UNITED STATES DEPARTMENT OF THE INTERIOR

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Chemical analyses of coal from the Knobloch and Flowers-Goodale beds, Tongue River Member of the Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Montana

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This report is preliminary and has not been edited or reviewed for conformity with U.S. Geological Survey standards.

Introduction

As part of a continuing program by the U.S. Geological Survey to collect and chemically analyze representative samples of U.S. coals, 44 samples of the Knobloch bed and six samples of the Flowers-Goodale bed were collected from four core holes drilled in the Paleocene Tongue River Member of the Fort Union Formation in Powder River County, Montana. These four holes (DH 74-101, DH 74-102, DH 74-105, and DH 74-107) were drilled by the U.S. Bureau of Reclamation in connection with the Otter Creek EMRIA (Energy Mineral Rehabilitation Inventory and Analyses) study (U.S. Department of the Interior, 1975). Drill holes DH 74-101, DH 74-102, and DH 74-105 are located in sections 26 and 34, T. 3 S., R. 45 E., in the southern part of the Ashland coal field; drill hole DH 74-107 is located in section 2, T. 4 S., R. 45 E., in the northwestern part of the Birney-Broadus coal field. The Ashland coal field was initially described by Bass (1932) and the Birney-Broadus coal field was initially described by Warren (1959). The locations of these two fields are shown in figure 1. Brief descriptions of all 50 samples are listed in table 1; the locations of the four drill holes are shown in figure 2.

Estimated coal resources for the Knobloch bed in the Otter Creek study site are in excess of 125 million tons (114 million metric tons) (U.S. Department of the Interior, 1975). There are currently no estimates of coal resources for the Flowers-Goodale bed from this area.

Analyses of samples D169028 through D169040, D169475 through D169480, and D169723 and D169724 have previously been published in U.S. Department of the Interior (1975) and McKay, Hatch and Landis (1976). These samples are included here in order to provide a more complete data listing.

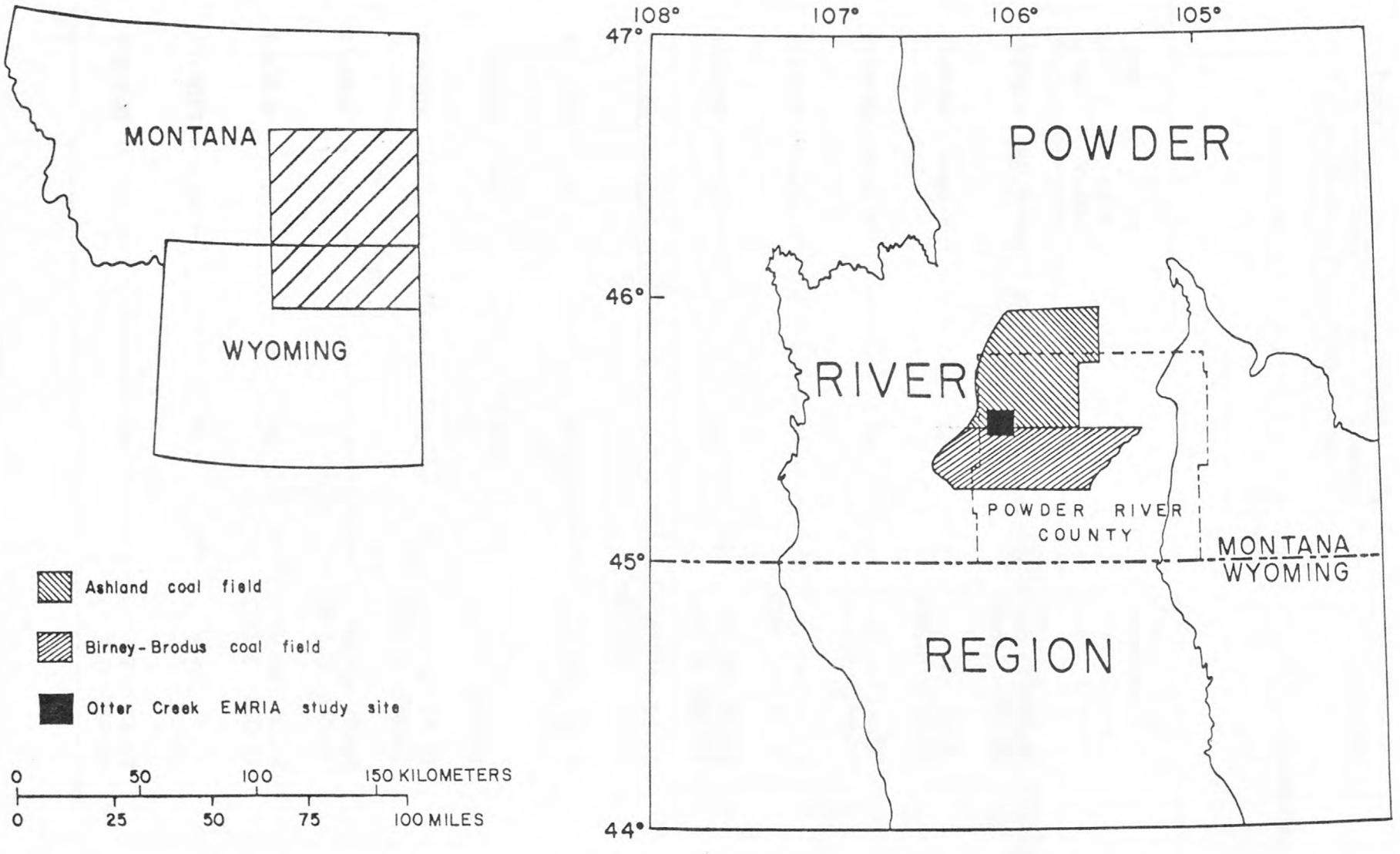

Figure 1.--Map of northeastern Wyoming and southeastern Montana showing the locations of the Otter Creek EMRIA study site, Ashland, and Birney-Broadus coal fields, Powder River County, Montana, and an outline of the Powder River coal region. Map modified from Averitt (1942).

Table 1.--USGS sample numbers, hole numbers, locations, depth intervals and bed names for 50 coal samples from the Otter Creek EMRIA study site, Powder River County, Mont.

[All samples are from the Paleocene Tongue River Member of the Fort Union Formation]

USGS sample number	Hole number	Location	Depth interval represented in meters and (feet)	Bed name
D169028	DH 74-101	NE 1/4 SW 1/4 sec. 34, T. 3 S., R. 45 E.	60.47- 61.02 (198.4 -200.2)	Knobloch.
D169029	---do---	----------do----------	61.02- 62.54 (200.2 -205.2)	Do.
D169030	---do---	----------do----------	62.54- 64.07 (205.2 -210.2)	Do.
D169031	---do---	----------do----------	64.07- 65.59 (210.2 -215.2)	Do.
D169032	---do---	----------do----------	65.59- 67.12 (215.2 -220.2)	Do.
D169033	---do---	----------do----------	67.12- 68.64 (220.2 -225.2)	Do.
D169034	---do---	----------do----------	68.64- 70.10 (225.2 -230.0)	Do.
D169035	---do---	----------do----------	70.10- 71.63 (230.0 -235.0)	Do.
D169036	---do---	----------do----------	71.63- 73.15 (235.0 -240.0)	Do.
D169037	---do---	----------do----------	73.15- 74.68 (240.0 -245.0)	Do.
D169038	---do---	----------do----------	74.68- 76.20 (245.0 -250.0)	Do.
D169039	---do---	----------do----------	76.20- 77.74 (250.0 -255.0)	Do.
D169040	---do---	----------do----------	77.74- 78.97 (255.0 -259.1)	Do.

Table 1.--USGS sample numbers, hole numbers, locations, depth intervals and bed names for 50 coal samples from the Otter Creek EMRIA study site, Powder River County, Mont.--Continued

USGS sample number	Hole number	Location	Depth interval represented in meters and (feet)	Bed name
D169475	DH 74-101	NE 1/4 SW 1/4 sec. 34, T. 3 S., R. 45 E.	114.5 -115.9 (375.7 -380.2)	Flowers-Goodale.
D169476	---do----	----------do----------	115.9 -117.5 (380.2 -385.4)	Do.
D169477	DH 74-102	NW 1/4 SE 1/4 sec. 26, T. 3 S., R. 45 E.	38.92- 41.57 (127.7 -136.4)	Knobloch.
D169478	---do----	----------do----------	41.57- 46.11 (136.4 -151.3)	Do.
D169479	---do----	----------do----------	46.11- 50.69 (151.3 -166.3)	Do.
D169480	---do----	----------do----------	50.69- 55.26 (166.3 -181.3)	Do.
D169723	---do----	----------do----------	88.15- 89.67 (289.2 -294.2)	Flowers-Goodale.
D169724	---do----	----------do----------	89.67- 91.20 (294.2 -299.2)	Do.
D170203	DH 74-105	SE 1/4 SE 1/4 sec. 34, T. 3 S., R. 45 E.	61.20- 62.73 (200.8 -205.8)	Knobloch.
D170204	---do----	----------do----------	62.73- 64.25 (205.8 -210.8)	Do.
D170205	---do----	----------do----------	64.25- 65.76 (210.8 -215.8)	Do.
D170206	---do----	----------do----------	65.76 67.30 (215.8 -220.8)	Do.
D170207	---do----	----------do----------	67.30- 68.82 (220.8 -225.8)	Do.
D170208	---do----	----------do----------	68.82- 70.35 (225.8 -230.8)	Do.
D170209	---do----	----------do----------	70.35- 71.87 (230.8 -235.8)	Do.

