

UNITED STATES DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

**Geologic, Geotechnical, and Geophysical Properties of Core from the
Acme Fire-Pit-1 Drill Hole, Sheridan County, Wyoming**

By

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This report is preliminary and has not been reviewed for conformity with U.S. Geological Survey editorial standards and stratigraphic nomenclature. Any use of trade names is for descriptive purposes only and does not imply endorsement by the USGS.

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GEOLOGIC, GEOTECHNICAL, AND GEOPHYSICAL PROPERTIES OF CORE FROM THE ACME FIRE-PIT-1 DRILL HOLE, SHERIDAN COUNTY, WYOMING

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ABSTRACT

A preliminary core study from the Acme Fire-Pit-1 drill hole, Sheridan County, Wyoming, revealed that the upper portion of the core had been baked by a fire confined to the underlying Monarch coal bed. The baked (clinkered) sediment above the Monarch coal bed was determined to have higher point-load strength values (greater than 2 MPa) than the sediment under the burned coal bed which has strength values under 2 MPa.

INTRODUCTION

This report presents a detailed geologic log, and selected geotechnical, and geophysical data acquired from one core hole which was drilled by the U.S. Geological Survey (USGS) during August 1978. The drill site is in the SW 1/4 sec. 3, T. 57 N., R. 39 E. of the 7 1/2-minute Acme Quadrangle in Sheridan County, Wyo. (fig. 1). Drilling of core began at the surface in surficial materials overlying beds near the top of the Tongue River Member of the Fort Union Formation (Paleocene age) (Kanizay, 1978) and reached total depth of 296 feet at the base of the Carney coal bed (Barnum, 1975).

The hole was drilled and the core recovered by use of a truck-mounted Mobile B-52 auger/core drill. Shelby tubes operating through a hollow stem auger were used to sample the first 8.5 ft from the hole; the following 8.0 ft of sample required augering. Below 16.5 ft, the hole was advanced with an NX-size wire coring system to a maximum depth of 296 ft. Water circulation was lost between 40 and 65 feet and no core samples were obtained from that interval.

The core samples acquired from this project are used to determine the principal rock types and their associated geotechnical characteristics and to identify the coal beds involved in a fire burning in the abandoned Acme coal mine.

Acknowledgments

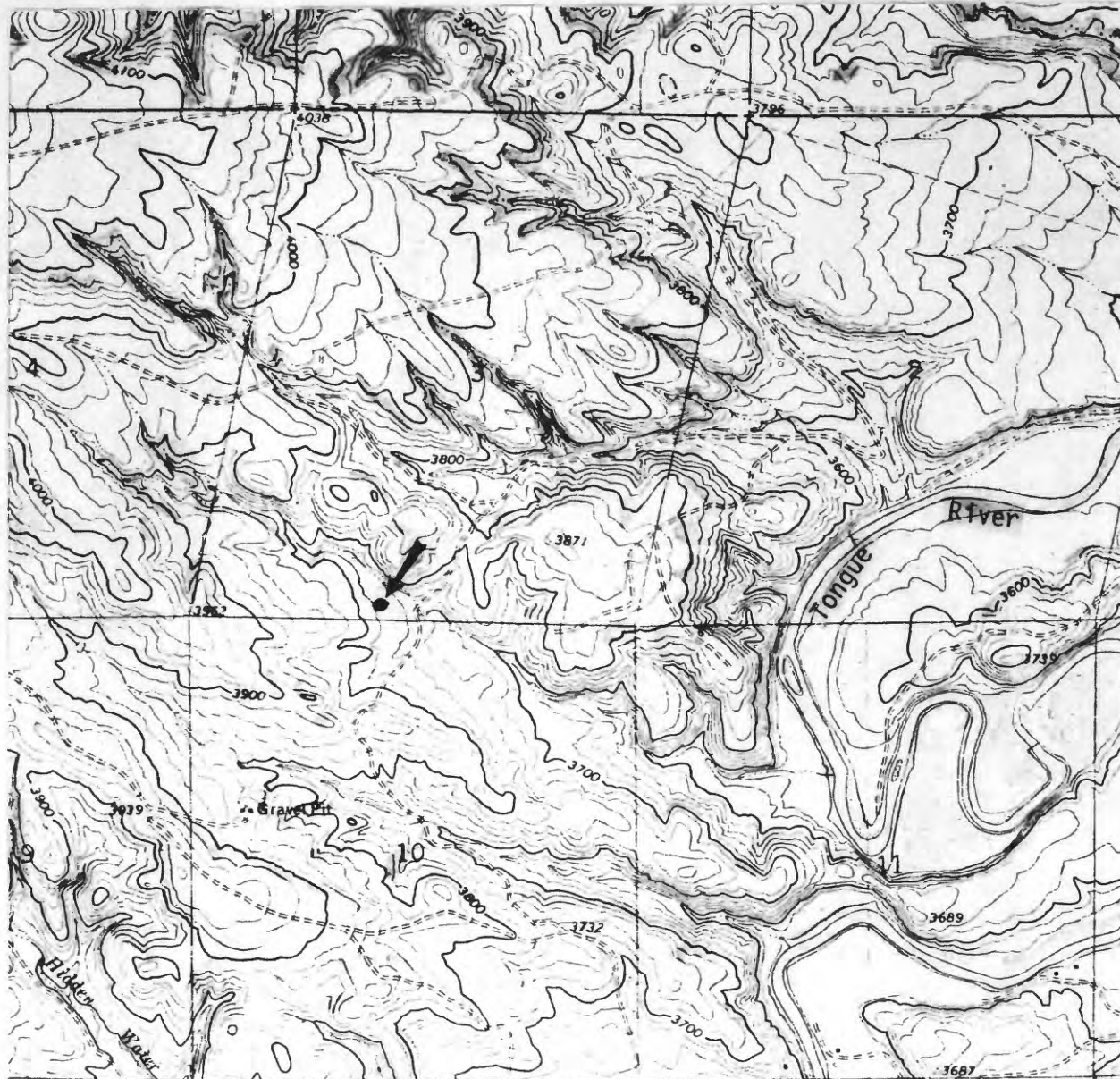
The author greatly acknowledges A. T. Jenkins of the USGS who made the preliminary log of the lithology of the core in the field and who also prepared the core for transport to the USGS laboratory, T. Fontaine (formerly with the USGS laboratory) for providing the geotechnical core data, and to D. Hayes of Peter Kiewit and Sons' Company who performed the downhole geophysics.

