CORE DESCRIPTION FROM GB-1 (GASBUGGY 1) IN THE NORTHEASTERN PART OF THE SAN JUAN BASIN, RIO ARRIBA COUNTY, NEW MEXICO

by

J. E. Fassett

OPEN-FILE REPORT 1967

UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

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U.S. Geological Survey, Farmington, N. Mex.

The core herein described came from the first test hole drilled for Project Gasbuggy--a project designed to stimulate gas production by the use of nuclear explosives from the Pictured Cliffs Sandstone in the northeastern part of the San Juan Basin, N. Mex. Project Gasbuggy is a cooperative experiment principally involving the El Paso Natural Gas Co., the Atomic Energy Commission, and the U.S. Bureau of Mines. Permission to describe the core from the well was kindly granted by these three organizations.

The borehole, Gasbuggy 1, is 1,324 feet from the south line and 1,614 feet from the west line of sec. 36, T. 29 N., R. 4 W., Rio Arriba County, N. Mex., at a surface elevation of 7,200.19 feet. The depths listed in the core description are measured from the Kelly bushing (K.B.) of the well, which is 9.9 feet above the ground surface at an elevation of 7,210.09 feet. This hole was started on February 11, 1967, and was drilled to a depth of 3,436 feet on March 16, 1967; 5¼-inch core was cut to 3,880 feet and 3½-inch core was cut to 4,316 feet. The hole was mud-drilled from the surface to a depth of 3,880 feet and was air-drilled from 3,880 feet to the bottom of the hole. During reaming the hole was deepened to 4,320 feet. Coring started in the base of the Paleocene Nacimiento Formation and, in descending order, the units cored include the Paleocene Ojo Alamo Sandstone and the following Upper Cretaceous formations: the Kirtland Shale and Fruitland Formation (undivided), the Pictured Cliffs Sandstone, and the Lewis Shale. The core description follows:

CORE NO. 1. 3436-3460 feet (24 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3436.0 -3436.4	0.4	Nacimiento Formation, sandstone, light-greenish-gray, fine- to coarse-grained, average coarse-grained; 20% feldspar and 80% quartz; feldspar, soft, weathered, all grains angular; claystone cement; friable.
2	3436.4 -3436.8	0.4	Shale, black, shiny; some gypsum; slickensided.
3	3436.8 -3437.15	0.35	Sandstone, fine-grained, like unit 1.
4	3437.15-3438.35	1.2	Sandstone, light-gray; siltstone, green; fine- to medium-grained, average medium-grained; 80% quartz, 20% feldspar; feldspar less weathered than unit 1; claystone cement; friable.
5	3438.35-3439.0	0.65	Sandstone, light-gray, very fine- to fine-grained; 90% quartz, 10% feldspar; claystone cement; friable.
6	3439.0 -3440.8	1.8	Sandstone, light-greenish-gray, fine- to coarse-grained; 80% quartz, 20% feldspar; salt-and-pepper, carbonaceous shale grains, muscovite mica; contains pebbles of finer grained sandstone to 3440.05 ft; claystone cement; friable, but less than sandstone above.
7	3440.8 -3441.2	0.4	Sandstone, light-green, very fine- to fine-grained; very dirty with abundant carbonaceous fragments and mica flakes, feldspar 5% or less; claystone cement; less friable than unit 6.
8	3441.2 -3441.4	0.2	Sandstone like unit 7 but with abundant coaly streaks and layers.
9	3441.4 -3441.85	0.45	Sandstone like unit 7.
10	3441.85-3441.9	0.05	Sandstone, coaly, like unit 8; 50% coal.
11	3441.9 -3443.0	1.1	Sandstone, very fine grained, like unit 7.
12	3443.0 -3444.8	1.8	Sandstone, fine- to medium-grained, like unit 7; grades into very fine grained sandstone to siltstone at base; contains 75° fracture; feldspar as much as 20%.

CORE NO. 1--continued

Unit	Interval (feet)	Thickness (feet)	Description
13	3444.8 -3445.6	0.8	Shale, gray, waxy, silty, micaceous; grades into unit 14 below.
14	3445.6 -3448.8	3.2	Siltstone to shale, green, micaceous; 80% feldspar; interval crossbedded with shale interbeds; 70° fracture between 3447 and 3448 ft.
15	3448.8 -3450.0	1.2	Shale, drab, dark-gray, slickensided.
16	3450.0 -3450.5	0.5	Siltstone, light-green, micaceous; salt-and-pepper with carbonaceous shale fragments; gradational with unit 15.
17	3450.5 -3452.9	2.4	Like unit 16 with fossil(?) stems; contains shale interbeds at 3451.4 and 3451.5 ft; 80° fracture.
18	3452.9 -3454.0	1.1	Siltstone to shale, light-green to gray; carbonaceous fragments; micaceous; contains conglomeratic fragments of dark-gray siltstone.
19	3454.0 -3454.7	0.7	Shale, dark-gray, carbonaceous, slickensided.
20	3454.7 -3460.0	5.3	Siltstone to shale, grayish-green; basal part contains thin layers of reddish micaceous siltstone in paper-thin interbeds with green shale.

CORE NO. 2. 3460-3520 feet (60 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3460.0 -3461.0	1.0	Shale, greenish-gray, silty, micaceous; grades into unit 2.
2	3461.0 -3464.2	3.2	Siltstone to very fine grained sandstone, green; salt-and-pepper with dark-green mica; 60% quartz, 40% feldspar.
3	3464.2 -3469.7	5.5	Siltstone, black, carbonaceous; grades into greenish-gray carbonaceous shale, gray silty shale, and gray dense shale.
4	3469.7 -3472.4	2.7	Shale, dark-gray, silty, micaceous; carbonaceous fragments, carbonaceous fossils(?); becomes siltier downward.
5	3472.4 -3473.6	1.2	Shale, greenish-gray, very silty, micaceous, drab.
6	3473.6 -3475.4	1.8	Sandstone, green, silty to very fine grained, arkosic, micaceous.
7	3475.4 -3478.2	2.8	Shale, black, drab, slickensided.
8	3478.2 -3480.0	1.8	Shale, gray, silty; grades into dirty-green argillaceous micaceous siltstone.
9	3480.0 -3481.1	1.1	Sandstone, light-green, very fine- to medium-grained, micaceous; claystone cement; somewhat friable. Top of unit is about the top of the Ojo Alamo Sandstone.
10	3481.1 -3482.3	1.2	Sandstone, light-green, fine- to coarse-grained; like unit 9.
11	3482.3 -3488.4	6.1	Sandstone, light-green, fine- to very coarse-grained; claystone cement; friable; 80% quartz, 20% feldspar and clay; grades into whiter sandstone with less clay; grades into slightly greener harder coarse-grained sandstone with scattered pink feldspar and mica.
12	3488.4 -3489.2	0.8	Sandstone, gray, medium-grained; micaceous papery carbonaceous layers; relatively tough.

