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Preliminary Results of Coal Exploratory Drilling in the Book Cliffs Coal Region, Garfield County, Colorado, and Grand County, Utah

By

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Preliminary results of Coal Exploratory Drilling in the Book Cliffs Coal Region, Garfield County, Colorado and Grand County, Utah

Abstract

Four holes were drilled in the Book Cliffs coal region of Garfield County, Colorado and Grand County, Utah to provide coal core samples suitable for analysis and stratigraphic information about coal-bearing strata. Three of the holes were completed; the fourth remains to be completed; a fifth is planned. A total of 1,693 feet (515 m) of pilot-hole rotary drilling and 843 feet (257 m) of core drilling was done. Mechanical and geophysical logs of the first, third, and fourth pilot holes were made; only the upper part of the second hole, which was almost entirely cored, was logged. Most of the cored rock is from the coal-bearing Neslen Formation and almost all of it is carbonaceous to some degree. Lithologies of the rotaried intervals are shown in the accompanying plate and were interpreted from geophysical logs and cuttings.

Introduction

Four holes were drilled in the Book Cliffs area of Garfield County, Colorado and Grand County, Utah (fig. 1) during the period June 11 to November 29, 1978; coring of selected sections of the fourth hole is yet to be done. Hole 2 was almost entirely cored. A total of 1,693 feet (515 m) of pilot-hole rotary drilling and 843 feet (257 m) of coring was completed. The drill-hole data provide information about the regional stratigraphy of the coal-bearing strata and of coal resources. Geophysical logs made of the coal-bearing rocks will further aid stratigraphic and coal studies. Methane-yield studies of the cored coal are being conducted by personnel of the Utah Geological and Mineral Survey.

Lithology of the rotaried parts of the drill holes (pl. 1) was interpreted from geophysical logs and cuttings; formational boundaries and coal zones are tentatively identified. Results of chemical analyses of coals, their methane yield, and other data will be subsequently reported.

Figure 1.--Part of the Book Cliff coal region, Utah and Colorado, showing location of coal exploratory drill sites

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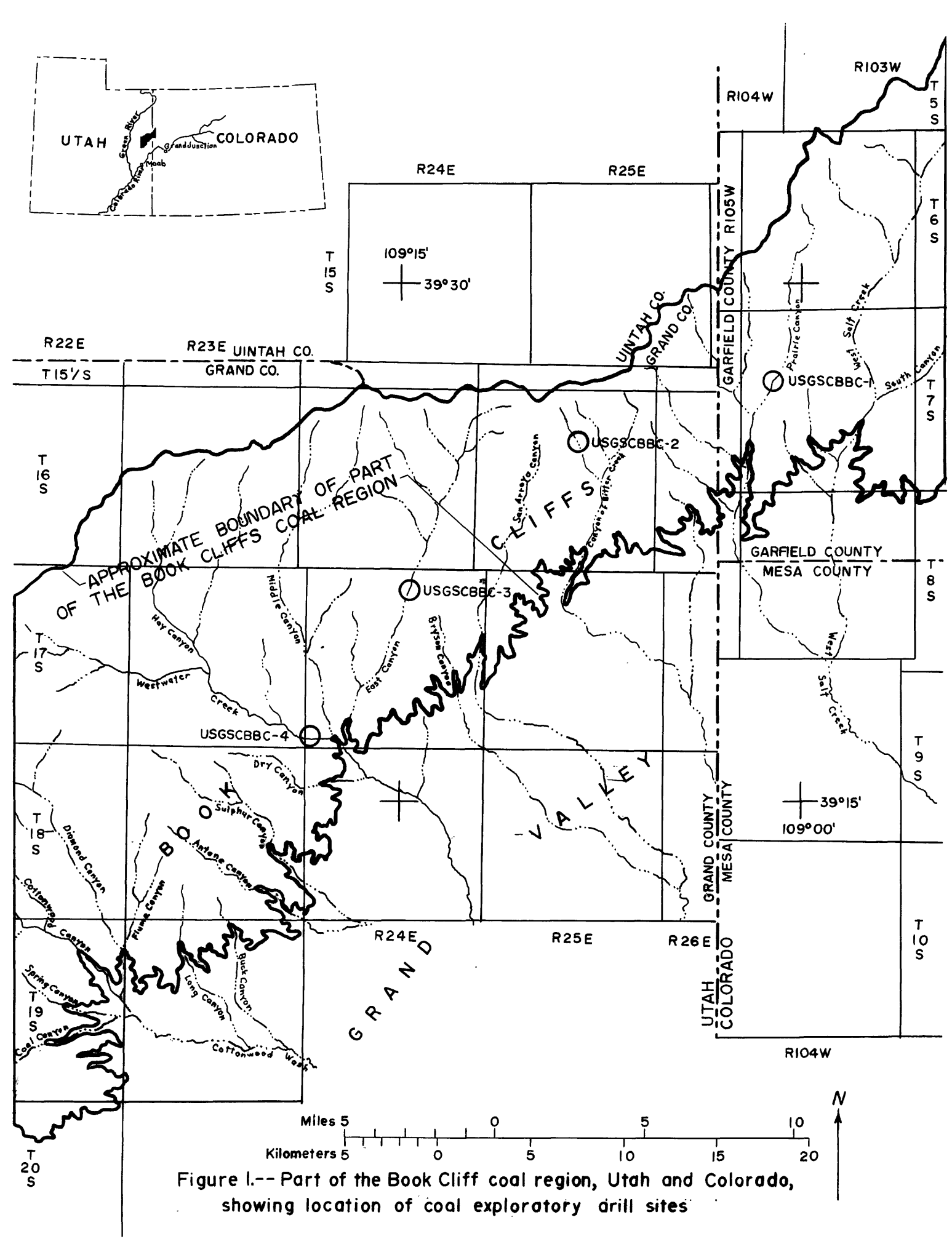

Figure 1.-- Part of the Book Cliff coal region, Utah and Colorado, showing location of coal exploratory drill sites

Geology

Coal-bearing rocks of the Book Cliffs coal region are of Late Cretaceous age. They crop oput along the lower part of the Book Cliffs near the southern periphery of the Uinta Basin. Most coal beds in the area are in the Neslen Formation and constitute four coal zones, Palisade, Ballard, Chesterfield, and Carbonera (pl. 1). Minor, nonextensive coal beds occur in the underlying Sego Sandstone and the overlying Farrer Formation.

The Sego Sandstone is an eastwardly pro-grading delta front unit. It is mostly sandstone, but contains siltstone, shale, and minor coal. Locally, the formation is mostly siltstone and shale. The overlying Neslen Formation was deposited in swampy fluvial and interfluvial areas of a coastal-plain environment. It consists of roughly equal proportions of sandstone, and siltstone and shale, almost all of which are carbonaceous to some degree. All important coal beds in this part of the Book Cliffs coal region occur in the Neslen. The Farrer Formation was deposited in mostly nonswampy fluvial and interfluvial areas of a coastal-plain environment. It consists of sandstone, siltstone, and shale; sandstone is dominant. Most of the rock is noncarbonaceous. These formations total more than 1,000 feet (305 m) in the area where the drilling took place.

The dip of the rocks in the area where drilling was conducted dip as much as 5 degrees, and commonly 3 degrees or less. Anticlines and synclines of low structural amplitude occur in the area. Sparse, high angle east or northeast trending faults occur in the region and are rarely traceable for more than a few miles. Fault throw is commonly less than 100 feet (30 m). Undiscovered faults are believed to be present in the area

Site Selection and Drilling Operations

Selection of drill sites was based on four criteria: 1) the land and mineral rights were to be Federally owned; 2) access was to be by way of preexisting roads--no road building or site preparation was to be undertaken; 3) drill hole collars were to be spudded as near as possible to the top of the coal-bearing (10 km). The first two criteria were met; the third and fourth criteria were only partially met. All holes were spudded considerable above the coal-bearing section; hole 2 spudded approximately 218 feet (66 m) above the highest coal. Intervals between some holes exceeded 6 miles (10 km) although not by much; the greatest distance between holes is less than 8 miles (13 km)

Drilling was done by a twin-hole method except hole 2, which was cored except for the uppermost 33 feet (10 m). Pilot holes were rotary drilled and geophysically and mechanically logged; the logs included focused density, natural gamma, apparent resistivity, and caliper. Coal-bearing intervals were identified on the logs of the pilot holes and offset holes were drilled close to the pilot holes. In the offset holes noncoal-bearing intervals were rotaried and coal-bearing intervals were cored.

The pilot holes and hole 2, which was almost entirely cored, bottomed in the Sego Sandstone. The top of the Sego Sandstone is regarded as a reliable horizon for coal correlation in this part of the Book Cliffs coal region.

Most coal beds were cored and will provide samples for proximate and ultimate analyses, trace element analysis, heating value determination, and methane yield.

Drill- and core-hole data are listed in feet and inches. One foot equals .3048 meter; one inch equals 2.54 centimeters.

Description of drill sites and drilling

Drill hole U.S.G.S.C.B.B.C. 1

The drill hole is located about 60 feet (18 m) from a natural gas well in Prairie Canyon about 7,300 feet (2,226 m) upstream from the confluence of Hells Hole Canyon on unsurveyed ground in T. 7 S., R. 104 W. (Jim Canyon quadrangle), Garfield County, Colorado. The ground elevation is approximately 5,950 feet (1,815 m) above sea level. Drilling commenced June 11, 1978 and was completed July 18, 1978.

The rocks penetrated include almost all of the Neslen Formation and the upper part of the Sego Sandstone. The pilot hole was drilled to a depth of 610 feet (186 m). Sixteen cores were cut in the offset hole totaling 134.7 feet (41 m). Lithology of the core is described in Table 1; the lithologic interpretation of the pilot hole is on Plate 1; and the geophysical logs are in the appendix.

Drill hole U.S.G.S.C.B.B.C. 2

The drill hole is located about 40 feet (12 m) from a natural gas well in the canyon of West Fork Bitter Creek in the NE $^1/_4$NE $^1/_4$ sec. 15, T. 16 S., R. 25 E. (San Arroyo Ridge quadrangle), Grand County, Utah. The ground elevation is approximately 6,460 feet (1,970 m) above sea level. Drilling commenced July 25, 1978 and was completed August 30, 1978.

The rocks penetrated include the basal part of the Farrer Formation, the Neslen Formation, and the uppermost part of the Sego Sandstone. The hole was cored except the uppermost 32.7 feet (9.9 m). Total depth was 690 feet (210 m). Lithology of the core is described in Table 1 and is shown on plate 1 together with the interpretation of pilot holes at the other drill sites. The geophysical logs are in the appendix but are not of the entire hole; a cave in a coal bed prevented the logging of the lower part of the hole.

Drill hole U.S.G.S.C.B.B.C. 3

The drill hole is near the canyon wall west of the road in East Canyon in the SW 1/4 SE 1/4 sec. 10, T. 17 S., R. 24 E. (Bryson Canyon quadrangle), Grand County, Utah. The ground elevation is approximately 5,920 feet (1,806 m) above sea level. Drilling commenced October 18, 1978 and was completed October 31, 1978.

The rocks penetrated include most of the Neslen Formation and the upper part of the Sego Sandstone. The pilot hole was drilled to a depth of 475 feet (145 m). Fifteen cores were cut in the offset hole totaling 115.8 feet (35.4 m). Lithology of the hole is described in Table 1; the interpretation of the pilot hole is on plate 1; and the geophysical logs are in the appendix.

Drill hole U.S.G.S.C.B.B.C. 4

The drill hole is near the canyon wall north of Westwater Creek in the NW 1/4 SW 1/4 sec. 31, T. 17 S., R. 24 E. (Dry Canyon quadrangle), Grand County, Utah. The ground elevation is approximately 5,330 feet (1,626 m) above sea level. Drilling commenced November 21, 1978 and ceased November 29, 1978. Coring of the hole was not completed.