Table 1.--USGS sample numbers, hole numbers, locations, depth intervals and bed names for 50 coal samples from the Otter Creek EMRIA study site, Powder River County, Mont.--Continued

USGS sample number	Hole number	Location	Depth interval represented in meters and (feet)	Bed name
D170210	DH 74-105	SE 1/4 SE 1/4 sec. 34, T. 3 S., R. 45 E.	71.87- 73.40 (235.8 -240.8)	Knobloch.
D170211	---do----	----------do----------	73.40- 74.91 (240.8 -245.8)	Do.
D170212	---do----	----------do----------	74.91- 76.44 (245.8 -250.8)	Do.
D170213	---do----	----------do----------	76.44- 77.97 (250.8 -255.8)	Do.
D170214	---do----	----------do----------	77.97- 79.49 (255.8 -260.8)	Do.
D170215	---do----	----------do----------	79.49- 81.02 (260.8 -265.8)	Do.
D170216	---do----	----------do----------	117.4 -118.9 (385.2 -390.2)	Flowers-Goodale.
D170217	---do----	----------do----------	118.9 -120.1 (390.2 -394.0)	Do.
D171967	DH 74-107	NE 1/4 SE 1/4 sec. 2, T. 4 S., R. 45 E.	16.5 - 18.0 (54.2 - 59.2)	Knobloch.
D171968	---do----	----------do----------	18.0 - 19.6 (59.2 - 64.2)	Do.
D171969	---do----	----------do----------	19.6 - 21.1 (64.2 - 69.2)	Do.
D171970	---do----	----------do----------	21.1 - 22.6 (69.2 - 74.2)	Do.
D171971	---do----	----------do----------	22.6 - 24.1 (74.2 - 79.2)	Do.
D171972	---do----	----------do----------	24.1 - 25.7 (79.2 - 84.2)	Do.
D171973	---do----	----------do----------	25.7 - 27.2 (84.2 - 89.2)	Do.

Table 1.--USGS sample numbers, hole numbers, locations, depth intervals and bed names for 50 coal samples from the Otter Creek EMRIA study site, Powder River County, Mont.--Continued

USGS sample number	Hole number	Location	Depth interval represented in meters and (feet)	Bed name
D171974	DH 74-107	NE 1/4 SE 1/4 sec. 2, T. 4 S., R. 45 E.	27.2 - 28.7 (89.2 - 94.2)	Knobloch.
D171975	---do----	----------do---------	28.7 - 30.2 (94.2 - 99.2)	Do.
D171976	---do----	----------do---------	30.2 - 31.76 (99.2 -104.2)	Do.
D171977	---do----	----------do---------	31.76- 33.28 (104.2 -109.2)	Do.
D171978	---do----	----------do---------	33.28- 34.81 (109.2 -114.2)	Do.
D171979	---do----	----------do---------	34.81- 36.33 (114.2 -119.2)	Do.
D171980	---do----	----------do---------	36.33- 36.67 (119.2 -120.3)	Do.

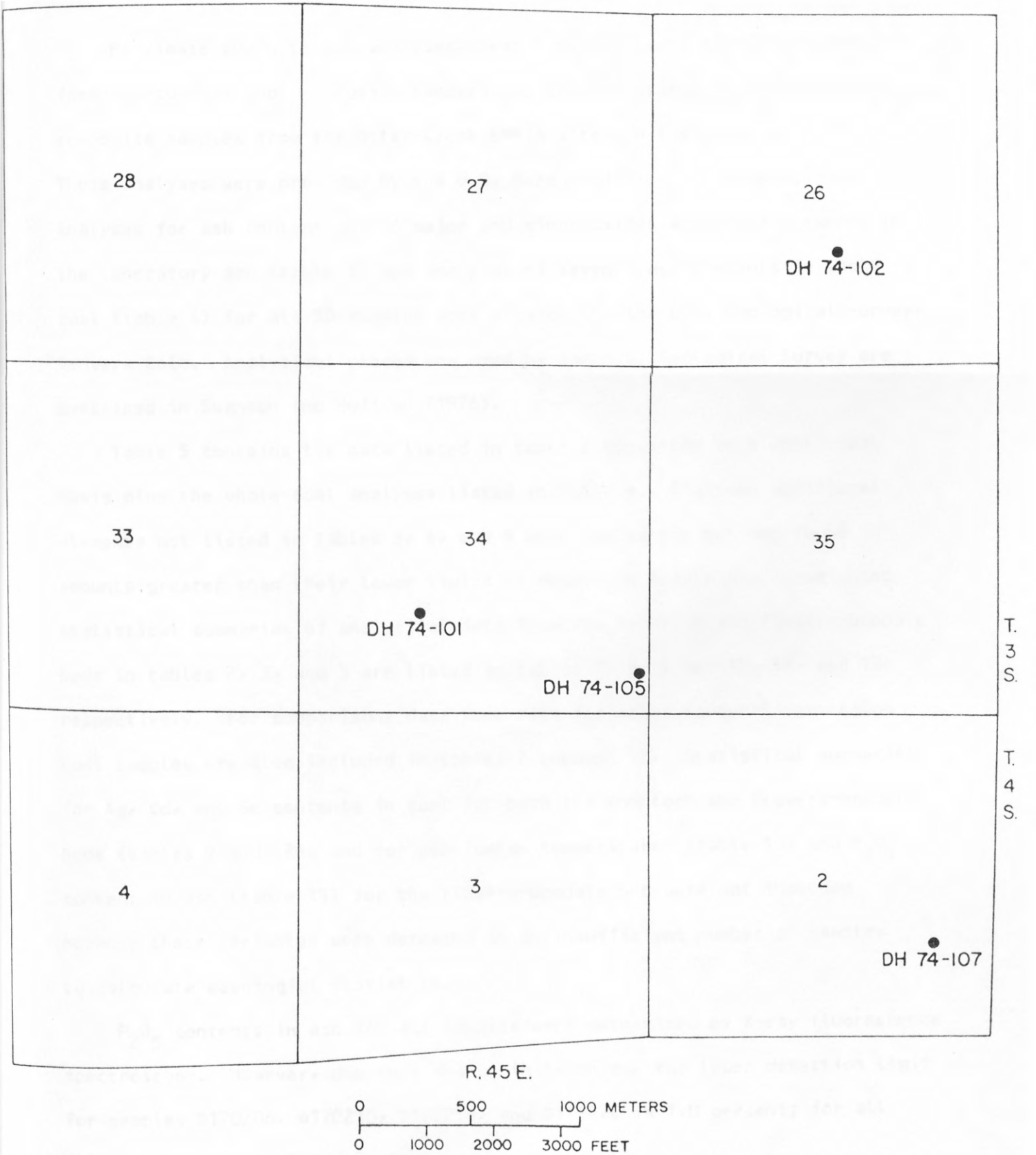

Figure 2.--Index map showing locations of four drill holes in the Tongue River Member of the Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont. Detailed location descriptions are in table 1.

Proximate and ultimate analyses, heat-of-combustion, air-dried-loss, forms-of-sulfur, and ash-fusion-temperature determinations on 21 single and composite samples from the Otter Creek EMRIA site are listed in table 2. These analyses were provided by the U.S. Bureau of Mines, Pittsburgh, Pa. Analyses for ash content and 36 major and minor oxides and trace elements in the laboratory ash (table 3) and analyses of seven trace elements in whole coal (table 4) for all 50 samples 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-coal basis plus the whole-coal analyses listed in table 4. Eighteen 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 Knobloch and Flowers-Goodale beds in tables 2, 3, and 5 are listed in tables 7, 8, 9 and 10, 11, and 12 respectively. For comparison, data summaries for other Powder River region coal samples are also included in tables 7 through 12. Statistical summaries for Ag, Cd, and Ge contents in coal for both the Knobloch and Flowers-Goodale beds (tables 9 and 12), and for ash fusion temperatures (table 10) and P_2O_5 content in ash (table 11) for the Flowers-Goodale bed were not included because these variables were detected in an insufficient number of samples to calculate meaningful statistics.

P_2O_5 contents in ash for all samples were determined by X-ray fluorescence spectroscopy. However, due to a change in technique the lower detection limit for samples D170206, D170210, D170216, and D171972 is 1.0 percent; for all other samples it is 0.1 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 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 all 21 single and composite coal samples from the Otter Creek EMRIA study site 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 heats of combustion for these samples (moist, mineral-matter-free basis) ranges from 4,390 to 5,180 Kcal/kg (7,900 to 9,310 Btu/lb) with a mean of 4,840 Kcal/kg (8,700 Btu/lb). The apparent rank of samples from the Knobloch bed ranges from lignite A (one sample, D170203*) to subbituminous C coal (17 samples). The apparent rank on the three Flowers-Goodale bed samples is subbituminous C coal.

A statistical comparison (student's t test, 95 percent confidence level) of the geometric means of the U.S. Bureau of Mines data for 18 Knobloch samples and 3 Flowers-Goodale samples from the Otter Creek EMRIA site, shows that the Knobloch bed is significantly higher in hydrogen and oxygen and significantly lower in fixed carbon, nitrogen, total sulfur and organic sulfur contents. Contents of moisture, volatile matter, ash, carbon, heat of combustion, and sulfate and pyritic sulfur are not significantly different. When compared at the 99 percent confidence level, fixed carbon and nitrogen contents are not significantly different.

A statistical comparison of the geometric means of the U.S. Bureau of Mines data for 18 Knobloch samples with 33 other Powder River region coal samples shows that the Knobloch bed is significantly higher in moisture, hydrogen and oxygen contents and significantly lower in volatile matter, ash, carbon, nitrogen, total sulfur, and sulfate, pyritic and organic sulfur contents and has a significantly lower heat of combustion. Contents of fixed carbon are not significantly different.

A statistical comparison of the geometric means of the U.S. Bureau of Mines data for 3 Flowers-Goodale samples with 33 other Powder River region coal samples shows that the Flowers-Goodale bed is significantly lower in volatile matter content. Moisture, fixed carbon, ash, hydrogen, carbon, nitrogen, carbon, nitrogen, oxygen, and total sulfur contents, and heats of combustion are not significantly different.

A statistical comparison of the geometric mean contents of coal ash and nine major and minor oxides in the ash for 44 Knobloch and 6 Flowers-Goodale samples, shows that the Knobloch bed ash is significantly higher in MgO content and significantly lower in contents of Al_2O_3, Fe_2O_3, and SO_3. Contents of ash and contents of SiO_2, CaO, Na_2O, K_2O, and TiO_2 in ash are not significantly different.

A statistical comparison of the geometric mean contents of coal ash and nine major and minor oxides in ash for 44 Knobloch samples with 410 other Powder River region coal samples shows that the Knobloch bed contains significantly lower ash and this ash has significantly higher SiO_2, Al_2O_3, Na_2O, and K_2O contents and significantly lower Fe_2O_3 and SO_3 contents. Contents of CaO, MgO and TiO_2 in ash are not significantly different. When compared at the 99 percent confidence level the ash content is not significantly different.

