COAL STUDIES

METHANE CONTENT OF UTAH COALS

by H. H. Doelling, A. D. Smith, and F. D. Davis

OBSERVATIONS ON THE SUNNYSIDE COAL ZONE

by H. H. Doelling, A. D. Smith, F. D. Davis and D. L. Hayhurst

CHEMICAL ANALYSES OF COAL FROM THE BLACKHAWK FORMATION
WASATCH PLATEAU COAL FIELD
CARBON, EMERY, AND SEVIER COUNTIES, UTAH

by J. R. Hatch, R. H. Affolter, and F. D. Davis

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METHANE CONTENT OF UTAH COALS

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AND

OBSERVATIONS ON THE SUNNYSIDE COAL ZONE, UTAH

by H. H. Doelling[1], A. D. Smith[2], and F. D. Davis[2] and D. L. Hayhurst[2]

ABSTRACT

164 core samples from 7 of the more important coal fields in Utah were collected to test their gas contents by the direct method. The greater gas contents appear to be restricted to coals of high volatile A or B rank, but inadequate numbers of lower ranked coals have been sampled. Utah has no coals of higher rank. Actual gas contents and gas desorption as tested appear to be influenced by the distance from outcrops, or mined areas; by the nature of the encasing rock, and by the physical makeup of the coal itself. Book Cliffs coal field tests normally produced the most gas, but only this field has been adequately tested. Aeromagnetic contours superimposed over the Book Cliffs interestingly coincide with the areas of gassy coals, but no connection between the phenomena can be proven. The adjacent Wasatch Plateau coals appear to desorb minor amounts of gas.

A marked dissimilarity in methane drainage from horizontal drill holes in two contiguous mines in the Sunnyside coal zone has been noted. A detailed coal bed study was undertaken in an effort to find an explanation. Along with a detailed study of coal bed characteristics, numerous samples were taken for analysis and a large amount of contributed data was studied and provided comment on the Sunnyside zone both locally and regionally concerning deposition, areal extent, physical characteristics, thickness and quality. The difference in degasification of the coal in the two mines was not sufficiently explained. The best observation indicates that parts of coal beds are more permeable than others and allow greater drainage of gas from horizontal drill holes.

This report was prepared by the Utah Geological and Mineral Survey under U.S. Bureau of Mines contract number GO 166041/ET-76-01-9004. The contract was initiated under the Advancing Mining Technology Program. It was administered under the technical direction of Pittsburgh Mining and Safety Research Center with William P. Diamond acting as Technical Project Officer. Richard Yox, Department of Energy, was the contract administrator for the Bureau of Mines. This report is a summary of the work recently completed as a part of this contract during the period October 26, 1975 to April 2, 1979. This report was submitted by the authors on April 2, 1979.

METHANE CONTENT OF UTAH COALS

by H. H. Doelling[1], *A. D. Smith*[2], *and F. D. Davis*[2]

INTRODUCTION

The Utah Geological and Mineral Survey has conducted an examination of Utah coals to determine their potential methane content. The work was undertaken as a cooperative project with the U.S. Bureau of Mines (Grant No. GO 166041), which later was modified to become a Department of Energy Grant No. ET-76-G-01-9004.

Methane is the preponderant gas emitted or produced during the maturation of coal. All coals probably emit some gas when mined; some more than others. We present data that quantifies to some extent the methane degasification to be expected when mining Utah coals. Methane degasification from coals is important for two reasons. First, the flammable gas is potentially dangerous during the mining of coal and adequate ventilation systems must be designed for the expected volumes of release. Secondly, some mines produce such large quantities of gas that it might be considered for commercial production. It is hoped that the quantitative data obtained for this study will be of use in both considerations.

One of the problems in gathering data comes from the realization that cores must be obtained from active drilling projects; the success of this effort is the result of the fine cooperation received from the several coal companies and property holders that were actively drilling from 1975 to 1979. Among the contributors were American Electric Power Co., Braztah Corporation, Clifford Minerals Corporation, Energy Fuels Corporation, Kaiser Steel Corporation, Pacific Gas and Electric Co., Phelps-Dodge Corporation, Utah Power and Light Co., Valley Camp of Utah, Inc., and the U.S. Geological Survey. We acknowledge the help of William P. Diamond, U.S. Bureau of Mines, for critically reviewing the manuscript.

METHODS

The method of measuring the gas contents of the coal is that prescribed in U.S. Bureau of Mines Reports of Investigation 7767 and 8043. Briefly, a section of coal core just obtained from a drilling operation is sealed in an air-tight canister (figure 1). The field set-up for determining lost gas is shown as figure 2 and uses the same apparatus diagrammatically shown on figure 1. The time the drill intercepts the coal is recorded as is the time the core is sealed in the canister. Gas is released from the cylinder at regular timed intervals and a graph is constructed. The rate of early gas discharge is thus determined and projected over the "lost gas" time interval (figure 3). The procedure serves to give an estimate of the amount of gas lost before the core can be sealed in the cylinder. After the early desorption rate has been determined the gas generated within the canister is measured about once a day. This is continued until the core no longer gives up gas for at least 5 consecutive days. The entire procedure may be complete within 10 days or may last 3 to 4 months.

Residual gas usually remains in the core and can only be measured by crushing the coal in laboratory apparatus. The residual gas content is a function of the physical nature of the coal and the time the sample is allowed to desorb. The coal sample is weighed and the volume of gas per unit weight calculated.

[1] Chief, Economic Geology Section, Utah Geological and Mineral Survey.

[2] Staff geologists, Economic Geology Section, Utah Geological and Mineral Survey.

GAS CHARACTERISTICS OF UTAH COALS

The available gas data are summarized in tables 1 to 4. Table 1 lists the test numbers, locations of drill holes, the name of the tested coal bed or zone, the coal bed thickness, the depth of the coal core tested, the graphically determined volume of lost gas per unit weight, the volume of gas per unit weight desorbed with the equipment illustrated on figure 1, the volume of gas per unit weight released by crushing the core after desorption, and the calculated cubic centimeters of total gas (lost, desorbed, and residual) per gram of coal. The residual gas of the first 57 samples of table 1 was determined by use of a graph given in U.S. Bureau of Mines Reports of Investigation 7767 and 8043 and only provides an approximation of what the exact residual gas content might be. All of the remaining samples were crushed in a sealed ball mill and the gas measured by the water displacement method by the U.S. Bureau of Mines.

One-hundred and sixty four cores were tested between July, 1975 and April, 1979. The samples are numbered roughly in chronological order, the order in which they were obtained modified by the time the desorption process could be terminated. Nine of the cores tested were not coal and include 7 tests of adjacent sandstone and 2 tests of siltstone. Some of these adjacent strata contain desorbable gas which may have migrated from the coal bed. Cores for testing were procured from the seven most important coal fields in Utah considering the modern economic climate. Utah has a listing of over 20 coal fields (figure 4), but only half have had a significent production or contain important reserves. Active mining and significant exploration are confined to the seven fields in which tests were made. Utah coal fields having produced over 1 million tons of coal or containing over 500 million tons in potential resources are ranked in table 2; the number of gas tests made in each of these fields is also given. Figure 5 gives the range of gas contents in cubic centimeters per gram for the coal fields of Utah. Approximately 27 coal zones or beds have been tested: eight in the Book Cliffs field, seven in the Wasatch Plateau field, four in the Sego field, two in the Alton field, three in the Kaiparowits Plateau field, two in the Emery field, and one in the Henry Mountains field.

Figure 6 relates the present depth of burial of the tested cores to the gas contents. Three random lines are drawn through the sample points on the figure and labelled A, B, and C. At first glance the sample points show no positive relationship between the depth of burial and expected gas contents, but when other factors are taken into consideration some conclusions can be reached. The graph indicates no Utah samples are expected to be exceptionally gassy that have never been buried deeper than 1,000 feet. The blank area in the upper left hand corner of the figure substantiates this assumption. If gassy coals were encountered at depths of less than 1,000 feet it might be assumed that they were once buried much deeper and have not been able to desorb fast enough naturally in response to the erosion of the overburden. One might consider an arbitrary line A as a straight line curve relating depth to gas contents where there has been little chance for natural or induced desorption. This would relate to coal far from the outcrop or a mine, in an area where natural desorption has not been favored. Therefore the gas contents are expected to be higher. Line B may indicate a straight line curve for coal that has had time for a certain amount of natural desorption. A coal would be able to desorb its gas if it were encased in porous and permeable rock, or if adjacent to some faults and fractured rock, or if it were elevated after burial and eroded close to the surface. Line C may represent a

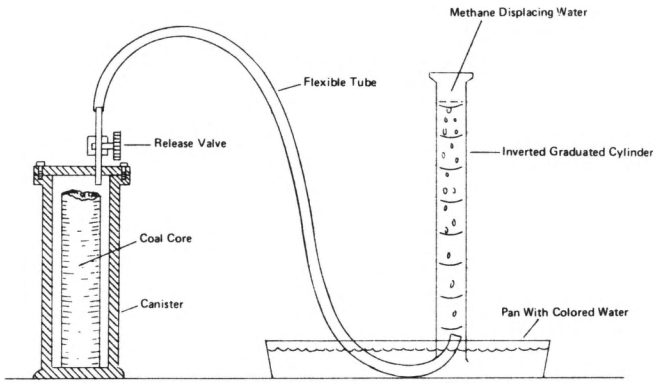


Figure 1. Schematic diagram of apparatus used to measure gas desorbed from coal core.

Figure 2. Field set-up for determining lost gas.

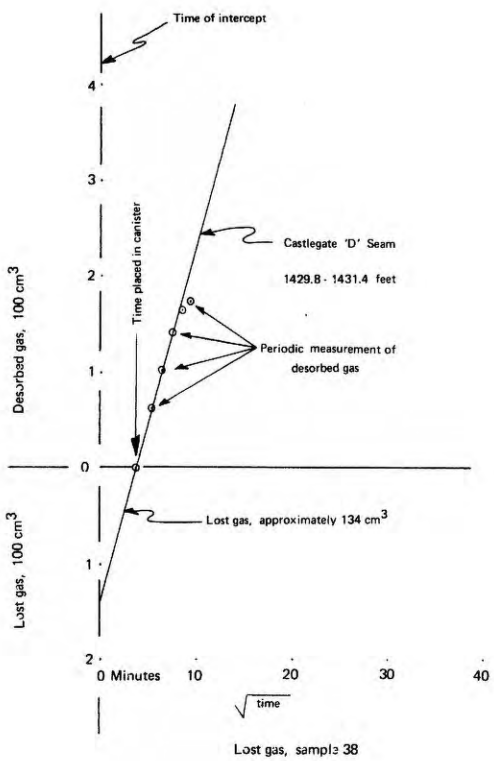


Figure 3. Lost gas diagram for sample 38.

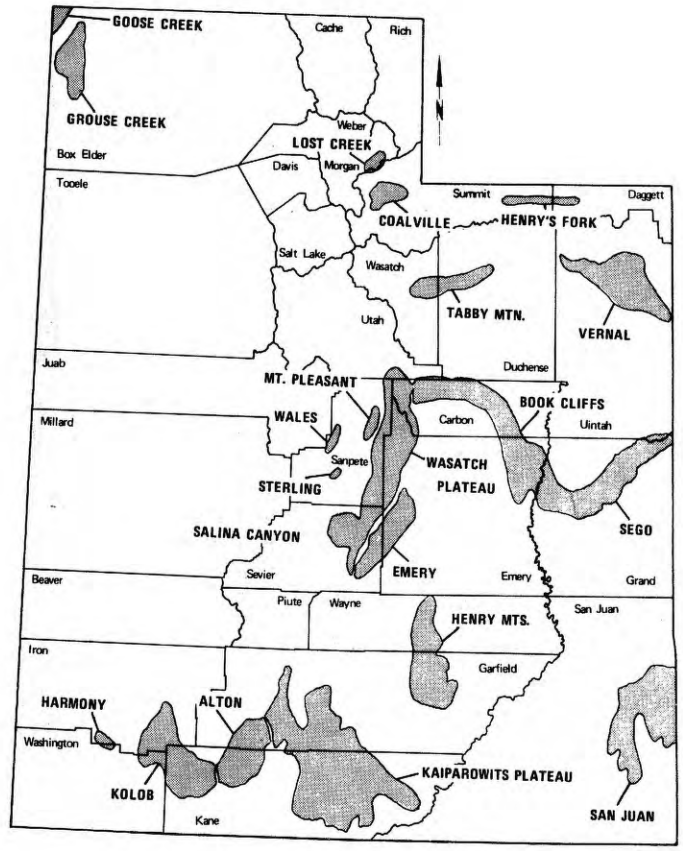


Figure 4. Index map to Utah coal fields.

Table 1. Methane gas content of Utah coals, test data summaries.

Sample No.	Location	Coal zone or bed	Thickness of bed (ft)	Depth interval (feet)	Lost and desorbed gas cm^3/gram	Residual gas cm^3/gram[1]	Total gas cm^3/gram
1.	SW22-16S- 6E	Hiawatha	4.6	871.8- 872.8	0.07	0.11	0.18
2.	SE 3-17S- 6E	Hiawatha	9.4	616.0- 617.0	0.90	0.43	1.33
3.	SE24-17S- 6E	Hiawatha	8.9	356.1- 357.1	0.05	0.08	0.13
4.	NW 3-18S- 6E	Hiawatha	7.5	447.8- 448.8	0.61	0.04	0.65
5.	SE 3-19S- 6E	Bear Canyon	3.5	970.3- 971.3	0.04	0.02	0.06
6.	NE15-24S- 4E	Upper Ivie	4.3	80.8- 81.8	0.08	0.05	0.13
7.	SE21-24S- 4E	Upper Ivie	4.0	275.6- 276.6	0.06	0.05	0.11
8.	4-13S-12E	Sunnyside	11.8	1797.8-1798.8	2.79	1.97	4.76
9.	4-13S-12E	Rock Canyon(l)	4.6	2352.1-2353.1	3.31	2.08	5.39
10.	4-13S-12E	Rock Canyon(u)	3.9	2339.2-2340.2	1.69	1.08	2.77
11.	10-13S-12E	Gilson	3.0	2038.6-2039.6	0.77	0.53	1.30
12.	SW17-14S-14E	Sunnyside	7.0	19.0- 21.0[2]	1.11	0.78	1.89
13.	SW17-14S-14E	Sunnyside	7.0	41.5- 43.0[2]	1.00	0.69	1.69
14.	SW17-14S-14E	Sunnyside	7.0	61.5- 64.0[2]	2.24	1.45	3.69
15.	SW17-14S-14E	Sunnyside	7.0	68.0- 70.2[2]	2.46	1.58	4.04
16.	SW17-14S-14E	Sunnyside	7.0	41.5- 44.5[2]	1.97	1.39	3.36
17.	SW17-14S-14E	Sunnyside	7.0	44.5- 47.0[2]	0.58	0.29	0.87
18.	NE23-17S- 7E	Hiawatha	10.5	112.0- 113.9[3]	0.99	0.66	1.65
19.	NE23-17S- 7E	Hiawatha	10.5	114.0- 116.8[3]	0.14	0.12	0.26
20.	NE23-17S- 7E	Blind Canyon	7.0	149.5- 152.0[3]	0.27	0.18	0.45
21.	NE36-12S- 9E	Castlegate C	13.0	1247.7-1249.0	0.42	0.28	0.70
22.	SW31-12S-10E	Castlegate Unk. 39.7' above D	3.2	128.6- 129.6	0.70	0.47	1.17
23.	SW31-12S-10E	Castlegate D	7.5	159.9- 160.7	0.67	0.45	1.12

[1] Residual gas for the initial 57 samples was determined graphically utilizing U. S. Bur. Mines RI 8043. Further work has shown the reliability of the graph to be in question. The accurate way to determine residual gas is by crushing. Tests after No. 57 were crushed.

[2] Horizontal drill holes in Sunnyside No. 1 mine.

[3] In-mine drilling

(continued)

Table 1. Methane gas content of Utah coals, test data summaries. (continued)

Sample No.	Location	Coal zone or bed	Thickness of bed (ft)	Depth interval (feet)	Lost and desorbed gas cm^3/gram	Residual gas cm^3/gram[1]	Total gas cm^3/gram
24.	SW31-12S-10E	Castlegate D	7.5	169.3- 170.1	0.76	0.50	1.26
25.	SW31-12S-10E	Kenilworth	26.0	245.0- 246.0	0.76	0.59	1.35
26.	SW31-12S-10E	Sandstone under Kenilworth	---	262.0- 263.0	0.21	4	4
27.	SW31-12S-10E	Castlegate C	11.5	299.5- 300.5	1.26	0.87	2.13
28.	SE34-39S-4½W	Smirl	7.0	752.5- 754.0	0.06	0.04	0.10
29.	SW30-37S- 3W	Bald Knoll	11.0	273.3- 274.3	0.25	0.17	0.42
30.	NE12-33S- 8E	Emery	5.0	1030.1-1030.8	0.24	0.16	0.40
31.	SW26-12S-10E	Kenilworth	7.4	2448.3-2449.5	6.69	4.25	10.94
32.	SW26-12S-10E	Sandstone under Kenilworth	---	2455.1-2456.1	0.09	4	4
33.	NE14-13S- 6E	Flat Canyon	3.0	1367.2-1368.2	0.16	0.11	0.27
34.	NE18-23S- 6E	"A"	3.0	388.3- 389.5	0.07	0.04	0.11
35.	SE33-33S- 2W	Smirl?	18.0	442.4- 443.3	0.06	0.04	0.10
36.	SE31-12S- 9E	Castlegate A	5.4	2170.0-2172.9	5.68	3.69	9.37
37.	SE31-12S- 9E	Sandstone under Castlegate A	---	2229.7-2232.5	0.04	4	4
38.	NE 4-13S- 9E	Castlegate D	6.4	1429.8-1431.4	0.99	0.59	1.58
39.	NE 4-13S- 9E	Castlegate A	10.0	1644.6-1646.0	0.09	0.06	0.15
40.	SE32-12S- 9E	Castlegate A	10.0	1952.1-1953.0	0.30	0.21	0.51
41.	SE32-12S- 9E	Sandstone under Castlegate A	---	1966.6-1968.1	0.06	4	4
42.	SE32-12S- 9E	Subseam 2	10.0	2186.1-2187.1	1.50	1.11	2.61
43.	SE32-12S- 9E	Sandstone under Subseam 2	---	2213.8-2214.4	0.07	4	4
44.	SE32-12S- 9E	Subseam 3	2.5	2221.3-2222.3	0.24	0.16	0.40
45.	SE32-12S- 9E	Sandstone under Subseam 3	---	2224.6-2225.6	0.04	4	4

[4] Not applicable, test on rock materials impractical.

(continued)

Table 1. Methane gas content of Utah coals, test data summaries. (continued)

Sample No.	Location	Coal zone or bed	Thickness of bed (ft)	Depth interval (feet)	Lost and desorbed gas $cm^3/gram$	Residual gas $cm^3/gram$[1]	Total gas $cm^3/gram$
46.	SW15-13S-12E	Rock Canyon	7.9	1705.4-1706.4	2.47	0.40	2.87
47.	SW15-13S-12E	Siltstone above Rock Canyon	---	1700.5-1701.5	0.29	4	4
48.	SW15-13S-12E	Siltstone under Rock Canyon	---	1709.4-1709.9	0.22	4	4
49.	SW15-13S-12E	Fish Creek	4.8	1726.7-1727.7	4.13	3.02	7.15
50.	SE11-13S- 6E	Lower O'Connor	7.5	1457.2-1458.2	0.01	0.004	0.01
51.	NW24-13S- 6E	Lower O'Connor	10.2	627.2- 628.2	0.02	0.01	0.03
52.	SE34-12S-10E	Unnamed	3.9	2079.7-2081.0	5.72	0.40	6.12
53.	NW24-13S- 6E	Upper O'Connor	15.9	699.3- 700.3	0.02	0.01	0.03
54.	SE23-13S- 6E	Upper O'Connor	10.1	1015.0-1016.0	0.00	0.00	0.00
55.	SW35-12S-10E	Unnamed	7.2	2056.0-2057.5	6.70	1.40	8.10
56.	SE34-12S-10E	Castlegate A	16.9	2558.0-2559.2	5.11	0.80	5.91
57.	SE34-12S-10E	Sandstone under Castlegate A	---	2562.2-2563.3	0.00	4	4
58.	SW16-40S- 4E	K2-Upper	5.3	479.0- 480.0	0.01	0.00	0.01
59.	SW16-40S- 4E	K2-Lower	5.2	491.0- 491.9	0.02	0.00	0.02
60.	SW16-40S- 4E	M1	4.3	534.8- 535.7	0.08	0.00	0.08
61.	SW16-40S- 4E	M2	5.8	574.3- 575.2	0.07	0.00	0.07
62.	SW16-40S- 4E	N	11.5	652.6- 653.5	0.16	0.00	0.16
63.	SW16-40S- 4E	P-Upper	5.6+	713.5- 714.4	0.22	0.00	0.22
64.	SE 5-13S-10E	Castlegate C	10.7	555.3- 556.5	0.61	0.70	1.31
65.	SE 5-13S-10E	Castlegate C	10.7	561.7- 563.0	0.70	0.70	1.40
66.	SE 5-13S-10E	Castlegate A	3.6	590.8- 591.8	1.09	1.50	2.59
67.	SE 5-13S-10E	Castlegate A	3.6	591.8- 592.8	1.03	1.20	2.23
68.	SE 5-13S-10E	Castlegate A	8.5	192.0- 193.5	0.10	0.00	0.10
69.	NE 5-13S-10E	Castlegate C	5.0	897.2- 898.4	1.16	0.50	1.66
70.	NE 5-13S-10E	Castlegate B	4.8	971.6- 972.8	0.50	0.60	1.10
71.	NE 5-13S-10E	Castlegate A	9.6	1002.6-1004.0	0.83	1.30	2.13
72.	NE28-12S- 9E	Castlegate A	24.0	2641.3-2642.7	8.03	0.90	8.93

(continued)

Table 1. Methane gas content of Utah coals, test data summaries. (continued)

Sample No.	Location	Coal bed or bed	Thickness of bed (ft)	Depth interval (feet)	Lost and desorbed gas cm^3/gram	Residual gas cm^3/gram	Total gas cm^3/gram
73.	NE28-12S- 9E	Castlegate A	24.0	2654.8-2656.3	9.17	0.22	9.40
74.	SE 6-13S- 9E	Castlegate D	4.0	147.5- 149.0	0.22	0.50	0.72
75.	SE 6-13S- 9E	Castlegate C	4.1	196.9- 198.0	0.17	0.50	0.67
76.	NE28-12S- 9E	Subseam	6.8	2819.8-2821.4	0.00	2.20	2.20
77.	SE 6-13S- 9E	Castlegate B	4.2	315.3- 316.3	0.36	0.66	1.02
78.	NW 6-13S- 9E	Castlegate B	5.6	351.5- 352.5	0.14	0.79	0.93
79.	SE28-12S- 9E	Castlegate D	3.6	1134.0-1135.8	4.77	0.80	5.57
80.	SE28-12S- 9E	Castlegate A	6.1	1194.6-1196.6	0.00	3.90	3.90
81.	SE28-12S- 9E	Castlegate A	3.6+	1215.5-1217.0	6.85	0.30	7.15
82.	SE28-12S- 9E	Subseam 1	4.9	1394.0-1395.3	7.45	0.80	8.25
83.	SE28-12S- 9E	Subseam 2	7.0	1435.1-1436.6	6.43	2.00	8.43
84.	16-17S- 7E	Hiawatha	7.9	87.7- 89.0	0.00	0.21	0.21
85.	NE 2-13S- 8E	Castlegate B	4.7	439.3- 440.6	0.05	1.19	1.24
86.	SW28-12S- 9E	Castlegate D	6.3	1099.1-1101.2	0.00	1.50	1.50
87.	SW28-12S- 9E	Castlegate B rider	1.5	1232.9-1234.1	6.40	0.80	7.20
88.	SW28-12S- 9E	Castlegate A	7.5	1333.4-1335.2	6.68	0.40	7.08
89.	SW28-12S- 9E	Subseam 1	4.1	1502.0-1503.9	6.72	0.68	7.40
90.	SW28-12S- 9E	Subseam 2	3.4	1512.5-1514.4	0.86	1.49	2.35
91.	SW28-12S- 9E	Subseam 3	7.6	1550.6-1552.4	0.01	0.50	0.51
92.	NE 6-13S- 9E	Castlegate B(u)	4.1	501.7- 503.4	0.65	1.10	1.75
93.	NE 6-13S- 9E	Castlegate B(l)	3.4	510.1- 511.4	0.63	0.40	1.03
94.	NW 5-13S- 9E	Castlegate B	4.9	736.1- 737.3	1.20	1.80	3.00
95.	NW 5-13S- 9E	Castlegate A	8.8	777.0- 778.9	0.00[5]	0.30	0.30
96.	NW 5-13S- 9E	Subseam 3	8.8	961.1- 962.9	1.24	0.60	1.84
97.	NW 5-13S- 9E	Subseam 2	4.8	935.0- 936.9	0.11	1.80	1.91
98.	SE 3-13S-10E	Castlegate B	8.3	774.5- 775.9	0.00	1.40	1.40
99.	SE 3-13S-10E	Castlegate A	11.7	824.3- 825.7	0.16	1.10	1.26
100.	NE12-13S-10E	Castlegate A	9.9	568.4- 569.7	2.44	0.30	2.74

[5] Close to old workings.

(continued)

Table 1. Methane gas content of Utah coals, test data summaries. (continued)

Sample No.	Location	Coal zone or bed	Thickness of bed (ft)	Depth interval (feet)	Lost and desorbed gas cm^3/gram	Residual gas cm^3/gram	Total gas cm^3/gram
101.	SE32-12S- 9E	Castlegate D	9.2	1306.4-1307.6	0.15	2.80	2.95
102.	SE32-12S- 9E	Subseam 2	5.1	1740.7-1742.0	0.00	1.50	1.50
103.	SE32-12S- 9E	Subseam 3	9.7	1760.7-1762.1	0.00	2.30	2.30
104.	NE10-24S- 5E	Upper Ferron	3.3	343.4- 344.4	0.00	[6]	[7]
105.	SE 8-37S- 2E	Rees	27.2	605.5- 606.7	0.00	0.00	0.00
106.	SE 8-37S- 2E	Rees	27.2	619.1- 620.1	0.09	0.00	0.09
107.	SE 8-37S- 2E	Christensen?	?	693.8- 694.9	0.00	0.00	0.00
108.	NE35-12S-10E	Kenilworth	9.4	2819.5-2820.6	0.00	2.20	2.20
109.	NE35-12S-10E	Kenilworth	9.4	2825.9-2827.2	0.94	1.70	2.64
110.	NE10-24S- 5E	Lower Ferron	1.9	584.2- 585.3	0.00	[6]	[7]
111.	NW22-23S- 4E	Ivie	4.5	755.2- 756.8	0.00	[6]	[7]
112.	NE34-22S- 4E	Ivie	4.5	812.0- 813.2	0.00	[6]	[7]
113.	NW27-12S-10E	Kenilworth	10.8	3175.9-3176.9	10.61	0.41	11.02
114.	NW27-12S-10E	Castlegate C	8.5	3291.3-3292.4	10.21	0.41	10.63
115.	NW27-12S-10E	Castlegate A	9.0	3353.9-3354.9	1.67	0.90	2.57
116.	SE 8-37S- 2E	Christensen	24.8	711.9- 713.0	0.22	0.00	0.22
117.	SE 8-37S- 2E	Christensen	24.8	724.9- 726.0	0.19	0.00	0.19
118.	SE 8-37S- 2E	Christensen	6.3	778.8- 780.0	0.00	0.00	0.00
119.	SW30-12S- 9E	Castlegate A	11.4	3014.5-3015.6	0.65	1.21	1.86
120.	SW30-12S- 9E	Castlegate A	11.4	3023.7-3025.0	3.45	1.20	4.65
121.	NE15-16S-25E	Ballard	0.7	296.6- 297.2	0.00	0.00	0.00
122.	NE15-16S-25E	Ballard	1.8	335.2- 336.4	0.00	0.00	0.00
123.	NE15-16S-25E	Ballard	3.3	392.1- 394.0	0.00	0.00	0.00
124.	NE15-16S-25E	Ballard	7.5	408.8- 409.6	0.09	0.00	0.09
125.	NE15-16S-25E	Ballard	2.3	415.0- 415.7	0.00	0.00	0.00
126.	NE15-16S-25E	Ballard	4.4	421.8- 422.8	0.00	0.00	0.00
127.	NE15-16S-25E	Palisade	1.9	491.3- 493.1	0.05	0.00	0.05
128.	NE15-16S-25E	Palisade	1.4	622.3- 623.8	0.11	0.00	0.11

[6]Sample returned to donor without obtaining residual gas measurement.
[7]Tests incomplete

(continued)

Table 1. Methane gas content of Utah coals, test data summaries. (continued)

Sample No.	Location	Coal zone or bed	Thickness of bed (ft)	Depth interval (feet)	Lost and desorbed gas cm^3/gram	Residual gas cm^3/gram	Total gas cm^3/gram
129.	NE15-16S-25E	Palisade	1.3	625.6- 626.8	0.00	0.00	0.00
130.	NE15-16S-25E	Palisade	2.0	652.3- 654.3	0.00	0.00	0.00
131.	NW26-22S- 6E	Ferron	24.4	83.8- 85.0	0.34 [8]	0.16	0.50
132.	NW26-22S- 6E	Ferron	24.4	98.1- 99.0	0.00	0.00	0.00
133.	NW17-16S-15E	Beckwith?	1.7	1073.0-1074.7	0.09	0.00	0.09
134.	NW17-16S-15E	Sunnyside	4.1	1202.8-1204.2	0.26	0.00	0.26
135.	NW26-22S- 6E	Ferron	2.8	239.0- 240.0	0.00	0.00	0.00
136.	NE19-17S-15E	Sunnyside	3.1	924.5- 926.0	0.39	0.00	0.39
137.	29-17S-15E	Sunnyside	2.9	915.9- 917.2	0.00	0.31	0.31
138.	SW 3-13S-11E	Unnamed 87.7' above Sunnyside	3.9	283.3- 284.9	2.43	0.50	2.93
139.	SW 3-13S-11E	Unnamed 19.5' above Sunnyside	3.0	353.4- 354.3	1.29	0.90	2.19
140.	SW 3-13S-11E	Sunnyside	1.2	373.2- 274.4	3.62	0.90	4.52
141.	SW 3-13S-11E	Rock Canyon	4.3	434.5- 435.7	0.39	0.91	1.30
142.	SW 3-13S-11E	Gilson	8.0	475.0- 476.0	0.00	1.58	1.58
143.	SW 3-13S-11E	Gilson	8.0	481.6- 482.6	0.00	0.51	0.51
144.	SW 3-13S-11E	Unnamed below Gilson	1.9	502.5- 503.9	1.71	0.30	2.01
145.	SW 3-13S-11E	Castlegate A	4.0	757.0- 758.4	0.52	0.51	1.03
146.	SE 3-17S-24E	Carbonera	1.0	107.8- 108.7	0.00	0.02	0.02
147.	SE 3-17S-24E	Carbonera	2.2	117.8- 118.4	0.02	0.00	0.02
148.	SE 3-17S-24E	Ballard	5.0	190.8- 191.7	0.00	0.02	0.02
149.	SE 3-17S-24E	Ballard	4.7	196.8- 197.5	0.00	0.00	0.00
150.	SE 3-17S-24E	Ballard	1.0	253.3- 254.0	0.15	0.16	0.31
151.	SE 3-17S-24E	Ballard?	0.8	370.3- 370.9	0.00	0.16	0.16
152.	SE 3-17S-24E	Palisade	3.8	408.0- 408.7	0.00	0.00	0.00

[8] Lost gas not recorded

(continued)

Table 1. Methane gas content of Utah coals, test data summaries. (continued)

Sample No.	Location	Coal zone or bed	Thickness of bed (ft)	Depth interval (feet)	Lost and desorbed gas cm^3/gram	Residual gas cm^3/gram	Total gas cm^3/gram
153.	NW15-20S-20E	Chesterfield	3.5	735.6- 736.4	0.00	0.31	0.31
154.	NW15-20S-20E	Chesterfield	1.8	742.3- 743.1	0.00	0.29	0.29
155.	NW15-20S-20E	Ballard?	3.4	860.0- 861.1	0.00	0.45	0.45
156.	SE17-20S-20E	Ballard(u)	4.2	504.1- 505.3	0.47	0.30	0.77
157.	SE17-20S-20E	Ballard(l)	3.2	528.8- 530.0	1.30	0.20	1.50
158.	SE17-20S-20E	Palisade	2.4	616.8- 617.8	0.81	0.30	1.11
159.	SW31-17S-24E	Carbonera	1.0	193.2- 193.7	0.60	0.20	0.80
160.	SW31-17S-24E	Carbonera	4.7	238.1- 238.9	1.03	0.40	1.43
161.	SW31-17S-24E	Chesterfield	2.2	277.8- 278.5	1.10	0.30	1.40
162.	NE29-12S- 9E	Castlegate A	6.1	1937.5-1938.7	0.38	2.30	2.68
163.	NE29-12S- 9E	Subseam 1	6.2	2082.8-2083.8	8.70	1.20	9.90
164.	NE29-12S- 9E	Subseam 2	3.3	2109.0-2110.0	0.97	1.10	2.07

Table 2. Coal production and coal resources for the principal coal fields of Utah

COAL FIELDS	PRODUCTION Millions of tons	Rank	POTENTIAL RESOURCES* Billions of tons	Rank	NUMBER OF GAS TESTS
Alton	<0.1	---	2.2	4	3
Book Cliffs	229.2	1 (2)[1]	4.2	3	98
Coalville	4.3	3	<0.2	---	0
Emery	3.5	4 (3)[1]	2.1	5	8
Henry Mountains	minor	---	0.5	---	1
Kaiparowits Plateau	minor	---	15.2	1	12
Kolob	0.8	6	2.0	6	0
Sego	2.7	5	0.5	---	26
Wasatch Plateau	132.1	2 (1)[1]	10.3	2	16
All others	1.3	---	2.4	---	0

*To 3,000 feet of overburden and excluding most thin seams.
[1]Numbers in parentheses indicate production rank for the years 1973-1978

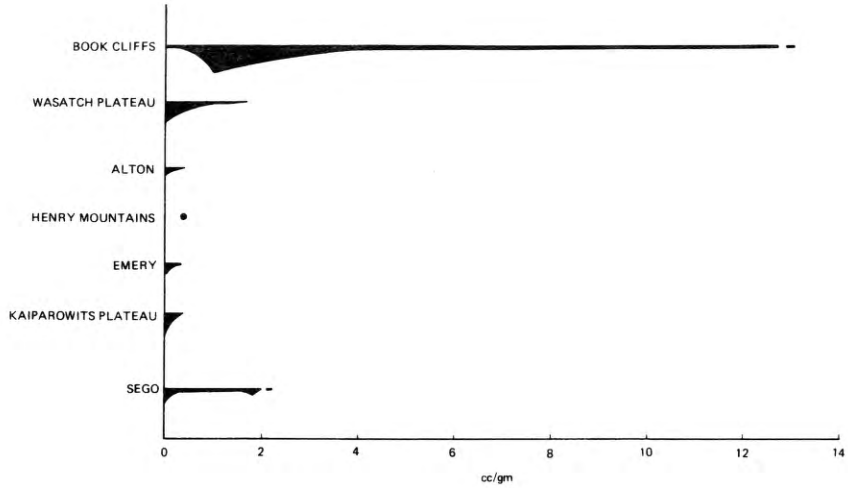


Figure 5. Range of gas contents in cubic centimeters per gram of coal for the principal coal fields of Utah. Thicker areas are those in which many tests have fallen.

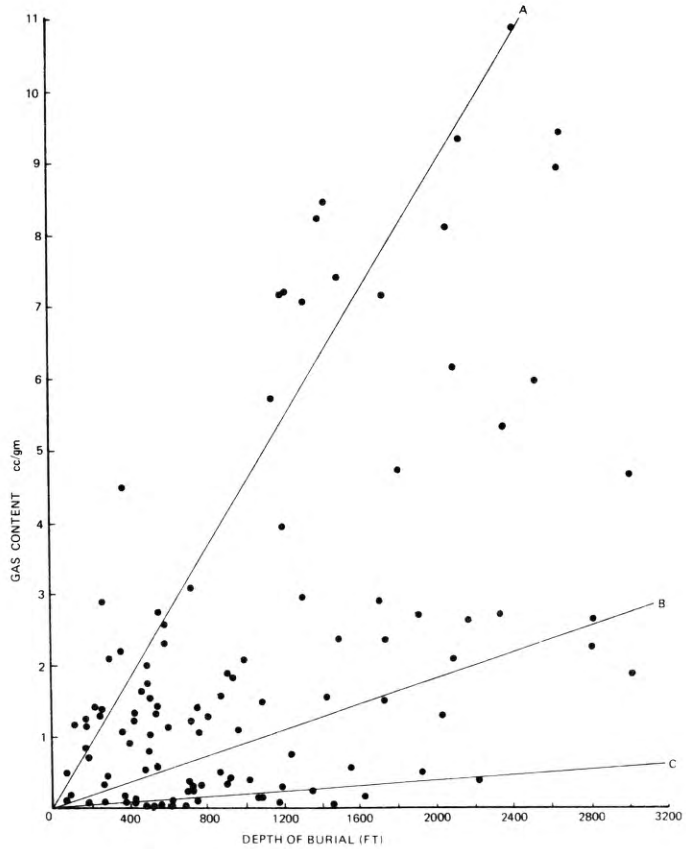


Figure 6. Depth of coal versus gas contents for Utah coals.

