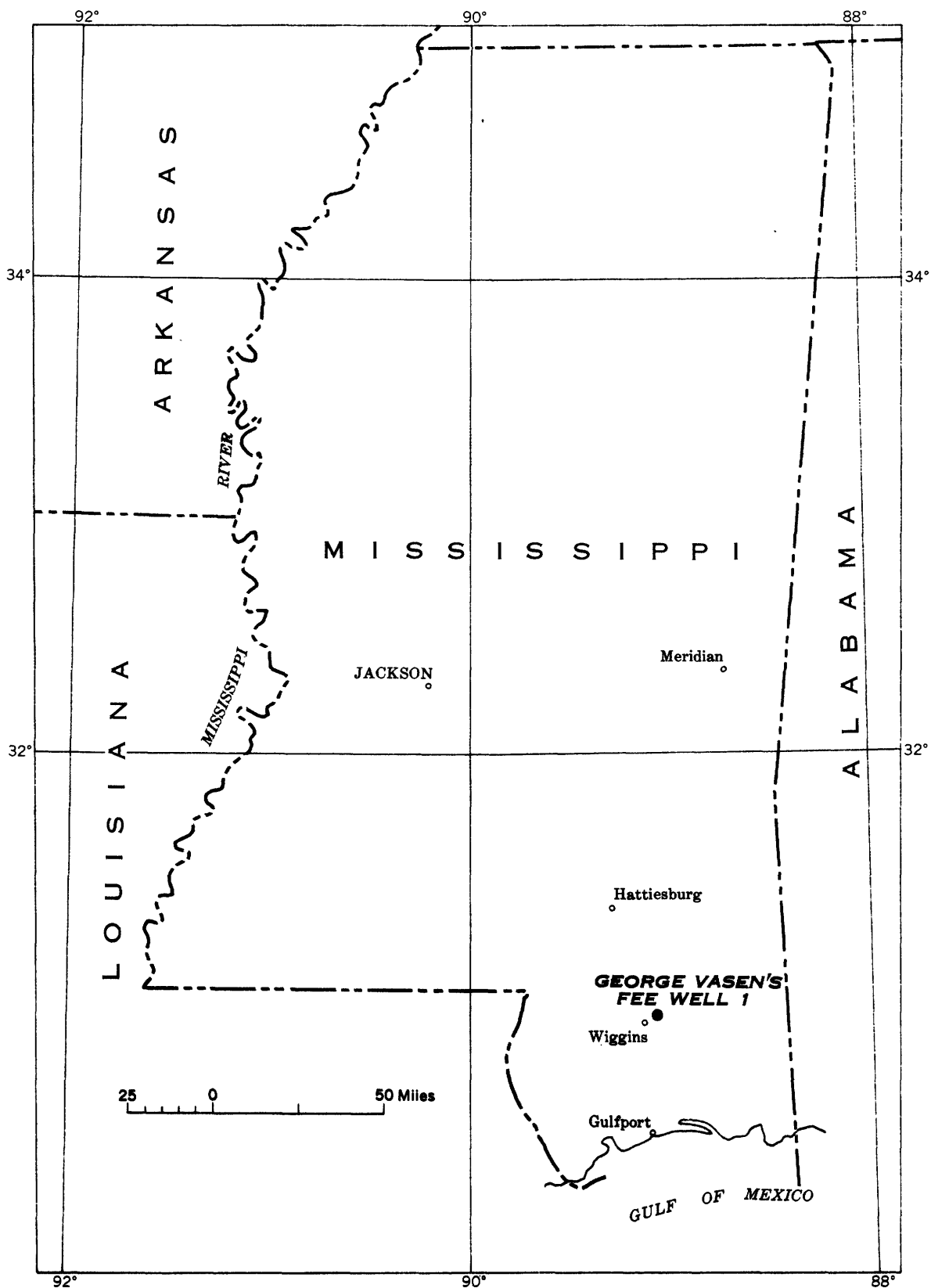


Figure 1. —Outline map of Mississippi showing location of George Vassen's Fee well 1.

Inc., and the members of the drilling crew provided assistance in arranging, boxing, and sampling the cores. J. D. Nunnally, geologist, Gulf Refining Co., Laurel, Miss., provided helpful information relating to problems of Jurassic stratigraphy in the Gulf Coast region.

Ralph W. Imlay conducted paleontologic studies of fossiliferous cores from the Vasen well and also collected fossils from cores between the depths of 18,767 and 19,314 feet. The age classification of most of the stratigraphic units used herein are based on his reports.

STRATIGRAPHY

Lower Cretaceous

Hosston(?) formation

Starting at the depth of 14,670 feet, the upper 275 feet of the cored section is tentatively classified, on the basis of lithology, as a part of the Hosston formation. Samples available for examination begin at 14,722 feet; from that depth to 14,945 feet the samples are composed mainly of unfossiliferous hard dark brownish-red shale that is irregularly silty, micaceous, and calcareous. The red shale is partly mottled and streaked with gray to greenish-gray silty micaceous shale and contains a few small inclusions or blebs of red limestone. The lithology of these possible Hosston strata and the absence of fossil remains indicate deposition in a fresh- to brackish-water environment.

Upper Jurassic

Cotton Valley group

It is difficult to select the top of the Cotton Valley group in the Vasen well owing to the lack of a definite stratigraphic break. The Hosston and the upper part of the Cotton Valley are closely similar in appearance. However near the depth of 14,945 feet the predominantly brownish-red color of the shale in the Hosston changes gradually in downward sequence to a darker and duller shade of red, and lenses of sandstone and siltstone increase in number and thickness. With progressive increase in depth, the strata show additional lithologic and faunal characteristics that suggest a correlation with known Cotton Valley deposits penetrated in other wells in the central Gulf Coast. From the foregoing considerations, the top of the Cotton Valley group is questionably placed at 14,945 feet. A pronounced lithologic and faunal break in the samples at the depth of 16,998 feet marks the base of the beds that are correlated with the Cotton Valley, giving the interval a possible thickness of 2,053 feet.

The Cotton Valley group in the Vasen well is separable into two parts on the basis of differences in lithology and faunal content. Approximately the upper three-fourths of the Cotton Valley interval is composed largely of nonmarine or deltaic deposits with rare occurrences of interbedded strata containing marine fossils; the lower one-fourth is composed of marine deposits containing beds that are abundantly fossiliferous.

From the depth of 14,945 feet to about 16,475 feet, shale and sandstone in nearly equal proportions comprise the samples of the upper chiefly nonmarine part of the Cotton Valley. Beds of hard, compact dark brownish-red shale with a lesser amount of dark-gray shale alternate and interlens with many layers of gray, greenish-gray, grayish-red, and red sandstone. Silt and mica are irregularly and unevenly distributed in the shales, the mica occurring as finely disseminated particles and as thin partings or laminations composed of distinct flakes. The lime content of the shales ranges from noncalcareous to highly calcareous. In many places, the cores of red shale are mottled greenish gray or bluish green, and a few lenses of highly micaceous carbonaceous black shale are present at widely spaced levels. The sandstones, for the most part, are dense, fine to medium grained, micaceous, and calcareous to noncalcareous; scattered lenses of sandstone are moderately coarse grained and conglomeratic, containing irregularly-shaped fragments of shale and limestone. At irregular intervals in the core samples of the upper part of the Cotton Valley sequence, red silty limestone and gray limestone occur as nodules or blebs in the shale and, in places, as thin strata or lenses. Shale and sandstone in half a dozen scattered cores contain fragments of lignite and shreds of carbonaceous material, some of which show definite wood structure. Tom McGlothlin, consulting geologist, Laurel, Miss., made an independent study of the cores from the upper part of the cored section and reported (personal communication to Ralph W. Imlay, April 6, 1950) that thin seams or laminae of coal occurred in a sample from the depth of 15,870 feet; Imlay reported (personal communication to Tom McGlothlin, May 3, 1950) the occurrence of coal in the core from the depths of 16,116 to 16,143 feet. Imlay stated that the presence of coal and coaly beds and the occurrence of a few specimens of marine fossils in the cores from 16,170 to 16,224 feet are suggestive of a Cotton Valley rather than a Hosston age assignment. Small amounts of anhydrite are present in 3 cores. In core 36, at the depth of 15,605 feet, red and blue-green mottled silty shale contains 1 fragment of pink anhydrite; a sample of core 61, at 16,273 feet, shows finely granular white anhydrite filling small crevices in gray sandy limestone; the middle fraction of core 66 is a dense sandstone in which a small amount of anhydrite is a component of the intergranular cement.

In the lower marine portion of the Cotton Valley group, roughly two-thirds of the samples from 16,475 to 16,998 feet are composed of dark shale, the remaining one-third being chiefly interbedded sandstone with lesser amounts of limestone and brownish-red shale. At several different levels in the 500-foot interval, the cores contain abundant specimens of megascopic fossils representing a variety of genera; fragmentary fossils are numerous, and a few cores yield ostracodes and charophytes. The hard, compact shale is mostly dark gray, greenish gray or olive gray, frequently mottled and streaked with brownish red; a few cores contain relatively thin strata of brownish-red shale. The shales are calcareous to noncalcareous, usually micaceous, silty or finely sandy, and frequently fossiliferous. The sandstones are hard, dense, fine to medium grained, and usually light colored, gray or greenish gray; they are calcareous to noncalcareous, micaceous, and contain numerous streaks and irregular thin seams of black carbonaceous shale. A few sandstone cores contain

megascopic fossils and fossil fragments: Relatively thin strata of fossiliferous gray sandy and shaly limestone occur at irregular intervals in the marine portion of the Cotton Valley. Lignite and carbonaceous material are fairly common constituents of the core samples; in some cores the lignite fragments are cut by calcite veinlets that form a distinctive reticulate pattern. Two cores contain traces of anhydrite. In the middle fraction of core 84, anhydrite is possibly the cementing material of a dense gray sandstone; the occurrence of a single bleb of pink anhydrite in core 72 was mentioned in a report by McGlothlin.

Imlay reports that some of the fossil species occurring in cores between the depths of 15,647 and 16,695 feet are identical or closely comparable with species in the Malone formation of West Texas. Imlay argues that since "the Malone formation corresponds to the Kimmeridgian and Portlandian stages of Europe, and is younger than the Smackover limestone of the southern states, it seems most probable that the fossiliferous beds in question [in the Vasen well] represent some part of the Jurassic younger than the Smackover." Supporting the Cotton Valley age classification of the fossiliferous beds, Imlay points out the close similarity of some of the species in the Vasen well to forms in the lower part of the Cotton Valley group of the Arkansas-Louisiana-East Texas area; to species from the depths of 11,492 to 12,369 feet in the Danciger Oil and Refining Co.'s York well¹ (sec. 1, T. 7 N., R. 1 W.), Clarke County, Ala.; and to species from the depths of 11,803 to 12,083 feet in the Union Producing Co.'s Waite well² (sec. 27, T. 8 N., R. 1 W.), Clarke County, Ala. In explanation of the discrepancy between the published stratigraphic section of the Waite well and the correlation with the Vasen test presented in this report, Imlay stated, "This correlation implies that the salt beds in the Union-Waite well are of Buckner rather than of Eagle Mills age and it alters considerably some published stratigraphic concepts."

Imlay further reports that none of the species between the depths of 15,647 and 16,695 feet in the Vasen well resemble the described species from the limestone of the Smackover formation.

Cotton Valley(?) group and Buckner(?) formation

From the depth of 16,998 to 18,695 feet, nearly 1,700 feet of unfossiliferous apparently nonmarine sediments are composed mostly of brownish-red, light-gray, and greenish-gray sandstone with interbedded layers of brownish-red and some dark-gray shale. Sandstone comprises, roughly, two-thirds of the interval, and shale about one-third; the upper 200 feet is mainly red shale, but, below the depth of 17,200 feet, sandstones predominate. The red and gray sandstones are hard, dense very fine to moderately coarse grained, frequently argillaceous, and usually calcareous and micaceous. Pink feldspar and light-green chlorite(?) grains are common constituents of the sandstone, and prominent highly micaceous lenses and partings are a distinctive characteristic of this portion of the cored section in the Vasen well. Occasional sandstone lenses are conglomeratic in appearance owing to included fragments and blebs of shale and limestone. The shales are hard, compact, usually calcareous, micaceous, and silty

or finely sandy; in the upper part of the interval, the red shale is frequently mottled with gray green and bluish green. The top part of core 112, at the depth of 17,606 feet, contains a thin bed of impure sandy limestone; scattered blebs and nodules of limestone occur in several other cores. Shreds of carbonaceous material and lignite fragments are fairly common in the sandstone and shale cores at many levels. Abundant, small even-sized black pellets of magnetite(?) occur in the top part of core 132, at the depth of 18,142 feet, and in a few deeper cores. Occurrences of anhydrite are rare and are confined to scattered blebs in cores 138 and 139 between the depths of 18,304 and 18,358 feet.

The age of the unfossiliferous red sandstones and shales between the depths of 16,998 and 18,695 feet has not been definitely determined although the upper and lower boundaries of the lithologic unit are clearly defined. The sharp lithologic change separating the unit from the overlying dark marine deposits suggests an unconformable contact although more conclusive physical evidence, such as gravel beds or a conglomerate, is lacking. At the base of the red sand and shale interval, a fault of unknown displacement apparently marks the contact with the underlying Smackover formation. Near the middle of core 152, a section of the core broke along a slickensided surface cutting at a high angle across horizontal bedding and marking an abrupt change in lithology between the predominantly red nonmarine section above and dark marine sandstone and shale below. Cores of the shale and sandstone below the fault contain fossils characteristic of the Smackover. The stratigraphic position of the unfossiliferous red interval, underlying beds of Cotton Valley age and resting on beds of Smackover age, suggests a correlation with the lower portion of the Cotton Valley, and, in part, with the stratigraphic equivalent of the Buckner formation. According to this interpretation, however, the typical anhydrite and salt beds of the Buckner are absent, due possibly to a change of facies, truncation, or nondeposition on the Wiggins anticline.

Based on the study of cuttings and electric logs of deep wells in north Louisiana, particularly wells in the Haynesville field, Claiborne Parish, La., and Columbia County, Ark., and the East Haynesville field, Claiborne Parish, La., the Shreveport Geological Society proposed the name Haynesville formation³ for a stratigraphic unit overlying the Smackover formation and underlying "a distinct break in the nature of a major unconformity within the Cotton Valley formation." According to the Shreveport Geological Society classification,⁴ "the term Cotton Valley as a formation [is] restricted to the gray sands and shales lying above the unconformity," and the name Haynesville formation is "introduced for the red sands, shales, and anhydrite lying below the unconformity and above Smackover formation. The stratigraphic equivalent of the Buckner formation of Arkansas would, in the north Louisiana area, be the basal member of the Haynesville formation." The current usage by some oil company geologists has extended the term Haynesville formation to beds in Mississippi and Alabama, where it is applied to a unit comprising the Buckner formation and the lower part of the Cotton Valley group.

¹Unpublished data in the files of R. W. Imlay, U. S. Geological Survey, Washington, D. C.

²Imlay, R. W., 1943, Jurassic formations of Gulf region: Am. Assoc. Petroleum Geologists Bull., v. 27, p. 1446.

³Philpott, T. H., and Hazzard, R. T., 1949, Preliminary correlation chart—upper Gulf Coast: Shreveport [La.] Geol. Soc. Guide Book, 17th annual field trip, Goebel, L. A., 1950, Cairo Field, Union County, Ark.: Am. Assoc. Petroleum Geologists Bull., v. 34, p. 1978-1979.

⁴Goebel, L. A., 1950, idem.

In the Vasen well, the interval composed of unfossiliferous red sand and shale, already discussed in this report, is tentatively correlated as the stratigraphic equivalent of at least a part of the so-called Haynesville formation.

Smackover formation

Between the depths of 18,695 and about 18,800 feet, a sequence of thinly interbedded, dark sandstone, siltstone, and shale is classified as the upper part of the Smackover on the basis of species of fossils occurring in cores 152, 154, and 155. The thickness of the interval is 105 feet. For the most part, the siltstones and dense fine-grained sandstones are dark gray, micaceous, and calcareous, with occasional greenish-gray and bluish-green lenses. The hard dark-gray, black, and brownish-black shales contain varying amounts of silt, mica, and carbonaceous material. In core 155, between the depths of 18,770 and 18,775 feet, thin beds of siltstone and black shale dip at angles ranging from 25° to 60°, the steep dips indicating possible association with nearby faults.

Imlay (personal communication to Paul Applin) reports that the dark shales and sandstones contain fossil species that he has described from the upper part of the limestone of the Smackover formation. He further reports, "In particular, *Astarte grubbi* Imlay, noted at the depth of 18,767 feet, is common in the upper oolitic part of the Smackover in Arkansas."

