UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

CHEMICAL ANALYSES OF COAL AND COAL-ASSOCIATED ROCK SAMPLES FROM THE ROSEBUD AND McKAY BEDS, TONGUE RIVER MEMBER OF THE FORT UNION FORMATION, COLSTRIP COAL DEPOSIT, ROSEBUD COUNTY, MONTANA

By

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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, 61 coal and coal-associated rock samples were collected from the Rosebud and McKay beds in the Paleocene Tongue River Member of the Fort Union Formation in Rosebud County, Montana. This area is located in the Montana part of the Powder River region, specifically within the Colstrip coal deposit as defined by Matson and Blumer, 1974. Forty of the samples (36 coal and 4 coal-associated rock) are from the Rosebud bed and 21 samples (all coal) are from the McKay bed. The McKay bed is between 5.5 and 18.6 m. below the Rosebud bed. The samples were collected from the Big Sky Mine and from 13 core holes in sec. 1, 2, and 27, T. 1 N., R. 41 E.; sec. 23 and 35, T. 2 N., R. 41 E.; and in sec. 1, 3, 5, 9, 15, and 16, T. 1 N., R. 40 E. The location of the sample collection area is shown in figure 1. Brief descriptions of all 61 samples are listed in table 1 and locations of sampling sites are shown in figure 2.

Estimated strippable coal resources for the Rosebud bed in this area exceed 1,305 metric tons (1,439 million short tons) (Matson and Blumer, 1974). There are currently no estimates of coal resources for the McKay bed from this area.

Analyses of samples D172034 through D172051 have previously been published in Swanson and others (1976) and are included here in order to provide a more complete data listing. For additional information on sulfur and trace element contents in the Rosebud and McKay coal beds, see Chadwick, Woodriff and others (1975) and Chadwick, Rice and others (1975).

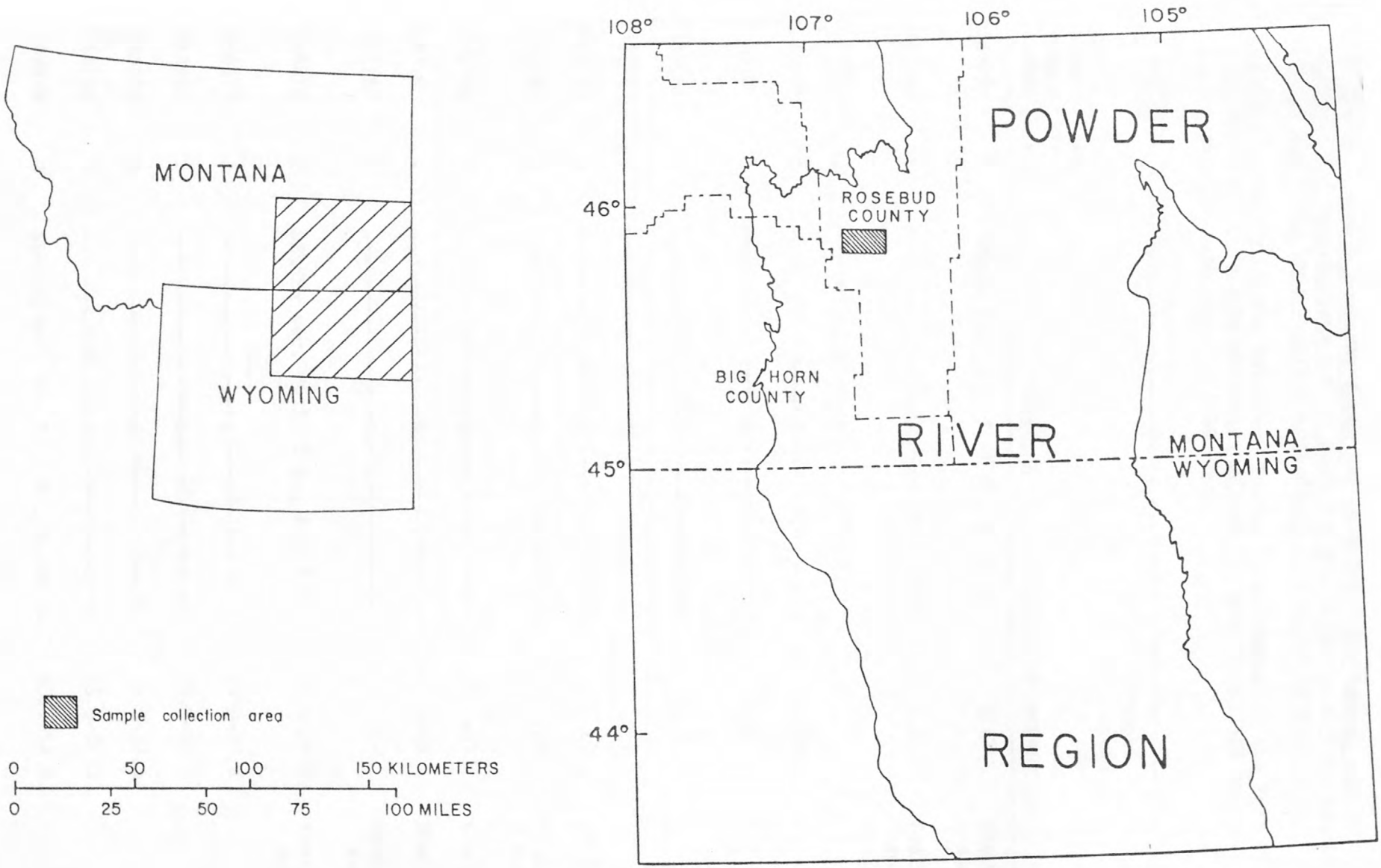

Figure 1.--Map of northeastern Wyoming and southeastern Montana showing the location of the sample collection area, Rosebud County, Montana, and an outline of the Powder River coal region. Map modified from Averitt (1942).

Table 1.--USGS sample numbers, index map locations, locations, sample thickness or depth intervals and descriptions for 61 coal and coal-associated rock samples from the Rosebud and McKay beds Colstrip coal deposit, Rosebud County, Mont.

[All samples are from the Paleocene Tongue River Member of the Fort Union Formation. Leaders (---) in sample thickness column for sample D163187 indicate information not available. One meter = 3.28 feet]

USGS sample number	Index map location	Location	Sample thickness or depth interval in meters	Description
D163189	1	NW¼NE¼ sec. 27, T. 1 N., R. 41 E.	0.12	Claystone, channel sample, roof rock.
D163179	1	----------do----------	2.1	Coal, channel sample, roof rock.
D163180	1	----------do----------	1.7	Do.
D163188	1	----------do----------	.03	Parting.
D163181	1	----------do----------	1.5	Coal, channel sample, Rosebud bed.
D163182	1	----------do----------	1.5	Do.
D163183	1	----------do----------	.64	Do.
D163192	1	----------do----------	.14	Parting.
D163184	1	----------do----------	.76	Coal, channel sample, Rosebud bed.
D163185	1	----------do----------	.05	Coal with pyrite.
D163193	1	----------do----------	.06	Shale.
D163187	1	----------do----------	---	Coal, Tipple sample, Rosebud bed.
D168872	2	SE¼SE¼ sec. 2, T. 1 N., R. 41 E.	27.1-29.0	Coal, core sample, Rosebud bed.
D168873	2	----------do----------	29.0-30.5	Do.
D168874	2	----------do----------	30.5-32.0	Do.
D168875	2	----------do----------	32.0-33.5	Do.
D168876	2	----------do----------	33.5-34.1	Do.
D168879	3	SW¼SE¼ sec. 23, T. 2 N., R. 41 E.	50.9-52.4	Do.

Table 1.--USGS sample numbers, index map locations, locations, sample thickness or depth intervals and descriptions for 61 coal and coal-associated rock samples from the Rosebud and McKay beds Colstrip coal deposit, Rosebud County, Mont.--Continued

USGS sample number	Index map location	Location	Sample thickness or depth interval in meters	Description
D168880	3	SW¼SE¼ sec. 23, T. 2 N., R. 41 E.	52.4-53.9	Coal, core sample, Rosebud bed.
D168881	3	----------do----------	53.9-55.8	Do.
D168882	3	----------do----------	55.8-57.6	Do.
D168885	4	SW¼NW¼ sec. 1, T. 1 N., R. 40 E.	15.8-17.4	Do.
D168886	4	----------do----------	17.4-18.9	Do.
D168887	4	----------do----------	18.9-20.4	Do.
D168888	4	----------do----------	20.4-21.9	Do.
D168889	4	----------do----------	21.9-23.5	Do.
D168892	5	SW¼NE¼ sec. 15, T. 1 N., R. 40 E.	17.7-19.2	Do.
D168893	5	----------do----------	19.2-20.7	Do.
D168894	5	----------do----------	20.7-22.3	Do.
D168895	5	----------do----------	22.3-23.8	Do.
D168896	5	----------do----------	23.8-24.7	Do.
D172034	6	NW¼NE¼ sec. 35, T. 2 N., R. 41 E.	31.4-39.3	Do.
D172036	7	SE¼SW¼ sec. 1, T. 1 N., R. 41 E.	34.1-41.4	Do.
D172038	8	SW¼NE¼ sec. 2, T. 1 N., R. 41 E.	22.6-30.8	Do.
D172040	9	SW¼SE¼ sec. 5, T. 1 N., R. 40 E.	24.7-31.1	Do.
D172042	10	SW¼NE¼ sec. 9, T. 1 N., R. 40 E.	38.1-44.3	Do.
D172044	11	NW¼SE¼ sec. 16, T. 1 N., R. 40 E.	41.8-48.5	Do.
D172046	12	NE¼SW¼ sec. 16, T. 1 N., R. 40 E.	61.0-68.4	Do.
D172048	13	NW¼NE¼ sec. 13, T. 1 N., R. 40 E.	29.6-36.5	Do.
D172050	14	NW¼SE¼ sec. 3, T. 1 N., R. 40 E.	36.6-44.5	Do.