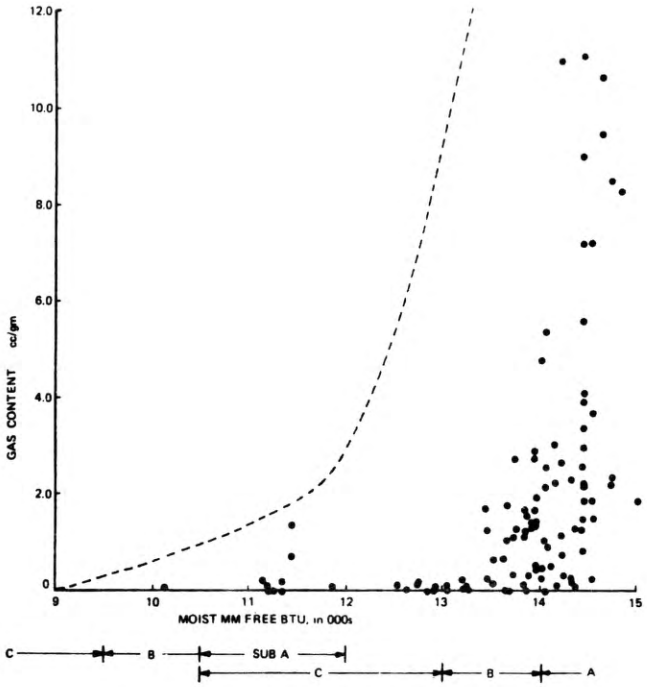


Figure 7. Moist mineral matter free Btu of tests compared with their gas content. Arrowed limits indicate rank of coal subbituminous A, B, and C, and high volatile A, B, and C bituminous. Samples are not expected to fall in area left of the dashed line if gas contents are linked to advanced rank.

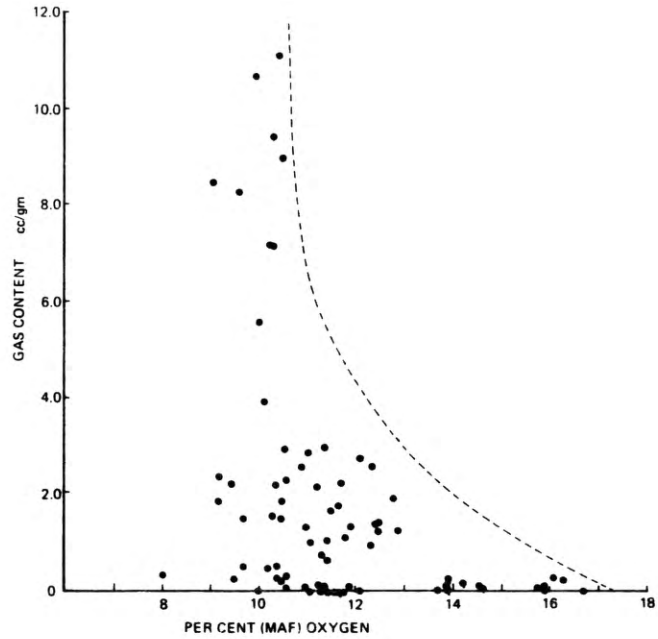


Figure 9. Gas content compared to moisture ash free oxygen.

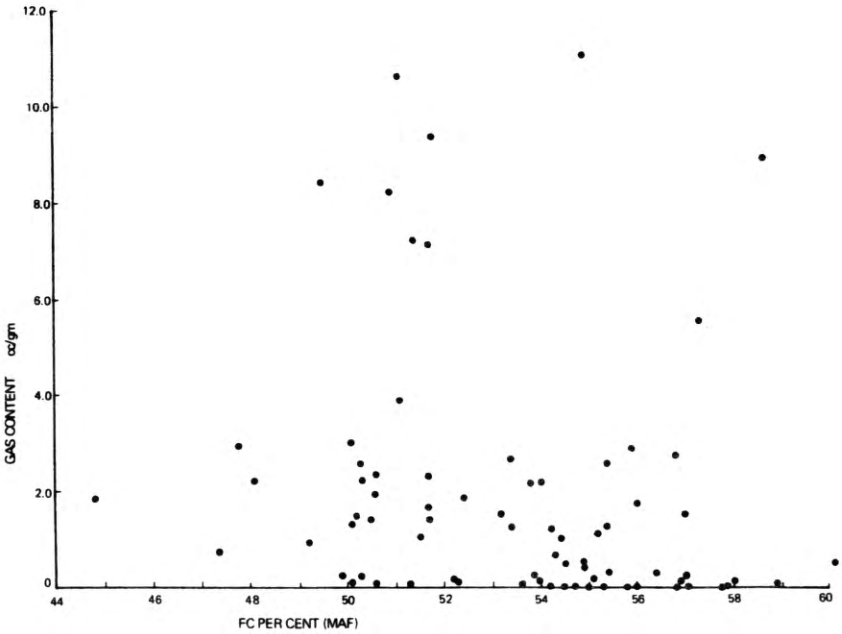


Figure 8. Comparing gas content to moisture ash free fixed carbon. There appears to be no correlation.

Table 3. Proximate analyses of coal samples tested for gas contents, as received.

Sample No.	As Received Percent M	Ash	VM	FC	S	AR Btu/lb.	Moist MM free Btu/lb.	Rank	Gas content cm^3/gram	Testing facility
1.	2.54	14.97	40.16	42.33	0.64	11978	14310	HV-A Bit.	0.18	CTE
2.	14.24	8.20	38.34	39.22	0.48	10428	11448	HV-C Bit.	1.33	CTE
3.	2.90	8.90	40.20	48.00	0.50	12510	13855	HV-B Bit.	0.13	BM
4.	5.60	4.80	43.50	46.10	0.40	12793	13503	HV-B Bit.	0.65	BM
5.	10.90	9.47	38.21	41.42	0.57	10649	11872	HV-C Bit.	0.06	CTE
6.	13.10	15.70	32.00	39.20	0.80	9334	11252	HV-C Bit.	0.13	BM
7.	13.70	34.40	25.60	26.30	0.60	6361	10128	Subbit. B	0.11	BM
8.	3.19	5.80	39.17	51.84	0.66	13139	14036	HV-A Bit.	4.76	CTE
9.	3.99	7.71	36.00	52.30	0.94	12872	14069	HV-A Bit.	5.39	CTE
10.	3.07	10.94	36.11	49.88	0.86	12259	13927	HV-B Bit.	2.77	CTE
11.	2.52	4.74	42.55	50.19	0.83	13637	14398	HV-A Bit.	1.30	CTE
12.	3.54	4.40	40.35	51.71	0.75	13806	14518	HV-A Bit.	1.89	CTE
13.	3.75	3.21	39.22	53.82	0.71	13932	14454	HV-A Bit.	1.69	CTE
14.	3.03	3.50	38.56	54.91	0.49	13965	14529	HV-A Bit.	3.69	CTE
15.	3.53	2.58	39.76	54.13	0.45	14064	14481	HV-A Bit.	4.04	CTE
16.	4.59	3.92	40.50	50.99	0.68	13818	14450	HV-A Bit.	3.36	CTE
17.	4.23	7.12	38.55	50.10	1.04	13284	14424	HV-A Bit.	0.87	CTE
18.	4.80	6.11	43.89	45.20	0.81	13044	13989	HV-B Bit.	1.65	CTE
19.	3.87	6.01	44.71	45.41	0.63	13086	14013	HV-A Bit.	0.26	CTE
20.	4.00	4.12	44.23	47.65	0.53	13337	13973	HV-B Bit.	0.45	CTE
21.	2.09	5.55	37.47	54.89	0.34	10728	11417	HV-C Bit.	0.70	CTE
22.	2.39	7.72	43.93	45.96	0.86	12998	14207	HV-A Bit.	1.17	CTE
23.	3.00	3.96	41.45	51.59	0.60	13121	13723	HV-B Bit.	1.12	CTE
24.	1.88	8.26	45.47	44.29	0.66	13121	14427	HV-A Bit.	1.26	CTE
25.	2.03	7.41	42.62	47.94	0.36	12824	13950	HV-B Bit.	1.35	CTE

Explanation: M = moisture, VM = volatile matter, FC = fixed carbon, S = Sulfur, AR = as received, MM = mineral matter, CTE = Commercial Testing & Engineering Co., Denver, Colorado, BM = U. S. Bur. Mines, Pittsburgh, Pennsylvania.

(continued)

Table 3. Proximate analyses of coal samples tested for gas contents, as received. (continued)

Sample No.	As Received Percent M	Ash	VM	FC	S	AR Btu/lb.	Moist MM free Btu/lb.	Rank	Gas content cm^3/gram	Testing facility
26.		Sandstone sample							0.21[1]	
27.	2.16	5.56	44.16	48.12	0.44	13193	14049	HV-A Bit.	2.13	CTE
28.		Sample returned to donor							0.10[1]	
29.		Sample returned to donor							0.42[1]	
30.		Sample returned to donor							0.40[1]	
31.	1.90	4.10	40.66	53.34	0.57	13559	14204	HV-A Bit	10.94	CTE
32.		Sandstone sample							0.09[1]	
33.	5.05	9.77	42.49	42.69	0.59	12057	13495	HV-B Bit.	0.27	CTE
34.		Sample returned to donor							0.11[1]	
35.		Not analyzed							0.10	
36.		Not analyzed							9.37	
37.		Sandstone sample							0.04[1]	
38.		Not analyzed							1.58	
39.		Not analyzed							0.15	
40.		Not analyzed							0.51	
41.		Sandstone sample							0.06[1]	
42.		Not analyzed							2.61	
43.		Sandstone sample							0.07[1]	
44.		Not analyzed							0.40	
45.		Sandstone sample							0.04[1]	
46.	4.20	4.90	40.10	50.80	0.70	13196	13953	HV-B Bit.	2.87	BM
47.		Siltstone sample							0.29[1]	
48.		Siltstone sample							0.22[1]	
49.		Not analyzed							7.15	
50.		Not analyzed							0.01	
51.		Not analyzed							0.03	
52.		Not analyzed							6.12	
53.		Not analyzed							0.03	
54.		Not analyzed							0.00	

[1] Lost and desorbed gas content only

(continued)

Table 3. Proximate analyses of coal samples tested for gas contents, as received.(continued)

Sample No.	As Received Percent M	Ash	VM	FC	S	AR Btu/lb.	Moist MM free Btu/lb.	Rank	Gas content cm^3/gram	Testing facility
55.		Not analyzed							8.10	
56.		Not analyzed							5.91	
57.		Sandstone sample							0.00[1]	
58.	7.30	3.60	43.40	45.70	0.40	12411	12922	HV-C Bit.	0.01	BM
59.	7.30	4.50	43.60	44.60	0.50	11995	12618	HV-C Bit.	0.02	BM
60.	7.30	3.50	41.00	48.20	0.70	12247	12743	HV-C Bit.	0.08	BM
61.	8.80	6.50	40.40	44.30	1.60	11627	12537	HV-C Bit.	0.07	BM
62.	7.90	2.90	42.60	46.60	0.60	12355	12767	HV-C Bit.	0.16	BM
63.	6.80	4.70	44.30	44.20	0.80	12343	13021	HV-B Bit.	0.22	BM
64.	3.20	3.50	43.20	50.10	0.40	13394	13931	HV-B Bit.	1.31	BM
65.	2.90	5.20	41.40	50.50	0.40	13118	13910	HV-B Bit.	1.40	BM
66.	3.10	3.00	44.30	49.60	0.60	13586	14058	HV-A Bit.	2.59	BM
67.	2.60	6.50	42.20	48.70	0.50	13155	14163	HV-A Bit.	2.23	BM
68.	2.60	5.90	44.20	47.30	0.30	13276	14189	HV-A Bit.	0.10	BM
69.	2.90	4.50	44.70	47.90	0.50	13167	13853	HV-B Bit.	1.66	BM
70.	2.70	6.00	40.90	50.40	0.50	12951	13862	HV-B Bit.	1.10	BM
71.	2.50	4.90	43.10	49.50	0.50	13284	14041	HV-A Bit.	2.13	BM
72.	1.50	5.50	38.40	54.50	0.40	13550	14418	HV-A Bit.	8.93	DOE
73.	1.20	5.50	45.00	48.30	0.30	13761	14640	HV-A Bit.	9.40	DOE
74.	2.80	6.80	47.50	42.90	0.60	13150	14211	HV-A Bit.	0.72	BM
75.	4.70	4.70	41.50	49.10	0.30	12912	13610	HV-B Bit.	0.67	BM
76.	1.40	6.10	42.50	50.00	1.30	13757	14771	HV-A Bit.	2.20	BM
77.	3.30	4.00	41.90	50.00	0.40	13080	13681	HV-B Bit.	1.02	BM
78.	2.60	8.90	44.90	43.60	0.50	12720	14088	HV-A Bit.	0.93	BM
79.	1.60	4.40	40.20	53.80	0.50	13749	14450	HV-A Bit.	5.57	DOE
80.	1.70	6.00	45.10	47.20	0.50	13532	14485	HV-A Bit.	3.90	BM
81.	1.70	7.80	43.70	46.80	0.60	13239	14476	HV-A Bit.	7.15	DOE
82.	1.20	5.90	45.60	47.30	0.60	13900	14866	HV-A Bit.	8.25	DOE
83.	1.80	5.30	46.90	46.00	0.50	13864	14722	HV-A Bit.	8.43	BM

DOE = Department of Energy, Pittsburgh, Pennsylvania

(continued)

Table 3. Proximate analyses of coal samples tested for gas contents, as received.(continued)

Sample No.	As Received Percent M	Ash	VM	FC	S	AR Btu/lb.	Moist MM free Btu/lb.	Rank	Gas content cm^3/gram	Testing facility
84.	3.60	6.90	44.40	45.10	0.50	13225	14305	HV-A Bit.	0.21	BM
85.	4.00	6.90	40.80	48.30	0.30	12441	13451	HV-B Bit.	1.24	BM
86.	1.90	6.50	45.60	46.00	0.40	13553	14589	HV-A Bit.	1.50	DOE
87.	1.70	3.90	45.90	48.50	0.60	13902	14532	HV-A Bit.	7.20	DOE
88.									7.08	[2]
89.	1.50	20.80	38.60	39.10	0.90	11520	14895	HV-A Bit.	7.40	DOE
90.	1.70	5.70	45.70	46.90	0.60	13792	14717	HV-A Bit.	2.35	DOE
91.									0.51	[2]
92.	4.10	6.00	39.60	50.30	0.40	12756	13651	HV-B Bit.	1.75	DOE
93.	3.20	3.80	45.10	47.90	0.40	13446	14033	HV-A Bit.	1.03	DOE
94.	2.70	4.30	46.40	46.60	0.40	13479	14147	HV-A Bit.	3.00	DOE
95.									0.30	[2]
96.	2.00	6.40	43.60	48.00	0.50	13480	14497	HV-A Bit.	1.84	DOE
97.	2.50	7.70	44.40	45.40	0.40	12812	13986	HV-B Bit.	1.91	DOE
98.	3.40	7.10	43.20	46.30	0.70	12884	13974	HV-B Bit.	1.40	DOE
99.	3.70	4.90	42.50	48.90	0.40	13108	13851	HV-B Bit.	1.26	DOE
100.	3.00	5.10	39.80	52.10	0.30	12969	13733	HV-B Bit.	2.74	DOE
101.	2.20	8.40	46.70	42.70	0.40	13143	14467	HV-A Bit.	2.95	DOE
102.	2.30	5.20	43.30	49.20	0.60	13586	14413	HV-A Bit.	1.50	DOE
103.	2.20	6.80	44.00	47.00	0.40	13243	14305	HV-A Bit.	2.30	DOE
104.		Sample returned to donor							0.00 [1]	
105.	13.50	8.40	35.80	42.30	0.60	10233	11262	HV-C Bit. [3]	0.00	DOE
106.	15.00	5.20	37.10	42.70	0.70	10572	11210	HV-C Bit. [3]	0.09	DOE
107.	14.50	4.80	36.70	44.00	0.50	10632	11219	HV-C Bit. [3]	0.00	DOE
108.	2.10	8.80	46.30	42.80	0.70	13085	14482	HV-A Bit.	2.20	DOE
109.	2.40	6.00	42.60	49.00	0.70	13278	14219	HV-A Bit.	2.64	DOE
110.		Sample returned to donor							0.00 [1]	
111.		Sample returned to donor							0.00 [1]	
112.		Sample returned to donor							0.00 [1]	

[2] Sample not returned from laboratory, April 2, 1979

[3] Or subbituminous A coal

(continued)

Table 3. Proximate analyses of coal samples tested for gas contents, as received.(continued)

Sample No.	As Received Percent M	Ash	VM	FC	S	AR Btu/lb.	Moist MM free Btu/lb.	Rank	Gas content cm^3/gram	Testing facility
113.	2.00	7.20	40.90	49.90	0.70	13346	14494	HV-A Bit.	11.02	DOE
114.	1.70	5.90	45.10	47.10	0.50	13694	14642	HV-A Bit.	10.63	DOE
115.	1.40	7.10	40.80	50.70	0.40	13302	14419	HV-A Bit.	2.57	DOE
116.	15.40	3.40	37.50	43.70	0.40	10738	11152	HV-C Bit.[3]	0.22	DOE
117.	13.60	5.10	36.50	44.80	0.50	10748	11381	HV-C Bit.[3]	0.19	DOE
118.	14.20	5.10	36.10	44.60	0.50	10690	11320	HV-C Bit.[3]	0.00	DOE
119.	1.20	6.60	50.90	41.30	0.50	13921	15007	HV-A Bit.	1.86	DOE
120.	1.80	6.50	47.30	44.40	0.50	13595	14638	HV-A Bit.	4.65	DOE
121.	5.60	37.60	24.60	32.20	0.70	7723	13029	HV-B Bit.	0.00	DOE
122.	7.90	10.10	37.10	44.90	1.20	11406	12830	HV-C Bit.	0.00	DOE
123.	7.70	10.20	36.10	46.00	0.60	11494	12931	HV-C Bit.	0.00	DOE
124.	7.60	6.10	35.50	50.80	0.50	12182	13053	HV-B Bit.	0.09	DOE
125.	6.90	11.70	34.20	47.20	0.50	11397	13058	HV-B Bit.	0.00	DOE
126.	6.50	9.10	36.50	47.90	0.50	11935	13248	HV-B Bit.	0.00	DOE
127.	7.10	6.30	34.20	52.40	0.60	12325	13240	HV-B Bit.	0.05	DOE
128.	4.80	20.90	32.00	42.30	0.70	10449	13517	HV-B Bit.	0.11	DOE
129.	4.30	27.90	30.00	37.80	2.50	9492	13676	HV-B Bit.	0.00	DOE
130.	4.70	7.80	36.90	50.50	0.70	12524	13695	HV-B Bit.	0.00	DOE
131.	3.50	5.30	41.40	49.80	1.80	13139	13988	HV-B Bit.	0.50	DOE
132.	2.80	16.40	36.40	44.40	2.20	11508	14058	HV-A Bit.	0.00	DOE
133.	2.30	10.90	36.50	50.30	1.50	12638	14374	HV-A Bit.	0.09	DOE
134.	2.00	4.30	40.10	53.60	0.60	13843	14536	HV-A Bit.	0.26	DOE
135.	2.60	18.20	35.00	44.20	0.70	11125	13870	HV-B Bit.	0.00	DOE
136.	3.10	1.50	42.40	53.00	1.00	14066	14327	HV-A Bit.	0.39	DOE
137.	4.00	3.20	41.40	51.40	0.90	13744	14263	HV-A Bit.	0.31	DOE
138.	4.60	4.60	39.10	51.70	0.60	12807	13492	HV-B Bit.	2.93	DOE
139.	4.20	9.70	38.90	47.20	1.10	12189	13646	HV-B Bit.	2.19	DOE
140.	3.30	6.60	41.10	49.00	0.70	12913	13924	HV-B Bit.	4.52	DOE
141.	3.60	4.80	40.90	50.70	0.60	13021	13749	HV-B Bit.	1.30	DOE

(continued)

Table 3. Proximate analyses of coal samples tested for gas contents, as received.(continued)

Sample No.	As Received Percent M	Ash	VM	FC	S	AR Btu/lb.	Moist MM free Btu/lb.	Rank	Gas content cm^3/gram	Testing facility
142.	3.80	4.60	39.40	52.20	0.60	13159	13864	HV-B Bit.	1.58	DOE
143.	3.00	3.50	42.20	51.30	0.50	13554	14101	HV-A Bit.	0.51	DOE
144.									2.01	2
145.	2.80	5.90	38.80	52.50	1.00	13125	14047	HV-A Bit.	1.03	DOE
146.	6.70	25.70	33.00	34.60	1.70	9362	13010	HV-B Bit.	0.02	DOE
147.	8.40	3.00	39.40	49.20	0.80	12731	13176	HV-B Bit.	0.02	DOE
148.	7.60	3.20	39.90	49.30	0.50	12919	13394	HV-B Bit.	0.02	DOE
149.	6.60	7.00	38.60	47.80	0.60	12481	13518	HV-B Bit.	0.00	DOE
150.	4.50	20.30	35.70	39.50	0.70	10581	13574	HV-B Bit.	0.31	DOE
151.	6.70	12.70	36.10	44.50	0.90	11627	13501	HV-B Bit.	0.16	DOE
152.	6.40	6.70	36.50	50.40	0.60	12581	13578	HV-B Bit.	0.00	DOE
153.	4.20	11.30	36.90	47.60	0.60	12023	13712	HV-B Bit.	0.31	DOE
154.	4.40	7.80	38.40	49.40	0.50	12708	13891	HV-B Bit.	0.29	DOE
155.	4.30	8.70	39.30	47.70	0.70	12676	14012	HV-A Bit.	0.45	DOE
156.	6.30	2.70	39.20	51.80	0.60	13024	13461	HV-B Bit.	0.77	DOE
157.	5.30	11.50	38.40	44.80	0.60	11804	13528	HV-B Bit.	1.50	DOE
158.	5.10	11.20	36.40	47.10	0.60	12015	13719	HV-B Bit.	1.11	DOE
159.	4.70	26.10	33.00	36.20	0.70	9760	13664	HV-B Bit.	0.80	DOE
160.	5.60	6.20	42.00	46.20	0.50	12738	13692	HV-B Bit.	1.43	DOE
161.	5.90	2.60	39.00	52.40	0.60	13236	13664	HV-B Bit.	1.40	DOE
162.	1.80	10.90	40.20	47.10	0.40	12797	14540	HV-A Bit.	2.68	DOE
163.	1.70	9.0	43.90	45.40	1.70	13040	14464	HV-A Bit.	9.90	DOE
164.	1.60	6.60	41.60	50.20	0.60	13762	14871	HV-A Bit.	2.07	DOE

straight line curve for coal samples taken near old workings or taken where desorption has been induced. In essence, depth of burial appears to favor the formation of gas in coal; natural or induced desorption cause the sample points to rain downward on the field of the graph.

Cores react in many ways to the desorption process. Some release the gas quickly and have little or no residual gas (samples 106, 116, 117, and 134); others give up little gas to desorption, but give up large amounts upon crushing (samples 84-86, 97-99,102,103, and 108). It is thought that these differences are due to the internal structure or physical nature of the coal itself, i.e., the absence or presence of cleat, microscopic shear zones, etc.

The total gas contents contained in the test samples range from 0 to 11.02 cubic centimeter/gram of coal. A gas content of one cubic centimeter/gram would indicate about 32 cubic feet of gas per ton of coal in place. After several years of operation a 3,000 ton per day mine should theoretically exhaust 96,000 cubic feet per day. However, experience has shown that mines, especially those with extensive old workings and gob areas, produce 6 to 9 times the direct amount. Hence the above mine would probably exhaust about 600,000 cubic feet per day. If the gas content of coal as calculated was as high as 11 cubic centimeter/gram that 3,000 ton per day mine might exhaust over 7,000,000 cubic feet of gas per day. For purposes of this report a coal containing 5 cubic centimeters/gram or more is gassy, 1 to 5 cubic centimeters/gram is moderately gassy, and less than 1 cubic centimeter/gram is considered a low gassy coal. This classification is intended for use in this paper only and is not to be construed as an attempt to classify coal or mine gases, but rather as a means to facilitate discussion in this paper. A mine with a record of emitting low amounts of gas may be hazardous if not properly ventilated. By the standard suggested the Book Cliffs coal field is moderately gassy to gassy, the Wasatch Plateau has mostly low gassy coals with occasional local areas of low moderately gassy coals, the Sego field coal is low to moderately gassy, and all the remaining tested fields have low gassy coals. Considering the number of tests made in most of the fields the assignments are by no means finalized.

COMPOSITION OF COAL GAS AND COAL ANALYSES

Donated coal cores were analyzed whenever permission was obtained from the donor. The proximate constituents, sulfur, and Btu/lb. determinations are reported in table 3. The moist mineral matter free Btu were calculated using a Parr formula and the rank was assigned using the ASTM (American Society for Testing and Materials) system. Moist mineral-matter free Btu/lb. figures are compared to the gas contents of the core samples in figure 7, MAF (moisture-ash free) fixed carbon figures are compared to the gas contents in figure 8, and the MAF oxygen of the available ultimate analyses are compared in figure 9. It is felt, through our work, that gas contents are related to rank or degree of metamorphism of the coal as well as to depth of burial. The depth of burial may only be indirectly responsible for gas development in coal; the pressure and temperature increases due to deep burial are recognzied as features favoring metamorphism.

Nevertheless there are no positive relationships shown in figures 7 to 9. There are too few samples available at this time for coals of lower rank. There is a hint in figure 7 that higher rank (higher moist mineral matter free Btu/lb.) coal will contain more gas as suggested by the curve. At least no samples to date can be classed as gassy that yield under 13,000 Btu/lb. on the moist mineral matter free basis. However, three samples between 11,000 and 13,000 Btu/lb. contained 1-2 cubic centimeter/gram of gas (low moderately gassy). Absolutely no

hint or correlation comes from figure 8 where fixed carbon content is compared to gas contents. No samples were checked containing less than 47 percent fixed carbon on a moisture-ash free basis. Fewer ultimate analyses were available so that fewer points could be plotted on figure 9 on which MAF (moisture ash free) oxygen is plotted against gas contents. The curve suggests that coals low in oxygen have higher gas content.

An attempt was made to see if one bed or zone of coal in the Book Cliffs field (where most samples were available) had a higher gas content. It was found that a particular coal bed shows no appreciable difference from another located in the same general area. Location makes more difference. Several coal beds intercepted by a single drill hole tend to have similar gas characteristics.

Samples of gas were collected in vacutainers. Vacutainers are hollow glass tubes containing a vacuum. When a seal is broken gas is drawn into the tube, whereupon it is resealed. About 20 samples of desorbing gases were taken and analyzed; the results are given in tables 4 and 5. Improper laboratory apparatus and conditions allowed atmospheric contamination, mostly with the introduction of nitrogen, oxygen, and argon. In the atmosphere the nitrogen/oxygen + argon ration is 3.57 and most of the tests approximated this. Analyses of all gases, including the atmospheric contaminants, are given in table 4. It is interesting to note that after correcting for the contamination the results were reasonably uniform (table 5). Methane (CH_4) made up 89 to 95 percent, ethane (C_2H_6) 1 to 4 percent, CO_2 1-8 percent and heavier combustible gases made up the remainder. The gas averages 95 percent combustibles and 5 percent noncombustibles, primarily carbon dioxide (CO_2). Occasionally a small amount of carbon monoxide was detected. The U.S. Bureau of Mines (Perry, Aul, and Cervik, 1978), analyzing gas desorbing from two horizontal drill holes in the Sunnyside No. 1 mine in the Book Cliffs coal field, reported methane in excess of 99 percent and Btu/cubic foot in excess of 1,000 (table 6).

UTAH COAL FIELDS

The general geology, coal bed data, and production and reserve statistics for Utah are discussed in Doelling and Graham, 1972 a & b, and Doelling, 1972. Coal production and coal resources for the principal coal fields of Utah are reviewed in table 2. Although coal has been found in many parts of the state, 96½ percent of the coal Utah has produced has been mined in the Book Cliffs and Wasatch Plateau coal fields (374 million tons, 1870-1978). This trend continues; in the last few years 97½ percent has come from these two fields. Since 1960 most of the exploratory effort has been concentrated in these two fields and in others with favorable futures: Emery, Kaiparowits Plateau, Henry Mountains, Alton, and Sego. All of the reported gas tests were made possible by recent exploration in these fields. No tests have been possible in the other fields as yet.

Important to the discussion of gas in coal is a description of the geologic, qualitative, and physiographic features of the coal fields with emphasis on areas where the tests have been available. This knowledge helps in understanding some of the inconsistencies that appear in the data and makes possible some interpretations and conclusions.

Table 4. Composition of gases collected in 15 and 20 ml vacutainers from coal core canisters.

Sample No.	H_2	O_2+Ar	N_2	CO_2	CO	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	Heavier	Analyzed by	N_2/O_2+Ar
79.	ND	3.60	18.00	6.25	ND	70.40	1.70	0.0700	0.0059	0.0002	ND	Bur.Mines	5.00
82.	ND	9.40	35.80	0.66	ND	52.30	1.70	0.1000	0.0204	0.0014	ND	Bur.Mines	3.81
83.	ND	9.60	36.00	2.20	ND	51.50	0.59	0.0700	0.0148	0.0010	ND	Bur.Mines	3.75
87.	ND	12.60	46.90	1.50	ND	37.95	0.96	0.0700	0.0078	0.0005	ND	Bur.Mines	3.72
88.	ND	9.80	35.90	1.60	ND	51.35	1.20	0.1300	0.0187	0.0010	ND	Bur.Mines	3.66
89.	ND	7.50	29.95	3.45	ND	56.85	2.10	0.1400	0.0213	0.0017	ND	Bur.Mines	3.99
90.	ND	5.50	20.10	3.55	ND	68.35	2.30	0.1900	0.0296	0.0021	ND	Bur.Mines	3.65
92.	ND	15.95	65.60	1.20	<0.01	16.65	0.56	0.0100	0.0049	0.0027	ND	Bur.Mines	4.11
93.	ND	18.35	71.15	0.49	<0.01	9.70	0.29	0.0077	0.0036	0.0005	ND	Bur.Mines	3.88
73.	ND	15.60	53.60	2.00	ND	26.90	0.90	---	---	---	---	Bur. Mines	3.44
81.	ND	8.65	25.60	4.80	ND	58.40	1.55	---	---	---	---	Bur. Mines	2.96
89.	ND	5.60	16.70	3.60	ND	70.20	2.90	---	---	---	---	Bur. Mines	3.04
88.	ND	5.60	18.85	2.20	ND	70.55	1.80	---	---	---	---	Bur. Mines	3.37
96.	ND	11.00	42.15	0.60	ND	43.80	1.50	---	---	---	---	Bur. Mines	3.83
	---	5.20	26.10	5.40	---	61.50	1.40	0.3000	0.0270	0.0050	0.0020	Bur. Mines	5.01
												Normal Atmospheric Ratio	3.57

Note: Additional analyses were performed by Utah Engineering Experiment Station and did not report the atmospheric contamination. These are reported with the above on table 5.

Note: The presence of oxygen, argon, and most nitrogen indicates contamination by atmospheric gases. Generally there was not enough sample to obtain completely accurate information, which may explain some of the erratic results. It is thought, however, that the data roughly do illustrate the composition of gases desorbed from coal cores. Table 4 shows the composition of gases eliminating the atmospheric contamination. Results in volume percent. ND = not detected.

Table 5. Composition of gases collected from coal core canisters, eliminating atmospheric contamination. (see table 3) (Results in volume percent) (PCG = Percent coal gas in vacutainer)

Sample No.	PCG	CO_2	CH_4	C_2H_6	C_3H_8	C_4H_{10}	C_5H_{12}	Analyst
79.	78.4	7.97	89.77	2.17	0.09	0.0075	0.0003	Bur. Mines
82.	54.8	1.20	95.47	3.10	0.18	0.0438	0.0026	Bur. Mines
83.	54.4	4.04	94.72	1.08	0.13	0.0272	0.0018	Bur. Mines
87.	40.5	3.70	93.74	2.37	0.17	0.0193	0.0012	Bur. Mines
88.	54.3	2.95	94.56	2.21	0.24	0.0344	0.0018	Bur. Mines
89.	62.6	5.52	90.86	3.36	0.22	0.0341	0.0027	Bur. Mines
90.	74.4	4.77	91.84	3.09	0.26	0.0398	0.0028	Bur. Mines
92.	18.5	6.51	90.36	3.04	0.05	0.0266	0.0146	Bur. Mines
93.	10.5	4.67	92.46	2.76	0.07	0.0343	0.0048	Bur. Mines
73.	30.8	6.71	90.27	3.02	---	---	---	Bur. Mines
81.	65.8	7.41	90.19	2.40	---	---	---	Bur. Mines
89.	77.7	4.69	91.53	3.78	---	---	---	Bur. Mines
88.	75.6	2.95	94.64	2.41	---	---	---	Bur. Mines
96.	46.9	1.31	95.43	3.26	---	---	---	Bur. Mines
	68.7	7.87	89.57	2.04	0.4367	0.0699	0.0102	Bur. Mines
79.	?	4.30	89.70	4.50	1.4	---	---	U. E. E. S*
73.	?	6.70	89.40	2.90	0.9	0.1	---	U. E. E. S*.
82.	?	4.90	91.40	2.30	0.6	0.8	---	U. E. E. S*
83.	?	4.90	92.80	1.00	0.5	0.8	---	U. E. E. S*
72.	?	4.90	92.20	2.10	0.8	---	---	U. E. E. S*
81.	?	4.90	92.58	2.12	0.5	---	---	U. E. E. S*

*Utah Engineering Experiment Station

Table 6. Analyses of gas from two holes drilled by U. S. Bureau of Mines in Sunnyside No. 1 mine, Book Cliffs coal field, Utah. (Ref. Perry, Aul, and Cervik, 1978).

Composition		Hole 1	Hole 2
Methane	pct	99.24	99.24
Ethane	pct	0.28	0.08
Propane	pct	0.03	0.03
Oxygen	pct	0	0.60
Nitrogen	pct	0.65	0.30
Carbon dioxide	pct	0	0
Btu		1,005	1,009
Specific gravity		0.56	ND

ND Not determined

Table 7. Average proximate analyses of Emery field coal in percent.

	SOUTH 13 drillholes	CENTRAL Dog Valley Mine	NORTH Browning Mine
Moisture	7.9	7.2	4.5
Volatile Matter	39.8	38.4	39.5
Fixed Carbon	45.2	44.9	48.5
Ash	7.1	9.5	7.5
Sulfur	1.28	0.7	0.85
Btu/lb.	11,246	11,903	12,686

Book Cliffs Coal Field

The Book Cliffs coal field consists of 70 miles of Cretaceous coal-bearing outcrop extending easterly from the North Gordon fault zone to Sunnyside and then southeasterly to the Green River (figure 10). The coal beds are in the Blackhawk Formation of the Mesaverde Group of Cretaceous age. The field is exposed along high cliffs at the south edge of the Uinta Basin. Although dips are gentle to moderate basin-ward, cover builds rapidly behind the outcrop so that only a 4-to 12-mile wide strip along the cliffs is available to easy mining. Farther north or northeastward the cover builds to more than 3,000 feet. The cliff-front is irregularly and deeply cut by perpendicular drainages so that the cover over the coal varies drastically between spur and canyon. Locally the coal-bearing rocks are cut by high-angle faults.

