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Chemical analyses of coal and shale from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

By

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Introduction

As part of a continuing program by the U.S. Geological Survey to collect and chemically analyze representative samples of U.S. coals, 32 coal and coal-associated shale samples were collected from three core holes in the Cretaceous Ferron Sandstone Member of the Mancos Shale. These drill holes are located in the Emery coal field in section 34, T. 22 S., R. 6 E.; section 3, T. 23 S., R. 6 E., and section 5, T. 24 S., R. 6 E., Emery County, Utah, and were drilled in connection with the U.S. Bureau of Land Management's Emery EMRIA (Energy Mineral Rehabilitation Inventory and Analyses) study.

The Emery coal field is situated in the southern part of Castle Valley, Emery and Sevier Counties, Utah (fig. 1). The field is elongate in a NNE-SSW direction. It has a length of approximately 55 km (34 mi), width that varies between approximately 6 and 13 km (3.7 and 8.1 mi), and a total area of about 540 km^2 (210 mi^2). Though it is one of the smaller coal fields in the state of Utah, the Emery coal field contains as much as 90 million metric tons (99 million short tons) of strippable coal in the area southeast of the town of Emery and is thus the object of considerable interest on the part of both the coal industry and a number of government agencies. Doelling (1972), largely following Lupton (1916), has estimated the total coal resources of the Emery field to be 1.87 billion metric tons (2.06 billion short tons).

The coal-bearing unit in the Emery coal field is the Ferron Sandstone Member of the Mancos Shale. The Ferron Sandstone Member records deposition of clastic sediments in a suite of deltaic environments that existed along the western margin of a vast epeiric seaway that occupied the Western Interior of North America during late Early Cretaceous and most of Late Cretaceous time. Descriptions of the stratigraphy of the Ferron Sandstone Member may be found in reports by Katich (1954), Davis (1954), Hale (1972), Cotter (1971, 1975, 1976), and Ryer (1979a, b). The Ferron forms a series of

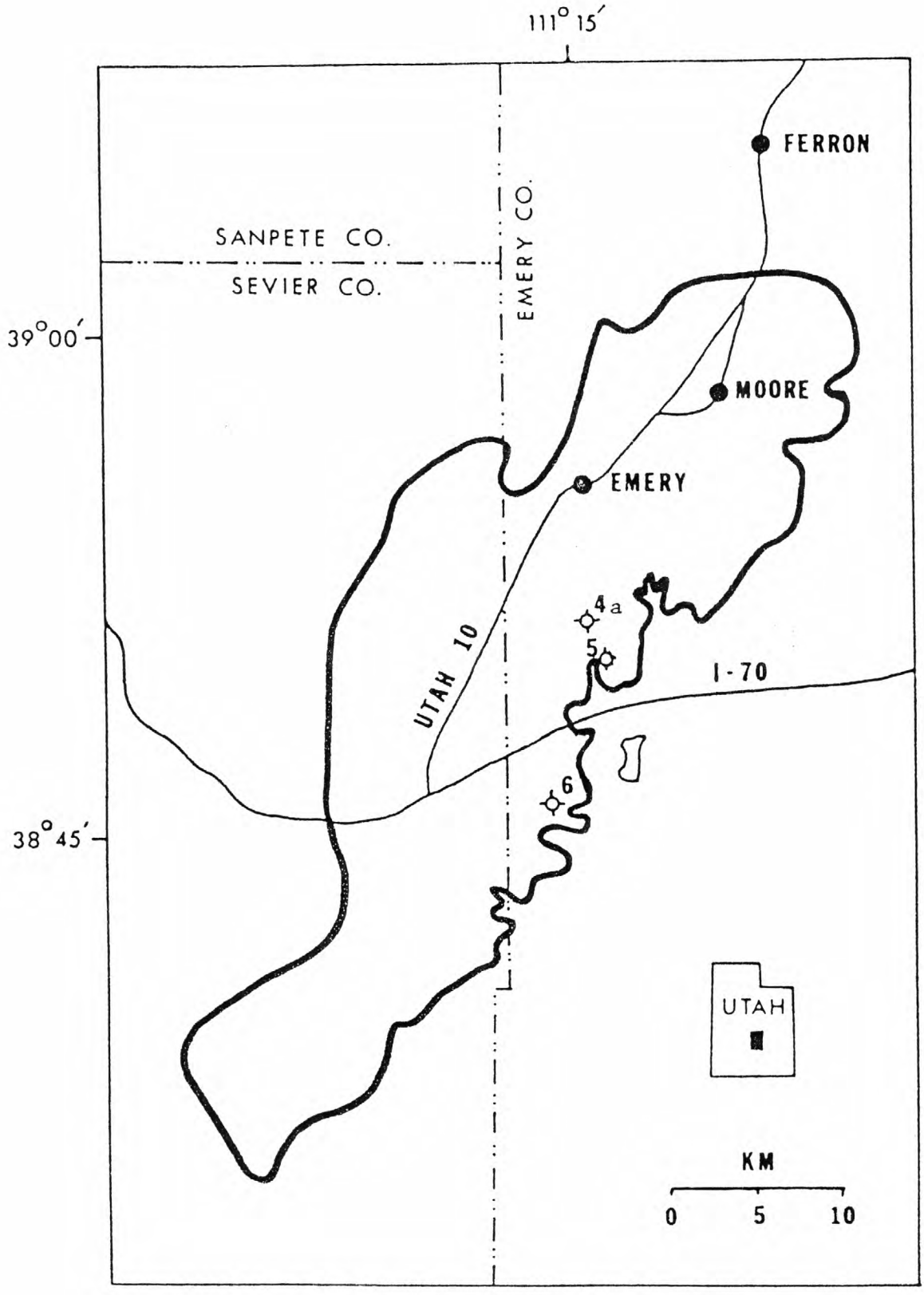

Figure 1. Outline of the Emery coal field, Emery and Sevier Counties, Utah, and locations of the EMRIA core holes.

very steep to vertical cliffs along the eastern boundary of the coal field. Thick, cliff-forming sandstone units of shallow marine origin increase in number from south to north within the coal field, the Ferron taking on a progressively more marine character in this direction. The thickest, economically most important coal beds occur in the southern and central parts of the field.

The only comprehensive study of the coal resources of the Emery coal field was conducted by Charles T. Lupton in the early part of the century. Lupton (1916) recognized 13 beds of coal in the Ferron and designated them, in ascending stratigraphic order, by the letters A through M. Figure 2, a generalized stratigraphic section through the Ferron Sandstone Member in the area south of Emery, shows the relative positions of the coal beds. Near core hole 5 the A and C beds have locally coalesced to form a single bed (A-C) approximately 5.0 m (16.4 ft) thick.

This report contains analyses of samples from the A bed (3 samples), A-C bed (5 samples), C bed (4 samples), G bed (2 samples), I bed (4 samples), J bed (1 sample), unnamed bed (1 sample), and 12 coal associated shale samples. These 32 samples are briefly described in table 1. The locations of the three core holes are shown in figure 1.