Table 1.--USGS sample numbers, index map locations, locations, sample thickness or depth intervals and descriptions for 61 coal and coal-associated rock samples from the Rosebud and McKay beds Colstrip coal deposit, Rosebud County, Mont.--Continued

USGS sample number	Index map location	Location	Sample thickness or depth interval in meters	Description
D163186	1	NW¼NE¼ sec. 27, T. 1 N., R. 41 E.	1.6	Coal, channel sample, McKay bed.
D168877	2	SE¼SE¼ sec. 2, T. 1 N., R. 41 E.	37.5-40.2	Coal, core sample, McKay bed.
D168878	2	----------do----------	40.2-41.5	Do.
D168883	3	SW¼SE¼ sec. 23, T. 2 N., R. 41 E.	69.8-71.1	Do.
D168884	3	----------do----------	71.1-72.4	Do.
D168890	4	SW¼NW¼ sec. 1, T. 1 N., R. 40 E.	28.3-29.3	Do.
D168891	4	----------do----------	29.3-30.3	Do.
D168897	5	SW¼NE¼ sec. 15, T. 1 N., R. 40 E.	46.9-47.2	Do.
D168898	5	----------do----------	47.2-47.5	Do.
D168899	5	----------do----------	47.5-48.1	Do.
D168900	5	----------do----------	48.1-48.5	Do.
D168901	5	----------do----------	48.5-48.8	Do.
D172035	6	NW¼NE¼ sec. 35, T. 2 N., R. 41 E.	45.1-47.5	Do.
D172037	7	SE¼SW¼ sec. 1, T. 1 N., R. 41 E.	45.1-47.6	Do.
D172039	8	SW¼ NE¼ sec. 2, T. 1 N., R. 41 E.	37.5-39.9	Do.
D172041	9	SW¼SE¼ sec. 5, T. 1 N., R. 40 E.	63.4-65.6	Do.
D172043	10	SW¼NE¼ sec. 9, T. 1 N., R. 40 E.	69.8-71.9	Do.
D172045	11	NW¼SE¼ sec. 16, T. 1 N., R. 40 E.	77.1-78.8	Do.
D172047	12	NE¼SW¼ sec. 16, T. 1 N., R. 40 E.	89.6-91.9	Do.
D172049	13	NW¼NE¼ sec. 13, T. 1 N., R. 40 E.	57.6-59.6	Do.
D172051	14	NW¼SE¼ sec. 3, T. 1 N., R. 40 E.	49.7-51.9	Do.

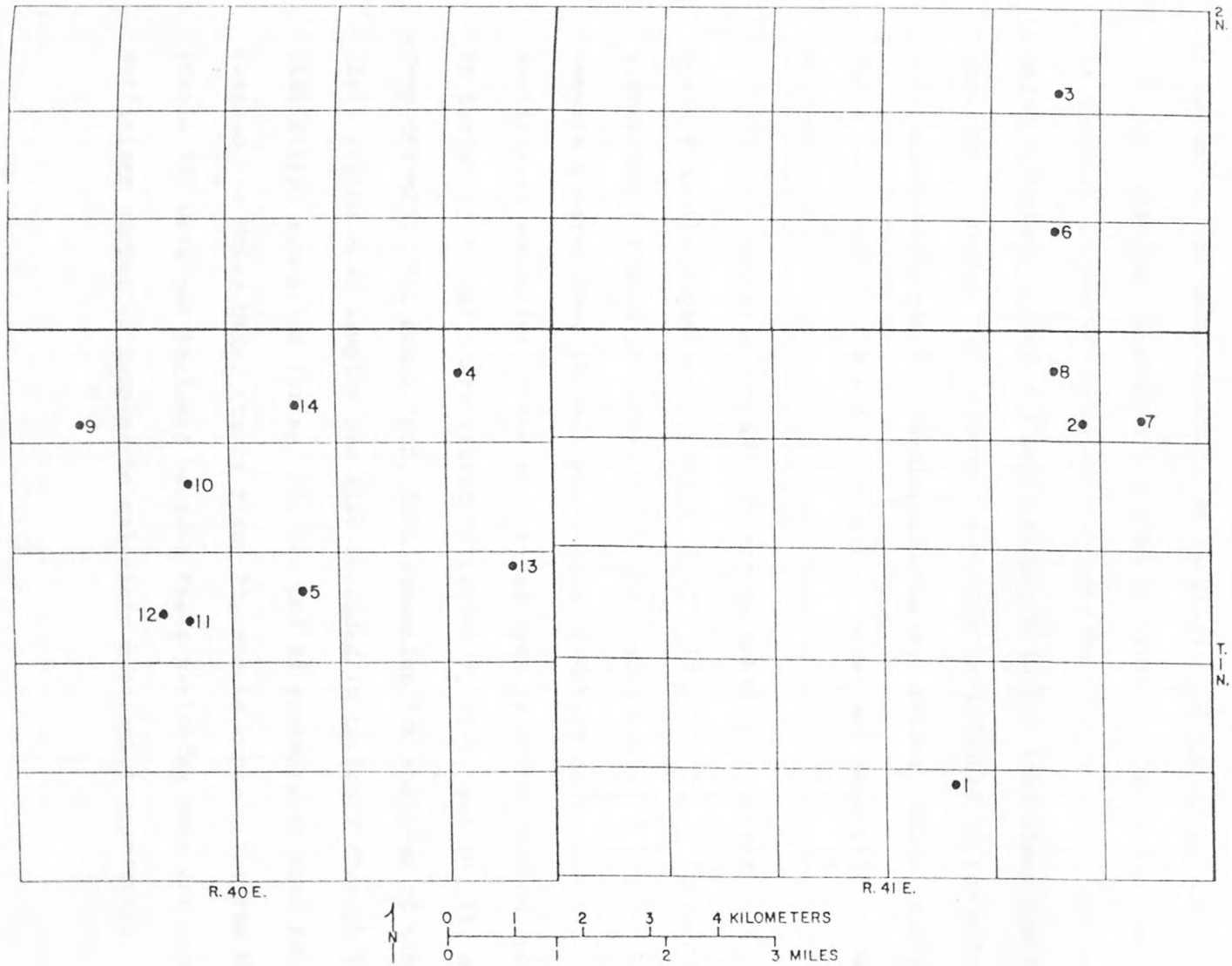

Figure 2.--Index map showing locations of the 14 sample collection sites in the Rosebud and McKay coal beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont. Detailed location descriptio are in table 1.

Explanation of tables

Proximate and ultimate analyses, heat-of-combustion, air-dried-loss, and forms-of-sulfur determinations on 16 single and composite coal samples from the Colstrip coal deposit are listed in table 2. These analyses were provided by the U.S. Bureau of Mines, Pittsburgh, Pa. Analyses for ash content and 35 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 61 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. Fifteen 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 the analytical data from the Rosebud and McKay 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 analyses of other Powder River region coal samples are also included in tables 7 through 12. Statistical summaries for Ag, Cd, Ge, and Nd contents in coal for both the Rosebud and McKay beds, (table 9 and 12) and La content for the McKay bed (table 12) were not included because these variables were not detected in a sufficient number of samples to calculate meaningful statistics.

K_2O and P_2O_5 contents in ash for all samples were determined by X-ray fluorescence spectroscopy. However, due to changes in technique the lower detection limits have changed. The lower detection limit for K_2O content in samples D163179 through D163196 is 0.10 percent; for all other samples it is 0.02 percent. The lower detection limit for P_2O_5 content in samples D163179 through D163196 is 0.05 percent; for samples D168872 through D168901 and D168913 through D168920 it is 0.10 percent; and for samples D172034 through D172051 it is 1.0 percent.

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

Explanation of statistical terms used in summary tables

In this report the geometric mean (GM) is used as the estimate of the most probable concentration (mode); the geometric mean is calculated by taking the logarithm of each analytical value, summing the logarithms, dividing the sum by the total number of values, and obtaining the antilogarithm of the result. The measure of scatter about the mode used here is the geometric deviation (GD), which is the antilog of the standard 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 samples from the Colstrip coal deposit 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 ranks for the Rosebud bed samples range from subbituminous C (four samples) to subbituminous B coal (seven samples). The apparent ranks for the McKay bed range from subbituminous C (four samples) to subbituminous B coal (one sample).