EXPERIMENTAL PROCEDURES

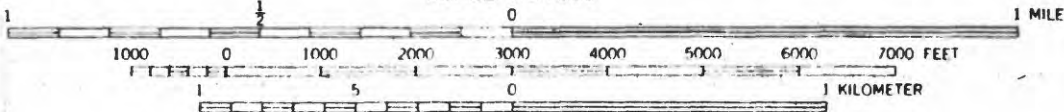
After each section of the core was drilled, it was removed from the core barrel, wiped with a damp cloth, scraped to remove drilling mud, logged, tested for effervescence with 10 percent HCl and for strength by pocket

R. 40E.

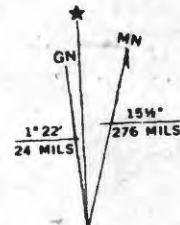
T. 58 N.



SCALE 1:24 000



CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL



UTM GRID AND 1968 MAGNETIC NORTH

Figure 1.--Map of part of the Acme, Wyoming, 1:24,000 quadrangle showing location of the Acme Fire-Pit-1 drill hole which is located 2 miles north of the Acme coal mine.

penetrometer, sealed in plastic-sleeve bags, and then sent to the laboratory in Denver, Colo., for detailed logging and geotechnical testing.

After reaching maximum drill depth, a continuous natural-gamma log was recorded through the drill string to a depth of 292 ft. The log was obtained by using the techniques described by Wyllie (1963) and Keys and MacCary (1971) and was used to cross check lithologic type and depth with that of the logger's lithologic descriptive log.

During the summer of 1980, the core was logged in detail at the U.S. Geological Survey laboratory and the following tests were performed on selected samples: slake durability, dry-bulk density, point load, and X-ray clay-mineral analysis. The slake durability test followed the procedures of Franklin and Chandra (1972). Point-load strength test procedures were done in accordance with the procedures described by Broch and Franklin (1972). X-ray techniques for clay mineralogy generally followed those suggested by Schultz (1964). The results for each sample are reported in four categories stating the relative abundance of each mineral group (fig. 2, in pocket). Figure 2 summarizes the lithology in relationship to the natural-gamma log of the hole and to geotechnical properties that were measured on samples selected from the core. A detailed lithologic description and laboratory data are documented in the appendix.

PRINCIPAL ROCK TYPES AND THEIR GEOTECHNICAL CHARACTERISTICS

The upper 8 ft of the cored section (fig. 2) consists of a relatively weak regolith which has a pocket-penetrometer value (table 1) of less than 0.44 MPa (Megapascals). The low strength is due to the loose packing of the material.

A fairly strong sequence of clinkered claystone, sandstone, and siltstone underlies the regolith and extends to a depth of approximately 55.5 ft. The relative strength of this sequence is indicated by the high point-load strength values of greater than 2 MPa. Resistance to air slaking, as indicated by the slake durability values (high percentages of weight loss indicate low resistance to air slaking), for the upper few feet of this portion of the section are moderate, but increase downward (fig. 2). Baking as a result of a burned underlying coal bed is probably the primary factor for the higher strength values. The carbonate cement (indicated by the weak to moderate HCl reactions) is not as important to the strength of the material. Also, the low slake values may be due to the brittleness of the upper portion of the clinkered claystone.

From 55.5 ft to the bottom of the cored section, the rocks have relatively low strength and consist of unclinkered mudstones, claystones, sandstones, bone, coal, carbonaceous shales, and shales. Regardless of the sediment type, the point-load strengths are consistently low (below 2 MPa), and the generally high slake-durability values (greater than 40 percent) indicate low strength due to the fissility, looser packing, composition, and structure.

For instance, material with slake durability values below 45 percent includes well-packed mudstones, carbonaceous shales, and unslickensided claystones containing very little to no sand and (or) silt. Material with

Table 1.--Detailed geotechnical log of core samples taken from
the Acme Fire-Pit-1 drill hole

[Leaders (----) indicate no data available]