Explanation of Tables

Proximate and ultimate analyses, heat-of-combustion, air-dried-loss, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations on 19 coal samples from the Emery coal field are listed in table 2. These analyses were provided by the 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 and shale (table 4) were run

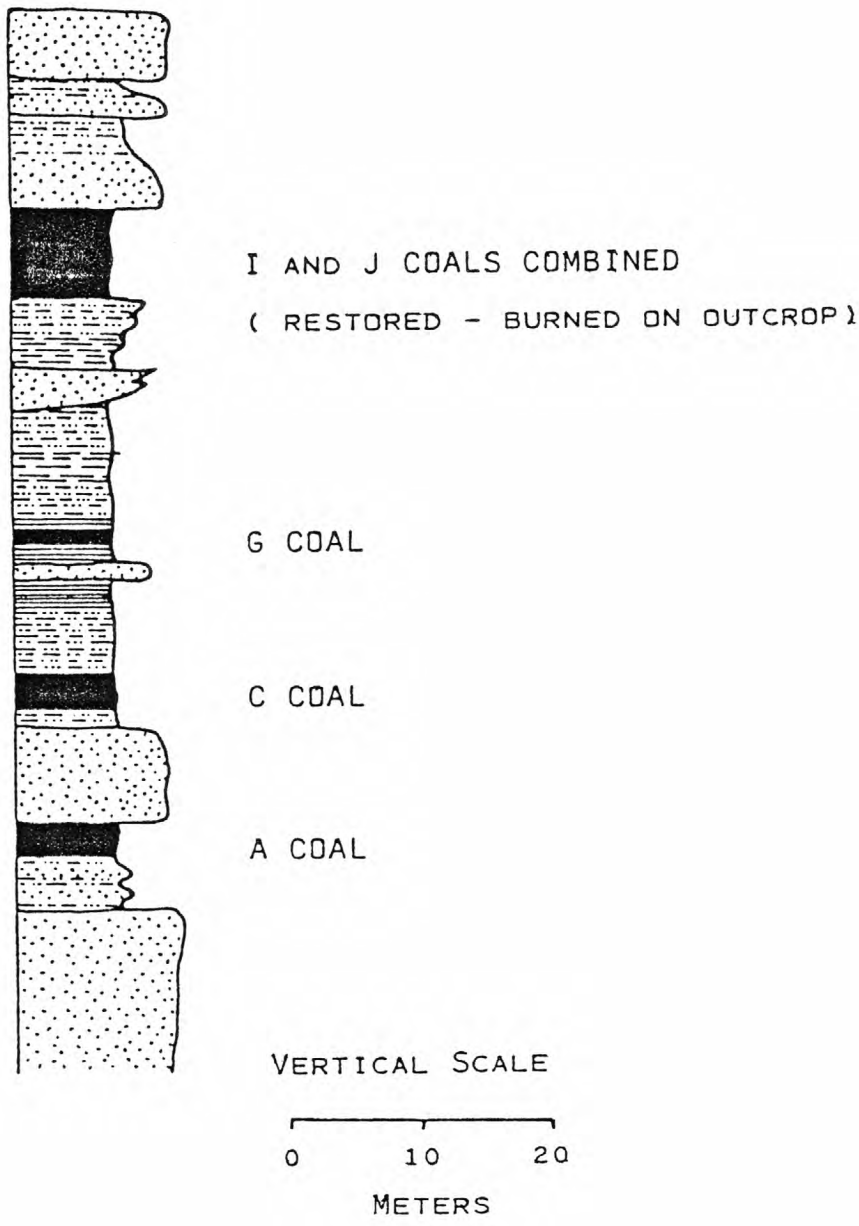

Figure 2.--Outcrop section representative of the coal-bearing part of the Ferron Sandstone Member of the Mancos Shale in the area south of Emery (near EMRIA core hole no. 4a) showing the relative positions of the coal beds.

Table 1.--USGS sample number, hole number, location, depth interval, and description for 32 coal and shale samples from the Emery coal field, Emery County, Utah

[All samples are from the Ferron Sandstone Member of the Mancos Shale of Cretaceous age. One foot = 0.3048 meters]

USGS sample number	Hole number	Location	Depth interval represented in meters and (feet)	Description
D200627	4a	SW¼SW¼ sec. 34, T. 22 S., R. 6 E.	16.0- 16.2 (52.6- 53.2)	Shale, coaly.
D200640	--do--	----------do----------	16.2- 17.3 (53.2- 56.8)	Coal, G bed.
D200641	--do--	----------do----------	28.6- 30.3 (93.9- 99.5)	Coal, C bed.
D200628	--do--	----------do----------	30.3- 30.6 (99.5-100.3)	Shale, coaly.
D200642	--do--	----------do----------	30.8- 33.1 (101.2-108.7)	Coal, C bed.
D200643	--do--	----------do----------	43.9- 45.4 (144.0-149.0)	Coal, A bed.
D200644	5	SE¼SE¼ sec. 3, T. 23 S., R. 6 E.	41.9- 42.5 (137.5-139.5)	Coal, G bed.
D200629	--do--	----------do----------	59.6-60.8 (195.6-199.5)	Shale, coaly.
D200645	--do--	----------do----------	60.8- 61.7 (199.5-202.3)	Coal, A-C bed.
D200630	--do--	----------do----------	61.7- 61.8 (202.3-202.6)	Shale, carbonaceous.
D200646	--do--	----------do----------	62.2- 63.5 (204.0-208.3)	Coal, A-C bed.
D200631	--do--	----------do----------	63.5- 63.6 (208.2-208.5)	Shale, coaly.
D200647	--do--	----------do----------	63.6- 64.6 (208.5-211.8)	Coal, A-C bed.
D200632	--do--	----------do----------	64.6- 64.9 (211.8-212.8)	Shale, coaly.
D200648	--do--	----------do----------	64.9- 65.7 (212.8-215.7)	Coal, A-C bed.

Table 1.--USGS sample number, hole number, location, depth interval, and description for 32 coal and shale samples from the Emery coal field, Emery County, Utah--Continued

USGS sample number	Hole number	Location	Depth interval represented in meters and (feet)	Description
D200633	5	SE¼SE¼ sec. 3, T. 23 S., R. 6 E.	65.7- 65.8 (215.7-216.0)	Shale, coaly.
D200649	--do--	----------do----------	65.8- 66.8 (216.0-219.0)	Coal, A-C bed.
D200634	6	NW¼NE¼ sec. 5, T. 24 S., R. 6 E.	16.0- 16.5 (52.5- 54.2)	Shale, coaly.
D200650	--do--	----------do----------	16.5- 17.3 (54.2- 56.9)	Coal, unnamed bed.
D200635	--do--	----------do----------	22.8- 23.7 (74.9- 77.8)	Shale, coaly.
D200651	--do--	----------do----------	24.7- 25.0 (80.9- 81.9)	Coal, J bed (?).
D200652	--do--	----------do----------	33.3- 33.7 (109.3-110.7)	Coal, I bed.
D200636	--do--	----------do----------	33.7- 33.9 (110.7-111.3)	Shale, coaly.
D200653	--do--	----------do----------	33.9- 34.9 (111.3-114.5)	Coal, I bed.
D200654	--do--	----------do----------	34.9- 35.9 (114.5-117.7)	Do.
D200637	--do--	----------do----------	35.9- 36.2 (117.8-118.7)	Shale, coaly.
D200655	--do--	----------do----------	36.2- 37.6 (118.7-123.2)	Coal, I bed.
D200656	--do--	----------do----------	62.7- 63.0 (205.7-206.8)	Coal, C bed (?).
D200657	--do--	----------do----------	74.1- 74.3 (243.0-243.7)	Do.

Table 1.--USGS sample number, hole number, location, depth interval, and description for 32 coal and shale samples from the Emery coal field, Emery County, Utah--Continued

USGS sample number	Hole number	Location	Depth interval represented in meters and (feet)	Description
D200638	6	NW¼NE¼ sec. 5, T. 24 S., R. 6 E.	74.3- 74.5 (243.8-244.5)	Shale, coaly.
D200639	--do--	----------do----------	86.3- 86.6 (283.3-284.2)	Coal shaley, A bed.
D200658	--do--	----------do----------	87.3- 89.4 (286.3-293.3)	Coal, A bed.

on all 32 samples. Additional analyses for sulfur, carbon, carbonate carbon, and organic carbon were run on the 12 shale samples (table 6). All of these analyses were provided by the U.S. Geological Survey, Denver, Colo. 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-rock basis plus the analyses listed in table 4. Twenty-five additional elements not listed in tables 3, 4, and 5 were looked for but not found in amounts greater than their lower limit of detection (table 7). Unweighted statistical summaries of analytical data for 20 coal samples in tables 2, 3, and 5 are listed in tables 8, 9, and 10, respectively. For comparison, data summaries for 52 Blackhawk Formation coal samples from the Wasatch Plateau field are included. Analytical data for 12 coal-associated shale samples in tables 3 and 5 are summarized in tables 11 and 12. Data summaries for Cd were not included in tables 10 and 12 because this element was detected in an insufficient number of samples to calculate meaningful statistics.