A statistical comparison (student's t test, 95-percent confidence level) of the geometric mean contents of the U.S. Bureau of Mines data from the 11 Rosebud bed coal samples with the 5 McKay bed coal samples shows that the Rosebud bed has a significantly higher nitrogen content. All other variables are not significantly different. When compared at the 99-percent confidence level, the contents of nitrogen are not significantly different.

A statistical comparison of the geometric mean contents of the U. S. Bureau of Mines data from the 11 Rosebud bed coal samples with analyses of 33 other Powder River region coal samples shows that the Rosebud bed has a significantly higher fixed carbon content and significantly lower contents of volatile matter, oxygen, and sulfate sulfur. The contents of moisture, ash, hydrogen, carbon, nitrogen, total, pyritic and organic sulfur, and heat of combustion are not significantly different. When compared at the 99-percent confidence level, the contents of oxygen are not significantly different.

A statistical comparison of the geometric mean contents of the U. S. Bureau of Mines data from the five McKay bed coal samples with analyses of 33 other Powder River region coal samples shows that the McKay bed has a significantly higher fixed carbon content and significantly lower contents of volatile matter and nitrogen. The contents of moisture, ash, hydrogen, carbon, oxygen, total, sulfate, pyritic and organic sulfur, and heat of combustion are not significantly different. When compared at the 99-percent confidence level the contents of fixed carbon and nitrogen are not significantly different.

A statistical comparison of the geometric mean contents of coal ash and the geometric mean contents of ten major and minor oxides in the ash from 35 Rosebud bed coal samples with 21 McKay bed coal samples shows that the Rosebud bed has a significantly higher ash content, significantly higher contents of SiO_2, Al_2O_3, MgO, and TiO_2 in ash, and significantly lower Na_2O, Fe_2O_3, SO_3, and P_2O_5 contents in ash. The contents of CaO and K_2O in ash are not significantly different. When compared at the 99-percent confidence level the MgO and P_2O_5 contents in ash are not significantly different.

A statistical comparison of the geometric mean contents of coal ash and the geometric mean contents of nine major and minor oxides in ash from 35 Rosebud bed coal samples with 410 other Powder River region coal samples shows that the Rosebud bed has a significantly higher ash content, significantly higher SiO_2 content in ash, and significantly lower CaO, Na_2O, and K_2O contents in ash. The contents of Al_2O_3, MgO, Fe_2O_3, TiO_2 and SO_3 in ash are not significantly different.

A statistical comparison of the geometric mean contents of coal ash and the geometric mean contents of nine major and minor oxides in the ash from 21 McKay bed coal samples with 410 other Powder River region coal samples shows that the McKay has significantly higher Fe_2O_3 and SO_3 contents in ash and significantly lower SiO_2, Al_2O_3, CaO, K_2O, and TiO_2 contents in ash. The contents of ash and MgO and Na_2O contents in ash are not significantly different. When compared at the 99-percent confidence level the contents of Al_2O_3 in ash are not significantly different.

A statistical comparison of the geometric mean contents of 36 elements in 35 Rosebud bed coal samples with 21 McKay bed coal samples shows that the Rosebud bed has significantly higher contents of Si, Al, Ca, Mg, Na, Ti, Ba, Cr, Cu, F, Ga, Hg, Li, Mn, Mo, Pb, Sc, U, V, Y, and Zr and significantly lower contents of Fe, P, Be, Co, and Sb. The contents of K, As, B, Nb, Ni, Se, Sr, Th, Yb, and Zn are not significantly different. When compared at the 99-percent confidence level, the contents of Ca, P, Ba, Hg, Mo, and Y are not significantly different.

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

A statistical comparison of the geometric mean contents of 35 elements in 21 McKay bed coal samples with 410 other Powder River region coal samples shows that the McKay bed has significantly higher contents of Fe, B, and Zn and significantly lower contents of Ca, Mg, K, Ti, Ba, Co, Cr, Cu, F, Hg, Mn, Mo, Ni, Pb, Sb, Sc, Se, Th, V, Y, Yb, and Zr. The contents of Si, Al, Na, As, Be, Ga, Li, Nb, Sr, and U are not significantly different. When compared at the 99-percent confidence level the contents of Mg, F, and Mo 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 Rosebud and McKay beds in the Colstrip coal deposit.

Compared to other U.S. coals (Swanson and other, 1976; Hatch and Swanson, 1977), coals of 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, heat of combustion, and forms-of-sulfur determinations for 16 coal samples from the Rosebud and McKay coal beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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. °F = (°C x 1.8) + 32; Kcal/kg = 0.556 (Btu/lb). L, means less than the value shown. Sample D168872* is a composite of samples D168872, D168873, D168874, D168875, and D168876; D168879* is a composite of D168879, D168880, D168881, and D168882; D168885* is a composite of D168885, D168886, D168887, D168888, and D168889; D168892* is a composite of D168892, D168893, D168894, D168895, and D168896; D168877* is a composite of D168877 and D168878; D168883* is a composite of D168883 and D168884; D168890* is a composite of D168890 and D168891; D168897* is a composite of D168897, D168898, D168899, D168900, and D168901.]

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D163179	19.8	29.5	43.3	7.4	5.8	56.0	0.9	29.4	0.5	5,310	9,550
	---	36.8	54.0	9.2	4.5	69.8	1.1	14.7	.6	6,620	11,910
	---	40.5	59.5	---	4.9	76.9	1.2	16.2	.7	7,290	13,120
D163180	20.2	31.4	40.1	8.3	6.1	55.1	.8	29.1	.6	5,310	9,550
	---	39.3	50.3	10.4	4.8	69.0	1.0	14.0	.8	6,650	11,970
	---	43.9	56.1	---	5.4	77.1	1.1	15.6	.8	7,420	13,360
D163181	20.7	30.9	41.4	7.0	6.1	55.2	.8	30.3	.6	5,340	9,610
	---	39.0	52.2	8.8	4.8	69.6	1.0	15.0	.8	6,730	12,120
	---	42.7	57.3	---	5.3	76.3	1.1	16.5	.8	7,380	13,290
D163182	19.1	29.7	42.2	9.0	5.7	54.6	.8	29.2	.7	5,280	9,510
	---	36.7	52.2	11.1	4.4	67.5	1.0	15.1	.9	6,530	11,760
	---	41.3	58.7	---	5.0	75.9	1.1	17.0	1.0	7,350	13,230
D163183	23.0	29.6	43.1	4.3	6.2	55.8	.8	32.3	.6	5,360	9,650
	---	38.4	56.0	5.6	4.7	72.5	1.0	15.4	.8	6,960	12,530
	---	40.7	59.3	---	5.0	76.8	1.1	16.3	.8	7,370	13,270
D163184	22.4	29.5	40.9	7.2	6.2	53.4	.8	31.5	.9	5,160	9,280
	---	38.0	52.7	9.3	4.8	68.8	1.0	14.9	1.2	6,640	11,960
	---	41.9	58.1	---	5.3	75.9	1.1	16.5	1.3	7,320	13,180
D163187	16.4	30.4	43.5	9.7	5.6	56.5	.8	26.5	.9	5,400	9,720
	---	36.4	52.0	11.6	4.5	67.6	1.0	14.3	1.1	6,460	11,630
	---	41.1	58.9	---	5.1	76.5	1.1	16.1	1.2	7,310	13,150
D168872*	24.9	27.8	36.8	10.5	6.1	49.0	.7	31.9	1.8	4,680	8,430
	---	37.0	49.0	14.0	4.4	65.2	.9	13.0	2.4	6,240	11,230
	---	43.0	57.0	---	5.2	75.9	1.1	15.1	2.8	7,250	13,050
D168879*	25.7	28.0	37.6	8.7	6.2	49.6	.8	33.7	1.0	4,750	8,550
	---	37.7	50.6	11.7	4.5	66.8	1.1	14.6	1.3	6,390	11,510
	---	42.7	57.3	---	5.1	75.6	1.2	16.5	1.5	7,240	13,030
D168885*	26.4	28.9	35.6	9.1	6.4	49.0	.7	34.3	.5	4,690	8,440
	---	39.3	48.4	12.4	4.7	66.6	1.0	14.7	.7	6,370	11,470
	---	44.8	55.2	---	5.4	76.0	1.1	16.8	.8	7,270	13,090
D168892*	24.1	27.1	33.3	15.5	5.8	44.4	.7	29.5	4.1	4,340	7,810
	---	35.7	43.9	20.4	4.1	58.5	.9	10.6	5.4	5,720	10,290
	---	44.9	55.1	---	5.2	73.5	1.2	13.4	6.8	7,180	12,930
D163186	19.7	27.5	46.3	6.5	5.5	56.4	.8	30.4	.4	5,210	9,380
	---	34.2	57.7	8.1	4.1	70.2	1.0	16.1	.5	6,490	11,680
	---	37.3	62.7	---	4.5	76.4	1.1	17.5	.5	7,060	12,710

