

STATE OF ARKANSAS

Arkansas Resources and Development Commission

Wayne C. Fletcher, Executive Director

DIVISION OF GEOLOGY

Harold B. Foxhall, Director

BULLETIN 18

GEOLOGICAL FORMATIONS PENETRATED BY
THE ARKANSAS-LOUISIANA GAS COMPANY NO. 1
BARTON WELL ON THE CECIL ANTICLINE,
FRANKLIN COUNTY, ARKANSAS

By

Robert J. Lantz

U. S. Geological Survey



Published in Cooperation with the U. S. Geological Survey

Little Rock, Arkansas

1950

Reprinted 1986

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LETTER OF TRANSMITTAL

Little Rock, Arkansas
October 17, 1950

Mr. Wayne C. Fletcher
Executive Director
Arkansas Resources and Development Commission
Little Rock, Arkansas

Dear Mr. Fletcher:

It gives me great pleasure to transmit herewith Bulletin 18, a report entitled, "Geological Formations Penetrated by the Arkansas-Louisiana Gas Company No. 1 Barton Well on the Cecil Anticline, Franklin County, Arkansas", by Robert J. Lentz of the United States Geological Survey.

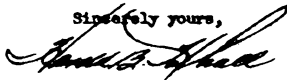
This report is especially valuable to the petroleum industry because, for the first time, an unusually complete and accurate record of the deeply buried formations below the gas-producing sands of the Arkansas Valley was obtained by means of diamond coring. This study will serve as a key point for future correlations and stratigraphic studies in the area. Lack of such knowledge has seriously hindered deep wildcat testing in central northern Arkansas. We are confident that this report will be of sufficient importance to encourage the drilling of more wildcat wells in this comparatively unknown area.

The Barton well is important in another sense. Not only is it the deepest wildcat well in the Arkansas Paleozoic area, but it also produces gas in commercial quantities from the Hale sandstone, a horizon hitherto unproductive in this State. Discovery of a gas field in the Hale sandstone opens up new possibilities for deeper production in the known gas fields of western Arkansas. It also encourages exploration in those non-productive areas of the State where the Hale is known to be present in the subsurface.

Through the courtesy of the Arkansas-Louisiana Gas Company, the Division of Geology now has in storage the major portion of the diamond core section and all of the cuttings. This material will be available to interested geologists who may want to check some of the correlation points.

Grateful acknowledgment is given Mr. Watson H. Monroe and Mr. John C. Maher, of the U. S. Geological Survey, for their assistance in reviewing the manuscript and offering valuable suggestions.

Sincerely yours,



Director
Division of Geology

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GEOLOGICAL FORMATIONS PENETRATED BY
THE ARKANSAS-LOUISIANA GAS COMPANY NO. 1
BARTON WELL ON THE CECIL ANTICLINE,
FRANKLIN COUNTY, ARKANSAS

By

Robert J. Lantz
U. S. Geological Survey

ABSTRACT

The first gas field in Arkansas producing from the lower Pennsylvanian Morrow rocks was discovered in 1949 by the Arkansas-Louisiana Gas Company No. 1 Barton well on the Cecil anticline in Franklin County. This well, drilled to a total depth of 6,650 feet before being plugged back to a depth of 5,000 feet, penetrated rocks of Pennsylvanian, Mississippian, Devonian, Silurian, and Ordovician age. Almost continuous cores were obtained from the middle of the Atoka formation (Pennsylvanian) to the top of the Boone formation (Mississippian) and excellent cable-tool cuttings of the formation not cored were collected. These cores and cuttings are described in detail and tentatively correlated with beds that crop out in northern Arkansas and eastern Oklahoma. A graphic log and an electric log of the well are included.

INTRODUCTION

Location and Drilling Data

The Arkansas-Louisiana Gas Company No. 1 Ralph S. Barton well, SE $\frac{1}{4}$ SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 27, T. 9 N., R. 28 W., Franklin County, Arkansas, was spudded November 14, 1948, and completed September 26, 1949. Cable tools were used from the surface to a depth of 2,860 feet, rotary tools from 2,860 to 5,783 feet, and cable tools again from 5,783 to 6,650 feet, the total depth of the well. Samples of drill cuttings were collected at 5- or 10-foot intervals except in the parts that were cored. Coring with diamond-head core barrels, 4 $\frac{1}{2}$ inches and 3 $\frac{1}{2}$ inches in diameter, was started at 2,958 feet in the Atoka formation and continued intermittently to a depth of 5,783 feet in the Boone formation. All this interval was cored except the thick shale beds. Core recovery was almost 100 percent. After reaching a depth of 6,650 feet, the well was plugged back to 5,000 feet, and is reported to be producing 7 million cubic feet of dry gas per day through perforations from 4,850 to 4,930 feet in depth opposite part of the Hale formation.

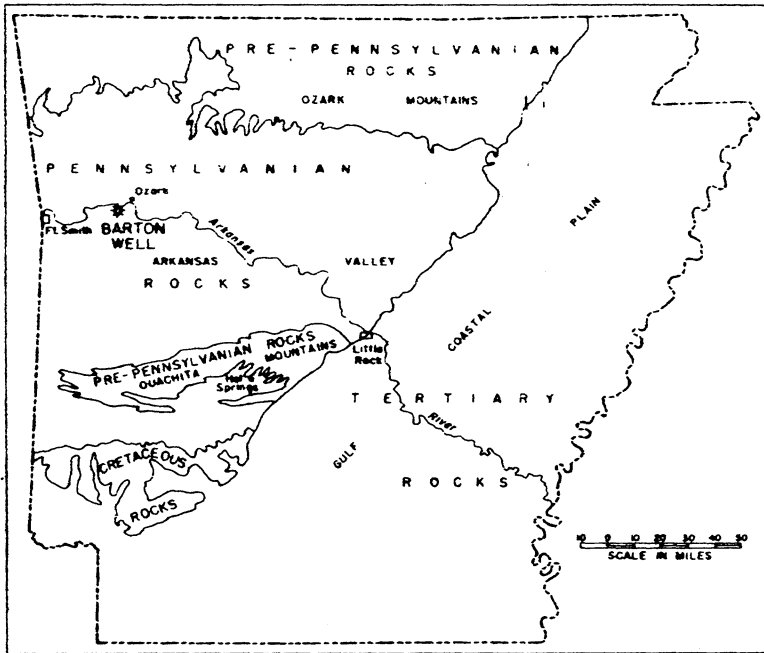


FIGURE 1. - GENERALIZED GEOLOGIC MAP OF ARKANSAS
SHOWING LOCATION OF BARTON WELL

Purpose and Methods of Investigation

The surface exposures of the Paleozoic formations are well known in the Ozark region of Arkansas; they have been mapped and described in detail by numerous geologists.¹ Their subsurface equivalents are relatively unknown in the Arkansas Valley, where few wells have been drilled through the Pennsylvanian rocks. The long cores, excellent samples, and electric log from the Barton well in Franklin County have provided a wealth of detailed stratigraphic information which is recorded in this report to aid in tracing the formational units of the Ozarks beneath the Arkansas Valley. The correlations suggested herein are only tentative because of the considerable distance from the well to the nearest outcrops. However, it is hoped that the detailed lithologic descriptions of the well cuttings and cores will aid in establishing more precise correlations later, and in the meantime serve as a stratigraphic guide in the development of oil and gas in northwestern Arkansas.

The descriptions of the cores have been made by both macroscopic and microscopic examination; those of the cuttings have been prepared by microscopic examination with reference in part to the electric log. The microscopic examinations were made with a binocular microscope using 6.3 magnification for mass character and 18 or 27 magnification for special minute features. The lithology was plotted in color on a log strip; symbols were used to indicate details of the lithology; and detailed descriptions of the rocks were lettered along the side of the log at the corresponding depth. To make a detailed record of the cored portions of the well, a vertical scale of 1 inch equals 40 feet was used on the log. This log was drafted on a vertical scale of 1 inch equals 100 feet for publication as plate 1.

The descriptive terminology in this report is essentially that used by most Midcontinent geologists making microscopic examinations of well samples, as this procedure seems to be the most useful. The terms *silt*, *very fine grained sandstone*, *fine-grained sandstone*, and *medium-grained sandstone* are used in accordance with the Wentworth grade scale—silt, 0.0038 mm to 0.062 mm in diameter; very fine grained sandstone, 0.062 mm to 0.125 mm in diameter; fine-grained sandstone, 0.125 mm to 0.25 mm in diameter; medium-grained sandstone, 0.25 mm to 0.50 mm in diameter. Sandstones which break into individual grains upon drilling are noted as *free drilling* or *drills free*. A limestone or dolomite that has rough tex-

¹ Adams, G. I. and Ulrich, E. O., U. S. Geol. Survey Geol. Atlas, Fayetteville folio (no. 119), 1905.

Purdue, A. H., U. S. Geol. Survey Geol. Atlas, Winslow folio (no. 154), 1907.

Purdue, A. H., and Miser, H. D., U. S. Geol. Survey Geol. Atlas, Eureka Springs-Harrison folio (no. 202), 1916.