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 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 19 coal samples from the Ferron Sandstone Member of the Mancos Shale, Emery field, 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 for 18 of the samples is high-volatile B bituminous coal. One sample (D200644) has an apparent rank of high-volatile C bituminous coal. The relatively high moisture content (8.8 vs a mean of 5.1 percent for the other 18 samples); lower heat of combustion (5,600 Kcal/kg (10,080 Btu/lb) vs a mean of 6,360 Kcal/kg (11,450 Btu/lb) for the other 18 samples) and a lack of agglomerating properties (0. free-swelling index) for this sample indicates that it is slightly weathered.

A statistical comparison (student's t test, 95 percent confidence level) of the mean contents of the U.S. Department of Energy's data for 19 coal samples from the Emery field with 40 coal samples from the Wasatch Plateau field, shows that coal from the Emery field has significantly higher contents of ash, total sulfur, sulfate and organic sulfur and a significantly lower hydrogen content. Heat of combustion, ash fusion temperatures, contents of moisture, volatile matter, fixed carbon, carbon, nitrogen, oxygen, and pyritic sulfur, are not significantly different. When compared at the 99 percent confidence level, the ash and hydrogen contents are not significantly different.

A statistical comparison of geometric means of the contents of coal ash and contents in ash of nine major and minor oxides for 20 coal samples from the Emery field with 52 Wasatch Plateau field samples shows that the Emery field samples have a significantly higher ash content, higher Al_2O_3, Fe_2O_3 and TiO_2 contents in the ash, and significantly lower Na_2O and SO_3 contents in ash. The contents of SiO_2, CaO, MgO, and K_2O in ash are not significantly different.

A statistical comparison of the geometric means of the contents of 36 elements in 20 Emery field coal samples with 52 Wasatch Plateau field coal samples shows that Emery field coal has significantly higher contents of Si, Al, Fe, Ti, As, Be, Co, Cu, Ga, Hg, La, Li, Mn, Mo, Ni, Pb, Sb, Sc, Th, U, V, Zn,and Zr, and significantly lower contents of Na and B. The contents of Ca, Mg, K, Ba, Cr, F, Nb, Se, Sr, Y, and Yb are not significantly different. When compared at the 99 percent confidence level the contents of Si, Be, V, and Zn 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 Emery field.

A comparison of contents of 35 trace elements in 12 coal-associated shale samples from the Emery field (table 12) with the average shale contents listed in Turekian and Wedepohl (1961) is not possible because the standard deviations and the number of samples for the average shale contents are not available. A scan of the data, however, shows probable higher contents of Ga, Pb, Th, U, Se, and lower contents of Si, Ca, Mg, Na, K, Fe, As, Ba, Co, Cr, Cu, F, Mn, Ni, Sc, Sr, V, Y, Yb, and Zn in the Emery field samples. Contents of Al, Ti, B, Be, Hg, Li, Mo, Nb, Sb, and Zr appear to be similar in both sample sets.

The low contents of many elements in the coal-associated shale samples from the Emery field are probably a result of the relatively high content of non-ash (organic) materials.

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Table 2.--Proximate and ultimate analyses, heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 19 coal samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

[All analyses except heat of combustion, free-swelling index, and ash-fusion temperatures in percent. For each sample number, analyses are reported three ways: first, as received; second, moisture free; and third, moisture and ash free. All analyses by Coal Analysis Section, U.S. Department of Energy, Pittsburgh, Pa. °F = (°C x 1.8) + 32; Kcal/kg = 0.556 (Btu/lb). L, less than the value shown]

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D200640	3.6	39.4	40.2	16.8	5.1	62.5	1.1	10.8	3.6	6,200	11,160
	---	40.9	41.7	17.4	4.9	64.8	1.1	7.9	3.7	6,430	11,580
	---	49.5	50.5	---	5.9	78.5	1.4	9.5	4.5	7,790	14,030
D200641	3.8	36.1	39.6	20.5	4.8	58.9	1.0	12.7	2.1	5,850	10,530
	---	37.5	41.2	21.3	4.6	61.2	1.0	9.7	2.2	6,080	10,940
	---	47.7	52.3	---	5.8	77.8	1.3	12.3	2.8	7,730	13,910
D200642	4.0	37.2	43.8	15.0	5.1	64.3	1.1	13.7	.7	6,330	11,390
	---	38.7	45.6	15.6	4.8	67.0	1.1	10.6	.7	6,590	11,870
	---	45.9	54.1	---	5.7	79.4	1.4	12.5	.9	7,810	14,070
D200643	3.7	40.2	46.8	9.3	5.5	70.0	1.2	13.0	1.0	6,950	12,500
	---	41.7	48.6	9.7	5.3	72.7	1.2	10.1	1.0	7,210	12,980
	---	46.2	53.8	---	5.8	80.5	1.4	11.2	1.1	7,980	14,370
D200644	8.8	36.6	39.2	15.4	5.1	57.2	1.1	18.9	2.3	5,600	10,080
	---	40.1	43.0	16.9	4.5	62.7	1.2	12.1	2.5	6,140	11,060
	---	48.3	51.7	---	5.4	75.5	1.5	14.6	3.0	7,390	13,300
D200645	4.1	38.8	44.1	13.0	5.2	65.9	1.1	13.8	.9	6,510	11,710
	---	40.5	46.0	13.6	4.9	68.7	1.1	10.6	.9	6,780	12,210
	---	46.8	53.2	---	5.7	79.5	1.3	12.3	1.1	7,850	14,130
D200646	4.5	37.9	42.0	15.6	5.1	63.3	1.1	14.3	.5	6,230	11,210
	---	39.7	44.0	16.3	4.8	66.3	1.2	10.8	.5	6,520	11,730
	---	47.4	52.6	---	5.8	79.2	1.4	12.9	.6	7,790	14,030
D200647	5.4	37.7	45.6	11.3	5.2	66.9	1.2	14.8	.6	6,550	11,800
	---	39.9	48.2	11.9	4.9	70.7	1.3	10.6	.6	6,930	12,470
	---	45.3	54.7	---	5.5	80.3	1.4	12.0	.7	7,870	14,160
D200648	5.1	38.3	45.2	11.4	5.3	66.8	1.2	14.4	.9	6,510	11,720
	---	40.4	47.6	12.0	5.0	70.4	1.3	10.4	.9	6,860	12,350
	---	45.9	54.1	---	5.7	80.0	1.4	11.8	1.1	7,800	14,040
D200649	3.9	38.2	43.3	14.6	5.2	65.6	1.1	12.7	.7	6,450	11,610
	---	39.8	45.1	15.2	5.0	68.3	1.1	9.6	.7	6,710	12,080
	---	46.9	53.1	---	5.8	80.5	1.3	11.3	.9	7,920	14,250
D200650	5.8	39.4	41.8	13.0	5.2	62.2	1.2	15.1	3.4	6,180	11,130
	---	41.8	44.4	13.8	4.8	66.0	1.3	10.6	3.6	6,560	11,810
	---	48.5	51.5	---	5.6	76.6	1.5	12.2	4.2	7,610	13,700
D200651	5.0	35.0	32.1	27.9	4.6	50.3	1.1	12.3	3.9	5,000	9,010
	---	36.8	33.8	29.4	4.3	52.9	1.2	8.3	4.1	5,270	9,480
	---	52.2	47.8	---	6.0	75.0	1.6	11.7	5.8	7,460	13,420