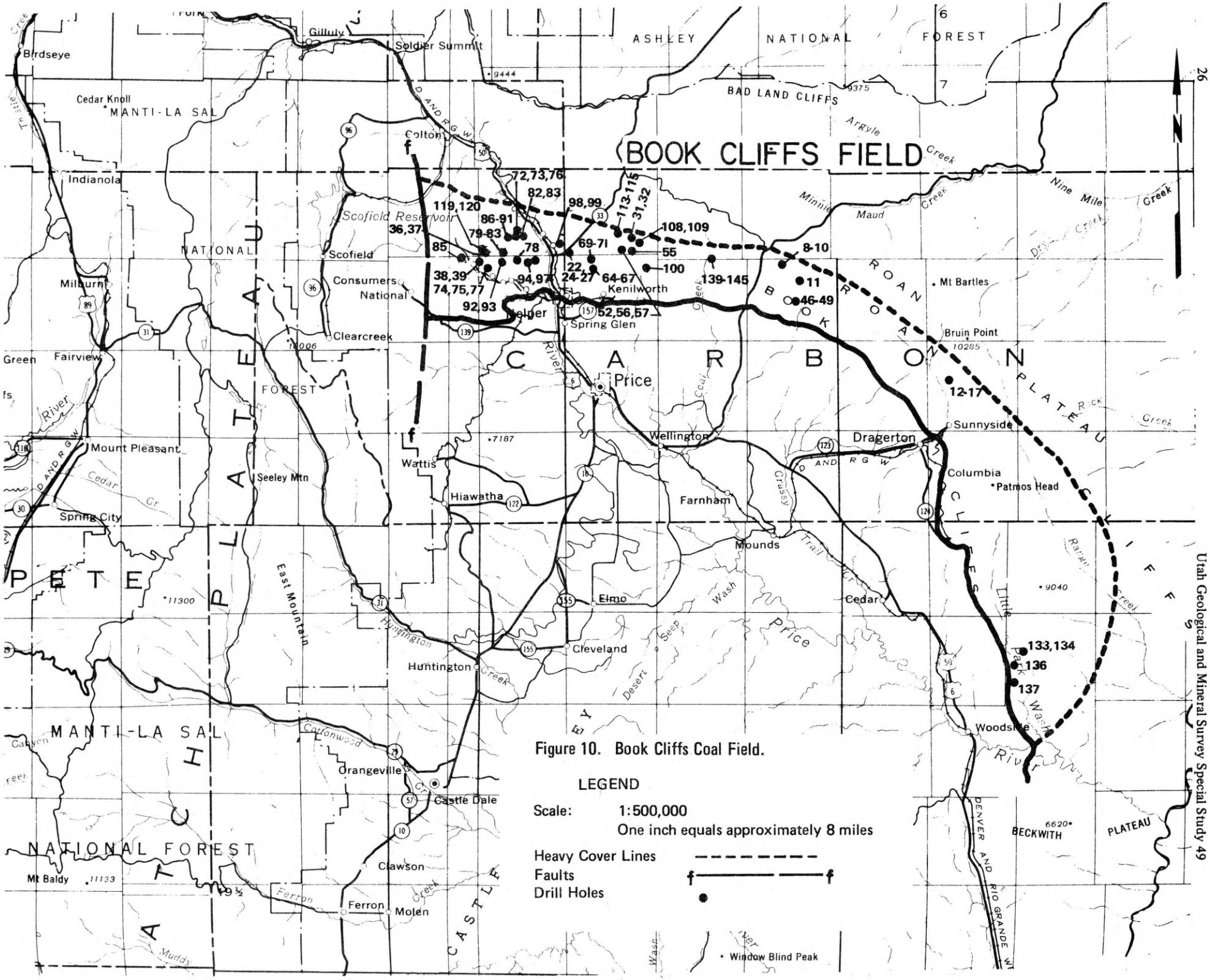
The field has been the most productive of any in Utah and important mines extend from the Emery-Carbon county line on the east to the west margins of the field some 12 miles west of Price. The mining has occurred under cover ranging to 2,700 feet. In some areas lengths to 13 miles have been mined out with 2 to 2.5 mile widths. In other areas multiple seams have successfully been mined.

The geology indicates an eastward-regressing sea during the Cretaceous period so that coal beds mined to the west are slightly older than those mined to the east (figure 11). Coal bed thicknesses range to more than 25 feet; most mined seams are in the 6 to 13 foot range. The older and lower beds are thick and minable to the west; the younger and upper beds are thick and minable to the east. Separation between beds ranges to several hundred feet.

The coal is mostly high volatile A or B bituminous coal in rank (many sources documented in Doelling, 1972) and has the following average proximate characteristics: moisture 4.8 percent, volatile matter 3.9 percent, fixed carbon 49.1 percent, ash 6.7 percent, sulfur 0.85 percent and 12,760 Btu/lb. The coal in the central part of the field is a coking coal, but must be blended with 20 to 25 percent of low or medium volatile coals from other sources to achieve a metallurgical grade.

Tests show that the coal beds of the Book Cliffs field north of the Carbon-Emery county line are moderately gassy to gassy only. Although the quality of the coal is the same south of the line, it contains much less gas. There are no obvious explanations, but an interesting suggestion comes by superimposing aeromagnetic contours over the area (figure 12). High magnetic readings coincide with Utah's area of gassy coals. The high magnetic areas may indicate the emplacement of magnetic materials in the basement may have been responsible for increasing heat or pressure and thereby favor gas formation or the formation of coking coal. Another reason may be that Book Cliffs coals in Emery county were not subject to as deep burial during their geologic history.

Every coal bed was tested and there appears to be very little difference between them in overall results, except for the difference in gas contents north and south of the county line. Exploratory drill holes were mostly placed in extension of mined areas or areas being mined. This probably explains the large number of tests yielding 0.5 to 4 cubic centimeters/gram of coal. There are significant numbers of tests yielding in excess of 5 cm^3/gram. Many of the tests yielding high gas contents were significantly removed


BOOK CLIFFS FIELD
ASHLEY NATIONAL FOREST
BAD LAND CLIFFS
MANTI-LA SAL
NATIONAL FOREST
PETETHCAN PLATEAU
CARBON
ROAN PLATEAU
BOOK CLIFFS
CASTLE VALLEY
Gilluly
Soldier Summit
Birdseye
Cedar Knoll
Colton
Indianola
Scofield Reservoir
Scofield
Consumers National
Helper
Kenilworth
Spring Glen
Price
Wellington
Dragerton
Sunnyside
Columbia
Patmos Head
Bruin Point
Mt Bartles
Milburn
Fairview
Clearcreek
Mount Pleasant
Spring City
Seeley Mtn
Wattis
Hiawatha
Farnham
Mounds
Cedar
Elmo
Cleveland
Huntington
Orangeville
Castle Dale
Clawson
Ferron
Molen
Woodside
Mt Baldy
BECKWITH PLATEAU
Window Blind Peak
Figure 10. Book Cliffs Coal Field.
LEGEND
Scale: 1:500,000
One inch equals approximately 8 miles
Heavy Cover Lines
Faults
Drill Holes

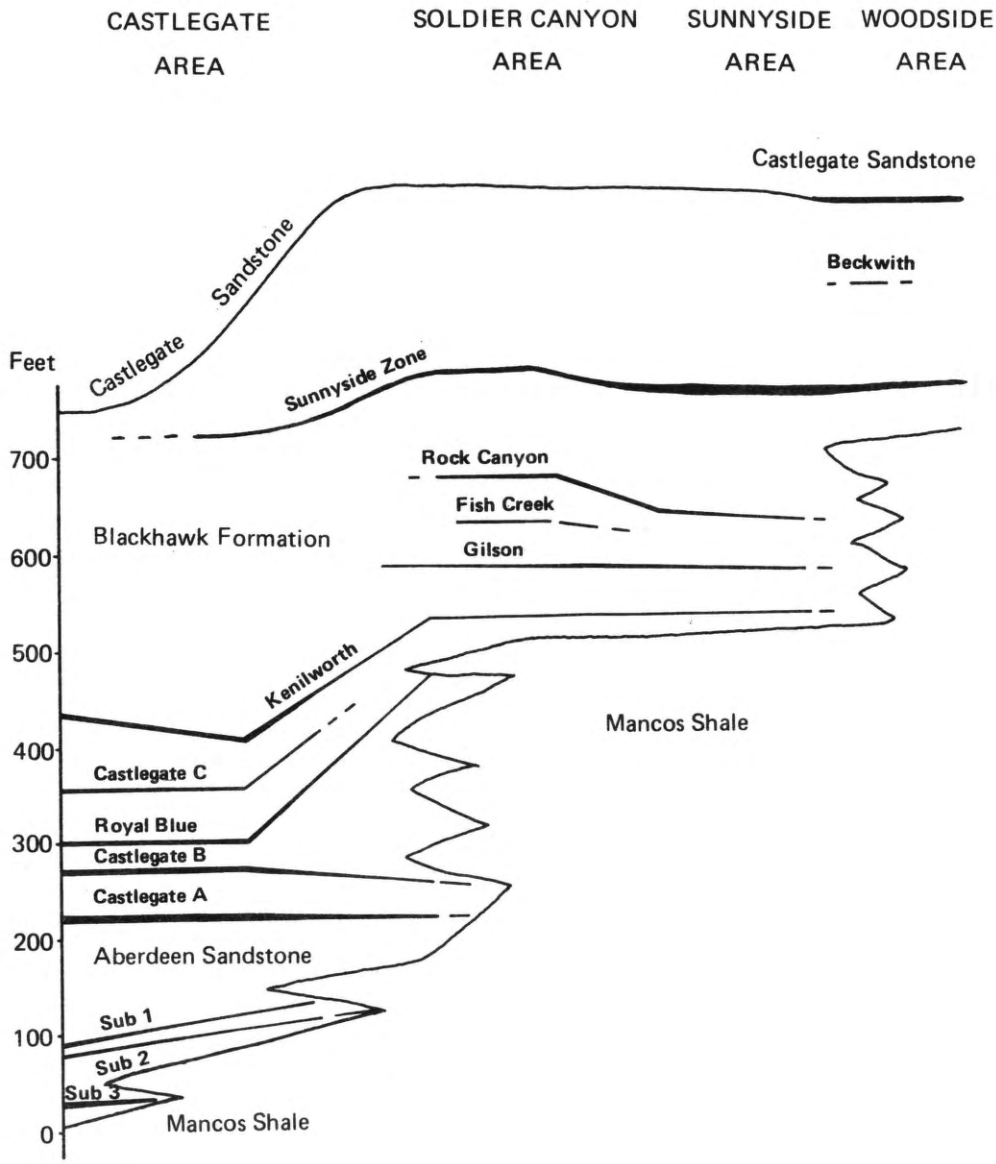


Figure 11. Coal beds of the Book Cliffs coal field. Horizontal distance between edges of the diagram represents about 40 miles.

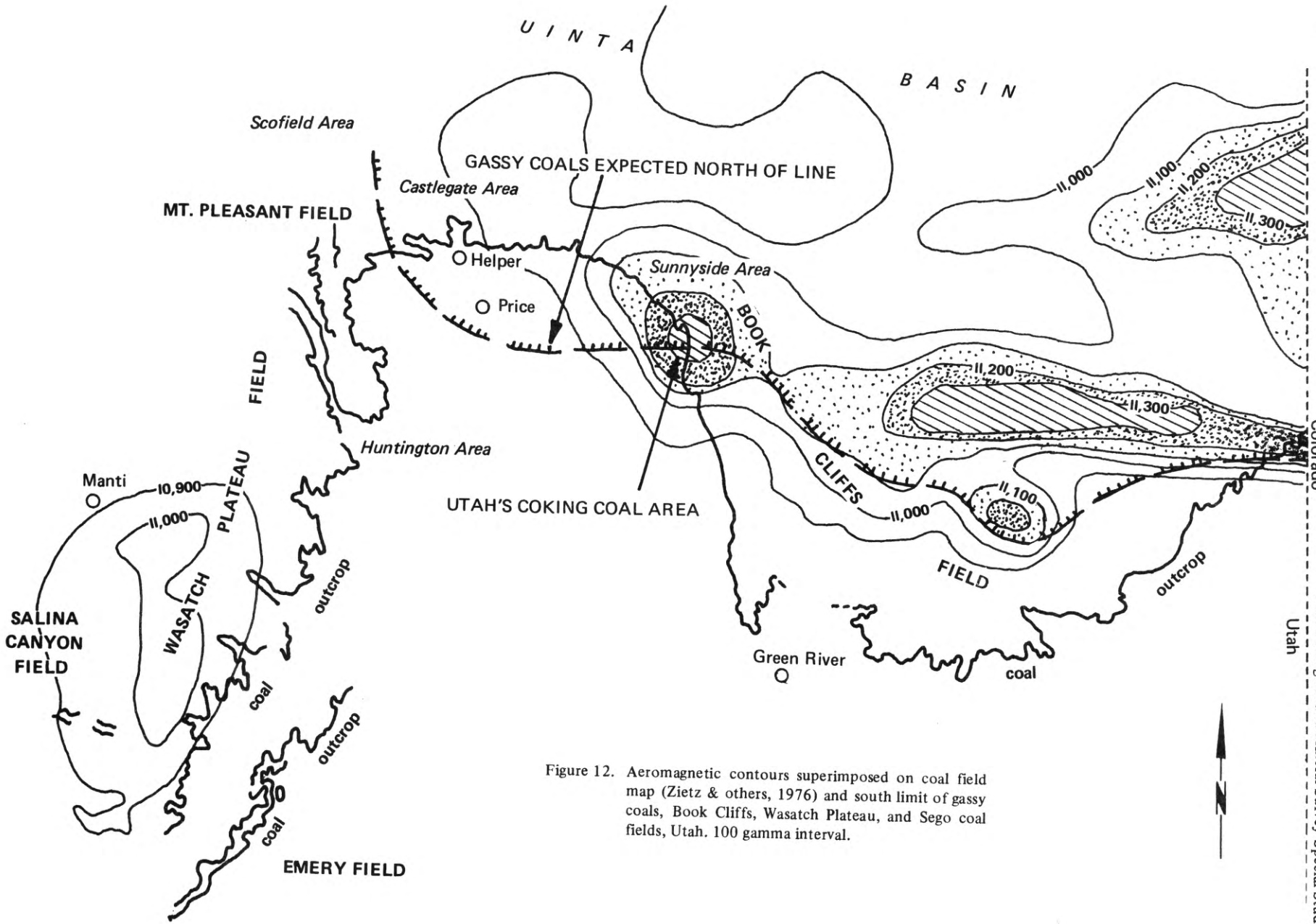


Figure 12. Aeromagnetic contours superimposed on coal field map (Zietz & others, 1976) and south limit of gassy coals, Book Cliffs, Wasatch Plateau, and Sego coal fields, Utah. 100 gamma interval.

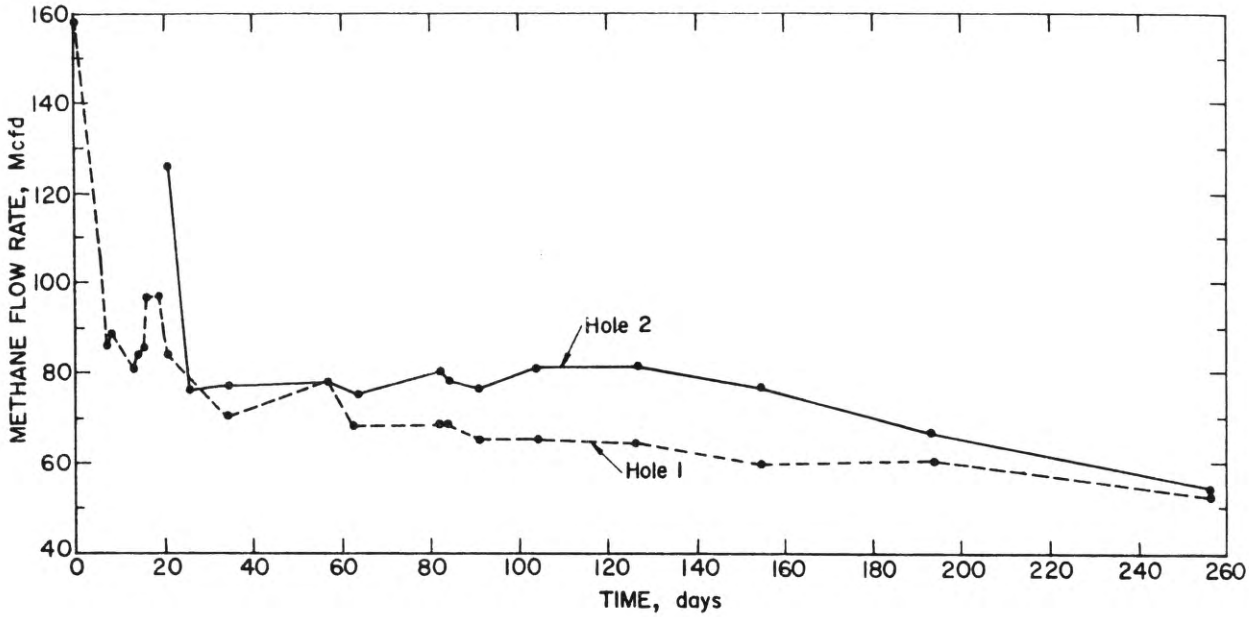
from old workings or outcrops, but a few were significantly close. This lends credence to the supposition that the internal character of the coal bed or its host rock is very important to the natural or induced desorption rate.

The U.S. Bureau of Mines drilled several holes in Kaiser Steel's Sunnyside mines in the Book Cliffs field to determine the effectiveness of long horizontal holes to degasify an area of coal (Perry, Aul and Cervik, 1978). Two holes were drilled, 430 and 450 feet long respectively, into an upper split of the Sunnyside coal zone. The two had initial gas flows of 160,000 and 127,000 cubic feet per day. After 16 days the combined flow decreased to a little over 144,000 cubic feet per day and after 9 months declined to about 106,000 cubic feet per day. The two holes reduced nearby face emissions about 40 percent. Methane decline curves for the holes and from a nearby face are given as figure 13. The Bureau of Mines' report indicates that methane was encountered during roof-bolting from a 2-foot-thick rider and that gas bubbles were observed from a lower split. Kaiser Steel has indicated a desire to convert a coal-fired boiler plant to coal gas with the fuel derived from degassing coal beds. Other companies and property holders have expressed similar interests. The U.S. Bureau of Mines also experimented in the Sunnyside No. 3 mine and found that there were considerable differences in the methane flow rates when compared with those in the Sunnyside No. 1 mine. The Utah Geological and Mineral Survey subsequently mapped and sampled the coal beds throughout the mines to determine what some of the factors might be contributing to the differences. Rib emissions in the Bureau's study area in the No. 3 mine measured less than 1 cubic foot/day/square foot whereas they were 8.4 cubic feet/day/square foot in the No. 1 mine in limited readings. The results of the Utah Survey's findings are given in part two of this report.

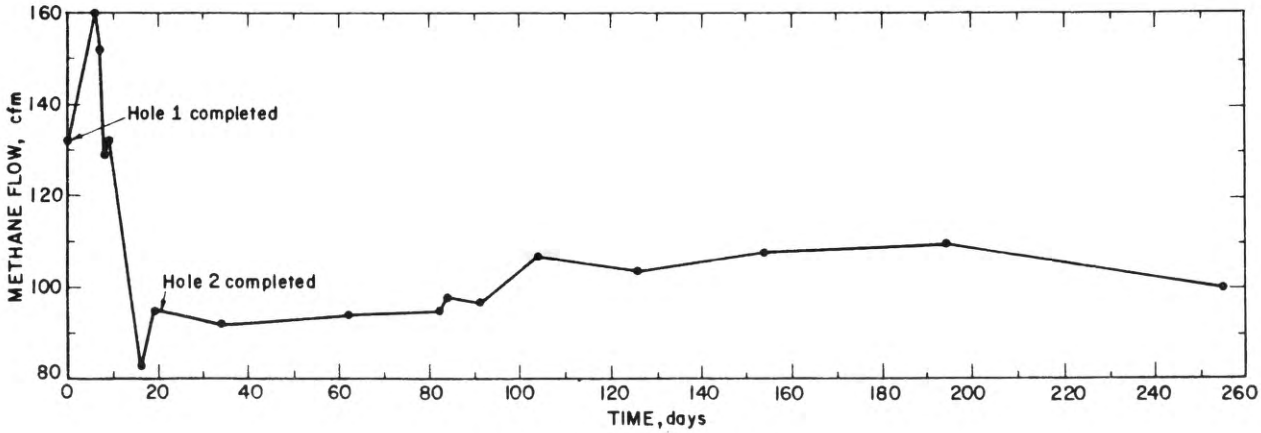
Wasatch Plateau Coal Field

The Wasatch Plateau coal field is an area in central Utah of nearly north-south trending Cretaceous coal-bearing outcrop about 90 miles in length and 7 to 20 miles in width. The east boundary consists of cliffs, the coal cropping out along the faces. Overlying units finally cover the coal-bearing unit, the Blackhawk Formation of the Mesaverde Group, with more than 2,500 feet of cover at the west margin. A structural feature known as the Wasatch monocline and faulting drop the favorable unit to uneconomical depths a short distance farther to the west. To the north the coal plunges into the Uinta Basin and to the south the coal is finally buried beneath volcanics. It is contiguous with the Book Cliffs coal field at its northeast end, but separated from it by the North Gordon fault zone. The field is cut by several significant fault zones that trend not quite parallel to the long axis of the field (figure 14). Dips are mostly gentle in a west-northwesterly direction. Numerous canyons cut the cliff front and indent the coal outcrops to the west.

The field has been the second most productive in Utah and is presently the leading producer. The most important mines of past and present are located in the north half of the field; a few mines are at the south end where there are thicker, more favorable seams and because of proximity to transportation routes. At the north end some multiple seam mining has been carried out. There are larger mined out areas within a mile of the cliff-fronts, but mined-out areas are not as extensive or as continuous as in the Book Cliffs field.



Methane decline curves for holes 1 and 2.



Methane flows through face.

Figure 13. Methane decline curves as reported in U. S. Bureau of Mines Report of Investigations 8323 for the Sunnyside No. 1 mine, Book Cliffs coal field.

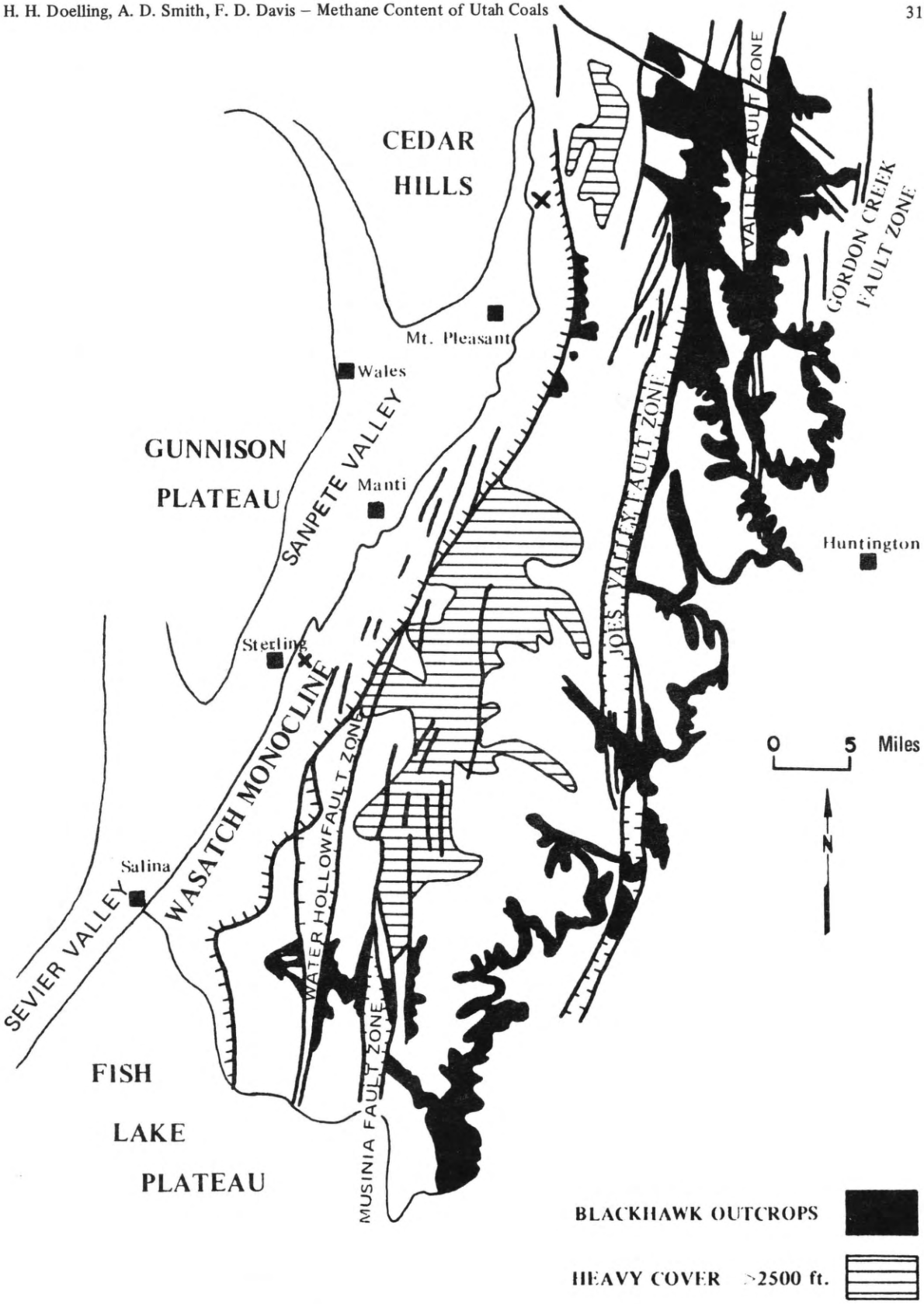


Figure 14. Principal structural features in the vicinity of the Wasatch Plateau.

The geology shows that the important coal beds are located in the lower 300 feet of the 700 to 1500-foot Blackhawk Formation. Coal bed thicknesses range to more than 25 feet, but most mined seams are in the 8 to 13-foot range. Separation between beds ranges to several hundred feet. Coal beds are not continuous north to south and there are areas with only thin coals present in the central and extreme southern parts of the field (figure 15).

Qualitatively the coal improves in rank south to north and to a lesser degree, west to east. The rank to the south is high volatile C bituminous and north of Straight Canyon is high volatile B bituminous (analyses from many sources as documented in Doelling, 1972). Within the criteria set for high volatile B bituminous coal, the northeast part of the field has a somewhat higher moist mineral matter free Btu than in the northwestern part. In the northwest part of the field occasional samples are collected that are high volatile C bituminous in rank. In the south the average as-received proximate characteristics read moisture 8.7 percent, volatile matter 38.3 percent, fixed carbon 46.5 percent, ash 6.5 percent, sulfur 0.46 percent and Btu/lb. 11,770. In the northwest the average proximate characteristics are moisture 6.3 percent, volatile matter 41.8 percent, fixed carbon 43.8 percent, ash 8.1 percent, sulfur 0.59 percent, and Btu/lb. 12,053. In the northeast the average proximate characteristics are moisture 5.6 percent, volatile matter 42.3 percent, fixed carbon 45.7 percent, ash 6.2 percent, sulfur 0.61 percent and Btu/lb. 12,719. Locally there are areas of high volatile A bituminous coal. No metallurgical coals have been found in the Wasatch Plateau coal field.

Tests show that most of the coal beds and areas of the Wasatch Plateau field have low measured gas content. Only 19 tests have been made, several of which were incomplete because the core had to be returned to the donor without obtaining residual gas measurements or coal analyses. More tests are necessary to finalize any conclusions about gas in the coal of the field. Tests taken in the southern and northwestern parts of the field have low measured gas content. A few in the northeastern part of the field are low moderately gassy, between 1 and 2 cm^3/gram. The tested coal beds include the Hiawatha, Blind Canyon, Ivie and Upper Ivie, Bear Canyon and O'Connor (Castlegate Group). All of the low moderately gassy tests were in the Hiawatha. About half of the drill holes were placed to extend mined areas or areas being mined. Handwritten historical notes by unknown Survey and Bureau of Mines workers, active prior to World War II, indicate that only one mine in the entire field ever noted any gas (Utah Geological and Mineral Survey archives). This was the Deer Creek mine in Lower Huntington Canyon. The present mine has no significant gas problems. The May 1, 1900 explosion at the Winterquarters mine near Scofield (northwest part of field), that killed 200 people, was caused by an accidental explosion of black powder. Coal dust may have been involved as well. No gas tests were available for the Gordon Creek area of the Wasatch Plateau field which is adjacent to the Spring Canyon area (west of Castlegate) of the Book Cliffs field. The two areas are separated by the North Gordon fault zone. Coal core tests indicate that the Spring Canyon area is moderately gassy to gassy. The old handwritten notes indicate that about half the mines in the Spring Canyon area were gassy or had problems with gas.

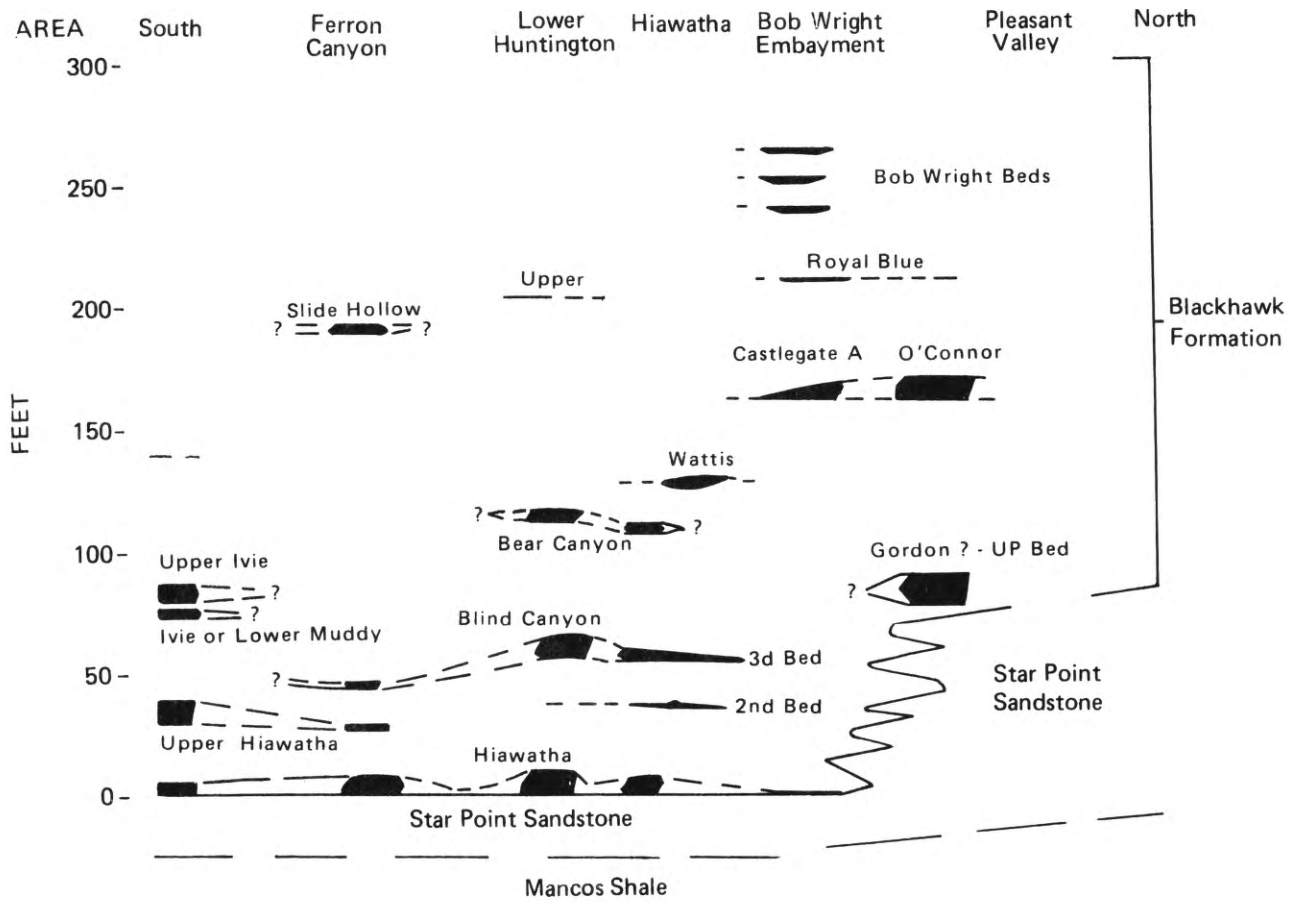


Figure 15. Coal beds of the Wasatch Plateau coal field. The horizontal distance between the edges of the diagram represents about 70 miles.

Emery Coal Field

The important part of the Emery coal field is located immediately east of the southern third of the Wasatch Plateau field and its outcrops roughly parallel it. About half is in Emery County, the other half is in Sevier County. The field is about 35 miles in length and 4 to 8 miles wide. Additional coal has been discovered in the subsurface in Carbon County under heavy cover; presently there is no gas data for that part of the field. In the principal area the coal crops out along the southeast margin of the field near the top and along a series of sandstone cliffs. These cliffs are indented northwestward at irregular intervals by transverse canyons. To the north the coal thins and disappears in outcrop; to the south the coal beds are lost under volcanics, and to the west and northwest the coal is buried under the heavy cover of overlying formations. The coal is contained in the upper part of the Ferron Sandstone Member of the Mancos Shale. Hence the coal is older than that in the Wasatch Plateau and Book Cliffs fields. Dips are mostly gentle in a west-northwesterly direction. The overburden over most areas is not significant, ranging from 0 to 1000 feet; very large areas are found where the coal is buried under less than 500 feet of cover.

The field has been a small but regular producer of coal in Utah, fourth in overall rank and third presently. There have only been one or two important mines and the mined areas are localized. Many small wagon mines produced a little coal in the early days and were scattered over the area, most not affecting more than a few acres close to the outcrop. The field has been hampered in its development because of its distance to traditional markets and because of its somewhat lower overall quality.

The geology indicates the presence of many coal beds in the coal-bearing part of the Ferron Sandstone Member. The coal-bearing part is 400 to 500 feet thick and coal beds have been given letter designations, A to M (ascending order). These can be grouped into three zones; lower, middle, and upper (figure 16). Coal beds range to about 13 feet in thickness, but they are notoriously lenticular and discontinuous and a thick bed can diminish very quickly over short distances. In some areas two coal beds fuse and fused beds can be found to 25 feet in thickness.

Coals in the northern part of the field are of higher rank than those in the south. Coal analyzed from drill-holes in the southern part of the field indicate a high volatile C bituminous rank and coal analyzed from operating mines in the northern part of the field indicate a high volatile B bituminous coal. Average proximate analyses are given in table 7. The ash and sulfur contents of coal beds can be locally very high and vary considerably from coal bed to coal bed.

Only six tests were made for gas contents in the Emery field and only three of these could be completed (figure 17). One was made of the A bed in the central part of the field (sample 34), which yielded a small amount of methane so as to be classed low gassy. The second was a test from the lower part of a thick fused bed in the Upper zone (probably the I bed) which yielded no gas (sample 132). The last was from a thin bed in the Middle or Lower zone and it did not yield any gas (sample 135). Test No. 110 to the Lower Ferron in the southern part of the field yielded no gas to desorption tests and could not be tested for residual gas.

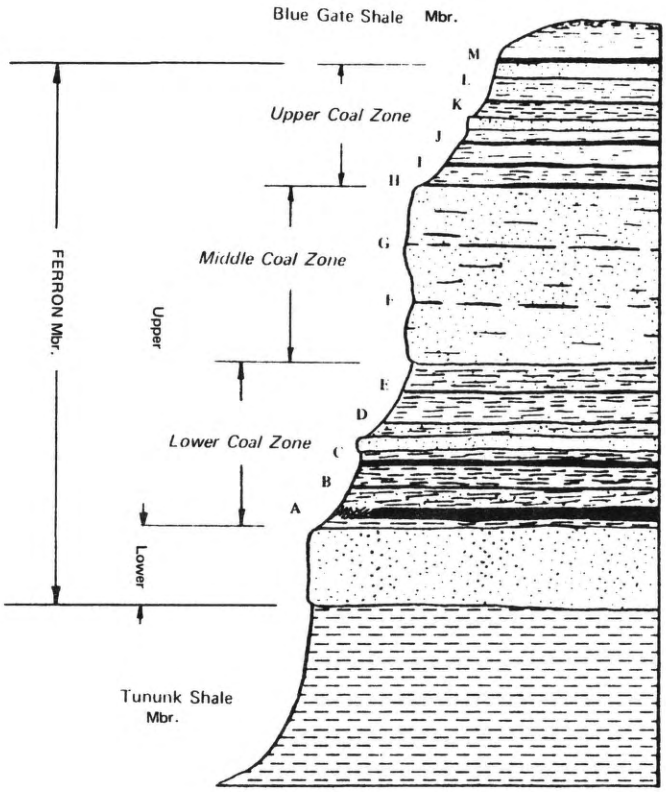


Figure 16. Generalized diagram of Ferron Member coal zones and beds, Emery coal field, Utah (Doelling, 1972).