Jurassic (undifferentiated)

Smackover(?) and pre-Smackover(?) formations

The sequence of limestone, dolomite, and anhydrite from about 18,800 to 20,420 feet is questionably assigned, in this report, to the middle and lower parts of the Smackover, with the possibility that older Jurassic formations are also represented. In connection with the study of specimens collected from the limestone and dolomite, Imlay (personal communication to Paul Applin, March 20, 1953 (reported, "The fossils*** below the depths of 18,800 feet are definitely not older than Jurassic, but it is not possible to state what part of the Jurassic they represent. They belong to species different from any that I have described from the Cotton Valley formation or the upper part of the Smackover formation and are therefore probably of a different age. Very few fossils have been obtained from the middle and lower parts of the Smackover that might be used for comparative purposes with those in the lower part of the Vasen well below 18,800 feet."

At the depth of 20,420 feet, in core 196, a foot of gray silty or very finely sandy micaceous clay marks the contact between the overlying dolomite and limestone sequence and the underlying anhydrite and salt which are the deepest rocks penetrated in the Vasen test.

Below the depth of 18,800 feet the almost uniformly dark brownish-gray limestones, dolomitic limestones, and dolomites are hard, dense, and finely granular,

usually breaking with a sharp conchoidal fracture but sometimes in platy fragments. A porous zone penetrated in cores 191 and 192, near the depth of 20,300 feet, is discussed in succeeding paragraphs. Oolitic zones of varying thickness and zones of fragmental fossils are scattered at different levels in the limestone and dolomite sequence. Thin strata and lenses of hard, brittle black and brownish-gray shale are particularly abundant below 19,800 feet. Between the depths of 18,800 and 19,550 feet, beds of anhydrite, ranging in thickness from a foot to more than 30 feet, comprise nearly one-third of the interval; anhydrite blebs and inclusions are common in the limestone and dolomite portion. The bedded anhydrite is usually gray or white, dense, and impure, containing irregular veins, seams, and inclusions of black shale and dark-brown dolomite. Anhydrite blebs and inclusions persist in the limestone below 19,550 feet, but anhydrite beds are absent. Small blebs of free sulfur occur near the top of core 181 at about 19,815 feet, and again in core 189 at the depth of 20,177 to 20,187 feet.

Pre-Smackover

Underlying the thin stratum of silty or very finely sandy clay at the depth of 20,420 feet, 18½ feet of gray crystalline anhydrite was recovered in the bottom part of core 196. No recovery was obtained in core 197 from the depth of 20,437 to 20,441 feet. From approximately 20,445 to 20,447 feet, a basket core recovered, in downward sequence, 1 foot of anhydrite and 1 foot of clear white rock salt. The foot of anhydrite in the basket core is similar in appearance to the anhydrite recovered in the bottom part of core 196. The crystalline anhydrite in the bottom cores of the Vasen well differs noticeably in appearance from the dense impure anhydrite in the cores from higher levels.

Imlay (personal communication to Paul Applin, March 20, 1953) reports that "the faunal evidence for considering the salt at the bottom of the Vasen well as pre-Smackover consists (1) of the presence of fossils at depths of about 18,750 to 18,800 feet that are found in Arkansas in the upper part of the Smackover limestone, and (2) of fossils at depths of 15,600 to 17,000 feet that are found in Arkansas and Louisiana in the lower part of the Cotton Valley formation."

CORE DESCRIPTIONS

In August 1950, the authors were assigned to make lithologic and paleontologic studies of the cores from the Vasen well. We arrived in Wiggins, Miss., August 18, 1950, at the time that core 126 was being cut. Representatives of Core Laboratories, Inc., stationed at the well since coring started in January 1950, had described and tested cores 1 to 125, from 14,670 to 17,982 feet, preserving samples of the top, middle, and bottom parts of each core. These fractions were subsequently examined during the course of our work. Cores 126 to 196, from 17,982 to 20,437 feet, were examined and sampled at the well by Paul L. Applin. In place of designating the fractional parts of the core as top, middle, and bottom, beginning with core 132, at 18,142 feet, the log shows, so far as practicable, the actual depths of the lithologic changes. Samples of all cores were

studied microscopically and described by Esther R. Applin. When the studies were completed, the core samples and fossil specimens that had been collected were deposited with the Geological Survey, Washington, D. C.

Gas and oil showings

On March 2, 1951, during the process of cutting core 191 in the Vasen test at the depth of 20,298 feet, gas having a strong odor of hydrogen sulfide blew oil-base drilling fluid from the well to the height of 20 or 25 feet above the derrick floor. In the 2-hour interval following the initial showing, the well made 3 or 4 additional heads, each lasting several minutes and acting in a manner similar to the first one.

Core 191 cut 21 feet of beds from 20,277 to 20,298 feet, of which 12 feet were recovered when the core barrel was pulled several days after the gas showing. As recorded in the section on "Lithology," the recovery from core 191 consisted of 4 feet of hard black dolomitic(?) shale in the top portion, followed, in sequence, by 4 feet of dense black dolomite and 4 feet of dark-gray dolomite containing fragments of unidentified brachiopods and irregularly scattered small pores apparently resulting from the removal of microfossils. Similar pore spaces occurred in dark-gray dolomite in core 192. The driller's foot-by-foot record of coring time for core 191 shows that at the depth of 20,284 feet the coring time of 20 minutes-per-foot dropped to 15 minutes-per-foot, followed by a further decrease to 10 minutes-per-foot at 20,285 feet. From 20,285 to 20,294 feet, the rate varied between 10 and 15 minutes-per-foot, increasing to 20 and 30 minutes-per-foot from 20,294 to 20,298 feet.

The pore spaces in the dark-gray dolomite in cores 191 and 192 were the first and only local area of porosity observed in the cored section. The pores,

considered in connection with the interval of relatively soft drilling in core 191, lead to the conclusion that the heads of gas came from the dolomite at or near the depth where the showing occurred.

The oil showings in Vasen Fee well 1 are apparently indigenous and occurred as films of light oil on the surface of fresh fractures in dolomitic limestone and dolomite. The film of oil evaporated rapidly after exposure to the air. The highest showing occurred in core 165 at the depth of about 19,215 feet; the deepest showing was in core 194 at about 20,360 feet.

Most of the oil showings associated with fractures are scattered at irregular intervals between the depths of 19,215 feet and 19,660 feet. The showings at the different levels are frequently concentrated in about 4 or 5 feet of a core and are separated by apparently barren intervals that range in thickness from a few feet to about 50 feet. Below the depth of 19,660 feet, the showings occur less frequently and are more widely spaced. Based on observation of the cores, and without the benefit of chemical tests, the showings just described apparently are not related to or derived from the oil-base drilling mud.

Paleontology

Specimens of megascopic fossils and ostracodes occurring in cores from the Vasen well were studied in Washington. Ralph W. Imlay reported on mollusks, crustaceans, and brachiopods; I. G. Sohn reported on the ostracodes. G. Arthur Cooper, U. S. National Museum, Washington, D. C., studied and reported on several of the brachiopod specimens. The paleontologic studies show that the sediments in which the fossils occur are definitely not older than Jurassic. The list that follows gives the names of the fossils that were identified in the different cores, the core numbers, and the depths at which the fossils occurred.

| Core no. | Depth (feet) | Fossils |
|----------|----------------------|--|
| 38 | 15,647 | <u>Lopha</u> sp. |
| 45 | 15,823-15,850 bottom | <u>Cyzicus</u> (= <u>Estheria</u>) sp. |
| 58 | 16,170-16,197 bottom | <u>Astarte</u> (<u>Coelastarte</u>) cf. <u>A. rathieri</u> Lorient. |
| 59 | 16,197-16,224 top | Gastropod, undetermined. |
| | 16,204 | <u>Isocyprina</u> sp., <u>Eocallista</u> sp., <u>Quenstedtia</u> cf. <u>Q. weeksi</u> Imlay, <u>Trapezium</u> ? cf. <u>T. subtrigonum</u> Imlay, <u>Tancredia</u> sp., <u>Grammatodon</u> ? sp. |
| 74 | 16,597-16,624 middle | <u>Voltsella</u> sp., <u>Voltsella</u> ? sp., <u>Extogyra</u> cf. <u>E. potosina</u> Castillo and Aguilera, <u>Pteroperna</u> ? sp., <u>Paracypris</u> ?, <u>Gomphocythere</u> ?, undetermined Ostracoda, Charophytes. |
| 75 | 16,624-16,651 middle | <u>Cyzicus</u> (= <u>Estheria</u>) sp. |
| 76 | 16,651-16,678 middle | Ostracoda, undetermined. |
| | 16,695 top | <u>Lopha</u> sp. |
| 77 | 16,786-16,813 bottom | <u>Cyzicus</u> (= <u>Estheria</u>) spp., <u>Tancredia</u> sp., <u>Schuleridea</u> ?, sp. aff. <u>Paracypris</u> Swain. |
| 81 | 16,786-16,813 bottom | <u>Exogyra</u> cf. <u>E. virgula</u> (DeFrance), <u>Chlamys</u> sp., ammonite, lateral lappet. |
| | 16,895 | <u>Exogyra</u> ? sp. |
| | 16,902 | <u>Exogyra</u> cf. <u>E. virgula</u> (DeFrance). |
| 152 | 18,702 | " <u>Cythereis</u> " sp. 1, <u>Cytheridea</u> s. l?, <u>Cypridea</u> s. l? Ostracoda, undetermined. |
| | 18,707-18,708 | Gastropod, undetermined, " <u>Cythereis</u> " sp. 2, <u>Illiciocypris</u> ? |
| 154 | 18,749-18,750 | <u>Cyzicus</u> (= <u>Estheria</u>) sp., " <u>Cythereis</u> " sp. 2?, <u>Cytheridea</u> s. l? <u>Lucina</u> sp. |

| Core no. | Depth (feet) | Fossils |
|----------|---------------|---|
| 155 | 18,767 | <u>Astarte grubbi</u> Imlay, <u>Trigonia</u> sp., <u>Coelastarte</u> sp., <u>Corbicellopsis</u> sp. |
| | 18,768 | <u>Entolium</u> sp. |
| | 18,769 | Perisphinctid ammonite |
| | 18,774 | <u>Cercomya</u> ? sp. |
| | 18,770-18,776 | <u>Astarte</u> ?, <u>Tancredia</u> ?, <u>Eocallista</u> ? |
| | 18,782-18,788 | <u>Lucina</u> sp., <u>Entolium</u> sp. |
| | 18,788-18,791 | <u>Corbicellopsis</u> ?, <u>Tancredia</u> ?, <u>Gervillia</u> , <u>Entolium</u> . |
| 157 | 18,812 | <u>Pleuromya</u> sp. |
| | 18,816 | <u>Isocyprina</u> ?, <u>Quenstedtia</u> ? |
| | 18,811-18,818 | <u>Exogyra</u> sp. juv. |
| | 18,824 | <u>Tancredia</u> ? |
| | 18,821-18,826 | <u>Lingula</u> ?, <u>Astarte</u> sp. |
| | 18,827 | <u>Exogyra</u> sp. juv., <u>Cyzicus</u> (= <u>Estheria</u>) sp. |
| 158 | 18,866 | <u>Cyzicus</u> (= <u>Estheria</u>) sp. |
| 163 | 19,081-19,086 | <u>Isocyprina</u> ? sp. |
| 166 | 19,266-19,276 | Terebratulid brachiopod. |
| 167 | 19,314 | <u>Exogyra</u> sp. juv. |
| 184 | 19,942-19,990 | <u>Chlamys</u> (<u>Camptochlamys</u>), brachiopod fragments. |
| 185 | 19,990-20,040 | Rhynchonellid and terebratulid brachiopods, <u>Sphaera</u> sp., undetermined pelecypod. |
| 191 | 20,277-20,298 | Brachiopod fragments. |

Lithology

Full recovery was obtained for each core taken in the Vasen well except as stated otherwise on the graphic log (pl. 1) and in the lithologic descriptions given below. In cores having less than 100 percent

recovery, the lithologic symbols representing the recovered fraction are shown on the graphic log beginning at the top of the core; space proportionate to the unrecovered fraction is shown by the symbol for "No samples" in the lower part of the core.

Lithologic description of cores

| Core no. | Depth (feet) | Description |
|----------|---------------|--|
| 1 | 14,670-14,696 | No samples. |
| 2 | 14,696-14,722 | No samples. |
| 3 | 14,722-14,748 | <u>Top</u> .—Shale, brownish-red, hard, silty, calcareous, highly and finely micaceous. <u>Middle</u> .—Shale, dark brownish-red, calcareous, somewhat finely micaceous. <u>Bottom</u> .—Shale, dull dark brownish-red, hard, calcareous, highly and finely micaceous; contains a few small red limestone inclusions. |
| 4 | 14,748-14,774 | <u>Top</u> .—Shale, dark brownish-red, calcareous, finely micaceous. <u>Middle</u> .—Shale, dark-gray, silty, slightly calcareous, micaceous, slightly carbonaceous. <u>Bottom</u> .—Shale, dark brownish-red, calcareous, finely micaceous. |
| 5 | 14,774-14,800 | <u>Top</u> .—Shale, as in bottom of core 4. <u>Middle</u> .—Shale, like bottom of core 4, dark-red with a few small bluish-gray to green patches. <u>Bottom</u> .—Shale, dark brownish-red, moderately hard, calcareous, highly and finely micaceous. |
| 6 | 14,800-14,825 | <u>Top</u> .—Shale, dull dark-red with some greenish-gray mottling, highly calcareous, marly. <u>Middle</u> .—Shale, like top with gray mottling in about 50 percent of sample; highly silty. <u>Bottom</u> .—Shale, dark brownish-red, hard, highly calcareous, sparsely and finely micaceous. |
| 7 | 14,825-14,851 | <u>Top</u> .—Shale; lenses of dark-red shale, similar to bottom of core 6, and hard slightly calcareous gray shale. <u>Middle and bottom</u> .—Shale, dark brownish-red, hard, calcareous, finely micaceous. |
| 8 | 14,851-14,877 | <u>Top</u> .—Shale, like middle and bottom of core 7, containing a few small sandstone inclusions. <u>Middle</u> .—Shale, dark brownish-red, irregularly streaked and spotted with greenish-gray highly silty shale; both shales micaceous and highly calcareous. <u>Bottom</u> .—Shale, dark brownish-red, somewhat silty, sparsely and finely micaceous. |
| 9 | 14,877-14,904 | <u>Top</u> .—Shale, dark brownish-red, hard, somewhat finely micaceous. <u>Middle and bottom</u> .—Shale, dark brownish-red, calcareous, highly and finely micaceous. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|---|
| 10 | 14,904-14,930 | <u>Top.</u> —Shale, dark brownish-red, somewhat darker and duller than core 9, slightly calcareous, very finely micaceous. <u>Middle and bottom.</u> —Shale, like top; many small slickensided areas. |
| 11 | 14,930-14,956 | <u>Top.</u> —Shale, dark brownish-red, hard, calcareous, highly and finely micaceous; a few small greenish-gray silty areas. <u>Middle.</u> —Shale, dark brownish-red, slightly calcareous, sparsely and finely micaceous. <u>Bottom.</u> —Siltstone, grayish-red, hard, dense, calcareous, finely micaceous, containing lenses of dull dark brownish-red shale. |
| 12 | 14,956-14,982 | <u>Top.</u> —Siltstone and shale, thinly and irregularly interbedded. Gray calcareous highly micaceous siltstone. Dark brownish-red highly silty and micaceous shale. <u>Middle.</u> —Shale, dark brownish-red, calcareous, finely micaceous. <u>Bottom.</u> —Sandstone, grayish-red, hard, dense, calcareous, very highly micaceous along parting planes. |
| 13 | 14,982-15,008 | <u>Top.</u> —Shale, dark brownish-red with a few small greenish-gray areas, hard, irregularly silty, calcareous, highly and finely micaceous. <u>Middle.</u> —Shale, dark brownish-red mottled with greenish-gray, micaceous; contains dark-red irregular limestone areas. <u>Bottom.</u> —Shale, dark-gray, interbedded with thin lenses of dark-red shale. The dark-gray shale is highly micaceous, contains thin irregular lenses of lighter gray dense calcareous siltstone. |
| 14 | 15,008-15,034 | <u>Top.</u> —Sandstone, light-tan to gray, fine- to medium-grained, calcareous; contains lenses of highly micaceous greenish-gray sandstone. Conglomeratic appearance due to irregular areas of dark-gray shale and greenish-gray silty limestone. <u>Middle.</u> —Shale, dark brownish-red, hard, highly silty and micaceous, calcareous. <u>Bottom.</u> —Shale, dark brownish-red, hard, highly and finely micaceous. |
| 15 | 15,034-15,060 | No samples. |
| 16 | 15,060-15,087 | <u>Top, middle, and bottom.</u> —Sandstone, dark grayish-red, hard, medium-grained to conglomeratic, highly calcareous. |
| 17 | 15,087-15,114 | <u>Top.</u> —Sandstone, light reddish-gray, medium-grained to moderately coarse grained, highly calcareous, micaceous. <u>Middle.</u> —Shale and sandstone lenses containing scattered flakes of colorless mica and many fragments of lignite. Dark brownish-red slightly calcareous slightly micaceous shale. Light-gray dense calcareous sandstone; conglomeratic appearance due to irregular patches of dark-gray carbonaceous shale. <u>Bottom.</u> —Shale as in middle of core. At 15,097 ft, a lense of micaceous dense medium-grained white conglomeratic sandstone contains many irregular hard gray shale inclusions and pebbles of dark-gray limestone. |
| 18 | 15,114-15,141 | <u>Top, middle, and bottom.</u> —Shale, dark brownish-red, silty, highly and finely micaceous. |
| 19 | 15,141-15,167 | <u>Top.</u> —Shale, dull dark brownish-red, slightly sandy, highly micaceous. <u>Middle.</u> —Shale, dark brownish-red, irregularly sandy, highly calcareous and micaceous. <u>Bottom.</u> —Sandstone, dark grayish-red, dense, fine-grained, calcareous. |
| 20 | 15,167-15,193 | <u>Top.</u> —Shale, dark brownish-red, hard, micaceous. <u>Middle.</u> —Limestone, dark-red, hard, shaly. <u>Bottom.</u> —Sandstone, grayish- to dark-red, fine-grained, calcareous, micaceous. |
| 21 | 15,193-15,219 | <u>Top.</u> —Sandstone, dark grayish-red, hard, dense, medium-grained, calcareous, micaceous. <u>Middle.</u> —Shale, dark brownish-red; slickensided areas. <u>Bottom.</u> —Shale, dark brownish-red, hard, silty, somewhat finely micaceous. |
| 22 | 15,219-15,245 | <u>Top.</u> —Shale, dark brownish-red, slightly calcareous, highly and finely micaceous. <u>Middle.</u> —Shale, dark-gray, highly micaceous especially on parting planes; contains irregular streaks of greenish-gray calcareous highly micaceous sandstone. <u>Bottom.</u> —Shale and sandstone. Dark-red smooth-textured noncalcareous somewhat finely micaceous shale. Light greenish-gray dense fine- to medium-grained highly calcareous micaceous sandstone. |