Sample inter- val (ft)	Reaction with HCl (10 per- cent)	Clay mineralogy ¹					Dry-bulk density (g/cm ³)	Pocket penetro- meter (MPa)	Point-load strength indices ² (MPa)		Aniso- tropy index ³	Slake dura- bility index for first cycle ⁴
		Chlorite	Illite	Kaolinite	Montmoril- lonite	Mixed layer			A	O		
0.60	moderate--	4	2	1	4	2	----	0.0	----	----	----	----
3.75	strong----	3	1	2	4	4	----	>.44	----	----	----	----
6.92	moderate--	4	2	1	4	4	----	>.44	----	----	----	----
19.60	strong----	-	-	-	-	-	2.08	>.44	----	----	----	46.06
23.60	--do-----	-	-	-	-	-	1.95	>.44	----	----	----	51.11
25.60	-----	-	-	-	-	-	2.12	>.44	----	----	----	74.63
26.25	-----	-	-	-	-	-	2.38	>.44	8.17	5.21	1.57	----
30.30	-----	-	-	-	-	-	2.51	>.44	8.03	4.24	1.89	----
31.00	-----	-	-	-	-	-	2.48	>.44	9.75	8.79	1.11	----
35.40	-----	-	-	-	-	-	2.39	>.44	----	----	----	----
36.00	-----	-	-	-	-	-	2.19	>.44	----	----	----	----
37.30	-----	-	-	-	-	-	1.95	>.44	----	----	----	----
38.70	-----	-	-	-	-	-	1.99	>.44	----	----	----	----
40.20	-----	-	-	-	-	-	1.95	>.44	----	----	----	----
42.50	-----	-	-	-	-	-	1.90	>.44	----	----	----	----
47.50	-----	-	-	-	-	-	1.06	>.44	3.29	3.83	.86	----
48.70	-----	-	-	-	-	-	1.94	>.44	3.14	3.83	.82	----
54.10	-----	-	-	-	-	-	1.98	>.44	----	----	----	3.41
67.10	-----	-	-	-	-	-	2.02	>.44	----	----	----	----
68.40	-----	-	-	-	-	-	2.05	>.44	----	----	----	----
71.80	-----	-	-	-	-	-	2.02	>.44	----	----	----	1.47
74.20	-----	4	3	1	4	3	----	>.44	----	----	----	18.08
75.20	-----	-	-	-	-	-	2.06	>.44	----	----	----	----
77.20	-----	-	-	-	-	-	1.95	>.44	.49	.51	.96	----
79.70	-----	-	-	-	-	-	2.11	>.44	----	----	----	----
80.50	-----	-	-	-	-	-	2.26	>.44	1.34	1.46	.92	----
82.60	-----	-	-	-	-	-	2.23	>.44	----	----	----	78.32
84.20	-----	3	1	2	4	4	2.03	>.44	----	----	----	27.23
86.80	-----	-	-	-	-	-	2.45	>.44	1.25	1.46	.86	----
89.70	-----	4	1	2	4	4	2.04	>.44	----	----	----	48.67
90.80	-----	-	-	-	-	-	2.09	>.44	----	----	----	80.88
91.70	-----	-	-	-	-	-	2.22	>.44	.69	.72	.96	----
93.40	-----	-	-	-	-	-	2.20	>.44	1.43	1.20	1.19	----
94.40	-----	-	-	-	-	-	2.28	>.44	----	----	----	----
97.40	-----	-	-	-	-	-	2.23	>.44	----	----	----	----
99.20	-----	-	-	-	-	-	2.23	>.44	----	----	----	----
100.40	-----	-	-	-	-	-	----	>.44	----	----	----	77.69
101.10	-----	-	-	-	-	-	2.25	>.44	----	----	----	----
103.00	-----	-	-	-	-	-	2.29	>.44	----	----	----	----
105.00	-----	-	-	-	-	-	2.19	>.44	----	----	----	----
105.30	-----	4	3	2	4	1	----	>.44	----	----	----	60.62
108.20	-----	-	-	-	-	-	2.11	>.44	----	----	----	----
109.50	-----	-	-	-	-	-	2.20	>.44	----	----	----	----
112.10	-----	-	-	-	-	-	1.92	>.44	----	----	----	----
114.60	-----	-	-	-	-	-	1.90	>.44	----	----	----	----
115.50	-----	-	-	-	-	-	2.11	>.44	----	----	----	----
117.20	-----	-	-	-	-	-	2.14	>.44	----	----	----	----
118.40	-----	-	-	-	-	-	2.70	>.44	----	----	----	----
120.50	-----	-	-	-	-	-	2.72	>.44	----	----	----	----
122.20	-----	-	-	-	-	-	1.96	>.44	----	----	----	----
123.10	-----	-	-	-	-	-	1.94	>.44	.03	.32	.09	----
126.90	-----	-	-	-	-	-	2.18	>.44	----	----	----	----
133.50	-----	-	-	-	-	-	2.21	>.44	----	----	----	----
134.00	-----	3	1	2	4	3	----	>.44	----	----	----	55.25
135.50	-----	-	-	-	-	-	2.08	>.44	----	----	----	----
137.00	-----	-	-	-	-	-	1.96	>.44	.46	.48	.96	----
139.60	-----	-	-	-	-	-	1.94	>.44	.54	.39	1.38	----
142.30	-----	4	1	1	4	4	2.17	>.44	----	----	----	----

Table 1.--Detailed geotechnical log of core samples taken from
the Acme Fire-Pit-1 drill hole--Continued