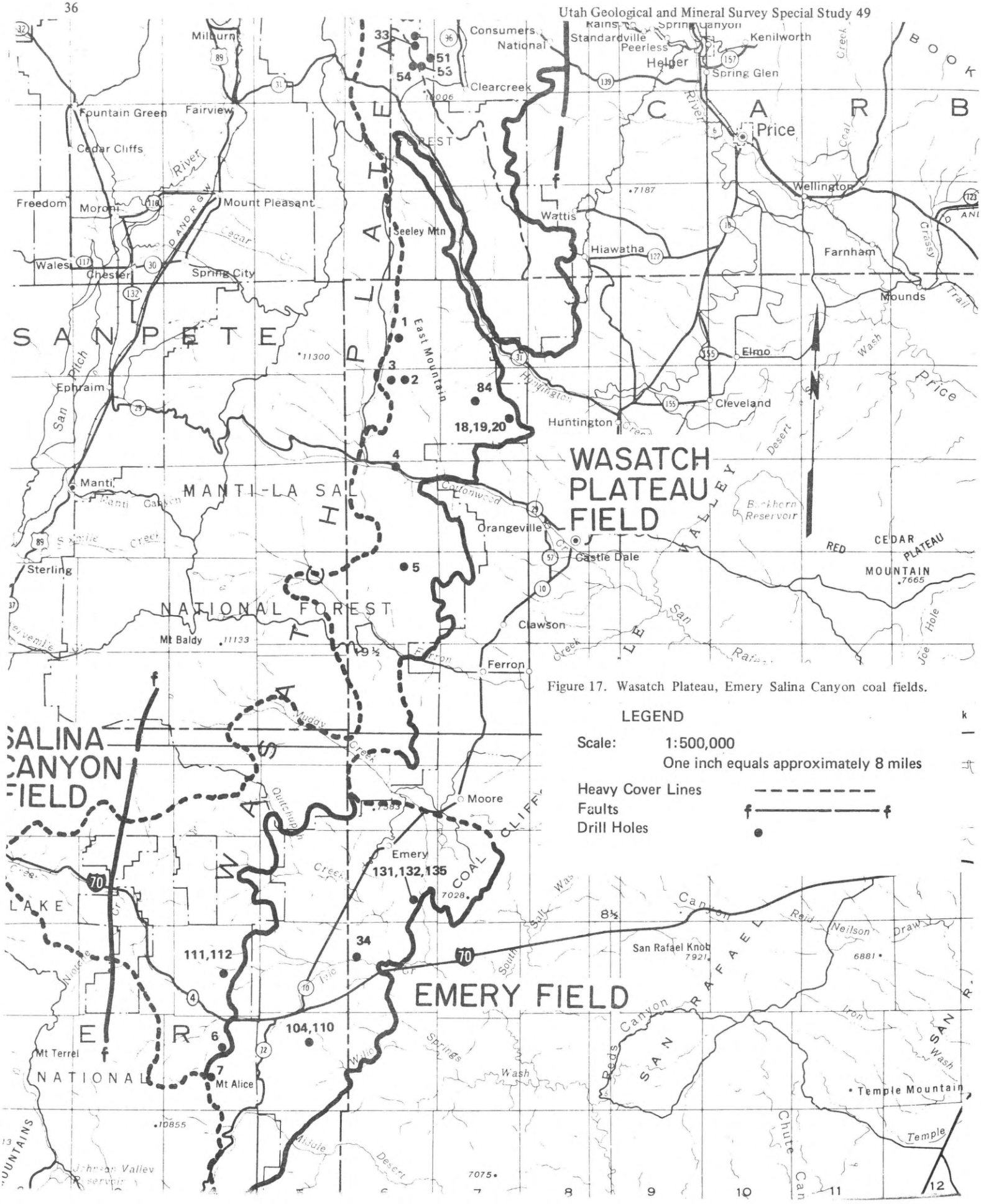


Figure 17. Wasatch Plateau, Emery Salina Canyon coal fields.

Sample 131 in the Upper Ferron in the northern part of the field yielded 437 cc of methane to desorption, but the core had to be returned to the donor so that no residual determinations could be made. Sample 104 to the Upper Ferron in the southern part of the field yielded no gas to desorption tests and had to be returned before residual testing. Thus only one sample indicated appreciable gas contents. Handwritten notes by an unknown U.S. Bureau of Mines worker (Utah Geological and Mineral Survey archives) describe the Browning mine (now the largest mine working as the Emery mine) as "gassy". Presently it is thought that moderately gassy coals may be intercepted in the Emery field if the samples taken are under sufficient cover and if taken farther from the outcrops. The ones obtained to date were close to outcrops. At present there is insufficient data to properly classify the field with respect to its gas contents.

Sego Coal Field

The Sego coal field is located in east-central Utah and extends 65 miles from the Green River to the Colorado State line in Grand County. As in the Book Cliffs field, the coal beds are exposed in high cliffs and cover increases rapidly above them so that the effective mining width is limited to about 6 miles. The coal-bearing unit is the Neslen Member of the Price River Formation (Late Cretaceous), and is younger than that in the Book Cliffs field. Dips are gentle to moderate northward into the Uinta Basin, but there are several anticlines and synclines that alter the picture. Again there are canyons that cut into the cliff-fronts. Locally the coal-bearing rocks are cut by high angle faults.

About 2.7 million tons of coal have been produced in the field, almost all from a single mine north of Thompsons. Other mines, which are scattered from one end of the field to the other, have produced only token amounts of coal primarily for ranch use. The average thickness of the Neslen Member of the Price River Formation is about 350 feet and coal beds can occur at any level in the sequence. However, about four useful coal zones have been identified:

Member		Feet
Farrer Member		
Neslen Member	Interval	100-150
	Carbonera Coal zone	
	Interval	50±
	Chesterfield coal zone	
	Thompson Canyon Sandstone-Sulphur Canyon Sandstone	10-50
	Ballard coal zone	
	Interval	100±
	Palisade coal zone	
	Interval	30-50
Sego Sandstone		

Coal beds are generally thin and rarely exceed 6 feet in thickness. In many areas the coal beds do not exceed 3 or 4 feet in thickness. Only a few analyses of the coal are available, most from the principal mine. The average proximate analysis reads: moisture 8.9 percent, volatile 34.1 percent, fixed carbon 46.0 percent, ash 11.0 percent, sulfur 0.6 percent and Btu/lb. 10,940. The coal is ranked high volatile C bituminous.

To date 25 samples have been collected for desorption from the Sego field. All were collected in the latter part of the contract period from the eastern part of the field. The tests yielded from no methane to 1.5 cm^3 /gram indicating the possibility of some moderately gassy coals. The samples were all taken from depths of less than 1,000 feet, most under 500 feet. At least 8 samples yielded no gas at all. There have been no reports of gas in the principal mine. The locations of the tests are shown on figure 18.

Kaiparowits Plateau Coal Field

The Kaiparowits Plateau is a north northwest trending area of coal-bearing Cretaceous rocks in south-central Utah that is about 65 miles long and 18 miles wide. The coal beds are in the John Henry Member of the Straight Cliffs Formation (Late Cretaceous) which has an age intermediate between the Blackhawk Formation and the Ferron Sandstone Member of the Mancos Shale of central Utah. Numerous paralleling synclines and anticlines warp the surface of the plateau; dips are gentle to steep, but in most areas are gentle. Erosion has stripped much over-burden from the plateau surface, which now consists largely of a hard sandstone unit about 650 feet thick over the deepest coal bed. Cliffy outcrops of coal occur on all sides of the Kaiparowits Plateau basin, except to the north where the coal measures disappear under the heavy cover of Tertiary and volcanic units. The interior of the plateau is greatly dissected by deep canyons, the walls of which expose the coal seams.

The field contains the largest reserve of any in Utah, but has only experienced token development. Development has been suppressed because of distance to market, physiographic barriers, and environmental concerns. Coal bed thicknesses range to more than 25 feet and there are plenty in the 6 to 12 foot class. There are multiple seams and the coals have been grouped into 3 zones in the 750-foot member. In ascending order these are known as the Christensen-Henderson, Rees, and Alvey. The upper and lower zones are the most widespread and important.

Qualitatively the coal ranges in rank from subbituminous B to high volatile C bituminous. Not enough fresh coal analyses are available to provide meaningful conclusions, except in the south. In general the coal becomes less valuable to the north with respect to quality. A typical analysis from the south might read 8 to 10 percent moisture, 5 to 8 percent ash, 39 to 41 percent volatile matter, 42 to 46 percent fixed carbon and 0.4 to 0.6 percent sulfur with 11,000 to 11,750 Btu/lb. as received.

Twelve tests for gas contents were made, half from the south and half from the Escalante area (northeast-see figure 19). All of the samples collected from the southern

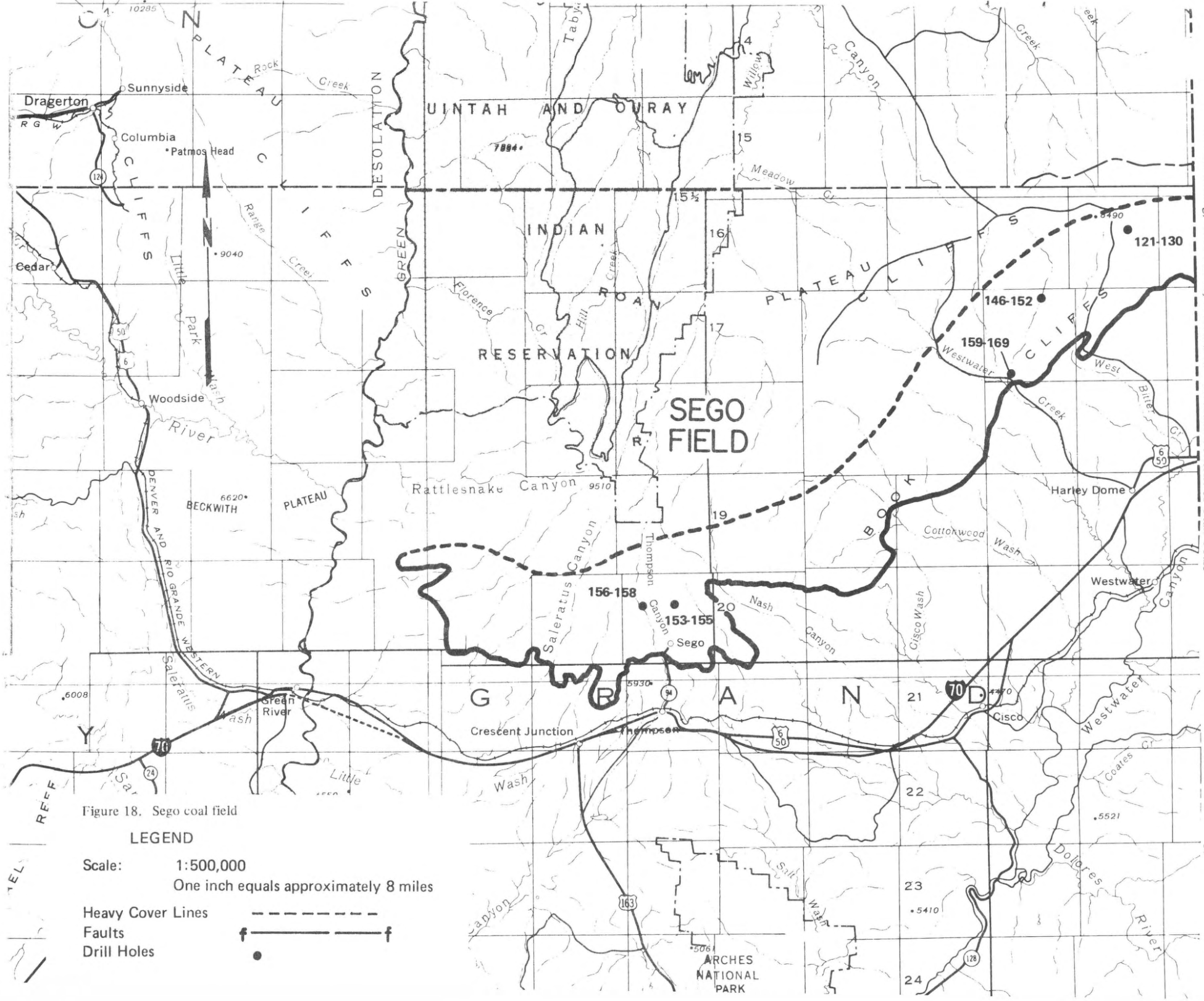


Figure 18. Sego coal field

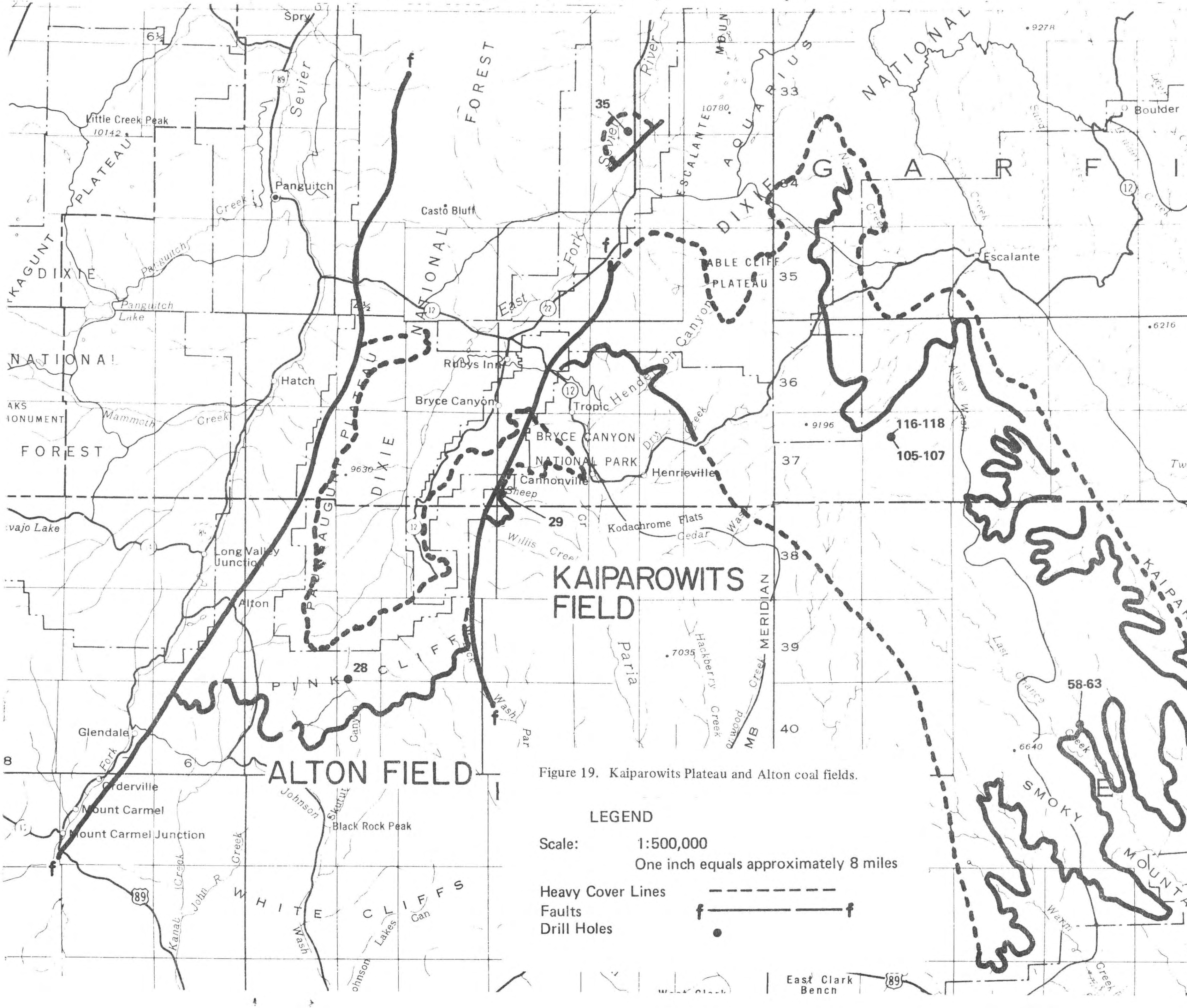


Figure 19. Kaiparowits Plateau and Alton coal fields.

part of the field gave up a little gas; the gas contents ranged from 0.01 to 0.22cm^3 gram. The 6 tests came from several seams from one drill hole put down ¼ mile from the outcrops. Similar results were obtained in the Escalante area from the Rees and Christensen zones. Three samples gave no gas at all, the other 3 gas contents ranged from 0.09 to 0.22 cm^3/gram. The latter 6 samples were also obtained from one drill hole placed near the outcrops. No final conclusions can be drawn at present as to whether the Kaiparowits Plateau coals will be gassy, moderately gassy, or low gassy. Based on present sampling evidence, it is contemplated that low gassy conditions will prevail in mines working within one mile of outcrop or where the present cover does not exceed 650 feet.

Alton Coal Field

The Alton coal field is a horseshoe-shaped area of coal surrounding the Paunsaugunt Plateau and is west of the Kaiparowits Plateau. The long axis of the field trends north-northeast and is bounded on the east and west by major faults. Cliffy outcrops indented by canyons make up the south boundary and the sequence plunges northward under heavy Tertiary and volcanic cover. The field is 18 miles wide and at least 24 miles long. The coal beds are in the Dakota Formation of Cretaceous age, the oldest unit discussed so far. The dips are usually gentle and northward; there are occasional high angle faults. A wide erosional bench that normally develops on top of the Dakota can be 1 or more miles wide.

A small amount of production has been realized for local markets from mines located near Alton in the southwest corner of the field. Mining has occurred under shallow cover from thick seams. There are two coal zones, one at the bottom and one at the top of the 250 to 350-foot formation, called the Bald Knoll and Smirl zones respectively. The coal bed thicknesses range to over 18 feet. The coal is subbituminous A in rank and contains a moderate amount of sulfur. The average proximate analysis for the mined area is: moisture 17.1 percent, volatile matter 33.2 percent, fixed carbon 41.4 percent, ash 8.3 percent, sulfur 1.23 percent and 9,959 Btu/lb. as received (Doelling and Graham, 1972a).

Only three tests were possible to examine the coal for gas contents. All 3 gave up a small amount of gas; all were low gassy. All tests were taken at depths of less than 700 feet. The number of tests is inadequate to classify the coal with respect to gas. The locations of the tests are given on figure 19.

Other Fields

One test, sample 30, was taken in the Henry Mountains coal field from the Emery coal zone (Emery Sandstone Member of the Mancos Shale), and yielded 0.40 cm^3/gram. The depth of burial was a little over 1,000 feet, which is the maximum cover for the field. Coal in the Henry Mountains is expected to be low gassy based on the single sample, with a few local areas of moderately gassy coal. The other coal fields were not tested.

SUMMARY, AND CONCLUSIONS

One hundred and sixty-four samples from 7 of the more important coal fields of Utah were collected to test their gas contents. Ninety-eight of the samples were obtained from the Book Cliffs coal field, 25 were collected from the Sego field, 16 from the Wasatch Plateau field, 12 from the Kaiparowits Plateau field, 8 from the Emery field, 3 from the Alton field, and 1 from the Henry Mountains field. The number of samples from each area was dictated by the availability of core from exploration.

Utah's coal resources vary from subbituminous B to high volatile A bituminous in rank. The greater gas contents are usually restricted to coals of high volatile A or B rank, but lesser amounts are desorbed from all coals. The gas contents of the various tests were classified gassy, moderately gassy, and low gassy. The limits are arbitrarily set; 5 cm^3/gram is gassy, 1 to 5 cm^3/gram is moderately gassy and 1 cm^3 /gram is low gassy. This classification is set up for use in this report only, to help in the discussion, and has no value in setting up safety or commercial guidelines. Only the Book Cliffs field coal tests produced gassy results, but only the Book Cliffs field has been adequately tested. Possible gassy coals may exist in the Emery and Sego fields. A few samples tested from the Wasatch Plateau and Sego fields proved to be low moderately gassy.

Gas contents and gas desorption appear to be influenced by the distance from outcrops or mined areas, by the permeability of the encasing rock and of the coal, and by the presence of some faults. Comparisons were attempted relating gas contents with depth of burial, moist mineral matter free Btu, moisture and ash free fixed carbon and oxygen. None show conclusive evidence that higher rank coals will be more gassy, but most show a tendency that this might be the case.

The gas emitted by the coal is preponderantly methane. Any ammonia that the coal may emit was never detected in the analyses. Methane makes up 89 to 99 percent; the remainder consists of the larger combustible molecular complexes and carbon dioxide. The cubic foot Btu of the gas ranges from 920 to more than 1,000. One coal company plans to use the methane gas as part of their operating energy needs. Coal gases are important with respect to proper mine ventilation and with respect to possible commercial production. About 3 million cubic feet of methane gas are vented from Book Cliffs mines daily through normal ventilation procedures. Gas contents tests are useful in planning a proper ventilation system for a mine. Tests conducted by the U. S. Bureau of Mines show that horizontal holes drilled into gassy coal beds will reduce emissions from the ribs and faces being mined in the Book Cliffs coal field.

The reasons why the Book Cliffs field coals are gassy are not completely clear. Most of the coal is high volatile A or B bituminous in rank, but the southeastern end of the field is low gassy. This area probably never carried as much cover over the coal as did the gassy portion. The west edge of the field is contiguous with that of the Wasatch Plateau field; the adjacent portion was probably under an equal amount of cover. Yet reports indicate that the adjacent Wasatch Plateau mines were low gassy. Coincidence of aeromagnetic contours over more gassy coals may indicate unique geologic events that favored the development of gas.

Further gas contents testing and describing of the physical and chemical characteristics of the coal are necessary to obtain better and more complete knowledge about the gas in Utah coals.

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OBSERVATIONS ON THE SUNNYSIDE COAL ZONE, UTAH

by H. H. Doelling[1], A. D. Smith[2], F. D. Davis[2], and D. L. Hayhurst[2]
April, 1979

INTRODUCTION

U. S. Bureau of Mines horizontal drilling tests for methane drainage were conducted in the Kaiser Steel Company's Sunnyside Nos. 1 and 3 mines (figures 1, 1-A) in 1977. The coals drilled in each mine were assumed to be similar in characteristics and should have yielded similar drainage results. However, large volumes of methane were desorbed from the holes in the No. 1 mine, whereas only small amounts were desorbed from the holes 2½ miles to the south in the No. 3 mine.

As part of a cooperative project with the U. S. Bureau of Mines (Grant No. GO 166041), later modified into a U. S. Department of Energy contract (No. ET 76-G-01-9004), the Utah Geological and Mineral Survey (UGMS) was engaged to do a detailed coal seam study in both mines to see if coal bed characteristics could be found that would help explain the gas desorption anomalies. A search was made for coal bed discontinuities that would divide the two areas into separate gas reservoirs. Coal thicknesses were measured; coal was described in detail, as were splits, riders and subseams; faults were examined. In addition numerous samples of coal were taken for proximate, ultimate, and heat value analyses. During the contract period UGMS borrowed considerable drill hole information about the Sunnyside coal zone in an area extending far beyond the limits of the Sunnyside mines. U. S. Steel Corp. provided opportunity to map the Sunnyside zone in its Geneva mine and contributed additional data for the now-closed Columbia mine (figure 1), which separates the Geneva mine from the Sunnyside mines. This report discusses the Sunnyside coal zone regionally, as well as the more local Sunnyside mines gas question.

GENERAL GEOLOGY AND IMPORTANCE OF THE SUNNYSIDE COAL ZONE

The Sunnyside coal zone is the uppermost unit of commercial importance in the Blackhawk Formation (Late Cretaceous) in the Book Cliffs coal field in central Utah. It has been identified in outcrops and in boreholes from Castlegate to Green River, a distance of 65 miles, but the valuable area extends from Soldier Canyon on the northwest to Woodside on the southeast.

Commercial production from the Sunnyside coal zone began about 1896-1899 and to date 106 million tons of high quality volatile A and B bituminous coal has been produced. In terms of production the Sunnyside zone is the most valuable in Utah. Practically all coal production has been along a 13-mile band of outcrop extending from the mouth of Lila Canyon to the south, past the towns of Columbia and Sunnyside, to B Canyon on the north (figure 1). The coal mined in this productive area of the Sunnyside zone has a "soft" coking characteristic and most has been used by the steel industry.

The Sunnyside coal zone varies from a few feet to more than 60 feet in thickness (vertical distance between lowermost and uppermost coal). The zone itself is found 200 to 275 feet beneath the base of the Castlegate Sandstone. The total thickness

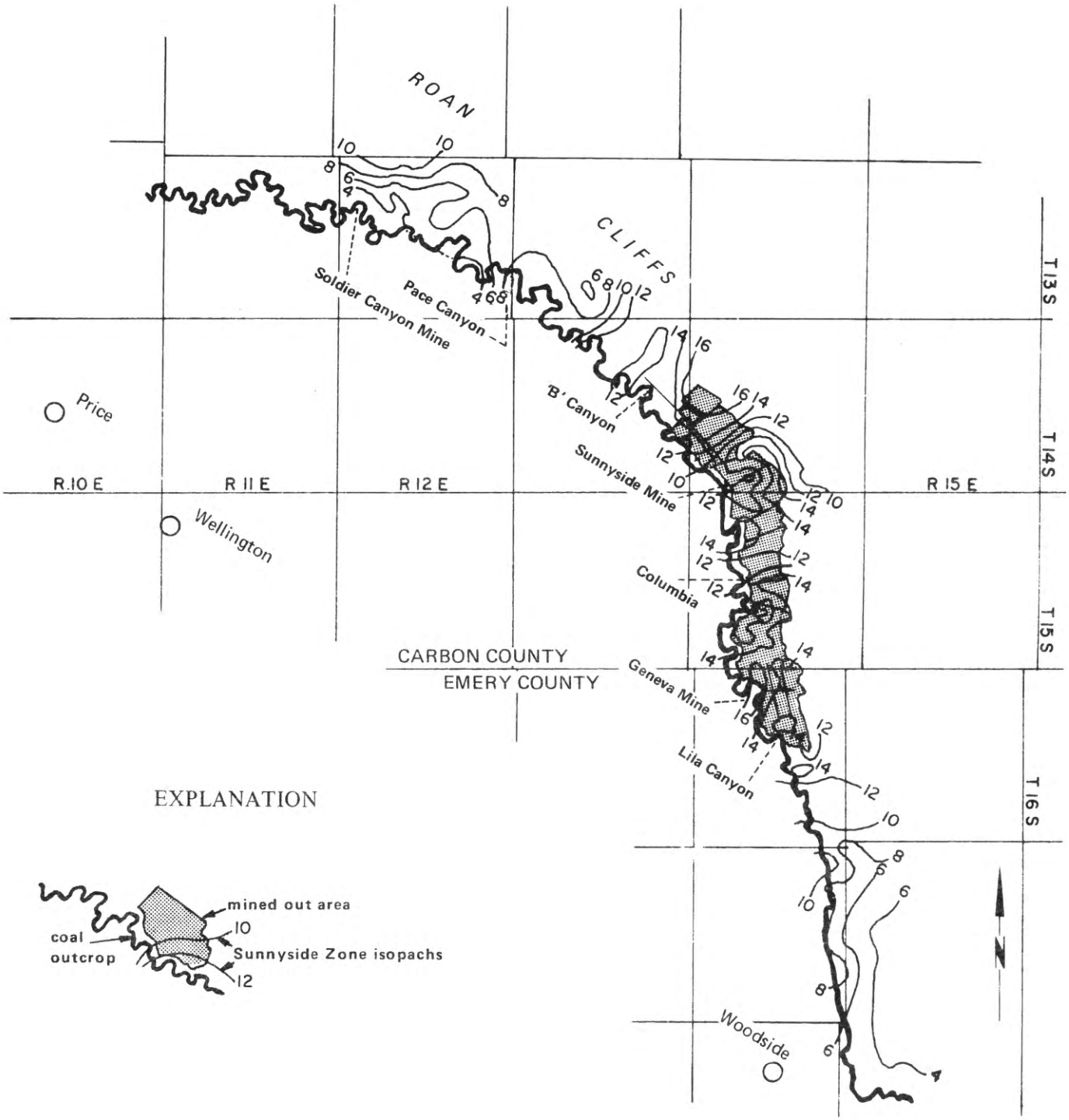


Figure 1. Sunnyside Coal Zone Area.

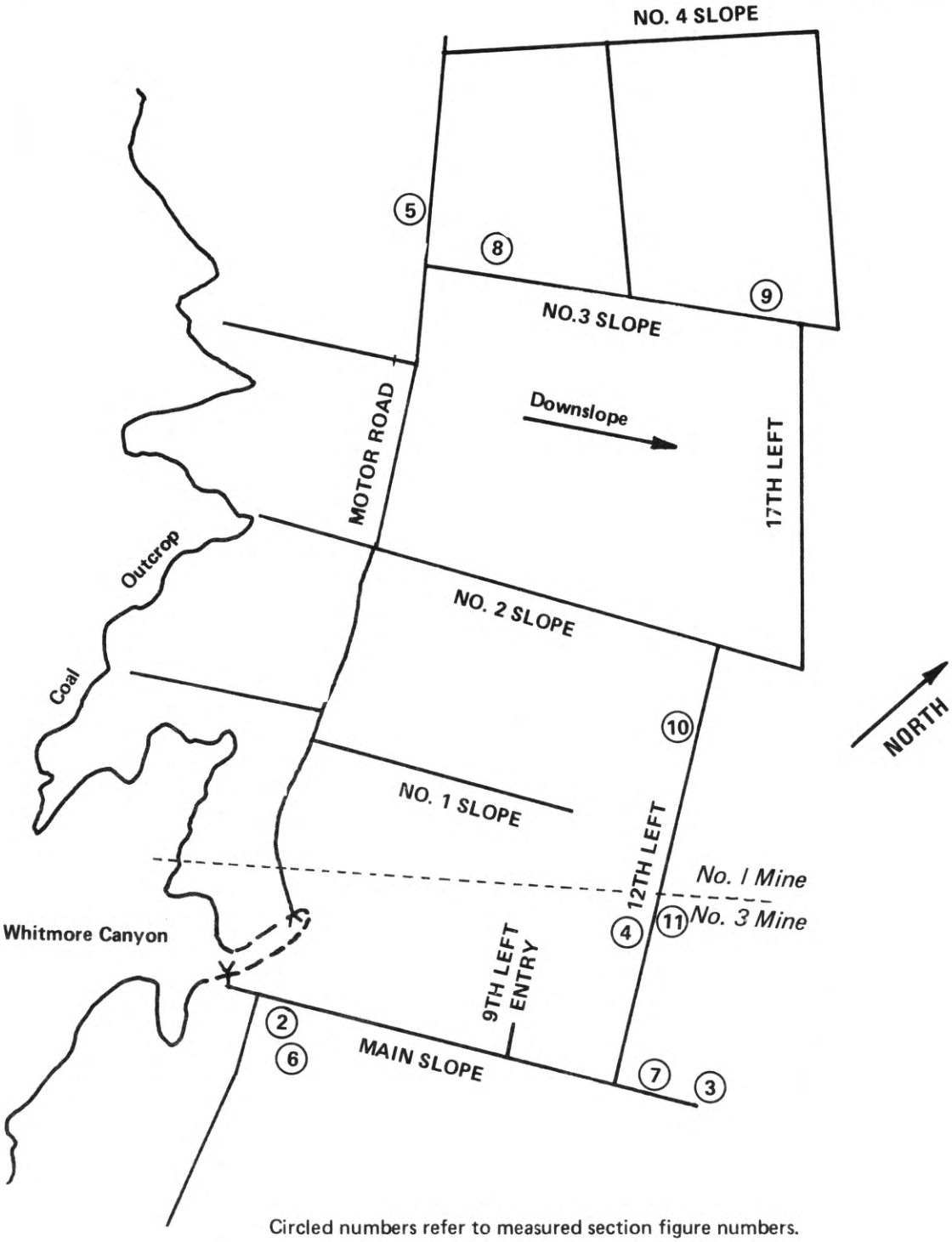


Figure 1A. Plan of Sunnyside No's. 1 and 3 Mines.

of the coal in the zone attains a maximum of 18 feet counting all beds greater than 3 feet. In the productive areas there are normally 1 or 2 mineable beds which together range from 10 to 16 feet in thickness. In areas where there are 2 beds each may measure up to 8 feet; the average thickness is about 6 feet. The lithology of roof and floor rock varies from place to place; principally there are fine-grained sandstones, carbonaceous siltstones, and carbonaceous mudstones. Plant fossils and shellfish fossils are abundant locally.

PHYSICAL APPEARANCE OF COAL

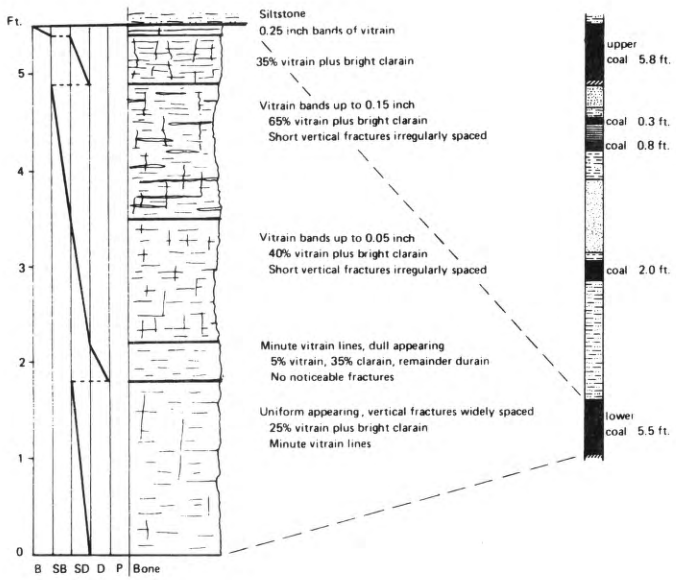
The Sunnyside coal is described macroscopically and microscopically as a hard, tough, bright coal lacking definite fracture or cleat lines, and breaks into large irregular lumps (Thiessen and Sprunk, 1937). It is a uniform attrital-anthraxylous bright coal largely derived from small plant materials such as small stems, twigs, roots, and leaves. The components consist of 30 percent anthraxylon, 61 percent translucent attritus, 6 percent opaque attritus, and 3 percent fusain. For the most part the vitrain bands and lenses are thin to medium (Goscinski, Robinson, and Chun, 1978) and the coal is typed as semidull, 25-50 percent vitrain plus bright clarain, as outlined by Cameron (1978).

The present authors described coal beds at key locations (figure 1A) in the manner provided by Cameron (1978) to see if the physical characteristics would help in correlation between the Sunnyside No. 1 and the Sunnyside No. 3 mines (sketches are provided in figures 2 to 11). The megascopic appearance of the various coal horizons in the Sunnyside zone is probably too uniform to allow correlations of those horizons over distances exceeding a mile, but subtle differences are useful in shorter spans if coupled with other data.

Figures 2 to 4 are of the lower mined seam (commonly known as the Lower Sunnyside bed) and show no features to help in their correlation. The section shown on figure 2 is about 1½ miles south from the sections shown on figures 3 and 4. These sections are known to correlate at least in part; one can walk from one to the other without leaving the coal bed. The section represented on figure 5 is 2½ miles north of the one in figure 2 and 2¼ miles northwest of the one in figure 4 (figure 1-A). Between the sections the lower mined seam (Lower Sunnyside) is thought to fuse with upper mined horizons (commonly known as the Upper Sunnyside bed) and separate again.

Figures 6 to 9 describe sections in the upper mined seam. Again there is little one can use for correlating. Figures 6 to 8 are of sections nearer the outcrop, 2½ miles apart. Figures 7 and 9 are downdip as far as has been mined; the sections are 2½ miles apart. The U. S. Bureau of Mines' horizontal drill holes to test methane drainage are near these two locations in the upper mined seam. At the time of drilling it was not known if these two upper mined seams correlated directly. Each shows a rock split; each was drilled below the split.

Figures 10 and 11 are only ½ mile apart and are set across the critical area of correlation. In the No. 1 mine section (figure 10), the upper and lower mined seams



Coal contains discontinuous vertical fractures with irregular spacings, no marked cleat, coal breaks into irregular shaped lumps, walls stand vertical in most areas, no particular horizons are more submissive to compression (no crush horizons).

Figure 2. Lower Mined Seam, No. 3 Mine, spad 178.

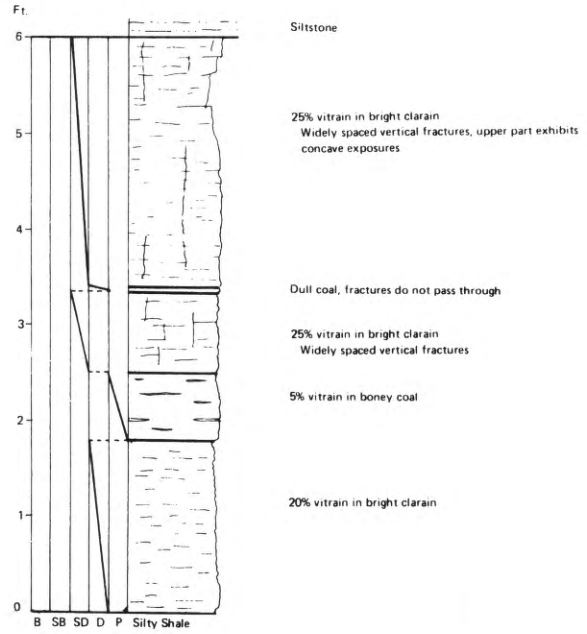


Figure 3. Lower Mined Seam in No. 3 Mine, main slope just below 14 left.