Cronis, C., *Geology of the Arkansas Paleozoic area*: Arkansas Geol. Survey Bull. 3, 1936.

McKnight, E. T., *Zinc and lead deposits of northern Arkansas*: U. S. Geol. Survey Bull. 853, 1935.

Gordon, M., Jr., and Kinney, D. M., *Geologic map and structure sections of the Batesville district, Independence County, Arkansas*: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 12, 1944.

ture is considered *crystalline* if crystal faces can be seen; if crystal faces cannot be seen, it is termed *granular*. A limestone or dolomite that has smooth texture is called *dense*.

Acknowledgments

This report has been prepared by the U. S. Geological Survey in cooperation with the Arkansas Division of Geology and the Arkansas-Louisiana Gas Company. H. B. Foxhall, State Geologist of Arkansas, N. F. Williams, of the Arkansas Division of Geology, and E. L. Caster, Superintendent of the Land and Geological Department of the Arkansas Fuel Oil Company, made the arrangements for providing cores, samples, and data from the well. J. L. Cummings, Jr., of the Arkansas-Louisiana Gas Company, and Brun Johnson, of the Arkansas-Oklahoma Gas Company, assisted the writer in obtaining samples. The writer is indebted to many geologists of the U. S. Geological Survey: H. D. Miser for his advice on the stratigraphy of the area; P. E. Cloud, Jr., Helen Duncan, and Jean M. Berdan for fossil identifications; and C. H. Dane and W. H. Monroe for reviewing the manuscript. The report was prepared under the supervision of John C. Maher; the drafting was done by Cathleen S. Collins.

STRATIGRAPHY

Lower Pennsylvanian and older rocks that crop out in the Ozark region of northern Arkansas dip southward under thick younger Pennsylvanian rocks in the Arkansas Valley region and appear again at the surface in the Ouachita Mountains. (See fig. 1). The outcrops in the Ozark region are mostly marine beds of limestone, dolomite, and shale; the rocks exposed in the Ouachita Mountains are mostly continental and near-shore deposits of sandstone and shale. The rocks penetrated by the Barton well in the northern part of the Arkansas Valley (fig. 1) resemble the Ozark section and not the clastic sequence of the Ouachita Mountains. This well, situated on the south flank of the Cecil anticline as mapped by Hendricks and Parks,² penetrated rocks of every age from Pennsylvanian to Ordovician (see pl. 1). A short description of these rocks follows, beginning with the youngest:

CARBONIFEROUS SYSTEM PENNSYLVANIAN SERIES

Hartshorne sandstone.—The Hartshorne sandstone, a white micaceous fine-grained sandstone, extends from the surface down to a depth of 55 feet. The light color of the Hartshorne sandstone distinguishes it from the underlying gray sandstones of the Atoka formation. Although the Hartshorne and the Atoka are separated by an unconformity, no evidence of it was seen in the samples.

Atoka formation.—The Atoka formation, 4,392 feet thick, consists of alternating beds of sandstone, siltstone, and dark shale. The beds of siltstone and silty shale in the lower 1,500 feet of the Atoka are remarkably fucoidal, the fucoid marks making a delicate pattern of whorls and scrolls on the outside of the cores. Probably more of the formation is fucoidal, but only the lower 1,500 feet was cored and fucoid marks could not be recognized in cuttings. The base of the Atoka formation is marked by a light-gray limy fine-grained sandstone. The only Atoka fossil collected was identified by P. E. Cloud, Jr., of the U. S. Geological Survey, as "a *Taonurus*-like marking." The unconformity which separates the Atoka formation from the underlying Boyd shale was not recognized in the samples.

Morrow Group

Boyd shale.—A succession of thick black shale beds, thin sandstone and siltstone layers, and two limestone members—the Kessler limestone member and the Brentwood limestone member—constitutes the Boyd shale. The Kessler limestone member near the top of the formation is 21 feet thick. It is overlain by a sequence of black shale and sandstone, 84 feet thick, and underlain

² Hendricks, T. A., and Parks, Bryan. Geology and mineral resources of the western part of the Arkansas coal field: U. S. Geol. Survey Bull. 847-E, pl. 35, 1937.

by a bed of limy fine-grained sandstone, 10 feet thick, and a sequence of black shale and siltstone, 163 feet thick. The Brentwood limestone member, which is next in the downward sequence, is a dark-gray argillaceous crinoidal limestone, 37 feet thick, underlain by a bed of black silty shale, 31 feet thick. Ostracodes from the Brentwood limestone were identified by Jean M. Berdan of the U. S. Geological Survey as: "*Bairdia* sp., *Kellettina* sp., also a subrhomboidal form possibly referable to *Ectodemites*, and a smooth form with a posterior keel apparently related to *Healdia*." The Bloyd shale overlies the Hale formation conformably.

Hale formation.—The Hale formation, 136 feet thick, consists of limestone, shale, and sandstone. The upper part of the formation is composed of gray oolitic fossiliferous slightly glauconitic porous limestone, 113 feet thick, which includes a few thin beds of black shale and limy sandstone. Below the limestone is a bed of porous white fine-grained sandstone, 23 feet thick, at the base of which is a brown phosphatic conglomerate. Bryozoa from the Hale formation were identified by Helen Duncan of the U. S. Geological Survey as: "*Meekopora*?, *Ramiporalia*?, stenoporoids, *Streblotrypa*, *Streblotrypa*?, *Rhombopora angusta* Ulrich?, other indeterminate rhomboporoids, *Fenestella* sp., possibly *F. multispinosa* Ulrich, *Polypora*, *Thamniscus*?, *Sulcoretepora* cf. *S. simulans* (Ulrich), *Sulcoretepora* sp. indet." Ostracodes from the Hale formation were identified by J. M. Berdan of the U. S. Geological Survey as: "*Paraparchites* sp., *Bairdia* sp., *Bythocypris*? sp., *Silenites* sp., and a unisulcate form similar to *Haploprimitia*."

Rocks of Questionable Age.—Below the conglomerate at the base of the sandstone and overlying the massive Pitkin limestone of Chester age is a 252-foot sequence of black siltstone, limestone, and shale, which the writer is unable to assign with certainty to either the Morrow or Chester group. This sequence can be split into two lithologic units—an upper unit, 175 feet thick, composed of beds of fucoidal shale and siltstone, and a lower unit, 77 feet thick, composed of a thin bed of dark-gray argillaceous limestone and a thick bed of black shale. Lithologically the core of the upper unit resembles parts of the Atoka formation penetrated higher in the well, whereas the lower unit is more similar to the underlying beds of Chester age. No evidence of an unconformity was found in or below this sequence. A similar sequence on the surface in northern Arkansas was mapped by Miser with Morrow rocks, but it appears that beds similar to the lower unit have been included in the Pitkin limestone in northeastern Oklahoma by Moore.⁴ Whether any part of the sequence is equivalent to the Springer formation is not known as no identifiable fossils were found in this part of the core.

³ Miser, H. D., personal communication, 1945.

⁴ Moore, Carl A., The Morrow series of northeastern Oklahoma: Oklahoma Geol. Survey Bull. 66, pp. 15-22, 1947.

MISSISSIPPIAN SERIES

Chester Group

Pitkin limestone.—The Pitkin limestone, 218 feet thick, consists of dark finely crystalline fossiliferous limestone which contains oolitic layers. Fossils from the Pitkin limestone were identified by P. E. Cloud, Jr. of the U. S. Geological Survey, as "*Spirifer*" cf. *S. keokuk* Hall, and *Dictyoelostus* cf. *D. inflatus* (McChesney) ?. The Pitkin rests conformably upon the Fayetteville shale.

Fayetteville shale.—The Fayetteville shale, 177 feet thick, is composed of a thick black shale bed which includes two thin limestone beds near the base. No evidence of the unconformity separating the Fayetteville from the underlying Moorefield formation was seen in the samples.

Meramec Group

Moorefield formation.—The Moorefield formation consists of an upper black shale bed, 40 feet thick, and a lower black calcareous argillaceous siltstone bed, 144 feet thick. Rocks resembling the Batesville sandstone or the Hindsville limestone member of the Batesville sandstone which overlie the Moorefield formation at some places were not present in the well. A basal conglomerate, which contains black chert pebbles and abundant glauconite, marks the unconformable contact of the Moorefield and the underlying Boone formation. Fossils from the Moorefield formation were identified by P. E. Cloud, Jr. of the U. S. Geological Survey as follows: "*Leiorhynchus carboniferum* Girty, *Moorefieldella* aff. *M. eurckensis* (Walcott), *Martinia* sp., *Orbiculoidea* sp., *Productella* cf. *P. hirsutiformis* Walcott."

Osage Group

Boone formation.—The Boone formation is composed of gray finely crystalline limestone with much interbedded and included chert which is dark-colored and highly fractured at the top, gray in the middle, and cream-colored at the bottom. A comparatively thin section of Boone, 52 feet, was penetrated in the well. The Boone formation is reported to rest unconformably on the Chattanooga shale from surface exposures.