Lithologic description of cores--Continued

| Core no. | Depth (feet) | Description |
|----------|-----------------|---|
| 23 | 15, 245-15, 271 | <u>Top.</u> —Sandstone, dull grayish-red, dense, fine-grained, shaly, highly calcareous, micaceous. <u>Middle.</u> —Sandstone, greenish-gray, dense, medium-grained, calcareous, micaceous with many copper-colored flakes. <u>Bottom.</u> —Shale, dark brownish-red, slightly calcareous, micaceous. |
| 24 | 15, 271-15, 298 | <u>Top.</u> —Sandstone, gray, fine- to medium-grained, calcareous, highly micaceous; many thin shaly dark-gray very highly micaceous partings. <u>Middle.</u> —Shale, gray, hard, silty or very finely granular, noncalcareous, micaceous. <u>Bottom.</u> —Shale, brownish-red, noncalcareous, micaceous. |
| 25 | 15, 298-15, 324 | <u>Top.</u> —Sandstone, brownish-red, dense, micaceous, irregularly streaked with highly calcareous red shale. <u>Middle.</u> —Shale, dark brownish-red, highly silty and calcareous, somewhat finely micaceous. <u>Bottom.</u> —Sandstone, light-gray, hard, fine-grained, calcareous; laminated with many thin very highly micaceous partings. |
| 26 | 15, 324-15, 350 | <u>Top.</u> —Shale, red, noncalcareous, slightly micaceous. <u>Middle.</u> —Sandstone, shaly, red, medium-grained, micaceous. <u>Bottom.</u> —Similar to middle part but more highly micaceous, somewhat coarser grained, and slightly calcareous. |
| 27 | 15, 350-15, 376 | <u>Top.</u> —Sandstone, light reddish-tan, hard, medium-grained, slightly calcareous, micaceous with many highly micaceous irregular partings. <u>Middle.</u> —Shale, red, slightly calcareous, finely and highly micaceous. <u>Bottom.</u> —Shale, brownish-red, hard, dense, calcareous. |
| 28 | 15, 376-15, 402 | <u>Top.</u> —Sandstone, shaly, grayish-red, fine-grained, calcareous, micaceous. <u>Middle.</u> —Shale, dark-red, irregularly silty, slightly calcareous, finely micaceous. <u>Bottom.</u> —Sandstone, shaly, light brownish-red, fine-grained, highly calcareous, micaceous. |
| 29 | 15, 402-15, 429 | <u>Top.</u> —Sandstone, red, hard, fine-grained, argillaceous, calcareous, micaceous. <u>Middle.</u> —Shale, dark-red with a few small gray-green mottlings, slightly calcareous, slickensided. <u>Bottom.</u> —Shale, red, silty to highly sandy; contains blue-green sandy areas in which sand is fine-grained, calcareous, and micaceous. |
| 30 | 15, 429-15, 456 | <u>Top.</u> —Shale, red, highly micaceous with a few small greenish-blue or gray sandy areas. <u>Middle.</u> —Shale, red, silty, calcareous, micaceous. <u>Bottom.</u> —Sandstone, light-red, fine-grained, argillaceous, calcareous, micaceous. |
| 31 | 15, 456-15, 483 | <u>Top.</u> —Shale, red, hard, noncalcareous. <u>Middle.</u> —Sandstone, light greenish-gray, hard, medium-grained, argillaceous, highly calcareous, with very highly micaceous partings. <u>Bottom.</u> —Shale, sandy, dark brownish-red, micaceous. Fine- to medium-grained slightly calcareous sand. |
| 32 | 15, 483-15, 510 | <u>Top, middle, and bottom.</u> —Shale, dark brownish-red, hard, calcareous, very highly micaceous. |
| 33 | 15, 510-15, 534 | <u>Top.</u> —Shale, dark reddish-brown, silty, slightly calcareous, highly micaceous. <u>Middle.</u> —Shale and sandstone. Dark-gray noncalcareous micaceous shale with irregular dark brownish-red streaks. Red hard moderately coarse grained argillaceous highly calcareous micaceous sandstone. <u>Bottom.</u> —Sandstone, light-red, hard, medium-grained, argillaceous, calcareous, micaceous; contains a thin lens of light greenish-gray sandstone, moderately coarse grained, calcareous, and micaceous. |
| 34 | 15, 534-15, 560 | <u>Top.</u> —Sandstone, light greenish-gray as in bottom of core 33. <u>Middle.</u> —Shale, sandy, dark brownish-red, slightly calcareous, micaceous. <u>Bottom.</u> —Sandstone, shaly, dark-red, hard, highly calcareous, micaceous. |
| 35 | 15, 560-15, 586 | <u>Top.</u> —Sandstone, red, fine- to medium-grained, slightly calcareous with a few irregular red shale inclusions. <u>Middle.</u> —Shale, red, silty, micaceous with very highly micaceous partings. <u>Bottom.</u> —Sandstone, light-gray, dense, medium-grained to moderately coarse grained, highly calcareous; conglomeratic appearance due to inclusions of lignite, black carbonaceous shale, and hard gray-green siltstone. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|---|
| 36 | 15,586-15,612 | <u>Top.</u> —Siltstone, greenish-gray, hard, calcareous. <u>Middle.</u> —Sandstone, light greenish-gray, very dense (quartzitic); fine- to medium-grained, calcareous. <u>Bottom.</u> —Shale, red, unctuous, with some greenish-blue mottling. At 15,604 ft, shale similar to above but highly silty, contains a thin layer of greenish-gray cryptocrystalline limestone. At 15,605 ft, red and blue-green mottled silty to sandy shale, contains one fragment of pink anhydrite. |
| 37 | 15,612-15,638 | <u>Top.</u> —Shale, dark reddish-brown, hard, silty, noncalcareous, micaceous. <u>Middle.</u> —Similar to top of core, but highly and finely sandy, highly micaceous. <u>Bottom.</u> —Shale, red with small blue-green mottlings, contains calcite inclusions and irregular areas of red limestone. |
| 38 | 15,638-15,664 | <u>Top and middle.</u> —Shale, dark brownish-red, hard, slightly calcareous and micaceous. <u>Bottom.</u> —Sandstone and shale. Grayish-red hard medium-grained highly calcareous, micaceous sandstone. Dark-gray hard shale, with thin lenses of greenish-gray micaceous sandstone and a lens of dark brownish-red sandy highly calcareous micaceous shale. At 15,647 ft, dark-gray hard shaly limestone contains fossil fragments and nearly complete bivalve shells; a lens of dark brownish-red hard shale shows a large slickensided surface. |
| 39 | 15,664-15,691 | <u>Top.</u> —Shale, dark brownish-red, irregularly gray-green mottled, silty, with a few irregular areas of red dense fine-grained sandstone. <u>Middle.</u> —Shale, dark brownish-red, calcareous, finely micaceous. <u>Bottom.</u> —Sandstone, grayish-red, dense, coarse-grained, highly calcareous, thickly and irregularly streaked and spotted with red shale fragments giving a conglomeratic appearance; contains a lens of dark-gray hard noncalcareous shale. |
| 40 | 15,691-15,718 | <u>Top.</u> —Sandstone and shale. Sandstone, white, dense, hard, highly calcareous, slightly micaceous. <u>Middle.</u> —Shale, dull reddish-brown, hard, slightly calcareous. <u>Bottom.</u> —Shale, brownish-red, hard, silty, noncalcareous, highly and finely micaceous. |
| 41 | 15,718-15,745 | <u>Top.</u> —Shale, like bottom of core 40. <u>Middle.</u> —Shale, red, slightly and finely micaceous. <u>Bottom.</u> —Shale, red, slightly calcareous, highly and finely micaceous. |
| 42 | 15,745-15,770 | <u>Top, middle, and bottom.</u> —Shale, red, finely sandy, calcareous, micaceous. |
| 43 | 15,770-15,797 | <u>Top.</u> —Like core 42. <u>Middle.</u> —Sandstone, reddish-brown, very dense, fine- to medium-grained, highly calcareous, micaceous, with many thin very highly micaceous red shale partings. <u>Bottom.</u> —Shale, red, calcareous, micaceous, with irregular highly sandy layers. |
| 44 | 15,797-15,823 | <u>Top, middle, and bottom.</u> —Shale, reddish-brown, hard, noncalcareous, somewhat micaceous. |
| 45 | 15,823-15,850 | <u>Top.</u> —Sandstone, light-gray, very dense, fine-grained, quartzitic, calcareous. <u>Middle.</u> —Shale, brownish-red with greenish-gray mottling, hard, highly silty; contains irregular areas of red limestone. <u>Bottom.</u> —Shale, dark brownish-red, hard, slightly calcareous, finely micaceous. |
| 46 | 15,850-15,876 | <u>Top.</u> —Shale, dark-red, calcareous, sparsely and finely micaceous. <u>Middle.</u> —Sandstone, gray, moderately coarse grained, highly calcareous, micaceous, with lenses of highly micaceous black shale. Irregularly shaped inclusions of black micaceous shale give sandstone a conglomeratic appearance. <u>Bottom.</u> —Shale, dark-red, silty, slightly calcareous, micaceous; contains a few questionable impressions of fossils. |
| 47 | 15,876-15,902 | <u>Top.</u> —Shale, like bottom of core 46, but highly silty and more micaceous. <u>Middle.</u> —Shale, dark brownish-red, silty, slightly calcareous, micaceous. <u>Bottom.</u> —Shale, red with greenish-gray mottling, slightly calcareous, finely micaceous. |
| 48 | 15,902-15,929 | <u>Top.</u> —Shale, dark-red, finely micaceous. <u>Middle.</u> —Sandstone, grayish-red, moderately hard, fine- to medium-grained, argillaceous, highly calcareous, micaceous. <u>Bottom.</u> —Sandstone, light-gray, calcareous, micaceous, with many paper-thin very highly micaceous lenses and partings. At 15,907 ft, light-gray dense moderately coarse grained calcareous micaceous sandstone, containing a thin lens of highly carbonaceous black shale. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|---|
| 49 | 15,929-15,955 | <u>Top.</u> —Sandstone, like bottom of core 48; a few thin highly micaceous lenses and scattered blebs of black shale. <u>Middle.</u> —Shale and shaly sandstone, irregularly interbedded. Black micaceous shale. Dull dark-brown slightly calcareous finely micaceous sandstone. <u>Bottom.</u> —Shale, dark brownish-red, silty, slightly calcareous, very highly and finely micaceous. |
| 50 | 15,955-15,982 | <u>Top.</u> —Shale and sandstone. Shale is in part, dark brownish-red, hard, dense, and non-calcareous and in part, dark-gray sandy noncalcareous and micaceous. Light greenish-gray dense moderately coarse grained sandstone, with many thin lenses or partings of mica in a small amount of shale. At 15,956 ft, hard highly micaceous sandstone. <u>Middle.</u> —Shale, dark brownish-red, moderately hard, micaceous. <u>Bottom.</u> —Shale and sandstone. Dark brownish-red highly silty and very finely micaceous noncalcareous shale. Gray hard highly micaceous sandstone with many thin partings. Another part of core is composed of light greenish-gray dense fine- to medium-grained shaly micaceous sandstone. |
| 51 | 15,982-16,009 | <u>Top.</u> —Shale, dark brownish-red, silty, noncalcareous, highly micaceous. <u>Middle.</u> —Sandstone and shale. Lenticular light-gray and red dense fine- to medium-grained argillaceous noncalcareous micaceous sandstone. Gray hard sandy irregularly bedded shale; contains fragments of lignite showing wood structure. <u>Bottom.</u> —Shale, dark brownish-red, noncalcareous, highly and very finely micaceous. |
| 52 | 16,009-16,035 | <u>Top, middle, and bottom.</u> —Shale, as in bottom of core 51. |
| 53 | 16,035-16,062 | <u>Top.</u> —Shale, dark brownish-red, hard, highly silty and micaceous, noncalcareous. <u>Middle.</u> —Shale or shaly sandstone, dark-gray, hard, noncalcareous, laminated with many thin lenses of mica. <u>Bottom.</u> —Sandstone, light-gray, coarse-grained, calcareous, micaceous, with thin irregular inclusions of black micaceous shale. |
| 54 | 16,062-16,089 | <u>Top.</u> —Sandstone, light-gray, hard, dense, fine-grained, argillaceous, noncalcareous, with irregular lenticular partings of mica flakes. <u>Middle.</u> —Shale, in part, dark brownish-red, hard, noncalcareous, micaceous; in part, dark-gray, micaceous, with thin lenses of very dense noncalcareous dark greenish-gray sandstone. <u>Bottom.</u> —Shale and conglomeratic sandstone. Dark brownish-red shale. Hard, dense fine-grained calcareous conglomeratic sandstone, containing many large nodular inclusions of black shale and brownish-gray limestone with one bleb of white calcite. |
| 55 | 16,089-16,116 | <u>Top.</u> —Sandstone and shale. Gray fine-grained calcareous sandstone. Dark-gray noncalcareous shale. <u>Middle.</u> —Shale, dark brownish-red, irregularly silty, noncalcareous, micaceous. <u>Bottom.</u> —Shale, red, dense, slightly and finely micaceous. |
| 56 | 16,116-16,143 | <u>Top.</u> —Shale, like bottom of core 55. <u>Middle.</u> —Sandstone, conglomeratic, white, fine-grained, calcareous, with abundant irregular nodules of red shale, a few of black shale, and a few of red limestone. <u>Bottom.</u> —Shale, dark brownish-red, hard, noncalcareous, finely micaceous. |
| 57 | 16,143-16,170 | <u>Top.</u> —Shale, like bottom of core 56. <u>Middle.</u> —Shale, hard, highly silty, noncalcareous, micaceous. <u>Bottom.</u> —Shale, dark brownish-red with small greenish-gray mottlings, noncalcareous. |
| 58 | 16,170-16,197 | <u>Top and middle.</u> —Shale, like bottom of core 57. <u>Bottom.</u> —No sample. |
| 59 | 16,197-16,224 | No samples. |
| 60 | 16,224-16,251 | <u>Top.</u> —Sandstone, gray, dense, medium-grained, slightly micaceous and carbonaceous, chloritic(?); contains lenses of hard highly and finely sandy somewhat micaceous gray shale. <u>Middle.</u> —Sandstone, gray, dense, medium-grained, chloritic(?), micaceous with moderately large mica flakes; contains scattered inclusions of gray shale and lenses of finely sandy highly and finely micaceous dark brownish-red shale. At 16,237 ft, black micaceous irregularly silty shale, with many carbonized plant fragments and some pyritic inclusions. <u>Bottom.</u> —Sandstone, greenish-gray, dense, medium-grained, micaceous; contains scattered grains of a blue-green waxy-textured material, irregular inclusions of brownish-black shale, and thin partings of highly micaceous dark-gray shale. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|-----------------|---|
| 61 | 16, 251-16, 277 | <u>Top.</u> —Siltstone, greenish-gray, hard, with irregular inclusions and lenses of highly micaceous finely sandy reddish-brown gray-mottled shale. <u>Middle.</u> —Sandstone, greenish-gray, dense, fine-grained, micaceous, thickly and irregularly streaked with thin seams of carbonaceous brownish-black and brownish-red shale. At 16, 273 ft, gray finely sandy micaceous limestone, with occasional green grains and fragments of calcite; contains impressions of fossil bivalves; a few small crevices filled with finely granular white anhydrite. <u>Bottom.</u> —Sandstone and sandy limestone, gray, dense, slightly micaceous; contains molds of fossil bivalves and a small amount of anhydrite in crevices. |
| 62 | 16, 277-16, 303 | <u>Top.</u> —Sandstone, gray, hard, dense, medium-grained, micaceous. <u>Middle.</u> —Shale, dark brownish-red, micaceous. <u>Bottom.</u> —Shale, like above, with lenses of dense medium-grained micaceous greenish-gray sandstone containing many small light blue-green shaly grains and peach-colored quartz(?) grains. |
| 63 | 16, 303-16, 330 | <u>Top.</u> —Sandstone, light greenish-gray, dense, medium-grained, micaceous. <u>Middle.</u> —Shale, black, hard, with small fragments of carbonaceous material. <u>Bottom.</u> —Shale, dark brownish-red, micaceous. |
| 64 | 16, 330-16, 356 | <u>Top, middle, and bottom.</u> —Shale, dark brownish-red, highly micaceous. |
| 65 | 16, 356-16, 383 | <u>Top.</u> —Shale, dark brownish-red with irregular small greenish-gray areas, micaceous. <u>Middle.</u> —Sandstone, light greenish-gray, dense, fine- to medium-grained, slightly micaceous. <u>Bottom.</u> —Shale, dark brownish-red, micaceous, showing slickensided surfaces. |
| 66 | 16, 383-16, 410 | <u>Top.</u> —Sandstone, brownish-gray, dense, fine-grained, micaceous, with occasional peach-colored grains; a small amount of blue-green shaly matrix. <u>Middle.</u> —Sandstone and siltstone. Light-gray dense medium-grained slightly micaceous pyritic sandstone; a few areas cemented with white finely granular anhydrite(?). Gray micaceous siltstone. <u>Bottom.</u> —Shale, dark brownish-red, micaceous. |
| 67 | 16, 410-16, 437 | <u>Top.</u> —Sandstone, brownish-red, dense, micaceous, irregularly and thickly streaked with highly micaceous brownish-red shale. <u>Middle.</u> —No samples. <u>Bottom.</u> —Shale and sandstone, interlaminated. Gray highly micaceous shale. Fine- to medium-grained shaly sandstone. |
| 68 | 16, 437-16, 464 | <u>Top.</u> —Siltstone, gray, hard, slightly micaceous. <u>Middle.</u> —Shale and sandstone. Dark brownish-red medium-grained sandy micaceous shale. Brownish-red medium-grained argillaceous micaceous sandstone. <u>Bottom.</u> —Sandstone, like above, containing moderately hard medium-grained argillaceous micaceous light greenish-gray lenses. |
| 69 | 16, 464-16, 489 | <u>Top.</u> —Shale and siltstone. Dark brownish-red and gray noncalcareous slightly micaceous shale, with gray-green mottling. Light greenish-gray siltstone. Another part of core is composed of gray-green unctuous shale, with small slickensided surfaces. <u>Middle.</u> —Shale, dark brownish-gray, silty, micaceous, with scattered carbonaceous fragments. <u>Bottom.</u> —Shale, gray, hard, noncalcareous. |
| 70 | 16, 489-16, 516 | <u>Top.</u> —Shale, gray with irregular dark streaks, somewhat silty; contains lenses of hard, dense gray sandstone, with irregular thin streaks of black carbonaceous shale. <u>Middle.</u> —Sandstone and shale. Gray hard, dense fine-grained sandstone, with many carbonaceous fragments. Dark-gray micaceous shale. <u>Bottom.</u> —Shale, gray, hard, granular-textured, calcareous, micaceous, with irregular silty areas. |
| 71 | 16, 516-16, 543 | <u>Top.</u> —Shale, dark-gray, containing thin veinlike streaks of lignite cut by calcite veinlets in a crosshatched pattern. <u>Middle.</u> —Limestone and sandstone. Dark-gray slightly sandy limestone, with impressions of fossil fragments. Light-gray dense fine- to medium-grained micaceous sandstone, with irregular thin streaks of shale. <u>Bottom.</u> —Shale, greenish-gray with brownish-red mottling, unctuous, irregularly micaceous. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|---|
| 72 | 16,543-16,570 | No sample. Tom McGlothlin, consulting geologist, Laurel, Miss., studied the core and described it as a greenish-gray silty micaceous shale containing a single fragment of pink anhydrite. |
| 73 | 16,570-16,597 | <u>Top.</u> —Shale, greenish-gray with brownish-red mottling, hard. <u>Middle.</u> —Sandstone, light-gray, dense, medium-grained, argillaceous. <u>Bottom.</u> —Limestone, gray, shaly, dense, hard, with fragments of fossil bivalves. |
| 74 | 16,597-16,624 | <u>Top.</u> —Limestone, dark-gray, shaly, with fragments of fossil bivalves. <u>Middle.</u> —Shale, gray-green or olive, unctuous, with small convex rounded holes of organic(?) origin and fragmental molds of fossil bivalves. <u>Bottom.</u> —Shale, dark-gray, highly calcareous, with many fragments of fossil bivalves. |
| 75 | 16,624-16,651 | <u>Top, middle, and bottom.</u> —Shale, dark-gray, hard, calcareous, containing ostracodes and many fragments of fossil bivalves and echinoid spines. |
| 76 | 16,651-16,678 | <u>Top.</u> —Shale, dark reddish-brown, calcareous, abundantly fossiliferous. <u>Middle.</u> —Shale, dark-gray, calcareous, with a few fossil fragments. <u>Bottom.</u> —Shale, dark-gray, calcareous, with abundant fossils and fossil fragments. |
| 77 | 16,678-16,705 | <u>Top and middle.</u> —Shale, dark-gray, calcareous, with abundant fossil fragments. <u>Bottom.</u> —Shale, dark-gray, hard, silty, with finely fragmental fossils. |
| 78 | 16,705-16,732 | <u>Top.</u> —Shale, dark-gray, calcareous, with molds and fragments of fossils. <u>Middle.</u> —Shale, greenish-gray or olive-gray with irregular red-brown mottling, unctuous, noncalcareous. <u>Bottom.</u> —Sandstone, dark-gray, hard, fine-grained, argillaceous, calcareous, micaceous, thinly and irregularly streaked with black shale. |
| 79 | 16,732-16,759 | <u>Top.</u> —Sandstone, dark-gray, hard, dense, micaceous, pyritic, with fragments of fossil bivalves, and veins of lignite cut by many reticulate calcite veinlets. <u>Middle.</u> —Shale, dark-gray, micaceous, noncalcareous, finely carbonaceous, containing lenses of light-gray dense fine-grained micaceous calcareous sandstone with many comminuted carbonaceous fragments. <u>Bottom.</u> —Shale, dark-gray, sandy, micaceous, with lenses of gray dense fine-grained sandstone; occasional fossil fragments. |
| 80 | 16,759-16,786 | <u>Top.</u> —Shale, gray, hard, silty, with a few fossil fragments and shreds of carbonaceous material. <u>Middle.</u> —Shale, dark-gray, hard, fine-grained, noncalcareous, with shreds of carbonaceous material. <u>Bottom.</u> —Shale, like above, with a few fragments of fossils and fossil impressions. |
| 81 | 16,786-16,813 | <u>Top.</u> —Shale, dark-gray, micaceous, irregularly and thinly laminated with silty to finely sandy lenses; carbonaceous fragments. <u>Middle.</u> —Sandstone, light-colored, very dense, quartzitic, containing moderately fine grains of calcite. <u>Bottom.</u> —Shale, dark brownish-red, somewhat finely sandy, noncalcareous, micaceous; contains a few molds of bivalves and a few ostracodes. |
| 82 | 16,813-16,840 | <u>Top.</u> —Dolomitic limestone(?) or hard silty shale(?) with reddish mottling and a few thin streaks and small inclusions of red shale. Material has the texture of limestone but does not react with cold acid. <u>Middle.</u> —Shale, gray, unctuous. <u>Bottom.</u> —Shale, dark reddish-brown, slightly gray-green mottled, unctuous, noncalcareous. |
| 83 | 16,840-16,866 | <u>Top.</u> —Shale, greenish-gray with brownish-red mottling, hard, noncalcareous. <u>Middle.</u> —Shale, black with occasional brownish-red mottling, unctuous; traces of carbonaceous material; slickensided surfaces. <u>Bottom.</u> —Shale and sandstone. Brownish-red shale with gray mottling. Gray dense fine-grained noncalcareous finely micaceous sandstone. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|--|
| 84 | 16,866-16,890 | <u>Top.</u> —Sandstone and siltstone. Gray dense highly micaceous slightly calcareous sandstone; a trace of chlorite(?) and comminuted carbonaceous material. Light-gray hard dense micaceous slightly calcareous siltstone. <u>Middle.</u> —Sandstone, gray, dense, medium-grained, argillaceous, calcareous, with white finely granular anhydrite(?) cement; a trace of chlorite(?); small fragments of lignite and pyritized lignite. <u>Bottom.</u> —Limestone and shale. Dark-gray shaly hard silty limestone. Dark-gray hard waxy textured shale; contains one impression of a fossil fragment, several small fragments of lignite, and lenses of greenish-gray red-mottled hard unctuous shale. |
| 85 | 16,890-16,917 | <u>Top.</u> —Limestone(?) or calcareous siltstone(?), dark-gray, hard, with shreds of carbonaceous material. <u>Middle.</u> —Shale, dark brownish-red with small blue-green mottlings, hard, waxy. <u>Bottom.</u> —Shale, greenish-gray with brownish-red mottling, hard, silty, slightly micaceous, possibly dolomitic. Material has the texture of limestone but does not react with cold acid. |
| 86 | 16,917-16,944 | <u>Top.</u> —Shale, dark-gray. <u>Middle.</u> —Shale, gray, hard, micaceous, with irregular streaks of brownish-red shale. <u>Bottom.</u> —Shale, dark-gray, hard, highly micaceous. |
| 87 | 16,944-16,971 | <u>Top and middle.</u> —Shale, dark-gray, hard, slightly micaceous, noncalcareous. <u>Bottom.</u> —Sandstone, light-gray, dense, fine-grained, micaceous; contains carbonaceous fragments and thin lenses of black carbonaceous finely and highly micaceous shale. |
| 88 | 16,971-16,998 | <u>Top.</u> —Shale, gray, silty, hard, slightly micaceous, with texture of limestone but does not react with cold acid. Black shale, containing many lenses and veins of lignite or lignitic material cut by reticulate calcite veinlets. Lignite shows well-defined wood structure. <u>Middle.</u> —Sandstone, light-gray, moderately hard, argillaceous, calcareous, with many streaks and blebs of black carbonaceous shale and a minor amount of pyritized lignite. <u>Bottom.</u> —Shale, dark-gray, hard, silty, with texture of limestone but does not react with cold acid; a small amount of dark brownish-red shale. |
| 89 | 16,998-17,025 | <u>Top, middle, and bottom.</u> —Shale, dark reddish-brown, slightly micaceous, slightly streaked with gray-green shale. |
| 90 | 17,025-17,052 | <u>Top.</u> —Shale, dark brownish-red. <u>Middle.</u> —Shale, dark reddish-brown, highly micaceous. <u>Bottom.</u> —Shale, like above, with blue-green streaks and splotches; occasional slickensided surfaces. |
| 91 | 17,052-17,067 | <u>Top.</u> —Shale, dark brownish-red, highly micaceous. <u>Middle.</u> —Sandstone, very hard, dense, highly calcareous; contains fine-grained reddish-brown mica, green chlorite(?) grains, and peach-colored feldspar grains. <u>Bottom.</u> —Shale, dark brownish-red with gray-green mottling, unctuous, slickensided. |
| 92 | 17,067-17,094 | <u>Top and middle.</u> —Shale, dark brownish-red, micaceous. <u>Bottom.</u> —Shale, sandstone, and lignite in interbedded thin lenses. Dark-gray hard shale. Conglomeratic sandstone, with many irregularly shaped angular to rounded fragments of hard dark-gray shale and carbonaceous material in matrix of light-gray dense fine-grained calcareous sand. |
| 93 | 17,094-17,121 | <u>Top.</u> —Shale, dark brownish-red with blue-green streaks and spots, unctuous. <u>Middle.</u> —Shale, dark brownish-gray, silty, highly micaceous. <u>Bottom.</u> —Shale, dull-red, hard, dense, granular-textured. |
| 94 | 17,121-17,148 | <u>Top.</u> —Shale, dark brownish-red with dark greenish-gray mottling, micaceous. <u>Middle.</u> —Shale, dark brownish-red, micaceous, hard. <u>Bottom.</u> —Shale, like above, irregularly sandy. |
| 95 | 17,148-17,175 | <u>Top and middle.</u> —Shale, dark brownish-red. <u>Bottom.</u> —Sandstone, light-gray, dense, medium- to coarse-grained, calcareous, micaceous; composed of clear quartz grains, a few pink feldspar grains, and green chlorite(?) flakes. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|--|
| 96 | 17,175-17,202 | <u>Top</u> .—Shale, dark brownish-red, hard. <u>Middle</u> .—Sandstone and shale. Greenish-gray dense very fine grained calcareous sandstone, with irregular thin lenses of greenish-gray shale. Dark brownish-red finely micaceous shale, streaked with red sandstone. <u>Bottom</u> .—Shale, dark brownish-red, finely and highly micaceous. |
| 97 | 17,202-17,229 | <u>Top and middle</u> .—No samples. <u>Bottom</u> .—Sandstone, dull grayish-red, dense, medium-grained, calcareous, micaceous. |
| 98 | 17,229-17,256 | <u>Top</u> .—Sandstone and shale. Light pinkish-gray micaceous moderately coarse grained sandstone, composed mainly of clear quartz with many reddish or peach-colored feldspar grains, many blue-green chlorite(?) flakes, and a few black shale inclusions. Dark brownish-red finely micaceous shale. <u>Middle</u> .—Sandstone and shale. Light greenish-gray dense medium-grained to moderately coarse grained calcareous, micaceous sandstone, with occasional chlorite(?) flakes. Dark brownish-red finely and highly micaceous shale. <u>Bottom</u> .—Shale, like above but moderately micaceous. |
| 99 | 17,256-17,283 | <u>Top</u> .—Shale, dark brownish-red, with a few thin blue-green veinlike streaks. <u>Middle</u> .—Sandstone, gray, dense, moderately coarse grained, highly micaceous, with scattered grains of red feldspar. <u>Bottom</u> .—Shale and sandstone. Dark brownish-red slightly and finely micaceous shale. Greenish-gray hard slightly calcareous finely micaceous sandstone. |
| 100 | 17,283-17,310 | <u>Top</u> .—Sandstone, dark brownish-red, dense, fine- to medium-grained, calcareous. <u>Middle</u> .—Shale, dark brownish-red, irregularly sandy, calcareous, with nodular inclusions of red limestone. <u>Bottom</u> .—Shale, dark brownish-red, calcareous; contains a few scattered streaks of calcareous fine-grained blue-gray sandstone. |
| 101 | 17,310-17,337 | <u>Top</u> .—Shale, dark brownish-red, highly and irregularly sandy; sand is medium grained, highly micaceous, and calcareous. <u>Middle</u> .—Sandstone, light-gray, moderately coarse, with lenses of dark-gray very highly micaceous shale. <u>Bottom</u> .—Sandstone, light-gray, medium-grained to moderately coarse grained, calcareous, micaceous. |
| 102 | 17,337-17,364 | <u>Top</u> .—Sandstone and shale. Conglomeratic sandstone, with irregularly distributed gray and brownish-gray pebbles and limestone nodules. <u>Middle</u> .—Mainly shale, dark reddish-brown, hard, calcareous, containing large fragments of lignitic plant material cut by thin calcite veins. Parts of core are a conglomerate composed of small fragments of lignite and nodules of dark-gray limestone. <u>Bottom</u> .—Sandstone, light-gray, dense, medium-grained, calcareous, micaceous. |
| 103 | 17,364-17,391 | <u>Top</u> .—No samples. <u>Middle</u> .—Shale, greenish-gray, very hard, dense, silty, slightly calcareous and micaceous. <u>Bottom</u> .—Shale, dark brownish-red, finely micaceous. |
| 104 | 17,391-17,417 | <u>Top</u> .—Sandstone, dark brownish-red, hard, dense, moderately coarse grained, calcareous. <u>Middle</u> .—Sandstone, light greenish-gray, medium- to coarse-grained, calcareous, micaceous, with many blue-green chlorite(?) grains and many peach-colored feldspar grains. <u>Bottom</u> .—Shale, dark reddish-brown, hard, calcareous, micaceous. |
| 105 | 17,417-17,444 | <u>Top</u> .—Shale, dark reddish-brown, hard, finely and highly micaceous. <u>Middle</u> .—No samples. <u>Bottom</u> .—Sandstone, light greenish-gray, hard, dense, calcareous, with many small blue-green chlorite(?) grains and a few peach-colored feldspar grains. |
| 106 | 17,444-17,471 | <u>Top</u> .—Sandstone, gray, conglomeratic, moderately coarse grained, calcareous, micaceous, with many irregular stringers and inclusions of shaly limestone and irregular lenses of black micaceous shale. <u>Middle</u> .—Sandstone, light-gray, hard, fine-grained, argillaceous, calcareous, somewhat micaceous. <u>Bottom</u> .—Shale and sandstone. Dark brownish-red and gray hard silty calcareous finely micaceous shale. Light-gray hard medium-grained to moderately coarse grained calcareous micaceous sandstone, containing irregularly shaped inclusions of gray limestone. |