A statistical comparison of the geometric mean contents of coal ash and nine major and minor oxides in ash for 6 Flowers-Goodale samples with 410 other Powder River region coal samples shows that the Flowers-Goodale bed ash has significantly higher Al_2O_3 and Na_2O and significantly lower in MgO contents. The contents of ash and contents of SiO_2, CaO, K_2O, Fe_2O_3, TiO_2 and SO_3 in ash are not significantly different. When compared at the 99 percent confidence level the contents of MgO in ash are not significantly different.

A statistical comparison of the geometric mean contents for 36 elements in 44 Knobloch and 6 Flowers-Goodale samples shows that the Knobloch bed has significantly higher contents of Mg and Mo and significantly lower contents of Al, Fe, As, Ba, Be, Cu, La, Mn, Sb, Sc, Se, Th, U, Y, and Yb. The contents of Si, Ca, Na, K, Ti, Co, Cr, F, Ga, Hg, Li, Nb, Ni, Pb, Sr, V, Zn, and Zr are not significantly different. When compared at the 99 percent confidence level the contents of Ba, Se, Y, and Yb are not significantly different.

A statistical comparison of the geometric mean contents for 35 elements in 44 Knobloch samples with 410 other Powder River region samples shows that the Knobloch has significantly higher contents of Na, B, Li, Mo, and Sr and significantly lower contents of Ca, Fe, As, Be, Co, Cr, Cu, Hg, Mn, Ni, Sc, Se, Th, V, Y, Yb, and Zn. The contents of Si, Al, Mg, K, Ti, Ba, F, Ga, Nb, Pb, Sb, U, and Zr are not significantly different. When compared at the 99 percent confidence level the contents of Ca are not significantly different.

A statistical comparison of the geometric mean contents of 35 elements for six Flowers-Goodale samples with 410 other Powder River region coal samples shows that the Flowers-Goodale bed is significantly higher in contents of Al, Na, Ba, Be, Sb, Sr, and U and significantly lower in contents of Mg and Co. The contents of Si, Ca, K, Fe, Ti, As, Ba, Cr, Cu, F, Ga, Hg, Li, Mn, Mo, Nb, Ni, Pb, Sc, Se, Th, V, Y, Yb, Zn, and Zr are not significantly different. When compared at the 99 percent confidence level the contents of Al, Be, and Sr 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 the Knobloch or Flowers-Goodale coal beds.

Compared to other U.S. coals (Swanson and others, 1976; Hatch and Swanson, 1977), coal from the Powder River region are characterized by relatively low ash, low sulfur, low heat of combustion, and high moisture content. The contents of elements of environmental concern such as As, Be, Hg, Mo, Sb, and Se are low in Powder River region coal when compared to most other U.S. coals.

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Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 21 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.

[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. All analyses by Coal Analysis Section, U.S. Bureau of Mines, Pittsburgh, Pa. $^{o}C = (^{o}F-32)\ 5/9$; Kcal/kg = 0.556 (Btu/lb). L, less than the value shown; B, not determined. Sample D169475* is a composite of D169475 and D169476; D169723* is a composite of D169723 and D169724; D170203* is a composite of D170203 and D170204; D170205* is a composite of D170205, D170206, and D170207; D170208* is a composite of D170208, D170209, and D170210; D170211* is a composite of D170211, D170212, and D170213; D170214* is a composite of D170214 and D170215; D170216* is a composite of D170216 and D170217; D171967* is a composite of D171967 and D171968; D171969* is a composite of D171969, D171970, and D171971; D171972* is a composite of D171972, D171973, and D171974; D171975* is a composite of D171975, D171976, and D171977; and D171978* is a composite of D171978, D171979, and D171980]

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D169028	30.9	27.0	34.7	7.4	6.6	45.4	0.8	39.7	0.1	4,330	7,790
	---	39.1	50.2	10.7	4.6	65.7	1.2	17.7	.1	6,260	11,270
	---	43.8	56.2	---	5.1	73.6	1.3	19.8	.2	7,010	12,630
D169032	30.3	28.7	35.4	5.6	6.7	47.7	.7	39.2	.1	4,570	8,220
	---	41.2	50.8	8.0	4.8	68.4	1.0	17.6	.1	6,550	11,790
	---	44.8	55.2	---	5.2	74.4	1.1	19.1	.2	7,120	12,820
D169035	28.2	29.3	36.0	6.5	6.5	48.6	.7	37.6	.1	4,650	8,370
	---	40.8	50.1	9.1	4.7	67.7	1.0	17.5	.1	6,480	11,660
	---	44.9	55.1	---	5.2	74.4	1.1	19.2	.2	7,120	12,820
D169038	29.3	26.8	36.5	7.4	6.4	46.9	.7	38.4	.2	4,470	8,050
	---	37.9	51.6	10.5	4.4	66.3	1.0	17.5	.3	6,330	11,390
	---	42.3	57.7	---	5.0	74.1	1.1	19.5	.3	7,070	12,720
D169475*	26.4	28.7	39.1	5.8	6.2	51.2	.9	35.5	.4	4,840	8,710
	---	39.0	53.1	7.9	4.4	69.6	1.2	16.3	.5	6,570	11,830
	---	42.3	57.7	---	4.8	75.5	1.3	17.7	.6	7,140	12,850
D169477	29.1	29.8	35.6	5.5	6.6	48.6	.7	38.4	.2	4,570	8,220
	---	42.0	50.2	7.8	4.7	68.5	1.0	17.7	.3	6,440	11,590
	---	45.6	54.4	---	5.1	74.3	1.1	19.2	.3	6,980	12,570
D169478	30.9	29.4	34.5	5.2	6.8	47.3	.7	39.9	.1	4,510	8,120
	---	42.5	49.9	7.5	4.9	68.5	1.0	18.0	.1	6,530	11,750
	---	46.0	54.0	---	5.3	74.0	1.1	19.5	.2	7,060	12,710
D169479	30.1	29.0	35.1	5.8	6.7	47.9	.7	38.8	.1	4,580	8,240
	---	41.5	50.2	8.3	4.8	68.5	1.0	17.2	.1	6,550	11,790
	---	45.2	54.8	---	5.2	74.7	1.1	18.8	.2	7,140	12,850
D169480	29.7	27.9	35.3	7.1	6.5	47.1	.7	38.4	.2	4,490	8,090
	---	39.7	50.2	10.1	4.6	67.0	1.0	17.1	.3	6,390	11,510
	---	44.1	55.9	---	5.1	74.5	1.1	19.0	.3	7,110	12,800
D169723*	28.8	27.8	36.4	7.0	6.5	48.1	.8	37.2	.4	4,570	8,220
	---	39.0	51.1	9.8	4.6	67.6	1.1	16.3	.6	6,410	11,540
	---	43.3	56.7	---	5.1	74.9	1.2	18.1	.6	7,110	12,800
D170203*	35.1	26.4	31.3	7.2	6.9	43.3	.7	41.7	.2	4,040	7,270
	---	40.7	48.2	11.1	4.6	66.7	1.1	16.2	.3	6,220	11,200
	---	45.8	54.2	---	5.2	75.0	1.2	18.2	.3	7,000	12,600
D170205*	32.3	27.6	34.0	6.1	6.8	45.9	.7	40.4	.1	4,370	7,860
	---	40.8	50.2	9.0	4.7	67.8	1.0	17.3	.1	6,450	11,610
	---	44.8	55.2	---	5.2	74.5	1.1	19.0	.2	7,090	12,760

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 21 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--Continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash-fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D169028	14.9	0.02	0.04	0.07	B	B	B	B
	---	.03	.06	.10				
	---	.03	.06	.11				
D169032	14.0	.02	.04	.09	B	B	B	B
	---	.03	.06	.13				
	---	.03	.06	.14				
D169035	11.4	.02	.04	.04	B	B	B	B
	---	.03	.06	.06				
	---	.03	.06	.06				
D169038	12.9	.01	.11	.02	B	B	B	B
	---	.01	.16	.03				
	---	.02	.17	.03				
D169475*	14.6	.01	.07	.29	B	B	B	B
	---	.01	.10	.39				
	---	.01	.10	.43				
D169477	10.8	.01	.01	.15	B	B	B	B
	---	.01	.01	.21				
	---	.02	.02	.23				
D169478	11.6	.02	.04	.08	B	B	B	B
	---	.03	.06	.12				
	---	.03	.06	.13				
D169479	22.0	.01	.01	.10	B	B	B	B
	---	.01	.01	.14				
	---	.02	.02	.16				
D169480	20.7	.01L	.06	.14	B	B	B	B
	---	.01L	.09	.20				
	---	.01L	.09	.22				
D169723*	18.7	.01	.07	.37	B	B	B	B
	---	.01	.10	.52				
	---	.02	.11	.58				
D170203*	27.2	.01	.07	.09	B	B	B	B
	---	.02	.11	.14				
	---	.02	.12	.16				
D170205*	24.1	.07	.06	.01	B	B	B	B
	---	.10	.09	.01				
	---	.11	.10	.02				