CORE NO. 2--continued

Unit	Interval (feet)	Thickness (feet)	Description
13	3489.2 -3503.2	14.0	Sandstone, white to light-green, medium- to very coarse-grained; claystone cement, relatively tough; some pink feldspar; quartz less angular; average grain size varies from medium to very coarse; this is cleanest (less claystone) sandstone so far, not very friable.
14	3503.2 -3509.2	6.0	Shale, green to black to 3506 ft grading to green, silty, slickensided, slightly micaceous; thin coaly layers in black shale.
15	3509.2 -3510.9	1.7	Shale to siltstone, dark-green, micaceous; siltstone increases downward; contains black shale fragments as much as 0.05 ft in diameter.
16	3510.9 -3512.4	1.5	Sandstone, dark-green, silty, micaceous, argillaceous.
17	3512.4 -3513.8	1.4	Sandstone, dark-green to brown, very fine- to fine-grained, micaceous, argillaceous.
18	3513.8 -3515.4	1.6	Sandstone, light-green, medium- to very coarse-grained; quartz fairly well rounded, frosted; claystone cement; fairly friable.
19	3515.4 -3515.8	0.4	Shale, gray, silty; papery carbonaceous layers throughout; some carbonaceous layers slightly thicker.
20	3515.8 -3516.4	0.6	Conglomerate (micro.), greenish-gray; two distinct grain sizes; very coarse grained frosted fairly well rounded quartz in very fine- to fine-grained matrix; fairly tough; contains carbonaceous layers and streaks.
21	3516.4 -3517.5	1.1	Siltstone, gray, very poorly sorted with some coarse to very coarse grains, argillaceous; coaly fragments and papery layers.
22	3517.5 -3517.8	0.3	Conglomerate; gray shale pebbles as much as 0.1 ft, flattened; in medium- to coarse-grained matrix of claystone; light-green quartz sandstone, fairly hard.
23	3517.8 -3520.0	2.2	Sandstone, white to light-green; relatively clean; angular quartz; interval from 3515.8 to 3520 ft is clay pebble conglomerate.

CORE NO. 3. 3520-3578 feet (58 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3520.0 -3525.0	5.0	Sandstone, white to light-green, fine- to coarse-grained; claystone cement; relatively clean.
2	3525.0 -3531.0	6.0	Sandstone as above with papery carbonaceous layers and a zone of claystone pebbles between 3529.6 and 3531 ft; sandstone is medium grained (average) and micaceous; claystone pebbles are small.
3	3531.0 -3538.6	7.6	Sandstone like unit 1.
4	3538.6 -3539.8	1.2	Same as unit 3 with sparse claystone pebbles.
5	3539.8 -3541.7	1.9	Sandstone, white to light-green, fine- to coarse-grained, average is coarse grained; relatively clean; claystone cement.
6	3541.7 -3541.8	0.1	Wedge-shaped claystone body through about one-third of core.
7	3541.8 -3549.0	7.2	Same as unit 5 but average is medium grained; contains small lensy coal bodies as much as 0.05 ft in diameter.
8	3549.0 -3550.0	1.0	Small sparse claystone pebble zone; matrix like unit 7.
9	3550.0 -3554.15	4.15	Same as unit 7.
10	3554.15-3555.0	0.85	Claystone pebble zone; matrix like unit 7.
11	3555.0 -3561.8	6.8	Sandstone, white, very poorly sorted, fine- to very coarse-grained; claystone cement.
12	3561.8 -3562.0	0.2	Claystone pebble zone; pebbles flattened to as much as 0.05 ft in diameter; some carbonaceous pebbles.
13	3562.0 -3566.8	4.8	Sandstone, light-green; average is medium to coarse grained; claystone cement.
14	3566.8 -3568.5	1.7	Sandstone, light-green; average is medium to coarse grained; thin carbonaceous streaks.

CORE NO. 3--continued

Unit	Interval (feet)	Thickness (feet)	Description
15	3568.5 -3569.4	0.9	Sandstone, light-green; average is medium to coarse grained.
16	3569.4 -3573.9	4.5	Sandstone, light-green, fine-grained, salt-and-pepper; claystone cement; becomes medium to coarse grained downward.
17	3573.9 -3573.95	0.05	Shale, brown.
18	3573.95-3574.2	0.25	Claystone pebble zone in medium-grained green claystone-cemented sandstone.
19	3574.2 -3575.1	0.9	Conglomerate; clay, chert, and siltstone pebbles as much as 0.2 ft in diameter in medium- to coarse-grained sandstone matrix; some pyrite.
20	3575.1 -3576.0	0.9	Like unit 19 with claystone pebbles less abundant and smaller downward; pebbles average 0.025 ft; one chert pebble 0.15 ft.
21	3576.0 -3578.0	2.0	Sandstone, white to light-green, coarse- to very coarse-grained; claystone cement.

NOTE: This core bled water throughout with the exception of the following dry intervals: 3523.0-3523.7; 3524.6-3525.0; 3529.0-3531.0; 3531.5-3533.0; 3534.9-3535.1; 3539.0-3540.0; 3545.5-3547.0; 3556.5-3557.0; 3559.0-3560.0; 3562.0-3563.0; 3565.3-3565.5; 3566.8-3566.85; 3567.2-3567.4; 3568.0-3568.1; 3569.4-3570.2; 3574.3-3575.0.

CORE NO. 4. 3578-3636 feet (58 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3578.0 -3580.1	2.1	Sandstone, white, medium- to coarse-grained; some flat claystone pebbles as much as 0.1 ft in diameter.
2	3580.1 -3580.2	0.1	Same as unit 1, with abundant claystone pebbles as much as 0.2 ft in diameter.
3	3580.2 -3580.5	0.3	Same as unit 1, with scattered chert pebbles as much as 0.12 ft in diameter.
4	3580.5 -3582.15	1.65	Sandstone, white to light-gray, medium- to coarse-grained; angular quartz with a few chert grains; some micaceous, some shaly grains; claystone cement; friable.
5	3582.15-3582.35	0.2	Chert and clay pebble zone in sandstone matrix like unit 4; pebbles as much as 0.15 ft in diameter, become larger downward.
6	3582.35-3584.75	2.4	Shale, black, drab; contains pyrite, gypsum, and coaly streaks; slickensided; becomes slightly silty downward.
7	3584.75-3585.0	0.25	Sandstone, gray, fine-grained; dry; claystone cement.
8	3585.0 -3585.7	0.7	Sandstone, gray, fine-grained; medium-grained interbeds; dry; claystone cement.
9	3585.7 -3593.45	7.75	Sandstone, white to gray, fine- to coarse-grained, average is medium grained; claystone cement; quartz grains angular; slightly micaceous, slightly cherty, slightly carbonaceous fragments and streaks; friable; wet.
10	3593.45-3594.65	1.2	Sandstone, gray, fine-grained; more claystone cement than above and below; some thin carbonaceous streaks; dry.
11	3594.65-3597.25	2.6	Sandstone, white, medium- to coarse-grained; quartz grains angular; some alkali feldspar; abundant claystone cement; scattered small claystone pebbles; carbonaceous streaks, wet; friable; minor calcareous cement.