Sample inter- val (ft)	Reaction with HCl (10 per- cent)	Clay mineralogy ¹					Dry-bulk density (g/cm ³)	Pocket penetro- meter (MPa)	Point-load strength indices ² (MPa)		Aniso- tropy index ³	Slake dura- bility index for first cycle ⁴
		Chlorite	Illite	Kaolinite	Montmoril- lonite	Mixed layer			A	O		
145.00	-----	-	-	-	-	-	1.95	>.44	.40	.46	.87	-----
147.00	-----	-	-	-	-	-	2.04	>.44	-----	-----	-----	-----
150.50	strong-----	-	-	-	-	-	1.89	>.44	-----	-----	-----	-----
152.00	-----	-	-	-	-	-	2.13	>.44	-----	-----	-----	53.46
154.40	strong-----	-	-	-	-	-	1.96	>.44	-----	-----	-----	-----
156.30	-----	-	-	-	-	-	2.00	>.44	-----	-----	-----	-----
158.50	moderate--	-	-	-	-	-	1.93	>.44	-----	-----	-----	-----
159.60	-----	-	-	-	-	-	2.01	>.44	.31	.76	.41	-----
163.40	moderate--	-	-	-	-	-	1.99	>.44	-----	-----	-----	-----
164.20	-----	-	-	-	-	-	2.21	>.44	-----	-----	-----	-----
165.10	moderate--	-	-	-	-	-	1.76	>.44	-----	-----	-----	-----
167.10	-----	-	-	-	-	-	2.03	>.44	-----	-----	-----	-----
169.50	-----	-	-	-	-	-	2.08	>.44	.43	1.05	.41	-----
172.80	-----	-	-	-	-	-	1.98	>.44	.51	.54	.94	-----
173.90	moderate--	-	-	-	-	-	1.78	>.44	-----	-----	-----	-----
176.50	-----	-	-	-	-	-	1.95	>.44	.33	.38	.87	-----
178.20	-----	-	-	-	-	-	1.92	>.44	.40	.38	1.05	-----
180.00	-----	-	-	-	-	-	2.04	>.44	-----	-----	-----	-----
183.70	-----	-	-	-	-	-	2.09	>.44	-----	-----	-----	-----
185.40	-----	-	-	-	-	-	2.20	>.44	-----	-----	-----	-----
185.80	-----	-	-	-	-	-	-----	>.44	-----	-----	-----	92.57
187.60	-----	-	-	-	-	-	2.14	>.44	-----	-----	-----	-----
190.20	-----	-	-	-	-	-	2.20	>.44	.73	.94	.78	-----
192.10	-----	4	1	1	4	3	-----	>.44	-----	-----	-----	58.39
193.50	-----	-	-	-	-	-	2.15	>.44	-----	-----	-----	-----
197.10	-----	-	-	-	-	-	1.15	>.44	-----	-----	-----	-----
199.40	-----	-	-	-	-	-	1.20	>.44	-----	-----	-----	-----
201.00	-----	-	-	-	-	-	1.12	>.44	-----	-----	-----	-----
202.40	-----	-	-	-	-	-	1.05	>.44	-----	-----	-----	-----
207.00	-----	-	-	-	-	-	1.10	>.44	-----	-----	-----	-----
211.00	-----	-	-	-	-	-	1.17	>.44	-----	-----	-----	-----
214.20	-----	-	-	-	-	-	1.38	>.44	-----	-----	-----	-----
215.80	-----	4	3	1	4	2	2.20	>.44	-----	-----	-----	-----
217.00	-----	-	-	-	-	-	2.22	>.44	-----	-----	-----	-----
219.60	-----	-	-	-	-	-	2.16	>.44	-----	-----	-----	-----
221.10	-----	-	-	-	-	-	2.21	>.44	-----	-----	-----	-----
222.50	none-----	-	-	-	-	-	-----	>.44	-----	-----	-----	-----
223.60	-----	-	-	-	-	-	2.30	>.44	1.08	.86	1.26	-----
224.40	-----	-	-	-	-	-	2.26	>.44	-----	-----	-----	-----
227.50	none-----	-	-	-	-	-	2.19	>.44	-----	-----	-----	-----
229.20	-----	-	-	-	-	-	2.26	>.44	.38	1.25	.30	-----
230.50	-----	-	-	-	-	-	-----	>.44	-----	-----	-----	80.70
231.80	-----	-	-	-	-	-	2.24	>.44	-----	-----	-----	-----
234.70	-----	-	-	-	-	-	2.26	>.44	1.06	.95	1.12	-----
236.20	-----	-	-	-	-	-	2.22	>.44	-----	-----	-----	90.87
238.40	-----	-	-	-	-	-	2.23	>.44	1.09	1.06	1.03	-----
241.30	-----	-	-	-	-	-	2.26	>.44	.88	.82	1.07	-----
242.20	-----	-	-	-	-	-	2.26	>.44	-----	-----	-----	-----
244.00	-----	-	-	-	-	-	2.23	>.44	-----	-----	-----	-----
245.10	-----	4	3	1	4	2	-----	>.44	.70	.37	1.89	91.26
247.10	-----	-	-	-	-	-	2.32	>.44	-----	-----	-----	-----
248.40	-----	4	3	1	4	2	2.19	>.44	-----	-----	-----	-----
248.70	-----	-	-	-	-	-	-----	>.44	-----	-----	-----	63.13
251.40	-----	-	-	-	-	-	2.10	>.44	-----	-----	-----	57.83
252.60	-----	4	3	1	4	2	-----	>.44	-----	-----	-----	-----
254.00	-----	-	-	-	-	-	1.11	>.44	-----	-----	-----	-----
256.00	-----	-	-	-	-	-	1.15	>.44	-----	-----	-----	-----
257.90	-----	-	-	-	-	-	1.11	>.44	-----	-----	-----	-----
259.50	-----	4	2	1	4	2	-----	>.44	-----	-----	-----	40.57

Table 1.--Detailed geotechnical log of core samples taken from
the Acme Fire-Pit-1 drill hole--Continued

Sample inter- val (ft)	Reaction with HCl (10 per- cent)	Clay mineralogy ¹					Dry-bulk density (g/cm ³)	Pocket penetro- meter (MPa)	Point-load strength indices ² (MPa)		Aniso- tropy index ³	Slake dura- bility index for first cycle ⁴
		Chlorite	Illite	Kaolinite	Montmoril- lonite	Mixed layer			Δ	0		
260.10	-----	-	-	-	-	-	-----	>.44	-----	-----	-----	46.35
264.10	-----	-	-	-	-	-	-----	>.44	-----	-----	-----	36.92
265.30	-----	-	-	-	-	-	1.15	>.44	-----	-----	-----	-----
267.20	-----	-	-	-	-	-	1.12	>.44	-----	-----	-----	-----
269.40	-----	-	-	-	-	-	-----	>.44	-----	-----	-----	60.30
271.50	-----	-	-	-	-	-	-----	>.44	-----	-----	-----	39.42
274.90	-----	-	-	-	-	-	1.40	>.44	-----	-----	-----	27.20
277.60	none-----	4	3	1	4	2	1.16	>.44	-----	-----	-----	-----
279.00	-----	-	-	-	-	-	2.27	>.44	-----	-----	-----	52.21
280.40	-----	-	-	-	-	-	2.25	>.44	-----	-----	-----	-----
281.30	-----	-	-	-	-	-	2.26	>.44	-----	-----	-----	84.74
282.80	-----	-	-	-	-	-	2.21	>.44	-----	-----	-----	-----
286.70	-----	-	-	-	-	-	1.21	>.44	-----	-----	-----	-----
287.70	-----	4	3	1	4	2	-----	>.44	-----	-----	-----	-----
290.30	-----	-	-	-	-	-	2.15	>.44	-----	-----	-----	-----
293.20	-----	-	-	-	-	-	2.25	>.44	-----	-----	-----	88.98

¹1, primary mineral (40-60 percent); 2, secondary mineral (20-40 percent); 3, minor mineral (10-20 percent); 4, trace mineral (less than 10 percent).

²Tested parallel to bedding, Δ; tested perpendicular to bedding, 0.

³ $\frac{\Delta}{0}$.