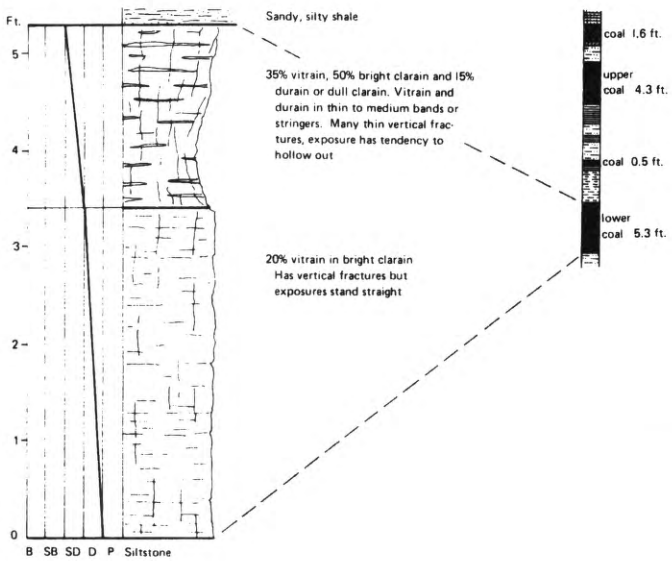


Figure 4. Lower Mined Seam, No. 3 Mine, 12th left near 35th crosscut.

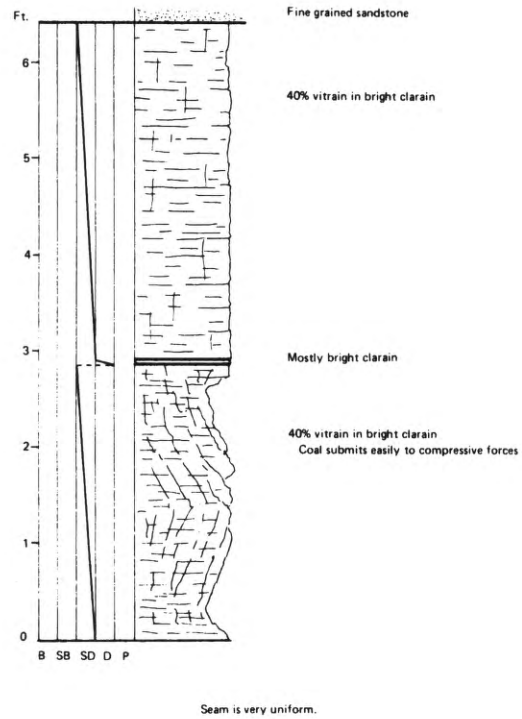
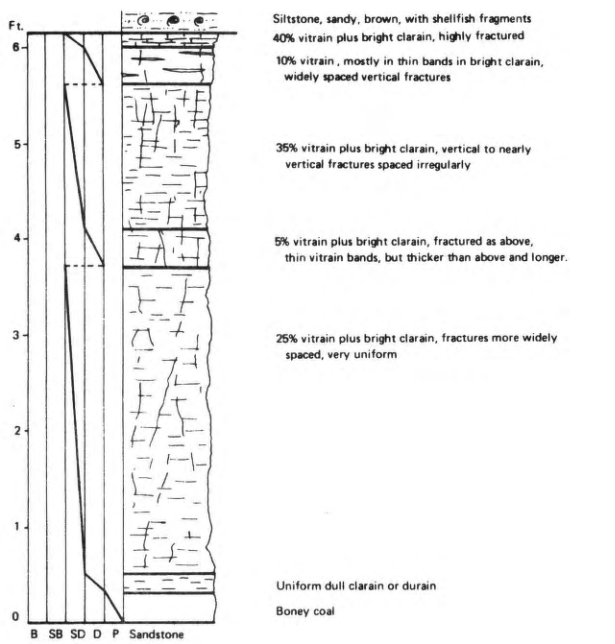


Figure 5. Lower Mined Seam No. 1 Mine, along motor road near left bleeders.



Coal stands well, only a few prominent horizontal partings, mostly in the upper part, no particular horizons are more submissive to compression (no crush horizons).

Figure 6. Upper Mined Seam, No 3. Mine, near portal or double doors to upper workings.

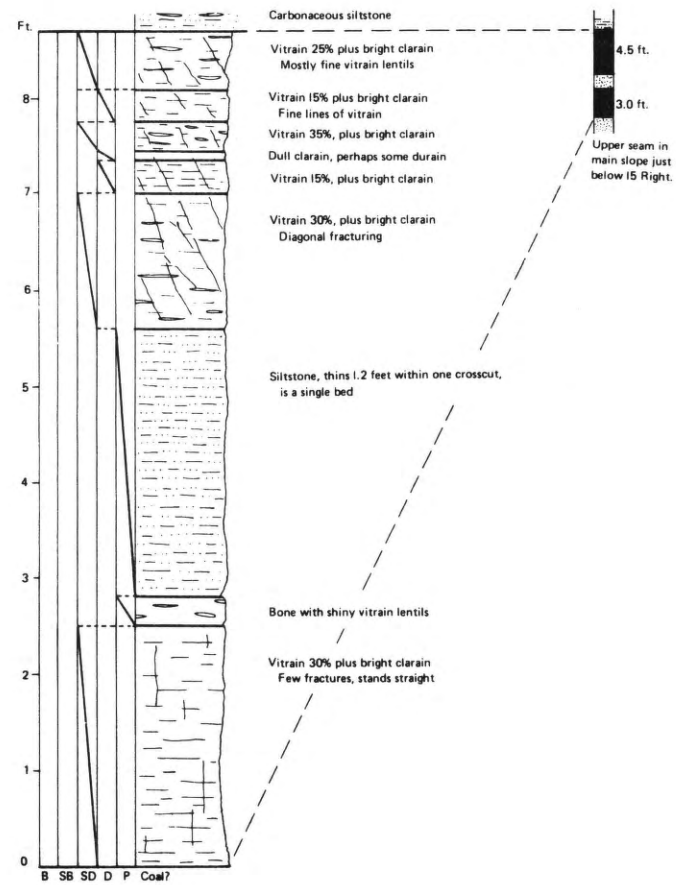


Figure 7. Upper Mined Seam, No. 3 Mine at bottom of main slope in vicinity of U. S. B. M. drill holes.

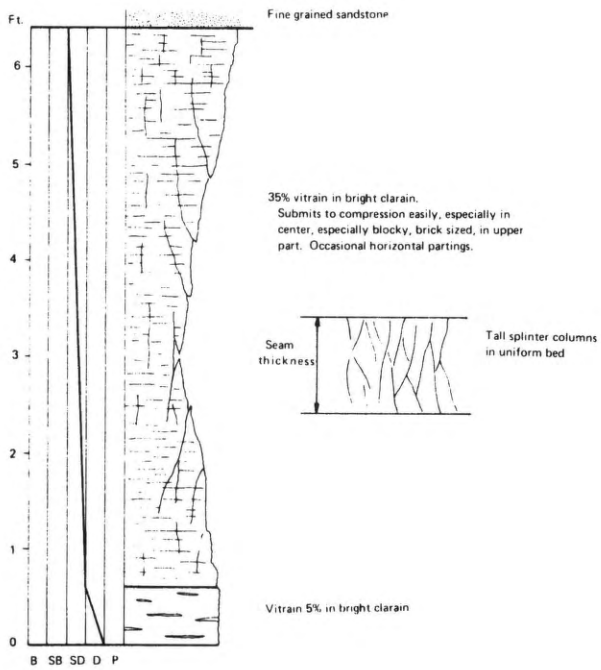


Figure 8. Upper Mined Seam No. 1 Mine, 4th crosscut below motor road left bleeders.

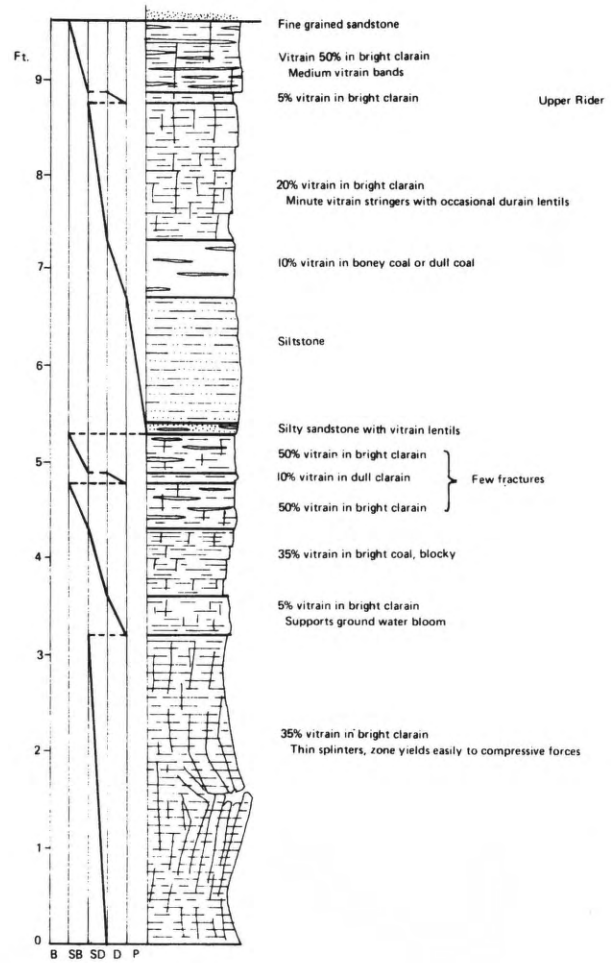


Figure 9. Upper Mined Seam No. 1 Mine, near U. S. B. M. drill holes, 16 near left bleeders.

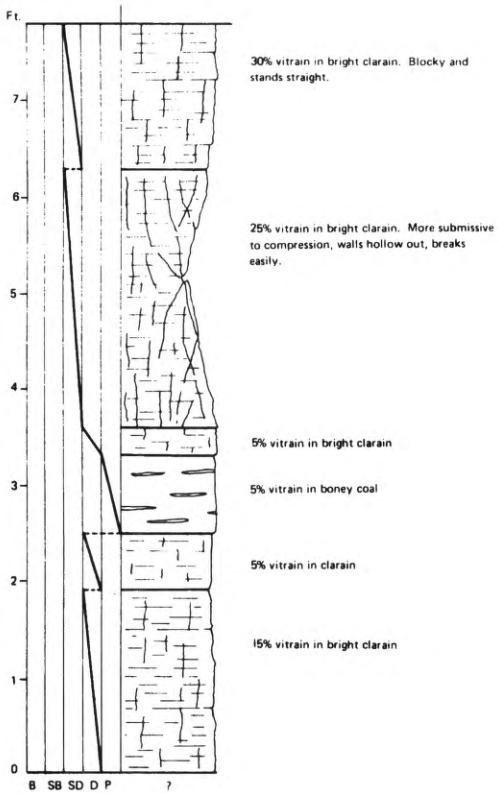


Figure 10. Mined Seam in No. 1 Mine, 15th right, opposite 12th left in No. 3 Mine.

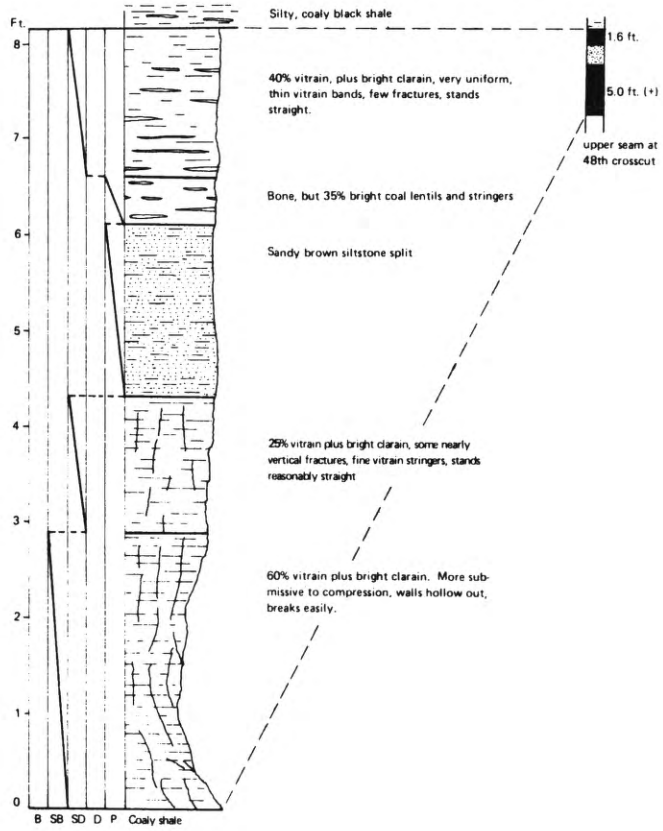


Figure 11. Upper Mined Seam, 12th left at 35th crosscut, No. 3 Mine.

are fused; in the No. 3 mine the seams are split into three or four beds of which the upper and lower are mined. Figure 11 is a section across two of the upper splits. Although the vitrain content in figure 11 was estimated to be higher than that in figure 10 it is believed that the lower two units of figure 11 (No. 3 mine) correlate with the upper two of figure 10 (No. 1 mine). The way the coal stands, or yields to stress, appears to be more helpful in recognizing parts of the coal beds. Beneath the correlated units in figure 10 is a 1-foot unit of dull bony coal which may be the edges of a split.

The estimated vitrain content of the upper seam sections, figures 2 and 5, which are nearer the outcrop, is about 40 percent; the measured sections 3 and 4 contain an estimated 20 to 25 percent in the same interval downdip. The lower parts of the lower mined seam, both at its outcrop and downdip, uniformly contain 20 to 25 percent vitrain. In the upper seam sections the vitrain content is somewhat greater in the No. 1 mine.

Davis (1978) indicates that Australian coal exhibits a higher swelling index as the percentage of vitrinite increases. In a table he infers that a vitrinite content of 30 percent (average in the Sunnyside mines) would have a swelling index of 3 to 3½. The swelling index of Sunnyside coal in the mines has ranged from 2½ to 6, improving downdip (Doelling, 1972, p. 380). The best Sunnyside coking coals have been mined in the Nos. 1 and 3 mines.

ANALYSES OF COAL

Many samples of coal were taken (table 1), mostly of the rider seam above the upper mined seam, as requested by the U. S. Bureau of Mines Technical Project Officer. The purpose was to see if correlations were possible on the basis of simple proximate and ultimate comparisons. The Utah Geological and Mineral Survey indicated early in the project the belief that at least part of the upper mined seam in the No. 3 mine might be the ubiquitous rider in the No. 1 mine. This would be important if the characteristics of a particular part of the Sunnyside coal zone were more favorable to natural methane drainage. The results of all analyses are presented in table 1; groupings of analyses related to specific locations in the mines are given in table 2.

As expected the ash and sulfur content varies locally throughout the two mines and the moisture and oxygen content increases in the upper parts of the mines. The closest groupings of analyses between the mines (across the area to be correlated), downdip area of the No. 2 slope of the No. 1 mine and the 9 left entry off the main slope of the No. 3 mine (figure 1-A), are compared on the moisture-ash free basis: volatile matter 41.9 to 40.4 percent, fixed carbon 58.1 to 59.6 percent, sulfur 0.7 to 0.6 percent, hydrogen 5.7 to 5.6 percent, oxygen 10.0 to 10.3 percent, Btu/lb. 14,650 to 14,534, and moist mineral matter free Btu/lb. 14,370 to 14,251. These and other analysis groupings do not show enough differences for use in correlating. They do verify that the coal of the Sunnyside zone in the Nos. 1 and 3 mines is a high quality, high volatile A bituminous product.

Table 1. Coal analyses taken in the Sunnyside Nos. 1 and 3 mines

Sample No.	Percent As Received Moisture	Ash	Btu/lb.	Percent Moisture-Ash Free VM	FC	S	H	O	Btu/lb.	Mmm Btu/lb.	Seam
9.	1.4	20.6	11464	47.1	52.9	0.6	5.9	11.1	14703	14764	R
10a	2.2	4.1	13745	42.6	57.4	0.6	5.6	9.4	14670	14397	US
10b	2.1	4.1	13843	41.1	58.9	0.5	5.7	---	14756	14497	US
10c	2.5	9.1	12460	43.5	56.5	0.4	5.3	10.6	14096	13830	US
10d	2.4	5.4	13629	40.7	59.3	0.5	5.6	9.3	14780	14486	US
10e	2.4	3.3	14065	42.2	57.8	0.6	5.7	9.1	14918	14601	US
11a	1.9	3.5	13909	42.1	57.9	0.7	5.7	9.7	14702	14474	US+LS
11b	2.0	3.0	13954	40.6	59.6	0.5	5.5	9.6	14684	14436	US
11c	2.0	4.7	13712	39.5	60.5	0.7	5.6	9.5	14708	14464	US
11d	1.8	2.9	13970	41.4	58.6	0.5	5.6	10.0	14652	14434	US
11e	2.0	11.6	12492	40.1	59.9	0.8	5.6	10.5	14450	14304	US
11f	2.2	2.6	14082	40.3	59.7	0.7	5.6	9.2	14791	14510	LS
11g	2.1	2.2	14135	39.8	60.2	0.6	5.6	9.2	14772	14497	LS
11h	1.6	24.9	10506	44.5	55.5	0.6	6.2	---	14290	14386	
12a	2.1	11.3	12737	42.7	57.3	1.2	5.8	8.8	14718	14549	R
12b	2.0	2.8	14023	41.1	58.9	0.6	5.6	8.7	14737	14479	R
13.	1.8	11.9	12679	43.7	56.3	1.6	5.9	8.5	14701	14597	R
14.	1.4	13.7	12569	47.3	52.7	0.8	6.0	9.1	14823	14777	R
15a.	2.1	4.2	13858	44.0	56.0	2.2	5.7	8.6	14789	14586	LS
15b.	1.9	6.3	13634	44.1	55.9	1.6	5.8	8.8	14858	14679	LS
15c.	2.1	4.0	13939	41.6	58.4	0.7	5.6	8.7	14872	14590	LS
15d.	2.1	3.6	13960	42.5	57.5	1.5	5.6	8.4	14789	14568	LS
16a.	2.2	3.7	13614	39.9	60.1	0.6	5.5	10.9	14466	14198	US Up½
16b.	2.3	5.2	13414	39.7	60.3	0.6	5.5	10.3	14503	14227	US Up½
16c.	2.3	1.7	14050	41.7	58.3	0.6	5.8	9.7	14633	14327	US Up½
16d.	2.4	2.2	13854	40.3	59.7	0.6	5.5	11.1	14514	14205	US Lo½
16e.	2.0	4.9	13690	43.1	56.9	0.6	5.5	9.5	14703	13792	US LO½
17a.	2.5	1.8	13949	42.7	57.3	0.9	5.5	10.5	14578	14249	US
17b.	1.6	31.1	9789	47.1	52.9	2.2	6.1	9.8	14534	14810	R

R = rider above upper mined seam. US = upper mined seam. LS = lower mined seam.
Up½ = upper half. Lo½ = lower half. Mmm = moist, mineral matter free.

(continued)

Table 1. Coal analyses taken in the Sunnyside Nos. 1 and 3 mines (continued).

Sample No.	Percent As Received Moisture	Ash	Btu/lb.	Percent Moisture-Ash Free VM	FC	S	H	O	Btu/lb.	Mmm Btu/lb.	Seam
18.	1.6	19.5	11566	46.3	53.7	1.7	5.9	9.6	14665	14702	R
19.	1.7	16.1	12042	45.3	54.7	1.8	5.8	9.5	14656	14576	R
20.	1.5	21.6	11258	46.3	53.7	1.6	5.9	9.6	14645	14735	R
21.	1.7	26.4	10463	47.3	52.7	3.0	6.2	8.2	14565	14731	R
22.	1.8	16.6	12027	46.7	53.3	1.5	6.0	9.4	14737	14699	R
23.	1.8	15.8	12115	46.0	54.0	1.7	5.9	9.1	14711	14659	R
24.	1.6	22.1	11280	45.5	54.5	1.3	6.1	9.0	14788	14858	R
25.	1.9	13.1	12503	44.6	55.4	1.7	5.9	9.2	14711	14659	R
26.	1.9	12.0	12714	45.2	54.8	1.6	5.9	9.8	14756	14652	R
27.	1.8	11.6	12791	45.2	54.8	1.6	5.9	9.3	14764	14672	R
28.	1.7	10.9	12922	45.0	55.0	2.3	5.9	8.9	14791	14702	R
29.	1.7	17.8	11889	44.9	55.1	2.0	6.0	9.1	14764	14780	R
30.	1.7	8.3	13229	45.8	54.2	2.0	6.0	8.9	14698	14591	R
31.	1.7	10.5	12948	45.3	54.7	1.6	5.9	10.1	14759	14652	R
32.	1.9	4.6	13898	47.3	52.7	1.3	5.9	10.4	14862	14663	R
33.	1.5	12.8	12365	45.5	54.5	1.2	5.9	10.7	14424	14382	R
34.	1.7	16.6	12025	47.4	52.6	0.8	6.0	9.7	14710	14677	R
35.	1.7	5.6	13732	48.4	51.6	1.2	5.9	8.8	14812	14651	R
36.	1.9	5.0	13785	46.2	53.8	1.3	5.9	9.5	14808	14610	R
37.	2.1	10.2	12957	43.5	56.5	1.0	5.8	9.2	14780	14591	R
38.	2.0	14.5	12208	46.7	53.3	1.2	5.8	9.5	14615	14510	R
39.	1.9	11.5	12792	44.5	55.5	1.2	5.8	10.0	14768	14644	R
40.	2.0	6.1	13627	43.3	56.7	0.8	5.8	10.4	14832	14614	R
41.	1.9	10.5	13048	46.1	53.9	1.6	5.9	8.8	14890	14766	R
42.	2.1	2.8	14098	43.0	57.0	0.8	5.8	9.9	14816	14562	R
43.	1.7	12.8	12440	46.7	53.3	1.0	5.7	10.1	14546	14463	R
44.	1.8	13.4	12543	46.5	53.5	1.3	6.0	8.9	14785	14705	R
45.	1.6	20.0	11559	48.7	51.3	1.7	6.1	8.9	14745	14795	R
46.	1.3	23.8	11185	48.9	51.1	0.7	6.2	9.9	14937	15081	R

(continued)

Table 1. Coal analyses taken in the Sunnyside Nos. 1 and 3 mines (continued).

Sample No.	Percent As Received Moisture	Ash	Btu/lb.	Percent Moisture-Ash Free VM	FC	S	H	O	Btu/lb.	Mmm Btu/lb.	Seam
47.	1.7	13.2	12635	46.7	53.3	1.3	6.1	9.8	14851	14775	R
48.	2.0	11.3	12763	46.3	53.7	1.6	5.9	9.6	14726	14585	R
49.	1.7	19.0	11582	45.2	54.8	1.5	5.9	9.9	14610	14610	R
50.	1.9	8.7	13141	44.4	55.6	1.0	5.9	9.4	14701	14533	R
51.	2.2	8.6	13107	44.5	55.5	1.4	5.9	9.4	14685	14488	R
52.	2.0	10.9	12792	44.6	55.4	1.3	5.9	9.9	14699	14536	R
53.	1.7	11.2	12835	44.6	55.4	1.0	6.0	9.7	14738	14632	R
54.	2.2	3.7	13775	43.2	56.8	1.1	5.6	10.2	14630	14380	R
55.	2.1	6.3	13415	43.6	56.4	1.1	5.8	10.3	14646	14425	R
56.	2.2	9.6	12895	43.8	56.2	1.1	5.8	10.5	14632	14416	R
57.	2.3	5.6	13489	43.8	56.2	1.2	5.7	10.3	14650	14391	R
58.	2.0	6.7	13404	44.3	55.7	1.0	5.9	10.3	14679	14478	R
59.	2.4	13.1	12216	41.9	58.1	1.8	5.7	10.3	14462	14272	R
60.	2.2	15.3	12056	44.6	55.4	2.0	6.0	9.3	14606	14503	R
61.	2.5	5.4	13452	43.5	56.5	1.5	5.6	10.4	14616	14327	R
62.	2.0	14.1	12352	46.2	53.8	0.7	6.1	10.0	14726	14592	R
63.	3.1	10.1	12522	41.4	58.6	0.8	5.7	10.4	14426	14076	R
64.	3.1	12.7	12168	42.1	57.9	1.4	5.6	10.4	14454	14140	R
65.	2.7	13.1	12176	42.0	58.0	1.0	5.6	10.9	14467	14208	R
66.	2.8	14.6	11973	43.4	56.6	0.9	5.7	10.9	14487	14241	R
67.	3.7	4.9	13148	39.6	60.4	1.1	5.5	10.6	14379	13910	R
68.	3.7	4.8	13101	39.4	60.6	1.1	5.2	11.9	14314	13844	R
69.	2.9	8.8	12719	41.8	58.2	1.2	5.6	11.3	14414	14088	R
70.	2.9	7.2	13027	41.8	58.2	1.1	5.8	10.3	14483	14155	R
71.	3.0	9.2	12791	42.2	57.8	1.0	5.8	10.3	14555	14230	R
72.	2.9	9.4	12644	41.8	58.2	1.0	5.6	11.0	14432	14100	R
73.	2.7	5.8	13225	41.5	58.5	1.2	5.5	10.9	14454	14141	R
74.	2.5	6.6	13054	41.7	58.3	0.9	5.7	11.2	14362	14079	R
75.	2.7	5.8	13186	41.5	58.5	1.2	5.7	10.5	14400	14099	R
76.	2.4	4.6	13448	42.0	58.0	0.9	5.6	10.5	14460	14177	R

(continued)

Table 1. Coal analyses taken in the Sunnyside Nos. 1 and 3 mines (continued).

Sample	Percent As Received			Percent Moisture-Ash Free						Mmm	
No.	Moisture	Ash	Btu/lb.	VM	FC	S	H	O	Btu/lb.	Btu/lb.	Seam
77.	2.9	4.8	13344	40.7	59.3	0.9	5.6	10.2	14462	14207	R
78.	2.4	10.6	12583	42.6	57.4	1.0	5.7	10.5	14461	14235	R
79.	2.1	10.5	12664	44.5	55.5	1.2	5.9	10.1	14497	14316	R
80.	2.2	3.8	13835	43.8	56.2	0.8	5.8	9.5	14721	14451	R
81.	2.8	1.7	13999	44.0	56.0	0.7	5.7	10.9	14666	14281	R
82.	2.3	5.3	13423	43.4	56.6	0.9	5.8	10.3	14532	14262	R
83.	2.3	5.6	13468	42.1	57.9	0.8	5.6	11.0	14623	14356	R
84.	2.3	3.3	13739	43.5	56.5	0.8	5.7	10.3	14560	14267	R
85.	2.7	3.8	13393	38.9	61.1	0.9	5.5	10.5	14322	13991	R
86.	2.5	4.5	13365	40.9	59.1	0.8	5.7	10.7	14368	14067	R
87.	2.7	6.2	13071	40.0	60.0	1.2	5.5	11.0	14338	14041	R
88.	2.6	3.4	13483	41.1	58.9	0.9	5.6	11.5	14353	14022	R
89.	2.3	6.2	13193	42.3	57.7	1.2	5.7	11.7	14426	14172	R
90.	2.6	4.4	13495	41.1	58.9	1.2	5.5	10.0	14499	14200	R
91.	2.3	2.4	13966	40.3	59.7	0.6	5.6	9.3	14646	14355	R
92.	2.6	2.2	13972	41.1	58.9	0.6	5.6	9.3	14686	14329	R
93.	2.6	6.5	13309	40.8	59.2	0.8	5.6	10.0	14641	14335	R
94.	2.7	3.3	13801	41.6	58.4	0.8	5.6	10.2	14680	14331	R
95.	2.3	2.3	14052	43.9	56.1	0.6	5.8	9.5	14729	14424	R
96.	2.2	2.5	14001	41.8	58.2	0.6	5.8	9.2	14699	14407	R
97.	3.1	5.3	13352	39.9	60.1	0.9	5.6	9.6	14567	14186	R
98.	2.4	10.7	12746	43.0	57.0	1.3	5.7	9.3	14677	14488	R
100.	2.4	8.8	13092	41.7	58.3	1.0	5.7	10.3	14751	14496	R
101.	2.0	5.5	13635	42.6	57.4	0.5	5.7	10.4	14736	14511	R
102.	2.3	3.0	13844	42.5	57.5	0.8	5.7	10.6	14616	14328	R
103.	2.1	5.4	13648	42.8	57.2	0.7	5.8	9.8	14754	14512	R
104.	2.4	3.2	13760	40.4	59.6	0.6	5.5	9.7	14580	14270	R
105.	3.0	10.8	12278	41.7	58.3	0.7	5.3	11.6	14250	13917	US
106.	3.2	5.8	13025	40.6	59.4	0.6	5.5	11.6	14317	13909	US

(continued)

Table 1. Coal analyses taken in the Sunnyside Nos. 1 and 3 mines.

Sample No.	Percent As Received Moisture	Ash	Btu/lb.	Percent Moisture Ash Free VM	FC	S	H	O	Btu/lb.	Mmm Btu/lb.	Seam
107.	3.3	1.8	13680	39.8	60.2	0.6	5.3	12.1	14420	13964	US
108.	3.2	6.8	13007	41.0	59.0	0.6	5.5	11.9	14451	14051	US
109.	3.4	12.0	11983	41.0	59.0	0.7	5.4	13.2	14157	13785	US
110.	4.1	4.9	12996	42.9	57.1	0.9	5.8	11.5	14276	13743	US
111.	4.1	3.0	13422	42.8	57.2	0.7	5.5	11.1	14452	13890	US
112.	4.2	4.7	13001	41.3	58.7	0.8	5.7	10.8	14262	13714	US
113.	4.1	8.4	12353	41.9	58.1	0.8	5.4	12.7	14114	13604	US
114.	4.5	3.3	13124	42.0	58.0	0.8	5.6	11.3	14225	13627	US
115.	4.4	5.3	12808	42.3	57.7	0.8	5.4	11.9	14176	13604	US
116.	4.4	5.8	12697	41.5	58.5	0.7	5.4	11.6	14124	13561	US
117.	4.5	4.2	13024	41.7	58.3	0.7	5.3	11.6	14271	13661	US
118.	3.8	4.3	13228	42.8	57.2	0.6	5.6	10.6	14383	13888	US
119.	2.6	10.9	12594	43.0	57.0	0.6	5.7	10.7	14558	14290	US
120.	3.0	4.3	13451	43.2	56.8	0.6	5.7	9.9	14515	14123	US
121.	2.8	6.2	13279	45.0	55.0	0.7	5.7	10.0	14601	14250	US
122.	2.8	5.0	13369	43.3	56.7	0.6	5.7	9.8	14505	14149	US
123.	2.8	3.8	13664	42.5	57.5	0.6	5.7	9.9	14633	14266	US
124.	3.1	7.1	13059	41.4	58.6	0.7	5.7	10.0	14551	14161	US
125.	2.7	6.2	13220	42.4	57.6	0.7	5.8	9.7	14509	14186	US
126.	2.7	5.6	13365	42.7	57.3	0.7	5.7	10.0	14583	14243	US
127.	3.0	3.6	13641	44.0	56.0	0.7	5.8	9.9	14596	14210	US
128.	2.8	8.3	12945	44.1	55.9	0.8	5.6	10.1	14561	14241	US
129.	2.9	5.2	13402	41.1	58.9	0.7	5.6	10.1	14588	14218	US
130.	3.1	5.0	14435	42.7	57.3	0.7	5.7	10.7	15718	15284	US
131.	3.0	4.0	13596	44.1	55.9	0.7	5.8	11.4	14629	14230	US
132.	2.7	9.0	12802	44.0	56.0	0.9	5.9	10.0	14498	14205	US

Table 2. Average coal analyses of sample groups taken in various parts of the Sunnyside Nos. 1 and 3 mines.

Sample Nos.	Percent As Received Moisture	Ash	Btu/lb.	Percent Moisture Ash Free VM	FC	S	H	O	Btu/lb.	Mmm Btu/lb.
Samples of upper mined seam, downdip area of No. 3 slope, No. 1 mine										
10a-10e	2.3	5.2	13548	42.0	58.0	0.5	5.5	9.6	14644	14362
Samples of upper mined seam, 17 left entry, No. 1 mine										
11b-11e	2.0	5.6	13532	40.4	59.6	0.6	5.6	9.9	14624	14410
Samples of lower mined seam, 12 left entry, crosscut 29, off main slope, No. 3 mine										
15a-15d	2.1	4.5	13844	43.1	56.9	1.5	5.7	8.6	14840	14612
Samples of upper mined seam, upper 4.6 feet (upper split), 9 left entry, off main slope, No. 3										
16a-16c	2.3	3.5	13693	40.4	59.6	0.6	5.6	10.3	14534	14251
Samples of upper mined seam, lower 3.1 feet (lower split), 9 left entry, off main slope, No. 3										
16d-16e	2.2	3.6	13772	41.7	58.3	0.6	5.5	10.3	14609	13999
Sample of upper mined seam, center of No. 4 slope, No. 1 mine										
17a	2.5	1.8	13949	42.7	57.3	0.9	5.5	10.5	14578	14249
Samples of rider above upper mined seam, downdip half of No. 4 slope, No. 1 mine										
17b-43	1.8	13.6	12463	45.7	54.3	1.5	5.9	9.5	14719	14651

(continued)

Table 2. Average coal analyses of sample groups taken in various parts of the Sunnyside Nos. 1 and 3 mines.

Sample Nos.	Percent As Received Moisture	Ash	Btu/lb.	Percent Moisture Ash Free VM	FC	S	H	O	Btu/lb.	Mmm Btu/lb.
Samples of rider above upper mined seam, updip half of No. 4 slope, No. 1 mine										
44-61	2.0	11.4	12714	44.4	55.6	1.4	5.9	9.8	14689	14552
Samples of rider above upper mined seam, motor road north of No. 4 slope, No. 1 mine										
62-78,9	2.8	9.3	12718	42.2	57.8	1.0	5.7	10.7	14469	14182
Samples of rider above upper mined seam, motor road in area of No. 3 slope, No. 1 mine										
79-84	2.3	5.0	13521	43.6	56.4	0.9	5.8	10.4	14600	14322
Samples of rider above upper mined seam, motor road in area of No.2 slope, No. 1 mine										
85-89	2.6	4.8	13301	40.6	59.4	1.0	5.6	11.1	14361	14059
Samples of rider above upper mined seam in downdip area of No. 3 slope, No. 1 mine										
90-101	2.5	4.9	13584	41.6	58.4	0.8	5.7	9.7	14664	14369
Samples of rider above upper mined seam in downdip area of No. 2 slope, No. 1 mine										
102-104	2.3	3.9	13751	41.9	58.1	0.7	5.7	10.0	14650	14370

Mmm = Moist mineral matter free. VM = volatile matter. FC = fixed carbon.
S = sulfur. H = hydrogen. O = oxygen.

CHARACTERISTICS OF THE SUNNYSIDE COAL ZONE

The sequence of rock beneath the Sunnyside coal zone varies from place to place with respect to thickness, number of key beds and other characteristics, but generally there is a sequence of about 25 to 30 feet of transgressive restricted marine rocks consisting of thin-bedded sandstones and interbedded mudstone overlain by at least 35 feet of offshore and shoreface (littoral) sandstone. The latter sandstone or sandstones are usually referred to as the Sunnyside Sandstone or Sunnyside Sandstone Tongue(s). The Sunnyside coal zone lies above this and may be described as restricted marine rocks with interspersed terrestrial facies. The coal deposits developed in the restricted marine units, in near-shore swampy areas. Rocks at the top of the zone indicate a near shore coastal plain or interdeltaic setting (Anderson, 1978).

It appears that the Sunnyside coals developed in one single, very large continuous swamp paralleling the shore of the Cretaceous sea lying to the east (figure 12). We are not implying that the coal was deposited in a non-deltaic system; merely that this particular swamp was of considerable size. The fluvial or terrestrial influence is much greater to the north and west (Plate 1; figures 13, 14) as indicated by the greater number of interbedded sandstone lenses between the coaly layers, and the greater total thickness of the zone (thickness between the base of the lowermost and the top of the uppermost coal beds, including contained rock).

Gross (1961) prepared an isopach map of the Blackhawk Formation in the southern Uinta Basin-Book Cliffs area (figure 12). The postulated position of the area of peat accumulation is also located on figure 12 along the southwest flank of the deepest part of the subsiding basin. The coals west of the line that roughly bisects the swamp appear to be more severely split than those to the east, indicating important depositional encroachments of sediments from the landward side from time to time. To the east the rock intervals between the coal horizons are generally much thinner. In the southern part of the swamp, south of Sunnyside or Columbia, the bisecting line approximates the position of the present line of outcrops. Sections of the Sunnyside interval are presented on maps, Plate 1, and the total coal (excluding some stringers) is isopached. These isopachs do not indicate the thickness of mineable coal and reliable reserves cannot be inferred from them.

Soldier Canyon-B Canyon Area

In this area, represented on Plate 1, the Sunnyside coals are generally separated into two or more seams. Generally there is a lower and an upper seam better developed than any of the others. This has inspired the much used terminology: Upper Sunnyside coal bed and Lower Sunnyside coal bed.