CORE NO. 4--continued

Unit	Interval (feet)	Thickness (feet)	Description
12	3597.25-3597.7	0.45	Sandstone, light-green, very fine- to fine-grained; claystone cement; fairly well sorted; slightly micaceous, trace alkali feldspar; tough; this interval grades down from silty to very fine- to fine-grained sandstone; crossbedded; dry.
13	3597.7 -3599.1	1.4	Sandstone, greenish-gray; grades to coarse-grained in center and back to fine-grained at base; wet.
14	3599.1 -3599.6	0.5	Sandstone, gray, medium-grained; papery silty layers; 0.01-ft-thick coaly lens through one-fourth of core; dry.
15	3599.6 -3601.15	1.55	Sandstone, greenish-gray, fine- to medium-grained; wet.
16	3601.15-3601.6	0.45	Sandstone like unit 15 with zone of sparse small claystone lenses; wet.
17	3601.6 -3614.0	12.4	Sandstone, light-greenish-gray, medium- to coarse-grained; claystone cement; minor amounts of dark-gray feldspar; trace mica and alkali feldspar; very poorly sorted; very friable; homogeneous; wet.
18	3614.0 -3614.2	0.2	Clay pebble zone in unit 17 matrix; pebbles as much as 0.15 ft in diameter and sparse; wet.
19	3614.2 -3615.0	0.8	Sandstone like unit 17; wet.
20	3615.0 -3615.5	0.5	Sandstone like unit 17, contains abundant claystone pebbles as much as 0.2 ft in diameter; wet.
21	3615.5 -3617.15	1.65	Sandstone, greenish-gray, medium-grained; wet.
22	3617.15-3617.4	0.25	Sandstone like unit 21; zone of shale pebbles as much as 0.2-0.3 ft in diameter; wet.
23	3617.4 -3617.8	0.4	Sandstone like unit 21; wet.
24	3617.8 -3618.1	0.3	Sandstone like unit 21; with shale grading to shale pebbles downward; shale present through core at top; dry.

CORE NO. 4--continued

Unit	Interval (feet)	Thickness (feet)	Description
25	3618.1 -3618.8	0.7	Sandstone, greenish-gray, fine- to medium-grained; BB-size flattened clay pebbles at base.
26	3618.8 -3620.6	1.8	Shale, greenish-gray to black; sandstone, greenish-gray, medium-grained, intermixed; black shale from 3619.3 to 3619.5 ft; scattered pyrite throughout; dry.
27	3620.6 -3623.1	2.5	Sandstone, greenish-gray, fine- to medium-grained; wet; 75° fracture at 3623 ft.
28	3623.1 -3625.3	2.2	Sandstone, greenish-gray, fine- to medium-grained; fairly well sorted; dry.
29	3625.3 -3629.5	4.2	Sandstone, gray; wet.
30	3629.5 -3630.8	1.3	Sandstone, greenish-gray, fine- to medium-grained; carbonaceous streaks; dry.
31	3630.8 -3635.9	5.1	Sandstone, greenish-gray, fine- to medium-grained; wet.
32	3635.9 -3636.0	0.1	Shale, gray.

CORE NO. 5. 3636-3696 feet (60 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3636.0 -3638.5	2.5	Shale, silty, gray to black; abundant pyrite; grades to dense black shale; contains vertical sandstone intrusion 0.2-0.3 ft thick with globular boundary.
2	3638.5 -3638.9	0.4	Sandstone, light-gray, fine- to medium-grained; some mica; claystone cement; dry.
3	3638.9 -3640.0	1.1	Sandstone like unit 2; wet.
4	3640.0 -3640.4	0.4	Sandstone, light-gray, very fine- to fine-grained; dry.
5	3640.4 -3644.7	4.3	Sandstone, light-green, medium- to coarse-grained; becomes finer upward; wet.
6	3644.7 -3645.2	0.5	Sandstone, light-gray, medium- to coarse-grained; wet at base.
7	3645.2 -3645.6	0.4	Shale pod in unit 6, 0.3 x 0.15 ft; shale, black to dark-gray, dense.
8	3645.6 -3646.2	0.6	Sandstone, light-gray, fine-grained; dry.
9	3646.2 -3652.0	5.8	Sandstone, light-gray, medium-grained; claystone cement; poorly sorted sparse small clay pebbles; trace of mica and alkali feldspar; wet.
10	3652.0 -3654.0	2.0	Sandstone, gray, medium-grained; dry; base of unit is sharp and possibly top of Kirtland Shale and Fruitland Formation (undivided).
11	3654.0 -3657.0	3.0	Shale, black, coaly, carbonaceous; becomes silty and light gray downward. (Below this unit the core was green when wet immediately after core was pulled.)
12	3657.0 -3658.0	1.0	Siltstone to shale, dark-greenish-gray; contains carbonaceous streaks.
13	3658.0 -3659.5	1.5	Sandstone, dark-greenish-gray; interbedded with black siltstone and shale.

CORE NO. 5--continued

Unit	Interval (feet)	Thickness (feet)	Description
14	3659.5 -3661.7	2.2	Sandstone, dark-green, medium- to coarse-grained; thin gray shale interbeds.
15	3661.7 -3665.1	3.4	Sandstone, green, coarse- to medium-grained; reacts vigorously in HCl; probably calcite cement with some claystone cement; contains small amounts of mica, pink feldspar, coaly fragments, jasper(?) fragments, and soft green rock fragments; rock is relatively tough.
16	3665.1 -3668.2	3.1	Sandstone like unit 15, with coarse- to very coarse-grained sandstone interbeds.
17	3668.2 -3670.2	2.0	Sandstone, greenish-gray, very fine- to fine-grained; contains scattered mica flakes; minor calcite cement, mostly claystone cement; tough; some medium-grained sandstone interbeds.
18	3670.2 -3670.4	0.2	Shale, dark-gray, drab, silty; scattered mica flakes.
19	3670.4 -3671.2	0.8	Sandstone, gray, silty to coarse-grained; thin black shale interbeds; very thin shale layer at 3670.8 ft.
20	3671.2 -3673.5	2.3	Sandstone, grayish-green, fine- to medium-grained; salt-and-pepper, dark grains of shale and mica; fairly well sorted; claystone cement, minor calcite cement.
21	3673.5 -3677.9	4.4	Sandstone, gray to very light green, fine- to very coarse-grained, very poorly sorted; contains abundant mica flakes and abundant small (0.05 ft and less) shale pods; sandstone grades down to fine-grained last 1.5 ft; claystone cement, some minor calcite cement; 80° fracture between 3673.3 and 3674.3 ft.
22	3677.9 -3678.95	1.05	Siltstone, gray, and dark-gray shale irregularly interbedded; scattered mica; shale gone about 3678.4 ft; 3678.4-3678.95-ft zone of very small cross-bed sets with black shale partings showing cross-beds in gray siltstone.

CORE NO. 5--continued

Unit	Interval (feet)	Thickness (feet)	Description
23	3678.95-3679.9	0.95	Sandstone, gray; grades from fine to coarse grained; reacts vigorously in HCl; calcareous cement with some claystone cement; 80° fracture between 3679 and 3680 ft. Possible top of Kirtland Shale and Fruitland Formation (undivided).
24	3679.9 -3689.9	10.0	Shale, light-greenish-gray, dense, drab; contains thin gradational siltstone interbeds; siltstone is greener and more micaceous than shale; contact with unit 23 is sharp; 75° fracture between 3683 and 3684 ft.
25	3689.9 -3691.2	1.3	Sandstone, greenish-gray; very fine grained siltstone; sparse mica flakes.
26	3691.2 -3692.4	1.2	Sandstone, dark-greenish-gray, very coarse grained; clay pebble conglomerate; abundant very small claystone pebbles (BB size), gray, green, and reddish-brown.
27	3692.4 -3694.5	2.1	Sandstone, greenish-gray, fine- to very coarse-grained; poorly sorted claystone cement; zone of very abundant claystone pebbles at 3693.1 ft, pea-size; lower pebbles become larger to as much as 0.1 ft, flattened.
28	3694.5 -3695.65	1.15	Conglomerate; small (0.1 ft) flattened claystone pebbles in medium- to very coarse-grained sandstone matrix.
29	3695.65-3696.0	0.35	Shale, dark-gray, silty.