⁴Percent of dry-soil weight loss.

higher than 45 percent slake-durability values includes the following: highly fissile shales; claystones combining sand, silt, or high-shale content; loosely packed and poorly cemented sandstones, mudstones, and claystones; and carbonaceous shales with slickensides.

The material below 55.5 ft ranges from strongly calcareous to noncalcareous and suggests the degree of carbonate cement present. Logically, the more cement present the stronger the sediment. But in the present study, carbonate content does not seem to contribute significantly to the strength of the rocks, as indicated by point-load and slake-durability results.

Burned Coal Bed

The baked (clinkered) sediment within the 8.5- to 55.5-ft interval (see detailed lithologic description in appendix; fig. 2) is probably a result of a previous coal-bed fire. Unfortunately, the core from 65.7 to 55.5 ft above the coal bed is missing. The driller, D. Hayes, reported that the material from this interval was highly fractured and that he was unable to recover it. This suggests that the fire at one time was confined to the upper missing portion of the remaining coal bed at 65.7 ft. Megascopically this coal bed and the underlying sediments did not reveal any baked or burned material. Numerous clinker fragments in the overlying regolith, however, indicate that the regolith is younger than the clinker, and therefore it was deposited or formed some time after the fire.

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APPENDIX
Detailed lithologic description

Description	Interval in feet
Regolith, very dark grayish brown (10YR 3/2), unconsolidated, silty with clinker and limestone fragments (less than 1 in. in size) increasing downward.....	0 - 4.6
Regolith, dark-brown to black (10YR 3/3-10YR 2/1), well-packed, rock fragments increase in size up to 1 in. in diameter; color changes to (5Y 7/1) at 6.0 ft.....	4.6- 6.0
Sand, dark-reddish-brown (5Y 3/4), unconsolidated, fine- to medium-grained, calcareous with carbonaceous material throughout; becomes black (5YR 2/1) with carbonate veinlets at 6.3-6.4 ft.....	6.0- 6.4
Mudstone, gray (5Y 7/1).....	6.4- 6.9
Silt, gray (5Y 7/1), clayey, very calcareous to calcareous.....	6.9- 8.0
Silt, gray (5Y 7/1), calcareous, shows indication of being baked by fire.....	8.0- 9.5
Core missing.....	9.5- 16.6
Claystone, pinkish-gray to light-reddish-brown (7.5YR 7/2-2.5YR 6/4), clinker, calcareous, and fossil plant fragments.....	16.6- 26.3
Siltstone, reddish-yellow to red (7.5YR 6/8-2.5YR 5/6), clinker, calcareous to slightly calcareous with a 2-ft-thick interbed of sandstone, dark-reddish-gray (5YR 4/2), clinker, very fine grained, silty, and slightly calcareous.....	26.3- 28.3
Siltstone, pinkish-gray (7.5YR 7/2), clinker, limy to slightly calcareous, plant fragments; fractures perpendicular to bedding.....	28.3- 44.0
Core missing.....	44.0- 45.3
Same as at 28.3-44.0 ft, but also jointed	45.3- 46.0
Core missing.....	46.0- 48.0
Same as unit above, but color changes to reddish-brown (2.5YR 4/4) and color changes to red (2.5YR 4/6) at 50.7 ft.....	48.0- 52.0
Core missing.....	52.0- 53.2

Detailed lithologic description--Continued

Description	Interval in feet
Siltstone, red (2.5YR 5/6), clinker, slightly calcareous.....	53.2- 54.7
Shale, red (2.5YR 5/6), clinker, slightly calcareous and abundant plant fossils.....	54.7- 55.5
Core missing.....	55.5- 65.7
Coal, black (7.5R 2/0), noncalcareous with sulfur on core surface (Monarch coal bed).....	65.7- 66.7
Bony.....	66.7- 66.8
Mudstone, very dark gray (2.5YR 3/0), noncalcareous with carbonaceous fragments and selenite crystals; plant carbonaceous film present.....	66.8- 69.7
Claystone, dark-gray (7.5YR 3/0), noncalcareous with plant carbonaceous film and sulfur on core surface; color changes to gray (7.5YR 4/0) at 70.8 ft, to dark gray (7.5YR 2/0) at 72.8 ft, and to gray (7.5YR 4/0) at 74.3 ft.....	69.7- 74.4
Sandstone, light-gray (10YR 7/2), very fine grained to silty, noncalcareous with plant material and burrows; becomes crossbedded with silty clay and silt laminae at 76.7 ft; clay laminae is gray (2.5YR 5/0).....	74.4- 78.4
Claystone, noncalcareous.....	78.4- 79.9
Siltstone, white (2.5Y 8/0), clayey, with claystone fragments and carbonaceous plant material.....	79.9- 81.0
Shale, gray (7.5R 4/0), noncalcareous with abundant carbonaceous plant fragments.....	81.0- 82.6
Claystone, light-gray (2.5YR 4/0), noncalcareous, with abundant carbonaceous plant material; becomes shaly and changes color to light gray (7.5R 5/0) at 84.2 ft; slickensides present; silty with carbonaceous laminae at 85.4 ft; changes color to light gray (2.5Y 6/0); contains shale laminae at 86.9 ft; at 87.1-87.3 ft a thin, gray (2.5Y 4/0) shale bed, noncalcareous with carbonaceous plant fragments.....	82.6- 88.7
Shale, black (7.5R 3/0), noncalcareous with carbonaceous plant material and sulfur; major joint between 90.5 and 91.5 ft; color changes to very dark gray (2.5Y 3/0) at 90.5 ft.....	88.7- 91.5