Lithologic description of cores--Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|---|
| 107 | 17,471-17,498 | <u>Top.</u> —Sandstone, greenish-gray, very dense, very fine-grained, quartzitic, highly calcareous. <u>Middle.</u> —Sandstone, dark reddish-brown, dense, fine-grained, quartzitic, highly calcareous. Other fragments of sandstone are light gray, coarse grained, and calcareous, with lenses of lignite and pyritized lignite cut by reticulate calcite veinlets. <u>Bottom.</u> —Shale, dark brownish-red, hard. |
| 108 | 17,498-17,525 | <u>Top.</u> —Sandstone, dark reddish-brown, dense, fine-grained, highly calcareous, slightly micaceous. <u>Middle and bottom.</u> —No samples. |
| 109 | 17,525-17,552 | <u>Top and middle.</u> —No samples. <u>Bottom.</u> —Shale, dark brownish-red, hard. |
| 110 | 17,552-17,579 | <u>Top.</u> —No samples. <u>Middle.</u> —Shale, dark brownish-red with a few small greenish-blue areas, hard. <u>Bottom.</u> —Shale, dark reddish-brown, calcareous, highly micaceous. |
| 111 | 17,579-17,606 | <u>Top.</u> —Sandstone, light-gray, moderately coarse grained, calcareous, somewhat micaceous, with small inclusions of dark-gray micaceous shale. <u>Middle.</u> —Sandstone, conglomeratic, calcareous, with many irregularly shaped fragments of gray shaly limestone and dark-gray micaceous calcareous shale. <u>Bottom.</u> —Sandstone, light-gray, dense, medium-grained to moderately coarse grained, calcareous, micaceous. |
| 112 | 17,606-17,631 | <u>Top.</u> —Limestone and sandstone. Brownish-gray limestone, with irregular veinlike streaks of sandstone. Dense moderately coarse grained calcareous sandstone, with irregular streaks of dark-gray micaceous calcareous sandy shale. <u>Middle.</u> —Shale, dark reddish-brown, somewhat calcareous, highly and moderately finely micaceous, with mica partings and streaks of dark-gray highly micaceous highly carbonaceous or lignitic shale. <u>Bottom.</u> —Sandstone, light-gray, dense, moderately coarse grained, calcareous, containing a lens of fine-grained micaceous calcareous greenish-gray sandstone. |
| 113 | 17,631-17,658 | No samples. |
| 114 | 17,658-17,685 | <u>Top.</u> —Shale, dark brownish-red, sandy, calcareous, highly micaceous. <u>Middle.</u> —Sandstone, light-gray, hard, moderately coarse grained, calcareous, somewhat micaceous, with thin highly micaceous partings; contains a few grains of chlorite(?) and a few grains of peach-colored feldspar. <u>Bottom.</u> —Shale, dark brownish-red, hard, highly micaceous, slightly sandy. |
| 115 | 17,685-17,712 | <u>Top and middle.</u> —Sandstone, dull dark brownish-red, hard, moderately coarse grained, shaly, calcareous, highly micaceous. <u>Bottom.</u> —Sandstone, light greenish-gray, dense, moderately coarse grained, highly calcareous, micaceous, with many peach-colored feldspar grains and some grains of chlorite(?). |
| 116 | 17,712-17,739 | <u>Top and middle.</u> —Sandstone, like bottom of core 115, with a few rounded or irregularly shaped inclusions of gray micaceous shale and brownish-red shale. <u>Bottom.</u> —Shale, dark reddish-brown, noncalcareous, very finely micaceous. |
| 117 | 17,739-17,766 | <u>Top and middle.</u> —Shale, dark brownish-gray, micaceous. <u>Bottom.</u> —Sandstone, dark reddish-brown, hard, medium-grained, shaly, calcareous, highly micaceous. |
| 118 | 17,766-17,793 | <u>Top.</u> —Sandstone, coarse-grained, with a few peach-colored grains and green chlorite(?) grains; conglomeratic appearance due to abundant irregular streaks and patches of dark brownish-red shale. <u>Middle.</u> —Shale, dark brownish-red, hard, granular-textured, calcareous, highly micaceous. <u>Bottom.</u> —Shale and sandstone. Very highly micaceous shale, similar to above. Light-gray hard, dense moderately coarse grained calcareous micaceous sandstone. |
| 119 | 17,793-17,820 | <u>Top.</u> —Sandstone, gray-green, dense, medium-grained, calcareous, micaceous. Another part of core is composed of light-gray dense moderately coarse grained calcareous sandstone. <u>Middle.</u> —Shale, dark-gray, hard, granular-textured, silty, calcareous, micaceous. <u>Bottom.</u> —Sandstone, greenish-gray, fine-grained, argillaceous, calcareous, micaceous. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|---|
| 120 | 17,820-17,847 | <u>Top.</u> —Sandstone, light-gray, hard, dense, moderately coarse grained, calcareous, somewhat micaceous. <u>Middle.</u> —Sandstone, like above, with irregular inclusions of black finely micaceous shale giving a conglomeratic appearance to parts of the core. <u>Bottom.</u> —No samples. |
| 121 | 17,847-17,874 | <u>Top.</u> —Sandstone and shale. Light greenish-gray hard, dense, fine- to medium-grained calcareous micaceous sandstone, with a few peach-colored grains and blue-green chlorite(?) grains. Dark brownish-red calcareous slightly and finely micaceous shale, with hard limestone areas. <u>Middle.</u> —Sandstone, light greenish-gray medium-grained, slightly calcareous, micaceous. Another part of core is composed of light-gray dense coarse-grained calcareous sandstone. <u>Bottom.</u> —Sandstone, light-gray, hard, medium-grained, argillaceous, slightly calcareous. Another part of core includes light greenish-gray coarse-grained sandstone, with peach-colored quartz grains, green chlorite(?) grains, and a few irregular dark-gray shale inclusions. |
| 122 | 17,874-17,901 | <u>Top.</u> —Sandstone, like bottom of core 121, but without shale inclusions. <u>Middle.</u> —Sandstone, dark brownish-red, hard, calcareous, finely micaceous. <u>Bottom.</u> —Shale, dark brownish-red, hard, finely micaceous. |
| 123 | 17,901-17,928 | <u>Top.</u> —Shale, dark brownish-red with a few small greenish-gray areas, calcareous, highly and finely micaceous. <u>Middle.</u> —Shale, dark brownish-red, slightly silty, calcareous, highly micaceous. <u>Bottom.</u> —Shale and sandstone. Dull dark brownish-red micaceous shale, with irregular areas of red limestone. Dull brownish-red dense moderately coarse grained argillaceous highly calcareous sandstone, containing a few green chlorite(?) grains and a few feldspar grains. |
| 124 | 17,928-17,955 | <u>Top.</u> —Sandstone, like bottom of core 123. <u>Middle.</u> —Sandstone and shale. Greenish-gray hard, very dense medium- to coarse-grained micaceous sandstone, with thin very highly micaceous lenses. Dark brownish-red hard thinly laminated slightly calcareous finely micaceous shale. <u>Bottom.</u> —Sandstone, light greenish-gray, moderately hard, moderately calcareous, micaceous. Another part of core is composed of dark greenish-gray very dense fine- to medium-grained calcareous micaceous sandstone. |
| 125 | 17,955-17,982 | <u>Top.</u> —Sandstone, hard, dense, lignitic, calcareous, micaceous, with many thin highly micaceous lenses. <u>Middle.</u> —Shale, dark brownish-red, hard, granular-textured, finely micaceous. <u>Bottom.</u> —Sandstone, greenish-gray, hard, dense, moderately coarse grained, calcareous, micaceous. |
| 126 | 17,982-18,009 | <u>Top.</u> —Sandstone, pinkish-gray, dense, moderately coarse grained, calcareous, micaceous; contains many pink-tinted grains and some chlorite(?) grains. Many thin, irregularly-shaped red shale inclusions give the sandstone a conglomeratic appearance. <u>Middle.</u> —Sandstone, like above, with shale inclusions and thin highly micaceous green unctuous shale lenses. <u>Bottom.</u> —Sandstone, like above, with red shale inclusions; contains a thick lens of dark brownish-red finely and highly micaceous shale. |
| 127 | 18,009-18,034 | <u>Top.</u> —Shale, dull dark-red, like bottom of core 126. <u>Middle and bottom.</u> —Shale, like above, with a lens of dull-red medium-grained micaceous calcareous sandstone. |
| 128 | 18,034-18,061 | <u>Top.</u> —Sandstone, dull brownish-red, medium-grained, highly calcareous, micaceous. <u>Middle.</u> —Similar to above but moderately coarse grained; contains a little chlorite(?) and lenses of red calcareous shale with small inclusions of sandstone. <u>Bottom.</u> —Sandstone and shale, red, thinly and irregularly interbedded. |
| 129 | 18,061-18,088 | <u>Top.</u> —Shale, dark brownish-red, silty, calcareous, very highly micaceous. <u>Middle.</u> —Shale, with thin shaly sandstone lenses. Dark brownish-red smooth-textured hard very finely micaceous shale. Dark brownish-red medium-grained shaly micaceous sandstone. <u>Bottom.</u> —Sandstone, very dense, moderately coarse grained, highly calcareous, slightly micaceous; contains small irregular inclusions and a lens of hard dark-red shale. At 18,086 ft, light-green shaly noncalcareous micaceous siltstone. At 18,088 ft, red highly silty finely micaceous shale. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|-----------------|--|
| 130 | 18, 088-18, 115 | <u>Top.</u> —Shale, dark brownish-red, hard, slightly and finely micaceous. <u>Middle.</u> —Shale and sandstone in thin highly micaceous lenses, mixed in irregular streaks and blebs as if roughly stirred together. Dark brownish-red shale. Dense medium-grained calcareous micaceous sandstone. <u>Bottom.</u> —Sandstone, grayish-red, fine-grained, micaceous. |
| 131 | 18, 115-18, 142 | <u>Top.</u> —Shale and sandstone. Dark grayish-red hard slightly sandy micaceous shale, containing hard red limestone areas. Pale brown moderately dense medium-grained micaceous sandstone; mica predominantly biotite with a few dark-green flakes. <u>Middle.</u> —Sandstone and a little sandy shale. Dark grayish-red dense medium-grained calcareous micaceous sandstone. Dark grayish-red hard micaceous shale. <u>Bottom.</u> —Sandstone, mottled light reddish-gray and light greenish-gray, dense, slightly calcareous, micaceous. Mica is apparently biotite and muscovite, with occasional copper-colored and dark-green flakes. |
| 132 | 18, 142-18, 169 | <u>18, 142-18, 146 ft.</u> —Sandstone, dark brownish-red, dense, medium-grained, slightly calcareous, micaceous; composed chiefly of quartz grains with a few grains of red feldspar and a few grains of green chlorite(?). Thin lenses in the sandstone contain abundant small even-sized hard dull-black nodules of magnetite(?). Sandstone contains thin irregular patches of red shale and thin highly micaceous lenses in which mica is colorless or copper-colored with occasional black flakes. <u>18, 146-18, 149 ft.</u> —Sandstone, like above, with many small thin irregularly shaped red shale inclusions. Black magnetite(?) nodules absent. <u>18, 149-18, 152 ft.</u> —Sandstone, like above, dense, fine-grained, micaceous, with thin very highly micaceous partings. <u>18, 152-18, 153 ft.</u> —Shale and sandstone. Dark brownish-red finely micaceous shale, with thin lenses of shaly micaceous red sandstone. Greenish-gray dense fine-grained calcareous micaceous sandstone, with many small nodular inclusions of gray shale and a few small inclusions of bluish-green chlorite(?). <u>18, 153-18, 161 ft.</u> —Sandstone, dull-red, dense, medium-grained, slightly calcareous micaceous, with thin highly micaceous partings and many moderately small irregular red shale inclusions. <u>18, 161-18, 164 ft.</u> —Sandstone, red, dense, fine-grained, slightly calcareous. <u>18, 164-18, 165 ft.</u> —Shale and sandstone. Dull dark brownish-red silty finely and highly micaceous shale. Greenish-gray dense medium-grained micaceous lignitic sandstone, with many irregular thin smears of gray shale containing green chlorite(?) flakes. <u>18, 165-18, 168 ft.</u> —Sandstone, dull dark-red, hard, fine-grained, shaly, micaceous. <u>18, 168-18, 169 ft.</u> —Sandstone and red shale, interbedded. Red very fine-grained micaceous sandstone. |
| 133 | 18, 169-18, 196 | <u>18, 169-18, 180 ft.</u> —Like bottom foot of core 132. <u>18, 180-18, 181 ft.</u> —Sandstone with thin micaceous shale partings. Light greenish-gray dense fine-grained micaceous sandstone, with thin lenses composed of abundant small lignite fragments. Gray highly micaceous somewhat carbonaceous shale, with thin lenses of dull-red micaceous dense medium-grained sandstone. <u>18, 181-18, 183 ft.</u> —Sandstone, dull brownish-red, dense, medium- to fine-grained, micaceous; a few very thin very highly micaceous red shale partings. <u>18, 183-18, 185 ft.</u> —Shale and sandstone. Gray hard finely and highly micaceous shale, with partings composed almost entirely of mica. Greenish-gray hard dense medium-grained micaceous sparsely lignitic densely and irregularly spotted sandstone, smeared with blebs of red shale and gray shale; contains areas coated with small rounded lumps of light-green chlorite(?). <u>18, 185-18, 186 ft.</u> —Sandstone, dull-red, dense, medium-grained, calcareous, micaceous; contains a little feldspar and small light bluish-green chlorite(?) grains. Sandstone is thickly and irregularly smeared with red shale. <u>18, 186-18, 187 ft.</u> —Sandstone, light-green, hard, dense, fine- to medium-grained, slightly calcareous, micaceous; contains many peach-colored grains of feldspar(?) and partings of black and colorless mica. <u>18, 187-18, 192 ft.</u> —Sandstone, light-pink, but otherwise similar to above; contains red highly micaceous shale partings in which most of the mica flakes are copper colored. <u>18, 192-18, 196 ft.</u> —Shale, chiefly dark-gray, with lenses of copper-colored mica; a minor amount of red micaceous shale; scattered lenses of gray to greenish-gray shaly sandstone containing carbonaceous fragments. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|-----------------|---|
| 134 | 18, 196-18, 223 | <p><u>18, 196-18, 198 ft.</u>—Sandstone, dull dark-red, shaly, micaceous.</p> <p><u>18, 198-18, 202 ft.</u>—Shale, dull dark-red, with carbonaceous(?) fragments showing peculiar leaflike structure.</p> <p><u>18, 202-18, 205 ft.</u>—Sandstone, dull-red, fine-grained, shaly, highly micaceous.</p> <p><u>18, 205-18, 214 ft.</u>—Sandstone, dull-red, dense, medium-grained, slightly calcareous, micaceous, with lenses of red micaceous shale and sandy shale.</p> <p><u>18, 214-18, 215 ft.</u>—Shale, dull dark-red, with irregular highly sandy lenses and thin highly micaceous partings.</p> <p><u>18, 215-18, 223 ft.</u>—Sandstone, red, hard, dense, fine-grained, shaly, micaceous.</p> |
| 135 | 18, 223-18, 250 | <p><u>18, 223-18, 228 ft.</u>—Like bottom of core 134.</p> <p><u>18, 228-18, 231 ft.</u>—Sandstone, light greenish-gray, micaceous, calcareous; conglomeratic appearance due to irregularly shaped inclusions of red and dark-gray shale. Sandstone contains many copper-colored mica flakes, light-green chlorite(?) grains, and peach-colored grains of feldspar(?).</p> <p><u>18, 231-18, 232 ft.</u>—Sandstone, like above, with a slight pinkish tinge; contains a large embedded pebble of novaculite(?) and large crystals which originally were probably pyrite, now altered to hematite.</p> <p><u>18, 232-18, 235 ft.</u>—Sandstone, light-red, medium-grained, slightly calcareous, with highly micaceous partings; contains scattered lenses of the small black magnetite(?) nodules which occurred first in the top 4 ft of core 132.</p> <p><u>18, 235-18, 236 ft.</u>—Sandstone, light-green, medium-grained, micaceous, irregularly streaked and smeared with dull-red shale.</p> <p><u>18, 236-18, 238 ft.</u>—Sandstone, dull-red, medium-grained, with highly micaceous partings.</p> <p><u>18, 238-18, 239 ft.</u>—Sandstone, light greenish-gray, medium-grained, micaceous, with many small blebs of red shale, and a few thin highly micaceous partings; contains a few hard black magnetite(?) pellets.</p> <p><u>18, 239-18, 250 ft.</u>—Sandstone, dark-red, medium-grained, shaly, micaceous.</p> |