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 21 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--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
D170208*	32.6	27.8	33.5	6.1	6.9	46.2	0.7	39.9	0.2	4,360	7,840
	---	41.2	49.7	9.1	4.9	68.5	1.0	16.2	.3	6,460	11,630
	---	45.4	54.6	---	5.3	75.4	1.1	17.8	.3	7,110	12,790
D170211*	32.8	26.7	34.7	5.8	6.7	46.2	.6	40.5	.2	4,350	7,830
	---	39.7	51.6	8.6	4.5	68.7	.9	16.9	.3	6,470	11,650
	---	43.5	56.5	---	5.0	75.2	1.0	18.5	.3	7,080	12,750
D170214*	33.6	27.0	34.9	4.5	6.8	46.3	.6	41.5	.3	4,400	7,920
	---	40.7	52.6	6.8	4.6	69.7	.9	17.5	.5	6,630	11,930
	---	43.6	56.4	---	5.0	74.8	1.0	18.8	.5	7,110	12,790
D170216*	27.5	26.2	34.4	11.9	6.0	45.8	.7	35.0	.6	4,330	7,790
	---	36.1	47.4	16.4	4.1	63.2	1.0	14.6	.8	5,970	10,740
	---	43.2	56.8	---	4.9	75.6	1.2	17.4	1.0	7,140	12,850
D171967*	26.0	32.5	34.7	6.8	6.5	48.3	.8	37.4	.2	4,620	8,310
	---	43.9	46.9	9.2	4.9	65.3	1.1	19.3	.3	6,240	11,230
	---	48.4	51.6	---	5.4	71.9	1.2	21.3	.3	6,870	12,370
D171969*	31.5	29.1	34.8	4.6	6.8	47.0	.7	40.7	.2	4,510	8,120
	---	42.5	50.8	6.7	4.8	68.6	1.0	18.5	.3	6,590	11,850
	---	45.5	54.5	---	5.2	73.6	1.1	19.9	.3	7,060	12,710
D171972*	29.1	31.2	35.3	4.4	6.7	49.3	.7	38.7	.2	4,710	8,480
	---	44.0	49.8	6.2	4.9	69.5	1.0	18.1	.3	6,640	11,960
	---	46.9	53.1	---	5.2	74.1	1.1	19.3	.3	7,080	12,750
D171975*	28.7	30.6	35.4	5.3	6.6	49.0	.7	38.2	.2	4,680	8,420
	---	42.9	49.6	7.4	4.8	68.7	1.0	17.8	.3	6,560	11,810
	---	46.4	53.6	---	5.2	74.2	1.1	19.2	.3	7,090	12,760
D171978*	30.4	29.3	35.9	4.4	6.7	48.9	.7	39.0	.3	4,660	8,390
	---	42.1	51.6	6.3	4.8	70.3	1.0	17.2	.4	6,700	12,050
	---	44.9	55.1	---	5.1	75.0	1.1	18.4	.5	7,150	12,870

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 21 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--Continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash-fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D170208*	20.8	0.01	0.02	0.12	B	B	B	B
	---	.01	.03	.18				
	---	.02	.03	.20				
D170211*	22.5	.01	.09	.08	B	B	B	B
	---	.01	.13	.12				
	---	.02	.15	.13				
D170214*	23.8	.01	.05	.26	B	B	B	B
	---	.02	.08	.39				
	---	.02	.08	.42				
D170216*	19.0	.01	.15	.43	B	B	B	B
	---	.01	.21	.59				
	---	.02	.25	.71				
D171967*	21.5	.01	.11	.13	B	1,130	1,155	1,175
	---	.01	.15	.18				
	---	.01	.16	.19				
D171969*	23.6	.01	.11	.06	B	1,160	1,180	1,205
	---	.01	.16	.09				
	---	.02	.17	.09				
D171972*	21.5	.01	.07	.13	B	1,205	1,220	1,240
	---	.01	.10	.18				
	---	.02	.11	.20				
D171975*	19.3	.01L	.08	.10	B	1,125	1,150	1,170
	---	.01L	.11	.14				
	---	.01L	.12	.15				
D171978*	23.3	.01	.12	.15	B	1,130	1,155	1,175
	---	.01	.17	.22				
	---	.02	.18	.23				

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.

[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 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
D169028	13.4	45	17	11	4.99	3.25	1.0	3.2	0.54	0.10L	D169028
D169029	12.9	45	18	11	3.18	3.52	1.3	3.6	.51	.10L	D169029
D169030	6.1	24	16	21	3.85	7.49	.47	3.6	.38	.10L	D169030
D169031	7.0	34	17	17	3.50	6.50	1.0	3.6	.52	.10L	D169031
D169032	6.9	33	16	17	3.75	6.79	.79	3.5	.54	.10L	D169032
D169033	8.5	33	18	16	3.13	5.54	.70	3.4	.92	.10L	D169033
D169034	7.6	30	19	15	3.03	5.65	.27	5.3	1.0	.10L	D169034
D169035	5.3	25	10	21	4.15	7.99	.49	4.4	.40	.10L	D169035
D169036	12.4	69	7.3	8.4	1.79	3.22	.10	1.5	.86	.10L	D169036
D169037	7.8	47	14	13	2.59	5.34	.090	2.6	.91	.10L	D169037
D169038	6.5	39	12	17	3.40	6.74	.040	3.0	.53	.10L	D169038
D169039	6.9	39	13	15	3.03	6.30	.11	3.0	.84	.10L	D169039
D169040	12.0	52	17	7.8	2.19	3.67	1.5	2.8	.71	.10L	D169040
D169475	8.4	37	24	15	2.55	4.49	.15	3.5	.65	.10L	D169475
D169476	6.8	30	22	16	2.57	5.55	.32	4.4	.71	.10L	D169476
D169477	8.5	39	23	17	5.80	1.54	1.0	3.9	.55	.10L	D169477
D169478	9.1	39	21	19	5.16	1.81	1.3	3.7	.67	.10L	D169478
D169479	8.5	41	20	20	4.20	1.79	.64	2.6	1.1	.10L	D169479
D169480	9.0	42	16	19	3.68	1.81	.56	2.7	.79	.10L	D169480
D169723	11.0	43	24	9.6	1.94	3.67	1.1	4.4	.64	.10L	D169723
D169724	6.3	26	17	19	3.08	6.38	.34	4.4	.55	.10L	D169724
D170203	9.8	38	16	14	3.45	5.85	1.1	4.1	.63	.68	D170203
D170204	11.0	41	19	11	3.05	5.00	1.2	3.6	.63	.19	D170204
D170205	7.4	31	17	16	3.65	7.49	.94	3.6	.50	.10L	D170205
D170206	11.6	42	18	12	2.65	4.70	1.3	2.7	1.0	1.0L	D170206
D170207	7.1	32	16	17	3.65	7.54	.86	3.1	.61	.10L	D170207
D170208	11.7	46	18	11	2.85	4.60	1.4	3.1	.89	.10L	D170208
D170209	9.0	37	19	13	3.00	5.99	1.2	3.1	.70	.10L	D170209
D170210	5.8	27	17	19	4.24	8.69	.77	3.1	.74	1.0L	D170210
D170211	9.8	51	13	12	2.60	4.97	.43	5.4	.86	.33	D170211
D170212	8.6	44	16	14	2.80	5.73	.28	2.8	.83	.28	D170212
D170213	7.1	35	17	16	3.15	6.96	.29	3.1	.70	.16	D170213
D170214	6.5	28	17	17	3.20	7.48	.21	3.6	.58	.19	D170214
D170215	6.9	39	15	15	2.80	7.13	.21	3.1	.67	.14	D170215
D170216	17.3	51	20	7.1	1.86	3.83	1.6	3.5	.92	1.0L	D170216
D170217	14.6	45	16	8.0	2.45	3.13	1.9	5.2	.59	.10L	D170217
D171967	6.5	26	15	18	6.72	6.03	.21	2.4	.55	.47	D171967
D171968	11.6	58	11	9.9	3.43	3.13	.32	1.6	.79	.51	D171968
D171969	8.0	35	18	15	5.32	4.93	.34	2.2	.80	.35	D171969
D171970	5.1	19	15	20	7.35	8.18	.33	2.8	.45	.32	D171970

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--Continued

Sample number	SO3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	Ga-S (ppm)	Sample number
D169028	9.3	N	300	3,000	20	1.0L	15	30	70	20	D169028
D169029	4.4	N	300	3,000	N	1.0L	10L	30	60	30	D169029
D169030	7.8	N	1,000	3,000	3	1.0L	10L	30	53	20	D169030
D169031	5.6	N	1,000	3,000	N	1.0L	10L	30	62	30	D169031
D169032	6.8	N	700	3,000	N	1.0L	10L	30	68	20	D169032
D169033	10	N	700	5,000	N	1.0L	10L	50	114	30	D169033
D169034	18	N	1,000	3,000	N	1.0L	10L	30	92	30	D169034
D169035	9.1	N	1,000	7,000	N	1.0L	10L	30	64	15	D169035
D169036	3.2	N	500	1,000	N	1.0L	N	20	48	15	D169036
D169037	7.5	N	1,000	2,000	N	1.0L	N	30	72	30	D169037
D169038	11	N	1,000	3,000	N	1.0L	N	20	56	15	D169038
D169039	16	N	1,000	1,500	N	1.0L	N	20	102	20	D169039
D169040	12	N	700	1,500	15	1.0L	10	70	98	30	D169040
D169475	11	N	1,000	7,000	10	1.0L	10L	30	94	30	D169475
D169476	18	N	1,500	7,000	20	1.0L	10	50	104	50	D169476
D169477	6.4	N	700	3,000	N	1.0L	10L	30	48	20	D169477
D169478	5.0	N	700	5,000	N	1.0L	10	30	63	20	D169478
D169479	5.6	N	700	5,000	N	1.0L	10L	50	96	20	D169479
D169480	7.4	N	700	2,000	N	1.0L	10L	30	78	20	D169480
D169723	14	N	700	3,000	10	1.0L	10	30	92	50	D169723
D169724	16	N	1,500	7,000	10	1.0L	10	20	92	30	D169724
D170203	5.0	N	500	7,000	2	1.0L	15	50	60	30	D170203
D170204	3.7	N	500	7,000	N	1.0L	10	50	52	20	D170204
D170205	4.1	N	1,000	7,000	2	1.0L	10	30	48	15	D170205
D170206	4.7	N	500	5,000	N	1.0L	5	30	84	15	D170206
D170207	4.2	N	1,000	7,000	2	1.0L	7	50	52	20	D170207
D170208	3.1	N	300	3,000	N	1.0L	7	50	60	20	D170208
D170209	4.4	N	700	3,000	N	1.0L	7	50	54	30	D170209
D170210	7.6	N	1,000	5,000	N	1.0L	7	70	60	15	D170210
D170211	4.6	N	500	5,000	N	1.0L	5	30	66	20	D170211
D170212	5.4	N	700	3,000	N	1.0L	5	20	70	20	D170212
D170213	7.8	N	1,000	2,000	7	1.0L	15	30	66	30	D170213
D170214	12	N	1,500	2,000	20	1.0L	30	30	70	70	D170214
D170215	7.6	N	1,500	3,000	3	1.0L	10	20	60	30	D170215
D170216	6.8	N	500	3,000	7	2.5	5	30	100	30	D170216
D170217	9.8	N	700	3,000	7	1.0	7	50	98	20	D170217
D171967	9.0	N	700	10,000	3L	1.0L	10L	30	56	30	D171967
D171968	6.6	N	300	5,000	7	1.0L	10L	30	56	30	D171968
D171969	8.2	N	700	10,000	N	1.0L	10L	30	68	50	D171969
D171970	9.6	N	1,000	15,000	N	1.0L	10	30	57	30	D171970