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 19 coal samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah--Continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D200640	0.1	0.10	2.04	1.44	1.5	1,130	1,165	1,290
	---	.10	2.12	1.49				
	---	.13	2.56	1.81				
D200641	.1	.05	1.05	.94	1.0	1,440	1,465	1,520
	---	.05	1.09	.98				
	---	.07	1.39	1.24				
D200642	.3	.03	.02	.61	1.0	1,445	1,470	1,525
	---	.03	.02	.64				
	---	.04	.02	.75				
D200643	.2	.03	.18	.75	1.0	1,370	1,410	1,520
	---	.03	.19	.78				
	---	.03	.21	.86				
D200644	2.7	.17	.96	1.19	.0	1,110	1,170	1,225
	---	.19	1.05	1.30				
	---	.22	1.27	1.57				
D200645	.3	.05	.32	.57	1.0	1,350	1,395	1,470
	---	.05	.33	.59				
	---	.06	.39	.69				
D200646	.6	.01	.07	.46	1.0	1,600+	1,600+	1,600+
	---	.01	.07	.48				
	---	.01	.09	.58				
D200647	.7	.05	.08	.46	1.0	1,150	1,175	1,290
	---	.05	.08	.49				
	---	.06	.10	.55				
D200648	.7	.05	.24	.60	1.0	1,165	1,200	1,310
	---	.05	.25	.63				
	---	.06	.29	.72				
D200649	.2	.01	.12	.61	1.0	1,590	1,600+	1,600+
	---	.01	.12	.63				
	---	.01	.15	.75				
D200650	.3	.19	1.81	1.40	.5	1,140	1,225	1,315
	---	.20	1.92	1.49				
	---	.23	2.23	1.72				
D200651	.0	.19	2.55	1.12	.5	1,140	1,195	1,270
	---	.20	2.68	1.18				
	---	.28	3.80	1.67				

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 19 coal samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, 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
D200652	6.1	37.6	44.8	11.5	5.4	65.4	1.3	15.6	0.8	6,370	11,460
	---	40.0	47.7	12.2	5.0	69.6	1.4	10.8	.9	6,780	12,200
	---	45.6	54.4	---	5.7	79.4	1.6	12.4	1.0	7,730	13,910
D200653	6.0	39.4	47.9	6.7	5.5	67.3	1.3	18.8	.4	6,810	12,250
	---	41.9	51.0	7.1	5.1	71.6	1.4	14.3	.4	7,240	13,030
	---	45.1	54.9	---	5.5	77.1	1.5	15.4	.5	7,800	14,030
D200654	6.7	40.3	48.0	5.0	5.7	69.9	1.3	17.7	.5	6,900	12,430
	---	43.2	51.4	5.4	5.3	74.9	1.4	12.6	.5	7,400	13,320
	---	45.6	54.4	---	5.6	79.2	1.5	13.3	.6	7,820	14,070
D200655	5.7	37.6	43.8	12.9	5.2	63.4	1.1	16.5	.9	6,260	11,270
	---	39.9	46.4	13.7	4.8	67.2	1.2	12.1	1.0	6,640	11,950
	---	46.2	53.8	---	5.6	77.9	1.4	14.0	1.1	7,690	13,840
D200656	5.2	40.3	47.9	6.6	5.7	68.6	1.3	16.4	1.4	6,830	12,300
	---	42.5	50.5	7.0	5.4	72.4	1.4	12.4	1.5	7,210	12,970
	---	45.7	54.3	---	5.8	77.8	1.5	13.4	1.6	7,750	13,940
D200657	5.0	40.7	46.9	7.4	5.6	68.1	1.3	15.8	1.9	6,770	12,190
	---	42.8	49.4	7.8	5.3	71.7	1.4	12.0	2.0	7,130	12,830
	---	46.5	53.5	---	5.8	77.7	1.5	13.0	2.2	7,730	13,920
D200658	5.1	38.5	45.0	11.4	5.4	65.7	1.4	15.5	.6	6,490	11,680
	---	40.6	47.4	12.0	5.1	69.2	1.5	11.6	.6	6,840	12,310
	---	46.1	53.9	---	5.8	78.7	1.7	13.1	.7	7,770	13,990

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 19 coal samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah--Continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D200652	0.4	0.05	0.19	0.57	0.5	1,380	1,425	1,530
	---	.05	.20	.61				
	---	.06	.23	.69				
D200653	.2	.04	.03	.36	.5	1,350	1,405	1,540
	---	.04	.03	.38				
	---	.05	.03	.41				
D200654	.6	.01L	.04	.42	.5	1,140	1,165	1,220
	---	.01L	.04	.45				
	---	.01L	.05	.48				
D200655	.2	.02	.03	.88	.5	1,260	1,290	1,350
	---	.02	.03	.93				
	---	.02	.04	1.08				
D200656	.5	.02	.89	.54	.5	1,055	1,080	1,290
	---	.02	.94	.57				
	---	.02	1.01	.61				
D200657	.0	.02	.57	1.27	.5	1,150	1,200	1,305
	---	.02	.60	1.34				
	---	.02	.65	1.45				
D200658	.2	.03	.08	.50	.5	1,590	1,600+	1,600+
	---	.03	.08	.53				
	---	.04	.10	.60				

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 32 coal and shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

[Values in percent or parts per million. Coal and shale 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 68 percent or plus-or-minus two brackets at 95 percent confidence level]

Sample number	Ash (percent)	SiO2 (percent)	Al2O3 (percent)	CaO (percent)	MgO (percent)	Na2O (percent)	K2O (percent)	Fe2O3 (percent)	TiO2 (percent)	P2O5 (percent)	Sample number
D200627	54.9	54	31	0.55	0.70	0.18	1.2	8.0	1.0	0.02L	D200627
D200640	18.7	45	19	2.4	.80	.38	1.1	20	1.0	.05L	D200640
D200641	19.7	51	26	4.3	.82	.38	.55	10	1.3	.05L	D200641
D200628	79.3	56	35	.32	.68	.32	.77	1.3	.96	.01L	D200628
D200642	16.5	50	29	6.2	1.04	.65	.32	4.5	1.3	.06L	D200642
D200643	8.9	54	24	5.7	.99	1.26	.23	4.7	1.4	.1	D200643
D200644	19.9	58	18	1.9	1.25	.63	1.8	12	1.2	.05L	D200644
D200629	70.1	67	18	.34	1.33	.23	2.5	6.6	.81	.01	D200629
D200645	12.8	56	24	4.3	.83	.32	.17	7.2	1.7	.08L	D200645
D200630	80.6	58	34	.43	.83	.20	.55	1.0	.94	.01L	D200630
D200646	15.7	57	29	2.7	1.15	.32	.17	3.7	1.3	.06L	D200646
D200631	81.7	53	34	.19	.40	.18	.40	2.9	1.2	.01L	D200631
D200647	11.9	54	27	4.4	1.72	.73	.47	4.6	1.5	.08L	D200647
D200632	71.7	57	25	1.1	1.39	.16	1.5	7.4	.79	.01L	D200632
D200648	12.3	50	28	6.6	1.44	.45	.23	5.0	1.0	.08L	D200648
D200633	85.7	52	36	.15	.28	.14	.45	1.3	.43	.01L	D200633
D200649	13.3	64	22	3.4	.60	.65	.23	3.0	1.1	.08L	D200649
D200634	62.6	60	29	.51	.58	.12	.70	2.5	1.1	.02	D200634
D200650	12.4	45	23	2.2	.60	.38	.28	24	1.0	.08L	D200650
D200635	55.4	60	21	.68	1.04	.30	1.3	11	.90	.02L	D200635
D200651	31.0	54	20	1.6	1.09	.32	1.2	17	.87	.03L	D200651
D200652	11.0	56	24	5.0	.80	.50	.58	5.6	1.3	.09L	D200652
D200636	69.0	57	34	.45	.63	.11	.62	1.7	1.4	.01L	D200636
D200653	7.9	49	25	8.2	1.82	.63	.020	5.6	1.4	.1	D200653
D200654	5.9	47	18	11	2.30	.93	.040	6.9	1.4	1	D200654
D200637	72.9	60	25	.58	1.33	.18	.94	2.4	1.0	.01	D200637
D200655	16.5	51	20	9.6	1.77	.46	.36	6.6	1.2	.1	D200655
D200656	7.9	47	19	1.6	.38	1.60	.26	21	1.0	.1L	D200656
D200657	9.9	49	18	6.4	.56	1.34	.41	16	1.2	.1L	D200657
D200638	56.0	59	27	.72	1.13	1.10	.96	5.2	.87	.02L	D200638
D200639	33.8	72	16	2.5	.58	.32	.57	5.0	1.1	.03	D200639
D200658	12.6	56	26	4.7	.99	.93	.28	3.7	1.3	.08L	D200658