Exposures along outcrop show a thin zone, perhaps 8 or 9 feet, at Soldier Creek, with three thin coal seams of which the thickest is 2½ feet. To the southwest, in an area now eroded, the coals are suspected to have disappeared at the landward edge of the swamp. To the east, the total coal in the zone irregularly increases to 8 or 9 feet near Pace Canyon. Simultaneously the thickness of the interval between the high and low seams increases to more than 40 feet. In a drill hole in the Left Fork of Whitmore Canyon, opposite B Canyon, this interval reaches a maximum of 60 feet and the total coal ranges from 12 to 18 feet, a maximum for the zone.

About 1½ miles north of the Soldier Creek outcrops the total coal discovered in drill holes is about 11 feet thick, with either a thin split or none at all. All northern drill holes in R. 12 E. (Plate 1) show thicker seams and thinner total rock intervals between the lower and upper better developed seams. In section 11, T. 13 S., R. 12 E., the "Lower Sunnyside" bed is 6.7 feet thick and is separated from a 2-foot "Upper Sunnyside" coal bed by about 10 feet of rock. The southeastern part of the map area (Plate 1) shows splitting at its maximum development nearer the central part of the coal swamp. In T. 14 S., R. 13 E., the coals reach their maximum thickness for the zone. In the Bear Canyon area the lower thick seam is 7 to 9 feet thick, the upper is 3 to 8 feet thick and the rock interval between them is 20 to 40 feet thick. This rock interval consists of highly lenticular units of fine-grained sandstone, siltstone, and carbonaceous mudstone. Interspersed are thin coal beds up to 2 feet in thickness.

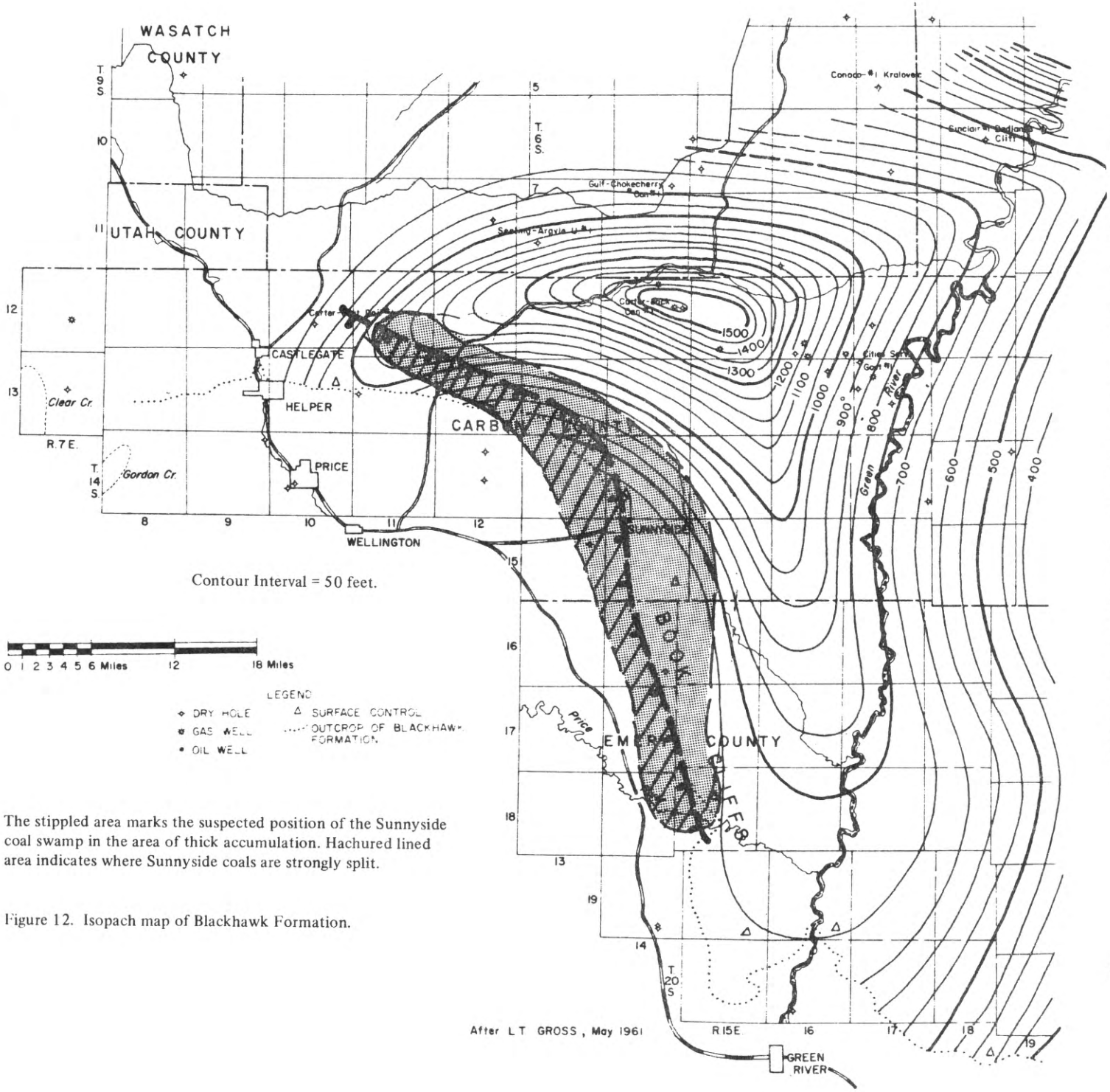
Sunnyside Nos. 1 and 3 Mines

The Sunnyside coal zone in the area of Kaiser Steel's Nos. 1 and 3 mines is represented by fence diagrams (figures 13 and 14), and shows the middle swamp area, where the landward splitting side meets the seaward side. The landward side and seaward side began as one continuous swamp. There is evidence of one or two "ancestral" swamps beneath the lower mined seam which were of local extent. The coals of these local swamps are up to 2 feet in thickness and appear to be separated everywhere from the lower mined seam by a uniform layer of fine-grained sandstone, siltstone, and mudstone.

Four to nine feet of coal are found across the entire area once covered by the lower Sunnyside swamp. From time to time influxes of clastic sediments from the west were spread over the lower swamp deposits; it is assumed that these sediments were deposited in intervals of short duration, perhaps as catastrophic events, and the areas over which the sand, silt, and mud were deposited subsided quickly to renew coal swamp conditions over the whole area. This concept is supported by the nearly constant 12 to 18-foot total thickness of coal in the zone across the area. The sediments did not arrive in a single surge, but perhaps as lobate turbidity phenomena, each occurring in its own time during the middle history of the swamp. In the mines the edges of splits are often very pronounced, and may thicken to maximum within a few hundred feet. The thickness of the split may be quite irregular, as shown in parts of the fence diagrams. Deposition of coaly materials continued undisturbed in unaffected parts of the swamp. In the latter part of its history the influxes of sediment from the west and southwest ceased and the upper mined seam was accumulated. Generally the upper mined seam is 3 to 7 feet in thickness; occasionally it thickens to 9 feet.

Sometime before the final demise of the swamp another widespread sheet of sediment was spread over the area; the swamp returned to these areas to deposit the rider seam. The rider is 0 to more than 4 feet thick, if correlations are correct. Generally, in the No. 1 mine, it is less than 2 feet thick.

In the northern part of the No. 1 mine the interval between the upper and lower mined seams varies from 0 to 35 feet and averages 6 feet. Except in entryways the upper



The stippled area marks the suspected position of the Sunnyside coal swamp in the area of thick accumulation. Hachured lined area indicates where Sunnyside coals are strongly split.

Figure 12. Isopach map of Blackhawk Formation.

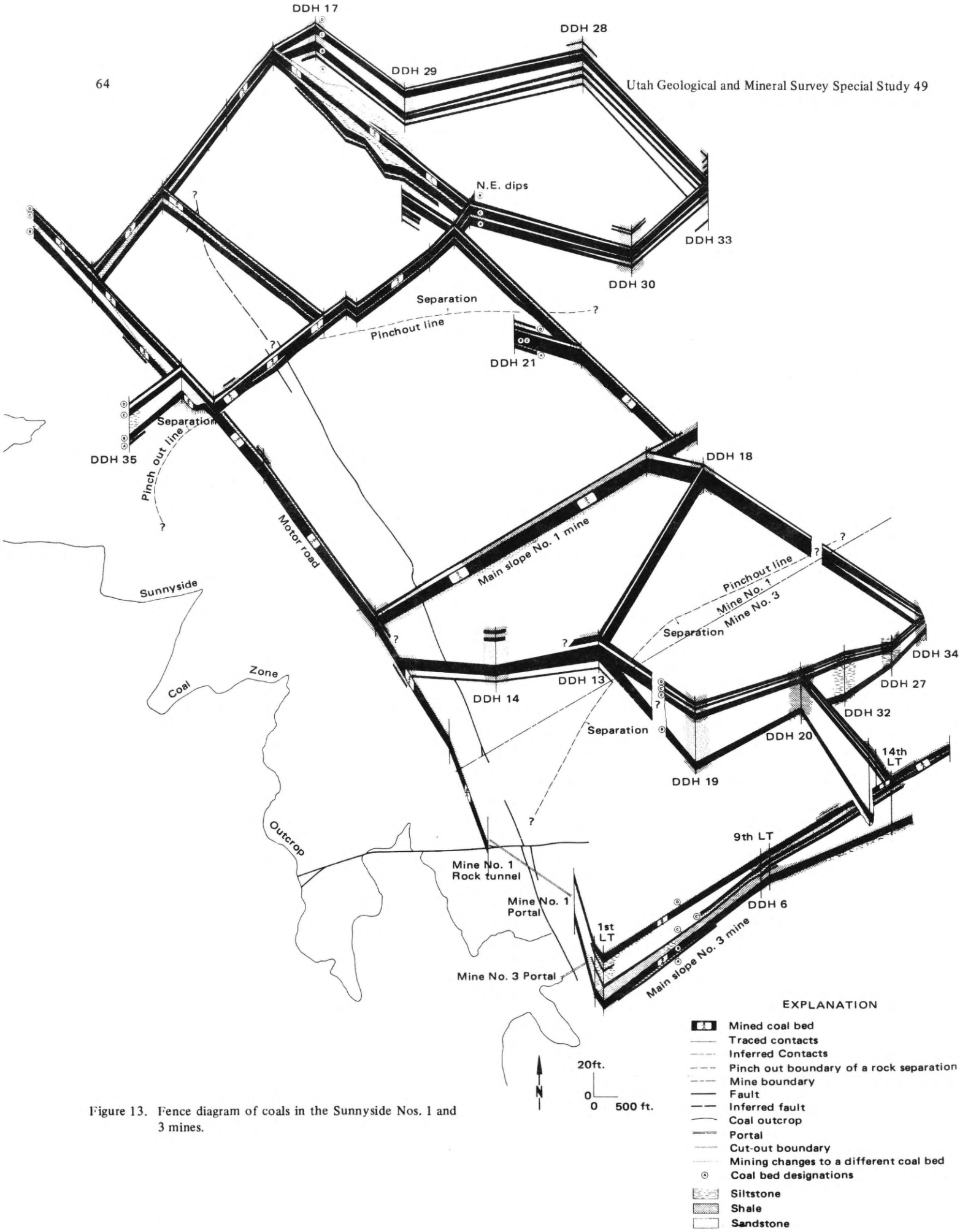


Figure 13. Fence diagram of coals in the Sunnyside Nos. 1 and 3 mines.

seam is the one that has been mined. In the southern part of the No. 1 mine there is no rock between the two and both have been mined together. In the No. 3 mine several episodes of clastic sedimentation formed a rock interval as much as 50 feet thick. Both seams are mined (figure 14).

Number Two Canyon To Lila Canyon

The Sunnyside coal outcrop extends southward from the Sunnyside No. 3 mine across the No. 2 mine and the Columbia mine, to the south end of the Geneva mine (Plate 1). To the north, in the No. 3 mine, the thickness of splitting rock intervals is up to 50 feet. The total coal thickness is somewhat diminished to about 10 feet, rather than the normal 12 to 18 feet evident in the remaining parts of the central swamp. It probably took a little time after each surge of sediment to renew coal swamp conditions. Southward into the No. 2 mine the separating rock intervals diminish in thickness and fusing of coal beds occurs.

The lower and upper mined Sunnyside coals in the Nos. 2 and 3 mines only partly correlate with upper and lower mined Sunnyside coal beds in the north No. 1 mine. The coal is split at different horizons; for example, only the lower part of the upper mined Sunnyside in the No. 3 mine was deposited simultaneously with the upper mined Sunnyside in the north No. 1 mine. In the Nos. 2 and 3 mines the lower mined seam ranges from 5 to more than 10 feet in thickness, the upper mined seam from 3 to 6.5 feet in thickness. There are occasional local areas of very thin coal in these beds signifying an island of sediment in the coal swamp.

The Columbia and Geneva mines are in the seaward half of the coal swamp. Generally there is one thick coal bed which may have a parting up to 5 or 6 feet thick locally, but generally is less than a foot or two thick. The total coal is 12 to 16 feet thick. In the Geneva mine, areas of parting have been mapped between the dotted lines on figure 14. Their configuration is much like that expected of a mudflow or a distributary river. The deposition of the sediment is believed to have taken place as a catastrophic event. The principal example in the Geneva mine shows sediments that flowed in from the south and divided just south of the Columbia mine. The turbidity current probably carried sediments in the area of the Columbia mine. Nine to twelve feet of coal are found under the flow (0 to 5 feet of siltstone), over which another 1 to 3 feet of coal were deposited.

Woodside Area

The most important part of the Woodside area of the Sunnyside coal bed (Plate 1) lies near the outcrop between the south end of U. S. Steel's Geneva mine and the Price River. Farther south, as reported by Fisher (1936) from outcrop data, the Sunnyside coals are thin and possibly discontinuous. All sections of the zone in the Beckwith Plateau show less than 4 feet of coal. This single seam may be thinly parted into two or more horizons. The zone seems to disappear eastward along the outcrop and in U. S. Geological Survey drill holes placed in sections 15 and 30, T. 17 S.,

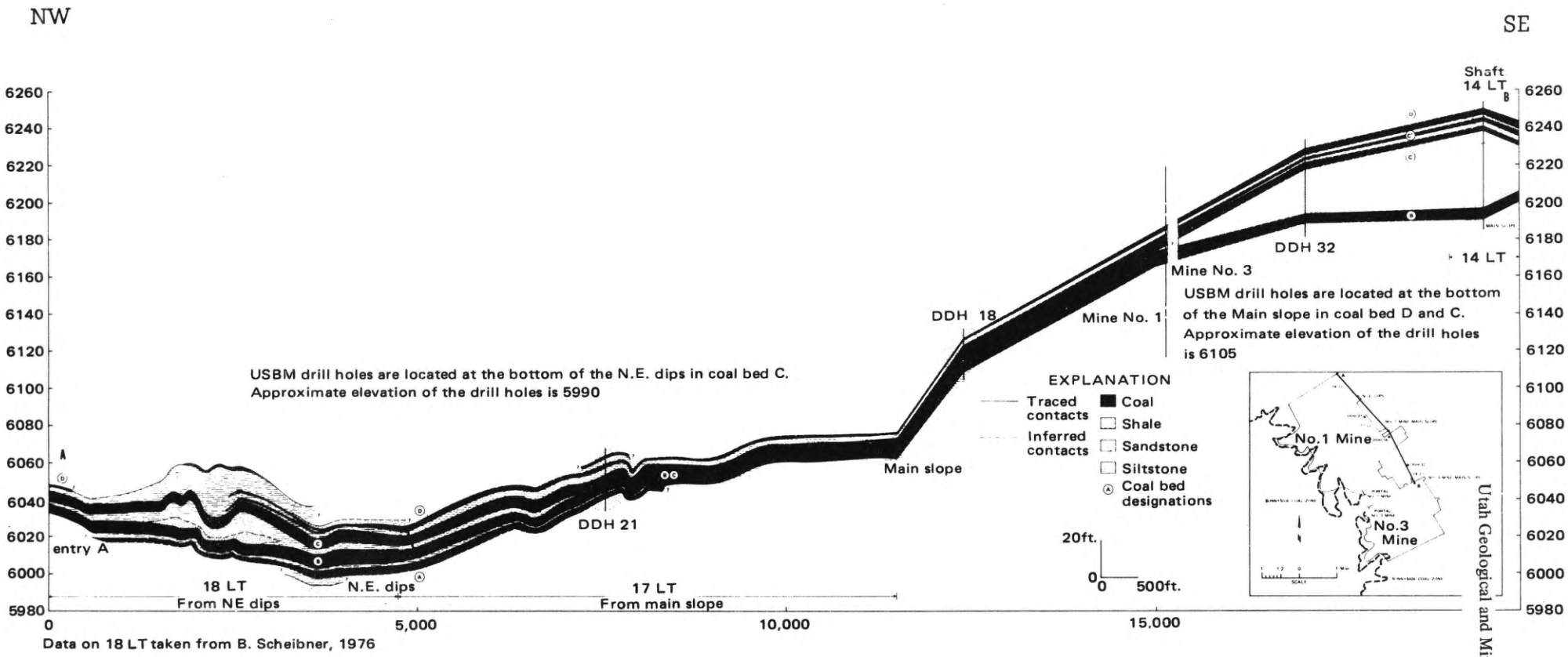


Figure 14. Geologic cross-section of Sunnyside Mine No. 1 and 3, Sunnyside, Utah.

R. 16 E., near Range Creek, thin horizons of bone or bony coal were all that were recognized of the Sunnyside zone. Two additional U. S. Geological Survey holes, drilled a mile and a half behind the outcrop in T. 17 S., R. 15 E., showed 2.9 and 3.1 feet of coal for the zone in a single bed. Therefore coal thicker than 4 feet is only to be expected in the western half of T. 17 and 18 S., R. 15 E. Farther to the north the favorable area is expected to be somewhat wider, but it is the opinion of the writers that thick coals probably do not extend farther east than the east edge of R. 15 E., at least in the Woodside area.

In the Woodside area, north of the Price River, the coals thicken northward from 4 feet to more than 12 feet. In most places there is a single important bed which is locally parted by silt and sand. Drill hole and outcrop sections of the Sunnyside coal zone are shown on Plate 1.

CONCLUSIONS

The Sunnyside coals appear to have been deposited in a large swamp geographically continuous from the Price River to the Matts Summit area between Castlegate and Soldier Canyon. The coal throughout the Sunnyside zone is remarkably uniform in physical and chemical characteristics and it is difficult to correlate individual horizons and beds by detailed geologic descriptions of the coal. Some degree of correlation is possible, however, across distances of less than a mile by employing the positions, nature, and sequence of partings and splits, and by the way certain horizons of the coal react to the compressive forces along the coal faces, along with the estimates of vitrain content. There is no appreciable change in coal composition vertically or laterally between the Sunnyside Nos. 1 and 3 mines. The species of plants and the makeup of materials supplied to the coal swamp did not vary much throughout its history.

The sedimentation that splits the coal was principally deposited during the middle history of the swamp and is most prevalent on the west of landward side. The sediments were probably supplied when a large distributary channel(s) to the west flooded and broke its levees depositing tongues of silt and sand over the coal-forming vegetation.

Few answers were found to explain why the No. 1 mine desorbs a great amount of methane gas and why the No. 3 does not. Megascopic description of the coal made it possible to correlate certain horizons across the span separating the two mines, but did not explain the difference in desorption.

A possible clue to the desorption difference may be offered by the manner in which the coal in the faces and ribs of the No. 1 mine yield somewhat to the compressive faces created by the overburden, indicating an internal fracture or cleat system. Such fracturing undoubtedly creates permeability that allows the gas to escape. No such fracturing was developed in the seams of the No. 3 mine.

In part 1 of this report (Doelling, Smith, and Davis, 1979), it was shown that certain core samples, not necessarily Sunnyside zone coal cores, desorb very little gas naturally until the coal is crushed, while others give it up readily.

No significant gas contents were derived from cores collected to the south of a line corresponding to the division of the two mines. Presumably the coalification and metamorphic history (including depth of burial) was different to the south.

Other parameters investigated showed no evidence of differences that might explain the different rates of CH_4 (methane) desorption between the two mines.

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CHEMICAL ANALYSES OF COAL FROM THE BLACKHAWK FORMATION, WASATCH PLATEAU COAL FIELD, CARBON, EMERY, AND SEVIER COUNTIES, UTAH

by Joseph R. Hatch[1], *Ronald H. Affolter*[1], *and Fitzhugh D. Davis*[2]

INTRODUCTION

As part of a continuing cooperative program between the U. S. Geological Survey and the Utah Geological and Mineral Survey to collect and chemically analyze representative samples of Utah coal, 52 coal samples were collected from the Upper Cretaceous Blackhawk Formation in the Wasatch Plateau coal field in Carbon, Emery, and Sevier Counties, Utah (figure 1). This report lists and summarizes chemical analyses made on these 52 samples. Twenty-two of the samples were collected from 10 operating coal mines; the other 30 samples were collected from seven core holes. Brief descriptions of the 52 samples are in table 1; sample locations are shown in figure 1. Detailed descriptions of the seven cores are in Davis and Doelling (1977).

GEOLOGIC SETTING

The Wasatch Plateau coal field lies on the eastern side of the Wasatch Plateau and includes parts of Utah, Carbon, Emery, Sanpete, and Sevier Counties. The field is elongate in a north-south direction, ranging in width from 7.0 to 20 miles and having a length of about 90 miles. It has an area of 1,100 square miles. Doelling (1972) estimated total coal resources in the Wasatch Plateau coal field to be 10.3 billion short tons. Of this amount 6.4 billion tons are the sum of measured, indicated, and inferred resource categories. The remaining 3.9 billion tons are hypothetical resources.

Coal of the Wasatch Plateau coal field is contained entirely within gently westward dipping strata of the Upper Cretaceous Blackhawk Formation. Ranging in thickness from 700 to 1,000 feet, the Blackhawk consists of sandstone, shale, carbonaceous shale, and coal; it generally forms slopes and small ledges between the prominent cliffs produced by the overlying Castlegate Sandstone and the underlying Star Point Sandstone. The thicker coal beds are in the lower 250-350 feet of the formation. These beds are lenticular; they are well developed and of minable thicknesses beneath limited areas. Thin coal beds are locally present throughout the formation (Hayes and others, 1977).

Genetically, the Blackhawk is closely related to the underlying Star Point Sandstone. The Star Point, 200-450 feet thick, consists of several cliff-forming units of fine- to medium-grained sandstone separated by non-resistant, platy sandstone and dark gray shale similar to that of the Mancos Shale. Its basal contact with the Masuk Shale Member of the Mancos Shale is gradational. The contact between the Blackhawk and the Star Point is sharp, but conformable, and is directly below or very close to the overlying Hiawatha coal bed in much of the field. The Star Point Sandstone was deposited in shallow-marine environments and records general eastward progradation of the western shoreline of the Cretaceous interior seaway during Late Cretaceous (Campanian) time (Spieker, 1931). The Blackhawk accumulated in nonmarine environments marginal to the shoreline (Hayes and others, 1977).

[1]U.S. Geological Survey
[2]Utah Geological and Mineral Survey

The Blackhawk Formation contains many beds of coal, 23 of which have been named (Doelling, 1972). The important beds occur in the lower third of the formation. The coal beds are lenticular, being well developed and of minable thicknesses beneath limited areas.

EXPLANATION OF TABLES

Proximate and ultimate analyses and heat-of-combustion, air-dried-loss, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations on 40 single and composite coal samples from the Blackhawk Formation are listed in table 2. These analyses were provided by the U.S. Bureau of Mines (now U.S. Department of Energy), Pittsburgh, Pa. Analyses for ash content and content of 38 major and minor oxides and trace elements in the laboratory ash (table 3) and analyses for contents of seven trace elements in whole coal for all 52 samples (table 4) were provided by the U.S. Geological Survey, Denver, Colorado. Analytical procedures used by the U.S. Geological Survey are described in Swanson and Huffman (1976).

Table 5 contains the data listed in table 3 converted to a whole-coal basis plus the whole-coal analyses listed in table 4. Twenty-two additional elements not listed in tables 3, 4, and 5 were looked for but not found in amounts greater than their lower limits of detection (table 6). Unweighted statistical summaries of analytical data from the Blackhawk Formation in tables 2, 3, and 5 are listed in tables 7, 8, and 9, respectively. For comparison, data summaries for other Rocky Mountain province coal samples are included. Statistical summaries for Ag, Ce, Ge, and Nd contents in coal from the Blackhawk Formation (table 9) were not included because these variables were detected in an insufficient number of samples to calculate meaningful statistics.

Arsenic contents of the samples summarized in this report have been determined by two different analytical methods: samples D173472, D173476–D173478, and D174663–D174679 were analyzed spectrophotometrically (lower detection limit 1.0 ppm); the remaining 31 samples were analyzed by the graphite furnace-atomic absorption method (lower detection limit 0.5 ppm).

P_2O_5 contents in ash for all samples were determined by X-ray fluorescence spectroscopy. However, owing to a change in technique, the lower detection limit for samples D173472, D173476-D173478, and D174663-D174679 is 0.1 percent; for the other 31 samples it is 1.0 percent.

To be consistent with the precision of the semiquantitative emission spectrographic technique, arithmetic and geometric means of elements determined by this method are reported as the midpoint of the enclosing six-step brackets (See subtitle of table 3, or Swanson and Huffman, (1976, p. 6) for an explanation of six-step brackets).

Explanation of Statistical Terms Used in Summary Tables

In this report the geometric mean (GM) is used as the estimate of the most probable concentration (mode); the geometric mean is calculated by taking the logarithm of each analytical value, summing the logarithms, dividing the sum by the total number of values, and obtaining the antilogarithm of the result. The measure of scatter about the mode used here is the geometric deviation (GD), which is the antilog of the standard

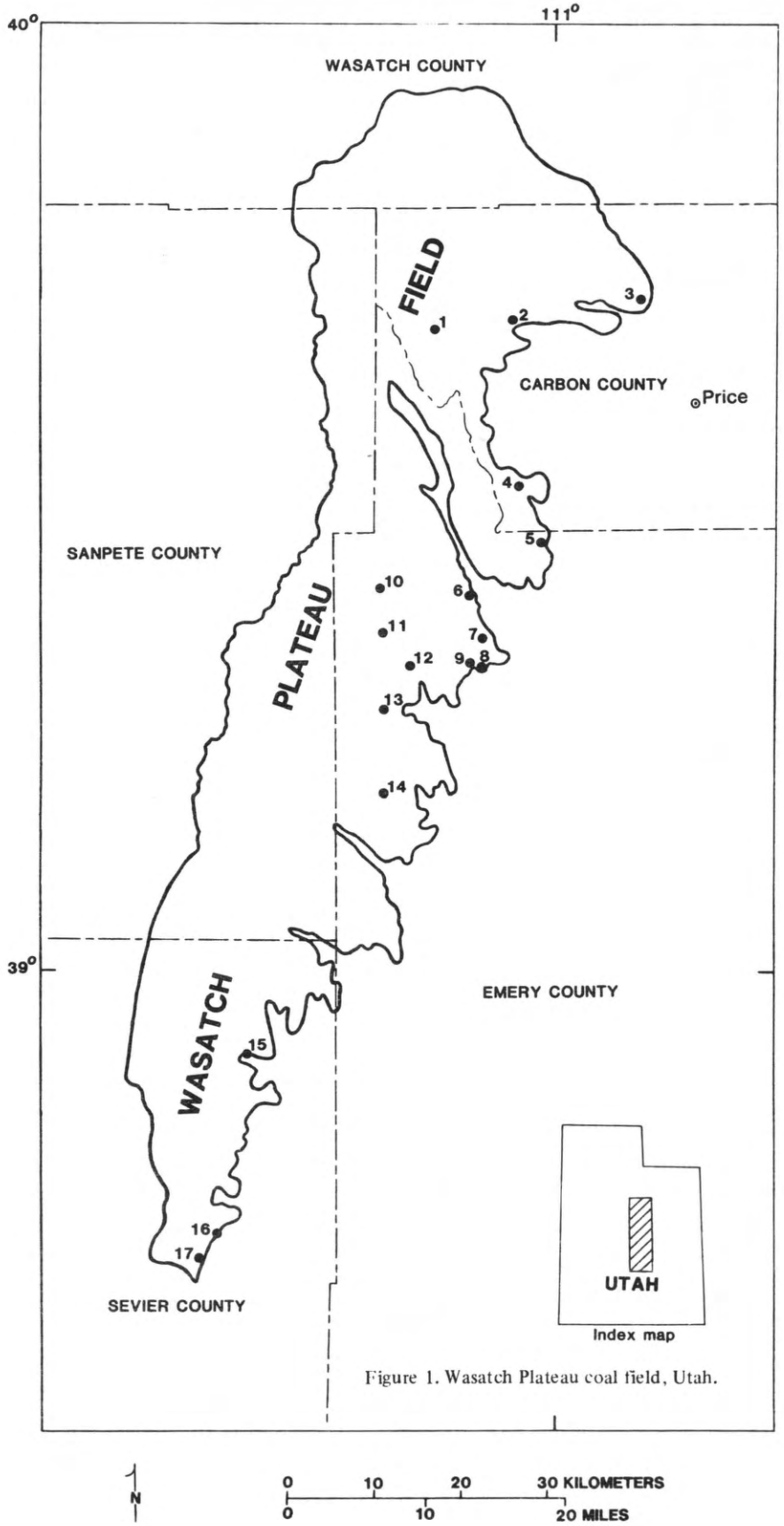

Figure 1. Wasatch Plateau coal field, Utah.

deviation of the logarithms of the analytical values. These statistics are used because the quantities of trace elements in natural materials commonly exhibit positively skewed frequency distributions; such distributions are normalized by analyzing and summarizing trace-element data on a logarithmic basis.

If the frequency distributions are lognormal, the geometric mean is the best estimate of the mode, and the estimated range of the central two-thirds of the observed distribution has a lower limit equal to GM/GD and an upper limit equal to GM·GD. The estimated range of the central 95 percent of the observed distribution has a lower limit equal to GM/GD^2 and an upper limit equal to $GM \cdot GD^2$ (Connor and others, 1976).

Although the geometric mean is, in general, an adequate estimate of the most common analytical value, it is, nevertheless, a biased estimate of the arithmetic mean. The estimates of the arithmetic means listed in the summary tables are Sichel's t statistic (Miesch, 1967).

A common problem in statistical summaries of trace-element data arises when the element content of one or more of the samples is below the limit of analytical detection. This results in a "censored" distribution. Procedures developed by Cohen (1959) were used to compute unbiased estimates of the geometric mean, geometric deviation, and arithmetic mean when the data are censored.

DISCUSSION

The apparent ranks of 40 single and composite coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah, were calculated using the data in table 2 and the formulas in ASTM designation D-388-77 (American Society for Testing and Materials, 1978). The apparent rank of samples from Carbon County ranges from high-volatile B bituminous coal (four samples) to high-volatile A bituminous coal (three samples), apparent rank of samples from Emery County ranges from high-volatile B bituminous coal (13 samples) to high-volatile A bituminous coal (14 samples); and apparent rank of samples from Sevier County ranges from subbituminous B coal (one sample) through subbituminous A coal (two samples) to high-volatile C bituminous coal (three samples).

A statistical comparison (students t test, 94 percent confidence level) of the geometric means of the U.S. Bureau of Mines data for 40 coal samples from the Blackhawk Formation with 86 other Rocky Mountain province coal samples shows that coal from the Blackhawk Formation has significantly higher contents of volatile matter, carbon, and organic sulfur and a significantly lower content of moisture and oxygen. The heat of combustion and contents of fixed carbon, ash, hydrogen, nitrogen, total sulfur, sulfate sulfur, and pyritic sulfur are not significantly different.

A statistical comparison of the geometric means of the contents of coal ash and contents in ash of nine major and minor oxides for 52 coal samples from the Blackhawk Formation with 295 other Rocky Mountain province coal samples shows that coal ash from the Blackhawk Formation has significantly higher contents of SiO_2 and Na_2O and significantly lower contents of Al_2O_3, MgO, and SO_3. The contents of ash and contents of CAO, K_2O, Fe_2O_3, and TiO_2 in ash are not significantly different.

A statistical comparison of the geometric mean-contents for 36 elements from 52 coal samples from the Blackhawk Formation with 295 other Rocky Mountain province

coal samples shows that coal from the Blackhawk Formation has significantly higher contents of Na, B, Be, Cr, Nb, Ni, Se, Y, and Yb, and significantly lower contents of Al, Ca, Mg, Fe, As, Ba, Cd, F, Mn, Mo, Sb, Sr, Th, U, and V. The contents of Si, K, Ti, Co, Cu, Ga, Hg, Li, Pb, Sc, Zn, and Zr are not significantly different. When compared at the 99 percent confidence level, the contents of Fe, Be, and U are not significantly different.

Differences in the oxide composition of coal ashes and the elemental contents of coal result from differences in the total and relative amounts of the various inorganic minerals, the elemental composition of these minerals, and the total and relative amounts of any organically bound elements. The chemical form and distribution of a given element are dependent on the geologic history of the coal bed. A partial listing of the geologic factors that influence element distributions would include chemical composition of original plants; amounts and compositions of the various detrital, diagenetic, and epigenetic minerals; chemical characteristics of the ground waters that come in contact with the bed; temperatures and pressures during burial; and extent of weathering. No evaluation of these factors has been made for any of the coal samples from the Blackhawk Formation.