The rocks penetrated include most of the Neslen Formation and the upper part of the Sego Sandstone. The pilot hole was drilled to a depth of 560 feet (171 m). Seven cores totaling 50.2 feet (15.3 m) were cut in the offset hole before drilling operations were recessed. Lithology of the core is described in Table 1; the interpretation of the pilot hole is on plate 1; and the geophysical logs are in the appendix.

Table 1.--Description of core from drill holes. U.S.G.S.C.B.B.C. 1 hole

Cretaceous:

Neslen Formation:

	From	To	Thickness
1. Rotary drilled	0′0″	80′0″	80′0″
2. Sandstone, very fine, very light gray (N8) and light gray (N7), obscurely laminated, highly bioturbated; contains irregular, wispy bodies of slightly carbonaceous siltstone, sparse flaky fragments of carbonaceous matter, and sparse pyrite. Contact with underlying unit irregular--slump contact	80′0″	81′2″	1′2″
3. Siltstone and sandstone, interbedded and interlaminated, bioturbated and slumped in parts: siltstone, medium gray (N5) and medium dark gray (N4), moderately carbonaceous; sandstone, very fine, very light gray (N8)	81′2″	84′6″	3′4″
4. Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/8 inch; cleat not apparent. Coal fractured; sparse non-calcitic mineral on fracture surfaces	84′6″	85′5 1/2′	0′11 1/2′
5. Siltstone, dark gray (N3), to medium light gray (N6), highly carbonaceous in upper few inches grading downward to moderately carbonaceous, bioturbated; contains carbonaceous lenses in upper part as thick as 1/8 inch	85′5 1/2′	86′8″	1′2 1/2′
6. Sandstone and siltstone, interlaminated and bioturbated; laminae inclined: sandstone very fine, very light gray (N8); siltstone, medium light gray (N6), slightly carbonaceous	86′8″	86′11″	0′3″
7. Siltstone, medium gray (N5) to dark gray (N3), moderately carbonaceous grading to highly carbonaceous in basal part; contains bioturbated and slumped bodies of very fine, very light gray sandstone, sparse carbonaceous lenses in basal part, some as thick as 1/8 inch	86′11″	89′6″	2′7″
8. Rotary drilled	89′6″	147′0″	57′6″

Neslen Formation--Continued:

		From	To	Thickness
9.	Sandstone, very fine, light gray (N7) and very light gray (N8); contains disseminated carbonaceous material, abundant carbonaceous flakes, some as much as 1 inch long, and numerous rounded bodies of pyrite and claystone	147'0"	147'4"	0'4"
10.	Coal, black (N1), vitrainous and attrital; contains sparse white mineral in bodies 1/16 inch diameter; basal cleat well developed	147'4"	148'4"	1'0"
11.	Claystone, light olive gray (5Y 6/1), grainy, kaolinitic	148'4"	148'5 1/4"	0'1 1/4"
12.	Impure coal, dark gray (N3) and grayish black (N2); contains vitrain lenses as thick as 1/4 inch; some lenses inclined	148'5 1/2"	150'3 1/4"	1'10"
13.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1 inch, most about 1/20 inch; cleat not apparent	150'3 1/4"	151'3 1/4"	1'0"
14.	Impure coal, dark gray (N3) and grayish black (N2); contains vitrain lenses as thick as 1/4 inch, and sandstone lens 1/2 inch thick in basal part. Contact with underlying unit undulous	151'3 1/4"	151'9 1/4"	0'6"
15.	Siltstone, medium light gray (N6) and medium gray (N5), slightly to moderately carbonaceous, laminated, microripple marked, bioturbated and slumped in parts; contains very fine, very light gray sandstone or sandy intervals, and sparse to numerous carbonaceous films and lenses in parts	151'9 1/4"	156'0"	4'2 3/4"
16.	Rotary drilled	156'0"	187'0"	31'0"
17.	Sandstone, very fine and coarser than very fine but less coarse than fine, very light gray (N8) and light gray (N7), laminated, bioturbated, and silty in parts; contains numerous to abundant carbonaceous films and lenses. Base in slump contact with underlying unit	187'0"	188'5 1/2"	1'5 1/2"

Neslen Formation--Continued:

		From	To	Thickness
18.	Siltstone, medium dark gray (N4), moderately carbonaceous, obscurely laminated; basal part grayish black (N2), highly carbonaceous. Unit contains sparse carbonaceous films, flakes, and lenses	188′5 1/2″	190′11″	2′5 1/2″
19.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch, most 1/16 to 1/8 inch thick; cleat not apparent. Coal fractured; abundant non-calcitic scale on fracture faces	190′11″	196′1″	5′2″
20.	Impure coal and highly carbonaceous siltstone, grayish black (N2), obscurely laminated; contains vitrain lenses as thick as 1/8 inch	196′1″	197′2″	1′1″
21.	Shale, silty, medium dark gray (N4), grading downward to grayish black (N2), highly carbonaceous siltstone, obscurely laminated; contains sparse carbonaceous lenses, some as thick as 1/8 inch	197′2″	200′10″	3′8″
22.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/16 to 1/8 inch; cleat not apparent	200′10″	201′7 1/2″	0′9 1/2″
23.	Impure coal or highly carbonaceous siltstone, obscurely laminated; contains sparse to abundant vitrain lenses in parts, some as thick as 1/8 inch, some inclined. Basal contact undulous	201′7 1/2″	202′9 1/2″	1′2″
24.	Siltstone, medium gray (N5) and medium dark gray (N4), moderately to highly carbonaceous, laminated, micro-ripple marked	202′9 1/2″	203′1 1/2″	0′4″
25.	Shale, silty, dark gray (N3), moderately carbonaceous grading to grayish black (N2), highly carbonaceous--impure coal--at base	203′1 1/2″	204′0″	0′10 1/2″
26.	Coal, black (N1), vitrainous and attrital; basal cleat well developed; white, scaley mineral on cleat face	204′0″	205′3″	1′3″

Neslen Formation--Continued:

		From	To	Thickness
27.	Siltstone, dark gray (N3) to medium light gray (N6), highly to moderately carbonaceous, obscurely to distinctly laminated; sandy in parts; contains carbonaceous flakes and lenses; lenses as thick as 1/4 inch. Unit grades to silty shale at base	205'3"	206'7"	1'4"
28.	Claystone, very light gray (N8), grainy, kaolinitic	206'7"	206'8 1/2"	0'1 1/2"
29.	Impure coal or highly carbonaceous siltstone, dark gray (N3); contains abundant vitrain lenses, some as thick as 1/4 inch	206'8 1/2"	207'4 1/2"	0'8"
30.	Shale, silty, medium light gray (N6), noncarbonaceous grading downward to medium dark gray (N4), moderately carbonaceous	207'4 1/2"	208'2 1/2"	0'10"
31.	Siltstone, medium dark gray (N4) to grayish black (N2), moderately carbonaceous in upper 18 inches, highly carbonaceous--impure coal--in basal part, obscurely laminated; contains sparse to abundant vitrain lenses in lower part, some as thick as 1/4 inch	208'2 1/2"	210'6 1/2"	2'4"
32.	Coal, black (N1), vitrainous and attrital; cleat not apparent	210'6 1/2"	211'4 1/2"	0'10"
33.	Siltstone, grayish black (N2) to medium dark gray (N4), grading downward to light gray (N7), slightly carbonaceous, sandy siltstone and silty sandstone; laminated and bioturbated where sandy; contains abundant carbonaceous lenses in upper part, some as thick as 1/4 inch; sparse carbonaceous flakes in lower part. Contact with underlying unit highly undulous--slumped	211'4 1/2"	213'1"	1'8 1/2"
34.	Sandstone, silty, very fine, pale yellowish brown (10 YR 6/2), slightly bioturbated; contains some disseminated carbonaceous material. Parts vuggy; vugs lined with white, earthy mineral. Contact with underlying unit gradational	213'1"	213'9"	0'8"

Neslen Formation--Continued:

		From	To	Thickness
35.	Siltstone, medium gray (N5) and medium light gray (N4), slightly to moderately carbonaceous	213′9″	214′0″	0′3″
	Rotary drilled	214′0″	232′0″	18′0″
36.	Sandstone and siltstone, interlaminated and intermixed; highly bioturbated and slumped; laminae contorted: sandstone, very fine, white (N9) to medium light gray (N6); siltstone, medium dark gray (N4), moderately carbonaceous; contains some carbonaceous films and lenses, and sparse pyrite	232′0″	232′9″	0′9″
37.	Coal, black (N1), vitrainous and attrital; vitrain lenses as thick as 1/4 inch; cleat not apparent	232′9″	234′10″	2′1″
38.	Siltstone, grayish black (N2) and dark gray (N3), highly carbonaceous--impure coal	234′10″	235′1″	0′3″
39.	Claystone, light olive gray (5Y 6/1); grainy, kaolinitic; contains carbonaceous films	235′1″	235′2″	0′1″
40.	Siltstone, grayish black (N2) and brownish black (5YR 2/1), highly carbonaceous, obscurely laminated; contains some carbonaceous lenses and pods, some as thick as 1/4 inch; sparse, minute irregular bodies of pale yellow, earthy mineral in middle part. Contact with underlying unit highly undulous	235′2″	236′6 1/2″	1′4 1/2″
41.	Siltstone, medium gray (N5) and dark gray (N3), slightly to moderately carbonaceous, obscurely laminated, shaley in parts, highly carbonaceous in uppermost 5 inches where slump-mixed with siltstone derived from overlying unit; contains contorted carbonaceous lenses and films, most inclined, and claystone lens near base	236′6 1/2″	237′11 1/2″	1′5″
42.	Impure coal, grayish black (N2); contains abundant vitrain lenses, thickest 3/4 inch	237′11 1/2″	239′1 1/2″	1′2″

Neslen Formation--Continued:

		From	To	Thickness
43.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/8 inch, cleat not apparent. Coal fractured; sparse scaley mineral on fracture faces	239′1 1/2″	240′2 1/2″	1′1″
44.	Impure coal, grayish black (N2); contains vitrain lenses as thick as 1/2 inch	240′2 1/2″	240′4 1/2″	0′2″
45.	Coal, black (N1), vitrainous and attrital; cleat not apparent	240′4 1/2″	241′0″	0′7 1/2″
46.	Impure coal, grayish black (N2); contains vitrain lenses 1/16 inch or less thick	241′0″	241′5″	0′5″
47.	Siltstone, medium dark gray (N4) and medium gray (N5), moderately carbonaceous; contains sparse to abundant carbonaceous lenses, thickest 1/8 inch	241′5″	242′2″	0′9″
48.	Sandstone and siltstone, intermixed--highly bioturbated: sandstone, very fine, medium dark gray (N4); siltstone, medium dark gray (N4); both lithologies moderately carbonaceous; contain abundant carbonaceous flakes and films. Some laminae intact in basal part. Base in slump contact with underlying unit	242′2″	244′0″	1′10″
49.	Sandstone, grading downward to siltstone: sandstone, very fine, very light gray (N8), non-carbonaceous, obscurely laminated; siltstone, grayish black (N2), highly carbonaceous; contains abundant carbonaceous lenses, some as thick as 1/4 inch, numerous irregular bodies of pale yellow mineral, as much as 1/4 inch long	244′0″	252′11″	8′11″
50.	Coal, black (N1), vitrainous and attrital; vitrain lenses as thick as 1/8 inch; cleat not apparent	252′11″	254′2″	1′3″
51.	Siltstone, medium dark gray (N4), moderately carbonaceous; contains some intermixed sandstone, abundant carbonaceous lenses, flakes, and films, and contorted sandstone bodies in basal part. Base in slump contact with underlying unit	254′2″	254′9″	0′7″