Table 2.--Proximate and ultimate analyses, heat-of-combustion, and forms-of-sulfur determinations for 16 coal samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.--Continued

Sample number	Air-dried loss	Forms of sulfur		
		Sulfate	Pyritic	Organic
D163179	0.0	0.01	0.11	0.36
	---	.01	.14	.45
	---	.01	.15	.49
D163180	.0	.01	.26	.30
	---	.01	.33	.38
	---	.01	.36	.42
D163181	.0	.01	.30	.31
	---	.01	.38	.39
	---	.01	.41	.43
D163182	.0	.01	.49	.21
	---	.01	.61	.26
	---	.01	.68	.29
D163183	.0	.01	.25	.38
	---	.01	.32	.49
	---	.01	.34	.52
D163184	.0	.02	.51	.37
	---	.03	.66	.48
	---	.03	.72	.53
D163187	.0	.01	.56	.29
	---	.01	.67	.35
	---	.01	.76	.39
D168872*	11.3	.01	1.56	.25
	---	.01	2.08	.33
	---	.02	2.41	.39
D168879*	11.9	.01	.73	.31
	---	.01	.98	.42
	---	.02	1.11	.47
D168885*	12.6	.01	.15	.32
	---	.01	.20	.43
	---	.02	.23	.50
D168892*	12.8	.01	3.98	.13
	---	.01	5.24	.17
	---	.02	6.59	.22
D163186	.0	.01	.09	.28
	---	.01	.11	.35
	---	.01	.12	.38

Table 2.--Proximate and ultimate analyses, heat-of-combustion, and forms-of-sulfur determinations for 16 coal samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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
D168877*	27.0	26.3	40.2	6.5	6.2	50.7	0.7	34.8	1.1	4,830	8,690
	---	36.0	55.1	8.9	4.4	69.5	1.0	14.8	1.5	6,610	11,900
	---	39.5	60.5	---	4.8	76.2	1.1	16.2	1.7	7,260	13,070
D168883*	25.5	26.5	38.2	9.8	5.9	46.8	.7	32.6	4.2	4,580	8,250
	---	35.6	51.3	13.2	4.1	62.8	.9	13.3	5.6	6,150	11,070
	---	41.0	59.0	---	4.7	72.3	1.1	15.4	6.5	7,080	12,750
D168890*	27.0	28.3	37.8	6.9	6.3	50.2	.8	34.9	.9	4,780	8,600
	---	38.8	51.8	9.5	4.5	68.8	1.1	14.9	1.2	6,540	11,780
	---	42.8	57.2	---	5.0	75.9	1.2	16.5	1.4	7,230	13,010
D168897*	25.5	27.1	37.5	9.9	6.0	48.3	.7	32.0	3.1	4,660	8,380
	---	36.4	50.3	13.3	4.3	64.8	.9	12.5	4.2	6,250	11,250
	---	42.0	58.0	---	4.9	74.8	1.1	14.4	4.8	7,210	12,970

Sample number	Air-dried loss	Forms of sulfur		
		Sulfate	Pyritic	Organic
D168877*	13.5	0.01	0.88	0.24
	---	.01	1.21	.33
	---	.02	1.32	.36
D168883*	11.5	.03	4.05	.15
	---	.04	5.44	.20
	---	.05	6.26	.23
D168890*	13.1	.01	.63	.29
	---	.01	.86	.40
	---	.02	.95	.44
D168897*	13.5	.01	2.64	.42
	---	.01	3.54	.56
	---	.02	4.09	.65

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.

[Values in percent or parts per million. Coal ashed at 525°C. L, means 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
D163189	B	72	14	0.20	1.90	0.54	4.0	3.5	0.30	0.13	D163189
D163179	9.2	48	16	9.3	4.59	.32	.10L	1.8	.30	.10	D163179
D163180	9.8	49	16	8.8	3.90	.34	.52	2.5	.30	.18	D163180
D163188	B	61	8.2	.30	.43	.08	2.8	1.0	.30	.050L	D163188
D163181	8.3	39	15	9.7	4.20	.22	.13	5.0	.30	.27	D163181
D163182	10.2	45	12	8.3	3.40	.22	.10L	7.7	.30	.67	D163182
D163183	5.0	22	15	13	6.00	.42	.10	5.3	.30	.22	D163183
D163192	51.7	37	13	.50	.55	.10	.10L	.20	.50	.050L	D163192
D163184	9.1	31	21	7.5	3.50	.22	.11	10	.30	.050L	D163184
D163185	26.3	1.0L	2.6	1.4	.75	.07	.30	77	.030	.050L	D163185
D163193	B	44	10	.20	1.60	.09	3.1	16	.15	.10	D163193
D163187	11.5	54	15	7.6	3.70	.36	.85	5.4	.30	.26	D163187
D168872	24.7	43	17	3.3	2.01	.14	.74	21	.41	.10L	D168872
D168873	9.3	31	16	17	4.39	.36	.030	4.8	.34	.10L	D168873
D168874	9.1	39	17	13	4.49	.40	.030	3.8	.62	.10L	D168874
D168875	9.0	37	20	10	3.98	.62	.080	1.2	.53	.10L	D168875
D168876	20.9	29	15	16	1.72	.26	.45	14	.43	.10L	D168876
D168879	13.3	47	12	8.3	2.99	.16	.020L	8.2	.62	.10L	D168879
D168880	11.9	50	16	8.6	3.28	.22	.94	3.1	.62	.10L	D168880
D168881	10.4	40	15	12	4.18	.20	.020L	4.4	.73	.10L	D168881
D168882	11.0	32	16	10	3.75	.24	.090	9.1	.65	.10L	D168882
D168885	16.9	44	17	11	2.50	.12	1.8	4.3	.52	.10L	D168885
D168886	9.0	34	17	15	4.34	.15	.020L	2.5	.56	.10L	D168886
D168887	12.4	33	10	10	3.00	.09	.020L	15	.78	.10L	D168887
D168888	18.6	11	6.5	49	2.16	.07	.020L	.39	.15	.10L	D168888
D168889	12.0	39	24	10	3.03	.12	.17	1.2	.68	.10L	D168889
D168892	12.6	41	15	7.7	3.75	.12	.020L	8.5	.64	.10L	D168892
D168893	20.9	53	16	6.3	2.55	.12	2.0	5.1	.56	.10L	D168893
D168894	7.8	36	17	15	5.90	.22	.080	3.0	.91	.10L	D168894
D168895	8.4	31	18	14	4.92	.20	.12	3.6	.49	.10L	D168895
D168896	15.0	40	16	6.4	2.54	.12	.070	13	.65	.10L	D168896
D172034	11.5	33	14	14	3.81	.22	.44	7.1	.74	.27	D172034
D172036	11.1	29	15	13	4.08	.43	.23	7.0	.68	.28	D172036
D172038	11.7	30	14	11	3.85	.19	.29	10	.71	.24	D172038
D172040	14.5	42	18	10	2.89	.38	.93	3.6	.75	.24	D172040
D172042	13.5	36	15	8.3	3.85	.36	.41	9.8	.69	.23	D172042
D172044	17.4	35	13	9.0	2.74	.24	.72	16	.58	.24	D172044
D172046	16.9	44	19	6.0	2.70	.24	.75	6.8	.75	.15	D172046
D172048	12.8	33	15	6.5	3.88	.16	.50	11	.89	1.0L	D172048
D172050	16.3	42	17	12	3.23	.14	1.5	3.9	.65	.26	D172050