CORE NO. 6. 3696-3712 feet (16 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3696.0 -3698.0	2.0	Shale, light-gray; sparse mica; a few scattered sandstone grains; vertical fractures with some calcite filling. Becomes silty downward.
2	3698.0 -3698.6	0.6	Siltstone, green.
3	3698.6 -3699.3	0.7	Siltstone, green, and black shale, interbedded; siltstone decreases downward.
4	3699.3 -3700.0	0.7	Shale, light-green, dense, tough, not fissile; 0.02-0.03-ft-thick clay-filled vertical fracture.
5	3700.0 -3705.7	5.7	Shale, light-gray to black; scattered mica flakes; tough, nonfissile, drab; at top becoming black, silty, waxy, more fissile downward.
6	3705.7 -3706.4	0.7	Shale, light-green, silty.
7	3706.4 -3706.5	0.1	Shale like unit 6, with papery carbonaceous layers.
8	3706.5 -3708.5	2.0	Shale, grayish-green; from 3707.3 to 3708.5 ft sparse pea-size green silty pebbles becoming more abundant downward; vertical fracture between 3707.85 and 3708.5 ft.
9	3708.5 -3708.7	0.2	Sandstone, black to dark-gray, very fine grained, silty; contains brown pebbles as in unit 8.
10	3708.7 -3708.8	0.1	Shale, gray, slightly silty.
11	3708.8 -3712.0	3.2	Shale, greenish-gray, silty; slightly micaceous at top; grades downward to more dense less silty shale; some slickensides.

CORE NO. 7. 3712-3757 feet (45 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3712.0 -3714.1	2.1	Shale, light-greenish-gray, waxy.
2	3714.1 -3716.45	2.35	Shale, black, drab.
3	3716.45-3716.5	0.05	Coal, very shiny; conchoidal fracture.
4	3716.5 -3719.6	3.1	Shale, light-gray, silty, drab, very slightly calcareous; contains sparse black shale fragments near base.
5	3719.6 -3720.3	0.7	Shale, black, drab; scattered carbonaceous fragments; some pyrite.
6	3720.3 -3725.5	5.2	Shale, dark- to light-gray at base, drab; coaly streaks; light-gray shale is slickensided, waxy, somewhat silty.
7	3725.5 -3726.1	0.6	Shale, gray, silty.
8	3726.1 -3726.65	0.55	Shale, black, drab; 0.05-ft coal at base.
9	3726.65-3726.85	0.2	Shale, black; two 0.03-ft coal strings.
10	3726.85-3730.0	3.15	Shale, dark-gray, drab; becomes light-gray downward; contains scattered carbonaceous fragments and stringers.
11	3730.0 -3733.3	3.3	Shale, light-greenish-gray, silty; some micaceous fragments; not fissile, tough; scattered carbonaceous fragments; some pyrite.
12	3733.3 -3733.8	0.5	Sandstone, light-greenish-gray, fine- to medium-grained; some shaly streaks; scattered mica; large siltstone to shale inclusions; sandstone is claystone- and calcareous-cemented.
13	3733.8 -3734.1	0.3	Shale, black, carbonaceous, silty, micaceous.
14	3734.1 -3735.0	0.9	Sandstone, white and gray, medium-grained; contains abundant shale to siltstone lenses and carbonaceous to coaly lenses much flattened to 0.02-0.05 ft; very tough rock; reacts vigorously in HCl; calcareous-cemented; contains scattered micaceous and small-size coaly fragments.

CORE NO. 7--continued

Unit	Interval (feet)	Thickness (feet)	Description
15	3735.0 -3746.2	11.2	Siltstone and shale, light-greenish-gray; contains abundant papery carbonaceous layers; near center grades to black carbonaceous silty slickensided shale; grades back to light-green silty shale toward base.
16	3746.2 -3748.4	2.2	Sandstone, light-greenish-gray, very fine grained to silty; abundant micaceous flakes; abundant carbonaceous fragments and layers; becomes darker and fine grained downward with calcareous cement increasing downward; several vertical fractures lined with calcite crystals between 3746.2 and 3749.3 ft.
17	3748.4 -3749.0	0.6	Sandstone like unit 16 grades into black shale.
18	3749.0 -3751.0	2.0	Shale, black, silty; carbonaceous fragments; grades into gray shale below; slickensided.
19	3751.0 -3753.8	2.8	Shale, dark-gray to black; coaly streaks; abundant slickensides to 3752.5 ft.
20	3753.8 -3754.8	1.0	Shale like unit 19; zone of calcite-filled low-angle intersecting fractures in shale.
21	3754.8 -3756.5	1.7	Shale, dark-grayish-black; slickensides, coaly streaks.
22	3756.5 -3756.8	0.3	Siltstone and shale, light-green to gray, massive, micaceous; calcareous cement.
23	3756.8 -3757.0	0.2	Shale, dark-gray to black; some coaly streaks.

CORE NO. 8. 3766-3784 feet (18 ft)

(3757-3766 ft drilled, not cored)

Unit	Interval (feet)	Thickness (feet)	Description
1	3766.0 -3766.5	0.5	Siltstone to very fine grained sandstone, light-gray; scattered mica; sparse carbonaceous fragments; reacts strongly in HCl; calcareous cement.
2	3766.5 -3767.1	0.6	Shale to siltstone, dark-gray; abundant carbonaceous to coaly fragments; slightly micaceous; poorly sorted; some calcareous cement.
3	3767.1 -3767.5	0.4	Siltstone, gray, with dark-gray wavy shaly interbeds; abundant layered carbonaceous fragments; siltstone is slightly calcareous cemented; grades to gray very fine grained sandstone, calcareous-cemented; reacts vigorously with HCl.
4	3767.5 -3768.1	0.6	Shale, silty, gray; sparse coaly fragments.
5	3768.1 -3770.0	1.9	Shale, light-greenish-gray, massive; some coaly fragments.
6	3770.0 -3772.6	2.6	Shale like unit 5, with scattered carbonaceous fragments.
7	3772.6 -3774.35	1.75	Shale, dark-gray; abundant large coaly fragments.
8	3774.35-3774.5	0.15	Shale, light-gray; silty to siltstone.
9	3774.5 -3775.0	0.5	Shale, light-greenish-gray to gray, dense; grades into black shale containing abundant coaly fragments.

NOTE: Nine feet of core are missing from this interval. In the above core description it is assumed that all 9 feet were lost at the bottom of the core.