CARBONIFEROUS (MISSISSIPPIAN) OR DEVONIAN SYSTEM

Chattanooga shale.—The Chattanooga shale is made up of a black shale bed, 41 feet thick, which includes a thin calcareous sandstone near the base. The unconformity between the Chattanooga shale and the underlying Penters chert could not be discerned from the cuttings.

DEVONIAN SYSTEM

Penters chert.—The Penters chert, which totals 58 feet in thickness, is composed of an upper unit of milky chert and thin interbedded limy siltstone layers, 33 feet thick, and a lower unit

of gray coarsely crystalline limestone, 25 feet thick. The Penters chert is reported to rest unconformably on Silurian rocks.

SILURIAN SYSTEM

Limestones and dolomitic limestones totaling 258 feet in thickness represent the Silurian system in the well. The upper part of the limestone sequence, which lies unconformably below the Penters chert, has not been correlated. This portion of the sequence is a white silty finely granular limestone, 48 feet thick, which occupies the stratigraphic position of the Lafferty limestone, but because the lithology does not resemble the Lafferty, a name is not attached to this part of the sequence. Below this interval the Silurian rocks were tentatively identified as St. Clair(?) limestone and Brassfield(?) limestone. It is thought that all, or part, of these formations make up the subsurface "Hunton" limestone of northeastern Oklahoma.

St. Clair(?) limestone.—The St. Clair(?) limestone is separated from the overlying limestone by a thin zone of pale-purple chert which may mark the unconformable contact of the beds. The St. Clair(?), 165 feet thick, consists of gray to pink, slightly dolomitic limestone. The contact of the St. Clair and the underlying Brassfield is unconformable where exposed on the surface, but this relation could not be recognized in the cuttings.

Brassfield(?) limestone.—The lowest Silurian formation identified in the well is the Brassfield(?) limestone, which is 45 feet thick. This formation is similar to the St. Clair(?) in appearance, but may be differentiated by color and crystallinity—the Brassfield(?) has an orange-red color in contrast to the pink color of the St. Clair(?), and is more coarsely crystalline. The Brassfield rests unconformably on the Cason shale where exposed on the surface.

ORDOVICIAN SYSTEM

Cason shale.—The Cason shale consists of a gray and green dolomitic shale bed, 42 feet thick, which lies unconformably on the Fernvale limestone. Phosphatic nodules, common in outcrops of the Cason, were not present in the cuttings.

Fernvale limestone.—The Fernvale limestone, 29 feet thick, is composed of gray, medium crystalline limestone. The Fernvale in the well did not contain pink calcite crystals as it does in most Fernvale surface exposures of the Ozark region. The Fernvale limestone rests unconformably on the Kimmswick limestone although this fact cannot be determined from the cuttings.

Kimmswick(?) limestone.—The Kimmswick(?) limestone, 41 feet thick, consists of gray finely crystalline limestone, which is silty near the base, and some dark-colored dense chert. The contact of the Kimmswick with the underlying Plattin is unconformable where seen on the surface.

Plattin limestone.—The Plattin limestone, 30 feet thick, is composed of gray and dark-gray dense limestone. The Plattin rests unconformably on the St. Peter sandstone, as the Joachim dolomite, which normally overlies the St. Peter, appears to be missing.

St. Peter sandstone.—The St. Peter sandstone, 100 feet thick, is composed of the typical rounded frosted sand grains usually associated with the St. Peter sandstone. The formation, as present in the well, is so tightly cemented by gray silty dolomite that some of the samples contain mostly broken sand grains. The formation did not carry enough water for cable-tool drilling, and little evidence of porosity was seen in the cuttings. The St. Peter overlies the Everton formation unconformably where the contact is exposed on the surface.

Everton formation.—The Everton formation consists of shale, sandstone, and dolomite. The top of the Everton is marked by a bed of gray-green shale, 17 feet thick, underlain by a sandstone bed, 34 feet thick, which closely resembles the St. Peter. This sandstone may correspond to McKnight's⁵ Newton sandstone member of the Everton formation. Below the sandstone, there is a sequence of Everton rocks, 173 feet thick, consisting of dolomite and sandy dolomite with occasional thin beds of sandstone and dark shale. Black shale and dark-gray silty dolomite make up the lowest 16 feet of the well. These rocks closely resemble the Powell dolomite, but may belong to the Everton formation. Due to the lack of conclusive evidence, it is here included in the Everton formation. Drilling was stopped 240 feet below the top of the Everton.

⁵ McKnight, E. T., op. cit. p. 36, 1935.

DETAILED DESCRIPTION OF LITHOLOGY

CARBONIFEROUS SYSTEM

PENNSYLVANIAN SERIES

Depth in Feet	Elevation (D.F.) 815 Feet
<i>Hasthorne sandstone</i>	
0-50	White micaceous fine-grained sandstone; some red and brown iron-staining; few magnetite grains.
50-55	Gray micaceous shaly sandstone with very fine subangular grains.
<i>Atoka formation</i>	
55-80	Dark-gray to black slightly fissile micaceous shale; ironstone concretions.
80-96	Dark-gray to black slightly fissile micaceous shale; fine pyrite crystals.
96-110	Dark-gray to black slightly fissile micaceous shale.
110-115	Dark-gray very micaceous very fine sandy shale.
115-120	Dark-gray micaceous very fine sandy shale.
120-124	Dark-gray to gray micaceous shaly siltstone to very fine grained sandstone.
124-128	Gray micaceous slightly shaly siltstone to very fine grained sandstone.
128-130	Gray to dark-gray micaceous shaly siltstone to very fine grained sandstone.
130-238	Dark-gray to black slightly fissile micaceous shale.
238-250	Dark-gray to gray very micaceous shaly very fine grained sandstone.
250-280	Dark-gray micaceous shaly siltstone to very fine grained sandstone.
280-300	Dark-gray to gray slightly micaceous shaly siltstone to very fine grained sandstone.
300-309	Gray micaceous slightly shaly siltstone to very fine grained sandstone.
309-311	Dark-gray to black micaceous slightly silty to very fine sandy shale.
311-327	Gray micaceous slightly shaly siltstone to very fine grained sandstone.
327-330	Dark-gray to black micaceous silty to very fine sandy shale.
330-333	Gray micaceous slightly shaly and silty very fine grained sandstone.
333-335	Dark-gray to black micaceous silty to very fine sandy shale.
335-367	Gray micaceous slightly shaly and silty very fine to fine-grained sandstone.
367-370	Dark-gray to black micaceous slightly silty shale.
370-379	Gray micaceous slightly shaly and silty very fine to fine-grained sandstone.
379-381	Dark-gray to black micaceous silty shale.
381-383	Gray micaceous slightly shaly and silty very fine to fine-grained sandstone.
383-390	Dark-gray to black micaceous silty shale.
390-393	Dark-gray micaceous shaly siltstone to very fine grained sandstone.
393-396	Gray micaceous slightly shaly and silty very fine grained sandstone.
396-398	Dark-gray micaceous shaly siltstone to very fine grained sandstone.
398-402	Dark-gray micaceous very silty shale.

402-408	Light-gray slightly micaceous very slightly shaly sandstone with fine subangular grains; drills free.
408-412	Dark-gray to black micaceous very silty shale.
412-422	Light-gray slightly micaceous very slightly shaly sandstone with fine subangular grains; drills free.
422-437	Gray micaceous shaly and silty fine- to very fine grained sandstone.
437-445	Gray micaceous silty shale.
445-449	Dark-gray shaly and silty very fine grained sandstone.
449-454	Dark-gray to black micaceous finely pyritic silty shale.
454-461	Gray and dark-gray micaceous shaly and silty very fine grained sandstone.
461-475	Dark-gray to black micaceous silty shale.
475-476	Light-gray micaceous very fine grained sandstone.
476-479	Dark-gray to black micaceous silty shale.
479-480	Gray micaceous silty very fine grained sandstone.
480-482	Dark-gray to black micaceous silty shale.
482-483	Gray micaceous silty very fine grained sandstone.
483-485	Dark-gray to black micaceous silty shale.
485-486	Gray micaceous silty very fine grained sandstone.
486-488	Dark-gray to black micaceous silty shale.
488-489	Gray micaceous silty very fine grained sandstone.
489-493	Dark-gray to black micaceous silty shale.
493-494	Gray micaceous silty very fine grained sandstone.
494-499	Dark-gray to black micaceous silty shale.
499-504	Gray micaceous silty very fine grained sandstone.
504-510	Dark-gray to black micaceous silty shale.
510-513	Gray micaceous silty very fine grained sandstone.
513-526	Black very micaceous fissile silty shale.
526-529	Gray micaceous silty very fine grained sandstone.
529-533	Black very micaceous fissile silty shale.
533-535	Gray micaceous silty very fine grained sandstone.
535-540	Dark-gray to black micaceous silty to very fine sandy shale.
540-552	Black slightly micaceous fissile shale.
552-562	Dark-gray to black micaceous slightly pyritic silty to very fine sandy shale.
562-565	Dark-gray micaceous very shaly and silty very fine grained sandstone.
565-568	Dark-gray to black micaceous silty to very fine sandy shale.
568-576	Dark-gray to black micaceous slightly silty to very fine sandy shale.
576-579	Dark-gray to black micaceous silty to very fine sandy shale.
579-582	Dark-gray micaceous shaly and silty very fine grained sandstone.
582-585	Dark-gray to black micaceous silty to very fine sandy shale.
585-594	Black micaceous slightly silty shale.
594-596	Dark-gray to black slightly micaceous silty shale.
596-606	Black slightly micaceous slightly silty shale.
606-608	Dark-gray to black slightly micaceous very silty shale.
608-621	Black slightly micaceous slightly silty shale.
621-624	Dark-gray micaceous silty to very fine sandy shale.
624-629	Gray micaceous shaly very fine to fine-grained sandstone.
629-632	Light-gray to white sandstone with fine subangular grains.
632-635	Gray micaceous shaly very fine to fine-grained sandstone.
635-636	Dark-gray micaceous silty shale.
636-639	Gray micaceous shaly very fine grained sandstone.
639-641	Dark-gray micaceous silty shale.
641-645	Gray micaceous shaly and silty very fine to fine-grained sandstone.
645-651	Dark-gray slightly micaceous silty shale.
651-670	Black micaceous shale.