| 136 | 18, 250-18, 277 | <p><u>18, 250-18, 256 ft.</u>—Sandstone, light greenish- to reddish-gray, dense, medium-grained, micaceous.</p> <p><u>18, 256-18, 258 ft.</u>—Sandstone, like above, calcareous, with thin highly micaceous partings and thin lenses of very highly micaceous dark-gray shale.</p> <p><u>18, 258-18, 266 ft.</u>—Shale, dull dark-red, finely micaceous, noncalcareous, with irregular thin lenses of medium-grained sandstone and occasional hard red sandy limestone areas.</p> <p><u>18, 266-18, 269 ft.</u>—Sandstone, dull-red or reddish-gray, dense, medium-grained, non-calcareous, micaceous; composed mainly of quartz with occasional feldspar, mica, and light-green chlorite(?) grains; contains scattered blebs of red shale.</p> <p><u>18, 269-18, 277 ft.</u>—Sandstone, like above; in part, shaly with highly micaceous partings.</p> |
| 137 | 18, 277-18, 304 | <p><u>18, 277-18, 296 ft.</u>—Sandstone, dull grayish-red, medium-grained to moderately coarse grained, containing a few scattered lignite fragments and red shale blebs.</p> <p><u>18, 296-18, 301 ft.</u>—Sandstone, red, dense, medium-grained, shaly, with numerous thin highly micaceous partings.</p> <p><u>18, 301-18, 304 ft.</u>—Shale, dull dark-red, irregularly bedded, somewhat sandy, micaceous.</p> |
| 138 | 18, 304-18, 331 | <p><u>18, 304-18, 306 ft.</u>—Sandstone and shale, irregularly interbedded, containing scattered blebs of pink anhydrite. Dull dark brownish-red, medium-grained sandstone. Red shale, with irregular streaks and patches of shaly sandstone.</p> <p><u>18, 306-18, 308 ft.</u>—Shale, dull dark-red, micaceous, silty to sandy, irregularly bedded.</p> <p><u>18, 308-18, 313 ft.</u>—Sandstone, dull dark-red, very dense, fine-grained, calcareous, micaceous, with dark-red shale lenses.</p> <p><u>18, 313-18, 316 ft.</u>—Sandstone, red, similar to above, with a few greenish-gray medium-grained highly micaceous sandstone lenses.</p> <p><u>18, 316-18, 319 ft.</u>—Sandstone, dull grayish-red, medium-grained to moderately coarse grained, calcareous, with a few thin highly micaceous partings and scattered pebblelike inclusions of red shale.</p> <p><u>18, 319-18, 322 ft.</u>—Sandstone, dull dark-red, dense, fine- to medium-grained, slightly calcareous, with occasional light-green chlorite(?) grains and grains of feldspar.</p> <p><u>18, 322-18, 325 ft.</u>—Sandstone, dull grayish-red, dense, moderately coarse grained, micaceous, calcareous; contains a few small fragments of lignite and small anhydritic areas. Conglomeratic appearance in parts of core due to many blebs and irregular streaks of dark-red shale and red to brown cryptocrystalline limestone.</p> <p><u>18, 325-18, 331 ft.</u>—Shale, dull dark-red, hard, micaceous, finely sandy to silty, with moderately large blebs of pink anhydrite.</p> |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|---|
| 139 | 18,331-18,358 | <p><u>18,331-18,338 ft.</u>—Shale, dark grayish-red, very finely and highly micaceous, with slickensided surfaces; contains lenses of grayish-red to greenish-gray hard, dense medium-grained sandstone with blebs of pink anhydrite about half an inch in diameter.</p> <p><u>18,338-18,350 ft.</u>—Sandstone and shale. Dense fine-grained shaly micaceous noncalcareous sandstone, grayish-red with gray-green mottling. Chiefly grayish-red slightly micaceous shale and a little sandy dark grayish-red shale.</p> <p><u>18,350-18,354 ft.</u>—Shale, dull grayish-red, highly and finely micaceous.</p> <p><u>18,354-18,358 ft.</u>—Shale, like above, with a few lenses of dense shaly micaceous dull grayish-red sandstone.</p> |
| 140 | 18,358-18,385 | <p><u>18,358-18,370 ft.</u>—Shale, dull dark grayish-red, finely and highly micaceous, noncalcareous.</p> <p><u>18,370-18,376 ft.</u>—Shale, like above, with lenses of dull-red micaceous calcareous dense fine-grained shaly sandstone.</p> <p><u>18,376-18,385 ft.</u>—Sandstone with scattered shale lenses. Dull grayish-red dense medium-grained noncalcareous micaceous sandstone (biotite and a copper-colored variety); composed chiefly of quartz grains with light bluish-green and orange- or peach-colored grains of other minerals.</p> |
| 141 | 18,385-18,412 | <p><u>18,385-18,391 ft.</u>—Sandstone, like above, with a few small blebs of red shale.</p> <p><u>18,391-18,409 ft.</u>—Sandstone, like above, with mica partings and irregular blebs of gray and greenish-gray shale. Shale contains scattered carbonaceous fragments which give a conglomerate appearance to parts of the core.</p> <p><u>18,409-18,412 ft.</u>—Sandstone, light grayish-red and light greenish-gray, medium-grained, micaceous (biotite), with blebs of red shale; composed chiefly of quartz with a few grains of light-green chlorite(?) and orange-colored feldspar(?).</p> |
| 142 | 18,412-18,439 | <p><u>18,412-18,430 ft.</u>—Sandstone, like bottom of core 141.</p> <p><u>18,430-18,439 ft.</u>—Shale, dark grayish-red, hard, finely micaceous, with platy fracture; contains a lens of light greenish-gray dense calcareous micaceous sandstone with blebs of gray shale and carbonaceous fragments.</p> |
| 143 | 18,439-18,466 | <p>Recovered 22 ft.</p> <p><u>5 ft.</u>—Sandstone, grayish-red, dense, fine-grained, slightly calcareous, micaceous.</p> <p><u>5 ft.</u>—Sandstone, like above, with partings of black biotite partly altered to copper-colored mica. A lens in the sandstone appears conglomeratic due to blebs of red shale.</p> <p><u>4 ft.</u>—Sandstone, dark grayish-red, micaceous, shaly, with a few red shale blebs; contains a $\frac{1}{2}$-inch layer of hard dark grayish-red platy finely micaceous shale.</p> <p><u>8 ft.</u>—Shale, dark grayish-red, finely micaceous, calcareous; contains scattered layers of dark-gray sandstone.</p> |
| 144 | 18,466-18,501 | <p>Recovered 32 ft.</p> <p><u>6 ft.</u>—Sandstone, grayish-red, dense, fine- to medium-grained, highly calcareous, micaceous, with partings of black micaceous shale and a few small brownish-gray limestone inclusions.</p> <p><u>6 ft.</u>—Sandstone with shale lenses. Greenish- to reddish-gray dense medium-grained calcareous micaceous sandstone. Dark grayish-red hard finely micaceous shale.</p> <p><u>6 ft.</u>—Sandstone, light-gray to greenish-gray, dense, medium-grained, calcareous, micaceous; appears conglomeratic due to areas of gray nodular limestone and blebs of black shale.</p> <p><u>6 ft.</u>—Sandstone, light-gray, light grayish-red and greenish-gray, dense, medium-grained, micaceous, slightly calcareous, with a few blebs of red shale.</p> <p><u>6 ft.</u>—Sandstone, light-gray, as above, with conglomeratic appearance due to many irregular red-brown limestone areas and blebs of red and gray shale.</p> <p><u>2 ft.</u>—Sandstone and thin lenses of shale. Grayish-red and greenish-gray sandstone, containing shale blebs and thin lenses of mica. Dark grayish-red finely micaceous shale.</p> |
| 145 | 18,501-18,509 | <p>Recovered 6 ft.</p> <p><u>3 ft.</u>—Sandstone composed of grayish-red and greenish-gray lenses. Dense medium-grained calcareous somewhat micaceous grayish-red lenses. Greenish-gray lenses contain biotite, many light-green chlorite(?) grains, orange feldspar(?) grains, and many small irregular blebs of red shale.</p> <p><u>3 ft.</u>—Sandstone, light reddish-gray, medium-grained, micaceous, with blebs of red shale.</p> |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|-----------------|--|
| 146 | 18, 509-18, 536 | <p><u>18, 509-18, 521 ft.</u>—Sandstone, light grayish-red, dense, fine- to medium-grained, micaceous, with flakes and partings of biotite and copper-colored mica; composed mainly of quartz with grains of light blue-green chlorite(?) and reddish-orange feldspar(?).</p> <p><u>18, 521-18, 527 ft.</u>—Sandstone, light greenish-gray, dense, fine- to medium-grained, slightly calcareous, with small blebs of dark-gray carbonaceous shale and a few thin lenses of biotite.</p> <p><u>18, 527-18, 533 ft.</u>—Sandstone, light-gray and greenish-gray, dense, fine- to medium-grained, with thin lenses of mica.</p> <p><u>18, 533-18, 536 ft.</u>—Sandstone, light greenish-gray, medium-grained, micaceous (biotite and muscovite), noncalcareous, with a few blebs of grayish-red shale.</p> |
| 147 | 18, 536-18, 584 | <p><u>18, 536-18, 542 ft.</u>—Sandstone, light greenish-gray, fine-grained, micaceous (muscovite); composed chiefly of quartz with a few reddish-brown grains of feldspar(?); contains carbonaceous fragments and thin layers of mica.</p> <p><u>18, 542-18, 548 ft.</u>—Sandstone, light greenish-gray, dense, fine- to medium-grained, slightly calcareous, with thin lenses of muscovite and biotite and a few streaks of copper-colored mica flakes.</p> <p><u>18, 548-18, 554 ft.</u>—Sandstone with scattered shale lenses. Light reddish-gray dense fine- to medium-grained sandstone, calcareous and micaceous (biotite and altered biotite). Dark grayish-red micaceous shale lenses, with silty limestone areas.</p> <p><u>18, 554-18, 560 ft.</u>—Sandstone and shale. Light reddish-gray dense medium-grained micaceous calcareous sandstone, similar to that in the last few cores. Sandstone contains blebs of red shale and lenses of dull grayish-red finely and highly micaceous noncalcareous shale.</p> <p><u>18, 560-18, 565 ft.</u>—Sandstone, light greenish-gray and light reddish-gray, medium-grained, quartzitic, micaceous, with many thin lenses of muscovite, biotite, and copper-colored mica; black carbonaceous(?) fragments common in lower portion of core.</p> <p><u>18, 565-18, 578 ft.</u>—Sandstone with shale lenses. Greenish-gray dense fine- to medium-grained micaceous sandstone, with thin lenses of mica. Chiefly dark grayish-red highly and finely micaceous shale lenses, with a few lenses of hard dark-gray thinly laminated very finely micaceous shale.</p> <p><u>18, 578-18, 584 ft.</u>—Sandstone and shale lenses. Light greenish-gray and grayish-red dense medium-grained micaceous sandstone, with biotite, muscovite, and copper-colored flakes. Dark grayish-red micaceous shale lenses, with occasional lignite inclusions.</p> |
| 148 | 18, 584-18, 633 | <p><u>18, 584-18, 589 ft.</u>—Shale, dark grayish-red, hard, micaceous, noncalcareous, in part highly and finely sandy.</p> <p><u>18, 589-18, 592 ft.</u>—Sandstone, grayish-red, dense, fine- to medium-grained, micaceous. Parts of core show aggregates of minute evenly distributed particles of black magnetite(?).</p> <p><u>18, 592-18, 593 ft.</u>—Shale, dark grayish-red, highly micaceous, noncalcareous.</p> <p><u>18, 593-18, 613 ft.</u>—Sandstone, interbedded red, grayish-red, light-gray, greenish-gray and light-green, dense, medium-grained to very fine grained, calcareous to noncalcareous, micaceous; composed chiefly of quartz with scattered grains of red feldspar; contains a few blebs of red shale and occasional thin highly micaceous partings.</p> <p><u>18, 613-18, 614 ft.</u>—Siltstone, reddish-gray, hard, dense, micaceous, calcareous.</p> <p><u>18, 614-18, 617 ft.</u>—Sandstone, light greenish-gray, dense, medium-grained to very fine grained, micaceous, calcareous, with thin streaks of lignite.</p> <p><u>18, 617-18, 619 ft.</u>—Shale, dark grayish-red, dense, with irregular micaceous finely sandy areas.</p> <p><u>18, 619-18, 620 ft.</u>—Sandstone, dark grayish-red, medium-grained, micaceous, with mica in irregular shaly streaks.</p> <p><u>18, 620-18, 621 ft.</u>—Shale, dark grayish-red, highly silty, highly and finely micaceous.</p> <p><u>18, 621-18, 623 ft.</u>—Sandstone, grayish-red and greenish-gray, dense, fine-grained, noncalcareous, micaceous with abundant copper-colored flakes.</p> <p><u>18, 623-18, 625 ft.</u>—Shale, dark grayish-red, highly micaceous, with irregular veinlike streaks of red shaly medium-grained micaceous sandstone.</p> <p><u>18, 625-18, 627 ft.</u>—Sandstone and shale, irregularly and thinly interbedded, dark grayish-red, very fine grained, highly micaceous.</p> <p><u>18, 627-18, 633 ft.</u>—Sandstone, light grayish-red, dense, fine-grained, micaceous; composed chiefly of quartz with scattered grains of red feldspar, green chlorite(?), and magnetite(?).</p> |
| 149 | 18, 633-18, 640 | Sandstone, light reddish-gray, dense, highly micaceous with abundant copper-colored flakes; contains scattered blebs of red shale. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|--|
| 150 | 18,640-18,659 | Recovered 15 ft. <u>15 ft.</u> —Sandstone, light greenish-gray and light reddish-gray, dense, medium- to fine-grained, slightly calcareous, micaceous, with many copper-colored flakes. Sandstone composed chiefly of quartz grains, with scattered grains of black magnetite(?), light-green chlorite(?), and red feldspar; contains occasional blebs of red to gray micaceous shale and shreds of carbonaceous material. |
| 151 | 18,659-18,685 | <u>18,659-18,662 ft.</u> —Sandstone, light-gray, medium-grained, micaceous, with conglomeratic appearance due to abundant small blebs of dark-gray shale; a few inclusions of selenite(?). <u>18,662-18,664 ft.</u> —Siltstone, greenish-gray, dense, noncalcareous. <u>18,664-18,666 ft.</u> —Sandstone, light-gray to grayish-red, dense, medium- to fine-grained, micaceous with black and colorless flakes; contains fragments of black highly carbonaceous shale. <u>18,666-18,667 ft.</u> —Shale, dark grayish-red, highly micaceous, sandy. <u>18,667-18,671 ft.</u> —Sandstone, interbedded greenish-gray, pinkish-gray and grayish-red, dense, medium- to fine-grained, slightly calcareous, highly micaceous with many copper-colored flakes. <u>18,671-18,674 ft.</u> —Shale, dark grayish-red, laminated, slightly carbonaceous, micaceous; bottom foot finely and irregularly sandy. <u>18,674-18,677 ft.</u> —Sandstone, dark grayish-red, dense, very fine grained, micaceous, with irregular shale lenses. <u>18,677-18,685 ft.</u> —Shale, dark grayish-red, highly micaceous; in part, irregularly and finely sandy. |
| 152 | 18,685-18,710 | <u>18,685-18,687 ft.</u> —Shale, dark grayish red, finely and highly micaceous, irregularly sandy to silty. <u>18,687-18,694 ft.</u> —Sandstone, mainly light greenish-gray with a minor part grayish-red, dense, medium- to fine-grained, slightly calcareous, micaceous with colorless, black and copper-colored flakes. Bottom foot contains irregular streaks and blebs of red sandy micaceous shale. <u>18,694-18,695 ft.</u> —Shale, black, with slickensided surface dipping at a very high angle suggesting a fault plane. The lithology of the samples changes markedly below the depth of 18,695 ft. <u>18,695-18,697 ft.</u> —Sandstone, light greenish-gray, fine-grained to moderately coarse grained, slightly calcareous, micaceous (mainly biotite), with small carbonaceous areas and irregularly rounded blebs of gray shale. <u>18,697-18,703 ft.</u> —Sandstone, gray, dense, medium- to fine-grained, calcareous, micaceous, with a few scattered thin lenses of black to brownish-black micaceous shale. <u>18,703-18,704 ft.</u> —Sandstone and shale. Sandstone like above. Black micaceous fossiliferous shale with numerous ostracodes and a few bivalves. <u>18,704-18,706 ft.</u> —Sandstone, gray, dense, calcareous, medium- to fine-grained, micaceous. <u>18,706-18,709 ft.</u> —Shale, brownish-black to reddish-brown, partly sandy, micaceous, noncalcareous; breaks with irregular fracture and shows small slickensided areas; contains many ostracodes and fragmentary fossils. <u>18,709-18,710 ft.</u> —Shaly sandstone or sandy shale, dark brownish-gray, slightly calcareous. |
| 153 | 18,710-18,737 | <u>18,710-18,716 ft.</u> —Sandstone, mainly bluish gray-green, very dense, fine-grained, calcareous, slightly to highly micaceous with black and colorless mica; at top of core, a few thin irregular lenses of black shale. <u>18,716-18,717 ft.</u> —Shale, dark-gray, silty, exceedingly highly micaceous, slightly carbonaceous. Core splits horizontally along highly micaceous parting planes. <u>17,717-18,732 ft.</u> —Sandstone, interbedded greenish-gray, bluish gray-green, light-gray and bluish-gray, hard, dense, fine-grained, slightly calcareous, slightly to highly micaceous. <u>18,732-18,734 ft.</u> —Shale, black, micaceous; bottom foot highly silty. <u>18,734-18,735 ft.</u> —Siltstone, gray, shaly, very highly micaceous, slightly carbonaceous. <u>18,735-18,736 ft.</u> —Shale, dark-gray, silty, highly micaceous. <u>18,736-18,737 ft.</u> —Sandstone, gray, dense, fine-grained, micaceous, with highly micaceous partings. |