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 32 coal and shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah--Continued

Sample number	SO3 (percent)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Cu (ppm)	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Li (ppm)	Sample number
D200627	0.28	70	150	3	1.0L	50	30	N	70	154	D200627
D200640	1.4	200	300	7	1.0L	90	30	N	70	142	D200640
D200641	1.4	200	500	3	1.0L	103	30	N	N	191	D200641
D200628	.14	70	300	N	1.0L	20L	50	N	N	88	D200628
D200642	1.3	200	700	15	1.0L	76	30	N	70	191	D200642
D200643	2.4	500	1,000	15	1.0L	111	30	N	N	272	D200643
D200644	2.9	150	500	15	1.0L	92	50	N	70	121	D200644
D200629	.94	100	200	7	1.0L	38	15	N	N	72	D200629
D200645	1.5	300	500	10	1.0L	82	30	N	N	80	D200645
D200630	.19	70	500	N	1.0L	20L	30	N	N	59	D200630
D200646	1.0	300	500	7	1.0L	94	30	N	70	126	D200646
D200631	.090	70	300	N	1.0L	20L	50	N	N	212	D200631
D200647	1.4	300	700	7	1.0L	103	30	N	70	158	D200647
D200632	.75	100	200	N	1.0L	50	30	N	N	66	D200632
D200648	1.7	500	300	7	1.0L	94	30	N	70	148	D200648
D200633	.090	70	150	N	1.0L	20L	50	N	N	97	D200633
D200649	1.6	300	150	15	1.0L	103	30	20	70	155	D200649
D200634	.56	100	100	3	1.0L	26	50	N	N	120	D200634
D200650	2.2	700	1,000	10	8.0	76	30	20	70	163	D200650
D200635	.94	150	300	7	1.0L	52	30	N	N	100	D200635
D200651	1.4	200	200	20	1.0L	103	30	30	N	139	D200651
D200652	1.9	700	3,000	15	1.0L	99	30	20	N	147	D200652
D200636	.19	70	70	N	1.0L	34	50	N	N	177	D200636
D200653	1.2	1,000	300	3	1.0L	78	30	N	70	208	D200653
D200654	5.0	1,000	1,000	7	1.0L	130	30	N	100	130	D200654
D200637	.38	70	200	N	1.0L	78	30	N	N	215	D200637
D200655	4.4	300	200	5	2.0	130	30	N	70	163	D200655
D200656	2.2	700	100	70	4.0	128	70	50	N	145	D200656
D200657	3.4	700	300	50	1.0L	140	50	70	N	139	D200657
D200638	.61	150	70	5	1.0	90	30	N	N	164	D200638
D200639	.99	100	70	7	1.0L	60	20	N	N	110	D200639
D200658	1.6	500	150	7	1.0L	111	30	N	N	198	D200658

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 32 coal and shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah--Continued

Sample number	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Sample number
D200627	34	N	N	15	27	10	150	70	20	2	D200627
D200640	80	15	30	30	40	30	300	150	50	3	D200640
D200641	100	15	20	15	57	20	300	150	30	3	D200641
D200628	20	N	20	N	75	N	150	30	N	N	D200628
D200642	120	10	30	20	53	20	500	100	30	3	D200642
D200643	295	7	30	20	47	30	700	100	50	5	D200643
D200644	110	15	N	70	73	30	500	150	70	7	D200644
D200629	64	N	N	30	29	15	70	70	20	2	D200629
D200645	120	15	20	15	61	15	300	70	30	3	D200645
D200630	26	N	20	N	70	N	100	30	N	N	D200630
D200646	56	10	30	15	82	15	500	70	30	2	D200646
D200631	20	N	20	N	25L	N	150	30	N	N	D200631
D200647	80	10	20	30	67	20	700	70	50	3	D200647
D200632	56	7	20	15	36	15	200	100	20	2	D200632
D200648	185	10	20	50	65	15	500	70	50	3	D200648
D200633	20	N	20	N	57	N	70	15	N	N	D200633
D200649	160	7	20	30	78	15	150	70	30	3	D200649
D200634	56	7	20	10L	38	N	30	70	20	2	D200634
D200650	98	15	20	50	47	15	150	70	30	B	D200650
D200635	60	10	N	30	41	15	150	100	30	3	D200635
D200651	88	15	N	70	36	30	200	150	70	7	D200651
D200652	140	10	N	30	62	30	300	150	70	7	D200652
D200636	30	N	20	10	42	10	70	70	N	N	D200636
D200653	160	15	30	20	59	15	700	100	30	3	D200653
D200654	150	15	20	50	37	20	1,500	70	70	3	D200654
D200637	34	N	20	15	32	15	100	100	20	2	D200637
D200655	170	15	20	70	47	30	500	200	30	3	D200655
D200656	145	30	30	150	88	150	150	150	200	20	D200656
D200657	310	50	30	150	49	30	200	150	150	15	D200657
D200638	60	15	20	50	31	10	200	150	20	2	D200638
D200639	105	N	20	30	33	15	70	70	20	2	D200639
D200658	280	7	30	30	54	15	300	70	50	3	D200658

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 32 coal and shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah--Continued

Sample number	Zn (ppm)	Zr-S (ppm)
D200627	70	150
D200640	124	200
D200641	57	300
D200628	52	300
D200642	103	500
D200643	51	500
D200644	74	300
D200629	145	150
D200645	54	300
D200630	27	300
D200646	61	300
D200631	47	300
D200647	74	200
D200632	161	200
D200648	210	200
D200633	21	70
D200649	101	300
D200634	67	200
D200650	88	200
D200635	136	150
D200651	123	150
D200652	201	300
D200636	40	200
D200653	45	500
D200654	49	300
D200637	81	150
D200655	24	300
D200656	518	500
D200657	96	300
D200638	156	100
D200639	76	150
D200658	63	300

Table 4.--Content of nine trace elements in 32 coal and shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