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--Continued

Sample number	Ge-S (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	Sample number
D169028	70	70	72	300	7	30	20	70	15	1,500	D169028
D169029	N	N	104	300	7	20	15	90	10	2,000	D169029
D169030	N	70	68	200	7	20L	20	50	15	5,000	D169030
D169031	N	70	60	200	7	20L	20	55	10	3,000	D169031
D169032	N	N	70	150	70	20L	15	80	10	3,000	D169032
D169033	N	N	114	200	7	20L	10	70	10	5,000	D169033
D169034	N	N	135	150	7	20L	10	70	10	5,000	D169034
D169035	N	N	45	150	10	20L	15	85	10L	5,000	D169035
D169036	N	N	52	70	10	20	10L	40	N	1,500	D169036
D169037	N	N	100	100	7L	20	10L	60	10	3,000	D169037
D169038	N	70	74	150	10	20L	10	40	10	5,000	D169038
D169039	N	70	60	150	7L	20L	10	50	10L	3,000	D169039
D169040	N	70	53	150	7	20	15	40	15	2,000	D169040
D169475	N	70	74	300	10	20L	15	60	20	5,000	D169475
D169476	N	70	62	300	15	20	15	40	30	5,000	D169476
D169477	N	70	68	300	7	20	10	70	10	3,000	D169477
D169478	N	70	64	300	15	20	15	145	10	3,000	D169478
D169479	N	70	104	200	7	20	15	65	15	5,000	D169479
D169480	N	70	54	300	N	20L	15	55	10	5,000	D169480
D169723	N	N	78	300	15	20L	20	45	20	3,000	D169723
D169724	N	70	46	500	7	20L	10	55	15	7,000	D169724
D170203	N	N	80	500	5	15	30	50	10	5,000	D170203
D170204	N	N	111	300	5	15	20	75	10	5,000	D170204
D170205	N	N	52	200	7	10	15	55	10	5,000	D170205
D170206	N	N	91	150	N	10	10	55	10	3,000	D170206
D170207	N	N	65	200	5	10	15	50	10	7,000	D170207
D170208	N	N	122	200	5	N	15	65	10	3,000	D170208
D170209	N	N	124	100	5	10	15	55	10	5,000	D170209
D170210	N	N	80	150	7	10	15	40	10	7,000	D170210
D170211	N	N	78	200	10	15	10	95	10	5,000	D170211
D170212	N	N	82	200	7	10	7	95	10	5,000	D170212
D170213	N	N	84	200	7	10	20	70	10	5,000	D170213
D170214	70	N	70	300	5	N	50	45	20	5,000	D170214
D170215	N	N	65	200	7	10	10	70	10	5,000	D170215
D170216	N	N	74	200	7	10	15	70	10	2,000	D170216
D170217	30	N	59	200	10	10	30	40	10	2,000	D170217
D171967	N	100L	69	200	15	20	15	45	15	3,000	D171967
D171968	N	100L	60	150	15	30	15	50	15	2,000	D171968
D171969	N	100L	158	150	15	30	15	50	15	2,000	D171969
D171970	N	100L	48	200	15	20	20	55	15	3,000	D171970

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--Continued

Sample number	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D169028	70	50	5	160	200
D169029	70	20	3	160	150
D169030	70	30	3	94	150
D169031	70	20	3	156	150
D169032	70	20	2	142	150
D169033	70	20L	2L	176	200
D169034	70	20L	2L	138	150
D169035	50	20	2	214	100
D169036	20	20	2	96	300
D169037	70	20	2	76	200
D169038	50	20	2	72	150
D169039	50	20L	2	80	150
D169040	150	30	3	100	150
D169475	70	50	5	60	200
D169476	100	50	5	69	200
D169477	50	20	3	106	150
D169478	70	20	3	294	150
D169479	100	30	3	84	300
D169480	70	20	3	82	150
D169723	100	30	3	129	200
D169724	50	30	3	67	150
D170203	70	30	2	106	200
D170204	70	20	2	140	150
D170205	70	20	2	116	100
D170206	70	20	2	102	150
D170207	70	20	2	120	150
D170208	100	20	2	88	150
D170209	100	20	2	118	150
D170210	70	20	2	92	100
D170211	50	20	2	188	200
D170212	50	20	2	142	150
D170213	70	20	2	82	150
D170214	70	50	5	45	200
D170215	50	20	2	92	200
D170216	70	20	2	110	200
D170217	100	20	2	102	200
D171967	70	30	2	61	200
D171968	100	50	5	156	300
D171969	70	30	3	64	300
D171970	70	30	3	101	150

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--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
D171971	5.9	29	15	16	6.18	3.24	0.44	3.1	0.72	0.27	D171971
D171972	7.7	26	20	13	5.27	4.96	.43	2.3	1.4	1.0L	D171972
D171973	6.3	26	16	17	6.28	5.96	.25	2.6	.69	.32	D171973
D171974	6.1	27	17	17	6.33	6.05	.28	2.6	.83	.20	D171974
D171975	6.4	29	13	18	5.94	5.49	.27	2.8	.66	.32	D171975
D171976	10.4	43	15	12	3.86	3.67	.28	1.9	.97	.26	D171976
D171977	7.0	31	16	17	5.55	5.18	.15	2.2	.56	.58	D171977
D171978	5.5	29	14	17	5.74	6.59	.19	2.8	.59	.38	D171978
D171979	6.5	30	16	15	5.42	5.64	.19	2.4	.62	.29	D171979
D171980	6.5	25	20	13	4.58	5.47	.17	2.3	.67	.22	D171980

Sample number	SO3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	Ga-S (ppm)	Sample number
D171971	10	N	700	10,000	N	1.0L	10	30	91	30	D171971
D171972	1.9	N	700	7,000	N	1.0L	10L	30	103	50	D171972
D171973	10	N	700	7,000	N	1.0L	10L	30	60	30	D171973
D171974	9.8	N	500	10,000	N	1.0L	10L	30	90	30	D171974
D171975	7.4	N	700	7,000	N	1.0L	10L	30	82	20	D171975
D171976	4.2	N	500	5,000	N	1.0L	10L	30	90	30	D171976
D171977	8.2	N	700	7,000	N	1.0L	10L	30	66	20	D171977
D171978	13	N	1,500	7,000	N	1.0L	10	30	72	30	D171978
D171979	13	1.5	700	5,000	N	1.0L	15	15	65	30	D171979
D171980	16	N	1,000	3,000	N	1.0L	30	30	90	70	D171980

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--Continued

Sample number	Ge-S (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sc-S (ppm)	Sr-S (ppm)	Sample number
D171971	N	100L	66	150	15	20	15	55	15	3,000	D171971
D171972	N	N	140	150	10	20	15	75	15	1,500	D171972
D171973	N	100L	115	150	7	20L	15	55	15	2,000	D171973
D171974	N	N	87	150	15	20	15	40	15	2,000	D171974
D171975	N	N	41	150	7	20	15	40	10	2,000	D171975
D171976	N	N	99	150	7	20	10	60	15	1,500	D171976
D171977	N	100L	64	200	7	20	70	40	15	2,000	D171977
D171978	N	100L	50	300	15	20L	15	85	15	2,000	D171978
D171979	N	100L	71	200	10	20L	20	50	15	1,500	D171979
D171980	70	N	93	300	15	20	30	55	50	1,500	D171980

Sample number	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D171971	70	30	3	115	150
D171972	70	20	2	113	150
D171973	70	30	3	72	150
D171974	70	20	3	75	150
D171975	70	30	3	69	150
D171976	70	30	3	110	300
D171977	70	30	3	60	150
D171978	70	30	2	194	150
D171979	50	30	2	73	150
D171980	100	100	10	92	150

Table 4.--Content of seven trace elements in 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.

[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
D169028	3.0	70	0.12	2.3	0.3	3.1	1.2	D169028
D169029	1.0	80	.02	.2	.2	4.0	1.3	D169029
D169030	1.0	40	.01	.1	.2	3.0L	.3	D169030
D169031	2.0	50	.03	.2	.2	2.3	.3	D169031
D169032	1.0	45	.01	.2	.2	1.9	.4	D169032
D169033	1.0	45	.02	.3	.1	2.2	.7	D169033
D169034	12	35	.01	.5	.3	2.3	.7	D169034
D169035	1.0	35	.01	.1	.4	3.0L	.2L	D169035
D169036	1.0L	30	.02	.2	.4	3.6	.8	D169036
D169037	1.0L	30	.01	.3	.3	2.9	1.1	D169037
D169038	1.0L	25	.01	.1	.2	1.9	.4	D169038
D169039	1.0L	25	.04	.2	.3	3.0L	.6	D169039
D169040	2.0	85	.06	.7	.5	2.6	1.2	D169040
D169475	2.0	25	.06	.8	.6	3.0L	1.5	D169475
D169476	2.0	30	.05	1.0	.7	3.1	1.0	D169476
D169477	1.0	65	.04	.2	.3	4.5	.8	D169477
D169478	1.0	50	.06	.3	.2	2.3	.6	D169478
D169479	1.0	45	.04	.3	1.6	3.2	.8	D169479
D169480	1.0	45	.05	.3	.8	3.6	.9	D169480
D169723	4.0	45	.11	1.4	.4	4.0	2.6	D169723
D169724	1.0	40	.04	.4	.2	3.0L	.6	D169724
D170203	1.0	45	.04	.3	.2	3.6	.9	D170203
D170204	1.0	60	.04	.4	.6	3.0L	1.6	D170204
D170205	1.0	40	.03	.2	.1L	3.0L	.6	D170205
D170206	1.0	45	.05	.4	.4	3.0L	.9	D170206
D170207	1.0	30	.04	.3	.3	3.0L	.4	D170207
D170208	1.0	55	.04	.5	.4	3.0L	1.0	D170208
D170209	1.0	45	.04	.5	.4	3.0L	.8	D170209
D170210	1.0	25	.04	.2	.2	3.0L	.4	D170210
D170211	1.0	30	.06	.3	.3	3.0L	.9	D170211
D170212	1.0	20	.06	.3	.5	3.0L	.9	D170212
D170213	1.0	25	.08	.5	.2	3.0L	.8	D170213
D170214	1.0	50	.07	1.6	.4	3.0L	.6	D170214
D170215	1.0	20L	.09	.5	.3	3.0L	.5	D170215
D170216	3.0	95	.08	1.7	.4	5.8	2.6	D170216
D170217	8.0	95	.07	2.8	.6	4.0	2.4	D170217
D171967	1.0L	20	.03	.2	.1L	3.0L	.4	D171967
D171968	1.0	30	.06	.5	.3	4.7	1.3	D171968
D171969	1.0L	35	.03	.4	.2	5.0	1.7	D171969
D171970	1.0L	25	.03	.2	.1L	3.0L	.5	D171970