Lithologic description of cores--Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|--|
| 154 | 18,737-18,764 | <p><u>18,737-18,745 ft.</u>—Sandstone, top 5 ft light gray-green, bottom 3 ft gray; hard, dense, very fine grained to silty, micaceous to highly micaceous. At 18,741-18,742 ft, conglomeratic appearance due to irregular blebs of highly micaceous shale.</p> <p><u>18,745-18,746 ft.</u>—Siltstone, dark-gray, thinly laminated, shaly, very highly micaceous, finely carbonaceous.</p> <p><u>18,746-18,747 ft.</u>—Sandstone, gray, dense, very fine grained, calcareous, highly micaceous.</p> <p><u>18,747-18,748 ft.</u>—Shale, black, micaceous.</p> <p><u>18,748-18,749 ft.</u>—Sandstone, gray, dense, very fine grained, micaceous.</p> <p><u>18,749-18,750 ft.</u>—Shale, black, silty, highly micaceous, with carbonaceous fragments; contains a few molds of fossil bivalves.</p> <p><u>18,750-18,755 ft.</u>—Sandstone, bluish- or greenish-gray, dense, very fine grained, calcareous, somewhat micaceous, with shreds of carbonaceous material.</p> <p><u>18,755-18,764 ft.</u>—Siltstone, mainly gray with occasional bluish gray-green layers, dense, hard, slightly calcareous, micaceous; contains carbonaceous areas and a few highly micaceous lenses of silty shale.</p> |
| 155 | 18,764-18,791 | <p><u>18,764-18,770 ft.</u>—Siltstone, gray, dense, calcareous, somewhat micaceous, with carbonaceous shreds.</p> <p><u>18,770-18,771 ft.</u>—Siltstone, like above, with interbedded layers of black highly micaceous finely carbonaceous shale. Core splits along shale layers at an angle of 25° to 30° with the horizontal.</p> <p><u>18,771-18,772 ft.</u>—Siltstone, light bluish- and greenish-gray, dense, hard, calcareous.</p> <p><u>18,772-18,773 ft.</u>—Siltstone, like above. Core splits along a shale layer at an angle of 50° to 60° with the horizontal. The steep dips in this core and in the second foot above and the second foot below are probably associated with nearby faults.</p> <p><u>18,773-18,774 ft.</u>—Siltstone, gray, hard, dense, micaceous, calcareous; contains impressions and molds of fossil bivalves.</p> <p><u>18,774-18,775 ft.</u>—Siltstone, gray, dense, micaceous, calcareous. Lenses of black highly micaceous shale dip at an angle of more than 30° with the horizontal.</p> <p><u>18,775-18,776 ft.</u>—Shale, black, silty, finely micaceous.</p> <p><u>18,776-18,778 ft.</u>—Shaly siltstone, dark-gray to black, hard, highly micaceous.</p> <p><u>18,778-18,779 ft.</u>—Shale, black, finely micaceous, with carbonaceous fragments and highly silty areas.</p> <p><u>18,779-18,780 ft.</u>—Siltstone, dark brownish-gray, micaceous, calcareous, with thin irregular areas of black shale.</p> <p><u>18,780-18,781 ft.</u>—Shale, dark-gray, hard, highly micaceous and silty.</p> <p><u>18,781-18,783 ft.</u>—Shale, dark-gray, silty, highly micaceous, calcareous, with shreds of carbonaceous material.</p> <p><u>18,783-18,784 ft.</u>—Siltstone, dark-gray, micaceous, calcareous.</p> <p><u>18,784-18,787 ft.</u>—Shale, dark-gray, micaceous; bottom foot contains small carbonaceous fragments, poor impressions of fossil bivalves, and traces of other fossils.</p> <p><u>18,787-18,791 ft.</u>—Shale, dark-gray to black, silty, highly micaceous, with lignite fragments, shreds of carbonaceous material and fossil impressions; bottom foot contains lenses of highly calcareous, dense, dolomitic(?) siltstone, streaked with partings of smooth black shale.</p> |
| 156 | 18,791-18,811 | <p>Recovered 12 feet.</p> <p><u>4 ft.</u>—Siltstone, gray, dense, hard, micaceous, calcareous.</p> <p><u>5 ft.</u>—Shale, dark-gray, silty, dense, micaceous, calcareous (or dolomitic?).</p> <p><u>3 ft.</u>—Shale, black, hard, micaceous, slightly silty, with lignitic fragments in bottom part.</p> |
| 157 | 18,811-18,838 | <p><u>18,811-18,816 ft.</u>—Shale, dark gray, silty, highly calcareous, finely micaceous, with carbonaceous shreds; sparsely fossiliferous.</p> <p><u>18,816-18,821 ft.</u>—Limestone with shale lenses. Dark brownish-gray limestone, with small inclusions of anhydrite and irregular calcite veins. Dark brownish-gray silty shale, similar to top 5 ft of core.</p> <p><u>18,821-18,826 ft.</u>—Shale, black, thinly laminated, silty, slightly calcareous, micaceous, finely carbonaceous, with lenses of shaly siltstone; sparsely fossiliferous.</p> <p><u>18,826-18,831 ft.</u>—Shale, dark brownish-gray, thinly laminated, slightly calcareous, micaceous, with lenses of dark brownish-gray hard limestone; sparsely fossiliferous.</p> <p><u>18,831-18,838 ft.</u>—Limestone, dark brownish-gray, hard, dense, with irregular blebs of anhydrite.</p> |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|--|
| 158 | 18,838-18,886 | <p><u>18,838-18,873 ft.</u>—Limestone, dark brownish-gray, hard, dense, with scattered blebs of anhydrite and calcite and thin discontinuous calcite veins; fragmental fossils, <i>Exogyra</i> sp. and others. Between 18,853 and 18,868 ft, limestone contains scattered areas of small oolites.</p> <p><u>18,873-18,878 ft.</u>—Anhydrite, irregularly veined with black shale(?).</p> <p><u>18,878-18,886 ft.</u>—Limestone, similar to top part of core.</p> |
| 159 | 18,886-18,936 | <p><u>18,886-18,896 ft.</u>—Limestone, dark brownish-gray, hard, dense, with scattered dolomitic(?) areas, fossil fragments, and traces of microfossils.</p> <p><u>18,896-18,901 ft.</u>—Anhydrite, with minor amounts of black shale and limestone. Black shale lenses in middle and bottom parts of core. Hard dense limestone, with small inclusions of brown calcite.</p> <p><u>18,901-18,916 ft.</u>—Limestone, dolomitic, dark brownish-gray, dense, with small calcite inclusions.</p> <p><u>18,916-18,936 ft.</u>—Anhydrite.</p> |
| 160 | 18,936-18,986 | <p><u>18,936-18,951 ft.</u>—Anhydrite, with veinlike streaks of black shale; a minor amount of dark brownish-gray dolomitic limestone containing blebs of anhydrite.</p> <p><u>18,951-18,986 ft.</u>—Anhydrite and limestone in approximately equal proportions, irregularly interbedded. Dolomitic dark brownish-gray hard dense limestone, with many small inclusions of coarsely crystalline brown dolomite.</p> |
| 161 | 18,986-19,031 | <p><u>18,986-19,004 ft.</u>—Dolomite, dark brownish-gray irregularly mottled with lighter brown, hard, dense, extremely fine grained, with scattered blebs of anhydrite.</p> <p><u>19,004-19,020 ft.</u>—Anhydrite.</p> <p><u>19,020-19,028 ft.</u>—Anhydrite and dolomite. Dark brownish-gray dense extremely fine grained dolomite; occurs as irregular streaks and veinlike inclusions in the anhydrite.</p> <p><u>19,028-19,031 ft.</u>—Dolomite, dark brownish-gray, dense, extremely fine grained.</p> |
| 162 | 19,031-19,081 | <p><u>19,031-19,036 ft.</u>—Dolomite, like bottom of core 161, containing a few molds of macro-fossils, anhydrite blebs, and irregular veins of calcite.</p> <p><u>19,036-19,042 ft.</u>—Anhydrite.</p> <p><u>19,042-19,049 ft.</u>—Dolomite, dark brownish-gray, dense, very finely granular.</p> <p><u>19,049-19,059 ft.</u>—Limestone, dolomitic, dark brownish-gray, hard, dense, with conchoidal fracture; contains irregular inclusions of dark-brown crystalline dolomite(?) and traces of fragmental fossils(?).</p> <p><u>19,059-19,069 ft.</u>—Anhydrite.</p> <p><u>19,069-19,074 ft.</u>—Limestone, dolomitic, gray, dense.</p> <p><u>19,074-19,078 ft.</u>—Anhydrite.</p> <p><u>19,078-19,081 ft.</u>—Limestone, dolomitic, dark brownish-gray, dense, with scattered crystals and aggregates of dolomite(?). When moistened, scattered areas and lenses in the limestone show moderately coarse oolitic structure.</p> |
| 163 | 19,081-19,131 | <p><u>19,081-19,090 ft.</u>—Limestone, dolomitic, like bottom part of core 162. When moistened, scattered lenses in the limestone show abundant small rounded to irregularly shaped sections of microfossils and oolites.</p> <p><u>19,090-19,099 ft.</u>—Anhydrite.</p> <p><u>19,099-19,104 ft.</u>—Limestone, dolomitic, similar to top 9 ft of core, showing abundant fragmental material and sections of microfossils(?).</p> <p><u>19,104-19,119 ft.</u>—Anhydrite.</p> <p><u>19,119-19,121 ft.</u>—Dolomite, in part shaly, dark brownish-gray, hard, with platy fracture.</p> <p><u>19,121-19,122 ft.</u>—Anhydrite.</p> <p><u>19,122-19,131 ft.</u>—Limestone, dolomitic, dark brownish-gray with light-gray streaks.</p> |
| 164 | 19,131-19,181 | <p><u>19,131-19,134 ft.</u>—Dolomite, light brownish-gray, dense, very fine grained.</p> <p><u>19,134-19,135 ft.</u>—Dolomite, like above, with light-gray anhydrite.</p> <p><u>19,135-19,160 ft.</u>—Limestone, dolomitic, dark brownish-gray, dense, with sharp conchoidal fracture; contains dark-brown coarsely crystalline areas and scattered blebs of anhydrite. Lenses in the limestone are composed of tightly packed well-cemented rounded and irregularly shaped fossil(?) fragments and oolites(?).</p> <p><u>19,160-19,165 ft.</u>—Dolomite, brownish-gray, dense, very finely granular.</p> <p><u>19,165-19,167 ft.</u>—Anhydrite.</p> <p><u>19,167-19,169 ft.</u>—Dolomite, gray, dense, very finely granular, with salty taste.</p> <p><u>19,169-19,180 ft.</u>—Anhydrite, irregularly streaked with dolomite. Gray to dark brownish-gray dense very finely granular dolomite.</p> <p><u>19,180-19,181 ft.</u>—Dolomite, like above.</p> |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|-----------------|---|
| 165 | 19, 181-19, 226 | <p><u>19, 181-19, 182 ft.</u> —Dolomite, like bottom of core 164.</p> <p><u>19, 182-19, 185 ft.</u> —Anhydrite.</p> <p><u>19, 185-19, 189 ft.</u> —Dolomite, brownish-gray, dense, very finely granular.</p> <p><u>19, 189-19, 194 ft.</u> —Anhydrite, with irregular areas of dolomite.</p> <p><u>19, 194-19, 199 ft.</u> —Dolomite, brownish-gray, very dense, very finely granular.</p> <p><u>19, 199-19, 201 ft.</u> —Anhydrite.</p> <p><u>19, 201-19, 209 ft.</u> —Limestone, dolomitic, dark brownish-gray, hard, with marked conchoidal fracture.</p> <p><u>19, 209-19, 226 ft.</u> —Limestone, dolomitic, like above; shows many sections of microfossils and macrofossil fragments when moistened with dilute acid. Limestone contains irregular inclusions of black bituminous(?) tarlike residue and shows a film of light oil on fresh fractures; oil evaporates rapidly.</p> |
| 166 | 19, 226-19, 276 | <p><u>19, 226-19, 247 ft.</u> —Limestone, dolomitic, dark brownish-gray, with conchoidal fracture; contains scattered lenses of tightly cemented macrofossil fragments and a few microfossils. Limestone contains scattered irregularly shaped inclusions of black bituminous(?) tarlike residue, and at irregular intervals through the core a film of light oil occurs on fresh fractures.</p> <p><u>19, 247-19, 254 ft.</u> —Dolomite, brownish-gray, showing traces of oolitic structure when moistened with dilute acid.</p> <p><u>19, 254-19, 261 ft.</u> —Limestone, dolomitic, with sharp conchoidal fracture. Like the top part of the core, the dolomitic limestone contains black inclusions and shows an oil film on fracture surfaces.</p> <p><u>19, 261-19, 268 ft.</u> —Dolomite, dark brownish-gray, very finely granular, showing traces of oolites and fossil fragments.</p> <p><u>19, 268-19, 276 ft.</u> —Limestone, dolomitic, containing many fossil fragments; conchoidal fractures coated with film of oil as in preceding parts of core.</p> |
| 167 | 19, 276-19, 326 | <p><u>19, 276-19, 281 ft.</u> —Dolomite, dark brownish-gray, dense, very fine grained, containing many scattered dark-brown crystals and crystalline aggregates of dolomite(?).</p> <p><u>19, 281-19, 286 ft.</u> —Dolomite and limestone. Dolomite, like above. Oolitic fragmental limestone, cut by many small calcite veins.</p> <p><u>19, 286-19, 296 ft.</u> —Limestone, dolomitic, dark to light brownish-gray, containing irregular coarsely crystalline areas and an anhydrite lens.</p> <p><u>19, 296-19, 306 ft.</u> —Dolomite, dark to light brownish-gray, hard, dense, very fine grained; contains many fossil fragments and brown, crystalline inclusions.</p> <p><u>19, 306-19, 316 ft.</u> —Limestone, dolomitic, like above.</p> <p><u>19, 316-19, 326 ft.</u> —Anhydrite and dolomite, irregularly interbedded. Dark brownish-gray hard dense very finely granular dolomite, with anhydrite inclusions and coarsely crystalline areas.</p> |
| 168 | 19, 326-19, 365 | <p><u>19, 326-19, 331 ft.</u> —Limestone, dolomitic, containing many anhydrite inclusions and fossil fragments.</p> <p><u>19, 331-19, 341 ft.</u> —Limestone, dolomitic, dark brownish-gray, dense, with conchoidal fracture. Many fractures show a thin film of oil like that described in preceding cores.</p> <p><u>19, 341-19, 346 ft.</u> —Anhydrite and dolomite, gray, dense.</p> <p><u>19, 346-19, 356 ft.</u> —Limestone, dolomitic, dark brownish-gray, dense, with inclusions of coarsely crystalline dolomite; contains irregular lenses of light-gray dolomite with anhydrite inclusions.</p> <p><u>19, 356-19, 365 ft.</u> —Dolomite, light-gray to light brownish-gray, dense, very fine grained, with scattered areas of coarsely crystalline brown dolomite.</p> |
| 169 | 19, 365-19, 415 | <p><u>19, 365-19, 367 ft.</u> —Anhydrite, irregularly gray and black streaked.</p> <p><u>19, 367-19, 373 ft.</u> —Limestone, dark grayish-brown, hard, containing much anhydrite in irregular streaks and inclusions.</p> <p><u>19, 373-19, 385 ft.</u> —Limestone, dark brownish-gray, dense; in part, dolomitic; in part, a dense oolite containing many fossil fragments.</p> <p><u>19, 385-19, 388 ft.</u> —Siltstone or dolomite(?), gray, highly micaceous, calcareous.</p> <p><u>19, 388-19, 390 ft.</u> —Dolomite, dark brownish-gray, dense, very fine grained, slightly micaceous.</p> <p><u>19, 390-19, 402 ft.</u> —Dolomite and limestone, dark brownish-gray, dense, with sharp conchoidal fracture, showing film of light oil on freshly broken surfaces. Top 7 ft of core is irregularly interbedded with dark brownish-gray to black shale.</p> <p><u>19, 402-19, 414 ft.</u> —Dolomite, dark brownish-gray, dense, very fine grained.</p> <p><u>19, 414-19, 415 ft.</u> —Limestone, dark brownish-gray, dense, coarsely oolitic; contains many irregular veinlets of brown crystalline calcite.</p> |