Neslen Formation--Continued:

		From	To	Thickness
52.	Sandstone, very fine and coarser than very fine but not as coarse as fine, very light gray (N8), laminated; laminae intact or only slightly disturbed; contains abundant carbonaceous lenses and films in lower part	254'9"	257'3"	2'6"
53.	Siltstone and silty shale, and sandstone, interlaminated; unit dominantly siltstone: siltstone and silty shale, medium gray (N5) to grayish black (N2), moderately to highly carbonaceous; sandstone, very fine, very light gray (N8). Sandstone laminae contorted, slumped	257'3"	259'9"	2'6"
54.	Coal, black (N1), vitrainous and attrital; vitrain laminae as thick as 3/4 inch, commonly 1/4 inch; cleat not apparent	259'9"	261'1"	1'4"
55.	Siltstone, medium light gray (N6) to grayish black (N2), mostly highly carbonaceous, almost impure coal	261'1"	261'2"	0'1"
56.	Sandstone, very fine, very light gray (N8), laminated; laminae undulous or inclined, some bioturbated, and slumped; contains sparse to numerous carbonaceous lenses and films	261'2"	264'0"	2'10"
57.	Rotary drilled	264'0"	295'0"	31'0"
58.	Siltstone and silty shale, and sandstone, interlaminated: siltstone and silty shale, medium gray (N5), and light olive gray (5Y 6/1), non-carbonaceous to moderately carbonaceous; sandstone, very fine, very light gray (N8), bioturbated. Calcite veinlets in uppermost 4 inches	295'0"	297'5"	2'5"
59.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses commonly 1/16 inch thick; cleat not apparent	297'5"	298'1"	0'8"
60.	Claystone, light olive gray (5Y 6/1); kaolinitic	298'1"	298'1 1/4"	0' 1/4"
61.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat well developed	298'1 1/4"	298'8"	0'6 3/4"

Neslen Formation--Continued:

		From	To	Thickness
62.	Impure coal, grayish black (N2); contains vitrain lenses as thick as 1/4 inch	298'8"	299'0"	0'4"
63.	Siltstone, medium gray (N5) to dark gray (N3), moderately to slightly carbonaceous, obscurely laminated; contains numerous beds and laminae of very fine, very light gray sandstone in upper half, all bioturbated or slumped, and sparse pyrite bodies in lower part	299'0"	303'2"	4'2"
64.	Rotary drilled	303'2"	379'0"	75'10"
65.	Sandstone, very fine, very light gray (N8) and light gray (N7), laminated, and bioturbated in parts; contains some laminae and beds of medium gray to dark gray siltstone, and sparse carbon-rich laminae	379'0"	380'0"	1'0"
66.	Coal, black (N1); vitrainous and attrital; contains vitrain lenses 1/16 inch thick; coal fragmented	380'0"	380'1"	0'1"
67.	Siltstone and silty shale, grayish black (N2) to medium light gray (N6) and light olive gray (5Y 6/1); highly to slightly carbonaceous; contains very fine, very light gray, bioturbated sandstone laminae in upper part	380'1"	382'4"	2'3"
68.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/8 inch and sparse claystone films; cleat not apparent	382'4"	384'6"	2'2"
69.	Shale, silty, and siltstone, grayish black (N2) and dark gray (N3), highly carbonaceous, obscurely laminated. Basal contact gradational	384'6"	385'9"	1'3"
70.	Sandstone and siltstone, intermixed--highly bioturbated: sandstone, very fine, very light gray (N8); siltstone, dark gray (N3), highly to moderately carbonaceous. Proportion of sandstone increases downward	385'9"	388'0"	2'3"
71.	Rotary drilled	388'0"	494'8"	106'8"

Neslen Formation--Continued:

		From	To	Thickness
72.	Siltstone and silty shale, obscurely laminated, olive gray (5Y 4/1), and medium gray (N5) to dark gray (N3); noncarbonaceous or very slightly carbonaceous in upper part grading to highly carbonaceous in basal part; contains abundant carbonaceous films and flakes in lower part, and very fine, very light gray bioturbated sandstone in uppermost 2 inches	494.8"	498'6"	3'10"
73.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat not apparent	498'6"	499'8"	1'2"
74.	Siltstone and silty shale, medium gray (N5) to dark gray (N3), and pale yellowish brown (10YR 6/2), moderately to highly carbonaceous, non-carbonaceous where yellowish brown, obscurely laminated; contains sparse to abundant carbonaceous lenses, some as thick as 1/4 inch, abundant vitrain lenses in one part, sparse resin in bodies as long as 1/2 inch, and very sparse pyrite	499'8"	507'2"	7'6"
75.	Sandstone and siltstone, intermixed--highly bioturbated, contorted--slump mixed: sandstone very fine, very light gray (N8); siltstone, dark gray (N3) and medium dark gray (N4), and pale yellowish brown (10YR 6/2), moderately to highly carbonaceous, non-carbonaceous where yellowish brown; contains pyritic silicified floral fragment near base	507'2"	513'5"	6'3"
76.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch, and sparse pyrite; cleat poorly developed; scaley calcite on cleat faces	513'5"	516'0"	2'7"
77.	Siltstone, medium dark gray (N4), moderately carbonaceous; contains sparse to abundant carbonaceous lenses, flakes, and films	516'0"	518'9"	2'9"

Neslen Formation--Continued:

		From	To	Thickness
78.	Siltstone, medium gray (N5) and medium dark gray (N4), and pale yellowish brown (10YR 6/2), modertely carbonaceous except where yellowish brown; contains very fine, very light gray, highly bioturbated, contorted sandstone bodies, and numerous to abundant carbonaceous flakes	518'9"	520'8"	1'11"
79.	Shale, silty, medium light gray (N6), slightly to moderately carbonaceous, obscurely laminated; contains sparse carbonaceous films and flakes	520'8"	521'6"	0'10"
80.	Sandstone, silty, very fine, very light gray (N8) and light gray (N7), obscurely laminated; contains sparse carbonaceous films and sparse rounded bodies of pale yellow earthy mineral	521'6"	523'0"	1'6"
81.	Sandstone, silty, very fine, very light gray (N8) to medium light gray (N6), and light olive gray (5YR 6/1) and pale yellowish brown (10YR 6/2), bioturbated; silty fraction slightly carbonaceous; contains very abundant carbonaceous films in parts	523'0"	525'8"	2'8"
82.	Siltstone and silty shale, medium gray (N5) to grayish black (N2), moderately to highly carbonaceous, obscurely laminated; contains sparse to abundant vitrain flakes and lenses	525'8"	528'8"	3'0"
83.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch, commonly 1/16 inch; cleat not apparent. Coal fractured; calcite scale on fracture faces	528'8"	529'2 1/2"	0'6 1/2"
84.	Siltstone, grayish black (N2), highly carbonaceous; contains carbonaceous lenses as thick as 1/4 inch	529'2 1/2"	529'11 1/2"	0'9"
85.	Siltstone, medium gray (N5) and brownish gray (5YR 4/1), slightly to moderately carbonaceous, obscurely laminated; contains very fine, very light gray bioturbated sandstone in lower 2 feet; numerous carbonaceous flakes and lenses in upper 1 1/2 feet, and pyrite lens 1/2 inch thick at base	529'11 1/2"	533'7 1/2"	3'8"

Neslen Formation--Continued:

	From	To	Thickness
86. Impure coal, grayish black (N2) and black (N1); contains vitrain lenses as thick as 1/8 inch	533′7 1/2″	533′8	0′ 1/2″
87. Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/2 inch; cleat not apparent	533′8″	534′4″	0′8″
88. Siltstone, grayish black (N2); highly carbonaceous; contains vitrain lenses commonly 1/16 inch thick	534′4″	534′8″	0′4″

Cretaceous

Farrer Formation:

	From	To	Thickness
1. Rotary drilled--overburden; man-made fill, and alluvium or colluvium	0′0″	26′0″	26′0″
2. Rotary drilled--bedrock	26′0″	32′8″	6′8″

Neslen Formation:

3. Shale, silty, medium dark gray (N4), moderately carbonaceous; contains abundant carbonaceous films	32′8″	33′1″	0′5″
4. Siltstone, medium gray (N5), very slightly carbonaceous; contains sparse carbonaceous films and pyrite in parts, obscurely laminated; laminae disturbed in parts	33′1″	35′6″	2′5″
5. Shale, silty, medium gray (N5) to grayish black (N2), moderately to highly carbonaceous; contains carbonaceous films and lenses	35′6″	40′6″	5′0″
6. Sandstone, very fine, light gray (N7), obscurely to distinctly laminated; laminae disturbed--contorted, inclined, bioturbated; contains sparse carbonaceous films	40′6″	43′7″	3′1″
7. Shale, silty and siltstone, medium gray (N5) to dark gray (N3), slightly carbonaceous, moderately carbonaceous in parts; contains sparse to abundant carbonaceous films and lenses	43′7″	45′9″	2′2″
8. Siltstone, sandy, light gray (N7) and light brownish gray (5YR 6/1), slightly carbonaceous; contains sparse carbonaceous films	45′9″	47′4″	1′7″
9. Shale, silty, medium gray (N6), slightly carbonaceous; contains sparse carbonaceous films	47′4″	48′5″	1′1″
10. Sandstone, siltstone and silty shale, intermixed--slumped, contorted, and bioturbated: sandstone, very fine, light gray (N7); siltstone and silty shale, medium light gray (N6) and medium gray (N5), slightly carbonaceous. Unit contains sparse carbonaceous films and flakes	48′5″	53′4″	4′11″

Neslen Formation--Continued:

		From	To	Thickness
11.	Shale, silty, and siltstone, dark gray (N3), moderately carbonaceous; contains sparse to abundant carbonaceous flakes and films. Unit obscurely laminated	53′4″	56′10″	3′6″
12.	Sandstone and siltstone, intermixed and interlaminated, bioturbated: sandstone, very fine, very light gray (N8); siltstone, medium gray (N5), slightly carbonaceous. Unit contains numerous carbonaceous films and flakes	56′10″	65′5″	8′7″
13.	Siltstone, yellowish gray (5Y 7/2), noncarbonaceous	65′5″	65′5 1/2″	0′ 1/2″
14.	Sandstone, very fine and fine, very light gray (N8), obscurely to distinctly laminated; laminae inclined in parts; contains sparse to abundant carbonaceous films, lenses, and laminae. Basal contact undulous	65′5 1/2″	73′2″	7′8 1/2″
15.	Siltstone, medium light gray (N6) to medium dark gray (N4), and brownish gray (5YR 4/1); slightly to moderately carbonaceous, sandy in parts; contains interbeds and interlaminae of bioturbated sandstone	73′2″	81′4″	8′2″
16.	Sandstone and sandy siltstone, highly bioturbated: sandstone, very fine, very light gray (N7); siltstone, medium light gray (N6), slightly carbonaceous	81′4″	86′1″	4′9″
17.	Siltstone and sandstone, intermixed--bioturbated: siltstone, medium gray (N5), slightly to moderately carbonaceous; sandstone, very fine, very light gray (N8)	86′1″	87′6″	1′5″
18.	Siltstone and sandy siltstone, medium gray (N5) to light gray (N7), slightly to moderately carbonaceous; contains contorted bodies of sandstone	87′6″	91′6″	4′0″

Neslen Formation--Continued:

	From	To	Thickness
19. Sandstone, silty sandstone, and minor siltstone; obscurely to distinctly laminated, bioturbated in parts: sandstone and silty sandstone, very fine, very light gray (N8) and light gray (N7); siltstone, medium light gray (N6) and light brownish gray (5YR 6/1), slightly carbonaceous; contains very sparse carbonaceous films	91'6"	109'5"	17'11"
20. Siltstone and shaley siltstone, medium light gray (N6) to dark gray (N3), moderately carbonaceous; contains sparse carbonaceous films	109'5"	110'7"	1'2"
21. Sandstone and sandy siltstone, interlaminated and intermixed--bioturbated: sandstone, very fine very light gray (N8); siltstone, light gray (N7) and medium gray (N6); slightly carbonaceous; contains sparse carbonaceous films	110'7"	112'0"	1'5"
22. Siltstone and shaley siltstone, medium gray (N5), moderately carbonaceous, obscurely to distinctly laminated, bioturbated; contains sparse to abundant carbonaceous films and flakes	112'0"	114'5"	2'5"
23. Siltstone and minor sandstone, intermixed--bioturbated: siltstone, medium gray (N5), slightly to moderately carbonaceous; sandstone, very fine, light gray (N7). Unit contains sparse to numerous carbonaceous films and flakes	114'5"	120'4"	5'11"
24. Sandstone, very fine, very light gray (N8), laminated in lower part; contains abundant carbonaceous films in lower part	120'4"	122'9"	2'5"
25. Siltstone, medium gray (N5) and medium dark gray (N4); moderately carbonaceous. Contact with underlying unit very irregular	122'9"	123'2"	0'5"
26. Sandstone, very fine, very light gray (N8), obscurely laminated--bioturbated. Contact with underlying unit very irregular	123'2"	124'3"	1'1"

Neslen Formation--Continued:

		From	To	Thickness
27.	Siltstone and sandstone, intermixed--bioturbated; siltstone, medium light gray (N6) to dark gray (N3), and light olive gray (5YR 6/1); very slightly to moderately carbonaceous, non-carbonaceous where olive gray; sandstone, very fine, very light gray (N8); contains sparse carbonaceous films and flakes	124'3"	139'0"	14'9"
28.	Siltstone, medium gray (N5), moderately carbonaceous	139'0"	139'8"	0'8"
29.	Siltstone, pale yellowish brown (10YR 6/2), limey, noncarbonaceous	139'8"	140'1"	0'5"
30.	Siltstone, mostly medium gray (N5), light olive gray (5YR 6/1) in parts, moderately carbonaceous	140'1"	150'10"	10'9"
31.	Sandstone and siltstone, intermixed--highly bioturbated: sandstone, very fine, light gray (N7) and yellowish gray (5Y 7/2); siltstone, medium light gray (N6), slightly carbonaceous. Unit contains abundant films and flakes of carbonaceous material, sparse subangular to rounded bodies of white sandy material, and sparse, ghostly outlined gastropods	150'10"	153'6"	2'8"
32.	Siltstone, medium light gray (N6); slightly to moderately carbonaceous, obscurely laminated; contains minor laminae and beds of slightly bioturbated sandstone, sparse films and flakes of carbonaceous material	153'6"	162'2"	8'8"
33.	Siltstone, medium dark gray (N4) to grayish black (N2), moderately to highly carbonaceous, obscurely laminated; contains sparse flakes of carbonaceous material; basal contact highly undulous--slumped; rounded inclusions of rock detached from underlying unit in basal few inches	162'2"	165'9"	3'7"

Neslen Formation--Continued:

		From	To	Thickness
34.	Siltstone, light gray (N7) and yellowish gray (5Y 8/1), non-carbonaceous	165′9"	166′8"	0′11"
35.	Sandstone, very fine, very light gray (N8) and light gray (N7), distinctly laminated; contains sparse to numerous films and lenses of carbonaceous material; irregularly rounded bodies of pale yellowish brown siltstone in parts; some laminae of medium light gray siltstone in basal 8 inches	166′8"	172′1 1/2"	5′5 1/2"
36.	Siltstone, medium gray (N5), moderately carbonaceous, obscurely laminated; contains sparse films and flakes of carbonaceous material, and laminae and beds of sandstone; sandstone more abundant in lower part	172′1 1/2"	179′1"	6′11 1/2"
37.	Sandstone, very fine, very light gray (N8), obscurely to distinctly laminated; contains abundant lensoidal and flaky bodies of medium gray siltstone in lower part	179′1"	191′7"	12′6"
38.	Siltstone, medium gray (N5) and medium dark gray (N4); moderately carbonaceous; contains sparse carbonaceous films	191′7"	193′8"	2′1"
39.	Claystone, silty, limey, very light gray (N8); contains calcite veinlets and pods, and irregular bodies of asphaltic(?) material that crosscut laminae and are enveined with calcite. Basal contact gradational	193′8"	195′9"	2′1"
40.	Siltstone, medium gray (N5) and medium dark gray (N4); moderately carbonaceous, obscurely laminated	195′9"	199′8"	3′11"
41.	Sandstone and siltstone, intermixed and interlaminated, bioturbated and slumped in parts: sandstone, very fine, very light gray (N8); siltstone, medium gray (N5) and medium dark gray (N4), moderately carbonaceous	199′8"	208′3"	8′7"

Neslen Formation--Continued:

		From	To	Thickness
42.	Sandstone, very fine, very light gray (N8), distinctly laminated in most parts; contains some laminae and irregular bodies of medium gray, moderately carbonaceous siltstone in upper part, sparse to abundant carbon-rich laminae and carbonaceous films and flakes throughout. Basal contact undulous	208′3″	213′5″	5′2″
43.	Siltstone, dark gray (N3) and grayish black (N2); highly carbonaceous, almost impure coal	213′5″	214′8 1/2″	1′3 1/2″
44.	Sandstone, very fine, very light gray (N8), obscurely laminated; silty near base	214′8 1/2″	215′10″	1′1 1/2″
45.	Siltstone, medium gray (N5), slightly carbonaceous	215′10″	217′5″	1′7″
46.	Siltstone, dark gray (N3) and grayish black (N2), highly carbonaceous; contains sparse resin blebs	217′5″	217′11″	0′6″
47.	Coal, black (N1), vitrainous and attrital; cleat not apparent	217′11″	218′3 1/2″	0′4 1/2″
48.	Siltstone, grayish black (N2) to medium gray (N5), highly carbonaceous in upper part grading to moderately carbonaceous, obscurely laminated; contains sparse to abundant carbonaceous films and flakes	218′3 1/2″	225′8″	7′4 1/2″
49.	Siltstone and sandstone, interlaminated and intermixed--bioturbated: siltstone, medium light gray (N6), slightly carbonaceous; sandstone, very fine, very light gray (N8) and light gray (N7), and pale yellowish brown (10YR 6/2). Unit contains abundant carbonaceous films and flakes	225′8″	228′6″	2′10″
50.	Sandstone, very fine, very light gray (N8) obscurely to distinctly laminated, bioturbated in parts; contains minor intermixed, interlaminated and interbedded medium light gray, slightly to moderately carbonaceous siltstone in upper part, abundant flaky to blocky angular siltstone bodies in lower part, and carbon-rich laminae in middle part	228′6″	241′11″	13′5″

Neslen Formation--Continued:

		From	To	Thickness
51.	Siltstone, dark gray (N3), moderately carbonaceous, laminated and bioturbated; contains sparse to abundant carbonaceous films and flakes	241'11"	243'1"	1'2"
52.	Sandstone, very fine, very light gray (N8), obscurely laminated	243'1"	245'2"	2'1"
53.	Siltstone and sandstone, interlaminated, bioturbated in parts: siltstone, medium light gray (N6), slightly carbonaceous; sandstone, very fine, very light gray (N8)	245'2"	245'9"	0'7"
54.	Sandstone, very fine, fine in parts, very light gray (N8), unlaminated; contains irregular rounded fragments of siltstone in basal 6 inches; basal contact undulous--slumped	245'9"	256'1"	10'4"
55.	Siltstone and sandstone, interlaminated, bioturbated in few parts: siltstone, medium dark gray (N4), moderately carbonaceous; sandstone, very fine, very light gray (N8)	256'1"	257'8"	1'7"
56.	Siltstone, and sandstone, intermixed--highly bioturbated: siltstone, mostly medium gray (N4), moderately carbonaceous; sandstone, very fine, very light gray (N8); contains abundant carbonaceous films and flakes	257'8"	261'6"	3'10"
57.	Siltstone, medium dark gray (N4), moderately carbonaceous, indistinctly laminated except where sandy; contains sparse laminae of very fine, very light gray bioturbated sandstone	261'6"	270'3"	8'9"
58.	Sandstone, very fine, very light gray (N8), bioturbated and slumped; contains contorted laminae of medium gray siltstone in upper part, abundant carbon-rich laminae in basal 8 inches. Unit less disturbed in basal part	270'3"	283'1"	12'10"

Neslen Formation--Continued:

		From	To	Thickness
59.	Siltstone, brownish gray (5YR 4/1), and medium dark gray (N4) to grayish black (N2), moderately to highly carbonaceous, slightly carbonaceous in uppermost foot, obscurely laminated	283'1"	288'9"	5'8"
60.	Claystone, very light gray (N8), grainy, kaolinitic	288'9"	288'10"	0'1"
61.	Siltstone, dark gray (N3) and grayish black (N2), highly carbonaceous, obscurely laminated; contains numerous vitrain lenses in lower part, thickest lens 1/2 inch	288'10"	294'3"	5'5"
62.	Siltstone, medium gray (N5) and yellowish gray (5Y 7/2), limey, slightly carbonaceous, gradational with underlying unit	294'3"	296'0"	1'9"
63.	Siltstone, dark gray (N3) and grayish black (N2), highly carbonaceous approaching impure coal; contains abundant vitrain lenses	296'0"	296'6"	0'6"
64.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat not apparent	296'6"	297'2"	0'8"
65.	Siltstone, dark gray (N3), highly carbonaceous; contains abundant vitrain lenses, commonly 1/16 inch thick	297'2"	297'8"	0'6"
66.	Sandstone and siltstone, interlaminated and intermixed--bioturbated: sandstone very fine, very light gray (N8); siltstone, medium gray (N5), moderately carbonaceous	297'8"	302'3"	4'7"
67.	Siltstone, medium dark gray (N4), moderately carbonaceous, laminated; contains sparse to abundant carbonaceous films and flakes	302'3"	304'10"	2'7"
68.	Sandstone, very fine, very light gray (N8), laminated and bioturbated; contains irregular wispy siltstone laminae and lenses, sparse to abundant carbonaceous films and flakes	304'10"	309'7"	4'9"

Neslen Formation--Continued:

		From	To	Thickness
69.	Siltstone, grayish black (N2) to medium dark gray (N4), mostly highly carbonaceous; contains vitrain lenses in parts	309'7"	315'5"	5'10"
70.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat well developed	315'5"	316'2"	0'9"
71.	Siltstone, dark gray (N3) and medium gray (N5), highly to moderately carbonaceous, laminated	316'2"	318'7"	2'5"
72.	Siltstone and sandstone, intermixed--bioturbated: siltstone, medium light gray (N6) and medium gray (N5), moderately carbonaceous; sandstone, very fine, very light gray (N8)	318'7"	323'6"	4'11"
73.	Sandstone, very fine, very light gray (N8), laminated; laminae slumped--deformed; contains minor interlaminated siltstone, and sparse carbonaceous films, flakes and lenses	323'6"	327'1"	3'7"
74.	Siltstone and sandstone, interbedded and interlaminated, bioturbated and slump folded in parts: siltstone, mostly dark gray (N3), light olive gray (5Y 6/1) in few parts, highly carbonaceous, noncarbonaceous where olive gray; sandstone, very fine, very light gray (N8). Unit contains abundant carbonaceous films, flakes and lenses	327'1"	333' 1/2"	5'11 1/2"
75.	Coal, black (N1) vitrainous and attrital; cleat not apparent	333' 1/2"	333'4 1/2"	0'4"
76.	Siltstone, medium gray (N5), moderately carbonaceous, highly carbonaceous in uppermost 1 1/2 inches	333'4 1/2"	335'2"	1'9 1/2"
77.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat well developed in parts	335'2"	337'0"	1'10"
78.	Impure coal, grayish black (N2) and black (N1); contains abundant vitrain lenses, some as thick as 1/4 inch	337'0"	337'4 1/2"	0'4 1/2"