Table 4.--Content of seven trace elements in 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--Continued

Sample number	As (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)	Sample number
D171971	1.0L	30	0.03	0.3	0.1L	3.0L	0.5	D171971
D171972	1.0	20	.03	.6	.1L	3.2	.6	D171972
D171973	1.0L	35	.03	.3	.1	3.0L	.4	D171973
D171974	1.0	20	.03	.3	.1L	3.0L	.4	D171974
D171975	1.0L	20	.03	.2	.3	3.0L	.5	D171975
D171976	1.0	30	.05	.4	.4	3.9	1.1	D171976
D171977	1.0L	30	.03	.3	.1	4.0	.2L	D171977
D171978	1.0L	30	.03	.3	.1	3.0L	.2L	D171978
D171979	1.0	30	.05	.3	.1	3.0L	.5	D171979
D171980	1.0	20	.31	2.5	.6	3.0L	.7	D171980

Table 5.--Major-, minor-, and trace-element composition of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.

[Values in percent or parts per million. As, F, Hg, Sb, Se, Th, and U values are from direct determinations on air-dried (32°C) coal; 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)	Ag-S (ppm)	As (ppm)	Sample number
D169028	2.8	1.2	1.0	0.40	0.32	0.11	0.30	0.043	N	3.0	D169028
D169029	2.7	1.2	1.1	.25	.34	.14	.32	.039	N	1.0	D169029
D169030	.69	.53	.90	.14	.34	.024	.15	.014	N	1.0	D169030
D169031	1.1	.62	.84	.15	.34	.058	.17	.022	N	2.0	D169031
D169032	1.1	.60	.85	.16	.35	.045	.17	.022	N	1.0	D169032
D169033	1.3	.79	.99	.16	.35	.050	.20	.047	N	1.0	D169033
D169034	1.0	.75	.83	.14	.32	.017	.28	.047	N	12	D169034
D169035	.63	.29	.80	.13	.31	.022	.16	.013	N	1.0	D169035
D169036	4.0	.48	.75	.13	.30	.010	.13	.064	N	1.0L	D169036
D169037	1.7	.57	.74	.12	.31	.006	.14	.043	N	1.0L	D169037
D169038	1.2	.42	.78	.13	.32	.002	.14	.021	N	1.0L	D169038
D169039	1.3	.46	.74	.13	.32	.006	.14	.035	N	1.0L	D169039
D169040	2.9	1.1	.66	.16	.33	.15	.23	.051	N	2.0	D169040
D169475	1.4	1.1	.90	.13	.28	.011	.21	.033	N	2.0	D169475
D169476	.96	.78	.76	.10	.28	.018	.21	.029	N	2.0	D169476
D169477	1.5	1.0	1.0	.30	.097	.072	.23	.028	N	1.0	D169477
D169478	1.6	1.0	1.2	.28	.12	.099	.23	.037	N	1.0	D169478
D169479	1.6	.91	1.2	.21	.11	.045	.15	.057	N	1.0	D169479
D169480	1.8	.77	1.2	.20	.12	.042	.17	.043	N	1.0	D169480
D169723	2.2	1.4	.75	.13	.30	.10	.34	.042	N	4.0	D169723
D169724	.78	.58	.83	.12	.30	.018	.19	.021	N	1.0	D169724
D170203	1.7	.80	.95	.20	.42	.087	.28	.037	N	1.0	D170203
D170204	2.1	1.1	.90	.20	.41	.11	.28	.042	N	1.0	D170204
D170205	1.1	.65	.84	.16	.41	.058	.19	.022	N	1.0	D170205
D170206	2.3	1.1	.99	.19	.40	.13	.22	.069	N	1.0	D170206
D170207	1.1	.61	.85	.16	.40	.051	.15	.026	N	1.0	D170207
D170208	2.5	1.1	.91	.20	.40	.14	.26	.062	N	1.0	D170208
D170209	1.5	.89	.81	.16	.40	.089	.20	.038	N	1.0	D170209
D170210	.73	.52	.79	.15	.37	.037	.13	.026	N	1.0	D170210
D170211	2.3	.66	.87	.15	.36	.035	.37	.050	N	1.0	D170211
D170212	1.8	.75	.87	.14	.37	.020	.17	.043	N	1.0	D170212
D170213	1.2	.64	.83	.13	.37	.017	.16	.030	N	1.0	D170213
D170214	.84	.59	.77	.13	.36	.011	.16	.023	N	1.0	D170214
D170215	1.3	.55	.72	.12	.36	.012	.15	.028	N	1.0	D170215
D170216	4.1	1.8	.88	.19	.49	.23	.42	.095	N	3.0	D170216
D170217	3.1	1.3	.84	.22	.34	.23	.53	.052	N	8.0	D170217
D171967	.77	.50	.84	.26	.29	.011	.11	.021	N	1.0L	D171967
D171968	3.1	.64	.82	.24	.27	.031	.13	.055	N	1.0	D171968
D171969	1.3	.77	.84	.26	.29	.023	.12	.038	N	1.0L	D171969
D171970	.45	.40	.73	.23	.31	.014	.099	.014	N	1.0L	D171970

Table 5.--Major-, minor-, and trace-element composition of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--Continued

Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)	Sample number
D169028	50	500	3	0.13L	2	5	9.4	70	3	10	D169028
D169029	50	500	N	.13L	1.5L	5	7.7	80	5	N	D169029
D169030	70	200	.2	.06L	.7L	2	3.2	40	1.5	N	D169030
D169031	70	200	N	.07L	.7L	2	4.3	50	2	N	D169031
D169032	50	200	N	.07L	.7L	2	4.7	45	1.5	N	D169032
D169033	70	500	N	.09L	1L	5	9.7	45	2	N	D169033
D169034	70	200	N	.08L	.7L	2	7.0	35	2	N	D169034
D169035	50	300	N	.05L	.5L	1.5	3.4	35	.7	N	D169035
D169036	70	150	N	.12L	N	2	6.0	30	2	N	D169036
D169037	70	150	N	.08L	N	2	5.6	30	2	N	D169037
D169038	70	200	N	.07L	N	1.5	3.6	25	1	N	D169038
D169039	70	100	N	.07L	N	1.5	7.0	25	1.5	N	D169039
D169040	100	200	2	.12L	1	10	12	85	3	N	D169040
D169475	100	700	1	.08L	1L	2	7.9	25	2	N	D169475
D169476	100	500	1.5	.07L	.7	3	7.1	30	3	N	D169476
D169477	70	200	N	.09L	1L	2	4.1	65	1.5	N	D169477
D169478	70	500	N	.09L	1	3	5.7	50	2	N	D169478
D169479	70	500	N	.09L	1L	5	8.2	45	1.5	N	D169479
D169480	70	200	N	.09L	1L	3	7.0	45	2	N	D169480
D169723	70	300	1	.11L	1	3	10	45	5	N	D169723
D169724	100	500	.7	.06L	.7	1.5	5.8	40	2	N	D169724
D170203	50	700	.2	.10L	1.5	5	5.9	45	3	N	D170203
D170204	50	700	N	.11L	1	5	5.7	60	2	N	D170204
D170205	70	500	.15	.07L	.7	2	3.6	40	1	N	D170205
D170206	70	700	N	.12L	.7	3	9.7	45	1.5	N	D170206
D170207	70	500	.15	.07L	.5	3	3.7	30	1.5	N	D170207
D170208	30	300	N	.12L	.7	7	7.0	55	2	N	D170208
D170209	70	300	N	.09L	.7	5	4.9	45	3	N	D170209
D170210	70	300	N	.06L	.5	5	3.5	25	1	N	D170210
D170211	50	500	N	.10L	.5	3	6.5	30	2	N	D170211
D170212	70	200	N	.09L	.5	1.5	6.0	20	1.5	N	D170212
D170213	70	150	.5	.07L	1	2	4.7	25	2	N	D170213
D170214	100	150	1.5	.07L	2	2	4.6	50	5	5	D170214
D170215	100	200	.2	.07L	.7	1.5	4.1	20L	2	N	D170215
D170216	100	500	1	.43	1	5	17	95	5	N	D170216
D170217	100	500	1	.15	1	7	14	95	3	5	D170217
D171967	50	700	.2L	.07L	.7L	2	3.6	20	2	N	D171967
D171968	30	700	.7	.12L	1L	3	6.5	30	3	N	D171968
D171969	50	700	N	.08L	.7L	2	5.4	35	5	N	D171969
D171970	50	700	N	.05L	.5	1.5	2.9	25	1.5	N	D171970

Table 5.--Major-, minor-, and trace-element composition of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--Continued