CORE NO. 9. 3784-3803 feet (19 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3784.0 -3785.5	1.5	Shale, gray, silty; abundant micaceous flakes; calcareous cement; some coaly fragments becoming more abundant downward; calcareous cement increases downward; vertical fracture, 3785-3785.4 ft.
2	3785.5 -3735.7	0.2	Shale, black, silty, micaceous; sparse carbonaceous fragments.
3	3785.7 -3786.1	0.4	Siltstone to very fine grained sandstone, gray to greenish-gray, micaceous; papery wavy interbeds of coaly fragments; calcareous cement.
4	3786.1 -3786.4	0.3	Shale, dark-gray to black, silty; abundant carbonaceous fragments.
5	3786.4 -3786.85	0.45	Siltstone like unit 3 at top, grading to very fine grained noncarbonaceous very fine grained sandstone at base; calcareous cement increasing downward with very vigorous reaction with HCl in part.
6	3786.85-3787.25	0.4	Shale, black, silty; abundant carbonaceous material; vertical fractures 3786.5-3786.9 ft.
7	3787.25-3788.7	1.45	Siltstone like unit 3; vertical fractures 3787.3-3787.6 ft; becomes darker and shalier downward.
8	3788.7 -3789.2	0.5	Shale, dark-gray to black, micaceous; some carbonaceous fragments.
9	3789.2 -3790.0	0.8	Shale like unit 8 but with more coaly material.
10	3790.0 -3792.0	2.0	Siltstone, dark-gray; abundant large coal fragments at top; grades into light-gray relatively pure siltstone at base; vertical fractures 3790.3-3791.5 ft; calcareous cement.
11	3792.0 -3795.0	3.0	Siltstone, light-gray; slightly micaceous; very sparse carbonaceous shale fragments; contains thin darker colored siltstone interbeds toward base; calcareous cement; vertical fractures abundant.

CORE NO. 9--continued

Unit	Interval (feet)	Thickness (feet)	Description
12	3795.0 -3796.0	1.0	Siltstone, light-gray, micaceous, very slightly calcareous; grades down into dark-gray silty micaceous shale.
13	3796.0 -3797.7	1.7	Sandstone, light-gray, very fine grained; sparse shale fragments, some coaly fragments in papery wavy interbeds; abundant calcareous cement; becomes cleaner downward.
14	3797.7 -3803.0	5.3	Siltstone, gray, and interbeds of black siltstone and shale; between 3798.6 and 3799.4 ft, series of low-angle (30° or less) fractures; from 3799.4 ft on, core badly broken; rock from 3792 ft on is fragile and massive, does not break on bedding planes.

NOTE: Core is badly broken between: 3786.05-3786.35 feet; 3792-3796 feet; 3797.2-3798.0 feet; and 3799.4-3803.0 feet.

CORE NO. 10. 3803-3819 feet (16 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3803.0 -3805.15	2.15	Shale, black, drab; slightly silty; coaly fragments.
2	3805.15-3805.4	0.25	Shale, dark-gray, drab; silty, finely micaceous; this interval crushed.
3	3805.4 -3805.6	0.2	Shale, black, carbonaceous; grades into unit 4.
4	3805.6 -3806.7	1.1	Shale, gray, dense; some coaly fragments; slickensides.
5	3806.7 -3806.9	0.2	Shale, dark-gray to black; some coaly fragments; this interval crushed; slickensides.
6	3806.9 -3807.4	0.5	Coal, lustrous; grading to black carbonaceous silty chale; only top 0.1 ft or less is pure coal.
7	3807.4 -3808.0	0.6	Shale, black, carbonaceous; contains abundant very thin coal partings; shale is silty, becoming siltier downward.
8	3808.0 -3808.9	0.9	Shale, gray; some coaly fragments; slickensides; rock is crushed between 3808.15 and 3808.3 ft.
9.	3808.9 -3809.5	0.6	Shale, gray, like unit 8 with fewer coaly fragments.
10.	3809.5 -3809.7	0.2	Shale, black, carbonaceous; abundant very thin coal interbeds.
11	3809.7 -3810.2	0.5	Shale, dark-gray; with coal pods as much as 0.15 ft in diameter; coal in pods contains abundant random calcite-filled fractures. Coal lustrous; conchoidal fracture.
12	3810.2 -3810.85	0.65	Shale, dark-gray; some coaly fragments.
13	3810.85-3810.95	0.1	Shale, black, coaly; thin coal interbeds and shale in about equal amounts; this interval crushed.
14	3810.95-3811.2	0.25	Siltstone, dark-gray; some coaly fragments; grades downward to black shale.

CORE NO. 10--continued

Unit	Interval (feet)	Thickness (feet)	Description
15	3811.2 -3811.4	0.2	Shale, black; very coaly; slickensides.
16	3811.4 -3811.9	0.5	Coal, very silty and shaly; lustrous with conchoidal fracture.
17	3811.9 -3819.0	7.1	Shale, gray to light-gray; this interval badly broken to 3816.2 ft, crushed to 3817.8 ft, broken to 3818.2 ft, crushed to 3818.7 ft, intact to 3819 ft; last 0.1 ft somewhat coaly.

CORE NO. 11. 3819-3844 feet (25 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3819.0 -3820.4	1.4	Shale, black, silty; abundant coaly fragments; grades into unit 2.
2	3820.4 -3820.9	0.5	Shale like unit 1; coaly fragments are lustrous with conchoidal fracture; interval badly broken.
3	3820.9 -3823.0	2.1	Shale like unit 2; grades into silty shale and siltstone and very fine- to fine-grained sandstone. Sandstone is light gray, poorly sorted; contains shale and coal grains and partings; reacts very vigorously with HCl, calcareous cement. Shale contains abundant slickensides.
4	3823.0 -3823.2	0.2	Siltstone, black; thin coal interbeds.
5	3823.2 -3824.1	0.9	Coal, lustrous; gradational from unit 4 at top 0.1-ft conchoidal fracture; reddish streak.
6	3824.1 -3824.4	0.3	Coal, drab, argillaceous; thin shiny coal interbeds.
7	3824.4 -3824.75	0.35	Coal, lustrous; conchoidal fracture; reddish streak.
8	3824.75-3825.3	0.55	Coal, dull; lustrous coal interbeds as much as 0.1 ft thick.
9	3825.3 -3826.1	0.8	Shale, gray, silty; coaly streaks; slickensides; interval broken.
10	3826.1 -3829.1	3.0	Shale, dark-gray, grading down to carbonaceous siltstone; siltstone is very micaceous; calcareous cement.
11	3829.1 -3829.3	0.2	Coal, lustrous with dull bands; some silty interbeds; abundant slickensides.
12	3829.3 -3831.6	2.3	Shale, black, shiny, grading to coal; abundant lustrous coal layers and fragments; slickensides.
13	3831.6 -3832.3	0.7	Shale, black, carbonaceous; slickensides; 3831.75-3831.9 ft broken; continuous thin bands of lustrous coal.

CORE NO. 11--continued

Unit	Interval (feet)	Thickness (feet)	Description
14	3832.3--3832.7	0.4	Shale, black, carbonaceous; slickensides.
15	3832.7 -3833.8	1.1	Shale, gray to light-gray; some carbonaceous fragments; slickensides; broken.
16	3833.8 -3836.0	2.2	Siltstone to very fine grained sandstone, light-gray to gray; coaly fragments; calcareous cement.
17	3836.0 -3837.4	1.4	Siltstone, black, carbonaceous; some calcareous cement.
18	3837.4 -3843.5	6.1	Siltstone to fine-grained sandstone, light-grayish-green; some mica flakes and carbonaceous shale grains; very vigorous reaction in HCl, calcareous cement; last 0.5 ft contains thin coaly interbeds; core badly broken 3836.4-3838.3 ft, several vertical fractures 3836.4-3843.5 ft.
19	3843.5 -3844.0	0.5	Siltstone, carbonaceous; grades into pure coal.