Neslen Formation--Continued:

		From	To	Thickness
79.	Siltstone, medium dark gray (N4) and dark gray (N3), moderately to highly carbonaceous, obscurely laminated; contains abundant carbonaceous films and flakes	337′4 1/2″	340′9 1/2″	3′5″
80.	Siltstone, medium dark gray (N4) and medium gray (N5), moderately carbonaceous, obscurely to distinctly laminated; laminae slumped; contains abundant carbonaceous films and flakes, many replaced by pyrite	340′9 1/2″	343′2 1/2″	2′5″
81.	Claystone, very light gray (N8), grainy, kaolinitic	343′2 1/2″	343′5 1/2″	0′3″
82.	Siltstone, grayish black (N2), highly carbonaceous; contains sparse to abundant carbonaceous films and flakes, sparse vitrain lenses, some as thick as 1/4 inch, and very sparse resin	343′5 1/2″	347′3″	3′9 1/2″
83.	Siltstone and sandstone, interlaminated, interbedded, and intermixed, bioturbated in parts, slump folded and faulted in parts: siltstone, olive gray (5Y 4/1), and medium gray (N5), slightly carbonaceous; sandstone, very fine, very light gray (N8); contains sparse to numerous carbonaceous films and flakes	347′3″	363′0″	15′9″
84.	Sandstone, very fine, very light gray (N8), distinctly laminated in parts, bioturbated in parts; contains minor medium gray and medium dark gray, moderately carbonaceous siltstone, abundant carbon-rich laminae in parts, and vitrain lenses in basal part	363′0″	375′4″	12′4″
85.	Coal, black (N1), vitrainous and attrital; cleat not apparent	375′4″	375′7″	0′3″
86.	Impure coal, grayish black (N2) and black (N1); contains vitrain lenses as thick as 1/4 inch	375′7″	376′4″	0′10″
87.	Siltstone, medium dark gray (N4), moderately carbonaceous, contains numerous carbonaceous films and flakes	376′4″	377′2″	0′10″

Neslen Formation--Continued:

		From	To	Thickness
88.	Siltstone, medium light gray (N6), slightly carbonaceous, obscurely laminated; contains numerous to abundant carbonaceous films and flakes	377′2"	380′6"	3′4"
89.	Siltstone and sandstone, intermixed--highly bioturbated, distinctly laminated in few parts: siltstone, medium light gray (N6), light olive gray (5Y 6/1) and yellowish gray (5Y 7/2), mostly slightly carbonaceous; contains sparse to abundant carbonaceous films and flakes; sandstone, very fine, very light gray (N8). Unit dominantly siltstone	380′6"	389′7"	9′1"
90	Siltstone, medium dark gray (N4) to grayish black (N2), moderately to highly carbonaceous; contains vitrain lenses in lower part	389′7"	391′7"	2′0"
91.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat well developed	391′7"	394′1 1/2"	2′6 1/2"
92.	Claystone, very light gray (N8), grainy, kaolinitic	394′1 1/2"	394′3"	0′1 1/2"
93.	Coal, black (N1), vitrainous and attrital; cleat not apparent	394′3"	394′10"	0′7"
94.	Siltstone, medium dark gray (N4) and dark gray (N3), moderately carbonaceous, obscurely laminated, bioturbated in parts; contains wispy, sandy laminae and abundant carbonaceous flakes and lenses in lower part, and noncalcitic mineral scale on partings	394′10"	402′2"	7′4"
95.	Impure coal and highly carbonaceous siltstone, grayish black (N2) and brownish black (5YR 2/1)	402′2"	402′8"	0′6"
96.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/8 inch; cleat moderately well to well developed	402′8"	410′3"	7′7"

Neslen Formation--Continued:

		From	To	Thickness
97.	Siltstone, grayish black (N2), mostly highly carbonaceous; contains few sandstone laminae in lower part	410'3"	411'1"	0'10"
98.	Sandstone and siltstone, interlaminated, bioturbated in few parts: sandstone, very fine, very light gray (N8); siltstone, medium gray (N5) to dark gray (N3), moderately carbonaceous; contains sparse carbon-rich laminae	411'1"	413'6"	2'5"
99.	Siltstone, dark gray (N3) and grayish black (N2), highly carbonaceous, obscurely laminated	413'6"	413'10"	0'4"
100.	Coal, black (N1), vitrainous and attrital; vitrain lenses as thick as 1/16 inch; cleat poorly developed; mineral scale on cleat faces	413'10"	416'2"	2'4"
101.	Impure coal, grayish black (N2); contains vitrain lenses as thick as 1/8 inch	416'2"	416'6"	0'4"
102.	Siltstone and sandstone, interlaminated and intermixed--bioturbated: siltstone, medium dark gray (N4), moderately carbonaceous; sandstone, very fine, light gray (N7). Unit contains abundant carbonaceous films and flakes	416'6"	419'2"	2'8"
103.	Siltstone, grayish black (N2), highly cabonaceous, almost impure coal	419'2"	419'4"	0'2"
104.	Coal, black (N2), vitrainous and attrital; vitrain lenses as thick as 1/16 inch; cleat well developed; coal slightly impure in one part	419'4"	423'7"	4'3"
105.	Impure coal and highly carbonaceous siltstone, grayish black (N2) and dark gray (N3); contains abundant vitrain lenses; lenses commonly 1/16-inch thick	423'7"	424'0"	0'5"
106.	Siltstone, medium dark gray (N4), moderately to highly carbonaceous, obscurely laminated; contains numerous carbonaceous films and flakes	424'9"	424'8"	0'8"

Neslen Formation--Continued:

		From	To	Thickness
107.	Sandstone and siltstone, interlaminated and intermixed--bioturbated; sandstone, very fine, very light gray (N8) and light gray (N7); siltstone, medium dark gray (N4), moderately carbonaceous. Unit dominantly sandstone	424′8"	426′3"	1′7"
108.	Sandstone, very fine, very light gray (N8), limey, unlaminated; contains sparse carbonaceous flakes and films	426′3"	427′5"	1′2"
109.	Sandstone, very fine, very light gray (N8), distinctly laminated in most parts, slightly bioturbated; contains some laminae of moderately carbonaceous siltstone, and abundant carbonaceous films and flakes	427′5"	430′3"	2′10"
110.	Shale, silty, and siltstone, medium dark gray (N4) and dark gray (N3), moderately to highly carbonaceous, oscurely laminated, bioturbated in parts; contains sparse sandstone lenses and laminae	430′3"	433′9"	3′6"
111.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat moderately well developed	433′9"	434′4"	0′7"
112.	Claystone, very light gray (N8), grainy, kaolinitic	434′4"	434′4 3/4"	0′3/4"
113.	Coal black (N1), vitrainous and attrital, vitrain lenses as thick as 1/4 inch; cleat well developed	434′4 3/4"	435′6 3/4"	1′2"
114.	Siltstone, medium dark gray (N4) and brownish gray (5YR 4/1), moderately carbonaceous; contains abundant carbonaceous flakes, and some bioturbated sandstone lenses in basal part	435′6 3/4"	436′6 3/4"	1′0"
115.	Sandstone and minor siltstone, interlaminated--laminae undulous, bioturbated in parts: sandstone, very fine, very light gray (N8); siltstone, medium dark gray (N4), moderately carbonaceous	436′6 3/4"	440′6"	3′11 1/4"

Neslen Formation--Continued:

		From	To	Thickness
107.	Sandstone and siltstone, interlaminated and intermixed--bioturbated: sandstone, very fine, very light gray (N8) and light gray (N7); siltstone, medium dark gray (N4), moderately carbonaceous. Unit dominantly sandstone	424'8"	426'3"	1'7"
108.	Sandstone, very fine, very light gray (N8), limey, unlaminated; contains sparse carbonaceous flakes and films	426'3"	427'5"	1'2"
109.	Sandstone, very fine, very light gray (N8), distinctly laminated in most parts, slightly bioturbated; contains some laminae of moderately carbonaceous siltstone, and abundant carbonaceous films and flakes	427'5"	430'3"	2'10"
110.	Shale, silty, and siltstone, medium dark gray (N4) and dark gray (N3), moderately to highly carbonaceous, obscurely laminated, bioturbated in parts; contains sparse sandstone lenses and laminae	430'3"	433'9"	3'6"
111.	Coal, black, (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat moderately well developed	433'9"	434'4"	0'7"
112.	Claystone, very light gray (N8), grainy, kaolinitic	434'4"	434'4 3/4"	0'3/4"
113.	Coal, black (N1), vitrainous and attrital, vitrain lenses as thick as 1/4 inch; cleat well developed	434'4 3/4"	435'6 3/4"	1'2"
114.	Siltstone, medium dark gray (N4) and brownish gray (5YR 4/1), moderately carbonaceous; contains abundant carbonaceous flakes, and some bioturbated sandstone lenses in basal part	435'6 3/4"	436'6 3/4"	1'0"
115.	Sandstone and minor siltstone, interlaminated--laminae undulous, bioturbated in parts: sandstone, very fine, very light gray (N8); siltstone, medium dark gray (N4), moderately carbonaceous	436'6 3/4"	440'6"	3'11 1/4"

Neslen Formation--Continued:

		From	To	Thickness
116.	Siltstone and shaley siltstone, dark gray (N3), moderately to highly carbonaceous, obscurely lamnated; contains few bioturbated sandstone lenses in upper part	440′6″	445′1″	4′7″
117.	Siltstone, slightly limey, dark yellowish brown (10YR 4/2), noncarbonaceous	445′1″	445′4″	0′3″
118.	Siltstone and sandystone, intermixed--highly bioturbated siltstone, medium gray (N5) and medium dark gray (N4), moderately carbonaceous; sandstone, very fine, very light gray (N8). Unit contains sparse to numerous carbonaceous films	445′4″	447′11″	2′7″
119.	Shale, silty, and shaley siltstone, and minor interlaminated sandstone, obscurely laminated, bioturbated in parts: shale and siltstone, mostly dark gray (N3), grayish black (N2), and brownish black (5YR 2/1), highly carbonaceous; sandstone, very fine, very light gray (N8). Proportion of sandstone generally increases downward	447′11″	468′3″	0′4″
120.	Sandstone and siltstone, interbedded and interlaminated, bioturbated in parts; cross laminated in parts: sandstone, very fine, very light gray (N8); siltstone, medium gray (N5), moderately carbonaceous. Proportion of sandstone-siltstone equal. Unit contains numerour carbonaceous films; gradational with underlying unit	468′3″	477′6″	9′3″
121.	Siltstone and silty shale, medium gray (N5) and medium dark gray (N4), moderately carbonaceous; highly carbonaceous, pyritic in basal 2 inches; contains very minor sandstone as thin lenses and laminae in upper and basal parts	447′6″	480′4 1/2″	2′10 1/2″
122.	Coal, black (N1), vitrainous and attrital; vitrain lenses commonly 1/16 inch thick; cleat poorly developed	480′4 1/2″	480′7 1/2″	0′3″

Neslen Formation--Continued:

		From	To	Thickness
123.	Shale, silty, dark gray (N3), highly carbonaceous, obscurely laminated; contains numerous thin sandstone lenses and laminae in lower part	480′7 1/2″	482′7 1/2″	2′0″
124.	Coal, black (N1), vitrainous and attrital; cleat not apparent	482′7 1/2″	482′9 1/2″	0′2″
125.	Shale, silty, dark gray (N3) and grayish black (N2), highly carbonaceous; contains vitrain lenses in uppermost 2 inches	482′9 1/2″	483′4″	0′6 1/2″
126.	Siltstone, medium gray (N5), moderately carbonaceous	483′4″	483′7″	0′3″
127.	Sandstone and siltstone, interlaminated, bioturbated in parts: sandstone, very fine, very light gray (N8); siltstone, medium dark gray (N4), moderately carbonaceous	483′7″	484′9 1/2″	1′2 1/2″
128.	Sandstone, very fine and fine, very light gray (N8), obscurely to distinctly laminated, micaceous; contains numerous siltstone lenses and pods, abundant carbonaceous films and flakes, sparse carbon-rich lenses	484′9 1/2″	490′3″	5′5 1/2″
129.	Siltstone, medium dark gray (N4), moderately carbonaceous, highly carbonaceous in basal 2 inches, obscurely laminated; contains sparse carbonaceous flakes	490′3″	491′3″	1′0″
130.	Coal, black (N1), vitrainous and attrital, clayey near top; cleat not apparent	491′3″	493′1″	1′10″
131.	Siltstone, dark gray (N3) and medium dark gray (N4), moderately carbonaceous, obscurely laminated; contains sparse to numerous carbonaceous films and few sandstone lenses and laminae near base	493′1″	494′5″	1′4″

Neslen Formation--Continued:

		From	To	Thickness
132.	Sandstone and siltstone, interbedded and interlaminated; laminae undulous--bioturbated; bioturbated parts progressively more developed downward: sandstone, very fine, very light gray (N8); siltstone, medium gray (N5) to dark gray (N3), slightly to moderately carbonaceous; contains sparse to numerous carbonaceous films and flakes	494′5"	505′8"	11′3"
133.	Siltstone, brownish gray (5YR 4/1), moderately carbonaceous, obscurely laminated; contains numerous carbonaceous flakes	505′8"	507′3"	1′7"
134.	Sandstone and siltstone, intermixed--highly bioturbated--homogeneous appearing: sandstone, very fine, very light gray (N8); siltstone, light gray (N7), noncarbonaceous; contains sparse carbonaceous flakes and films; gradational with underlying unit	507′3"	509′8"	2′5"
135.	Siltstone and sandstone, intermixed--highly bioturbated: siltstone, medium dark gray (N4), moderately carbonaceous; sandstone, very fine, very light gray (N8). Unit contains rounded, pebble-size fragments of pale yellowish brown silty claystone in basal 1 1/2 inches. Proportion of sandstone increases downward. Contact with underlying unit undulous	509′8"	516′5"	6′9"
136.	Claystone, silty, pale yellowish brown (10YR 6/2), reacts with HCl if pulverized; contact with underlying unit undulous	516′5"	516′6 1/2"	0′1 1/2"
137.	Siltstone, and some interlaminated and intermixed, bioturbated sandstone: siltstone, medium gray (N5), moderately to slightly carbonaceous; sandstone, very fine, very light gray (N8); sandstone laminae slump-folded and -faulted. Unit contains sparse carbonaceous films and flakes	516′6 1/2"	519′4"	2′9 1/2"

Neslen Formation--Continued:

		From	To	Thickness
138.	Claystone, silty, and siltstone, intergrading: claystone, very pale orange (10YR 8/2) and grayish orange (10 YR 7/4), slightly limey; siltstone, medium light gray (N6), slightly carbonaceous. Unit appears internally disturbed; contains few sandstone lenses	519′4"	519′10 1/2"	0′6 1/2"
139.	Siltstone, medium dark gray (N4) and brownish gray (5YR 4/1), moderately carbonaceous, obscurely laminated, much disturbed--slumped in upper part; contains sparse to abundant carbonaceous films and flakes	519′10 1/2"	525′6"	5′7 1/2"
140.	Sandstone, very fine, very light gray (N8), obscurely to distinctly laminated; laminae slightly inclined in parts; contains abundant carbon-rich laminae in parts, abundant opaque mineral grains; sparse to numerous grayish orange, ragged-filmy bodies less than 1/25 inch long	525′6"	536′2"	10′8"
141.	Shale, silty, and siltstone, grayish black (N2) and brownish black (5YR 2/1), highly carbonaceous, approaching impure coal, slightly less carbonaceous near base; contains numerous vitrain lenses, some as thick as 1/4 inch; contorted sandstone lenses in basal part. Contact with underlying unit undulous	536′2"	537′5 1/2"	1′3 1/2"
142.	Sandstone, very fine, very light gray (N8), mostly obscurely laminated; contains abundant opaque mineral grains, numerous carbon-rich laminae and sparse grayish orange silty claystone lenses in basal part, and abundant vitrain lenses in basal 1 1/2 inches	537′5 1/2"	544′3 1/2"	6′10"
143.	Siltstone, dark gray (N3) and grayish black (N2), highly carbonaceous, almost impure coal; contains abundant vitrain lenses, commonly 1/16 inch thick	544′3 1/2"	545′4"	1′ 1/2"
144.	Siltstone, medium dark gray (N4) and brownish gray (5YR 4/1), moderately carbonaceous, bioturbated; contains minor intermixed sandstone	545′4"	546′10"	1′6"

Neslen Formation--Continued:

		From	To	Thickness
145.	Sandstone, very fine and fine, very light gray (N8), mostly indistinctly laminated; contains abundant opaque mineral grains, numerous carbon-rich laminae and carbonaceous films, and sparse flakey siltstone bodies; some laminae contain concentrations of grayish orange claystone(?) grains	546′10"	552′0"	5′2"
146.	Siltstone, medium dark gray (N4) and brownish gray (5YR 4/1), moderately carbonaceous	552′0"	552′4 1/2"	0′4 1/2"
147.	Siltstone and minor intermixed sandstone, obscurely laminated, much slump folded, bioturbated in parts: siltstone, medium light gray (N6), very slightly carbonaceous; sandstone, very fine, very light gray (N8). Unit contains sparse carbonaceous films and flakes, very sparse rounded, grayish orange claystone(?) bodies in upper part, and sparse angular, moderately carbonaceous bodies in basal 4 inches. Sandstone dike, 10 inches long, 1/16 inch wide, containing carbonaceous material, in middle part of unit	552′4 1/2"	558′7"	6′2 1/2"
148.	Siltstone, medium dark gray (N4) and dark gray (N3), and brownish gray (5YR 4/1), moderately carbonaceous in upper part grading to highly carbonaceous in lower part, obscurely laminated--bioturbated; contains contorted grayish orange and yellowish brown silty claystone(?) in upper part, sparse contorted sandstone bodies and vitrain lenses in lower part, and sparse to abundant carbonaceous flakes throughout	558′7"	565′3"	6′8"
149.	Siltstone, medium dark gray (N4), moderately carbonaceous; contains sparse carbonaceous films and flakes	565′3"	565′10"	0′7"
150.	Sandstone and siltstone, intermixed--highly bioturbated: sandstone, very fine, very light gray (N8); siltstone, medium dark gray (N4), moderately carbonaceous; contains sparse carbonaceous flakes throughout, sparse carbon-rich laminae in basal part, and sparse rounded, grayish orange silty claystone(?) bodies in middle part	565′10"	569′0"	3′2"

Neslen Formation--Continued:

		From	To	Thickness
151.	Siltstone, grayish black (N2), highly carbonaceous; contains abundant vitrain lenses commonly 1/16 inch thick	569′0″	569′5 ½″	0′5 ½″
152.	Siltstone, brownish gray (5YR 4/1), moderately carbonaceous; contains numerous carbonaceous films and flakes. Contact with underlying unit undulous	569′5 ½″	570′0″	0′6 ½″
153.	Sandstone, very fine, very light gray (N8), obscurely laminated; contains sparse carbonaceous films and flakes, numerous carbon-rich laminae in basal 4 inches	570′0″	572′8 ½″	2′8 ½″
154.	Siltstone, medium gray (N5) and pale yellowish brown (10YR 2/2), bioturbated; rock of different colors non-gradational, in irregular but distinct contact. Yellowish brown siltstone slightly limey	572′8 ½″	573′9 ½″	1′1″
155.	Siltstone, medium light gray (N6) to medium dark gray (N4), slightly to moderately carbonaceous, obscurely laminated; contains abundant carbonaceous films and flakes	573′9 ½″	583′4″	9′6 ½″
156.	Sandstone and siltstone, interlaminated and intermixed--bioturbated: sandstone, very fine, very light gray (N8); siltstone medium gray (N5), moderately carbonaceous. Proportion of sandstone increases downward	583′4″	589′9″	6′5″
157.	Sandstone, fine and very fine, very light gray (N8), obscurely to distinctly laminated; laminae horizontal to inclined; contains abundant opaque mineral grains, sparse carbonaceous films and vitrain lenses, and sparse to abundant lenses and rounded bodies of siltstone and claystone	589′9″	600′5″	10′8″
158.	Siltstone, medum dark gray (N4) and dark gray (N3), and brownish gray (5YR 4/1), moderately carbonaceous, obscurely laminated; contains numerous to abundant carbonaceous films and flakes; grades to grayish orange, limey siltstone in one part	600′5″	613′6″	13′1″

Neslen Formation--Continued:

		From	To	Thickness
159.	Siltstone, dark gray (N3) and grayish black (N2), highly carbonaceous; contains abundant carbonaceous films and flakes throughout, sparse vitrain lenses in lower part and 1 1/2-inch-thick bed of carbonaceous and noncarbonaceous angular, flaky siltstone bodies in lower part	613'6"	615'10"	2'4"
160.	Sandstone and siltstone, interlaminated and intermixed, slump-folded and -faulted, slightly bioturbated: sandstone, very fine, very light gray (N8); siltstone, mostly brownish gray (5YR 4/1), slightly carbonaceous; contains sparse carbonaceous films and flakes	615'10"	618'6"	2'8"
161.	Siltstone, medium gray (N5) to dark gray (N3), moderately to highly carbonaceous; contains numerous carbonaceous films and flakes throughout, and numerous vitrain flakes and lenses in basal 10 inches	618'6"	622'4	3'10"
162.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/8 inch; cleat moderately well developed	622'4"	623'9"	1'5"
163.	Siltstone, grayish black (N2) and brownish black (5YR 2/1), highly carbonaceous; contains abundant carbonaceous films and flakes, and abundant vitrain lenses, some as thick as 1/8 inch	623'9"	624'6"	0'9"
164.	Coal, vitrainous and attrital; contains vitrain lenses commonly 1/16 inch thick; cleat moderately well developed	624'6"	625'9"	1'3"
165.	Siltstone, grayish black (N2), highly carbonaceous; contains abundant vitrain lenses commonly 1/16 inch thick; contact with underlying unit' gradational	625'9"	626'3"	0'6"
166.	Sandstone and siltstone, interlaminated; many laminae undulous, some bioturbated: sandstone, very fine, very light gray (N8); siltstone, dark gray (N3), highly carbonaceous; proportion of sandstone and siltstone differs throughout unit	626'3"	634'11"	8'8"

Neslen Formation--Continued:

		From	To	Thickness
167.	Siltstone and minor sandstone, interlaminated and interlensing; bioturbated in few parts: siltstone, pale yellowish brown (10 YR 6/2), medium gray (N5) in few parts, mostly non-carbonaceous to very slightly carbonaceous; sandstone, very fine, very light gray (N8); calcite veinlets emplaced on fractures in sandstone; fractures pre-exist overlying siltstone. Unit contains sparse carbonaceous flakes	634'11"	636'8 1/2"	1'9 1/2"
168.	Sandstone and siltstone, interlaminated, slump folded, contorted: sandstone, very fine, very light gray (N8); siltstone, brownish gray (5YR 4/1), moderately carbonaceous	636'8 1/2"	641'9"	4'3 1/2"
169.	Siltstone, grayish black (N2) and brownish black (5YR 2/1), highly carbonaeous; contains abundant vitrain lenses, some as thick as 1/4 inch, and sparse yellowish brown, silty claystone lenses, some as long as 1 inch	641'9"	641'4"	0'4"
170.	Siltstone and sandstone, interlaminated; siltstone, brownish gray (5YR 4/1), moderately carbonaceous; sandstone, very fine, very light gray (N8); contains numerous vitrain lenses in basal part, and grayish orange silty claystone bed in upper part	461'4"	642'2"	0'10"
171.	Siltstone, medium dark gray (N4) to medium light gray (N6), mostly moderately carbonaceous, obscurely to distinctly laminated; contains very minor intermixed sandstone, and numerous carbonaceous films and flakes	642'2"	647'8 1/2"	5'6 1/2"
172.	Siltstone, grayish black (N2), brownish black (5YR 2/1), and brownish gray (5YR 4/1), mostly highly carbonaceous; contains vitrain lenses in lower part, thickest 1/2 inch; white mineral fills fractures in vitrain lenses	647'8 1/2"	561'4"	3'7 1/2"

Neslen Formation--Continued:

		From	To	Thickness
173.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/2 inch; cleat moderately well developed	651'4"	653'3 1/2"	1'11 1/2"
174.	Siltstone, grayish black (N2) to medium dark gray (N4), highly carbonaceous, obscurely laminated	663'3 1/2"	655'10 1/2"	2'7"
175.	Siltstone and sandstone, interlaminated--slump-folded and contorted, bioturbated in few parts: siltstone, grayish black (N2) and brownish black (5YR 2/1), highly carbonaceous; sandstone, very fine, very light gray (N8); contains abundant carbonaceous films and flakes; proportin of sandstone increases downward	655'10 1/2"	663'7"	7'8 1/2"

Sego Sandstone

176.	Sandstone, very fine and fine, very light gray (N8), obscurely to distinctly laminated, bioturbated in few parts; contains abundant opaque mineral grains, very sparse mica, abundant carboaceous siltstone laminae in upper and basal parts, sparse grayish orange, silty claystone(?) beds and lenses in upper part; thickest claystone(?) unit 3/4 inch	663'7"	688'6"	24'11"
177.	Sandstone and siltstone, interlaminated, slightly bioturbated: sandstone, very fine, very light gray (N8); siltstone, dark gray (N3), highly carbonaceous	688'6"	690'0"	1'6"

Cretaceous:

Neslen Formation

	From	To	Thickness
1. Rotary drilled	0′0″	104′0″	104′0″
2. Shale, silty, dark gray (N3) and grayish black (N2), moderately to highly carbonaceous; contains sparse vitrain lenses in upper part	104′0″	105′7″	1′7″
3. Siltstone, medium light gray (N6) and medium gray (N5), slightly to moderately carbonaceous, obscurely laminated, sandy in basal 2 1/2 inches; contains abundant carbonaceous films and flakes	105′7″	106′9″	1′2″
4. Siltstone and sandstone, interlaminated and intermixed, bioturbated in parts: siltstone, medium light gray (N6) and medium gray (N5), slightly to moderately carbonaceous; sandstone, very fine, very light gray (N8). Unit contains sparse to numerous carbonaceous films and flakes	106′9″	107′6″	0′9″
5. Siltstone, dark gray (N3) and grayish black (N2), highly carbonaceous, unlaminated; contains abundant carbonaceous lenses. Contact with underlying unit undulous	107′6″	107′8″	0′2″
6. Claystone, very pale orange (10YR 8/2), grainy, kaolinitic; contains abundant carbonaceous films and flakes. Contact with underlying unit undulous	107′8″	107′9 1/2″	0′1 1/2″
7. Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch, and pyrite on fracture faces; cleat not apparent	107′9 1/2″	108′8 1/2″	0′11″
8. Shale, silty, grayish black (N2), highly carbonaceous; contains vitrain lenses in upper part, some as thick as 1/4 inch	108′8 1/2″	109′5 1/2″	0′9″
9. Coal, black (N1), vitrainous and attrital; cleat not apparent	109′5 1/2″	110′0″	0′6 1/2″

Neslen Formation--Continued:

		From	To	Thickness
10.	Shale, silty, dark gray (N3) grading downward to medium gray (N5), moderately carbonaceous; contains vitrain lenses in upper part	110'0"	111'9"	1'9"
11.	Siltstone and sandstone, interlaminated and intermixed--bioturbated and slumped: siltstone, light gray (N6), very slightly carbonaceous; sandstone, very fine, light gray (N7). Unit contains numerous carbonaceous films and flakes	111'9"	113'9"	2'0"
12.	Siltstone, medium dark gray (N4) and dark yellowish brown (10YR 4/2), moderately carbonaceous, obscurely laminated, limey where yellowish brown, and shaley, slightly more carbonaceous toward base	113'9"	116'10"	3'1"
13.	Coal, black (N1), vitrainous and attrital, fractured; contains noncalcitic, white scaley mineral on fracture faces; numerous bodies of yellowish white, soft, earthy mineral, and sparse pyrite; cleat not apparent	116'10"	119'4"	2'2"
15.	Siltstone, medium dark gray (N4) and brownish gray (5YR 4/1), moderately carbonaceous; contains abundant carbonaceous films and flakes. Unit sandy near base	119'4"	119'6"	0'2"
16.	Sandstone, very fine, very light gray (N8), unlaminated	119'6"	124'0"	4'6"
17.	Rotary drilled	124'0"	173'0"	49'0"
18.	Sandstone, very fine, very light gray (N8), laminated; contains abundant carbon-rich laminae, films, and flakes. Contact with underlying unit undulous	173'0"	173'8"	0'8"
19.	Siltstone and sandstone, interlaminated and interbedded: siltstone, brownish gray (5YR 4/1), moderately carbonaceous; sandstone, very fine, very light gray (N8). Parts conspicuously ripple marked, other parts slightly bioturbated. Unit dominantly siltstone; contains abundant carbonaceous films and flakes	173'8"	174'10"	1'2"

Neslen Formation--Continued:

		From	To	Thickness
20.	Sandstone, very fine, very light gray (N8), laminated; laminae undulous; contains abundant carbon-rich laminae, films, and flakes, and sparse brownish gray siltstone laminae	174'10"	176'8 1/2"	1'10 1/2"
21.	Coal, black (N1), vitrainous and attrital, contains vitrain lenses as thick as 1/8 inch, and sparse resin; cleat well developed in upper part	176'8 1/2"	178'3 1/2"	1'7"
22.	Siltstone, medium gray (N5) grading downward to dark gray (N3), moderately to highly carbonaceous, obscurely laminated; contains abundant vitrain lenses in basal part	178'3 1/2"	182'5"	4'1 1/2"
23.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/8 inch, and sparse resin; cleat well developed; calcite scale on cleat faces	182'5"	184'0"	1'7"
24.	Siltstone, dark gray (N3) and very dark gray (N2), highly carbonaceous, almost impure coal; contains abundant vitrain lenses commonly 1/16 inch or less thick, and sparse vertical calcite veinlets	184'0"	184'2"	0'2"
25.	Siltstone, grading downward to shaley siltstone, medium dark gray (N4) and dark gray (N3), and brownish black (5YR 2/1), moderately to highly carbonaceous; contins numerous carbonaceous films and flakes	184'2"	186'8 1/2"	2'6 1/2"
26.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/8 inch, and pyrite, commonly in minute bodies; one body 1/2 inch long; cleat well developed. Coal much fragmented in one 6-inch section	186'8 1/2"	191'8 1/2"	5'0"
27.	Siltstone, silty shale, and shale, intergrading, dark gray (N3) and grayish black (N2), highly carbonaceous; contains abundant carbonaceous films and flakes in parts; some carbonaceous material replaced by pyrite	191'8 1/2"	193'9"	2' 1/2"

Neslen Formation--Continued:

		From	To	Thickness
28.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses commonly 1/8 to 1/4 inch thick; one lens 1/2 inch thick; cleat not apparent	193'9"	195'0"	1'3"
29.	Claystone, pale yellowish brown (10YR 6/2), grainy, kaolinitic	195'0"	195'1"	0'1"
30.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat well developed, spaced 2 inches	195'1"	197'6 1/2"	2'5 1/2"
31.	Claystone, pale yellowish brown (10YR 6/2), grainy, kaolinitic	197'6 1/2"	197'6 3/4"	0' 1/4"
32.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat well developed; calcite scale on cleat faces; part of coal highly fragmented	197'6 3/4"	198'6 1/4"	0'11 1/2"
33.	Siltstone and sandstone, interlaminated and interbedded, bioturbated and slumped: siltstone, dark gray (N3) and medium dark gray (N4), and brownish gray (5YR 4/1), moderately carbonaceous; sandstone, very fine, very light gray (N8). Proportion of sandstone increases downward. Unit contains sparse to abundant carbonaceous films and flakes	198'6 1/4"	200'9"	2'2 3/4"
34.	Siltstone, medium dark gray (N4), moderately carbonaceous, highly carbonaceous in basal 3 inches, obscurely to distinctly laminated, bioturbated in parts; contains minor thin sandstone lenses in parts, and sparse to abundant carbonaceous films and flakes	200'9"	206'9"	6'0"
35.	Claystone, pale yellowish brown (10YR 6/2), grainy, kaolinitic; contains vitrain lenses	206'9"	206'10"	0'1"
36.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses commonly less than 1/16 inch thick, and sparse minute bodies of resin and pyrite; cleat well developed, spaced 2 inches or more; calcite scale on cleat face	206'10"	208'6 1/2"	1'8 1/2"

Neslen Formation--Continued:

		From	To	Thickness
37.	Siltstone, dark gray (N3), moderately to highly carbonaceous; contains abundant carbonaceous films and flakes	208'6 1/2"	209'0"	0'5 1/2"
38.	Siltstone and sandstone, intermixed--slumped and bioturbated: siltstone, dark gray (N3), highly carbonaceous; sandstone, very fine, very light gray (N8). Unit contains abundant carbonaceous films and flakes	209'0"	209'9"	0'9"
39.	Sandstone, very fine, very light gray (N8), unlaminated	209'9"	211'0"	1'3"
40.	Rotary drilled	211'0"	250'0"	39'0"
41.	Sandstone and siltstone, interlaminated and intermixed--slumped, micro-faulted, and bioturbated in parts: sandstone, very fine, very light gray (N8); siltstone, medium dark gray (N4), moderately carbonaceous; contains sparse carbon-rich laminae. Unit dominantly sandstone	250'0"	253'5"	3'5"
42.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/16 inch; cleat not apparent	253'5"	253'10"	0'5"
43.	Claystone, pale yellowish brown (10YR 6/2), grainy, kaolinitic	253'10"	253'10 3/4"	0'3/4"
44.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch, sparse minute bodies of resin and pyrite; cleat not apparent	253'10 3/4"	254'5 1/4"	0'6 1/2"
45.	Siltstone, dark gray (N3), moderately to highly carbonaceous, obscurely laminated; contains numerous vitrain lenses. Gradational with underlying unit	254'5 1/4"	255'1 1/4"	0'8"
46.	Siltstone and sandstone, interlaminated and intermixed--bioturbated: siltstone, brownish gray (5YR 4/1) and brownish black (5YR 2/1), moderately carbonaceous; sandstone, very fine, very light gray (N8). Proportion of sandstone increases downward	255'1 1/4"	258'0"	2'10 3/4"

Neslen Formation--Continued:

		From	To	Thickness
47.	Rotary drilled	258′0"	328′0"	70′0"
48.	Siltstone and sandstone, intermixed--intricately slumped and bioturbated: siltstone, brownish gray (5YR 4/1), moderately carbonaceous; sandstone, very fine, very light gray (N8); contains very abundant carbonaceous films and flakes, lenticular and podular bodies of pale yellowish brown, non-carbonaceous siltstone in lower part, vitrain lenses in basal 2 inches. Unit dominantly siltstone	328′0"	329′6"	1′6"
49.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses commonly 1/16 inch or less thick, some as thick as $\frac{1}{2}$ inch; cleat not apparent	329′6"	329′10"	0′4"
50.	Shale, silty, grayish black (N2), highly carbonaceous, almost impure coal	329′10"	330′0"	0′2"
51.	Impure coal, grayish black (N2), highly carbonaceous; contains abundant vitrain lenses, most commonly 1/16 inch or less thick	330′0"	330′3 $\frac{1}{2}$"	0′3 $\frac{1}{2}$"
52.	Siltstone, grayish black (N2), highly carbonaceous, almost impure coal, obscurely laminated; contains abundant vitrain lenses, and numerous bodies of resin, pyrite, and calcite	330′3 $\frac{1}{2}$"	330′8 $\frac{1}{2}$"	0′5"
53.	Siltstone, dark gray (N3), and brownish gray (5YR 4/1) to light brownish gray (5YR 6/1), moderately to very slightly carbonaceous, obscurely laminated; contains very sparse carbonaceous films and flakes. Unit shaley in upper part	330′8 $\frac{1}{2}$"	335′0"	4′3 $\frac{1}{2}$"
54.	Rotary drilled	335′0"	370′0"	35′0"
55.	Siltstone, grayish black (N2), highly carbonaceous; contains vitrain lenses	370′0"	370′4"	0′4"
56.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as $\frac{1}{4}$ inch; cleat moderately well developed; calcite scale on cleat face	370′4"	371′1 $\frac{1}{2}$"	0′9 $\frac{1}{2}$"

Neslen Formation--Continued:

		From	To	Thickness
57.	Siltstone, grayish black (N2), highly carbonaceous; contains abundant vitrain lenses, some as thick as 1/8 inch	371'1 1/2"	371'4 1/2"	0'3"
58.	Shale, silty, brownish black (5YR 2/1), highly carbonaceous; contains abundant vitrain lenses, some as thick as 1/4 inch	371'4 1/2"	371'9"	0'4 1/2"
59.	Siltstone, medium gray (N5), moderately carbonaceous, obscurely laminated; contains abundant carbonaceous films and flakes. Basal contact undulous	371'9"	373'11"	2'2"
60.	Sandstone and siltstone, intermixed--highly bioturbated, slumped, and microfaluted: sandstone, very fine, very light gray (N8); contains numerous carbonaceous films and flakes; siltstone, brownish gray (5YR 4/1), moderately carbonaceous. Unit dominantly sandstone	373'11"	376'3"	2'4"
61.	Shale, silty, brownish black (5YR 2/1), highly carbonaceous; contains abundant vitrain lenses	376'3"	376'8"	0'5"
62.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat moderately well developed	376'8"	377'3"	0'7"
63.	Siltstone, grayish black (N2) and brownish black (5YR 2/1), mostly highly carbonaceous, somewhat less so near base, obscurely laminated; contains numerous to abundant carbonaceous films and flakes, and numerous vitrain lenses, some as thick as 1/2" inch	377'3"	384' 1/2"	6'9 1/2"
64.	Siltstone, medium gray (N5), moderately carbonaceous, mostly obscurely laminated; contains minor intermixed, highly bioturbated sandstone in upper part, and abundant carbonaceous films and flakes throughout	384' 1/2"	385'7 1/2"	1'7"
65.	Siltstone, shaley, brownish black (5YR 2/1), highly carbonaceous; contains abundant vitrain lenses	385'7 1/2"	386'2 1/2"	0'7"

Neslen Formation--Continued:

		From	To	Thickness
66.	Siltstone, brownish gray (5YR 4/1), moderately carbonaceous; contains abundant carbonaceous films and flakes	386′2 1/2″	386′5 1/2″	0′3″
67.	Sandstone, very fine, light olive gray (5Y 6/1) and olive gray (5Y 4/1), sparsely micaceous, laminated; laminae inclined; contains sparse carbon-rich laminae, films and flakes	386′5 1/2″	386′10 1/2″	0′5″
68.	Sandstone and siltstone, intermixed--highly bioturbated, slumped in parts: sandstone, vey fine, very light gray (N8); siltstone, brownish gray (5YR 4/1), moderately carbonaceous; contains 2-inch thick undulous bed of pale yellowish gray noncarbonaceous siltstone	386′10 1/2″	392′10″	5′11 1/2″
69.	Sandstone and siltstone, rhythmically laminated, micro-ripple marked, micro-slumped and -faulted, slightly bioturbated: sandstone, very fine, very light gray (N8); siltstone, brownish gray (5YR 4/1), moderately carbonaceous	392′10″	394′2″	1′4″
70.	Sandstone and siltstone, interlaminated; slumped and bioturbated in few parts: sandstone, very fine, very light gray (N8); siltstone, brownish gray (5YR 4/1), moderately carbonaceous	394′2″	399′8″	5′6″
71.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/16 inch, and sparse minute bodies of resin and pyrite; cleat not apparent	399′8″	400′2″	0′6″
72.	Siltstone and shaley siltstone, mostly dark gray (N3) and medium gray (N5), brownish gray (5YR 4/1) in parts, moderately carbonaceous, obscurely laminated; contains abundant carbonaceous films and flakes and vitrain lenses	400′2″	406′3 1/2″	6′1 1/2″
73.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4″ inch; cleat not apparent	406′3 1/2″	409′ 1/2″	2′9″
74.	Impure coal, grayish black (N2); contains abundant vitrain lenses	409′ 1/2″	409′6″	0′5 1/2″

Neslen Formation--Continued:

		From	To	Thickness
75.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/8 inch; cleat not apparent	409'6"	410'1 1/4"	0'7 1/4"
76.	Impure coal, grayish black (N2); contains very abundant vitrain lenses, some as thick as 1/8 inch	410'1 1/4"	410'5 1/4"	0'4"
77.	Siltstone, dark gray (N3), highly carbonaceous, obscurely laminated; contains abundant carbonaceous films and flakes	410'5 1/4"	412'2 1/4"	1'9"
78.	Sandstone and siltstone, interlaminated and intermixed--slump-folded and -faulted: sandstone, very fine, very light gray (N8); siltstone, brownish gray (5YR 4/1), moderately carbonaceous; contains numerous carbon-rich laminae	412'2 1/4"	412'10"	0'7"

U.S.G.S.C.B.B.C. 4

Cretaceous

Neslen Formation:

		From	To	Thickness
1.	Rotary drilled	0′0″	183′0″	183′0″
2.	Sandstone, very fine, very light gray (N8), obscurely laminated; laminae inclined; contains abundant opaque mineral grains, sparse to numerous yellowish gray, minute, ragged, flake-like bodies--clay mineral(?), and sparse carbon-rich films	183′0″	186′1 1/2″	3′1 1/2″
3.	Siltstone, pale yellowish brown (10YR 6/2), very slightly carbonaceous, distinctly laminated; laminae inclined; contains abundant carbonaceous films and flakes, and numerous carbon-rich laminae	186′1 1/2″	186′5 1/2″	0′4″
4.	Sandstone, very fine, very light gray (N8), distinctly to obscurely laminated; laminae inclined; contains abundant opaque mineral grains, sparse siltstone laminae in uppermost 4 inches, abundant rounded to angular, pale yellowish brown and brownish gray siltstone bodies in basal 6 inches, sparse carbon-rich laminae, and numerous vitrain flakes in upper and basal parts	186′5 1/2″	191′8″	5′2 1/2″
5.	Siltstone and silty shale, medium dark gray (N4) to grayish black (N2), moderately to highly carbonaceous, unlaminated; contains vitrain flakes	191′8″	193′2 1/2″	1′6 1/2″
6.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch and resin bodies as much as 1/4 inch long; cleat not apparent	193′2 1/2″	194′2 1/2″	1′0″
7.	Siltstone and shaley siltstone, medium dark gray (N4), moderately carbonaceous, unlaminated	194′2 1/2″	196′8 1/2″	2′6″
8.	Rotary drilled	196′8 1/2″	230′0″	33′3 1/2″

Neslen Formation--Continued:

		From	To	Thickness
9.	Sandstone, very fine, very light gray (N8), obscurely laminated; contains abundant opaque mineral grains, sparse carbon-rich laminae, and sparse to abundant angular to rounded, pale yellowish brown and brownish gray siltstone bodies in lower part	230′0″	233′11″	3′11″
10.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch; cleat not apparent. Coal fractured; fractures inclined	233′11″	234′7″	0′8″
11.	Shale, silty, grayish black (N2), highly carbonaceous; contains abundant vitrain lenses, some as thick as 1/4 inch	234′7″	235′11″	1′4″
12.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/2 inch, and sparse resin bodies; cleat well developed, spaced 1 inch or more. Sparse pyrite on cleat facies	235′11″	239′11 1/2′	4′8 1/2′
13.	Siltstone, grayish black (N2) and dark gray (N3), highly carbonaceous, unlaminated; contains abundant carbonaceous films throughout, and abundant vitrain lenses in uppermost 4 inches	239′11 1/2′	242′2″	2′2 1/2′
14.	Siltstone, medium light gray (N6), very slightly carbonaceous; contains numerous carbonaceous films and flakes	242′2″	245′0″	2′10″
15.	Rotary drilled	245′0″	273′0″	28′0″
16.	Siltstone and sandstone, interlaminated, slumped and bioturbated in few parts: siltstone, medium dark gray (N4), moderately carbonaceous; sandstone, very fine, very light gray (N8). Unit dominantly siltstone	273′0″	276′3 1/2′	3′3 1/2′
17.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses as thick as 1/4 inch, and sparse pyrite in one part; cleat not apparent. Coal fractured; fractures inclined; contains 1/4-inch-thick claystone lens in middle part	276′3 1/2′	278′6″	2′2 1/2′
18.	Siltstone, grayish black (N2), highly carbonaceous; contains abundant vitrain lenses, some as thick as 1/8 inch, and numerous filmy bodies of pyrite	278′6″	278′8″	0′2″

Neslen Formation--Continued:

		From	To	Thickness
19.	Siltstone and sandstone, interlaminated and intermixed--bioturbated: siltstone, medium dark gray (N4), moderately carbonaceous; sandstone, very fine, very light gray (N8). Unit contains numerous carbonaceous films and flakes	278′8"	283′11"	5′3"
20.	Siltstone, medium dark gray (N4), moderately carbonaceous; contains very minor, very fine, very light gray, intermixed--bioturbated sandstone, sparse carbonaceous films, and abundant casts of flat pelecypods in upper part	283′11"	289′1"	5′2"
21.	Siltstone and shaley siltstone, dark gray (N3) and grayish black (N2), highly carbonaceous, obscurely laminated; contains vitrain lenses in uppermost and basal parts, and very sparse sandstone laminae in lower part	289′1"	290′8 1/2"	1′7 1/2"
22.	Coal, black (N1), vitrainous and attrital; contains vitrain lenses commonly 1/16 inch thick; cleat well developed; sparse pyrite on cleat faces	290′8 1/2"	291′6 1/4"	0′9 3/4"
23.	Siltstone, grayish black (N2) and brownish black (5 YR 2/1), highly carbonaceous; contains sparse vitrain lenses, and numerous bioturbated and slumped sandstone lenses and laminae in lower part	291′6 1/4"	292′5 1/4"	0′11"
24.	Sandstone, very fine, very light gray (N8) and light gray (N7); contains minor interlaminated, highly carbonaceous siltstone lenses and laminae in lower part	292′5 1/4"	294′6"	2′1/4"