Detailed lithologic description--Continued

Description	Interval in feet
Siltstone, light-gray (7.5YR 7/0), noncalcareous with carbonaceous plant fragments and sulfur.....	91.5- 93.7
Sandstone, white (2.5Y 8/2), very fine grained, noncalcareous with 85 percent quartz, 13 percent feldspar, and 3 percent dark minerals.....	93.7- 94.2
Siltstone, gray (2.5Y 6/0), noncalcareous with carbonaceous material.....	94.2- 95.0
Claystone, gray (2.5Y 6/0), shaly, noncalcareous with carbonaceous plant fragments.....	95.0- 96.4
Shale, gray (2.5Y 5/0), silty, noncalcareous, with coal and carbonaceous plant fragments and sulfur.....	96.4- 96.9
Sandstone, white (10YR 7/0), fine-grained, noncalcareous, with 40 percent quartz, 20 percent feldspar, and 20 percent dark minerals; carbonaceous material also percent.....	96.9- 98.9
Siltstone, light-gray (7.5YR 7/0), noncalcareous; becomes clayey with carbonaceous plant fragments and color changes to gray (2.5Y 6/0) at 99.6 ft.....	98.9-100.4
Claystone, light-gray (2.5Y 7/0), noncalcareous with plant fragments.....	100.4-101.1
Siltstone, light-gray (2.5Y 7/0), noncalcareous with plant fragments.....	101.1-102.2
Sandstone, white (2.5Y 8/0), very fine grained to silty, noncalcareous with 55 percent quartz, 40 percent silt and feldspar, and 5 percent dark minerals.....	102.2-104.3
Claystone, gray (2.5Y 6/0), noncalcareous with plant fragments.....	104.3-105.2
Mudstone, gray (2.5Y 4/0), noncalcareous with slickensides, some plant fragments and sulfur.....	105.2-106.2
Core missing.....	106.2-106.8
Mudstone, same as unit at 105.2-106.2 ft.....	106.8-107.3
Claystone, gray (2.5YR 6/0), silty, noncalcareous with sulfur, coal, and carbonaceous plant fragments.....	107.3-108.0
Siltstone, light-gray (2.5Y 7/0), clayey, noncalcareous.....	108.0-110.4

Detailed lithologic description--Continued

Description	Interval in feet
Claystone, very dark gray (2.5Y 3/0), noncalcareous with carbonaceous plant fragments and sulfur.....	110.4-110.7
Siltstone, white (2.5Y 8/0), noncalcareous.....	110.7-111.4
Sandstone, light-gray (5Y 7/1), very fine grained to silty, noncalcareous to calcareous near base; 80 percent quartz, 18 percent feldspar and silt, and 2 percent dark minerals; from 113.1 to 116.0 ft becomes clayey, very fine grained, crossbedded with carbonaceous material present.....	111.4-116.0
Siltstone, color varies downward from light-gray to white to very pale brown (2.5Y 7/2 to 2.5Y 8/0 to 10YR 7/3), noncalcareous to calcareous with carbonaceous material; between 118.6 and 118.8 ft is a sandstone laminae that cuts through the parallel siltstone laminae.....	116.0-118.8
Sandstone, varies from light-gray to gray (2.5Y 7/0-5Y 6/1) and from calcareous to noncalcareous downward; also varies from very fine to fine-grained downward, composition of sand at 85-80 percent quartz, 11-16 percent feldspar and silt, and 2-4 percent dark minerals; carbonaceous plant fragments and crossbedding.....	118.8-122.6
Siltstone, gray (5Y 5/1), clayey, noncalcareous with organic material and leaf fossils.....	122.6-123.0
Claystone, gray (5Y 5/1), noncalcareous with carbonaceous material.....	123.0-123.2
Siltstone, same as unit at 122.6-123.0 ft.....	123.2-124.6
Core missing.....	124.6-126.1
Siltstone, same as unit at 123.2-124.6 ft.....	126.1-128.0
Core missing.....	128.0-131.3
Claystone, black (2.5Y 2/0), noncalcareous with carbonaceous material.....	131.3-131.5
Siltstone, light-gray (5Y 7/2), calcareous with carbonaceous plant material.....	131.5-132.2
Shale, black (2.5Y 2/0), noncalcareous with carbonaceous material and sulfur.....	132.2-133.0

Detailed lithologic description--Continued

Description	Interval in feet
Claystone, gray (2.5YR 6/0-2.5Y 5/0), noncalcareous with plant fragments.....	133.0-134.8
Siltstone, light-gray (5Y 7/2), calcareous with carbonaceous material; becomes sandy between 136.3 and 136.6 ft.....	134.8-136.6
Sandstone, light-gray (2.5Y 7/0), silty, clayey, very fine grained, calcareous with 85 percent quartz, 12 percent feldspar and silt, and 3 percent dark minerals; joint at 136.0 ft.....	136.6-138.0
Core missing.....	138.0-138.5
Sandstone, same as unit at 136.6-138.0 ft, but becomes fine- to very fine grained with 85 percent quartz, 11 percent feldspar, and 4 percent dark minerals.....	138.5-140.9
Claystone, gray to light-gray (2.5Y 5/0-2.5YR 6/0), calcareous with carbonaceous material.....	140.9-141.9
Siltstone, gray (2.5Y 7/0), clayey, calcareous with carbonaceous plant fragment and slickensides.....	141.9-142.4
Claystone, gray (2.5Y 6/0), silty, noncalcareous with carbonaceous plant fragments.....	142.4-143.4
Shale, very dark gray (2.5Y 3/0), noncalcareous with slickensides.....	143.4-143.6
Siltstone, gray (2.5Y 6/0), sandy and clayey, calcareous with carbonaceous plant fragments and crossbedding.....	143.6-146.0
Sandstone, light-gray (2.5Y 7/0), silty, very fine to fine-grained, very calcareous with 90 percent quartz, 6 percent feldspar, 4 percent dark minerals, claystone laminae, carbonaceous material, and crossbedding.....	146.0-149.0
Core missing.....	149.0-149.2
Sandstone, same as unit at 146.0-149.0 ft, but color changes to gray (5Y 6/1), well-cemented and calcareous; poorly cemented and color changes to light brownish gray (2.5Y 6/2) at 152.0 ft; composition change to 85 percent quartz, 10 percent feldspar, 5 percent dark minerals and color changes to light brownish gray (10YR 6/2) at 158.7 ft; limonitic nodules at 161.3 and 163.0 ft.....	149.2-163.9