670-702	Dark-gray to black micaceous silty shale.
702-706	Dark-gray to black micaceous very silty shale.
706-708	Dark-gray micaceous shaly and silty very fine grained sandstone.
708-713	Dark-gray to black micaceous silty shale.
713-715	Dark-gray to black micaceous very silty shale.
715-718	Dark-gray to black micaceous silty shale.
718-719	Dark-gray micaceous shaly and silty very fine grained sandstone.
719-730	Dark-gray micaceous shale.
730-732	Dark-gray very micaceous silty shale.
732-736	Dark-gray micaceous shale.
736-739	Dark-gray very micaceous silty shale.
739-743	Gray micaceous shaly and silty very fine grained sandstone.
743-801	Black micaceous shale.
801-820	Dark-gray to black micaceous finely pyritic shale.
820-830	Dark-gray to black silty to very fine sandy shale.
830-840	(No samples)
840-841	Dark-gray micaceous very fine sandy shale.
841-847	Light-gray to white micaceous very fine to fine-grained sandstone.
847-851	Dark-gray micaceous very fine sandy shale.
851-871	Light-gray to white micaceous poorly sorted very fine to medium-grained sandstone.
871-945	Dark-gray to black micaceous silty shale.
945-955	Gray micaceous shaly siltstone to very fine grained sandstone.
955-973	Dark-gray to black micaceous silty shale.
973-979	Gray micaceous slightly shaly sandstone with fine to medium subangular grains.
979-990	Light-gray to white micaceous sandstone with fine to medium subangular grains.
990-994	Gray micaceous shaly siltstone to very fine grained sandstone.
994-997	Dark-gray micaceous silty to very fine sandy shale.
997-999	Gray micaceous shaly siltstone to very fine grained sandstone.
999-1005	Dark-gray micaceous silty to very fine sandy shale.
1005-1007	Gray micaceous shaly siltstone to very fine grained sandstone.
1007-1011	Dark-gray micaceous silty shale.
1011-1012	Dark-gray micaceous shaly siltstone to very fine grained sandstone.
1012-1018	Dark-gray to black micaceous silty shale.
1018-1019	Dark-gray micaceous shaly siltstone to very fine grained sandstone.
1019-1026	Dark-gray to black micaceous silty shale.
1026-1028	Gray slightly shaly sandstone with fine to medium subangular grains; drills free.
1028-1047	Light-gray to white sandstone with fine to medium subangular grains; drills free.
1047-1058	Gray to dark-gray micaceous shaly very fine grained sandstone.
1058-1062	Light-gray micaceous siltstone to very fine grained sandstone.
1062-1072	Dark-gray to black micaceous shale.
1072-1075	Gray micaceous slightly shaly siltstone to very fine grained sandstone.
1075-1083	Dark-gray to black micaceous silty shale.
1083-1090	Light-gray to white slightly micaceous very fine to fine-grained sandstone.
1090-1093	Dark-gray micaceous silty shale.
1093-1113	Light-gray to white micaceous silty very fine to fine-grained sandstone.
1113-1120	Dark-gray micaceous silty to very fine sandy shale.

1120-1127	Light-gray to gray micaceous shaly and silty very fine to fine-grained sandstone.
1127-1129	Dark-gray micaceous very silty shale.
1129-1138	Gray to dark-gray micaceous shaly siltstone to very fine grained sandstone.
1138-1144	Dark-gray micaceous very shaly siltstone to very fine grained sandstone.
1144-1152	Dark-gray micaceous silty shale.
1152-1166	Black micaceous shale.
1166-1173	Gray micaceous shaly very fine grained sandstone.
1173-1192	Dark-gray to black micaceous silty shale.
1192-1211	Black micaceous shale.
1211-1216	Black micaceous finely pyritic shale.
1216-1231	Black micaceous shale.
1231-1235	Dark-gray to black micaceous silty shale.
1235-1240	Gray to light-gray micaceous very fine to fine-grained sandstone.
1240-1243	Gray to light-gray micaceous very fine to fine-grained sandstone; free drilling in part.
1243-1259	Light-gray to white micaceous very fine to fine-grained sandstone; free drilling in part.
1259-1264	Dark-gray micaceous silty to very fine sandy shale.
1264-1274	Gray micaceous shaly siltstone to very fine grained sandstone.
1274-1281	Light-gray to white micaceous silty very fine to fine-grained sandstone; grains drill free.
1281-1302	Light-gray micaceous silty very fine to fine-grained sandstone.
1302-1313	Gray, grading downward to dark-gray, micaceous shaly siltstone to very fine grained sandstone.
1313-1318	Dark-gray to black micaceous slightly very fine sandy shale.
1318-1323	Gray micaceous shaly siltstone to very fine grained sandstone.
1323-1326	Dark-gray micaceous very fine sandy shale.
1326-1332	Black micaceous slightly silty shale.
1332-1337	Dark-gray micaceous silty to very fine sandy shale.
1337-1345	Dark-gray to black micaceous slightly silty shale.
1345-1347	Dark-gray micaceous silty to very fine sandy shale.
1347-1386	Black micaceous shale.
1386-1395	Dark-gray micaceous silty to very fine sandy shale.
1395-1401	Black micaceous shale.
1401-1405	Gray to light-gray micaceous slightly shaly siltstone to very fine grained sandstone.
1405-1408	Light-gray to white micaceous very fine grained sandstone.
1408-1411	Gray micaceous slightly shaly very fine grained sandstone.
1411-1428	Gray to dark-gray micaceous silty to very fine sandy shale.
1428-1434	Dark-gray to black micaceous slightly silty shale.
1434-1436	Gray micaceous silty to very fine sandy shale.
1436-1440	Light-gray micaceous very fine to fine-grained sandstone.
1440-1442	Gray micaceous silty to very fine sandy shale.
1442-1447	Dark-gray to black micaceous shale.
1447-1448	Dark-gray micaceous slightly silty shale.
1448-1495	Black micaceous shale.
1495-1508	Light-gray to white siltstone to very fine grained sandstone; drills free.
1508-1522	Dark-gray micaceous silty to very fine sandy shale.
1522-1536	Gray micaceous shaly siltstone to very fine grained sandstone.
1536-1540	Dark-gray micaceous very fine sandy shale.
1540-1541	Light-gray micaceous siltstone to very fine grained sandstone.
1541-1542	Dark-gray micaceous silty shale.
1542-1545	Light-gray micaceous siltstone to very fine grained sandstone.
1545-1556	Dark-gray to black micaceous silty shale.
1556-1560	Light-gray micaceous slightly shaly very fine grained sandstone.