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Table 1.--U.S. Geological Survey sample numbers, Utah Geological and Mineral Survey field numbers, index-map locations, mine-portal or core-hole locations, bed names, sample types, and thicknesses or depth intervals represented for 52 Blackhawk Formation coal samples, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah

[All samples are of late Cretaceous age]

Sample number	Field number	Index map location (fig. 1)	Mine-portal or core-hole location	Coal bed name	Sample type	Thickness or depth interval represented, in feet
			Carbon County			
D174663	W-P3-75	1	sec. 17, T. 13 S., R. 8 E.	Castlegate "A"	Face channel	6.0
D173472	WP-1-75	2	sec. 17, T. 13 S., R. 7 E.	Upper O'Connor	-----do-----	6.0
D173476	WP-2a-75	3	sec. 10, T. 13 S., R. 9 E.	Hiawatha------	-----do-----	5.5
D173477	WP-2b-75	3	----------do----------	------do------	-----do-----	7.5
D173478	WP-2c-75	3	----------do----------	------do------	-----do-----	7.5
D178666	WP-5a-75	4	sec. 17, T. 15 S., R. 8 E.	------do------	-----do-----	10.5
D174667	WP-5b-75	4	----------do----------	------do------	-----do-----	8.5
D174668	WP-5c-75	4	----------do----------	Wattis--------	-----do-----	7.0
			Emery County			
D174664	WP-4a-75	5	sec. 3, T. 16 S., R. 8 E.	Castlegate "B"	Face channel	8.5
D174665	WP-4b-75	5	----------do----------	------do------	-----do-----	8.5
D174679	WP-8-75	6	sec. 22, T. 16 S., R. 7 E.	Bear Canyon---	-----do-----	7.0
D174669	WP-6a-75	7	sec. 10, T. 17 S., R. 7 E.	Blind Canyon--	-----do-----	6.0
D174670	WP-6b-75	7	----------do----------	------do------	-----do-----	8.2
D174671	WP-6c-75	7	----------do----------	------do------	-----do-----	8.0
D174674	WP-7c-75	8	sec. 26, T. 17 S., R. 7 E.	------do------	-----do-----	9.0
D174675	WP-7d-75	8	----------do----------	------do------	-----do-----	9.0
D174672	WP-7a-75	8	Hiawatha----------	------do------	-----do-----	9.0
D174673	WP-7b-75	8	----------do----------	------do------	-----do-----	9.0
D178171	WP-10-75	9	sec. 27, T. 17 S., R. 7 E.	Uncorrelated--	-----do-----	?
D178149	WP-2-1	10	SE 1/4 SW 1/4 sec. 22, T. 16 S., R. 6 E.----------	Castlegate"A"-	Core--------	640.9-644.9
D178150	WP-2-2	10	----------do----------	Upper Bear Canyon	-----do-----	728.9-732.5

Table 1.--U.S. Geological Survey sample numbers, Utah Geological and Mineral Survey field numbers, index-map locations, mine-portal or core-hole locations, bed names, sample types, and thicknesses or depth intervals represented for 52 Blackhawk Formation coal samples, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Field number	Index map location (fig. 1)	Mine-portal or core-hole location	Coal Bed name	Sample type	Thickness or depth interval represented, in feet
			Emery County--continued			
D178151	WP-2-3	10	SE 1/4 SW 1/4 sec. 22, T. 16 S., R. 6 E.----------	Bear Canyon---	Core--	766.8-769.6
D178152	WP-2-4	10	----------do----------	Hiawatha------	--do--	774.0-777.7
D178153	WP-2-5	10	----------do----------	Uncorrelated--	--do--	870.8-874.1
D178154	WP-2-6	10	----------do----------	-----do-------	--do--	874.1-875.4
D178155	WP-3-1	11	SE 1/4 SE 1/4 sec. 3, T. 17 S., R. 6 E.----------	Uncorrelated---	--do--	502.3-503.9
D178156	WP-3-2	11	----------do----------	Hiawatha-------	--do--	614.1-616.0
D178157	WP-3-3	11	----------do----------	-----do--------	--do--	617.0-620.0
D178158	WP-3-4	11	----------do----------	-----do--------	--do--	620.0-623.8
D178159	WP-4-1	12	SW 1/4 SE 1/4 sec. 24, T. 17 S., R. 6 E.----------	Uncorrelated---	--do--	173.6-175.1
D178160	WP-4-2	12	----------do----------	-----do--------	--do--	267.6-268.9
D178161	WP-4-3	12	----------do----------	-----do--------	--do--	270.4-273.3
D178162	WP-4-4	12	----------do----------	-----do--------	--do--	346.6-348.6
D178163	WP-4-5	12	----------do----------	Hiawatha-------	--do--	352.7-356.1
D178164	WP-4-6	12	----------do----------	-----do--------	--do--	357.1-359.4
D178165	WP-4-7	12	----------do----------	-----do--------	--do--	359.4-361.5
D176976	WP-5-1	13	SW 1/4 NW 1/4 sec. 3, T. 18 S., R. 6 E.----------	Blind Canyon---	--do--	333.6-335.2
D176977	WP-5-2	13	----------do----------	Hiawatha-------	--do--	443.6-445.9
D176978	WP-5-3	13	----------do----------	-----do--------	--do--	445.9-447.8
D176979	WP-5-4	13	----------do----------	-----do--------	--do--	448.8-450.9
D176980	WP-6-2	14	SE 1/4 SE 1/4 sec. 3, T. 19 S., R. 6 E.----------	Bear Canyon(?)-	--do--	843.4-844.7

Table 1.--U.S. Geological Survey sample numbers, Utah Geological and Mineral Survey field numbers, index-map locations, mine-portal or core-hole locations, bed names, sample types, and thicknesses or depth intervals represented for 52 Blackhawk Formation coal samples, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Field number	Index map location (fig. 1)	Mine-portal or core-hole location	Coal bed name	Sample type	Thickness or depth interval represented, in feet
			Emery County--continued			
D176981	WP-6-1	14	SE 1/4 SE 1/4 sec. 3, T. 19 S., R. 6 E.	Uncorrelated	Core	922.3- 924.7
D176982	WP-6-3	14	do	Blind Canyon(?)	do	970.3- 973.8
D176983	WP-6-4	14	do	Hiawatha(?)	do	1,023.7-1,024.9
			Sevier County			
D174676	WP-9a-75	15	Sec. 12, T. 22 S., R. 4 E.	Upper Hiawatha	Face channel	9.0
D174677	WP-9b-75	15	do	do	do	8.0
D174678	WP-9c-75	15	do	do	do	9.0
D178167	WP-7-1a	16	NW 1/4 NE 1/4 sec. 15, T. 24 S., R. 4 E.	Upper Ivie(?)	Core	78.6- 82.8
D178168	WP-7-1b	16	do	do	do	84.0- 85.3
D178166	WP-7-2	16	do	Lower Ivie(?)	do	167.8-171.3
D178169	WP-8-1	17	NE 1/4 SE 1/4 sec. 21, T. 24 S., R. 4 E.	Upper Ivie(?)	do	274.4-278.4
D178170	WP-8-2	17	do	Uncorrelated	do	369.8-372.9

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 40 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah

[All analyses except heat of combustion, free-swelling index, and ash-fusion temperatures in percent. For each sample number, the analyses are reported three ways: first, as received; second, moisture free; and third, moisture and ash free. Kcal/kg = 0.556 (Btu/lb); °F = (°C x 1.8) + 32; L, less than the value shown, B, not determined. Sample D174666* is a composite of samples D174666 and D174667; D174664* is a composite of D174664 and D174665; D174669* is a composite of D174669, D174670, and D174671; D174674* is a composite of D174674 and D174675; D174672* is a composite of D174672 and D174673; D178153* is a composite of D178153 and D178154; D178157* is a composite of D178157 and D178158; D178164* is a composite of D178164 and D178165; and D174676* is a composite of D174676, D174677, and D174678]

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D174663	4.9	45.5	42.2	7.4	6.1	69.9	1.4	14.8	0.4	7,060	12,710
	---	47.8	44.4	7.8	5.8	73.5	1.5	11.0	.4	7,420	13,360
	---	51.9	48.1	---	6.3	79.7	1.6	11.9	.5	8,050	14,490
D173472	6.5	46.3	43.5	3.7	6.0	70.7	1.5	17.4	.7	7,040	12,670
	---	49.5	46.5	4.0	5.6	75.6	1.6	12.4	.7	7,530	13,550
	---	51.6	48.4	---	5.9	78.7	1.7	12.9	.8	7,840	14,110
D173476	2.8	44.0	43.5	9.7	5.6	70.2	1.5	12.4	.6	7,030	12,650
	---	45.3	44.8	10.0	5.4	72.2	1.5	10.2	.6	7,230	13,010
	---	50.3	49.7	---	6.0	80.2	1.7	11.3	.7	8,030	14,460
D173477	2.5	42.2	45.0	10.3	5.5	69.8	1.4	12.3	.7	6,970	12,540
	---	43.3	46.2	10.6	5.4	71.6	1.4	10.3	.7	7,150	12,860
	---	48.4	51.6	---	6.0	80.0	1.6	11.6	.8	7,990	14,380
D173478	1.9	45.2	43.9	9.0	5.7	72.2	1.5	11.0	.6	7,210	12,980
	---	46.1	44.8	9.2	5.6	73.6	1.5	9.5	.6	7,350	13,230
	---	50.7	49.3	---	6.2	81.0	1.7	10.5	.7	8,090	14,570
D174666*	5.7	38.1	39.5	16.7	5.2	60.8	1.3	15.3	.7	6,040	10,880
	---	40.4	41.9	17.7	4.8	64.5	1.4	10.9	.7	6,410	11,540
	---	49.1	50.9	---	5.9	78.4	1.7	13.2	.9	7,790	14,020
D174668	5.2	46.7	40.1	8.0	5.8	68.2	1.3	16.0	.7	6,840	12,310
	---	49.3	42.3	8.4	5.5	71.9	1.4	12.0	.7	7,210	12,990
	---	53.8	46.2	---	6.0	78.6	1.5	13.1	.8	7,880	14,180
D174664*	4.8	46.5	42.7	6.0	5.7	71.3	1.4	15.1	.5	7,160	12,880
	---	48.8	44.9	6.3	5.4	74.9	1.5	11.4	.5	7,520	13,530
	---	52.1	47.9	---	5.8	79.9	1.6	12.1	.6	8,020	14,440
D174679	6.1	44.8	43.3	5.8	5.9	71.4	1.3	15.1	.5	7,170	12,910
	---	47.7	46.1	6.2	5.6	76.0	1.4	10.3	.5	7,640	13,750
	---	50.9	49.1	---	5.9	81.0	1.5	11.0	.6	8,140	14,650
D174669*	3.7	44.0	46.9	5.4	5.9	73.4	1.4	13.4	.5	7,370	13,270
	---	45.7	48.7	5.6	5.7	76.2	1.5	10.5	.5	7,660	13,780
	---	48.4	51.6	---	6.0	80.7	1.5	11.1	.6	8,110	14,600
D174674*	3.8	45.3	42.9	8.0	5.9	70.8	1.4	13.5	.4	7,140	12,850
	---	47.1	44.6	8.3	5.7	73.6	1.5	10.5	.4	7,420	13,360
	---	51.4	48.6	---	6.2	80.3	1.6	11.5	.5	8,090	14,570
D174672*	5.2	42.3	45.6	6.9	5.6	70.3	1.4	15.3	.5	6,960	12,520
	---	44.6	48.1	7.3	5.3	74.2	1.5	11.3	.5	7,340	13,210
	---	48.1	51.9	---	5.7	80.0	1.6	12.1	.6	7,910	14,240

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 40 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D174663	0.2	0.02	0.08	0.35	1.5	1,165	1,195	1,230
	---	.02	.08	.37				
	---	.02	.09	.40				
D173472	.7	.01	.17	.48	B	B	B	B
	---	.01	.18	.51				
	---	.01	.19	.53				
D173476	.4	.02	.12	.45	B	B	B	B
	---	.02	.12	.46				
	---	.02	.14	.51				
D173477	.3	.01	.07	.63	B	B	B	B
	---	.01	.07	.65				
	---	.01	.08	.72				
D173478	.01L	.02	.09	.44	B	B	B	B
	---	.02	.09	.45				
	---	.02	.10	.49				
D174666*	.9	.01	.10	.58	1.5	1,295	1,320	1,350
	---	.01	.11	.62				
	---	.01	.13	.75				
D174668	.4	.01	.07	.66	1.0	1,260	1,290	1,320
	---	.01	.07	.70				
	---	.01	.08	.76				
D174664*	.2	.02	.12	.34	2.0	1,120	1,150	1,175
	---	.02	.13	.36				
	---	.02	.13	.38				
D174679	1.7	.02	.16	.30	2.5	1,200	1,230	1,260
	---	.02	.17	.32				
	---	.02	.18	.34				
D174669*	.01L	.01	.05	.39	1.5	1,140	1,165	1,200
	---	.01	.05	.40				
	---	.01	.06	.43				
D174674*	.1	.01	.08	.31	1.5	1,170	1,200	1,255
	---	.01	.08	.32				
	---	.01	.09	.35				
D174672*	.4	.02	.10	.42	1.5	1,260	1,290	1,320
	---	.02	.11	.44				
	---	.02	.11	.48				

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 40 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D178171	3.0	41.9	45.1	9.5	5.5	69.4	0.9	14.2	0.5	6,920	12,460
	---	43.4	46.7	9.8	5.3	71.9	.9	11.5	.5	7,170	12,910
	---	48.2	51.8	---	5.9	79.8	1.0	12.7	.6	7,960	14,320
D178149	3.6	42.0	50.8	3.6	5.9	74.1	1.1	14.7	.6	7,480	13,470
	---	43.6	52.7	3.7	5.7	76.9	1.1	11.9	.6	7,760	13,970
	---	45.3	54.7	---	5.9	79.8	1.2	12.4	.6	8,060	14,520
D178150	3.2	38.9	47.9	10.0	5.8	71.1	1.1	11.4	.6	7,030	12,650
	---	40.2	49.5	10.3	5.6	73.5	1.1	8.8	.6	7,260	13,070
	---	44.8	55.2	---	6.3	81.9	1.3	9.9	.7	8,100	14,570
D178151	3.0	44.7	45.1	7.2	6.0	72.5	1.1	12.5	.7	7,370	13,260
	---	46.1	46.5	7.4	5.8	74.7	1.1	10.1	.7	7,590	13,670
	---	49.8	50.2	---	6.3	80.7	1.2	11.0	.8	8,200	14,770
D178152	3.1	40.7	46.4	9.8	5.6	69.5	1.2	13.1	.8	7,010	12,610
	---	42.0	47.9	10.1	5.4	71.7	1.2	10.7	.8	7,230	13,010
	---	46.7	53.3	---	6.0	79.8	1.4	11.9	.9	8,040	14,480
D178153*	2.8	39.8	48.5	8.9	5.8	71.5	1.1	12.1	.6	7,190	12,950
	---	40.9	49.9	9.2	5.6	73.6	1.1	9.9	.6	7,400	13,320
	---	45.1	54.9	---	6.2	81.0	1.2	10.9	.7	8,150	14,670
D178155	3.0	44.0	42.5	10.5	5.9	69.6	1.3	11.9	.8	6,970	12,550
	---	45.4	43.8	10.8	5.7	71.8	1.3	9.5	.8	7,190	12,940
	---	50.9	49.1	---	6.4	80.5	1.5	10.7	.9	8,060	14,510
D178156	3.6	39.1	44.7	12.6	5.7	67.5	1.1	12.5	.6	6,680	12,030
	---	40.6	46.4	13.1	5.5	70.0	1.1	9.6	.6	6,930	12,480
	---	46.7	53.3	---	6.3	80.5	1.3	11.1	.7	7,980	14,360
D178157*	4.2	41.4	48.2	6.2	6.0	72.7	1.1	13.5	.5	7,210	12,980
	---	43.2	50.3	6.5	5.8	75.9	1.1	10.2	.5	7,530	13,550
	---	46.2	53.8	---	6.2	81.1	1.2	10.9	.6	8,050	14,490
D178159	3.2	38.4	43.0	15.4	5.3	64.8	1.1	12.8	.6	6,460	11,630
	---	39.7	44.4	15.9	5.1	66.9	1.1	10.3	.6	6,670	12,010
	---	47.2	52.8	---	6.1	79.6	1.4	12.2	.7	7,940	14,290
D178160	3.0	43.9	42.8	10.3	5.9	69.4	1.2	12.6	.6	7,010	12,610
	---	45.3	44.1	10.6	5.7	71.5	1.2	10.2	.6	7,220	13,000
	---	50.6	49.4	---	6.4	80.0	1.4	11.5	.7	8,080	14,540
D178161	2.9	43.9	46.0	7.2	5.9	72.2	1.1	13.1	.5	7,260	13,070
	---	45.2	47.4	7.4	5.7	74.4	1.1	10.8	.5	7,480	13,460
	---	48.8	51.2	---	6.2	80.3	1.2	11.7	.6	8,080	14,540

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 40 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D178171	0.5	0.02	0.11	0.36	1.0	1,150	1,200	1,225
	---	.02	.11	.37				
	---	.02	.13	.41				
D178149	.4	.01	.10	.48	2.5	1,140	1,165	1,195
	---	.01	.10	.50				
	---	.01	.11	.52				
D178150	.4	.10	.17	.32	2.5	1,600+	1,600+	1,600+
	---	.10	.18	.33				
	---	.12	.20	.37				
D178151	.4	.08	.23	.39	2.5	1,250	1,275	1,310
	---	.08	.24	.40				
	---	.09	.26	.43				
D178152	.1	.11	.57	.20	3.5	1,290	1,320	1,380
	---	.11	.59	.21				
	---	.13	.65	.23				
D178153*	.3	.06	.29	.29	3.5	1,260	1,290	1,320
	---	.06	.30	.30				
	---	.07	.33	.33				
D178155	.1	.01	.16	.67	1.0	1,290	1,345	1,455
	---	.01	.16	.69				
	---	.01	.18	.77				
D178156	.4	.01	.06	.51	1.5	1,250	1,290	1,455
	---	.01	.06	.53				
	---	.01	.07	.61				
D178157*	.6	.01	.10	.35	1.5	1,075	1,105	1,170
	---	.01	.10	.37				
	---	.01	.11	.39				
D178159	.2	.03	.08	.54	1.5	1,320	1,395	1,505
	---	.03	.08	.56				
	---	.04	.10	.66				
D178160	.4	.01	.07	.53	1.0	1,260	1,305	1,465
	---	.01	.07	.55				
	---	.01	.08	.61				
D178161	.2	.07	.14	.32	1.0	1,140	1,195	1,380
	---	.07	.14	.33				
	---	.08	.16	.36				

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 40 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D178162	3.3	39.7	43.9	13.1	5.6	65.9	1.0	13.6	0.8	6,620	11,920
	---	41.1	45.4	13.5	5.4	68.1	1.0	11.0	.8	6,850	12,330
	---	47.5	52.5	---	6.3	78.8	1.2	12.8	1.0	7,920	14,260
D178163	3.0	38.2	48.4	10.4	5.4	68.9	1.0	13.7	.6	6,830	12,300
	---	39.4	49.9	10.7	5.2	71.0	1.0	11.4	.6	7,040	12,680
	---	44.1	55.9	---	5.9	79.6	1.2	12.7	.7	7,890	14,200
D178164*	2.9	41.6	47.7	7.8	5.6	71.4	1.1	13.6	.5	7,120	12,820
	---	42.8	49.1	8.0	5.4	73.5	1.1	11.4	.5	7,330	13,200
	---	46.6	53.4	---	5.9	80.0	1.2	12.3	.6	7,980	14,360
D176976	2.3	44.3	45.6	7.8	6.0	72.2	.8	12.4	.8	7,260	13,070
	---	45.3	46.7	8.0	5.9	73.9	.8	10.6	.8	7,430	13,380
	---	49.3	50.7	---	6.4	80.3	.9	11.5	.9	8,080	14,540
D176977	1.9	38.8	50.7	8.6	5.4	68.3	1.1	16.2	.4	6,710	12,080
	---	39.6	51.7	8.8	5.3	69.6	1.1	14.8	.4	6,840	12,310
	---	43.4	56.6	---	5.8	76.3	1.2	16.2	.4	7,500	13,500
D176979	2.6	43.0	49.7	4.7	5.9	74.5	.3	14.0	.6	7,400	13,320
	---	44.1	51.0	4.8	5.8	76.5	.3	12.0	.6	7,600	13,680
	---	46.4	53.6	---	6.1	80.4	.3	12.6	.6	7,980	14,370
D176980	4.3	39.2	48.4	8.1	5.6	69.0	1.2	15.5	.6	6,750	12,150
	---	41.0	50.6	8.5	5.4	72.1	1.3	12.2	.6	7,050	12,700
	---	44.7	55.3	---	5.8	78.8	1.4	13.3	.7	7,710	13,870
D176981	4.0	41.2	50.5	4.3	5.7	72.0	.8	16.3	.9	7,070	12,720
	---	42.9	52.6	4.5	5.5	75.0	.8	13.3	.9	7,360	13,250
	---	44.9	55.1	---	5.7	78.5	.9	13.9	1.0	7,710	13,870
D176982	4.3	43.0	48.5	4.2	5.9	72.2	.6	16.5	.6	7,160	12,880
	---	44.9	50.7	4.4	5.7	75.4	.6	13.2	.6	7,480	13,460
	---	47.0	53.0	---	5.9	78.9	.7	13.9	.7	7,820	14,080
D176983	3.1	36.2	39.9	20.8	5.0	59.2	1.0	13.5	.5	5,860	10,550
	---	37.4	41.2	21.5	4.8	61.1	1.0	11.1	.5	6,050	10,890
	---	47.6	52.4	---	6.1	77.8	1.3	14.1	.7	7,700	13,860
D174676*	7.7	38.6	39.3	14.4	5.2	60.5	1.1	18.0	.8	5,910	10,630
	---	41.8	42.6	15.6	4.7	65.5	1.2	12.1	.9	6,400	11,520
	---	49.6	50.4	---	5.6	77.7	1.4	14.3	1.0	7,580	13,650
D178167	13.1	32.0	39.2	15.7	5.3	54.7	.6	22.9	.8	5,240	9,440
	---	36.8	45.1	18.1	4.4	62.9	.7	13.0	.9	6,040	10,860
	---	44.9	55.1	---	5.4	76.8	.8	15.8	1.1	7,370	13,260

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 40 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D178162	0.1	0.02	0.30	0.51	1.5	1,360	1,415	1,490
	---	.02	.31	.53				
	---	.02	.36	.61				
D178163	.2	.02	.08	.48	1.5	1,260	1,320	1,355
	---	.02	.08	.49				
	---	.02	.09	.55				
D178164*	.2	.02	.06	.38	1.5	1,220	1,255	1,280
	---	.02	.06	.39				
	---	.02	.07	.43				
D176976	.2	.02	.14	.61	1.0	1,090	1,155	1,245
	---	.02	.14	.62				
	---	.02	.16	.68				
D176977	.3	.02	.06	.36	1.0	1,110	1,240	1,430
	---	.02	.06	.37				
	---	.02	.07	.40				
D176979	.2	.02	.12	.49	1.5	1,030	1,075	1,100
	---	.02	.12	.50				
	---	.02	.13	.53				
D176980	.4	.02	.18	.41	1.0	1,095	1,200	1,340
	---	.02	.19	.43				
	---	.02	.21	.47				
D176981	.2	.02	.30	.54	1.0	970	1,025	1,080
	---	.02	.31	.56				
	---	.02	.33	.59				
D176982	.3	.02	.24	.37	.0	1,110	1,165	1,190
	---	.02	.25	.39				
	---	.02	.26	.40				
D176983	.1	.02	.06	.44	1.0	1,505	1,600+	1,600+
	---	.02	.06	.45				
	---	.03	.08	.58				
D174676*	1.2	.01	.27	.54	.0	1,200	1,230	1,260
	---	.01	.29	.59				
	---	.01	.35	.69				
D178167	2.2	.02	.48	.30	.0	1,280	1,290	1,305
	---	.02	.55	.35				
	---	.03	.67	.42				

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, form-of-sulfur, free-swelling index, and ash-fusion-temperature determinations for 40 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D178168	9.3	26.8	30.4	33.5	4.3	43.2	0.7	17.7	0.6	4,170	7,510
	---	29.5	33.5	36.9	3.6	47.6	.8	10.4	.7	4,600	8,280
	---	46.9	53.1	---	5.7	75.5	1.2	16.5	1.0	7,290	13,130
D178166	11.9	34.6	44.8	8.7	5.6	59.9	.8	22.7	2.3	5,830	10,500
	---	39.3	50.9	9.9	4.9	68.0	.9	13.8	2.6	6,620	11,920
	---	43.6	56.4	---	5.4	75.4	1.0	15.3	2.9	7,350	13,220
D178169	13.7	25.6	26.3	34.4	4.5	37.6	.4	22.5	.6	3,580	6,440
	---	29.7	30.5	39.9	3.5	43.6	.5	12.0	.7	4,150	7,460
	---	49.3	50.7	---	5.7	72.4	.8	19.9	1.2	6,890	12,410
D178170	13.0	28.3	29.1	29.6	4.7	42.5	.6	22.1	.5	4,130	7,430
	---	32.5	33.4	34.0	3.7	48.9	.7	12.1	.6	4,740	8,540
	---	49.3	50.7	---	5.7	74.0	1.0	18.4	.9	7,190	12,940

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D178168	1.5	0.02	0.41	0.20	0.0	1,470	1,530	1,600+
	---	.02	.45	.22				
	---	.03	.72	.35				
D178166	1.1	.04	1.61	.66	.0	1,080	1,110	1,120
	---	.05	1.83	.75				
	---	.05	2.03	.83				
D178169	3.0	.08	.35	.22	.0	1,600+	1,600+	1,600+
	---	.09	.41	.25				
	---	.15	.67	.42				
D178170	2.3	.02	.14	.32	.0	1,415	1,470	1,540
	---	.02	.16	.37				
	---	.03	.24	.56				

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah

[Values in percent or parts per million. Coal ashed at 525°C. L, less than the value shown; N, not detected; B, not determined. S after element title indicates determinations by semiquantitative emission spectrography. The spectrographic results are to be identified with geometric brackets whose boundaries are part of the ascending series 0.12, 0.18, 0.26, 0.38, 0.56, 0.83, 1.2, etc. but reported as midpoints of the brackets, 0.1, 0.15, 0.2, 0.3, 0.5, 0.7, 1.0, etc. Precision of the spectrographic data is plus-or-minus one bracket at or 68 percent plus-or-minus two brackets at 95 percent confidence level]

Sample number	Ash (percent)	SiO_2 (percent)	Al_2O_3 (percent)	CaO (percent)	MgO (percent)	Na_2O (percent)	K_2O (percent)	Fe_2O_3 (percent)	TiO_2 (percent)	P_2O_5 (percent)	Sample number
D174663	8.3	53	13	7.6	1.08	1.48	0.77	6.0	0.83	0.33	D174663
D173472	3.9	60	12	5.4	1.23	.67	.20	8.9	.80	.10L	D173472
D173476	10.7	47	18	9.7	1.66	1.35	.17	4.8	1.2	.19	D173476
D173477	12.4	38	24	9.2	2.40	1.96	.095	4.5	1.5	.34	D173477
D173478	10.4	47	20	9.5	2.65	2.10	.057	5.0	1.2	.40	D173478
D174666	8.9	65	19	2.6	.50	.50	.53	3.8	1.2	.21	D174666
D174667	23.5	65	18	2.1	1.63	.24	2.1	2.8	.83	.15	D174667
D174668	10.8	61	15	4.1	1.18	.89	1.5	4.0	.82	.20	D174668
D174664	5.5	31	10	19	1.06	2.27	.25	6.9	.53	.80	D174664
D174665	9.7	49	23	6.2	.70	2.45	.25	3.5	1.3	.33	D174665
D174679	6.8	24	10	24	2.34	2.97	.17	7.6	.70	.74	D174679
D174669	7.7	54	18	4.4	.41	4.18	.30	2.7	1.2	.16	D174669
D174670	6.1	39	17	13	.66	3.76	.13	5.4	1.0	.54	D174670
D174671	5.0	35	11	19	.80	3.45	.18	7.3	.77	.71	D174671
D174674	5.5	37	11	9.8	1.43	8.37	.062	11	.80	.34	D174674
D174675	9.3	57	12	6.3	.94	3.73	.86	3.8	.88	.22	D174675
D174672	7.7	43	19	10	.60	2.56	.53	3.5	1.1	.65	D174672
D174673	8.1	47	21	5.6	.60	4.58	.54	3.0	.97	.52	D174673
D178171	9.9	48	19	7.6	.73	5.68	.26	4.1	1.1	1.0L	D178171
D178149	3.8	51	16	6.4	.98	3.73	.71	5.5	.94	1.0L	D178149
D178150	10.3	53	29	2.2	.44	1.55	.44	1.5	1.3	1.0L	D178150
D178151	7.3	59	16	3.7	.79	3.75	.78	2.3	1.1	1.0L	D178151
D178152	9.9	67	14	2.1	.61	2.10	1.3	3.4	.87	1.0L	D178152
D178153	7.5	61	14	3.7	.83	3.93	.73	3.4	.84	1.0L	D178153
D178154	12.1	56	22	3.0	.45	2.23	.48	1.4	1.0	1.0L	D178154
D178155	10.3	61	14	4.0	1.03	2.33	1.2	2.9	.87	1.0L	D178155
D178156	12.7	50	23	4.1	.59	4.03	.28	2.1	1.1	1.1	D178156
D178157	6.9	21	6.3	25	1.79	3.48	.090	7.1	.43	1.0L	D178157
D178158	6.6	53	11	8.2	.85	3.93	.080	3.8	.90	1.0L	D178158
D178159	20.3	70	16	1.1	1.11	.42	2.0	1.4	.93	1.0L	D178159
D178160	11.3	66	13	2.9	.81	2.75	.98	2.0	1.1	1.0L	D178160
D178161	7.9	56	23	1.8	.78	4.95	2.2	2.6	1.1	1.0L	D178161
D178162	14.0	55	23	1.7	1.31	1.75	2.2	2.6	1.1	1.0L	D178162
D178163	13.4	55	22	2.8	1.28	3.35	.75	2.3	1.1	1.0L	D178163
D178164	9.5	51	20	5.4	.44	5.20	.11	2.3	1.2	1.0L	D178164
D178165	7.2	57	14	4.9	.41	5.38	.090	2.6	.96	1.0L	D178165
D176976	8.9	58	13	4.1	1.38	3.48	1.5	2.9	.93	1.0L	D176976
D176977	14.9	56	19	2.9	1.13	3.19	.92	2.2	1.1	1.0L	D176977
D176978	6.9	40	12	10	1.57	6.55	.10	5.4	.61	1.0L	D176978
D176979	5.3	62	14	3.4	1.58	5.70	.96	2.4	.82	1.0L	D176979

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	SO3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	Sample number
D174663	4.0	N	1,000	300	7	1.0L	N	15	70	95	D174663
D173472	9.5	N	1,500	70	N	1.5	N	15	50	100	D173472
D173476	5.6	N	1,000	500	7	1.0L	N	10L	30	56	D173476
D173477	4.3	N	700	1,500	N	1.0L	N	10L	30	50	D173477
D173478	5.8	N	1,000	2,000	3	1.0L	N	10	50	62	D173478
D174666	2.2	N	1,500	200	7	1.0	500L	15	70	70	D174666
D174667	1.1	15	300	200	5	1.0	500L	15	100	40	D174667
D174668	3.0	N	1,500	500	7	1.0	500L	15	70	56	D174668
D174664	6.5	N	2,000	1,000	3	1.0L	N	15	70	98	D174664
D174665	2.1	N	1,000	200	3	1.0L	500L	10	70	62	D174665
D174679	8.4	N	1,500	1,500	N	1.0L	N	10	70	97	D174679
D174669	2.9	N	1,500	500	5	1.0L	500L	15	70	82	D174669
D174670	4.8	2	2,000	500	7	1.0L	500	15	70	80	D174670
D174671	7.7	N	2,000	2,000	5	1.0L	500L	15	70	77	D174671
D174674	9.8	N	3,000	300	3	1.0L	N	15	70	78	D174674
D174675	3.7	N	1,500	150	3L	1.0L	N	15	70	81	D174675
D174672	3.1	N	1,500	300	3	1.0L	500L	15	70	75	D174672
D174673	2.3	N	1,500	500	3	1.0L	500L	10	70	68	D174673
D178171	4.3	N	1,000	1,000	3	1.0L	N	10L	70	66	D178171
D178149	6.7	N	1,500	1,000	30	2.0	N	30	150	158	D178149
D178150	1.5	N	300	500	15	1.0	N	15	70	103	D178150
D178151	3.1	N	700	700	20	1.0L	N	15	70	266	D178151
D178152	1.9	N	700	1,500	20	1.5	N	15	100	194	D178152
D178153	3.3	N	1,000	1,000	30	1.5	N	30	100	155	D178153
D178154	1.5	N	500	700	30	1.0L	N	15	100	149	D178154
D178155	3.9	N	700	500	20	1.0L	N	15	100	106	D178155
D178156	2.6	N	700	700	20	1.0L	N	15	50	81	D178156
D178157	8.7	N	1,500	2,000	N	1.0L	N	10L	50	49	D178157
D178158	6.6	N	1,000	3,000	10	1.0L	N	10	150	91	D178158
D178159	.74	N	300	3,000	20	1.0L	N	10	150	44	D178159
D178160	3.3	N	700	300	30	1.0L	N	15	200	106	D178160
D178161	1.6	N	1,500	300	15	1.0L	N	15	150	143	D178161
D178162	1.7	N	1,000	700	20	1.0	N	20	200	124	D178162
D178163	1.9	N	700	500	10	1.0	N	10	70	75	D178163
D178164	3.6	N	1,000	1,000	5	1.0L	N	10	70	66	D178164
D178165	3.8	N	1,500	300	20	1.0L	N	10	70	208	D178165
D176976	5.1	N	700	200	15	1.0	500L	30	70	123	D176976
D176977	2.1	N	700	700	15	1.0L	500L	30	70	80	D176977
D176978	5.9	N	1,500	700	N	1.0L	500L	15	30	95	D176978
D176979	2.5	N	2,000	700	10	1.5	500L	20	70	92	D176979

Table 3.--Major- and Minor-oxide and trace-element composition of the laboratory ash of 52 coal samples from the Blackhawk Formation Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sample number
D174663	30	N	N	63	145	15	20	B	30	30	D174663
D173472	10	N	N	90	50	15	20	B	50	25	D173472
D173476	30	N	100L	194	70	7	20	N	15	45	D173476
D173477	30	N	100L	328	70	N	20	N	15	45	D173477
D173478	30	N	100L	236	70	N	20	N	15	30	D173478
D174666	30	N	100L	244	50	10	30	N	30	40	D174666
D174667	30	N	100L	243	50	7	30	N	30	30	D174667
D174668	30	N	100L	166	95	7	30	N	50	35	D174668
D174664	15	N	100L	100	145	10	20L	N	50	35	D174664
D174665	50	N	150	125	60	7	50	150L	15	50	D174665
D174679	20	N	N	84	200	15	20L	B	20	25	D174679
D174669	30	N	100L	125	35	15	50	150L	30	40	D174669
D174670	30	N	200	83	100	15	30	150	30	50	D174670
D174671	30	N	150	62	130	15	20	150L	30	40	D174671
D174674	20	N	100L	35	160	7	30	N	30	25	D174674
D174675	20	N	100L	78	40	7	30	N	50	25L	D174675
D174672	30	N	100L	204	70	15	30	N	30	50	D174672
D174673	30	N	100L	130	40	10	20	N	30	50	D174673
D178171	50	N	N	134	80	N	20	B	10	25	D178171
D178149	70	20L	150	80	95	15	20	N	100	95	D178149
D178150	50	N	100	168	30	N	30	N	100	55	D178150
D178151	30	N	100L	50	50	15	30	N	100	195	D178151
D178152	50	N	N	93	60	10	30	B	100	145	D178152
D178153	70	N	100L	86	75	15	30	N	100	95	D178153
D178154	70	N	100	188	50	N	30	N	100	120	D178154
D178155	50	N	100L	150	60	15	20	N	70	35	D178155
D178156	50	N	100L	159	60	N	30	N	30	45	D178156
D178157	15	N	N	28	205	N	N	B	15	30	D178157
D178158	70	20L	100L	58	90	N	20	N	30	45	D178158
D178159	50	N	N	162	45	N	20	B	50	35	D178159
D178160	50	N	100	84	35	7	30	N	70	55	D178160
D178161	50	N	100	58	65	15	30	N	30	120	D178161
D178162	70	N	100	288	45	15	20	N	70	100	D178162
D178163	30	N	100L	153	50	10	20	N	30	75	D178163
D178164	30	N	150	171	35	10	20	N	15	40	D178164
D178165	30	N	100	73	45	7	30	N	30	190	D178165
D176976	30	N	100L	66	55	10	20L	150L	150	45	D176976
D176977	30	20	100	97	35	N	20	150L	70	40	D176977
D176978	15	N	100L	34	70	7	20L	N	50	55	D176978
D176979	30	N	100	26	90	10	20L	N	100	35	D176979

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
D174663	15	500	70	30	5	77	300	D174663
D173472	10	700	70	30	3	46	200	D173472
D173476	15	2,000	70	30	3	78	200	D173476
D173477	15	2,000	70	30	3	82	200	D173477
D173478	15	2,000	70	30	3	78	200	D173478
D174666	15	1,000	100	50	5	60	300	D174666
D174667	15	500	100	50	3	110	200	D174667
D174668	15	1,000	100	50	3	140	300	D174668
D174664	15	700	70	70	5	46	300	D174664
D174665	30	1,000	150	50	5	70	500	D174665
D174679	15	500	70	30	3	19	200	D174679
D174669	15	500	100	50	5	107	500	D174669
D174670	20	500	100	70	7	100	300	D174670
D174671	20	700	100	70	7	30	300	D174671
D174674	15	1,500	70	30	3	47	300	D174674
D174675	15	700	70	50	3	186	200	D174675
D174672	20	3,000	100	70	7	70	300	D174672
D174673	15	3,000	100	50	5	68	200	D174673
D178171	15	300	150	50	7	37	300	D178171
D178149	30	700	150	150	15	66	200	D178149
D178150	15	150	150	70	7	120	200	D178150
D178151	20	3,000	150	70	7	68	200	D178151
D178152	20	500	150	70	7	131	200	D178152
D178153	30	500	150	150	15	117	200	D178153
D178154	30	3,000	150	100	10	39	300	D178154
D178155	20	500	200	100	10	60	200	D178155
D178156	30	3,000	150	150	15	237	300	D178156
D178157	10L	700	70	30	3	26	100	D178157
D178158	20	500	150	50	7	77	300	D178158
D178159	20	200	150	70	7	130	150	D178159
D178160	30	700	150	150	15	51	150	D178160
D178161	30	1,000	200	100	15	55	200	D178161
D178162	20	1,500	300	100	10	167	150	D178162
D178163	15	1,000	150	70	7	120	150	D178163
D178164	20	3,000	150	70	7	55	300	D178164
D178165	30	2,000	100	150	15	51	500	D178165
D176976	20	300	100	70	7	166	300	D176976
D176977	30	300	150	70	7	90	500	D176977
D176978	15	300	70	30	3	43	200	D176978
D176979	15	300	70	100	7	113	200	D176979

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Ash (percent)	SiO2 (percent)	Al2O3 (percent)	CaO (percent)	MgO (percent)	Na2O (percent)	K2O (percent)	Fe2O3 (percent)	TiO2 (percent)	P2O5 (percent)	Sample number
D176980	9.8	58	13	3.4	0.85	2.75	0.94	2.3	0.78	1.0L	D176980
D176981	1.8	46	17	5.1	.50	1.94	.10	5.0	1.7	1.5	D176981
D176982	4.9	46	9.8	5.9	.58	8.40	.15	4.8	.76	1.0L	D176982
D176983	21.8	68	14	.86	.59	.84	.63	.83	.86	1.0L	D176983
D174676	9.3	46	12	7.8	1.53	1.25	.85	9.0	.82	.28	D174676
D174677	17.5	50	19	4.0	1.69	1.23	1.2	4.1	.83	.13	D174677
D174678	17.8	46	15	10	2.54	.61	.97	3.7	.70	.36	D174678
D178167	14.2	55	17	5.9	2.02	.20	.47	2.1	.71	1.0L	D178167
D178168	36.2	84	8.3	1.4	.51	.11	.20	1.2	.56	1.0L	D178168
D178166	11.2	52	6.2	5.0	2.07	.17	.48	12	.42	1.0L	D178166
D178169	36.6	57	23	2.3	1.56	.15	.94	2.3	.89	1.0L	D178169
D178170	31.6	73	14	2.2	.99	.11	.56	1.1	.82	1.0L	D178170