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

Sample number	As (ppm)	Co (ppm)	Cr (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)	Sample number
D200627	7.4	4.7	25	250	0.27	1.4	2.9	24	13	D200627
D200640	12	2.7	15	95	.36	.9	2.0	4.3	4.2	D200640
D200641	5.6	2.1	14	60	.43	1.6	3.5	5.8	3.4	D200641
D200628	.4	.9	6.1	470	.02	1.1	.1L	38	12	D200628
D200642	2.1	3.3	5.0	40	.06	.9	2.2	7.5	3.6	D200642
D200643	.5	1.0	6.1	20	.06	.3	1.8	2.5	1.0	D200643
D200644	7.4	6.4	20	170	.34	.9	2.0	4.1	3.4	D200644
D200629	16	9.2	59	850	.35	.6	2.1	11	7.5	D200629
D200645	1.1	2.3	6.0	50	.07	1.5	2.5	4.5	3.0	D200645
D200630	.5	1.0	6.4	620	.03	1.1	.1L	47	16	D200630
D200646	2.3	2.6	4.6	40	.03	1.5	2.1	6.8	3.8	D200646
D200631	1.1	2.0	8.5	320	.03	.6	.1L	20	3.7	D200631
D200647	.5	2.1	7.3	55	.05	.6	2.3	5.0	3.1	D200647
D200632	54	4.9	56	620	1.70	2.3	4.3	23	10	D200632
D200648	.7	1.8	5.5	35	.21	.4	2.1	3.4	2.7	D200648
D200633	.7	.5	4.7	240	.04	.2	.1L	16	2.2	D200633
D200649	2.5	1.6	5.9	25	.07	.4	1.5	4.0	2.1	D200649
D200634	2.6	2.2	25	300	.17	1.2	.1L	36	12	D200634
D200650	5.9	2.8	5.7	30	.34	.4	1.4	4.3	2.5	D200650
D200635	12	8.3	42	340	.45	1.1	2.0	10	8.7	D200635
D200651	15	4.7	30	160	.56	1.3	2.3	5.5	5.8	D200651
D200652	1.0	2.5	9.0	35	.07	.8	1.4	2.9	2.9	D200652
D200636	1.1	1.9	33	300	.06	.6	.1L	23	5.1	D200636
D200653	.5	1.0	4.8	15	.04	.5	1.1	4.7	2.2	D200653
D200654	.5	1.1	4.4	35	.03	.3	.9	1.5	1.0	D200654
D200637	2.5	3.5	75	430	.28	.9	2.5	13	7.1	D200637
D200655	3.8	6.9	17	40	.56	.9	1.8	4.2	2.9	D200655
D200656	3.5	4.4	6.9	20	.21	.9	1.1	1.6	5.7	D200656
D200657	4.2	3.9	6.4	110	.14	1.9	1.5	2.7	5.4	D200657
D200638	4.6	6.9	31	430	.24	2.3	4.6	12	31	D200638
D200639	1.6	2.9	33	120	.15	.6	2.1	6.9	5.8	D200639
D200658	.9	2.4	6.2	150	.03	.4	2.1	3.2	1.5	D200658

Table 5.--Major-, minor-, and trace-element composition of 32 coal and shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

[Values in percent or parts per million. As, Co, Cr, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal and shale; all other values calculated from analyses of 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)	As (ppm)	B-S (ppm)	Sample number
D200627	14	9.0	0.22	0.23	0.073	0.55	3.1	0.33	7.4	50	D200627
D200640	3.9	1.9	.32	.090	.053	.17	2.6	.11	12	30	D200640
D200641	4.7	2.7	.60	.097	.055	.090	1.4	.15	5.6	50	D200641
D200628	21	15	.18	.32	.19	.51	.72	.46	.4	50	D200628
D200642	3.9	2.5	.73	.10	.079	.044	.52	.13	2.1	30	D200642
D200643	2.2	1.1	.36	.053	.083	.017	.29	.075	.5	50	D200643
D200644	5.4	1.9	.27	.15	.093	.30	1.7	.14	7.4	30	D200644
D200629	22	6.7	.17	.56	.12	1.5	3.2	.34	16	70	D200629
D200645	3.3	1.6	.39	.064	.030	.018	.64	.13	1.1	50	D200645
D200630	22	14	.25	.40	.12	.37	.56	.45	.5	70	D200630
D200646	4.2	2.4	.30	.11	.037	.022	.41	.12	2.3	50	D200646
D200631	20	15	.11	.20	.11	.27	1.7	.59	1.1	70	D200631
D200647	3.0	1.7	.37	.12	.064	.047	.38	.11	.5	30	D200647
D200632	19	9.5	.56	.60	.085	.90	3.7	.34	54	70	D200632
D200648	2.9	1.8	.58	.11	.041	.024	.43	.074	.7	70	D200648
D200633	21	16	.092	.14	.089	.32	.78	.22	.7	70	D200633
D200649	4.0	1.5	.32	.048	.064	.025	.28	.088	2.5	50	D200649
D200634	18	9.6	.23	.22	.056	.37	1.1	.41	2.6	70	D200634
D200650	2.6	1.5	.19	.045	.035	.029	2.1	.074	5.9	100	D200650
D200635	16	6.2	.27	.35	.12	.60	4.3	.30	12	100	D200635
D200651	7.8	3.3	.35	.20	.074	.31	3.7	.16	15	70	D200651
D200652	2.9	1.4	.39	.053	.041	.053	.43	.086	1.0	70	D200652
D200636	18	12	.22	.26	.056	.36	.82	.58	1.1	50	D200636
D200653	1.8	1.0	.46	.087	.037	.001	.31	.066	.5	70	D200653
D200654	1.3	.56	.46	.082	.041	.002	.28	.049	.5	70	D200654
D200637	20	9.6	.30	.58	.097	.57	1.2	.44	2.5	50	D200637
D200655	3.9	1.7	1.1	.18	.056	.049	.76	.12	3.8	50	D200655
D200656	1.7	.79	.090	.018	.094	.017	1.2	.047	3.5	50	D200656
D200657	2.3	.94	.45	.033	.098	.034	1.1	.071	4.2	70	D200657
D200638	15	8.0	.29	.38	.46	.45	2.0	.29	4.6	100	D200638
D200639	11	2.9	.60	.12	.080	.16	1.2	.22	1.6	30	D200639
D200658	3.3	1.7	.42	.075	.087	.029	.33	.098	.9	70	D200658

Table 5.--Major-, minor-, and trace-element composition of 32 coal and shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah--Continued

Sample number	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co (ppm)	Cr (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)	Hg (ppm)	Sample number
D200627	70	1.5	0.55L	4.7	25	27	250	15	N	0.27	D200627
D200640	50	1.5	.19L	2.7	15	17	95	5	N	.36	D200640
D200641	100	.7	.20L	2.1	14	20	60	7	N	.43	D200641
D200628	200	N	.79L	.9	6.1	16L	470	50	N	.02	D200628
D200642	100	2	.17L	3.3	5.0	13	40	5	N	.06	D200642
D200643	100	1.5	.09L	1.0	6.1	9.9	20	3	N	.06	D200643
D200644	100	3	.20L	6.4	20	18	170	10	N	.34	D200644
D200629	150	5	.70L	9.2	59	27	850	10	N	.35	D200629
D200645	70	1.5	.13L	2.3	6.0	10	50	5	N	.07	D200645
D200630	500	N	.81L	1.0	6.4	16L	620	20	N	.03	D200630
D200646	70	1	.16L	2.6	4.6	15	40	5	N	.03	D200646
D200631	200	N	.82L	2.0	8.5	16L	320	50	N	.03	D200631
D200647	100	1	.12L	2.1	7.3	12	55	3	N	.05	D200647
D200632	150	N	.72L	4.9	56	36	620	20	N	1.7	D200632
D200648	30	1	.12L	1.8	5.5	12	35	3	N	.21	D200648
D200633	150	N	.86L	.5	4.7	17L	240	50	N	.04	D200633
D200649	20	2	.13L	1.6	5.9	14	25	5	3	.07	D200649
D200634	70	2	.63L	2.2	25	16	300	30	N	.17	D200634
D200650	150	1.5	.99	2.8	5.7	9.4	30	3	2	.34	D200650
D200635	150	5	.55L	8.3	42	29	340	15	N	.45	D200635
D200651	70	7	.31L	4.7	30	32	160	10	10	.56	D200651
D200652	300	1.5	.11L	2.5	9.0	11	35	3	2	.07	D200652
D200636	50	N	.69L	1.9	33	23	300	30	N	.06	D200636
D200653	20	.2	.08L	1.0	4.8	6.2	15	2	N	.04	D200653
D200654	70	.5	.06L	1.1	4.4	7.7	35	1.5	N	.03	D200654
D200637	150	N	.73L	3.5	75	57	430	20	N	.28	D200637
D200655	30	.7	.33	6.9	17	21	40	5	N	.56	D200655
D200656	7	5	.32	4.4	6.9	10	20	5	5	.21	D200656
D200657	30	5	.10L	3.9	6.4	14	110	5	7	.14	D200657
D200638	50	3	.56	6.9	31	50	430	15	N	.24	D200638
D200639	20	2	.34L	2.9	33	20	120	7	N	.15	D200639
D200658	20	1	.13L	2.4	6.2	14	150	3	N	.03	D200658