Lithologic description of cores--Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|---|
| 170 | 19,415-19,461 | <p><u>19,415-19,428 ft.</u>—Limestone, dark brownish-gray, irregularly banded, somewhat oolitic; contains many irregular scattered veinlets and inclusions of crystalline calcite and a few anhydrite inclusions.</p> <p><u>19,428-19,430 ft.</u>—Anhydrite.</p> <p><u>19,430-19,433 ft.</u>—Limestone, dark brownish-gray, dense, oolitic, with a little anhydrite; contains calcite veinlets and small crystalline calcite aggregates. Fresh fractures show a film of oil; when core was moistened with water, small bubbles of brown oil issued slowly from very minute scattered pores.</p> <p><u>19,433-19,439 ft.</u>—Dolomite, dense, very fine grained, with many areas of brown crystalline dolomite.</p> <p><u>19,439-19,452 ft.</u>—Anhydrite, with reticulate black streaks.</p> <p><u>19,452-19,461 ft.</u>—Dolomite, dense, very fine grained with many areas of brown crystalline dolomite.</p> |
| 171 | 19,461-19,511 | <p><u>19,461-19,462 ft.</u>—Dolomite, dark brownish-gray, very fine grained.</p> <p><u>19,462-19,464 ft.</u>—Anhydrite, irregularly streaked dark- and light-gray.</p> <p><u>19,464-19,465 ft.</u>—Dolomite, dark brownish-gray, dense, very fine grained.</p> <p><u>19,465-19,467 ft.</u>—Anhydrite, irregularly streaked and spotted dark- and light-gray.</p> <p><u>19,467-19,477 ft.</u>—Dolomite, dark brownish-gray, dense, with many elliptical, dark-brown crystalline areas; breaks with platy fracture and shows film of oil on fresh surfaces.</p> <p><u>19,477-19,479 ft.</u>—Anhydrite, with large dolomite inclusions.</p> <p><u>19,479-19,484 ft.</u>—Limestone, dolomitic, dark brownish-gray, dense, with conchoidal fracture; scattered irregular areas show sections of fragmental fossils and elliptical, crystalline inclusions; a film of light oil on fresh fractures.</p> <p><u>19,484-19,489 ft.</u>—Dolomite, dark brownish-gray, hard, dense, with anhydrite lenses and inclusions in middle part of core.</p> <p><u>19,489-19,492 ft.</u>—Anhydrite, irregularly dark and light-banded.</p> <p><u>19,492-19,498 ft.</u>—Dolomite, dark brownish-gray, hard, dense, with many irregularly shaped inclusions of brown crystalline calcite.</p> <p><u>19,498-19,499 ft.</u>—Anhydrite, dark and light-banded.</p> <p><u>19,499-19,503 ft.</u>—Limestone, dolomitic, dark brownish-gray, hard, dense, containing fossil fragments and inclusions of crystalline calcite.</p> <p><u>19,503-19,505 ft.</u>—Anhydrite.</p> <p><u>19,505-19,509 ft.</u>—Limestone, dolomitic, dark brownish-gray, dense, with inclusions of crystalline calcite.</p> <p><u>19,509-19,510 ft.</u>—Anhydrite.</p> <p><u>19,510-19,511 ft.</u>—Limestone, dolomitic, hard, dense, with calcite(?) inclusions and veinlets of black pyritic material.</p> |
| 172 | 19,511-19,559 | <p>Recovered 35 ft.</p> <p><u>20 ft.</u>—Dolomite and dolomitic limestone, dark brownish-gray, dense, finely granular, with flaky conchoidal fracture. Fresh breaks show a film of light oil and have a strong sulfur odor. Top part of core is pseudo-oolitic finely fragmental and cut by calcite veinlets; shows a few minute pores.</p> <p><u>15 ft.</u>—Anhydrite, with minor amount of brownish-gray dense saccharoidal dolomite.</p> |
| 173 | 19,559-19,585 | <p>Recovered 10 ft.</p> <p><u>Top.</u>—Limestone, dolomitic, brownish-gray, dense, with many coarsely crystalline inclusions of dolomite(?).</p> <p><u>Middle.</u>—Limestone, dolomitic, dark brownish-gray, dense, somewhat silty, friable; shows film of oil on fresh surfaces.</p> <p><u>Bottom.</u>—Dolomite, dark brownish-gray, dense, highly oolitic, microfossiliferous.</p> |
| 174 | 19,585-19,624 | <p>Recovered 21 ft.</p> <p><u>5 ft.</u>—Oolite, dolomitic, with clearly defined oolites giving a rough appearance to fracture surfaces; strong sulfur odor.</p> <p><u>15 ft.</u>—Shale, black, friable, with dolomitic oolite; fragmental fossils in parts of core; film of oil on fresh breaks.</p> <p><u>1 ft.</u>—Oolite, dolomitic, more dense and firmly consolidated than preceding parts of core; contains impressions of ribbed fossil(?) fragments.</p> |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|---|
| 175 | 19,624-19,658 | Recovered $1\frac{1}{2}$ ft. <u>$1\frac{1}{2}$ ft.</u> —Limestone, dolomitic, black, hard, somewhat oolitic, with a thin lens and many irregular veinlets and inclusions of calcite; strong sulfur odor. |
| 176 | 19,658-19,667 | Recovered 7 ft. <u>2 ft.</u> —Limestone, black, very dense, cut by calcite veinlets; wet surfaces show coarsely oolitic texture; film of oil on fresh surfaces. <u>5 ft.</u> —Limestone, dolomitic, dark brownish-gray, dense, oolitic, with conchoidal fracture and fragmental fossils; film of oil on fresh surfaces. Bottom part of core is cut by irregular calcite veinlets. |
| 177 | 19,667-19,707 | Recovered 38 ft. <u>38 ft.</u> —Limestone, dolomitic, dark brownish-gray, hard, dense, oolitic, with sulfur odor; contains sections of microfossils and fossil fragments, scattered inclusions of quartz and anhydrite. Five or six feet at the bottom of the core are slightly silty. |
| 178 | 19,707-19,739 | Limestone, dolomitic, dark-gray and dark brownish-gray, hard, with scattered inclusions of anhydrite or gypsum. The lower one-half of the core contains chert inclusions and is cut by irregular thin veins of black calcite. At the depth of about 19,712 to 19,720 ft and in the bottom 2 ft of the core, streaks or lenses in the limestone show abundant large oolites when moistened with dilute acid. Freshly broken pieces of the core have a strong sulfur odor. |
| 179 | 19,739-19,769 | Limestone, dolomitic, dark-gray, hard, brittle, with sharp conchoidal fracture; contains scattered blebs of white anhydrite or gypsum and a few irregular veinlets of black calcite. Fresh fractures in the top 10 ft of the core frequently show a film of light oil; throughout the core, freshly broken pieces have a strong sulfur odor. |
| 180 | 19,769-19,808 | Limestone, dolomitic, dark brownish-gray, dense, brittle, with sharp conchoidal fracture; contains scattered blebs of anhydrite or gypsum. The lowest 5 ft of the core contain anhydrite inclusions and veinlets of calcite and pyrite. Fresh fractures in the lower one-half of the core frequently show a film of light oil; throughout the core, freshly broken pieces have a strong sulfur odor. |
| 181 | 19,808-19,847 | Recovered 30 feet. <u>5 ft.</u> —Limestone, dolomitic, like bottom of core 180, with a few dark-gray shaly lenses. <u>5 ft.</u> —Limestone, dolomitic, dark-gray, with large veins and inclusions of anhydrite or gypsum and a few inclusions of sulfur. Fairly large pores occur in the limestone near the anhydrite and sulfur inclusions. <u>10 ft.</u> —Limestone, dolomitic, dark brownish-gray, dense, brittle, with scattered blebs of white anhydrite or gypsum; a film of light oil frequently occurs on freshly broken surfaces. <u>5 ft.</u> —Shale, black, hard, highly calcareous, with white anhydrite blebs, sparsely fossiliferous. <u>5 ft.</u> —Limestone, dolomitic, shaly dark brownish-gray, brittle, with white anhydrite blebs. Throughout the core, freshly broken pieces have a strong sulfur odor. |
| 182 | 19,847-19,893 | Limestone, dark-gray, dense, with small inclusions of white anhydrite or gypsum, and scattered irregular streaks of dark brownish-gray brittle shale. |
| 183 | 19,893-19,942 | Limestone, shaly, dark-gray, brittle, with conchoidal fracture; contains scattered oolitic lenses and anhydrite blebs; a few molds of bivalves in upper part. Limestone has strong sulfur odor on fresh breaks and at depth of approximately 19,920 ft showed a film of light oil. |
| 184 | 19,942-19,990 | Limestone, shaly, dark-gray, brittle, dense; contains scattered fragments of ribbed bivalves and, in lower two-thirds of core, inclusions and veins of white anhydrite or gypsum. |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|----------|---------------|--|
| 185 | 19,990-20,040 | <p><u>19,990-19,995 ft.</u>—Limestone and shale, thinly interbedded or laminated. Dark-gray limestone, with smooth platy fracture; contains blebs of white anhydrite. Black pyritic shale. Core breaks along thin shale partings where the black shale coats finely pitted rough-textured limestone. A film of oil occurs along fresh cleavages and core has a strong sulfur odor.</p> <p><u>19,995-20,005 ft.</u>—Limestone, shaly, dark-gray, brittle, with a few blebs of anhydrite and veins of black calcite; contains molds and fragments of small ribbed bivalves.</p> <p><u>20,005-20,010 ft.</u>—Limestone, dark-gray; in part, dense with large blebs of anhydrite; in part, laminated with black shale and breaking along rough-textured pitted surfaces as in top 5 ft of core.</p> <p><u>20,010-20,030 ft.</u>—Limestone, shaly, dark-gray to black, hard, brittle, with small, scattered blebs of anhydrite; contains fragments of ribbed bivalves.</p> <p><u>20,030-20,035 ft.</u>—Limestone, dark-gray, interbedded with black, calcareous shale; fracture is in part conchoidal, in part along thin overlapping plates.</p> <p><u>20,035-20,040 ft.</u>—Limestone, shaly, black, with small anhydrite blebs; shows oil film on fresh breaks and has a strong sulfur odor.</p> |
| 186 | 20,040-20,090 | <p><u>20,040-20,045 ft.</u>—Limestone, very dark-gray, with large anhydrite inclusions.</p> <p><u>20,045-20,050 ft.</u>—Limestone and shale. Limestone, like above. Shale is dark gray to black, possibly dolomitic, very finely granular, finely and highly micaceous, and pyritic.</p> <p><u>20,050-20,055 ft.</u>—Limestone, dark-gray, with highly oolitic areas. In places, oolites are in a matrix of anhydrite.</p> <p><u>20,055-20,065 ft.</u>—Limestone and shale. Dark-gray highly oolitic limestone. Black finely granular calcareous shale.</p> <p><u>20,065-20,075 ft.</u>—Shale, black, thinly laminated, finely granular, highly calcareous; contains a lens of hard dark brownish-gray limestone.</p> <p><u>20,075-20,080 ft.</u>—Shale, like above, with a little anhydrite and a lens of highly oolitic limestone in which oolites are in part embedded in anhydrite.</p> <p><u>20,080-20,090 ft.</u>—Limestone, black, in part dolomitic, stylolitic, with anhydrite blebs. A thin section shows that limestone is minutely laminated (0.1 mm to 0.8 mm thick) with extremely thin silty bituminous(?) partings. Fragments of the core break diagonally across the laminations, giving an extremely fine-stepped or tiered appearance.</p> |
| 187 | 20,090-20,140 | <p><u>20,090-20,130 ft.</u>—Limestone with irregular shale lenses. Limestone, dark-gray to black, hard, with scattered anhydrite blebs and veins; minutely laminated like bottom of core 186. Black thinly laminated finely granular shale, possibly dolomitic, occasionally pyritic.</p> <p><u>20,130-20,140 ft.</u>—Limestone, like preceding part of core; minutely laminated.</p> |
| 188 | 20,140-20,177 | <p><u>20,140-20,155 ft.</u>—Limestone, brownish-black, hard, with a few small blebs and thin veins of anhydrite or gypsum; when moistened with dilute acid, shows faint outlines suggesting oolitic structure. Fragments of core break vertically and show regularly spaced laminae of black shale(?).</p> <p><u>20,155-20,160 ft.</u>—Limestone and shale. Dolomitic brownish-black limestone, with irregular finely and highly oolitic lenses. Black finely granular dolomitic(?) shale.</p> <p><u>20,160-20,165 ft.</u>—Dolomite and shale. Brownish-black microgranular dolomite, with a lens containing oolites and partly dolomitized fossil fragments.</p> <p><u>20,165-20,175 ft.</u>—Limestone and shale. Dolomitic dark brownish-gray limestone, containing traces of fragmental fossils. Dolomitic(?) black granular thinly laminated shale, with scattered oolitic areas.</p> <p><u>20,175-20,177 ft.</u>—Limestone, dolomitic, brownish-black, dense, with traces of fragmental fossils.</p> |
| 189 | 20,177-20,227 | <p><u>20,177-20,187 ft.</u>—Dolomite, brownish-black, microgranular, with blebs and irregular areas of white anhydrite containing inclusions of sulfur.</p> <p><u>20,187-20,192 ft.</u>—Limestone, dolomitic, brownish-black, with blebs of white anhydrite or gypsum; contains irregular lenses of black finely granular shale.</p> <p><u>20,192-20,197 ft.</u>—Dolomite and dolomitic limestone, brownish-black, dense, microgranular, with anhydrite inclusions.</p> <p><u>20,197-20,217 ft.</u>—Limestone and shale. Dolomitic brownish-black and dark brownish-gray dense brittle limestone, with conchoidal fracture; fresh fractures at top of core show a film of light oil and have a strong sulfur odor. Black granular thinly laminated highly calcareous shale, contains finely disseminated mica and pyrite.</p> <p><u>20,217-20,227 ft.</u>—Dolomite, brownish-black, microgranular, with a few veins of anhydrite or gypsum.</p> |