Sample number	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	Sb (ppm)	Sample number
D169028	0.12	10	9.6	40	1	5	3	59L	9.4	2.3	D169028
D169029	.02	N	13	39	1	2	2	56L	12	.2	D169029
D169030	.01	5	4.1	12	.5	1.5L	1.5	27L	3.1	.1	D169030
D169031	.03	5	4.2	14	.5	1.5L	1.5	31L	3.9	.2	D169031
D169032	.01	N	4.8	10	5	1.5L	1	30L	5.5	.2	D169032
D169033	.02	N	9.7	17	.7	1.5L	1	37L	6.0	.3	D169033
D169034	.01	N	10	11	.5	1.5L	.7	33L	5.3	.5	D169034
D169035	.01	N	2.4	8.0	.5	1L	.7	23L	4.5	.1	D169035
D169036	.02	N	6.4	8.7	1.5	2	1.5L	54L	5.0	.2	D169036
D169037	.01	N	7.8	7.8	.5L	1.5	.7L	34L	4.7	.3	D169037
D169038	.01	5	4.8	9.8	.7	1.5L	.7	28L	2.6	.1	D169038
D169039	.04	5	4.1	10	.5L	1.5L	.7	30L	3.5	.2	D169039
D169040	.06	10	6.4	18	1	2	2	52L	4.8	.7	D169040
D169475	.06	7	6.2	25	1	1.5L	1.5	37L	5.1	.8	D169475
D169476	.05	5	4.2	20	1	1.5	1	30L	2.7	1.0	D169476
D169477	.04	7	5.8	26	.7	1.5	1	37L	6.0	.2	D169477
D169478	.06	7	5.8	27	1.5	2	1.5	40L	13	.3	D169478
D169479	.04	7	8.8	17	.7	1.5	1.5	37L	5.5	.3	D169479
D169480	.05	7	4.9	27	N	2L	1.5	39L	5.0	.3	D169480
D169723	.11	N	8.6	33	1.5	2L	2	48L	5.0	1.4	D169723
D169724	.04	5	2.9	32	.5	1.5L	.7	28L	3.5	.4	D169724
D170203	.04	N	7.8	49	.5	1.5	3	290	4.9	.3	D170203
D170204	.04	N	12	33	.5	1.5	2	91	8.3	.4	D170204
D170205	.03	N	3.8	15	.5	.7	1	32L	4.1	.2	D170205
D170206	.05	N	11	17	N	1	1	510L	6.4	.4	D170206
D170207	.04	N	4.6	14	.3	.7	1	31L	3.6	.3	D170207
D170208	.04	N	14	23	.7	N	1.5	51L	7.6	.5	D170208
D170209	.04	N	11	9.0	.5	1	1.5	39L	5.0	.5	D170209
D170210	.04	N	4.6	8.7	.5	.7	1	250L	2.3	.2	D170210
D170211	.06	N	7.6	20	1	1.5	1	140	9.3	.3	D170211
D170212	.06	N	7.1	17	.7	1	.7	110	8.2	.3	D170212
D170213	.08	N	6.0	14	.5	.7	1.5	50	5.0	.5	D170213
D170214	.07	N	4.6	20	.3	N	3	54	2.9	1.6	D170214
D170215	.09	N	4.5	14	.5	.7	.7	42	4.8	.5	D170215
D170216	.08	N	13	35	1	1.5	2	760L	12	1.7	D170216
D170217	.07	N	8.6	29	1.5	1.5	5	64L	5.8	2.8	D170217
D171967	.03	7L	4.5	13	1	1.5	1	130	2.9	.2	D171967
D171968	.06	10L	7.0	17	1.5	3	1.5	260	5.8	.5	D171968
D171969	.03	7L	13	12	1	2	1	120	4.0	.4	D171969
D171970	.03	5L	2.4	10	.7	1	1	71	2.8	.2	D171970

Table 5.--Major-, minor-, and trace-element composition of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--Continued

Sample number	Sc-S (ppm)	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
D169028	2	0.3	200	3.1	1.2	10	7	0.7	21	30	D169028
D169029	1.5	.2	200	4.0	1.3	10	2	.5	21	20	D169029
D169030	1	.2	300	3.0L	.3	5	2	.2	5.7	10	D169030
D169031	.7	.2	200	2.3	.3	5	1.5	.2	11	10	D169031
D169032	.7	.2	200	1.9	.4	5	1.5	.15	9.8	10	D169032
D169033	1	.1	500	2.2	.7	7	1.5L	.15L	15	15	D169033
D169034	.7	.3	300	2.3	.7	5	1.5L	.15L	10	10	D169034
D169035	.5L	.4	300	3.0L	.2L	3	1	.1	11	5	D169035
D169036	N	.4	200	3.6	.8	2	2	.2	12	30	D169036
D169037	.7	.3	200	2.9	1.1	5	1.5	.15	5.9	15	D169037
D169038	.7	.2	300	1.9	.4	3	1.5	.15	4.7	10	D169038
D169039	.7L	.3	200	3.0L	.6	3	1.5L	.15	5.5	10	D169039
D169040	2	.5	200	2.6	1.2	20	3	.3	12	20	D169040
D169475	1.5	.6	500	3.0L	1.5	7	5	.5	5.1	15	D169475
D169476	2	.7	300	3.1	1.0	7	3	.3	4.7	15	D169476
D169477	1	.3	200	4.5	.8	5	1.5	.2	9.0	15	D169477
D169478	1	.2	300	2.3	.6	7	2	.3	27	15	D169478
D169479	1.5	1.6	500	3.2	.8	10	2	.2	7.1	20	D169479
D169480	1	.8	500	3.6	.9	7	2	.3	7.4	15	D169480
D169723	2	.4	300	4.0	2.6	10	3	.3	14	20	D169723
D169724	1	.2	500	3.0L	.6	3	2	.2	4.2	10	D169724
D170203	1	.2	500	3.6	.9	7	3	.2	10	20	D170203
D170204	1	.6	500	3.0L	1.6	7	2	.2	15	15	D170204
D170205	.7	.1L	300	3.0L	.6	5	1.5	.15	8.6	7	D170205
D170206	1	.4	300	3.0L	.9	7	2	.2	12	15	D170206
D170207	.7	.3	500	3.0L	.4	5	1.5	.15	8.5	10	D170207
D170208	1	.4	300	3.0L	1.0	10	2	.2	10	15	D170208
D170209	1	.4	500	3.0L	.8	10	2	.2	11	15	D170209
D170210	.7	.2	500	3.0L	.4	5	1	.1	5.3	7	D170210
D170211	1	.3	500	3.0L	.9	5	2	.2	18	20	D170211
D170212	1	.5	500	3.0L	.9	5	1.5	.15	12	15	D170212
D170213	.7	.2	300	3.0L	.8	5	1.5	.15	5.8	10	D170213
D170214	1.5	.4	300	3.0L	.6	5	3	.3	2.9	15	D170214
D170215	.7	.3	300	3.0L	.5	3	1.5	.15	6.3	15	D170215
D170216	1.5	.4	300	5.8	2.6	10	3	.3	19	30	D170216
D170217	1.5	.6	300	4.0	2.4	15	3	.3	15	30	D170217
D171967	1	.1L	200	3.0L	.4	5	2	.15	4.0	15	D171967
D171968	1.5	.3	200	4.7	1.3	10	7	.7	18	30	D171968
D171969	1	.2	150	5.0	1.7	5	2	.2	5.1	20	D171969
D171970	.7	.1L	150	3.0L	.5	3	1.5	.15	5.2	7	D171970

Table 5.--Major-, minor-, and trace-element composition of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--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
D171971	0.80	0.47	0.69	0.22	0.14	0.022	0.13	0.025	N	1.0L	D171971
D171972	.93	.81	.71	.24	.28	.028	.12	.065	N	1.0	D171972
D171973	.76	.53	.75	.24	.28	.013	.11	.026	N	1.0L	D171973
D171974	.77	.53	.76	.23	.27	.014	.11	.030	N	1.0	D171974
D171975	.87	.42	.80	.23	.26	.014	.12	.025	N	1.0L	D171975
D171976	2.1	.80	.87	.24	.28	.024	.14	.060	N	1.0	D171976
D171977	1.0	.59	.86	.23	.27	.009	.11	.023	N	1.0L	D171977
D171978	.74	.40	.67	.19	.27	.009	.11	.019	N	1.0L	D171978
D171979	.91	.54	.71	.21	.27	.010	.11	.024	.1	1.0	D171979
D171980	.76	.68	.61	.18	.26	.009	.10	.026	N	1.0	D171980

Sample number	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	F (ppm)	Ga-S (ppm)	Ge-S (ppm)	Sample number
D171971	50	700	N	0.06L	0.7	1.5	5.4	30	1.5	N	D171971
D171972	50	500	N	.08L	.7L	2	7.9	20	5	N	D171972
D171973	50	500	N	.06L	.7L	2	3.8	35	2	N	D171973
D171974	30	700	N	.06L	.7L	2	5.5	20	2	N	D171974
D171975	50	500	N	.06L	.7L	2	5.2	20	1.5	N	D171975
D171976	50	500	N	.10L	1L	3	9.4	30	3	N	D171976
D171977	50	500	N	.07L	.7L	2	4.6	30	1.5	N	D171977
D171978	70	500	N	.06L	.5	1.5	4.0	30	1.5	N	D171978
D171979	50	300	N	.07L	1	1	4.2	30	2	N	D171979
D171980	70	200	N	.07L	2	2	5.9	20	5	5	D171980

Table 5.--Major-, minor-, and trace-element composition of 50 coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.--Continued

Sample number	Hg (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Ni-S (ppm)	P (ppm)	Pb (ppm)	Sb (ppm)	Sample number
D171971	0.03	7L	3.9	8.9	1	1	1	70	3.2	0.3	D171971
D171972	.03	N	11	12	.7	1.5	1	340L	5.8	.6	D171972
D171973	.03	7L	7.2	9.5	.5	1.5L	1	88	3.5	.3	D171973
D171974	.03	N	5.3	9.2	1	1.5	1	53	2.4	.3	D171974
D171975	.03	N	2.6	9.6	.5	1.5	1	89	2.6	.2	D171975
D171976	.05	N	10	16	.7	2	1	120	6.2	.4	D171976
D171977	.03	7L	4.5	14	.5	1.5	5	180	2.8	.3	D171977
D171978	.03	5L	2.8	17	.7	1L	.7	91	4.7	.3	D171978
D171979	.05	7L	4.6	13	.7	1.5L	1.5	82	3.3	.3	D171979
D171980	.31	N	6.0	20	1	1.5	2	62	3.6	2.5	D171980

Sample number	Sc-S (ppm)	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
D171971	1	0.1L	150	3.0L	0.5	5	1.5	0.15	6.8	10	D171971
D171972	1	.1L	100	3.2	.6	5	1.5	.15	8.7	10	D171972
D171973	1	.1	150	3.0L	.4	5	2	.2	4.5	10	D171973
D171974	1	.1L	150	3.0L	.4	5	1.5	.2	4.6	10	D171974
D171975	.7	.3	150	3.0L	.5	5	2	.2	4.4	10	D171975
D171976	1.5	.4	150	3.9	1.1	7	3	.3	11	30	D171976
D171977	1	.1	150	4.0	.2L	5	2	.2	4.2	10	D171977
D171978	.7	.1	100	3.0L	.2L	5	1.5	.1	11	7	D171978
D171979	1	.1	100	3.0L	.5	3	2	.15	4.7	10	D171979
D171980	3	.6	100	3.0L	.7	7	7	.7	6.0	10	D171980

Table 6.--Elements looked for, but not detected in coal samples from the Knobloch and Flowers-Goodale beds, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.