Table 5.--Major-, minor-, and trace-element composition of 32 coal and shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah--Continued

Sample number	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	Sb (ppm)	Sc-S (ppm)	Sample number
D200627	50	85	19	N	N	7	50L	15	1.4	5	D200627
D200640	15	27	15	3	5	5	40L	7.5	.9	5	D200640
D200641	N	38	20	3	5	3	40L	11	1.6	5	D200641
D200628	N	70	16	N	15	N	40L	59	1.1	N	D200628
D200642	10	32	20	1.5	5	3	40L	8.7	.9	3	D200642
D200643	N	24	26	.7	3	2	40	4.2	.3	3	D200643
D200644	15	24	22	3	N	15	40L	15	.9	7	D200644
D200629	N	50	45	N	N	20	30	20	.6	10	D200629
D200645	N	10	15	2	2	2	50L	7.8	1.5	2	D200645
D200630	N	48	21	N	15	N	40L	56	1.1	N	D200630
D200646	10	20	8.8	1.5	5	2	40L	13	1.5	2	D200646
D200631	N	170	16	N	15	N	40L	20L	.6	N	D200631
D200647	10	19	9.5	1	2	3	40L	8.0	.6	2	D200647
D200632	N	47	40	5	15	10	30L	26	2.3	10	D200632
D200648	10	18	23	1.5	2	7	40L	8.0	.4	2	D200648
D200633	N	83	17	N	15	N	40L	49	.2	N	D200633
D200649	10	21	21	1	3	5	50L	10	.4	2	D200649
D200634	N	75	35	5	15	7L	60	24	1.2	N	D200634
D200650	10	20	12	2	2	7	40L	5.8	.4	2	D200650
D200635	N	55	33	5	N	15	50L	23	1.1	10	D200635
D200651	N	43	27	5	N	20	40L	11	1.3	10	D200651
D200652	N	16	15	1	N	3	40L	6.8	.8	3	D200652
D200636	N	120	21	N	15	7	30L	29	.6	7	D200636
D200653	5	16	13	1	2	1.5	40	4.7	.5	1	D200653
D200654	7	7.7	8.9	1	1	3	300	2.2	.3	1	D200654
D200637	N	160	25	N	15	10	30	23	.9	10	D200637
D200655	10	27	28	2	3	10	70	7.8	.9	5	D200655
D200656	N	11	11	2	2	10	40L	7.0	.9	10	D200656
D200657	N	14	31	5	3	15	40L	4.9	1.9	3	D200657
D200638	N	92	34	10	10	30	50L	17	2.3	5	D200638
D200639	N	37	35	N	7	10	40	11	.6	5	D200639
D200658	N	25	35	1	3	3	40L	6.8	.4	2	D200658

Table 5.--Major-, minor-, and trace-element composition of 32 coal and shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah--Continued

Sample number	Se (ppm)	Sr-S (ppm)	Th (ppm)	U (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
D200627	2.9	70	24	13	50	10	1	38	70	D200627
D200640	2.0	50	4.3	4.2	30	10	.5	23	30	D200640
D200641	3.5	70	5.8	3.4	30	7	.7	11	70	D200641
D200628	.1L	100	38	12	20	N	N	41	200	D200628
D200642	2.2	70	7.5	3.6	15	5	.5	17	70	D200642
D200643	1.8	70	2.5	1.0	10	5	.5	4.5	50	D200643
D200644	2.0	100	4.1	3.4	30	15	1.5	15	70	D200644
D200629	2.1	50	11	7.5	50	15	1.5	100	100	D200629
D200645	2.5	50	4.5	3.0	10	5	.5	6.9	50	D200645
D200630	.1L	70	47	16	20	N	N	22	200	D200630
D200646	2.1	70	6.8	3.8	10	5	.3	9.6	50	D200646
D200631	.1L	150	20	3.7	20	N	N	38	200	D200631
D200647	2.3	100	5.0	3.1	10	7	.3	8.8	20	D200647
D200632	4.3	150	23	10	70	15	1.5	120	150	D200632
D200648	2.1	70	3.4	2.7	10	7	.3	26	20	D200648
D200633	.1L	70	16	2.2	15	N	N	18	70	D200633
D200649	1.5	20	4.0	2.1	10	5	.5	13	50	D200649
D200634	.1L	20	36	12	50	15	1.5	42	150	D200634
D200650	1.4	20	4.3	2.5	10	3	B	11	20	D200650
D200635	2.0	100	10	8.7	50	15	1.5	75	100	D200635
D200651	2.3	70	5.5	5.8	50	20	2	38	50	D200651
D200652	1.4	30	2.9	2.9	15	7	.7	22	30	D200652
D200636	.1L	50	23	5.1	50	N	N	28	150	D200636
D200653	1.1	50	4.7	2.2	7	2	.2	3.6	50	D200653
D200654	.9	100	1.5	1.0	5	5	.15	2.9	15	D200654
D200637	2.5	70	13	7.1	70	15	1.5	59	100	D200637
D200655	1.8	70	4.2	2.9	30	5	.5	4.0	50	D200655
D200656	1.1	10	1.6	5.7	10	15	1.5	41	50	D200656
D200657	1.5	20	2.7	5.4	15	15	1.5	9.5	30	D200657
D200638	4.6	100	12	31	100	10	1	87	50	D200638
D200639	2.1	20	6.9	5.8	20	7	.7	26	50	D200639
D200658	2.1	30	3.2	1.5	10	7	.3	7.9	30	D200658

Table 6.--Sulfur, carbon, carbonate carbon and organic carbon contents for 12 shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

[L, less than the value shown]

Sample number	S (percent)	C (percent)	CO3-C (percent)	Organic C (percent)	Sample number
D200627	3.3	29	0.01L	29	D200627
D200628	.01L	8.3	.01L	8.3	D200628
D200629	2.7	18	.01L	18	D200629
D200630	.01L	7.4	.08	7.3	D200630
D200631	.08	6.7	.01L	6.7	D200631
D200632	2.6	15	.04	15	D200632
D200633	.26	7.3	.01L	7.3	D200633
D200634	.61	20	.01L	20	D200634
D200635	4.1	28	.01L	28	D200635
D200636	.09	18	.01L	18	D200636
D200637	.34	15	.01L	15	D200637
D200638	2.1	28	.01L	28	D200638

Table 7.--Elements looked for, but not detected, in coal and shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

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

Element name	Symbol	Lower limit of detection (ppm) in ash
Silver	Ag	1
Gold	Au	50
Bismuth	Bi	20
Cerium	Ce	500
Dysprosium	Dy	100
Erbium	Er	100
Europium	Eu	200
Gadolinium	Gd	100
Hafnium	Hf	200
Holmium	Ho	50
Indium	In	20
Lutetium	Lu	70
Neodymium	Nd	150
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 8.--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 19 coal samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