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.--Continued

Sample number	SO3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	Sample number
D163189	1.1	N	50	700	2	1.0L	150	7	70	48	D163189
D163179	13	N	700	7,000	7	1.0L	N	N	50	83	D163179
D163180	12	N	700	1,500	N	1.0L	N	N	50	63	D163180
D163188	.40	N	70	500	1.5	1.0L	150	N	20	15	D163188
D163181	17	N	700	2,000	N	1.0L	N	N	50	79	D163181
D163182	15	N	500	1,500	N	1.0L	N	N	30	85	D163182
D163183	23	N	1,500	2,000	3	1.0L	N	10	30	71	D163183
D163192	.50	N	70	150	N	1.0L	N	N	30	83	D163192
D163184	16	N	700	1,000	7	1.0	N	N	20	77	D163184
D163185	5.2	N	100	7,000	10	1.0L	N	N	7	42	D163185
D163193	28	N	50	300	1.5	1.0L	N	10	30	42	D163193
D163187	12	N	500	5,000	5	1.0L	N	10	30	67	D163187
D168872	8.4	N	150	700	3	1.0L	N	N	30	64	D168872
D168873	17	N	700	3,000	N	1.0L	N	N	20	58	D168873
D168874	17	N	700	2,000	N	1.0L	N	N	20	60	D168874
D168875	11	N	1,000	1,500	2	1.0L	N	N	30	58	D168875
D168876	9.4	N	300	1,000	7	1.0L	N	N	15	40	D168876
D168879	16	N	500	1,000	3	1.0L	N	N	50	52	D168879
D168880	13	N	1,000	7,000	N	1.0L	N	N	50	52	D168880
D168881	18	N	700	15,000	N	1.0L	N	N	20	68	D168881
D168882	18	N	700	3,000	3	1.0L	N	10	20	46	D168882
D168885	9.6	N	500	2,000	N	1.0L	N	10L	30	52	D168885
D168886	19	N	700	2,000	N	1.0	N	10L	20	58	D168886
D168887	21	N	300	1,000	N	1.0L	N	10L	30	64	D168887
D168888	6.3	N	200	3,000	N	1.0L	N	N	30	30	D168888
D168889	13	N	500	3,000	2	1.0L	N	N	20	88	D168889
D168892	18	N	300	500	N	1.0	N	N	20	62	D168892
D168893	8.9	N	300	1,500	N	1.0L	N	10	50	58	D168893
D168894	19	N	1,000	300	N	1.0	N	10L	30	72	D168894
D168895	20	N	1,000	7,000	N	1.0L	N	10L	30	66	D168895
D168896	14	N	300	2,000	3	1.0L	N	10L	20	52	D168896
D172034	19	N	500	7,000	3	1.0L	N	10L	30	85	D172034
D172036	18	N	700	7,000	5	1.0L	N	10L	100	61	D172036
D172038	20	7	700	5,000	5	1.0L	N	10L	30	56	D172038
D172040	9.7	.3	300	2,000	7	1.0L	N	15	30	66	D172040
D172042	18	N	500	5,000	7	1.0L	N	10L	50	73	D172042
D172044	13	N	300	3,000	7	1.0L	N	10L	30	56	D172044
D172046	12	N	300	15,000	5	1.0L	N	10L	30	56	D172046
D172048	9.5	3	500	5,000	7	1.0L	N	10L	30	61	D172048
D172050	11	N	300	2,000	3	1.0L	N	10	100	57	D172050

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.--Continued

Sample number	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sample number
D163189	20	N	70	42	70	3	15	70	15	40	D163189
D163179	30	N	70	126	500	100	N	N	15	65	D163179
D163180	30	N	70	186	700	20	20	N	15	60	D163180
D163188	10	N	70	18	30	15	15	70	3	25L	D163188
D163181	30	N	70	152	300	20	N	N	15	60	D163181
D163182	30	N	N	98	300	30	N	N	10	55	D163182
D163183	50	N	100	74	1,000	100	N	N	30	60	D163183
D163192	30	N	N	236	150	10	N	N	N	70	D163192
D163184	50	N	70	98	700	30	50	N	15	70	D163184
D163185	B	N	N	5L	70	50	N	N	15	30	D163185
D163193	15	N	100L	34	50	N	20L	N	30	40	D163193
D163187	30	N	N	120	300	70	15	N	30	65	D163187
D168872	20	N	70	84	150	10	20L	N	10	40	D168872
D168873	15	N	N	92	700	N	N	B	10L	40	D168873
D168874	20	N	N	160	700	7L	N	B	10	40	D168874
D168875	30	N	70	152	700	15	20L	N	10	35	D168875
D168876	30	N	N	62	500	10	20L	B	10L	35	D168876
D168879	30	N	N	80	300	15	20L	B	10L	45	D168879
D168880	20	N	N	128	700	20	20L	B	10	30	D168880
D168881	20	N	N	158	500	10	20L	B	10	35	D168881
D168882	30	N	70	82	300	10	20L	N	15	55	D168882
D168885	30	N	70	114	500	7L	N	N	10	35	D168885
D168886	30	N	N	138	700	N	20	B	20	50	D168886
D168887	20	N	N	94	300	10	N	B	15	35	D168887
D168888	15	N	N	52	2,000	7L	N	B	10L	25	D168888
D168889	30	N	70	116	700	7	20L	N	15	40	D168889
D168892	20	N	70	106	300	30	20L	N	10	50	D168892
D168893	30	N	70	92	300	15	20L	N	20	35	D168893
D168894	30	N	N	108	500	20	20L	B	15	55	D168894
D168895	30	N	N	86	700	20	20L	B	10	25L	D168895
D168896	30	N	N	90	200	15	20L	B	10L	30	D168896
D172034	30	N	N	115	500	7	20L	B	15	25	D172034
D172036	30	N	100L	118	500	15	20	N	15	25L	D172036
D172038	30	N	N	97	500	15	20	B	15	25	D172038
D172040	30	N	100L	91	300	15	20	N	30	30	D172040
D172042	30	N	N	95	200	30	20	B	15	25	D172042
D172044	30	N	N	68	300	15	20	B	15	25L	D172044
D172046	30	N	N	98	200	15	20L	B	15	25	D172046
D172048	30	N	N	85	300	30	20L	B	15	25L	D172048
D172050	30	N	100L	98	300	10	20	N	20	30	D172050

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.--Continued

Sample number	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
D163189	15	100	150	15	3	76	150	D163189
D163179	15	3,000	70	30	3	21	300	D163179
D163180	15	2,000	70	30	3	24	200	D163180
D163188	10	100	50	20	3	9	150	D163188
D163181	15	1,000	70	30	3	32	200	D163181
D163182	15	1,000	70	30	3	29	300	D163182
D163183	20	1,500	100	50	3	40	200	D163183
D163192	N	150	70	20	2	44	300	D163192
D163184	20	1,000	70	50	3	34	200	D163184
D163185	15	150	20	30	B	41	20	D163185
D163193	7	50	70	15	B	58	50	D163193
D163187	15	1,500	70	20	3	47	200	D163187
D168872	15	500	70	30	B	156	150	D168872
D168873	10L	3,000	50	20L	2L	360	150	D168873
D168874	N	2,000	70	20L	2L	260	200	D168874
D168875	10	3,000	70	20	2	164	200	D168875
D168876	10	1,000	50	20	B	308	100	D168876
D168879	10L	1,000	50	20	2	180	200	D168879
D168880	10L	1,500	70	20	2	166	150	D168880
D168881	10L	3,000	50	20	2	212	200	D168881
D168882	10	2,000	70	30	2	246	150	D168882
D168885	10	2,000	70	20	3	460	100	D168885
D168886	10L	3,000	70	20L	2L	1,000	150	D168886
D168887	N	2,000	50	20	3	428	150	D168887
D168888	N	3,000	20	N	N	156	70	D168888
D168889	10L	2,000	70	20	2	380	200	D168889
D168892	10L	300	50	20	2	592	200	D168892
D168893	10	700	70	30	3	236	150	D168893
D168894	10L	1,500	70	20	2	800	150	D168894
D168895	10L	2,000	50	20	2	880	150	D168895
D168896	10L	700	50	30	B	504	150	D168896
D172034	10	1,500	70	30	2	288	150	D172034
D172036	15	1,000	70	30	3	266	150	D172036
D172038	10	1,000	70	30	3	268	150	D172038
D172040	15	700	70	30	3	292	150	D172040
D172042	15	1,000	70	30	3	322	150	D172042
D172044	10	700	70	30	3	496	150	D172044
D172046	10	700	70	30	3	228	150	D172046
D172048	10	300	70	30	B	288	150	D172048
D172050	15	700	70	30	3	316	150	D172050

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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
D163186	7.2	33	18	12	5.36	0.38	0.10L	6.7	0.20	0.050L	D163186
D168877	9.8	24	14	11	3.10	.45	.020	16	.12	.10L	D168877
D168878	8.3	16	11	10	2.59	.90	.090	29	.080	.10L	D168878
D168883	9.0	23	16	11	2.70	2.08	.040	16	.33	.10L	D168883
D168884	11.4	14	7.9	7.3	1.96	1.78	.080	39	.20	.10L	D168884
D168890	7.9	16	12	13	2.90	.90	.13	16	.24	.10L	D168890
D168891	9.8	24	13	12	2.50	.62	.070	16	.41	.10L	D168891
D168897	15.8	31	14	6.0	2.40	.22	.080	22	.68	.10L	D168897
D168898	8.0	26	19	13	3.60	.40	.020	6.8	.43	.10L	D168898
D168899	13.5	20	11	6.9	2.60	.26	.050	35	.32	.10L	D168899
D168900	7.7	13	11	11	4.18	.42	.020	25	.13	.10L	D168900
D168901	16.9	12	4.3	4.4	1.76	.23	.30	55	.10	.10L	D168901
D172035	8.1	28	15	13	3.68	.90	.29	9.4	.48	.23	D172035
D172037	10.4	31	15	9.4	3.17	1.33	.57	12	.48	.16	D172037
D172039	8.6	23	13	11	3.53	1.00	.15	15	.47	.18	D172039
D172041	8.2	23	12	12	2.35	4.21	.22	14	.42	.21	D172041
D172043	7.1	21	12	14	3.76	1.67	.20	13	.42	.27	D172043
D172045	9.3	19	13	9.0	3.32	.90	.21	18	.41	1.0L	D172045
D172047	8.1	23	13	12	2.54	3.99	.26	15	.44	.24	D172047
D172049	7.7	27	16	11	5.01	.58	.15	11	.40	.21	D172049
D172051	9.9	22	11	11	2.29	1.39	.43	21	.36	.22	D172051