CORE NO. 12. 3844-3863 feet (19 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3844.0 -3844.2	0.2	Coal, lustrous, shiny.
2	3844.2 -3844.7	0.5	Coal, drab; thin lustrous coal interbeds; broken.
3	3844.7 -3844.9	0.2	Coal; lustrous coal interbeds in shaly drab coal.
4	3844.9 -3845.0	0.1	Coal; grades to silty carbonaceous shale.
5	3845.0 -3846.7	1.7	Shale, black, carbonaceous; coaly layers.
6	3846.7 -3847.8	1.1	Shale to silty shale, gray; thin coaly partings; core broken; vertical fractures.
7	3847.8 -3854.2	6.4	Coal, lustrous; coal crushed between 3848.15 and 3848.3 ft; vertical fracture between 3849.5 and 3850.5 ft with coal slightly broken; coal crushed between 3851.7 and 3851.85 ft.
8	3854.2 -3855.6	1.4	Shale, dark-gray, silty; some coaly fragments.
9	3855.6 -3862.0	6.4	Sandstone, light-greenish-gray, very fine grained; some mica; some calcareous cement; contains some papery carbonaceous layers and thin wavy dark siltstone lenses; becomes darker, dirtier, and siltier downward; contains horizontal to low-angle regularly spaced fractures throughout (0.1-0.2 ft apart); vertical fracture between 3860 and 3861 ft.
10	3862.0 -3863.0	1.0	Siltstone, black, carbonaceous; badly broken.

CORE NO. 13. 3863-3880 feet (17 ft)

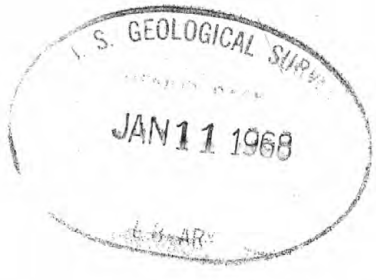
Unit	Interval (feet)	Thickness (feet)	Description
1	3863.0 -3865.7	2.7	Shale, gray, silty; carbonaceous fragments very sparse; becomes slightly darker, siltier, and more micaceous downward.
2	3865.7 -3870.2	4.5	Siltstone, gray to dark-gray; abundant interlayered papery coaly micaceous interbeds; calcareous cement decreasing downward.
3	3870.2 -3870.5	0.3	Siltstone, black, carbonaceous.
4	3870.5 -3872.5	2.0	Siltstone, gray, to very fine grained sandstone; slightly micaceous; calcareous cement.
5	3872.5 -3872.9	0.4	Siltstone like unit 4 but with finely interbedded carbonaceous micaceous layers.
6	3872.9 -3875.8	2.9	Siltstone, gray, micaceous; calcareous cement; grades to very fine grained sandstone downward; 80° fracture.
7	3875.8 -3876.0	0.2	Siltstone like unit 6; abundant papery carbonaceous shale interbeds.
8	3876.0 -3876.2	0.2	Siltstone like unit 6; some thin shale interbeds; vertical fracture, calcite-lined.
9	3876.2 -3876.5	0.3	Shale, black, silty, carbonaceous; some coaly fragments.
10	3876.5 -3877.3	0.8	Sandstone, gray, very fine grained; grades into unit 9 at top 0.15 ft; vertical fracture lined with very small black calcite crystals.
11	3877.3 -3877.5	0.2	Shale, black, silty; calcite-lined vertical fracture.
12	3877.5 -3877.65	0.15	Siltstone, gray; calcareous cement; carbonaceous fragments; vigorous reaction with HCl; grades into unit 13.
13	3877.65-3880.0	2.35	Shale, black; abundant coaly fragments; slightly silty; interval between 3877 and 3880 ft badly crushed and broken with a few intact discs.

CORE NO. 14. 3880-3910 feet (30 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3880.0 -3883.65	3.65	Shale, very black to coaly, silty; grades to siltstone, dark-gray to black; carbonaceous; vertical fractures lined with calcite; grades to black silty shale at base; outside of core oil stained with abundant minute copper particles indicating staining may be thread dope.
2	3883.65-3884.0	0.35	Coal, dull.
3	3884.0 -3884.5	0.5	Coal, dull, with lustrous coal bands; dull coal is silty; carbonaceous silty band contains abundant pyrite between 3884.45 and 3884.5 ft.
4	3884.5 -3885.0	0.5	Coal, somewhat lustrous.
5	3885.0 -3885.6	0.6	Coal, crushed.
6	3885.6 -3887.2	1.6	Coal, somewhat shaly.
7	3887.2 -3887.3	0.1	Siltstone to shale, black, carbonaceous; thin coal interbeds.
8	3887.3 -3887.9	0.6	Coal, very slightly silty.
9	3887.9 -3887.95	0.05	Shale, black, silty.
10	3887.95-3888.2	0.25	Coal.
11	3888.2 -3888.95	0.75	Shale, very black, silty; carbonaceous.
12	3888.95-3891.2	2.25	Coal, somewhat lustrous.
13	3891.2 -3891.4	0.2	Siltstone to shale, black, carbonaceous.
14	3891.4 -3906.4	15.0	Coal, relatively drab; scattered thin lustrous bands. (10 ft of core missing; probably from this interval and probably coal.)
15	3906.4 -3907.3	0.9	Shale, black, carbonaceous, silty; abundant coal fragments.
16	3907.3 -3910.0	2.7	Coal, lustrous, banded; three or more 0.1-ft-thick micaceous carbonaceous pyritiferous bands.

CORE NO. 15. 3910-3922 feet (12 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3910.0 -3910.85	0.85	Coal.
2	3910.85-3910.92	0.07	Siltstone band.
3	3910.92-3912.6	1.68	Coal, lustrous.
4	3912.6 -3913.3	0.7	Coal, slightly silty.
5	3913.3 -3913.65	0.35	Coal and argillaceous to carbonaceous shale. Top of Pictured Cliffs Sandstone at 3913.65 ft.
6	3913.65-3913.75	0.1	Sandstone, black, fine- to very fine-grained; thin coaly interbeds; horizontal parting or fracture at thin coal; has oil stain and is reported to have bled oil when core was pulled.
7	3913.75-3915.0	1.25	Sandstone, dark-brown; abundant carbonaceous material at top grading to little carbonaceous material downward; sandstone is fine to very fine grained; some calcareous cement.
8	3915.0 -3922.0	7.0	Sandstone, light-gray to white, very fine- to fine-grained, salt-and-pepper with dark grains of carbonaceous shale and coal; some mica, some glauconite; some oil stain; quartz grains angular, calcareous cement; fairly well sorted.