1560-1562	Dark-gray micaceous silty shale.
1562-1571	Light-gray to white micaceous very fine to fine-grained sandstone; free drilling in part.
1571-1579	Gray micaceous slightly shaly very fine to fine-grained sandstone.
1579-1592	Dark-gray to black micaceous silty shale.
1592-1603	Black micaceous shale.
1603-1604	Gray micaceous shaly very fine grained sandstone.
1604-1608	Black micaceous shale.
1608-1610	Gray micaceous shaly very fine grained sandstone.
1610-1616	Black micaceous shale.
1616-1617	Gray micaceous shaly very fine grained sandstone.
1617-1638	Black micaceous shale.
1638-1640	Gray micaceous shaly very fine grained sandstone.
1640-1684	Black micaceous shale.
1684-1688	Black micaceous finely pyritic shale.
1688-1705	Black micaceous shale.
1705-1713	Light-gray to white micaceous siltstone to very fine grained sandstone.
1713-1720	Black micaceous shale.
1720-1727	Light gray-green micaceous very fine to fine-grained sandstone.
1727-1731	Black micaceous shale.
1731-1733	Light gray-green micaceous siltstone to very fine grained sandstone.
1733-1735	Black micaceous shale.
1735-1740	White micaceous fine-grained sandstone; drills free.
1740-1750	White micaceous fine- to medium-grained sandstone; drills free.
1750-1752	Light-gray micaceous shaly very fine to fine-grained sandstone.
1752-1753	Black micaceous shale.
1753-1761	Light-gray micaceous shaly very fine to fine-grained sandstone.
1761-1788	Dark-gray micaceous shale.
1788-1800	Dark-gray micaceous very fine sandy shale.
1800-1814	Gray micaceous shaly siltstone to very fine grained sandstone.
1814-1818	Dark-gray micaceous very fine sandy shale.
1818-1842	Maroon micaceous silty shale.
1842-1845	Maroon micaceous very fine sandy shale.
1845-1922	Dark-gray slightly micaceous shale.
1922-1924	Dark-gray very fine sandy shale.
1924-1972	Dark-gray slightly micaceous shale.
1972-1979	Gray shaly siltstone to very fine grained sandstone.
1979-1984	Dark-gray slightly micaceous shale.
1984-2006	White micaceous sandstone with very fine subangular grains; free drilling in part.
2006-2048	Black micaceous fissile shale.
2048-2052	Dark-gray very fine sandy shale.
2052-2075	Black micaceous fissile shale.
2075-2083	Gray to light-gray micaceous very fine grained sandstone.
2083-2090	Black micaceous fissile shale.
2090-2098	White micaceous very fine grained sandstone; drills free.
2098-2106	White micaceous very fine to fine-grained sandstone; drills free.
2106-2113	White micaceous very fine to fine-grained sandstone.
2113-2136	White micaceous sandstone with very fine to fine subangular grains; free drilling in part.
2136-2140	Gray micaceous shaly very fine to fine-grained sandstone.
2140-2142	Dark-gray micaceous shale.
2142-2148	Gray micaceous shaly very fine grained sandstone.
2148-2152	Dark-gray micaceous shale.

2152-2154	Gray micaceous very fine sandy shale.
2154-2167	Light-gray micaceous slightly shaly very fine grained sandstone.
2167-2172	Dark-gray micaceous shale.
2172-2174	Dark-gray micaceous silty shale.
2174-2177	Gray micaceous shaly siltstone to very fine grained sandstone.
2177-2179	Dark-gray micaceous silty shale.
2179-2191	Black micaceous shale.
2191-2194	White micaceous siltstone to very fine grained sandstone.
2194-2196	Black micaceous shale.
2196-2201	Light-gray to white micaceous siltstone to very fine grained sandstone.
2201-2211	Light-gray to gray micaceous slightly shaly very fine to fine-grained sandstone.
2211-2220	Black micaceous very fine sandy shale.
2220-2235	Black micaceous shale.
2235-2238	Dark-gray micaceous silty shale.
2238-2259	Light-gray micaceous slightly shaly sandstone with very fine to fine subangular grains.
2259-2266	White micaceous very fine to fine-grained sandstone.
2266-2298	Dark-gray to black micaceous shale.
2298-2322	Light-gray silty sandstone with very fine to fine subangular grains.
2322-2338	White micaceous very fine to fine-grained sandstone; drills free.
2338-2356	White micaceous sandstone with fine subangular to subround grains; drills free.
2356-2359	Black micaceous shale.
2359-2366	White micaceous very fine to fine-grained sandstone; drills free.
2366-2370	Black micaceous shale.
2370-2375	White micaceous very fine grained sandstone.
2375-2378	Black micaceous shale.
2378-2382	Light-gray micaceous slightly shaly siltstone to very fine grained sandstone.
2382-2393	Black micaceous shale.
2393-2395	Dark-gray very fine sandy shale.
2395-2401	Black micaceous shale.
2401-2403	Dark-gray very fine sandy shale.
2403-2437	Black micaceous slightly silty shale.
2437-2452	Dark-gray micaceous very fine sandy shale.
2452-2477	Black micaceous shale.
2477-2479	Dark-gray micaceous very fine sandy shale.
2479-2497	Black micaceous shale.
2497-2503	White micaceous very fine grained sandstone.
2503-2508	Black micaceous silty shale.
2508-2511	White micaceous very fine grained sandstone.
2511-2514	Black micaceous silty shale.
2514-2518	White micaceous very fine grained sandstone.
2518-2520	Black micaceous shale.
2520-2527	White to light-gray slightly shaly siltstone to very fine grained sandstone.
2527-2534	Black micaceous shale.
2534-2539	Light-gray slightly shaly siltstone to very fine grained sandstone.
2539-2542	Black micaceous shale.
2542-2550	Light-gray slightly shaly siltstone to very fine grained sandstone.
2550-2552	Dark-gray micaceous slightly silty shale.
2552-2562	Light-gray micaceous slightly shaly siltstone to very fine grained sandstone.

2562-2565	Dark-gray micaceous shale.
2565-2567	White micaceous very fine grained sandstone.
2567-2569	Dark-gray micaceous shale.
2569-2572	White micaceous very fine grained sandstone.
2572-2574	Dark-gray micaceous shale.
2574-2586	White micaceous very fine grained sandstone.
2586-2590	Dark-gray micaceous shale.
2590-2592	Light-gray micaceous siltstone to very fine grained sandstone.
2592-2596	Dark-gray micaceous shale.
2596-2600	White micaceous very fine grained sandstone.
2600-2603	Dark-gray micaceous shale.
2603-2604	White micaceous very fine grained sandstone.
2604-2607	Dark-gray micaceous shale.
2607-2609	Light-gray micaceous slightly shaly very fine grained sandstone.
2609-2632	Dark-gray micaceous slightly very fine sandy shale.
2632-2648	Black micaceous shale.
2648-2650	Gray micaceous slightly shaly siltstone to very fine grained sandstone.
2650-2663	White slightly micaceous very fine grained sandstone.
2663-2672	Dark-gray micaceous silty to very fine sandy shale.
2672-2684	Black micaceous shale.
2684-2693	White slightly micaceous very fine to fine-grained sandstone.
2693-2698	Dark-gray micaceous silty shale.
2698-2705	Black micaceous shale.
2705-2711	Gray micaceous slightly shaly very fine grained sandstone.
2711-2716	Black micaceous shale.
2716-2722	White micaceous very fine to fine-grained sandstone.
2722-2725	Black micaceous shale.
2725-2731	White micaceous very fine to fine-grained sandstone.
2731-2737	Dark-gray micaceous very fine sandy shale.
2737-2741	White micaceous siltstone to very fine grained sandstone.
2741-2768	Light-gray micaceous slightly shaly siltstone to very fine grained sandstone.
2768-2773	Black micaceous shale.
2773-2780	White micaceous very fine to fine-grained sandstone.
2780-2784	Dark-gray micaceous shale.
2784-2790	Gray micaceous shaly very fine to fine-grained sandstone.
2790-2805	Black micaceous slightly silty shale.
2805-2809	Light-gray micaceous very fine to fine-grained sandstone.
2809-2854	Black micaceous shale.
2854-2856	Light-gray slightly micaceous slightly shaly fine-grained sandstone.
2856-2881	White slightly micaceous sandstone with fine subround grains.
2881-2904	Black micaceous slightly silty shale.
2904-2906	Gray micaceous shaly very fine grained sandstone.
2906-2915	White micaceous very fine to fine-grained sandstone.
2915-2925	Dark-gray micaceous silty sandstone.
2925-2934	White micaceous very fine to fine-grained sandstone.
2934-2940	Black micaceous shale.
2940-2943	White micaceous very fine to fine-grained sandstone.
2943-2945	Black micaceous shale.
2945-2952	White micaceous very fine to fine-grained sandstone.
2952-2991	Black micaceous fissile, jointed shale; light gray-green silty fucoid marks.
2991-2992	Black fissile, jointed shale.
2992-3007	Black micaceous fissile, jointed shale; light gray-green silty fucoid marks.
3007-3040	Black micaceous fissile, jointed shale; very thin silty streaks.
3040-3051	Dark-gray to gray micaceous shaly siltstone to very fine grained sandstone; shale fragments.