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.--Continued

Sample number	SO3 (percent)	Ag-S (ppm)	B-S (ppm)	Ba-S (ppm)	Be-S (ppm)	Cd (ppm)	Ce-S (ppm)	Co-S (ppm)	Cr-S (ppm)	Cu (ppm)	Sample number
D163186	17	N	1,000	3,000	15	1.0L	N	N	30	64	D163186
D168877	22	N	700	1,000	3	1.0L	N	N	15	42	D168877
D168878	22	N	1,000	2,000	10	1.0L	N	30	15	46	D168878
D168883	23	N	1,000	7,000	2	1.0L	N	N	7	46	D168883
D168884	20	N	500	7,000	5	1.0L	N	10	15	44	D168884
D168890	30	N	700	30,000	10	1.0L	N	15	30	68	D168890
D168891	26	N	700	1,000	N	1.0L	N	N	20	56	D168891
D168897	17	N	300	150	5	1.0L	N	N	10	90	D168897
D168898	22	N	700	7,000	N	1.0	N	10L	15	64	D168898
D168899	17	N	300	7,000	N	1.0L	N	N	10	46	D168899
D168900	27	N	1,000	150	3	3.0	N	10L	10	32	D168900
D168901	12	N	200	150	10	1.0L	N	15	15	52	D168901
D172035	23	N	1,000	1,500	10	1.0L	N	10L	20	66	D172035
D172037	21	N	700	7,000	10	1.0L	N	15	30	52	D172037
D172039	22	N	1,000	1,000	15	1.0L	N	15	30	66	D172039
D172041	21	N	700	300	10	1.0L	N	15	30	56	D172041
D172043	31	N	1,000	700	15	1.0L	N	15	30	77	D172043
D172045	12	N	700	150	7	1.0L	N	15	15	66	D172045
D172047	25	N	1,500	300	7	1.0L	N	15	15	61	D172047
D172049	18	N	700	2,000	7	1.0L	N	15	30	76	D172049
D172051	23	N	700	3,000	7	1.0L	N	20	20	56	D172051

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.--Continued

Sample number	Ga-S (ppm)	Ge-S (ppm)	La-S (ppm)	Li (ppm)	Mn (ppm)	Mo-S (ppm)	Nb-S (ppm)	Nd-S (ppm)	Ni-S (ppm)	Pb (ppm)	Sample number
D163186	30	30	70	92	200	10	15	N	30	75	D163186
D168877	20	N	70	62	200	10	20L	N	10	40	D168877
D168878	30	N	N	36	150	20	N	B	30	30	D168878
D168883	30	N	N	76	100	7L	N	B	10L	40	D168883
D168884	20	N	N	30	70	N	N	B	30	30	D168884
D168890	30	N	70	34	200	10	20L	N	30	35	D168890
D168891	20	N	N	62	300	10	N	B	10L	25	D168891
D168897	30	N	N	62	150	7	20L	B	10L	35	D168897
D168898	30	N	N	84	300	N	20L	B	10L	60	D168898
D168899	20	N	N	44	300	10	N	B	10L	40	D168899
D168900	30	N	N	34	300	10	N	B	20	35	D168900
D168901	30	N	N	10	150	15	N	B	30	25	D168901
D172035	30	N	N	66	200	10	20	B	15	30	D172035
D172037	30	N	N	52	300	15	20	B	20	25L	D172037
D172039	50	N	N	47	200	15	20L	B	30	25L	D172039
D172041	30	N	N	42	200	15	20	B	15	35	D172041
D172043	30	N	N	40	200	15	20L	B	30	25L	D172043
D172045	30	N	N	26	200	15	20L	B	20	25L	D172045
D172047	30	N	100L	43	500	15	20L	N	20	25	D172047
D172049	30	N	N	59	200	15	20L	B	20	35	D172049
D172051	30	N	N	39	300	15	20	B	30	25	D172051

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.--Continued

Sample number	Sc-S (ppm)	Sr-S (ppm)	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)	Sample number
D163186	15	3,000	70	50	5	35	150	D163186
D168877	10L	3,000	30	20	B	370	150	D168877
D168878	10L	3,000	30	30	B	500	70	D168878
D168883	N	2,000	20	20L	2L	232	100	D168883
D168884	N	2,000	20	20	B	294	70	D168884
D168890	15	7,000	70	50	B	460	100	D168890
D168891	10L	3,000	30	N	B	468	150	D168891
D168897	N	2,000	30	30	B	368	200	D168897
D168898	10L	3,000	20	20	2	980	150	D168898
D168899	N	1,500	20	N	B	980	70	D168899
D168900	N	2,000	30	20	B	2,480	50	D168900
D168901	10	1,500	20	50	B	500	70	D168901
D172035	10	2,000	70	30	3	400	150	D172035
D172037	15	1,000	70	50	3	188	150	D172037
D172039	15	2,000	70	30	3	428	150	D172039
D172041	10	1,500	50	30	3	880	150	D172041
D172043	15	2,000	50	50	3	640	150	D172043
D172045	10L	2,000	50	50	B	600	150	D172045
D172047	10	2,000	70	50	B	420	150	D172047
D172049	10L	1,500	50	30	B	760	150	D172049
D172051	15	1,500	70	30	B	350	150	D172051

Table 4.--Content of seven trace elements in 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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
D163189	4.0	1,000	0.05	1.1	1.1	4.7	3.2	D163189
D163179	1.0	105	.04	.3	.7	3.0L	.4	D163179
D163180	1.0	20L	.03	.3	.2	1.9	.6	D163180
D163188	1.0	600	.02	.6	.1L	4.9	1.9	D163188
D163181	1.0	20L	.06	.3	.2	3.0L	.4	D163181
D163182	1.0	40	.08	.3	.8	3.0L	.5	D163182
D163183	1.0	20L	.06	.4	.8	3.0L	.5	D163183
D163192	2.0	100	.05	.5	2.4	4.0	1.5	D163192
D163184	2.0	20	.14	.5	.8	3.0L	.8	D163184
D163185	15	50	.63	.9	1.3	3.0L	1.8	D163185
D163193	20	900	.44	4.3	2.1	4.2	2.1	D163193
D163187	2.0	60	.07	.5	.5	3.0L	.7	D163187
D168872	3.0	140	.23	B	.7	6.0	2.1	D168872
D168873	1.0	45	.13	B	.6	3.3	.8	D168873
D168874	1.0	60	.11	B	.4	2.9	.7	D168874
D168875	1.0L	60	.02	.3	.5	3.3	1.0	D168875
D168876	45	80	.64	1.5	1.0	3.0L	1.6	D168876
D168879	2.0	40	.07	B	.4	4.3	1.4	D168879
D168880	1.0L	55	.02	B	.6	3.1	.9	D168880
D168881	1.0L	45	.06	B	.3	3.0L	1.0	D168881
D168882	1.0	45	.08	B	.7	3.2	1.1	D168882
D168885	1.0	130	.07	B	.7	4.6	1.5	D168885
D168886	1.0L	40	.03	B	.3	3.0L	1.3	D168886
D168887	2.0	135	.19	B	.3	2.9	1.2	D168887
D168888	1.0L	85	.01	B	.1	3.0L	.5	D168888
D168889	1.0	40	.04	B	.7	3.0L	1.4	D168889
D168892	3.0	160	.13	B	.2	4.3	1.7	D168892
D168893	5.0	155	.26	.5	.5	6.0	1.7	D168893
D168894	1.0	75	.13	B	.3	3.0L	.7	D168894
D168895	1.0	45	.04	B	.2	3.0L	.5	D168895
D168896	4.0	40	.13	1.1	1.1	3.6	1.5	D168896
D172034	2.0	35	.05	.7	1.4	2.0	.8	D172034
D172036	3.0	30	.13	.6	.4	3.0L	1.1	D172036
D172038	15	35	.19	.8	1.2	3.0L	.9	D172038
D172040	2.0	70	.08	1.2	1.5	3.0L	1.4	D172040
D172042	3.0	55	.07	.7	1.4	3.0L	1.3	D172042
D172044	5.0	65	.13	1.2	1.6	2.0	1.2	D172044
D172046	3.0	65	.10	.7	.8	3.0L	1.3	D172046
D172048	2.0	50	.09	.7	.6	3.0L	1.4	D172048
D172050	2.0	80	.08	.8	.4	2.1	1.3	D172050

Table 4.--Content of seven trace elements in 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.--Continued