Sample number	SO3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	Sample number
D176980	2.3	N	1,000	700	15	1.5	N	15	70	73	D176980
D176981	5.9	N	2,000	1,000	50	1.0	700	50	70	154	D176981
D176982	10	N	1,500	150	5	2.0	N	15	70	142	D176982
D176983	.66	N	300	100	7	1.0	N	15	70	69	D176983
D174676	8.3	N	1,000	300	5	1.0L	N	10	70	84	D174676
D174677	3.2	N	500	300	5	1.0L	N	15	150	78	D174677
D174678	4.7	N	200	500	3L	1.0L	N	10	100	76	D174678
D178167	5.2	N	1,000	700	15	1.0L	N	10	100	66	D178167
D178168	1.8	N	300	300	15	1.0L	N	15	70	32	D178168
D178166	7.5	N	1,500	200	15	1.0L	N	10L	50	41	D178166
D178169	2.2	N	300	200	10	1.0L	N	10L	150	63	D178169
D178170	2.1	N	500	200	15	1.0L	N	10	70	72	D178170

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sample number
D176980	20	N	100L	75	70	N	20L	N	50	45	D176980
D176981	50	20	300	53	50	15	30	300	200	50	D176981
D176982	20	N	100L	15	60	7	20	N	70	85	D176982
D176983	30	N	N	96	30	N	20	B	30	45	D176983
D174676	20	N	N	54	140	7	30	B	30	30	D174676
D174677	30	N	100L	180	110	20	30	N	50	25L	D174677
D174678	20	N	100L	98	160	15	20	N	30	25	D174678
D178167	50	N	N	111	145	N	20	B	30	60	D178167
D178168	30	N	100L	55	35	N	30	N	20	30	D178168
D178166	30	20L	N	31	145	7	N	B	15	25L	D178166
D178169	70	N	100L	151	105	N	30	N	30	40	D178169
D178170	30	N	N	99	50	N	30	B	30	40	D178170

Sample number	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
D176980	20	1,000	100	70	7	79	200	D176980
D176981	50	5,000	300	300	15	47	500	D176981
D176982	20	700	100	70	5	21	300	D176982
D176983	30	100	70	70	3	84	300	D176983
D174676	15	300	100	50	3	55	200	D174676
D174677	15	300	150	50	3	100	150	D174677
D174678	15	700	150	30	3	112	150	D174678
D178167	10	1,000	100	50	7	71	200	D178167
D178168	10	200	70	70	7	64	300	D178168
D178166	10L	500	70	70	7	54	150	D178166
D178169	15	300	150	70	7	80	150	D178169
D178170	10	200	100	70	7	110	200	D178170

Table 4.--Content of seven trace elements in 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah

[Analyses on air-dried (32°C) coal. L, less than the value shown]

Sample number	As (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)	Sample number
D174663	1.0	20	0.03	0.2	1.5	3.0L	0.6	D174663
D173472	1.0L	20L	.01	.2	1.1	3.0L	.2L	D173472
D173476	1.0L	50	.02	.2	2.4	3.0L	.7	D173476
D173477	1.0L	50	.02	.2	2.4	3.0L	.7	D173477
D173478	1.0L	70	.01	.2	2.0	3.0L	.7	D173478
D174666	1.0	50	.06	.2	2.4	3.0L	1.0	D174666
D174667	1.0	240	.04	.4	1.8	3.0L	2.4	D174667
D174668	1.0	105	.08	.2	1.4	3.0L	.9	D174668
D174664	1.0L	20L	.01	.1L	1.2	3.0L	.2L	D174664
D174665	1.0L	20	.04	.2	2.1	3.0L	1.3	D174665
D174679	1.0	20L	.03	.1	1.3	5.0	.2L	D174679
D174669	1.0L	20L	.01	.1	1.6	3.0L	.6	D174669
D174670	1.0L	20L	.03	.1L	1.3	3.0L	.6	D174670
D174671	1.0	25	.05	.1L	1.3	3.0L	.2L	D174671
D174674	1.0L	20L	.02	.1	.9	3.0L	.2L	D174674
D174675	1.0	35	.01	.2	1.1	3.0L	1.0	D174675
D174672	1.0L	65	.01	.2	1.9	3.0L	1.1	D174672
D174673	1.0	70	.03	.2	2.2	3.0L	.9	D174673
D178171	.5	20	.04	.2	1.4	3.0L	1.0	D178171
D178149	.5	20	.04	.3	1.0	3.0L	.8	D178149
D178150	.5	40	.05	.1L	1.4	3.0L	1.3	D178150
D178151	.5	90	.05	.2	1.3	3.0L	1.2	D178151
D178152	3.0	80	.08	.6	1.5	3.0L	1.3	D178152
D178153	.5	30	.03	.5	1.1	3.0	1.2	D178153
D178154	.5	100	.02	.4	1.9	3.0L	1.7	D178154
D178155	1.0	95	.05	.4	1.4	3.0L	2.0	D178155
D178156	.5	145	.03	.3	1.8	3.0L	.9	D178156
D178157	.5L	20	.03	.1L	1.0	3.0L	.3	D178157
D178158	.5	20	.04	.2	1.7	3.0L	.5	D178158
D178159	.5	220	.04	.5	.9	4.4	2.1	D178159
D178160	.5	85	.03	.7	1.6	3.0L	1.7	D178160
D178161	.5	30	.05	.3	1.3	3.0L	1.3	D178161
D178162	2.0	215	.08	.4	2.2	3.0L	2.2	D178162
D178163	1.0	75	.04	.3	1.9	4.7	2.1	D178163
D178164	.5	55	.07	.2	1.3	3.0L	.6	D178164
D178165	.5	30	.02	.2	2.4	3.0L	.7	D178165
D176976	1.5	55	.13	.7	1.7	3.0L	.6	D176976
D176977	.5	90	.01	.4	5.7	3.0L	1.1	D176977
D176978	.5	25	.01	.1L	1.2	3.0L	.2L	D176978
D176979	.5	20	.03	.2	1.0	3.0L	.4	D176979
D176980	1.0	90	0.02	0.3	1.1	3.0L	0.5	D176980
D176981	2.0	20	.08	.5	1.1	3.0L	.5	D176981
D176982	.5	20L	.03	.1	2.0	3.0L	.2L	D176982
D176983	.5	90	.04	.4	1.6	5.2	1.5	D176983
D174676	1.0	30	.21	.3	2.1	4.6	.2L	D174676
D174677	2.0	160	.12	.4	3.4	3.0L	3.1	D174677
D174678	2.0	120	.06	.4	2.6	3.0L	2.3	D174678
D178167	1.0	50	.03	.3	1.3	3.0L	1.3	D178167
D178168	.5	65	.09	.5	1.5	3.5	2.1	D178168
D178166	.5	25	.11	.2	.8	3.0L	.7	D178166
D178169	1.5	215	.09	.5	2.2	3.0L	3.4	D178169
D178170	1.0	110	.08	.6	2.0	3.0L	3.5	D178170

Table 5.--Major-, minor-, and trace-element composition of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah

[Values in percent of parts per million. As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°) coal; all other values calculated from analyses of coal ash. S means analysis by emission spectrography; L, less than the value shown N, not detected; B, not determined]

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S (ppm)	As (ppm)	Sample number
D174663	2.1	0.57	0.45	0.054	0.091	0.053	0.35	0.041	N	1.0	D174663
D173472	1.1	.24	.15	.029	.019	.006	.24	.018	N	1.0L	D173472
D173476	2.3	1.0	.74	.11	.11	.015	.36	.079	N	1.0L	D173476
D173477	2.2	1.6	.81	.18	.18	.010	.39	.11	N	1.0L	D173477
D173478	2.3	1.1	.70	.17	.16	.005	.36	.074	N	1.0L	D173478
D174666	2.7	.89	.17	.027	.033	.039	.24	.064	N	1.0	D174666
D174667	7.1	2.2	.35	.23	.042	.41	.46	.12	3	1.0	D174667
D174668	3.1	.86	.32	.077	.071	.13	.30	.053	N	1.0	D174668
D174664	.80	.29	.75	.035	.093	.011	.27	.017	N	1.0L	D174664
D174665	2.2	1.2	.43	.041	.18	.020	.24	.076	N	1.0L	D174665
D174679	.76	.36	1.2	.096	.15	.010	.36	.029	N	1.0	D174679
D174669	1.9	.73	.24	.019	.24	.019	.15	.055	N	1.0L	D174669
D174670	1.1	.55	.57	.024	.17	.007	.23	.037	.15	1.0L	D174670
D174671	.82	.29	.68	.024	.13	.008	.26	.023	N	1.0	D174671
D174674	.95	.32	.38	.047	.34	.003	.42	.026	N	1.0L	D174674
D174675	2.5	.59	.42	.053	.26	.067	.25	.049	N	1.0	D174675
D174672	1.5	.77	.55	.028	.15	.034	.19	.051	N	1.0L	D174672
D174673	1.8	.90	.32	.029	.27	.036	.17	.047	N	1.0	D174673
D178171	2.2	1.0	.54	.044	.42	.021	.28	.065	N	.5	D178171
D178149	.91	.32	.17	.022	.11	.022	.15	.021	N	.5	D178149
D178150	2.5	1.6	.16	.027	.12	.038	.11	.080	N	.5	D178150
D178151	2.0	.62	.19	.035	.20	.047	.12	.048	N	.5	D178151
D178152	3.1	.73	.15	.036	.15	.11	.24	.052	N	3.0	D178152
D178153	2.1	.56	.20	.037	.22	.046	.18	.038	N	.5	D178153
D178154	3.2	1.4	.26	.033	.20	.048	.12	.072	N	.5	D178154
D178155	2.9	.76	.29	.064	.18	.10	.21	.054	N	1.0	D178155
D178156	3.0	1.5	.37	.045	.38	.030	.19	.084	N	.5	D178156
D178157	.68	.23	1.2	.074	.18	.005	.34	.018	N	.5L	D178157
D178158	1.6	.38	.39	.034	.19	.004	.18	.036	N	.5	D178158
D178159	6.6	1.7	.16	.14	.063	.34	.20	.11	N	.5	D178159
D178160	3.5	.78	.23	.055	.23	.092	.16	.074	N	.5	D178160
D178161	2.1	.96	.10	.037	.29	.14	.14	.052	N	.5	D178161
D178162	3.6	1.7	.17	.11	.18	.26	.25	.092	N	2.0	D178162
D178163	3.4	1.6	.27	.10	.33	.084	.22	.088	N	1.0	D178163
D178164	2.3	1.0	.37	.025	.37	.009	.15	.068	N	.5	D178164
D178165	1.9	.53	.25	.018	.29	.005	.13	.041	N	.5	D178165
D176976	2.4	.61	.26	.074	.23	.11	.18	.050	N	1.5	D176976
D176977	3.9	1.5	.31	.10	.35	.11	.23	.098	N	.5	D176977
D176978	1.3	.44	.49	.065	.33	.006	.26	.025	N	.5	D176978
D176979	1.5	.39	.13	.050	.22	.042	.089	.026	N	.5	D176979

Table 5.--Major-, minor-, and trace-element composition of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Sample number
D174663	100	20	0.7	0.08L	N	1.5	7	7.9	20	2	D174663
D173472	70	3	N	.06	N	.7	2	3.9	20L	.5	D173472
D173476	100	50	.7	.11L	N	1L	3	6.0	50	3	D173476
D173477	100	200	N	.12L	N	1.5L	3	6.2	50	3	D173477
D173478	100	200	.3	.10L	N	1	5	6.4	70	3	D173478
D174666	150	20	.7	.09	50L	1.5	7	6.2	50	3	D174666
D174667	70	50	1	.24	100L	3	20	9.4	240	7	D174667
D174668	150	50	.7	.11	50L	1.5	7	6.0	105	3	D174668
D174664	100	50	.15	.06L	N	.7	5	5.4	20L	.7	D174664
D174665	100	20	.3	.10L	50L	1	7	6.0	20	5	D174665
D174679	100	100	N	.07L	N	.7	5	6.6	20L	1.5	D174679
D174669	100	50	.5	.08L	50L	1	5	6.3	20L	2	D174669
D174670	150	30	.5	.06L	30	1	5	4.9	20L	2	D174670
D174671	100	100	.2	.05L	20L	.7	3	3.9	25	1.5	D174671
D174674	150	15	.15	.06L	N	.7	5	4.3	20L	1	D174674
D174675	150	15	.3L	.09L	N	1.5	7	7.5	35	2	D174675
D174672	100	20	.2	.08L	50L	1	5	5.8	65	2	D174672
D174673	150	50	.2	.08L	50L	.7	7	5.5	70	2	D174673
D178171	100	100	.3	.10L	N	1L	7	6.5	20	5	D178171
D178149	70	30	1	.08	N	1	7	6.0	20	3	D178149
D178150	30	50	1.5	.10	N	1.5	7	11	40	5	D178150
D178151	50	50	1.5	.07L	N	1	5	19	90	2	D178151
D178152	70	150	2	.15	N	1.5	10	19	80	5	D178152
D178153	70	70	2	.11	N	2	7	12	30	5	D178153
D178154	70	100	3	.12L	N	2	10	18	100	10	D178154
D178155	70	50	2	.10L	N	1.5	10	11	95	5	D178155
D178156	100	100	2	.13L	N	2	7	10	145	7	D178156
D178157	100	150	N	.07L	N	.7L	3	3.4	20	1	D178157
D178158	70	200	.7	.07L	N	.7	10	6.0	20	5	D178158
D178159	70	700	5	.20L	N	2	30	8.9	220	10	D178159
D178160	70	30	3	.11L	N	1.5	20	12	85	7	D178160
D178161	100	20	1	.08L	N	1	10	11	30	5	D178161
D178162	150	100	3	.14	N	3	30	17	215	10	D178162
D178163	100	70	1.5	.13	N	1.5	10	10	75	5	D178163
D178164	100	100	.5	.10L	N	1	7	6.3	55	3	D178164
D178165	100	20	1.5	.07L	N	.7	5	15	30	2	D178165
D176976	70	20	1.5	.09	50L	3	7	11	55	3	D176976
D176977	100	100	2	.15L	70L	5	10	12	90	5	D176977
D176978	100	50	N	.07L	30L	1	2	6.6	25	1	D176978
D176979	100	30	.5	.08	30L	1	3	4.9	20	1.5	D176979

Table 5.--Major-, minor-, and trace-element composition of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Ge-S (ppm)	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	P (ppm)	Sample number
D174663	N	0.03	N	5.2	12	1.5	1.5	B	2	120	D174663
D173472	N	.01	N	3.5	1.9	.7	.7	B	2	17L	D173472
D173476	N	.02	10L	21	7.5	.7	2	N	1.5	89	D173476
D173477	N	.02	15L	41	8.7	N	2	N	2	180	D173477
D173478	N	.01	10L	25	7.3	N	2	N	1.5	180	D173478
D174666	N	.06	10L	22	4.5	1	3	N	3	82	D174666
D174667	N	.04	20L	57	12	1.5	7	N	7	150	D174667
D174668	N	.08	10L	18	10	.7	3	N	5	94	D174668
D174664	N	.01	5L	5.5	8.0	.5	1L	N	3	190	D174664
D174665	N	.04	15	12	5.8	.7	5	15L	1.5	140	D174665
D174679	N	.03	N	5.7	14	1	1.5L	B	1.5	220	D174679
D174669	N	.01	7L	9.6	2.7	1	5	10L	2	54	D174669
D174670	N	.03	15	5.1	6.1	1	2	10	2	140	D174670
D174671	N	.05	7	3.1	6.5	.7	1	7L	1.5	160	D174671
D174674	N	.02	5L	1.9	8.8	.5	1.5	N	1.5	82	D174674
D174675	N	.01	10L	7.3	3.7	.7	3	N	5	89	D174675
D174672	N	.01	7L	16	5.4	1	2	N	2	220	D174672
D174673	N	.03	7L	11	3.2	.7	1.5	N	2	180	D174673
D178171	N	.04	N	13	7.9	N	2	B	1	430L	D178171
D178149	.7L	.04	7	3.0	3.6	.7	.7	N	3	170L	D178149
D178150	N	.05	10	17	3.1	N	3	N	10	450L	D178150
D178151	N	.05	7L	3.7	3.7	1	2	N	7	320L	D178151
D178152	N	.08	N	9.2	5.9	1	3	B	10	430L	D178152
D178153	N	.03	7L	6.5	5.6	1	2	N	7	330L	D178153
D178154	N	.02	10	23	6.1	N	3	N	10	530L	D178154
D178155	N	.05	10L	15	6.2	1.5	2	N	7	450L	D178155
D178156	N	.03	15L	20	7.6	N	3	N	3	610	D178156
D178157	N	.03	N	1.9	14	N	N	B	1	300L	D178157
D178158	1.5L	.04	7L	3.8	5.9	N	1.5	N	2	290L	D178158
D178159	N	.04	N	33	9.1	N	5	B	10	890L	D178159
D178160	N	.03	10	9.5	4.0	.7	3	N	7	490L	D178160
D178161	N	.05	7	4.6	5.1	1	2	N	2	350L	D178161
D178162	N	.08	15	40	6.3	2	3	N	10	610L	D178162
D178163	N	.04	15L	21	6.7	1.5	3	N	5	590L	D178163
D178164	N	.07	15	16	3.3	1	2	N	1.5	420L	D178164
D178165	N	.02	7	5.3	3.2	.5	2	N	2	310L	D178165
D176976	N	.13	10L	5.9	4.9	1	2L	15L	15	390L	D176976
D176977	3	.01	15	14	5.2	N	3	20L	10	650L	D176977
D176978	N	.01	7L	2.3	4.8	.5	1.5L	N	3	300L	D176978
D176979	N	.03	5	1.4	4.8	.5	1L	N	5	230L	D176979

Table 5.--Major-, minor-, and trace-element composition of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Pb (ppm)	Sb (ppm)	Sc-S (ppm)	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Sample number
D174663	2.5	0.2	1.5	1.5	50	3.0L	0.6	7	2	0.5	D174663
D173472	1.0	.2	.5	1.1	30	3.0L	.2L	3	1	.1	D173472
D173476	4.8	.2	1.5	2.4	200	3.0L	.7	7	3	.3	D173476
D173477	5.6	.2	2	2.4	200	3.0L	.7	10	3	.3	D173477
D173478	3.1	.2	1.5	2.0	200	3.0L	.7	7	3	.3	D173478
D174666	3.6	.2	1.5	2.4	100	3.0L	1.0	10	5	.5	D174666
D174667	7.1	.4	3	1.8	100	3.0L	2.4	20	10	.7	D174667
D174668	3.8	.2	1.5	1.4	100	3.0L	.9	10	5	.3	D174668
D174664	1.9	.1L	.7	1.2	50	3.0L	.2L	5	5	.3	D174664
D174665	4.9	.2	3	2.1	100	3.0L	1.3	15	5	.5	D174665
D174679	1.7	.1	1	1.3	30	5.0	.2L	5	2	.2	D174679
D174669	3.1	.1	1	1.6	50	3.0L	.6	7	5	.5	D174669
D174670	3.1	.1L	1.5	1.3	30	3.0L	.6	7	5	.5	D174670
D174671	2.0	.1L	1	1.3	30	3.0L	.2L	5	3	.3	D174671
D174674	1.4	.1	.7	.9	70	3.0L	.2L	5	1.5	.15	D174674
D174675	2.3L	.2	1.5	1.1	70	3.0L	1.0	7	5	.3	D174675
D174672	3.9	.2	1.5	1.9	200	3.0L	1.1	7	5	.5	D174672
D174673	4.1	.2	1.5	2.2	200	3.0L	.9	7	5	.5	D174673
D178171	2.5	.2	1.5	1.4	30	3.0L	1.0	15	5	.7	D178171
D178149	3.6	.3	1	1.0	30	3.0L	.8	7	7	.7	D178149
D178150	5.7	.1L	1.5	1.4	15	3.0L	1.3	15	7	.7	D178150
D178151	14	.2	1.5	1.3	200	3.0L	1.2	10	5	.5	D178151
D178152	14	.6	2	1.5	50	3.0L	1.3	15	7	.7	D178152
D178153	7.1	.5	2	1.1	30	3.0	1.2	10	10	1	D178153
D178154	15	.4	3	1.9	300	3.0L	1.7	20	10	1	D178154
D178155	3.6	.4	2	1.4	50	3.0L	2.0	20	10	1	D178155
D178156	5.7	.3	3	1.8	300	3.0L	.9	20	20	2	D178156
D178157	2.1	.1L	.7L	1.0	50	3.0L	.3	5	2	.2	D178157
D178158	3.0	.2	1.5	1.7	30	3.0L	.5	10	3	.5	D178158
D178159	7.1	.5	5	.9	50	4.4	2.1	30	15	1.5	D178159
D178160	6.2	.7	3	1.6	70	3.0L	1.7	15	15	1.5	D178160
D178161	9.5	.3	2	1.3	70	3.0L	1.3	15	7	1	D178161
D178162	14	.4	3	2.2	200	3.0L	2.2	50	15	1.5	D178162
D178163	10	.3	2	1.9	150	4.7	2.1	20	10	1	D178163
D178164	3.8	.2	2	1.3	300	3.0L	.6	15	7	.7	D178164
D178165	14	.2	2	2.4	150	3.0L	.7	7	10	1	D178165
D176976	4.0	.7	2	1.7	30	3.0L	.6	10	7	.7	D176976
D176977	6.0	.4	5	5.7	50	3.0L	1.1	20	10	1	D176977
D176978	3.8	.1L	1	1.2	20	3.0L	.2L	5	2	.2	D176978
D176979	1.9	.2	.7	1.0	15	3.0L	.4	3	5	.3	D176979

Table 5.--Major-, minor-, and trace-element composition of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Zn (ppm)	Zr-S (ppm)
D174663	6.4	20
D173472	1.8	7
D173476	8.3	20
D173477	10	20
D173478	8.1	20
D174666	5.3	30
D174667	26	50
D174668	15	30
D174664	2.5	15
D174665	6.8	50
D174679	1.3	15
D174669	8.2	50
D174670	6.1	20
D174671	1.5	15
D174674	2.6	15
D174675	17	20
D174672	5.4	20
D174673	5.5	15
D178171	3.7	30
D178149	2.5	7
D178150	12	20
D178151	5.0	15
D178152	13	20
D178153	8.8	15
D178154	4.7	30
D178155	6.2	20
D178156	30	30
D178157	1.8	7
D178158	5.1	20
D178159	26	30
D178160	5.8	15
D178161	4.3	15
D178162	23	20
D178163	16	20
D178164	5.2	30
D178165	3.7	30
D176976	15	30
D176977	13	70
D176978	3.0	15
D176979	6.0	10

Table 5.--Major-, minor-, and trace-element composition of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Si (percent)	Al (percent)	Ca (percent)	Mg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S (ppm)	As (ppm)	Sample number
D176980	2.7	0.67	0.24	0.050	0.20	0.077	0.16	0.046	N	1.0	D176980
D176981	.39	.16	.066	.005	.026	.002	.063	.018	N	2.0	D176981
D176982	1.1	.25	.21	.017	.31	.006	.16	.022	N	.5	D176982
D176983	6.9	1.6	.13	.077	.14	.11	.13	.11	N	.5	D176983
D174676	2.0	.59	.52	.086	.086	.066	.59	.046	N	1.0	D174676
D174677	4.1	1.8	.50	.18	.16	.17	.50	.087	N	2.0	D174677
D174678	3.8	1.4	1.3	.27	.080	.14	.46	.075	N	2.0	D174678
D178167	3.6	1.3	.60	.17	.021	.056	.21	.060	N	1.0	D178167
D178168	14	1.6	.36	.11	.030	.060	.30	.12	N	.5	D178168
D178166	2.7	.37	.40	.14	.014	.045	.94	.028	N	.5	D178166
D178169	9.7	4.5	.60	.34	.041	.29	.59	.20	N	1.5	D178169
D178170	11	2.3	.50	.19	.026	.15	.24	.16	N	1.0	D178170

Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Sample number
D176980	100	70	1.5	0.15	N	1.5	7	7.2	90	2	D176980
D176981	30	20	1	.02	15	1	1.5	2.8	20	1	D176981
D176982	70	7	.2	.10	N	.7	3	7.0	20L	1	D176982
D176983	70	20	1.5	.22	N	3	15	15	90	7	D176983
D174676	100	30	.5	.09L	N	1	7	7.8	30	2	D174676
D174677	100	50	1	.18L	N	3	30	14	160	5	D174677
D174678	30	100	.5L	.18L	N	2	20	14	120	3	D174678
D178167	150	100	2	.14L	N	1.5	15	9.4	50	7	D178167
D178168	100	100	5	.36L	N	5	20	12	65	10	D178168
D178166	150	20	1.5	.11L	N	1L	5	4.6	25	3	D178166
D178169	100	70	3	.37L	N	3L	50	23	215	20	D178169
D178170	150	70	5	.32L	N	3	20	23	110	10	D178170

Sample number	Ge-S (ppm)	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	P (ppm)	Sample number
D176980	N	0.02	10L	7.4	6.9	N	2L	N	5	430L	D176980
D176981	.3	.08	5	1.0	.9	.3	.5	5	3	120	D176981
D176982	N	.03	5L	.7	2.9	.3	1	N	3	210L	D176982
D176983	N	.04	N	21	6.5	N	5	B	7	950L	D176983
D174676	N	.21	N	5.0	13	.7	3	B	3	110	D174676
D174677	N	.12	15L	32	19	3	5	N	10	99	D174677
D174678	N	.06	20L	17	28	3	3	N	5	280	D174678
D178167	N	.03	N	16	21	N	3	B	5	620L	D178167
D178168	N	.09	30L	20	13	N	10	N	7	1,600L	D178168
D178166	2L	.11	N	3.5	16	.7	N	B	1.5	490L	D178166
D178169	N	.09	30L	55	38	N	10	N	10	1,600L	D178169
D178170	N	.08	N	31	16	N	10	B	10	1,400L	D178170

Table 5.--Major-, minor-, and trace-element composition of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah--Continued

Sample number	Pb (ppm)	Sb (ppm)	Sc-S (ppm)	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Sample number
D176980	4.4	0.3	2	1.1	100	3.0L	0.5	10	7	0.7	D176980
D176981	.9	.5	1	1.1	100	3.0L	.5	5	5	.3	D176981
D176982	4.2	.1	1	2.0	30	3.0L	.2L	5	3	.2	D176982
D176983	9.8	.4	7	1.6	20	5.2	1.5	15	15	.7	D176983
D174676	2.8	.3	1.5	2.1	30	4.6	.2L	10	5	.3	D174676
D174677	4.4L	.4	3	3.4	50	3.0L	3.1	30	10	.5	D174677
D174678	4.5	.4	3	2.6	150	3.0L	2.3	30	5	.5	D174678
D178167	8.5	.3	1.5	1.3	150	3.0L	1.3	15	7	1	D178167
D178168	11	.5	3	1.5	70	3.5	2.1	20	20	2	D178168
D178166	2.8L	.2	1L	.8	50	3.0L	.7	7	7	.7	D178166
D178169	15	.5	5	2.2	100	3.0L	3.4	50	20	2	D178169
D178170	13	.6	3	2.0	70	3.0L	3.5	30	20	2	D178170

Sample number	Zn (ppm)	Zr-S (ppm)
D176980	7.7	20
D176981	.8	10
D176982	1.0	15
D176983	18	70
D174676	5.1	20
D174677	18	30
D174678	20	30
D178167	10	30
D178168	23	100
D178166	6.0	15
D178169	29	50
D178170	35	70

Table 6.--Elements looked for, but not detected, in coal samples form the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery and Sevier Counties, Utah

[Approximate lower detection limits for these elements in ash, using the six-step spectrographic method of the U.S. Geological Survey, are included]

Element name	Symbol	Lower limit of detection (ppm) in ash
Gold	Au	50
Bismuth	Bi	20
Dysprosium	Dy	100
Erbium	Er	100
Europium	Eu	200
Gadolinium	Gd	100
Hafnium	Hf	200
Holmium	Ho	50
Indium	In	20
Lutetium	Lu	70
Palladium	Pd	5
Praseodymium	Pr	200
Platinum	Pt	100
Rhenium	Re	100
Samarium	Sm	200
Tin	Sn	20
Tantalum	Ta	1,000
Terbium	Tb	700
Tellurium	Te	5,000
Thallium	Tl	100
Thulium	Tm	50
Tungsten	W	200

Table 7.--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures of 40 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah

[For comparison, geometric mean for analyses of 87 other Rocky Mountain province coal samples are included (from Swanson and others, 1976, table 33a). All values are in percent except Kcal/kg, Btu/lb, ash-fusion temperatures, and geometric deviations; they are reported on the as-received basis. L, less than the value shown. Leaders (---) indicate no data. Kcal/kg = 0.556 (Btu/lb). °F = (°C x 1.8) = 32]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Rocky Mountain province geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	4.7	1.9	13.7	4.2	1.7	10.5
Volatile matter	40.6	25.6	46.7	40.2	1.2	35.7
Fixed carbon	43.9	26.3	50.8	43.4	1.2	41.5
Ash	10.7	3.6	34.4	9.3	1.7	7.7
Hydrogen	5.6	4.3	6.1	5.6	1.1	5.6
Carbon	67.0	37.6	74.5	66.2	1.2	58.9
Nitrogen	1.1	.3	1.5	1.0	1.4	1.1
Oxygen	14.9	11.0	22.9	14.7	1.2	22.4
Sulfur	.6	.4	2.3	.6	1.3	.5
Heat of combustion						
Kcal/kg	6,670	3,580	7,490	6,585	1.2	6,180
Btu/lb	12,000	6,440	13,470	11,840	1.2	11,110
Forms of sulfur						
Sulfate	0.03	0.01L	0.11	0.02	2.0	0.02
Pyritic	.19	.05	1.61	.14	2.1	.11
Organic	.43	.20	.67	.41	1.4	.22
Ash-fusion temperatures, °C						
Initial deformation	1,230	970	1,600 +	1,225	1.1	---
Softening temperature	1,250	1,025	1,600 +	1,245	1.1	---
Fluid temperature	1,300	1,080	1,600 +	1,300	1.1	---

Table 8.--Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of 10 major and minor oxides in the laboratory ash of 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah

[For comparison, geometric means for analyses of 295 Rocky Mountain province coal samples are included (Hatch and Swanson, 1977, table 3a). All samples were ashed at 525°C; all analyses except geometric deviation are in percent. L, less than the value shown. Leaders (---) indicate no data]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Rocky Mountain province geometric mean
		Minimum	Maximum			
(Ash)	11.3	1.8	36.6	9.7	1.8	10.9
SiO_2	53	21	84	51	1.3	44
Al_2O_3	16	6.2	29	15	1.4	19
CaO	6.4	.86	25	4.8	2.1	6.2
MgO	1.1	.41	2.7	.98	1.7	1.4
Na_2O	3.4	.11	8.4	1.8	3.1	.68
K_2O	.72	.057	2.2	.42	2.8	.45
Fe_2O_3	4.0	.83	12	3.4	1.8	4.5
TiO_2	.94	.42	1.7	.91	1.3	.81
SO_3	4.3	.66	10	3.4	1.9	5.1
P_2O_5	.25	.13L	1.5	.10	3.8	---

Table 9.--Arithmetic mean, observed range, geometric mean, and geometric deviation of 38 elements in 52 coal samples from the Blackhawk Formation, Wasatch Plateau coal field, Carbon, Emery, and Sevier Counties, Utah

[For comparison, geometric means for analyses of 295 Rocky Mountain province coal samples are included (Hatch and Swanson, 1977, table 3b). All analyses except geometric deviation are in percent or parts per million and are reported on a whole-coal basis. As, F, Hg, Sb, Se, Th, and U values used to calculate the statistics were determined directly on whole coal. All other values used were calculated from determinations made on coal ash. L, less than the value shown. Leaders (---) indicate no data]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Rocky Mountain province geometric mean
		Minimum	Maximum			
			Percent			
Si	3.0	0.39	14	2.3	2.0	2.3
Al	1.0	.16	4.5	.78	2.0	1.1
Ca	.41	.066	1.3	.33	1.9	.48
Mg	.080	.005	.34	.057	2.3	.089
Na	.19	.014	.42	.13	2.4	.055
K	.085	.001	.41	.034	3.9	.041
Fe	.26	.063	.94	.23	1.7	.34
Ti	.062	.017	.20	.053	1.8	.047
P	.009	.005L	.061	.005	3.2	---
			Parts per million			
As	0.8	0.5L	3	0.7	1.8	2
B	100	30	150	100	1.5	70
Ba	70	3	700	50	2.6	150
Be	1.5	.15L	5	.7	3.5	.5
Cd	.06	.02L	.24	.007	9.5	.05
Co	1.5	.7L	5	1.5	1.8	1.5
Cr	10	1.5	50	7	2.1	5
Cu	9.3	2.8	23	8.2	1.7	8.4
F	67	20L	240	46	2.4	69
Ga	5	.5	20	3	2.2	3
Hg	.05	.01	.21	.04	2.1	.05
La	5	5L	15	3	2.6	---
Li	16	.7	57	9.2	2.8	8
Mn	8.4	.9	38	6.7	2.0	20
Mo	.7	.3	3	.5	2.4	1.5
Nb	3	.5L	10	2	2.7	.5
Ni	5	1	15	3	2.1	2
Pb	5.8	.9L	15	4.1	2.3	4.7
Sb	.3	.1L	.7	.2	1.9	.3
Sc	2	.5L	7	1.5	1.8	1.5
Se	1.7	.8	5.7	1.6	1.4	1.2
Sr	100	15	300	70	2.3	100
Th	1.8	.3L	5.2	1.5	1.9	2.9
U	1.2	.3L	3.5	.8	2.3	1.1
V	15	3	50	10	1.9	100
Y	7	1	20	7	2.0	5
Yb	.7	.1	2	.7	2.0	.5
Zn	11	.8	35	7	2.5	6.8
Zr	30	7	100	20	1.8	20

UTAH GEOLOGICAL AND MINERAL SURVEY

606 Black Hawk Way
Salt Lake City, Utah 84108

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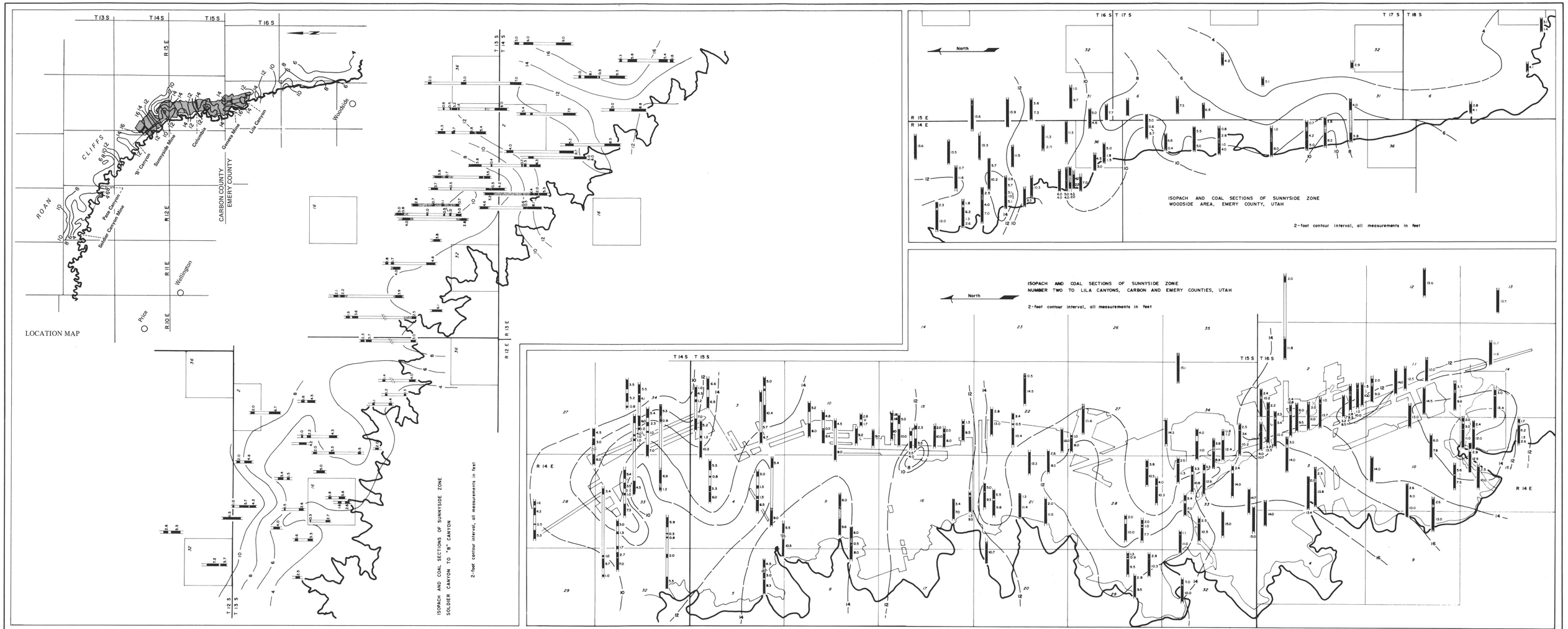

ISOPACH AND COAL SECTIONS OF SUNNYSIDE COAL ZONE
CARBON AND EMERY COUNTIES, UTAH

Appropriation No. 016103
Approval No. 7900149