[For comparison geometric means for analyses of 40 coal samples from the Blackhawk Formation, Wasatch Plateau field, Utah are included. All values are in percent except geometric deviation, Kcal/kg, Btu/lb, and ash-fusion temperatures and are reported on the as-received basis. °F = (°C x 1.8) + 32; Kcal/kg = 0.556 (Btu/lb). L, less than the value shown]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Wasatch Plateau field geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	5.1	3.6	8.8	5.0	1.3	4.1
Volatile matter	38.3	35.0	40.7	38.3	1.0	40.0
Fixed carbon	43.6	32.1	48.0	43.4	1.1	44.1
Ash	13.0	5.0	27.9	11.9	1.5	8.9
Hydrogen	5.3	4.6	5.7	5.3	1.1	5.6
Carbon	64.4	50.3	70.0	64.1	1.1	66.7
Nitrogen	1.2	1.0	1.4	1.2	1.1	1.1
Oxygen	14.9	10.8	18.9	14.7	1.2	14.5
Sulfur	1.4	.4	3.9	1.1	2.0	.6
Heat of combustion						
Kcal/kg	6,360	5,010	6,950	6,345	1.1	6,635
Btu/lb	11,450	9,010	12,500	11,410	1.1	11,930
Forms of sulfur						
Sulfate	0.06	0.01L	0.19	0.04	2.4	0.02
Pyritic	.70	.02	2.6	.22	4.7	.15
Organic	.77	.36	1.4	.71	1.5	.42
Ash-fusion temperatures, °C						
Initial deformation	1,290	1,050	1,600	1,280	1.1	1,230
Softening temperature	1,330	1,080	1,600	1,320	1.1	1,270
Fluid temperature	1,410	1,220	1,600	1,400	1.1	1,330

Table 9.--Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of nine major and minor oxides in the laboratory ash of 20 coal samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

[For comparison geometric means for analyses of 52 coal samples, from the Blackhawk Formation, Wasatch Plateau field, Utah are included. All samples were ashed at 525°C; all analyses except geometric deviation are in percent]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Wasatch Plateau field geometric mean
		Minimum	Maximum			
(Ash)	14.9	5.9	33.8	13.6	1.5	9.4
SiO_2	53	45	72	53	1.1	51
Al_2O_3	23	16	29	22	1.2	15
CaO	4.8	1.6	11	4.1	1.8	4.9
MgO	1.08	.38	2.30	.97	1.6	.99
Na_2O	.66	.32	1.60	.58	1.7	1.77
K_2O	.52	.02	1.8	.31	2.8	.42
Fe_2O_3	9.3	3.0	24	7.5	1.9	3.4
TiO_2	1.2	.87	1.7	1.2	1.2	.91
SO_3	2.0	1.0	5.0	1.8	1.6	3.4

Table 10.--Arithmetic mean, observed range, geometric mean and geometric deviation of the contents of 37 elements in 20 coal samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

[For comparison geometric means of analyses for 52 coal samples from the Blackhawk Formation, Wasatch Plateau field, Utah are included. All values except geometric deviation are in percent or parts per million and are reported on a whole-coal basis. As, Co, Cr, 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	Wasatch Plateau field geometric mean
		Minimum	Maximum			
			Percent			
Si	3.8	1.3	11	3.3	1.6	2.2
Al	1.8	.56	3.3	1.6	1.6	.77
Ca	.45	.09	1.1	.39	1.7	.33
Mg	.094	.018	.20	.079	1.8	.056
Na	.062	.030	.098	.058	1.5	.12
K	.087	.001	.31	.035	4.0	.033
Fe	.99	.28	3.7	.71	2.3	.23
Ti	.11	.047	.22	.099	1.5	.051
			Parts per million			
As	3.7	0.5	15	2	3.0	0.6
B	50	30	100	50	1.4	100
Ba	70	7	300	50	2.5	50
Be	2	.2	7	1.5	2.3	.7
Co	3.0	1	6.9	2.5	1.7	1.5
Cr	10	4.4	33	8.5	1.9	7
Cu	14	6.1	32	13	1.5	7.7
F	65	15	170	50	2.1	47
Ga	5	1.5	10	5	1.6	3
Ge	2	2	10	1	3.2	---
Hg	.20	.03	.56	.12	2.8	.04
La	7	5	15	7	1.9	3
Li	23	7.7	43	21	1.6	9.2
Mn	20	8.8	35	18	1.6	7
Mo	2	.7L	5	1.5	1.9	.7
Nb	3	1L	7	2	2.0	2
Ni	7	1.5	20	5	2.2	3
Pb	8.2	2.2	15	7.4	1.6	4.1
Sb	.9	.3	1.9	.7	1.8	.2
Sc	3	1	10	3	1.9	1.5
Se	1.9	.9	3.5	1.8	1.4	1.6
Sr	70	10	100	50	2.0	70
Th	4.3	1.5	7.5	3.9	1.6	.4
U	3.4	1.0	5.8	3.0	1.7	.8
V	15	5	50	15	1.8	10
Y	7	2	20	7	1.8	7
Yb	.7	.15L	2	.5	2.0	.5
Zn	15	2.9	41	12	2.2	6.9
Zr	50	15	70	50	1.6	20

Table 11.--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 12 shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

[All samples were ashed at 525°C; all analyses except geometric deviation in percent. L, less than the value shown]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation
		Minimum	Maximum		
(Ash)	70.1	54.9	85.7	69.2	1.2
SiO_2	58	52	67	58	1.1
Al_2O_3	29	18	36	28	1.2
CaO	.51	.15	1.1	.44	1.8
MgO	.88	.28	1.40	.77	1.7
Na_2O	.26	.11	1.10	.21	1.8
K_2O	.99	.40	2.5	.86	1.7
Fe_2O_3	4.4	1.0	11	3.2	2.3
TiO_2	.96	.43	1.4	.92	1.3
SO_3	.46	.09	.94	.32	2.4
P_2O_5	.008	.01L	.02	.007	1.7

Table 12.—Arithmetic mean, observed range, geometric mean, and geometric deviation of contents of 35 elements in 12 shale samples from the Ferron Sandstone Member of the Mancos Shale, Emery coal field, Emery County, Utah

[For comparison, average shale contents are included (Turekian and Wedepohl, 1961). All values except geometric deviation are in percent or parts per million and are reported on a whole-shale basis. As, Co, Cr, F, Hg, Sb, Se, Th, and U values used to calculate the statistics were determined directly on whole shale. All other values used were calculated from determinations made on shale ash. L, less than value shown]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Average shale
		Minimum	Maximum			
			Percent			
Si	19	14	22	19	1.1	27
Al	11	6.2	16	10	1.4	8.0
Ca	.24	.09	.56	.22	1.6	2.2
Mg	.36	.14	.60	.32	1.6	1.6
Na	.13	.060	.46	.11	1.8	.96
K	.56	.27	1.5	.50	1.6	2.7
Fe	2.0	.56	4.2	1.5	2.0	4.7
Ti	.40	.22	.59	.38	1.3	.46
			Parts per million			
As	8.5	0.4	54	2.9	4.6	13
B	70	50	100	70	1.3	100
Ba	150	50	500	150	1.9	580
Be	2	1.5L	5	1.5	2.6	3
Co	3.8	.5	9.2	2.7	2.6	19
Cr	31	4.7	75	22	2.7	90
Cu	26	16L	57	22	1.9	45
F	430	240	850	400	1.5	740
Ga	30	10	50	20	1.7	19
Hg	.32	.02	1.70	.13	3.9	.4
Li	88	47	170	80	1.6	66
Mn	27	16	45	25	1.5	850
Mo	5	5L	10	5	1.6	2.6
Nb	15	10L	15	15	1.3	11
Ni	10	7L	30	7	2.1	68
Pb	30	15L	59	26	1.7	20
Sb	1.2	.2	2.3	.9	1.9	1.5
Sc	7	5L	10	5	1.7	13
Se	3.1	2.0L	4.6	2.9	1.4	.6
Sr	100	20	150	70	1.7	300
Th	23	10	47	20	1.7	12
U	11	2.2	31	8.7	2.0	3.7
V	50	15	100	50	1.8	130
Y	10	10L	15	10	1.4	26
Yb	1	1L	1.5	1	1.4	2.6
Zn	56	18	120	47	1.8	95
Zr	150	50	200	100	1.6	160