Lithologic description of cores—Continued

| Core no. | Depth (feet) | Description |
|--------------|-----------------|--|
| 190 | 20, 227-20, 277 | When core barrel was opened, core fell out on the derrick floor and sequence was lost. Representative samples of dolomite, dolomitic limestone, and shale are lithologically similar, in general, to the materials described in core 189. Several dolomite and dolomitic limestone fragments show a film of light oil on fresh fractures. |
| 191 | 20, 277-20, 298 | Recovered 12 ft. <u>4 ft.</u> —Shale, dolomitic(?), black, hard, granular. <u>4 ft.</u> —Dolomite, black, dense, microgranular, with thin lenses of black dolomitic shale. <u>4 ft.</u> —Dolomite, dark-gray, very finely granular, sparsely fossiliferous, with a few blebs of anhydrite; contains many irregularly scattered small pores, apparently resulting from removal of microfossils, <i>Ophthalmitidae</i> , <i>Spirophthalmidium</i> , and others. At depth of 20, 298 ft, gas smelling strongly of hydrogen sulfide made three or four heads blowing oil-base drilling mud about 15 to 20 feet into the derrick. |
| 192 | 20, 298-20, 337 | Recovered 16 ft. <u>7 ft.</u> —Dolomite with a minor amount of shale. Dolomite is in part, black, dense, microgranular and in part, dark-gray, finely granular, with small pores, as in bottom of core 191. Dolomitic black hard shale. <u>9 ft.</u> —Dolomite, dark-gray, finely granular, with dense microgranular areas of black dolomite; a little anhydrite. The dark-gray dolomite contains small pores similar to those in core 191. |
| 193 | 20, 337-20, 357 | Recovered 6 ft. <u>6 ft.</u> —Dolomite, black, dense, microgranular, shaly. |
| 194 | 20, 357-20, 404 | Recovered 21 ft. <u>16 ft.</u> —Dolomite, black, dense, brittle, microgranular, with veinlets and blebs of anhydrite; shows film of oil on fresh fractures. <u>5 ft.</u> —Dolomite, like above, containing finely disseminated anhydrite. |
| 195 | 20, 404-20, 415 | Recovered 9 ft. <u>5 ft.</u> —Dolomite, black, dense, microgranular, shaly, with thin lenses of black dolomitic(?) shale. <u>4 ft.</u> —Dolomite, black, hard, dense, microgranular, with conchoidal fracture and stylolitic structure. |
| 196 | 20, 415-20, 437 | Recovered 21 ft. <u>1 ft.</u> —Dolomite, black, dense, microgranular, with thin partings of black dolomitic shale. Core breaks into thin plates. <u>1/2 ft.</u> —Dolomite, black, hard, dense, microgranular, with sharp conchoidal fracture. <u>1 ft.</u> —Clay, gray, very finely sandy, micaceous with colorless mica. <u>15 ft.</u> —Anhydrite, gray, with crystalline structure. The anhydrite in this core is a solid mass and differs in appearance from the fragmental, spotted, and veined anhydrite in the cores from higher levels <u>3 1/2 ft.</u> —Anhydrite, similar to above, but darker and harder; lacks crystalline structure of the preceding 15 ft. |
| 197 | 20, 437-20, 441 | No recovery. |
| Basket core. | 20, 445-20, 447 | Approximate depths. <u>1 ft.</u> —Anhydrite, similar to above. <u>1 ft.</u> —Rock salt, clear, white. |