CORE NO. 16. 3922-3982 feet (60 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3922.0 -3232.2	10.2	Sandstone, white, salt-and-pepper, fine-grained; black grains are mostly coal; glauconitic; some mica; fairly well sorted; contains a few papery black interbeds composed of coal fragments and mica.
2	3232.2 -3932.35	0.15	Sandstone, dark-gray to black, very fine- to fine-grained; very micaceous.
3	3932.35-3932.6	0.25	Sandstone, white; sparse papery carbonaceous streaks.
4	3932.6 -3932.8	0.2	Sandstone, black, like unit 2.
5	3932.8 -3937.4	4.6	Sandstone, white, like unit 1.
6	3937.4 -3938.05	0.65	Sandstone, dark-gray; abundant papery carbonaceous micaceous layers.
7	3938.05-3938.2	0.15	Sandstone, with very abundant carbonaceous material.
8	3938.2 -3969.7	31.5	Sandstone, white to gray, fine- to very fine-grained; scattered thin black shale and siltstone layers.
9	3969.7 -3970.05	0.35	Sandstone and wavy black siltstone interbeds as much as 0.05 ft thick.
10	3970.05-3970.70	0.65	Shale, dark-gray, dense; grades into sandstone below.
11	3970.70-3979.3	8.6	Sandstone, gray, very fine- to fine-grained; salt-and-pepper, dark grains, representing about 15% of the rock, consist of carbonaceous shale grains, glauconite, and mica flakes; some calcareous cement.
12	3979.3 -3979.6	0.3	Sandstone and thin black shale layers.
13	3979.6 -3981.48	1.88	Sandstone, white to greenish-gray, very fine- to fine-grained, salt-and-pepper.
14	3981.48-3981.55	0.07	Shale, black, silty.
15	3981.55-3981.8	0.25	Sandstone, gray, and thin shale interbeds.
16	3981.8 -3982.0	0.2	Sandstone, gray, very fine grained, salt-and-pepper; dark grains of carbonaceous shale, mica, glauconite.

NOTE: From 3972-3982 feet core has a continuous vertical fracture. Face of fracture was wet. Gas smell throughout core.

CORE NO. 17. 3982-4005 feet (23 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	3982.0 -3982.7	0.7	Sandstone, dark-gray, very fine grained; salt-and-pepper, dark grains of carbonaceous shale, mica, glauconite; calcareous cement; shale between 3982.4-3982.6 ft; vertical fractures between 3982.0 and 3982.5 ft.
2	3982.7 -3986.1	3.4	Sandstone like unit 1, with thin dark-gray shale layers.
3	3986.1 -3991.8	5.7	Sandstone like unit 1.
4	3991.8 -3992.4	0.6	Sandstone like unit 1, with thin shale layers.
5	3992.4 -3994.0	1.6	Sandstone like unit 1.
6	3994.0 -3994.2	0.2	Sandstone like unit 1, with thin papery coal and shale layers.
7	3994.2 -3998.5	4.3	Sandstone like unit 1.
8	3998.5 -4005.0	6.5	Sandstone, gray, very fine grained, fairly well sorted; salt-and-pepper, dark grains mostly coal and carbonaceous shale, some mica, and very small amount glauconite; calcareous cement; Ophiomorpha burrows lined with black very micaceous very argillaceous siltstone and some coaly grains; vertical fractures between 4002.5 and 4005 ft; Ophiomorpha abundant between 3986 and 4001.75 ft.

NOTE: Core is wet on fresh broken surface. Faint gas smell at 3999.7 ft.

CORE NO. 18, 4005-4056 feet (51 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	4005.0 -4032.1	27.1	Sandstone, gray, very fine- to fine-grained; salt-and-pepper, dark grains of coal, carbonaceous shale, mica, and sparse glauconite; calcareous-cemented vertical fractures at 4005.0-4015.0 ft and 4025.5-4026.15 ft; incipient vertical fracture at 4017.0 ft; fracture faces wet.
2	4032.1 -4032.8	0.7	Sandstone, black; abundant thin coal partings; grades to pure sandstone downward; vertical fracture.
3	4032.8 -4034.0	1.2	Sandstone like unit 1, except very fine grained; vertical fracture.
4	4034.0 -4034.1	0.1	Shale, black, drab, silty.
5	4034.1 -4034.45	0.35	Sandstone like unit 3; incipient calcareous-lined fracture.
6	4034.45-4035.0	0.55	Shale and sandstone interbedded; shale is black, very slightly silty; slickensides.
7	4035.0 -4036.15	1.15	Sandstone like unit 3; calcareous-coated vertical fractures.
8	4036.15-4036.9	0.75	Sandstone like unit 7; about four black shale bands, with small scattered pyrite concentrations, as much as 0.15 ft thick.
9	4036.9 -4037.85	0.95	Sandstone like unit 3.
10	4037.85-4038.5	0.65	Shale, black, and irregularly interbedded sandstone.
11	4038.5 -4039.3	0.8	Sandstone like unit 3.
12	4039.3 -4039.4	0.1	Shale, black.
13	4039.4 -4040.7	1.3	Sandstone like unit 3.
14	4040.7 -4041.47	0.77	Sandstone and shale interbedded; mostly sandstone.

CORE NO. 18--continued

Unit	Interval (feet)	Thickness (feet)	Description
15	4041.47-4041.9	0.43	Shale, black, very slightly sandy; sparse small-size coal grains.
16	4041.9 -4042.5	0.6	Sandstone and interbedded black shale.
17	4042.5 -4051.4	8.9	Sandstone and interbedded black shale; shale increases downward; incipient vertical fractures between 4043 and 4044 ft; vertical fractures at 4047.0-4047.3 ft and 4050.0-4050.5 ft. Top of unit is about the base of the upper tongue of Pictured Cliffs Sandstone and the top of the tongue of Fruitland Formation.
18	4051.4 -4052.55	1.15	Coal, grading from black shale above; slightly arenaceous, very thin silty layers and (or) pods.
19	4052.55-4056.0	3.45	Shale to siltstone, black; scattered coaly layers and fragments; some slickensides.

CORE NO. 19. 4056-4116 feet (60 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	4056.0 -4057.0	1.0	Shale, black, carbonaceous, silty; oil smell; vertical fracture. Oil may be thread dope because core from this interval coated with copper particles.
2	4057.0 -4057.6	0.6	Siltstone to very fine grained sandstone, dark-gray; thin carbonaceous shale partings; crystals of calcite are integral part of rock.
3	4057.6 -4058.0	0.4	Shale, black, silty; coaly fragments.
4	4058.0 -4058.65	0.65	Siltstone, calcareous; very carbonaceous to 4058.2 ft, vertical fracture with calcareous crystals.
5	4058.65-4059.25	0.60	Coal, thinly interbedded with black silty shale.
6	4059.25-4060.8	1.55	Shale, black; scattered sandstone-size coaly fragments.
7	4060.8 -4061.0	0.2	Siltstone, dark-gray; vertical fracture with calcareous crystals.
8	4061.0 -4061.9	0.9	Shale, black, silty; becomes siltier downward.
9	4061.9 -4062.25	0.35	Sandstone, dark-gray, very fine grained; incipient vertical fracture from 4061.7-4062.25 ft.
10	4062.25-4062.6	0.35	Shale, black, drab, slightly sandy; grades to sandstone downward.
11	4062.6 -4063.05	0.45	Sandstone, dark-gray, very fine grained; quartz cement; 70° fracture between 4062.9 and 4063.0 ft.
12	4063.05-4063.4	0.35	Shale, black, and coal in thin interbeds; coal decreases downward. Base of unit is the top of the tongue of Pictured Cliffs Sandstone and the base of the lower tongue of Fruitland Formation.
13	4063.4 -4072.2	8.8	Sandstone, light-gray, very fine- to fine-grained; fairly well sorted; salt-and-pepper, dark grains of ferro-magnesium mineral, mica, some carbonaceous shale, and relatively abundant glauconite. 70° fracture between 4064.0 and 4064.25 ft, some calcareous cement; becomes lighter colored downward.