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

Element	Lower limit of detection in coal ash (ppm)
Au	50
Bi	20
Ce	500
Eu	200
Ge	20
Hf	200
In	20
Nd	150
Pd	5
Pr	200
Pt	100
Re	100
Sm	200
Sn	20
Ta	1,000
Te	5,000
Tl	100
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 18 coal samples from the Knobloch bed, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.

[For comparison geometric means for 33 Powder River region samples are included (Swanson and others, 1976, Tables 31b and 32b). All values are in percent except Kcal/kg, Btu/lb, and ash-fusion temperatures, and are reported on the as-received basis. $^{o}C = (^{o}F-32)\ 5/9$; Kcal/kg = 0.556 (Btu/lb). Leaders (---) indicate no data]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	30.6	26.0	35.1	30.5	1.1	23.1
Volatile matter	28.7	26.4	32.5	28.6	1.1	32.0
Fixed carbon	34.9	31.3	36.5	34.8	1.0	36.0
Ash	5.9	4.4	7.4	5.8	1.2	7.5
Hydrogen	6.7	6.4	6.9	6.7	1.0	6.2
Carbon	47.2	43.3	49.3	47.2	1.0	50.3
Nitrogen	.7	.6	.8	.7	1.1	.9
Oxygen	39.4	37.4	41.7	39.3	1.0	32.9
Sulfur	.18	.10	.30	.16	1.5	.8
Heat of combustion						
Kcal/kg	4,500	4,040	4,715	4,490	1.0	4,860
Btu/lb	8,090	7,270	8,480	8,080	1.0	8,740
Forms of sulfur						
Sulfate	0.02	0.01	0.07	0.01	1.7	0.02
Pyritic	.07	.01	.12	.05	2.1	.29
Organic	.11	.01	.26	.08	2.2	.31
Ash-fusion temperatures, ^{o}C						
Initial deformation	1,150	1,130	1,200	1,150	1.0	---
Softening temperature	1,170	1,150	1,220	1,170	1.0	---
Fluid temperature	1,150	1,130	1,200	1,150	1.0	---

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 44 coal samples from the Knobloch bed, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.

[For comparison geometric means for 410 Powder River region samples are included (Hatch and Swanson, 1977, Table 6A). 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	Powder River region geometric mean
		Minimum	Maximum			
(Ash)	8.2	5.1	13.4	7.9	1.3	9.0
SiO_2	36	19	69	35	1.3	28
Al_2O_3	16	7.3	23	16	1.2	14
CaO	15	7.8	21	15	1.3	15
MgO	4.1	1.8	7.4	3.9	1.4	3.6
Na_2O	5.4	1.5	8.7	5.0	1.5	.93
K_2O	.61	.04	1.5	.42	2.4	.28
Fe_2O_3	3.1	1.5	5.4	3.0	1.3	5.8
TiO_2	.72	.38	1.4	.69	1.3	.61
SO_3	7.9	1.9	18	7.1	1.6	14
P_2O_5	.19	.14L	.68	.13	2.4	---

Table 9.--Arithmetic mean, observed range, geometric mean and geometric deviation of 37 elements in 44 coal samples from the Knobloch bed, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.

[For comparison geometric means for 410 Powder River region samples are included (Hatch and Swanson, 1977, Table 6b). All analyses 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 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	Powder River region geometric mean
		Minimum	Maximum			
			Percent			
Si	1.5	0.45	4.0	1.3	1.7	1.2
Al	.70	.29	1.2	.66	1.4	.66
Ca	.85	.61	1.2	.84	1.2	.98
Mg	.19	.12	.40	.19	1.3	.195
Na	.31	.097	.42	.29	1.4	.063
K	.046	.002	.15	.028	2.7	.022
Fe	.17	.099	.37	.16	1.4	.37
Ti	.036	.013	.069	.033	1.5	.035
P	.006	.004L	.029	.004	2.7	---
			Parts per million			
As	1.1	1L	12	1.0	1.7	2
B	70	30	100	70	1.3	50
Ba	500	100	700	300	1.8	300
Be	.2	.15L	3	.03	8.3	.5
Co	.7	.5L	2	.5	2.1	2
Cr	3	1	10	2	1.7	5
Cu	5.7	2.9	12	5.4	1.4	9.5
F	38	20L	85	35	1.5	40
Ga	2	.7	5	2	1.6	2
Hg	.04	.01	.31	.04	2.0	.08
La	5	5	10	3	1.7	---
Li	6.8	2.4	14	6.1	1.6	3.9
Mn	17	7.8	49	15	1.6	34
Mo	.7	.3L	5	.7	1.8	1.5
Nb	1.5	.7L	5	1	2.0	1
Ni	1.5	.7L	5	1.5	1.6	3
Pb	5.1	2.3	13	4.7	1.5	5.1
Sb	.4	.1	2.5	.3	2.0	.4
Sc	1	.7L	3	1	1.4	1.5
Se	.3	.1L	1.6	.2	2.1	.7
Sr	300	100	500	200	1.7	150
Th	2.2	1.9L	5	1.8	1.8	3.3
U	.7	.3L	1.7	.6	1.7	.6
V	7	2	20	5	1.5	10
Y	2	1L	7	2	1.6	3
Yb	.2	.1L	.7	.2	1.6	.3
Zn	9.6	2.9	27	8.4	1.7	12.5
Zr	15	5	30	15	1.5	15

Table 10.--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, and forms of sulfur of three coal samples from the Flowers-Goodale bed, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.

[For comparison geometric means for 33 Powder River region samples are included (Swanson and others, 1976, tables 31b and 32b). All values are in percent except Kcal/kg, and Btu/lb, and are reported on the as-received basis. Kcal/kg = 0.556 (Btu/lb)]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	27.6	26.4	28.8	27.5	1.0	23.1
Volatile matter	27.6	26.2	28.7	27.5	1.0	32.0
Fixed carbon	36.7	34.4	39.1	36.6	1.1	36.0
Ash	8.4	5.8	11.9	7.8	1.5	7.5
Hydrogen	6.2	6.0	6.5	6.2	1.0	6.2
Carbon	48.4	45.8	51.2	48.3	1.1	50.3
Nitrogen	.8	.7	.9	.8	1.1	.9
Oxygen	35.9	35.0	37.2	35.9	1.0	32.9
Sulfur	.47	.40	.60	.46	1.3	.8
Heat of combustion						
Kcal/kg	4,580	4,330	4,840	4,575	1.1	4,860
Btu/lb	8,240	7,790	8,710	8,230	1.1	8,740
Forms of sulfur						
Sulfate	0.01	0.01	0.01	0.01	1.0	0.02
Pyritic	.10	.07	.15	.09	1.6	.29
Organic	.37	.29	.43	.36	1.2	.31

Table 11.--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 six coal samples from the Flowers-Goodale bed, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.

[For comparison geometric means for 410 Powder River region samples are included (Hatch and Swanson, 1977, table 6a). All samples were ashed at 525°C; all analyses except geometric deviation are in percent]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
(Ash	10.9	6.3	17.3	10.0	1.5	9.0
SiO_2	39	27	51	38	1.3	28
Al_2O_3	21	16	24	20	1.2	14
CaO	13	7.1	19	12	1.5	15
MgO	2.4	1.9	3.1	2.4	1.2	3.6
Na_2O	4.5	3.1	6.4	4.4	1.3	.93
K_2O	1.0	.15	1.9	.61	2.8	.28
Fe_2O_3	4.2	3.5	5.2	4.2	1.2	5.8
TiO_2	.68	.55	.92	.67	1.2	.61
SO_3	13	6.8	18	12	1.4	14

Table 12--Arithmetic mean, observed range, geometric mean and geometric deviation of 36 elements in six coal samples from the Flowers-Goodale bed, Tongue River Member, Fort Union Formation, Otter Creek EMRIA study site, Powder River County, Mont.

[For comparison geometric means for 410 Powder River region samples are included (Hatch and Swanson, 1977, table 6b). All analyses 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	Powder River region geometric mean
		Minimum	Maximum			
			Percent			
Si	2.2	.78	4.1	1.8	1.9	1.2
Al	1.2	.58	1.8	1.1	1.5	.66
Ca	.83	.75	.90	.83	1.1	.98
Mg	.15	.11	.22	.14	1.3	.195
Na	.33	.28	.49	.32	1.2	.063
K	.12	.011	.23	.051	4.0	.022
Fe	.32	.19	.53	.29	1.5	.37
Ti	.046	.021	.095	.040	1.7	.035
			Parts per million			
As	3.4	1.0	8.0	2.7	2.0	2
B	100	70	100	100	1.2	50
Ba	500	300	700	500	1.3	300
Be	1	.7	1.5	1	1.3	.5
Co	1	.7L	1	.7	1.3	2
Cr	3	1.5	7	3	1.8	5
Cu	11	5.8	17	9.7	1.5	9.5
F	56	25	95	48	1.8	40
Ga	3	2	5	3	1.5	2
Hg	.07	.04	.11	.06	1.4	.08
La	7	5	7	7	1.2	---
Li	7.4	2.9	13	6.4	1.7	3.9
Mn	29	20	35	29	1.2	34
Mo	1	.5	1.5	1	1.5	1.5
Nb	1.5	1.5	1.5	1.5	1.0	1
Ni	2	.7	5	1.5	2.0	3
Pb	5.8	2.7	12	5.0	1.7	5.1
Sb	1.4	.4	2.8	1.1	2.0	.4
Sc	1.5	1	2	1.5	1.3	1.5
Se	.5	.2	.7	.4	1.6	.7
Sr	300	300	500	300	1.3	150
Th	3.7	3.1L	5.8	3.5	1.4	3.3
U	1.9	.6	2.6	1.6	1.9	.6
V	10	3	15	7	1.7	10
Y	3	2	5	3	1.3	3
Yb	.3	.2	.5	.3	1.3	.3
Zn	11	4.2	19	8.6	2.0	12.5
Zr	20	10	30	20	1.5	15