- 3051-3062 Light-gray fucoidal sandstone with very fine to fine subround grains.
- 3062-3062 ½ Black micaceous fissile shale.
- 3062 ½-3074 Light-gray fucoidal sandstone with very fine to fine subround grains.
- 3074-3075 Black micaceous fissile, jointed shale.
- 3075-3087 Light-gray fucoidal sandstone with very fine to fine subround grains. "Taonurus-like markings" at 3078 feet.
- 3087-3088 Black micaceous fissile, jointed shale.
- 3088-3090 Dark-gray micaceous shaly very fine to fine-grained sandstone.
- 3090-3110 Black micaceous fissile slightly fucoidal shale.
- 3110-3127 Black micaceous fissile, jointed shale.
- 3127-3148 Gray to light-gray micaceous shaly siltstone to very fine grained sandstone.
- 3148-3166 Gray to light-gray micaceous fucoidal slightly shaly siltstone to very fine grained sandstone.
- 3166-3175 Light-gray micaceous siltstone to very fine grained sandstone.
- 3175-3191 Light-gray to gray slightly shaly siltstone to very fine grained sandstone; shale fragments and thin shale partings.
- 3191-3206 Gray to dark-gray very shaly siltstone to very fine grained sandstone; thin shale partings.
- 3206-3215 Black micaceous fucoidal silty shale.
- 3215-3218 Alternating thin beds of black micaceous shale and light-gray siltstone.
- 3218-3240 Gray to light-gray micaceous fucoidal slightly shaly siltstone.
- 3240-3243 Dark-gray micaceous very fucoidal shaly siltstone.
- 3243-3265 Dark-gray micaceous fucoidal shaly siltstone to very fine grained sandstone; thin shale partings.
- 3265-3276 Dark-gray micaceous silty shale.
- 3276-3286 Black micaceous fissile shale.
- 3286-3291 Brown micaceous slightly limy sandstone with very fine to fine subangular grains; small fragments of crinoids, bryozoa, and brachiopoda.
- 3291-3335 Black micaceous fissile, jointed slightly fucoidal shale.
- 3335-3340 Gray to gray-brown micaceous very fine to fine-grained sandstone.
- 3340-3345 ½ Gray-brown micaceous slightly limy very fine to fine-grained sandstone; many crinoid fragments.
- 3345 ½-3348 Gray-brown micaceous very fine to fine-grained sandstone.
- 3348-3354 Black micaceous fucoidal silty shale.
- 3354-3371 Black micaceous fissile, jointed silty shale.
- 3371-3380 ½ Light-gray fucoidal very slightly limy very fine to fine-grained sandstone.
- 3380 ½-3389 Black micaceous fucoidal silty shale.
- 3389-3402 White very slightly limy siltstone to very fine grained sandstone.
- 3402-3403 Black fucoidal very shaly siltstone.
- 3403-3406 White very slightly limy siltstone to very fine grained sandstone.
- 3406-3410 Black micaceous fucoidal silty shale.
- 3410-3418 Dark-gray micaceous shaly siltstone to very fine grained sandstone.
- 3418-3429 Gray micaceous slightly shaly siltstone to very fine grained sandstone; thin black shale partings.
- 3429-3442 Black micaceous fissile, jointed slightly fucoidal shale.
- 3442-3443 ½ Dark-gray micaceous shaly siltstone to very fine grained sandstone.
- 3343 ½-3478 Black micaceous fissile, jointed shale.
- 3478-3481 Dark-gray micaceous fucoidal shaly siltstone.
- 3481-3484 Black micaceous fissile shale; few thin layers of light-gray siltstone.

3484-3494	Dark-gray micaceous shaly siltstone to very fine grained sandstone; thin black shale partings.
3494-3498	Black micaceous fissile, jointed shale.
3498-3518	Light-gray micaceous siltstone to very fine grained sandstone; worm burrows.
3518-3519	Dark-gray micaceous shaly siltstone to very fine grained sandstone.
3519-3521	Light-gray micaceous siltstone to very fine grained sandstone.
3521-3522	Black micaceous fissile, jointed shale.
3522-3525	Light-gray micaceous siltstone to very fine grained sandstone.
3525-3526	Black micaceous fissile, jointed shale.
3526-3530	Gray to light-gray micaceous fucoidal siltstone to very fine grained sandstone.
3530-3545	Black micaceous fissile, jointed shale.
3545-3560	Gray sandstone with very fine to fine subangular grains; thin black micaceous shale partings.
3560-3563	Dark-gray shaly sandstone with very fine to fine subangular grains.
3563-3576	Gray sandstone with very fine to fine subangular grains.
3576-3577	Dark-gray shaly sandstone with very fine to fine subangular grains.
3577-3590	Gray sandstone with very fine to fine subangular grains.
3590-3595	Dark-gray shaly very fine grained sandstone.
3595-3641	Gray-green micaceous fucoidal slightly shaly siltstone.
3641-3649	Dark-gray micaceous fucoidal shaly siltstone.
3649-3654	Black micaceous fissile, jointed shale.
3654-3664	Gray micaceous fucoidal silty shale.
3664-3724	Black micaceous fissile, jointed shale.
3724-3743	Dark-gray micaceous fucoidal silty shale.
3743-3803	Black micaceous fissile, jointed shale.
3803-3805	Gray micaceous siltstone; black shale fragments.
3805-3812½	Black micaceous fissile, jointed slightly fucoidal shale.
3812½-3814	Light-gray micaceous siltstone.
3814-3838	Light-gray slightly limy siltstone to very fine grained sandstone; few small black shale fragments; small cavities; few plant remains.
3838-3844	Black micaceous fissile, jointed slightly fucoidal shale.
3844-3853	Gray micaceous slightly shaly very fine grained sandstone.
3853-3857	Light-gray fucoidal siltstone; thin black shale partings.
3857-3860	Black micaceous fissile, jointed shale.
3860-3864	Gray fucoidal siltstone.
3864-3867	Black micaceous fissile, jointed slightly fucoidal shale.
3867-3871	Black micaceous fissile, jointed shale.
3371-3872	Black micaceous fucoidal shale.
3872-3880	Black micaceous fissile, jointed shale.
3880-3881	Black micaceous fucoidal shale.
3881-3891	Black micaceous fissile, jointed shale.
3891-3908	Light-gray to white siltstone to very fine grained sandstone.
3908-3913	White siltstone to very fine grained sandstone; large black micaceous shale fragments included.
3913-3920	Black micaceous fissile, jointed shale.
3920-3931	Gray very slightly limy siltstone to very fine grained sandstone.
3931-3934½	Gray micaceous siltstone to very fine grained sandstone; few small black shale fragments included.
3934½-3943	Gray micaceous fucoidal shaly siltstone.
3943-3967	Black micaceous fissile, fucoidal silty shale.
3967-3971	Alternating thin beds of black micaceous fissile shale and gray siltstone.
3971-3972	Gray micaceous fucoidal shaly siltstone.

- 3972-3974 Light-gray micaceous very slightly limy siltstone to very fine grained sandstone; few small shale fragments included.
- 3974-3976 Alternating thin beds of black micaceous fissile shale and light-gray siltstone.
- 3976-4015 Black micaceous fissile, jointed shale.
- 4015-4021 Light-gray very slightly limy siltstone to very fine grained sandstone.
- 4021-4022 Gray fucoidal shaly siltstone.
- 4022-4024 Light-gray very slightly limy siltstone.
- 4024-4025 Gray fucoidal shaly siltstone.
- 4025-4026 Light-gray very slightly limy siltstone.
- 4026-4029 Gray fucoidal shaly siltstone.
- 4029-4045 Black micaceous fucoidal silty shale.
- 4045-4069 Black micaceous fissile, jointed shale.
- 4069-4076 Light-gray micaceous siltstone to very fine grained sandstone.
- 4076-4077 White slightly micaceous slightly limy siltstone to very fine grained sandstone.
- 4077-4078 Light-gray micaceous siltstone to very fine grained sandstone.
- 4078-4079 White micaceous very slightly limy siltstone to very fine grained sandstone.
- 4079-4081 Alternating thin beds of gray and white micaceous siltstone to very fine grained sandstone.
- 4081-4107 White micaceous very slightly limy siltstone to very fine grained sandstone; thin black shale partings.
- 4107-4112 Gray micaceous silty shale.
- 4112-4183 Black micaceous fissile, fucoidal silty shale.
- 4183-4231 Gray micaceous fucoidal shaly siltstone; thin black micaceous shale partings.
- 4231-4232 Black micaceous fissile, jointed shale.
- 4232-4240 Light-gray micaceous siltstone to very fine grained sandstone; thin black micaceous shale partings.
- 4240-4266 Gray micaceous fucoidal shaly siltstone.
- 4266-4270 Black micaceous slightly fucoidal silty shale.
- 4270-4401 Black micaceous fissile, jointed shale; finely pyritic in part.
- 4401-4406 Gray micaceous shaly siltstone to very fine grained sandstone.
- 4406-4433 Black micaceous fissile shale.
- 4433-4446 Gray limy shaly sandstone with very fine to fine subangular grains.

MORROW GROUP

Boyd shale

- 4446-4454 Black micaceous fissile shale.
- 4454-4455 Light-gray micaceous siltstone.
- 4455-4457 Black micaceous fissile shale.
- 4457-4458 Light-gray micaceous siltstone.
- 4458-4470 Black micaceous fissile shale.
- 4470-4480 (No samples)
- 4480-4490 Gray to dark-gray shaly very fine to fine-grained sandstone.
- 4490-4530 (No samples)

(Kessler limestone member)

- 4530-4551 Gray to gray-buff fine sandy coarsely crystalline limestone with dark-gray medium-sized oolites; small fragments of brachiopods, bryozoa, and crinoids.
- 4551-4555 Light-gray limy sandstone with fine subround to subangular grains; little green shale.
- 4555-4561 1/2 Gray to dark-gray slightly limy shaly sandstone with fine subround to subangular grains; little gray-green shale.
- 4561 1/2-4568 Black fissile shale.