Sample number	As (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)	Sample number
D163186	1.0	70	0.05	2.7	0.4	3.0L	0.8	D163186
D168877	2.0	55	.10	B	.4	2.8	.8	D168877
D168878	2.0	55	.11	B	.3	2.5	.3	D168878
D168883	1.0	40	.05	B	.3	3.0L	1.0	D168883
D168884	8.0	140	.11	1.0	.4	3.0L	.7	D168884
D168890	2.0	20	.02	B	.1	3.0L	.8	D168890
D168891	1.0	40	.08	B	.1L	2.3	1.0	D168891
D168897	8.0	30	.19	1.9	.6	6.1	1.8	D168897
D168898	1.0	20L	.06	B	1.1	3.0L	1.5	D168898
D168899	3.0	20	.13	B	2.1	2.6	.6	D168899
D168900	2.0	25	.05	B	.6	3.0L	.3	D168900
D168901	20	20	.22	2.5	1.0	1.9	1.1	D168901
D172035	1.0	30	.03	1.0	2.6	3.0L	.7	D172035
D172037	4.0	30	.05	1.7	.1L	3.0L	.8	D172037
D172039	1.0	25	.03	1.4	.3	3.0L	.7	D172039
D172041	2.0	25	.03	1.7	3.4	1.9	.7	D172041
D172043	2.0	20	.03	1.8	1.1	3.0L	.6	D172043
D172045	2.0	20L	.03	1.1	1.8	3.0L	.6	D172045
D172047	1.0	20	.02	1.0	.3	3.0L	.7	D172047
D172049	2.0	20	.03	1.0	.1L	3.0L	.4	D172049
D172051	3.0	30	.05	1.4	2.2	3.0L	1.0	D172051

Table 5.--Major, minor-, and trace-element composition of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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
D163189	B	B	B	B	B	B	B	B	B	4.0	D163189
D163179	2.1	.78	.61	.25	.022	.008L	.12	.017	N	1.0	D163179
D163180	2.2	.83	.62	.23	.025	.042	.17	.018	N	1.0	D163180
D163188	B	B	B	B	B	B	B	B	B	1.0	D163188
D163181	1.5	.66	.57	.21	.014	.009	.29	.015	N	1.0	D163181
D163182	2.1	.65	.60	.21	.017	.009L	.55	.018	N	1.0	D163182
D163183	.51	.40	.46	.18	.016	.004	.19	.009	N	1.0	D163183
D163192	8.8	3.7	.18	.17	.038	.043L	.072	.15	N	2.0	D163192
D163184	1.3	1.0	.49	.19	.015	.008	.64	.016	N	2.0	D163184
D163185	.12L	.36	.26	.12	.014	.066	14	.005	N	15	D163185
D163193	B	B	B	B	B	B	B	B	B	20	D163193
D163187	2.9	.91	.62	.26	.031	.081	.43	.021	N	2.0	D163187
D168872	5.0	2.2	.58	.30	.026	.15	3.6	.061	N	3.0	D168872
D168873	1.3	.78	1.2	.25	.025	.002	.31	.019	N	1.0	D168873
D168874	1.7	.80	.82	.24	.027	.002	.24	.034	N	1.0	D168874
D168875	1.5	.95	.66	.21	.041	.006	.074	.028	N	1.0L	D168875
D168876	2.8	1.6	2.3	.22	.040	.078	2.0	.054	N	45	D168876
D168879	2.9	.87	.79	.24	.016	.002L	.76	.049	N	2.0	D168879
D168880	2.8	1.0	.73	.23	.019	.093	.26	.044	N	1.0L	D168880
D168881	1.9	.81	.88	.26	.015	.002L	.32	.045	N	1.0L	D168881
D168882	1.7	.95	.82	.25	.020	.008	.70	.043	N	1.0	D168882
D168885	3.5	1.5	1.3	.25	.015	.25	.51	.053	N	1.0	D168885
D168886	1.4	.81	.96	.24	.010	.002L	.16	.030	N	1.0L	D168886
D168887	1.9	.67	.90	.22	.008	.002L	1.3	.058	N	2.0	D168887
D168888	.95	.64	6.5	.24	.010	.003L	.051	.017	N	1.0L	D168888
D168889	2.2	1.5	.90	.22	.011	.017	.10	.049	N	1.0	D168889
D168892	2.4	.99	.69	.28	.011	.002L	.75	.048	N	3.0	D168892
D168893	5.1	1.8	.93	.32	.019	.36	.75	.070	N	5.0	D168893
D168894	1.3	.69	.86	.28	.013	.005	.16	.043	N	1.0	D168894
D168895	1.2	.78	.87	.25	.012	.008	.21	.025	N	1.0	D168895
D168896	2.8	1.2	.68	.23	.013	.009	1.3	.058	N	4.0	D168896
D172034	1.8	.85	1.1	.26	.019	.042	.57	.051	N	2.0	D172034
D172036	1.5	.89	1.1	.27	.035	.021	.54	.045	N	3.0	D172036
D172038	1.6	.86	.94	.27	.016	.028	.84	.050	.7	15	D172038
D172040	2.8	1.4	1.1	.25	.041	.11	.37	.065	.5	2.0	D172040
D172042	2.3	1.1	.80	.31	.036	.046	.92	.056	N	3.0	D172042
D172044	2.8	1.2	1.1	.29	.031	.10	1.9	.060	N	5.0	D172044
D172046	3.5	1.7	.72	.27	.030	.11	.80	.076	N	3.0	D172046
D172048	2.0	1.0	.59	.30	.015	.053	.98	.068	.5	2.0	D172048
D172050	3.2	1.5	1.4	.32	.017	.21	.44	.063	N	2.0	D172050

Table 5.--Major, minor-, and trace-element composition of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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
D163189	B	B	B	B	B	B	B	1,000	B	B	D163189
D163179	70	700	.7	.09L	N	5	7.6	105	3	N	D163179
D163180	70	150	N	.10L	N	5	6.2	20L	3	N	D163180
D163188	B	B	B	B	B	B	B	600	B	B	D163188
D163181	70	150	N	.08L	N	5	6.6	20L	2	N	D163181
D163182	50	150	N	.10L	N	3	8.7	40	3	N	D163182
D163183	70	100	.15	.05L	.5	1.5	3.6	20L	2	N	D163183
D163192	30	70	N	.52L	N	15	43	100	15	N	D163192
D163184	70	100	.7	.09	N	2	7.0	20	5	N	D163184
D163185	30	2,000	3	.26L	N	2	11	50	B	N	D163185
D163193	B	B	B	B	B	B	B	900	B	B	D163193
D163187	70	700	.7	.12L	1	3	7.7	60	3	N	D163187
D168872	30	150	.7	.25L	N	7	16	140	5	N	D168872
D168873	70	300	N	.09L	N	2	5.4	45	1.5	N	D168873
D168874	70	200	N	.09L	N	2	5.4	60	2	N	D168874
D168875	100	150	.2	.09L	N	3	5.2	60	3	N	D168875
D168876	70	200	1.5	.21L	N	3	8.4	80	7	N	D168876
D168879	70	150	.5	.13L	N	7	6.9	40	5	N	D168879
D168880	100	1,000	N	.12L	N	7	6.2	55	2	N	D168880
D168881	70	1,500	N	.10L	N	2	7.1	45	2	N	D168881
D168882	70	300	.3	.11L	1	2	5.1	45	3	N	D168882
D168885	100	300	N	.17L	1.5L	5	8.8	130	5	N	D168885
D168886	70	200	N	.09	1L	2	5.2	40	3	N	D168886
D168887	30	150	N	.12L	1.5L	3	7.9	135	2	N	D168887
D168888	30	500	N	.19L	N	5	5.6	85	3	N	D168888
D168889	70	300	.2	.12L	N	2	11	40	3	N	D168889
D168892	30	70	N	.13	N	2	7.8	160	2	N	D168892
D168893	70	300	N	.21L	2	10	12	155	7	N	D168893
D168894	70	20	N	.08	.7L	2	5.6	75	2	N	D168894
D168895	100	700	N	.08L	1L	2	5.5	45	2	N	D168895
D168896	50	300	.5	.15L	1.5L	3	7.8	40	5	N	D168896
D172034	70	700	.3	.12L	1L	3	9.8	35	3	N	D172034
D172036	70	700	.5	.11L	1L	10	6.8	30	3	N	D172036
D172038	70	700	.7	.12L	1L	3	6.6	35	3	N	D172038
D172040	50	300	1	.15L	2	5	9.6	70	5	N	D172040
D172042	70	700	1	.14L	1.5L	7	9.9	55	5	N	D172042
D172044	50	500	1.5	.17L	1.5L	5	9.7	65	5	N	D172044
D172046	50	2,000	1	.17L	1.5L	5	9.5	65	5	N	D172046
D172048	70	700	1	.13L	1.5L	5	7.8	50	5	N	D172048
D172050	50	300	.5	.16L	1.5	15	9.3	80	5	N	D172050