CORE NO. 19--continued

Unit	Interval (feet)	Thickness (feet)	Description
14	4072.2 -4073.3	1.1	Sandstone like unit 13, with papery coaly interbeds.
15	4073.3 -4075.25	1.95	Sandstone like unit 13, with dark grains of coal fragments, plagioclase feldspar, mica, and glauconite; more fine grained than very fine grained sandstone; contains large platy coal fragments and Ophiomorpha; 70° fracture between 4074.5 and 4075.0 ft, calcareous-lined; very little calcareous cement.
16	4075.25-4075.3	0.05	Sandstone like unit 15, with papery coaly layers.
17	4075.3 -4078.2	2.9	Sandstone like unit 15; 70° calcareous-lined fracture between 4075.6-4076.3 ft.
18	4078.2--4081.1	2.9	Sandstone like unit 15; very fine grained.
19	4081.1 -4082.6	1.5	Sandstone, white, like unit 15, but fewer dark grains.
20	4082.6 -4083.8	1.2	Sandstone, light-gray, and thin black drab shale interbeds.
21	4083.8 -4084.1	0.3	Shale, black, silty; thin coal interbeds; incipient vertical fracture.
22	4084.1 -4085.6	1.5	Sandstone, light-gray, fine- to medium-grained; salt-and-pepper, dark grains of carbonaceous shale, glauconite, and coal; very little mica, some calcareous cement.
23	4085.6 -4085.75	0.15	Shale, dark, drab, very slightly arenaceous, non-fissile, brittle.
24	4085.75-4087.7	1.95	Sandstone like unit 22, but slightly coarser grained; some thin coaly interbeds.
25	4087.7 -4089.2	1.5	Sandstone like unit 22.
26	4089.2 -4089.6	0.4	Sandstone like unit 22; papery coaly micaceous interbeds.
27	4089.6 -4089.95	0.35	Sandstone like unit 22.

CORE NO. 19--continued

Unit	Interval (feet)	Thickness (feet)	Description
28	4089.95-4090.2	0.25	Sandstone like unit 22; two coaly bands, one at each end.
29	4090.2 -4092.4	2.2	Sandstone like unit 22.
30	4092.4 -4092.65	0.25	Sandstone, dark-gray, micaceous; abundant papery coaly layers.
31	4092.65-4093.2	0.55	Sandstone like unit 22, but darker gray.
32	4093.2 -4093.3	0.1	Sandstone; sparse coaly layers.
33	4093.3 -4094.58	1.28	Sandstone, gray, fine- to very fine-grained; salt-and-pepper, dark grains are carbonaceous shale, coal, glauconite, and some plagioclase feldspar; calcareous cement.
34	4094.58-4094.6	0.02	Shale, black, coaly, silty.
35	4094.6 -4095.7	1.1	Sandstone like unit 33
36	4095.7 -4096.1	0.4	Sandstone, dark-gray; thin micaceous coaly interbeds.
37	4096.1 -4116.0	19.9	Sandstone like unit 33; abundant Ophiomorpha; core is relatively intact to 4111 ft, badly broken from 4111-4115 ft, last foot relatively intact with small broken zone.

CORE NO. 20. 4116-4175 feet (59 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	4116.0 -4150.6	34.6	Sandstone, white to light-gray, very fine grained; salt-and-pepper, dark grains are carbonaceous shale, coal, mica, and glauconite; calcareous cement.
2	4150.6 -4150.8	0.2	Sandstone like unit 1; papery coaly streaks.
3	4150.8 -4156.1	5.3	Sandstone like unit 1, but less glauconite.
4	4156.1 -4156.4	0.3	Shale, dark-gray, silty, arenaceous; some coal grains.
5	4156.4 -4157.0	0.6	Sandstone like unit 1, with decreasingly thin shale beds downward.
6	4157.0 -4166.65	9.65	Sandstone like unit 1.
7	4166.65-4166.75	0.1	Shale, black, coaly, silty.
8	4166.75-4171.75	5.0	Sandstone like unit 1, but with less cement.
9	4171.75-4172.13	0.38	Shale, black; thin sandstone interbeds.
10	4172.13-4172.3	0.17	Like unit 9, but with more sandstone.
11	4172.3 -4172.5	0.2	Shale, black, silty, slightly arenaceous.
12	4172.5 -4175.0	2.5	Sandstone like unit 1; core badly broken between 4173.15 and 4174.6 ft; a 0.2-ft-thick black shale band, probably at 4173.2 ft.

NOTE: Core looked wet throughout on fresh broken surface; Ophiomorpha throughout with abundant Ophiomorpha at 4121.5-4123.0 ft, 4125.1-4125.5 ft, and 4156.8-4157.6 ft.

CORE NO. 21. 4175-4235 feet (60 ft)

Unit	Interval (feet)	Thickness (feet)	Description
1	4175.0 -4178.9	3.9	Sandstone, light-gray, very fine grained; salt-and-pepper, dark grains are coal, carbonaceous shale, mica, and glauconite; possible fossil ammonite (Baculites) at 4178.55 ft.
2	4178.9 -4179.55	0.65	Shale, black, silty.
3	4179.55-4180.55	1.0	Sandstone like unit 1, with papery carbonaceous micaceous layers decreasing downward.
4	4180.55-4190.35	9.8	Sandstone like unit 1; abundant calcareous cement.
5	4190.35-4191.1	0.75	Sandstone; black silty shale interbeds as much as 0.2 ft thick.
6	4191.1 -4191.6	0.5	Sandstone and papery coaly micaceous layers.
7	4191.6 -4191.9	0.3	Shale, black.
8	4191.9 -4194.3	2.4	Sandstone like unit 1.
9	4194.3 -4194.35	0.05	Shale, black, silty.
10	4194.35-4196.30	1.95	Sandstone like unit 1.
11	4196.30-4196.65	0.35	Sandstone, dark-gray.
12	4196.65-4197.05	0.4	Sandstone like unit 1.
13	4197.05-4199.3	2.25	Sandstone, dark-gray, and interbedded dark-gray to black shale.
14	4199.3 -4200.35	1.05	Sandstone like unit 1; base of unit is base of Pictured Cliffs Sandstone and top of Lewis Shale.
15	4200.35-4235.0	34.65	Sandstone, shale, and silty shale, interbedded. From top down the shales contain oval (in cross-section) dime-size sandstone or siltstone tubes. Vertical calcite-lined fracture between 4206.0-4206.6 ft; incipient fracture at 4208.3-4208.6 ft; calcite-lined vertical fracture at 4212.0-4213.1 ft. Downward, sandstone decreases and black silty massive brittle shale increases.

CORE NO. 22. 4235-4286 feet (51 ft)

Entire core consists of interbedded siltstone and shale, similar to last part of core No. 21. Vertical fractures at 4247.7-4249.5 ft and 4269.0-4269.4 ft.

CORE NO. 23. 4286-4316 feet (30 ft)

Much the same as core No. 22 with progressively less siltstone downward and more shale. The siltstone tubes in the black shales are not present below about 4300 ft. Vertical fracture at 4312-4312.8 ft.