- 4568-4579 Black finely pyritic fissile shale.
 4579-4580 Light-gray very fine grained sandstone.
 4580-4582 Black fissile shale.
 4582-4583 Light-gray very fine grained sandstone.
 4583-4648 Black fissile slightly silty shale.
 4648-4693 Black fissile shale.
 4693-4707 Light-gray micaceous slightly limy siltstone to very fine grained sandstone.
 4707-4708 ½ Light-gray micaceous slightly limy siltstone to very fine grained sandstone; brown pebbles up to ¼-inch in diameter; crinoid fragments.
 4708 ½-4711 Dark-gray finely crystalline limestone: small fragments of crinoids, bryozoa, and brachiopods.
 4711-4715 Gray micaceous slightly limy siltstone to very fine grained sandstone.
 4715-4724 Dark-gray micaceous silty shale.

(*Brentwood limestone member*)

- 4724-4732 Dark gray-black silty finely crystalline limestone; crinoid fragments.
 4732-4737 Black micaceous fissile, jointed shale; few thin streaks of black crinoidal finely crystalline limestone.
 4737-4743 Black silty finely crystalline limestone; crinoid fragments. *Bairdia* sp., *Kellettina* sp., *Ectodemites*(?), and *Healdia*(?) at 4740 feet.
 4743-4748 Black micaceous fissile, jointed shale.
 4748-4752 Black silty finely crystalline limestone; crinoid fragments.
 4752-4754 Black slightly limy shale.
 4754-4761 Black silty to shaly finely crystalline limestone; crinoid fragments; thin black shale partings.
 4761-4789 Black micaceous fissile, jointed shale.
 4789-4792 Light-gray micaceous siltstone.

Hale formation

- 4792-4810 Dark gray-buff medium crystalline limestone with dark medium-sized oolites; brachiopod spines and shell fragments.
 4810-4815 (No samples)
 4815-4821 Black micaceous fissile shale.
 4821-4840 Gray-buff to buff and tan mottled, medium crystalline limestone with dark medium-sized oolites; little pyrite.
 4840-4850 Gray-buff to buff mottled, medium crystalline limestone with dark medium-sized oolites; little glauconite.
 4850-4853 Black micaceous fissile shale.
 4853-4860 Cream-colored very fine to fine sandy, fine to medium crystalline limestone with medium-sized oolites.
 4860-4873 Black micaceous fissile shale.
 4873-4879 White slightly limy siltstone to very fine grained sandstone.
 4879-4894 Gray to dark gray-buff coarsely crystalline very fossiliferous limestone; fragments of brachiopods, crinoids, corals, and many bryozoa. *Meekopora*(?), *Ramiporalia*(?), stenoporoids, *Streblotrypa*(?), *Rhombopora angusta* Ulrich(?) and other indeterminate rhomboporoids, *Fenestella* sp., *Sulcoretepora* sp., *Paraparchites* sp., *Bairdia* sp., and *Bythocypris* sp. at 4,884 feet. *Meekopora*(?), *Streblotrypa*, rhomboporoids, *Fenestella* sp. possibly *F. multispinosa* Ulrich, *Polypora*, *Thamniscus*(?), *Sulcoretepora* cf. *S. simulans* (Ulrich), *Bythocypris* sp., *Bairdia* sp., *Silenites* sp., and *Haploprimitia*(?) at 4,891 feet.

- 4894-4896 Light-gray limy very fine grained sandstone.
 4896-4905 Gray to dark gray-buff coarsely crystalline very fossiliferous limestone with medium-sized oolites; fragments of brachiopods, crinoids, corals, and many bryozoa.
 4905-4928 White porous slightly limy very fine grained sandstone; brown phosphatic conglomeratic zone, 4 inches thick, at base.

Rocks of questionable age

- 4928-4959 Black micaceous fissile, fucoidal silty shale.
 4959-4965 Light-gray micaceous shaly siltstone.
 4965-5001 Black micaceous fissile, fucoidal silty shale.
 5001-5012 Dark-gray micaceous fucoidal shaly siltstone.
 5012-5015 Black micaceous fissile shale.
 5015-5031 Black micaceous fissile, fucoidal silty shale.
 5031-5032 Dark-gray micaceous shaly siltstone.
 5032-5037 Alternating thin beds of black micaceous fucoidal shale and gray micaceous fucoidal siltstone.
 5037-5066 Black micaceous fissile, fucoidal shale.
 5066-5068 Gray micaceous siltstone.
 5068-5096 Black micaceous fissile, slightly fucoidal shale.
 5096-5100 Dark-gray micaceous slightly fucoidal shaly siltstone.
 5100-5103 Dark micaceous fissile shale.
 5103-5110 Dark-gray shaly finely crystalline limestone; many brachiopod fragments.
 5110-5180 Black slightly micaceous fissile, jointed shale.

MISSISSIPPIAN SERIES

CHESTER GROUP

Pitkin limestone

- 5180-5185 Brown-buff coarsely oolitic limestone.
 5185-5187 Brown-buff silty finely crystalline limestone; large coral fragments.
 5187-5194 Dark-gray to black finely crystalline limestone; many crinoid fragments.
 5194-5195 Dark-gray micaceous fissile shale.
 5195-5201 Dark-gray to black finely crystalline limestone; many crinoid fragments.
 5201-5205 Black micaceous slightly limy shale; brachiopod and crinoid fragments.
 5205-5207 Irregular dark-brown finely crystalline limestone masses in black micaceous slightly limy siltstone.
 5207-5220 Dark-brown to black finely crystalline limestone; crinoid fragments; thin black micaceous shale partings.
 5220-5222 Black micaceous fissile shale.
 5222-5234 Dark-brown to black finely crystalline limestone; crinoid fragments; thin black micaceous shale partings.
 5234-5236 Black micaceous fissile shale.
 5236-5266 Dark brown-buff finely oolitic limestone.
 5266-5298 Dark-brown finely crystalline limestone; crinoid and brachiopod fragments.
 5298-5300 Black micaceous slightly limy shale.
 5300-5303 Black very finely crystalline limestone.
 5303-5310 Dark-brown coarsely oolitic limestone; crinoid and brachiopod fragments.
 5310-5311 Black micaceous fissile shale.
 5311-5313 Dark-brown coarsely oolitic limestone; crinoid and brachiopod fragments.
 5313-5315 Black silty shale.

- 5315-5322 Brown-buff slightly oolitic limestone.
 5322-5324 Black micaceous fissile shale.
 5324-5365 Brown-buff to dark-brown limestone with medium-sized oolites; few thin black micaceous shale partings. "*Spirifer*" cf. *S. keokuk* Hall at 5,357 feet.
 5365-5366 Black fissile, slightly limy shale.
 5366-5386 Gray-buff very finely crystalline limestone; few crinoid and brachiopod fragments; thin black micaceous shale partings.
 5386-5394 Black hard slightly limy shale. *Dictyoclostus* cf. *D. inflatus* (McChesney) ? at 5,390 feet.
 5394-5398 Black slightly shaly finely crystalline limestone; crinoid and brachiopod fragments.

Fayetteville shale

- 5398-5405 Black hard slightly limy shale.
 5405-5554 Black micaceous fissile, jointed shale.
 5554-5557 Dark-brown to brown-buff mottled, medium crystalline limestone.
 5557-5566 Black micaceous fissile, jointed shale.
 5566-5572 Dark-gray to buff mottled, finely to medium crystalline limestone; few capsule-shaped oolites.
 5572-5576 Dark-gray silty finely crystalline limestone.

MERAMEC GROUP

Moorefield formation

- 5575-5594 Black hard slightly limy shale.
 5594-5615 Dark-gray slightly limy silty shale. *Leiorhynchus carboniferum* Girty, *Moorefieldella* aff. *M. eurekaensis* (Walcott) at 5,607 feet.
 5615-5714 Dark-gray to black limy slightly shaly siltstone. *Leiorhynchus carboniferum* Girty, *Moorefieldella* aff. *M. eurekaensis* (Walcott) at 5,646 feet. *Leiorhynchus carboniferum* Girty, *Moorefieldella* aff. *M. eurekaensis* (Walcott) at 5,655 feet.
 5714-5717 Black slightly limy silty shale.
 5717-5748 Dark-gray to black limy slightly shaly siltstone. *Martinia* sp. at 5,721 feet. *Orbiculoidea* sp., *Productella* cf. *P. hirsutiformis* Walcott at 5,740 feet.
 5748-5759 Black micaceous limy shale.
 5759-5760 Black very glauconitic chert pebble conglomerate.

OSAGE GROUP

Boone formation

- 5760-5762 Black slightly silty finely to medium crystalline limestone; black to brown, fractured dense chert; streaks of pyrite in chert.
 5762-5771 Gray-buff medium crystalline limestone; gray to light-gray dense chert.
 5771-5773 Black micaceous limy shale.
 5773-5783 Light gray-buff very finely crystalline limestone; gray dense chert.
 5783-5785 Dark-gray to black very finely crystalline limestone; little pyrite; cream-colored chalcidonic chert.
 5785-5790 Cream-colored chalcidonic chert; light-gray finely crystalline limestone.
 5790-5802 Light-gray chalcidonic chert; little light-gray finely crystalline limestone.
 5802-5808 Dark-gray finely crystalline limestone; cream-colored chalcidonic chert.
 5808-5811 Black finely crystalline limestone; cream-colored chalcidonic chert.