Detailed lithologic description--Continued

Description	Interval in feet
Sandstone, light-gray (7.5YR 7/0), well-cemented, very fine grained, calcareous with 90 percent quartz 6 percent feldspar, 4 percent dark minerals and noncrossbedded; becomes gray (5Y 6/1), silty, very fine to fine grained with carbonaceous material and crossbedding at 164.7 ft.....	163.9-166.4
Siltstone, light-brownish-gray (2.5Y 6/2), calcareous and noncrossbedded.....	166.4-166.5
Sandstone, gray (5Y 6/1), silty, very fine to fine-grained, calcareous with 90 percent quartz, 5 percent feldspar, and 5 percent dark minerals; at 169.5 ft, 95 percent quartz, 2 percent feldspar, 3 percent dark minerals, and carbonaceous material.....	166.5-170.7
Siltstone, light-olive-brown (2.5Y 5/4), calcareous and noncrossbedded.....	170.7-171.0
Sandstone, same as unit at 166.5-170.5 ft.....	171.0-173.3
Sandstone, gray (5Y 6/1), silty, very fine grained, calcareous with 90 percent quartz, 7 percent feldspar, 3 percent dark minerals and crossbedding; changes downward to light gray (2.5Y 7/2) and to 95 percent quartz, 4 percent feldspar, and 1 percent dark minerals.....	173.3-174.9
Siltstone, light-gray (2.5Y 7/0), sandy, calcareous, well-cemented and crossbedded.....	174.9-175.5
Sandstone, light-gray (2.5Y 7/2), silty, very fine grained, calcareous with 90 percent quartz, 7 percent feldspar, 3 percent dark minerals and crossbedding.....	175.5-176.8
Siltstone, light-gray (2.5Y 7/0), calcareous and noncrossbedded.....	176.8-177.0
Sandstone, light-gray (5Y 7/1), silty, very fine grained, calcareous with 85 percent quartz, 10 percent feldspar, 5 percent dark minerals and crossbedded.....	177.0-178.8
Siltstone, grayish-brown (2.5Y 5/2), sandy, calcareous with clay and carbonaceous laminae.....	178.8-179.2
Sandstone, gray (2.5Y 6/0), silty, very fine grained, calcareous with 85 percent quartz, 10 percent feldspar, 5 percent dark minerals, and crossbedding.....	179.2-181.5

Detailed lithologic description--Continued

Description	Interval in feet
Siltstone, pale-yellow (2.5Y 7/4), increasing clay downward, calcareous with plant fossils and crossbedding; color changes to light gray (2.5Y 7/0) at 182.7 ft.....	181.5-183.4
Sandstone, light-gray (2.5Y 7/2), silty, very fine grained, calcareous with 90 percent quartz, 7 percent feldspar, 3 percent dark minerals, and crossbedding.....	183.4-183.8
Siltstone, grayish-brown (2.5Y 5/2), calcareous with carbonaceous material, plant fragments and crossbedding; color changes to light gray (2.5Y 7/0) at 186.6 ft; between 188.1 and 190.0 ft, color changes to light brownish gray (2.5Y 6/2), and becomes noncalcareous and clay content increases downward.....	183.8-190.0
Claystone, light-gray (2.5Y 7/0), shaly, noncalcareous with carbonaceous plant fragments.....	190.0-191.1
Shale, gray (2.5 Y 6/0), noncalcareous with carbonaceous plant material and numerous slickensides; coal fragments at 192.7 ft.....	191.1-192.7
Claystone, gray (2.5Y 6/0), shaly, noncalcareous with fossil plant material and some carbonaceous material.....	192.7-193.9
Shale, gray (2.5Y 5/0), noncalcareous with carbonaceous plant material.....	193.9-194.1
Shale, black (2.5Y 2/0), carbonaceous, noncalcareous with resin blebs and slickensides near coal contact below.....	194.1-194.7
Coal, black (7.5Y 2/0), noncalcareous, cleat perpendicular to bedding, resin blebs, conchoidal fractures with pyrite nodules and crusts on surfaces, and some sulfur; bony between 202.0 and 203.7 ft (Carney coal bed).....	194.7-212.6
Bone, black (7.5Y 2/0) with resin blebs and conchoidal fractures.....	212.6-212.9
Shale, black (10YR 2/1), carbonaceous, noncalcareous with coal fragments and sulfur.....	212.9-213.8
Claystone, black (2.5YR 2.0), shaly, noncalcareous with sulfur and slickensides; color changes to dark gray (2.5Y 4/0) and carbonaceous material is present; also mud content increases.....	213.8-216.9

Detailed lithologic description--Continued

Description	Interval in feet
Siltstone, light-gray (7.5YR 7/0), noncalcareous with clay laminae, carbonaceous plant fragments, crossbedding, and an increase in sand content downward.....	216.9-221.0
Sandstone, light-gray (5Y 7/1), noncalcareous with 90 percent quartz, 5 percent feldspar, 5 percent dark minerals, clay and silt laminae, and crossbedding.....	221.0-221.8
Claystone, gray (2.5Y 6/0), silty, noncalcareous with silt laminae; slickensides present at 222.1 ft; at 222.8 ft, color changes to dark gray (2.5Y 4/0) and becomes sandy; slickensides also present.....	221.8-223.1
Siltstone, gray (2.5YR 6/0), sandy, noncalcareous with clay laminae, carbonaceous material and crossbedding.....	223.1-224.2
Claystone, noncalcareous.....	224.2-224.4
Siltstone, same as unit at 223.1-224.2 ft, but color changes to gray (2.5YR 5/0).....	224.4-226.7
Claystone, dark-gray (2.5YR 4/0), silty, carbonaceous, noncalcareous showing crossbedded structure; at 228.0 ft, becomes very dark gray (2.5YR 3/0) and has carbonaceous plant material and silt and sand laminae showing crossbedded structure; at 230.5 ft, becomes shaly, lacks sand and silt crossbedded laminae; sulfur is also present.....	226.7-231.1
Shale, black (2.5Y 2/0), carbonaceous, noncalcareous with coal fragments, sulfur and H ₂ S odor.....	231.1-231.4
Claystone, gray (2.5Y 5/0), noncalcareous with carbonaceous material and slickensides throughout.....	231.4-231.9
Siltstone, very dark gray (2.5YR 3/0), noncalcareous with sandstone and clay laminae; sandstone composition of 90 percent quartz, 7 percent feldspar, and 3 percent dark minerals; crossbedded.....	231.9-233.0
Sandstone, gray to dark-gray (2.5Y 5/0-2.5Y 4/0), very fine grained, well-cemented, noncalcareous with carbonaceous plant material; clay and silt laminae; bioturbation and crossbedding.....	233.0-234.4