CARBONIFEROUS (MISSISSIPPIAN) OR DEVONIAN SYSTEM

Chattanooga shale

- 5811-5815 Black slightly limy shale; little pyrite.
5815-5846 Black slightly micaceous shale; little pyrite.
5846-5848 Light-gray slightly limy fine-grained sandstone.
5848-5852 Black slightly micaceous shale; little pyrite.

DEVONIAN SYSTEM

Penters chert

- 5852-5856 Light-gray chalcidonic chert; little gray limy siltstone.
5856-5862 Milky chalcidonic chert; little gray limy siltstone to very fine grained sandstone.
5862-5866 Cream-colored translucent chert; little gray limy siltstone.
5866-5868 Black slightly limy shale.
5868-5872 Cream-colored translucent chert; little gray limy siltstone.
5872-5881 Milky chalcidonic chert; little light-gray to gray mottled limy siltstone.
5881-5883 Black shale.
5883-5885 Milky chalcidonic chert; little light-gray and dark-gray mottled, limy siltstone.
5885-5896 White, dark-mottled, medium to coarsely crystalline limestone; brachiopod fragments; little light-gray chalcidonic chert.
5896-5898 White to light-gray coarsely crystalline limestone; black shale between calcite crystals.
5898-5906 White to light-gray coarsely crystalline limestone with interstitial black shale and scattered pink calcite crystals.
5906-5910 Black shale.

SILURIAN SYSTEM

- 5910-5921 White finely crystalline limestone.
5921-5941 White silty very finely granular limestone.
5941-5943 Black slightly limy shale.
5943-5956 White silty very finely granular limestone.
5956-5958 Black slightly limy shale.

St. Clair(?) limestone

- 5958-5973 White to light-gray finely to medium crystalline slightly silty limestone; scattered small dolomite rhombs; pale pinkish-purple chalcidonic chert.
5973-5986 Pink to pinkish-gray finely to medium crystalline limestone.
5986-6012 Light-gray finely to medium crystalline limestone; small dolomite rhombs in the limestone.
6012-6021 Light-gray finely to medium crystalline limestone; scattered pink calcite crystals; small dolomite rhombs in the limestone.
6021-6024 Light-gray finely to medium crystalline limestone; small dolomite rhombs in limestone.
6024-6025 Black shale.
6025-6028 Light-gray finely to medium crystalline limestone; scattered dolomite rhombs in limestone.
6028-6029 Black shale.
6029-6057 Light-gray finely to medium crystalline limestone; small dolomite rhombs in limestone.
6057-6072 Light-gray finely to medium crystalline limestone; pink calcite crystals; small dolomite rhombs in limestone.
6072-6093 Light-gray finely to medium crystalline limestone; small dolomite rhombs in limestone.
6093-6099 Light-gray to white finely to medium crystalline limestone; pink calcite crystals; small dolomite rhombs in limestone.

- 6099-6116 White finely to medium crystalline limestone; small dolomite rhombs in limestone.
 6116-6117 Black shale.
 6117-6122 White finely to medium crystalline limestone; small dolomite rhombs in limestone.
 6122-6123 Black shale.

Brassfield(?) limestone

- 6123-6168 Reddish-gray medium crystalline limestone; small dolomite rhombs in limestone; red-orange calcite crystals give the light-gray limestone a reddish-gray color.

ORDOVICIAN SYSTEM

Cason shale

- 6168-6169 Gray silty shale.
 6169-6178 Green silty slightly dolomitic shale; light-gray to smoky chalcudonic chert; little pyrite.
 6178-6183 Dark-gray silty slightly dolomitic shale.
 6183-6185 Green silty slightly dolomitic shale.
 6185-6210 Dark-gray silty slightly dolomitic shale.

Feravale limestone

- 6210-6212 Gray medium crystalline limestone.
 6212-6213 Gray shale.
 6213-6222 Gray medium crystalline limestone.
 6222-6223 Gray silty shale.
 6223-6233 Gray medium crystalline limestone.
 6233-6234 Gray silty shale.
 6234-6238 Gray medium crystalline limestone; little gray dense limestone.
 6238-6239 Gray silty shale.

Kimmswick(?) limestone

- 6239-6242 Gray to light-gray finely to medium crystalline limestone.
 6242-6247 Light-gray finely crystalline limestone; smoky chalcudonic chert.
 6247-6251 Light-gray to gray finely crystalline limestone; dark-brown to black chalcudonic chert.
 6251-6265 Dark-gray finely crystalline limestone; little pyrite.
 6265-6269 Black shale.
 6269-6280 Dark-gray to black silty finely crystalline limestone; little black dense chert and pyrite.

Plattin limestone

- 6280-6282 Gray finely crystalline limestone.
 6282-6288 Dark-gray finely crystalline limestone.
 6288-6293 Black dense limestone.
 6293-6296 Dark-gray silty limestone.
 6296-6301 Dark-gray silty limestone; little black dense chert.
 6301-6302 Black shale.
 6302-6308 Light-gray very finely crystalline to dense limestone.
 6308-6310 Gray dense fine to medium sandy limestone.

St. Peter sandstone

- 6310-6316 White sandstone with fine to medium, subangular to subround, grains; few round grains; little gray silty limestone cement.
 6316-6325 White tightly cemented sandstone with medium, subround to round, frosted grains; little gray very finely granular silty dolomite cement.

- 6325-6327 **Black shale.**
6327-6339 **White tightly cemented sandstone with fine to medium, sub-round to round, frosted grains; gray to light-gray silty very finely granular dolomite cement.**
- 6339-6341 **Black shale.**
6341-6347 **White tightly cemented sandstone with fine to medium, sub-round to round, frosted grains; gray to light-gray silty very finely granular dolomite cement.**
- 6347-6350 **Black silty very finely granular dolomite; finely pyritic.**
6350-6356 **Gray dolomitic sandstone with fine to medium, subround to round, frosted grains.**
- 6356-6362 **Gray very finely crystalline to very finely granular dolomite.**
6362-6374 **Light-gray to white dolomitic sandstone with fine to medium, subround to round, frosted grains.**
- 6374-6376 **Black dolomitic shale.**
6376-6384 **White sandstone with fine to medium, subround to round, frosted grains; gray silty very finely granular dolomite cement.**
- 6384-6385 **Black shale.**
6385-6396 **White sandstone with fine to medium, subround to round, frosted grains; gray silty very finely granular dolomite cement.**
- 6396-6400 **Gray silty very finely granular dolomite.**
6400-6404 **White sandstone with fine to medium, subround to round, frosted grains; gray silty, very finely granular dolomite cement.**
- 6404-6406 **Black shale.**
6406-6410 **White sandstone with fine to medium, subround to round, frosted grains; gray silty, very finely granular dolomite cement.**

Everton formation

- 6410-6427 **Gray to slightly greenish-gray hard shale; finely pyritic.**
6427-6445 **White sandstone with fine to medium, subround to round, frosted grains; gray silty, very finely granular dolomite cement.**
- 6445-6447 **Black shale.**
6447-6461 **White sandstone with fine to medium, subround to round, frosted grains; gray silty, very finely granular dolomite cement.**
- 6461-6466 **Light-gray very silty, very finely granular dolomite.**
6466-6469 **Gray to slightly greenish-gray hard shale.**
6469-6486 **Light-gray to gray silty, very finely granular dolomite; scattered fine to medium, subround to round, frosted sand grains.**
- 6486-6498 **White sandstone with fine to medium, subround to round, frosted grains; gray silty very finely granular dolomite cement.**
- 6498-6499 **Black shale.**
6499-6509 **Light-gray to gray silty very finely granular dolomite; scattered fine to medium, subround to round, frosted sand grains.**
- 6509-6510 **Black dolomitic shale.**
6510-6529 **Light-gray to gray silty very finely granular dolomite; scattered fine to medium, subround to round, frosted sand grains.**
- 6529-6531 **Black shale.**
6531-6534 **Gray sandstone with fine to medium, subround to round, frosted grains; gray silty very finely granular dolomite cement.**
- 6534-6535 **Black shale.**
6535-6551 **Gray silty very finely granular dolomite; scattered fine to medium, subround to round, frosted sand grains.**
- 6551-6556 **Gray dolomitic sandstone with fine to medium, subround to round, frosted grains.**
- 6556-6561 **Gray silty very finely granular dolomite; scattered fine to medium, subround to round, frosted sand grains.**

6561-6565	Gray dolomitic sandstone with fine to medium, subround to round, frosted grains.
6565-6569	Gray silty sandy very fine granular dolomite.
6569-6580	Gray silty very finely granular dolomite; scattered fine to medium, subround to round, frosted sand grains.
6580-6589	Gray silty sandy very finely granular dolomite.
6589-6619	White sandstone with fine to medium, subround to round, frosted grains; gray silty very finely granular dolomite cement.
6619-6621	Black shale.
6621-6630	Gray silty sandy very finely granular dolomite.
6630-6632	Gray silty very finely granular dolomite; scattered fine to medium, subround to round, frosted sand grains.
6632-6634	Dark-gray to black silty very finely granular dolomite.
6634-6639	Black shale.
6639-6647	Dark-gray to black silty very finely granular dolomite.
6647-6650	Black shale.
6650	Total depth.