Detailed lithologic description--Continued

Description	Interval in feet
Claystone, dark-gray (7.5YR 4/0), noncalcareous with carbonaceous plant fragments, very fine grained sandstone laminae and crossbedding; same as unit at 233.0-234.4 ft, but at 235.3 ft, becomes very dark gray (2.5YR 3/0) and both silt and sand laminae are present; at 235.9 ft, color changes to dark gray (2.5YR 4/0); at 237.7 ft, color changes to light gray (2.5YR 7/0) and burrows are present; at 238.5 ft, color changes to dary gray (2.5Y 4/0).....	234.4-239.3
Sandstone, light-gray (5Y 7/0), silty, fine-grained, calcareous with 90 percent quartz, 5 percent feldspar 5 percent dark minerals, carbonaceous material and clay laminae; also crossbedded.....	239.3-239.7
Claystone, very dark gray (2.5Y 3/0), noncalcareous with both carbonaceous plant and coal fragments, and silt and sand laminae.....	239.7-242.4
Sandstone, noncalcareous.....	242.4-242.7
Claystone, same as unit at 239.7-242.4 ft.....	242.7-244.4
Claystone, very dark gray (2.5Y 3/0), noncalcareous with carbonaceous plant fragments.....	244.4-246.1
Mudstone, gray (2.5Y 6/0), noncalcareous with carbonaceous material and slickensides throughout; also strong petroleum odor.....	246.1-252.9
Bone, very dark gray (2.5Y 3/0), noncalcareous with slickensides.....	252.9-253.4
Coal, black (7.5R 2/0), two-direction cleat--both 90° to bedding, conchoidal fractures and slickensides in upper 0.1 ft of coal.....	253.4-259.0
Core missing.....	259.0-259.5
Claystone, black (10YR 2/1), noncalcareous with coal fragments and sulfur in last 2 ft; also numerous slickensides.....	259.5-260.5
Shale, very dark gray (7.5YR 3/0), noncalcareous with sulfur and plant fragments; also strong petroleum and H ₂ S odor.....	260.5-262.0
Bone, black (7.5YR 2/0), noncalcareous with some coal present and slickensides at base.....	262.0-263.3

Detailed lithologic description--Continued

Description	Interval in feet
Shale, black (7.5YR 2/0), carbonaceous, noncalcareous with sulfur on core surface and numerous slickensides.....	263.3-265.0
Coal, black (7.5YR 2/0), cleat perpendicular to bedding and conchoidal fractures; at 265.7 ft, sulfur on coal surface.....	265.0-268.2
Core missing.....	268.2-268.9
Shale, black (7.5YR 2/0), noncalcareous with sulfur and slickensides throughout.....	268.9-270.1
Coal, black (7.5YR 2/0), noncalcareous with two-directional cleat perpendicular to bedding; conchoidal fractures and vitrain.....	270.1-271.2
Shale, black (7.5YR 2/0), carbonaceous, noncalcareous with sulfur and slickensides throughout.....	271.2-272.5
Coal, black (7.5YR 2/0), cleat perpendicular to bedding, resin blebs, and numerous conchoidal fractures and slickensides.....	272.5-273.3
Shale, black (7.5YR 2/0), noncalcareous with sulfur.....	273.3-273.9
Bone, black (7.5YR 2/0) with cleat perpendicular to bedding.....	273.9-274.5
Shale, black (2.5YR 2/0), carbonaceous, noncalcareous with slickensides between 275.1 and 275.5 ft; sulfur at 276.3 ft.....	274.5-277.0
Coal, black (7.5YR 2/0), noncalcareous with two sets of cleat that are perpendicular to each other and to bedding; conchoidal fractures also present.....	277.0-278.0
Claystone, very dark gray (7.5R 3/0), noncalcareous with carbonaceous plant material and slickensides throughout.....	278.0-279.8
Mudstone, gray (7.5YR 5/0), silty, noncalcareous with carbonaceous fragments, burrows, and slickensides near the top and bottom of unit.....	279.8-281.2
Claystone, gray to very dark gray (7.5YR 5/0-7.5YR 3/0), noncalcareous with carbonaceous material; slickensides at 282.2-282.9 ft and at 283.3 ft; at 283.9 ft, color changes to gray (10YR 6/1), well compacted and becomes silty; at 284.9 ft, color changes to gray (7.5YR 5/0) with slickensides.....	281.2-285.2

Detailed lithologic description--Continued

Description	Interval in feet
Mudstone, very dark gray (7.5YR 3/0), noncalcareous with slickensides.....	285.2-285.6
Shale, black (7.5YR 2/0), carbonaceous, noncalcareous, sulfur, and slickensides at top of bed.....	285.6-286.4
Bone and coal, black (7.5YR 2/0).....	286.4-287.2
Shale, carbonaceous, same as unit at 285.6-286.4 ft.....	287.2-287.7
Claystone, dark-gray to gray (7.5YR 4/0-7.5YR 6/0), noncalcareous and carbonaceous material; slickensides at 288.5, 289.3, 289.7, 290.3, and 290.7 ft.....	287.7-291.7
Core missing.....	291.7-293.5
Claystone, same as unit at 287.7-291.4 ft, but color changes to gray (5Y 5/1); at 295.0 ft, color changes to gray (7.5YR 5/0); slickensides throughout the interval at 293.5 to 295.0 ft.....	293.5-296.0
Total depth.....	296.0