Table 5.--Major, minor-, and trace-element composition of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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
D163189	0.05	B	B	B	B	B	B	B	B	1.1	D163189
D163179	.04	7	12	46	10	N	1.5	40	6.0	.3	D163179
D163180	.03	7	18	69	2	2	1.5	77	5.9	.3	D163180
D163188	.02	B	B	B	B	B	B	B	B	.6	D163188
D163181	.06	7	13	25	1.5	N	1.5	98	5.0	.3	D163181
D163182	.08	N	10	31	3	N	1	300	5.6	.3	D163182
D163183	.06	5	3.7	50	5	N	1.5	48	3.0	.4	D163183
D163192	.05	N	120	78	5	N	N	110L	36	.5	D163192
D163184	.14	7	8.9	64	3	5	1.5	20L	6.4	.5	D163184
D163185	.63	N	1.3L	18	15	N	5	57L	7.9	.9	D163185
D163193	.44	B	B	B	B	B	B	B	B	4.3	D163193
D163187	.07	N	14	35	7	1.5	3	130	7.5	.5	D163187
D168872	.23	15	21	37	2	5L	2	110L	9.9	B	D168872
D168873	.13	N	8.6	65	N	N	1L	41L	3.7	B	D168873
D168874	.11	N	14	63	.7L	N	1	40L	3.6	B	D168874
D168875	.02	7	14	63	1.5	2L	1	39L	3.1	.3	D168875
D168876	.64	N	13	100	2	5L	2L	91L	7.3	1.5	D168876
D168879	.07	N	11	40	2	3L	1.5L	58L	6.0	B	D168879
D168880	.02	N	15	83	2	2L	1	52L	3.6	B	D168880
D168881	.06	N	16	52	1	2L	1	45L	3.6	B	D168881
D168882	.08	7	9.0	33	1	2L	1.5	48L	6.1	B	D168882
D168885	.07	10	19	85	1L	N	1.5	74L	5.9	B	D168885
D168886	.03	N	12	63	N	2	2	39L	4.5	B	D168886
D168887	.19	N	12	37	1.5	N	2	54L	4.3	B	D168887
D168888	.01	N	9.7	370	1.5L	N	2L	81L	4.7	B	D168888
D168889	.04	10	14	84	1	2L	2	52L	4.8	B	D168889
D168892	.13	10	13	38	3	2L	1.5	55L	6.3	B	D168892
D168893	.26	15	19	63	3	5L	5	91L	7.3	.5	D168893
D168894	.13	N	8.5	39	1.5	1.5L	1	34L	4.3	B	D168894
D168895	.04	N	7.2	59	1.5	1.5L	1	37L	2.1L	B	D168895
D168896	.13	N	14	30	2	3L	1.5L	66L	4.5	1.1	D168896
D172034	.05	N	13	58	.7	2L	1.5	140	2.9	.7	D172034
D172036	.13	10L	13	56	1.5	2	1.5	140	2.8L	.6	D172036
D172038	.19	N	11	59	1.5	2	1.5	120	2.9	.8	D172038
D172040	.08	15L	13	44	2	3	5	150	4.4	1.2	D172040
D172042	.07	N	13	27	5	3	2	140	3.4	.7	D172042
D172044	.13	N	12	52	2	3	2	180	4.4L	1.2	D172044
D172046	.10	N	17	34	2	3L	2	110	4.2	.7	D172046
D172048	.09	N	11	38	5	2L	2	560L	3.2L	.7	D172048
D172050	.08	15L	16	49	1.5	3	3	190	4.9	.8	D172050

Table 5.--Major, minor-, and trace-element composition of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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
D163189	B	1.1	B	4.7	3.2	B	B	B	B	B	D163189
D163179	1.5	.7	300	3.0L	.4	7	3	.3	1.9	30	D163179
D163180	1.5	.2	200	1.9	.6	7	3	.3	2.4	20	D163180
D163188	B	.1L	B	4.9	1.9	B	B	B	B	B	D163188
D163181	1.5	.2	100	3.0L	.4	7	2	.2	2.7	15	D163181
D163182	1.5	.8	100	3.0L	.5	7	3	.3	3.0	30	D163182
D163183	1	.8	70	3.0L	.5	5	2	.15	2.0	10	D163183
D163192	N	2.4	70	4.0	1.5	30	10	1	23	150	D163192
D163184	2	.8	100	3.0L	.8	7	5	.3	3.1	20	D163184
D163185	5	1.3	50	3.0L	1.8	5	7	B	11	5	D163185
D163193	B	2.1	B	4.2	2.1	B	B	B	B	B	D163193
D163187	1.5	.5	150	3.0L	.7	7	2	.3	5.4	20	D163187
D168872	3	.7	150	6.0	2.1	15	7	B	39	30	D168872
D168873	1L	.6	300	3.3	.8	5	2L	.2L	33	15	D168873
D168874	N	.4	200	2.9	.7	7	2L	.2L	24	20	D168874
D168875	1	.5	300	3.3	1.0	7	2	.2	15	20	D168875
D168876	2	1.0	200	3.0L	1.6	10	5	B	64	20	D168876
D168879	1.5L	.4	150	4.3	1.4	7	3	.3	24	30	D168879
D168880	1L	.6	200	3.1	.9	10	2	.2	20	20	D168880
D168881	1L	.3	300	3.0L	1.0	5	2	.2	22	20	D168881
D168882	1	.7	200	3.2	1.1	7	3	.2	27	15	D168882
D168885	1.5	.7	300	4.6	1.5	10	3	.5	78	15	D168885
D168886	1L	.3	300	3.0L	1.3	7	2L	.2L	90	15	D168886
D168887	N	.3	200	2.9	1.2	7	2	.3	53	20	D168887
D168888	N	.1	500	3.0L	.5	3	N	N	29	15	D168888
D168889	1L	.7	200	3.0L	1.4	10	2	.2	46	20	D168889
D168892	1.5L	.2	30	4.3	1.7	7	2	.2	75	20	D168892
D168893	2	.5	150	6.0	1.7	15	7	.7	49	30	D168893
D168894	.7L	.3	100	3.0L	.7	5	1.5	.15	63	10	D168894
D168895	1L	.2	150	3.0L	.5	5	1.5	.15	74	15	D168895
D168896	1.5L	1.1	100	3.6	1.5	7	5	B	76	20	D168896
D172034	1	1.4	150	2.0	.8	7	3	.2	33	15	D172034
D172036	1.5	.4	100	3.0L	1.1	7	3	.3	30	15	D172036
D172038	1	1.2	100	3.0L	.9	7	3	.3	31	15	D172038
D172040	2	1.5	100	3.0L	1.4	10	5	.5	42	20	D172040
D172042	2	1.4	150	3.0L	1.3	10	5	.5	43	20	D172042
D172044	1.5	1.6	150	2.0	1.2	15	5	.5	86	20	D172044
D172046	1.5	.8	100	3.0L	1.3	10	5	.5	39	20	D172046
D172048	1.5	.6	50	3.0L	1.4	10	5	B	37	20	D172048
D172050	2	.4	100	2.1	1.3	10	5	.5	52	20	D172050

Table 5.--Major, minor-, and trace-element composition of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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
D163186	1.1	0.69	0.62	0.23	0.020	0.006L	0.34	0.009	N	1.0	D163186
D168877	1.1	.73	.76	.18	.033	.002	1.1	.007	N	2.0	D168877
D168878	.61	.48	.60	.13	.055	.006	1.7	.004	N	2.0	D168878
D168883	.98	.75	.68	.15	.14	.003	.99	.018	N	1.0	D168883
D168884	.74	.48	.59	.13	.15	.008	3.1	.014	N	8.0	D168884
D168890	.59	.50	.74	.14	.052	.009	.87	.011	N	2.0	D168890
D168891	1.1	.67	.83	.15	.045	.006	1.1	.024	N	1.0	D168891
D168897	2.3	1.2	.68	.23	.026	.011	2.4	.064	N	8.0	D168897
D168898	.97	.81	.74	.17	.024	.001	.38	.021	N	1.0	D168898
D168899	1.2	.81	.66	.21	.026	.006	3.3	.026	N	3.0	D168899
D168900	.46	.44	.61	.19	.024	.001	1.3	.006	N	2.0	D168900
D168901	.95	.39	.53	.18	.029	.042	6.5	.010	N	20	D168901
D172035	1.1	.66	.76	.18	.054	.020	.53	.023	N	1.0	D172035
D172037	1.5	.80	.70	.20	.10	.049	.85	.030	N	4.0	D172037
D172039	.92	.61	.66	.18	.064	.011	.90	.024	N	1.0	D172039
D172041	.88	.53	.68	.12	.26	.015	.80	.021	N	2.0	D172041
D172043	.70	.44	.71	.16	.088	.012	.66	.018	N	2.0	D172043
D172045	.83	.64	.60	.19	.062	.016	1.2	.023	N	2.0	D172045
D172047	.87	.57	.67	.12	.24	.018	.87	.021	N	1.0	D172047
D172049	.98	.64	.59	.23	.033	.010	.58	.018	N	2.0	D172049
D172051	1.0	.60	.75	.14	.10	.035	1.5	.021	N	3.0	D172051

Table 5.--Major, minor-, and trace-element composition of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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
D163186	70	200	1	0.07L	N	2	4.6	70	2	2	D163186
D168877	70	100	.3	.10L	N	1.5	4.1	55	2	N	D168877
D168878	100	150	1	.08L	2	1.5	3.8	55	2	N	D168878
D168883	100	700	.2	.09L	N	.7	4.1	40	3	N	D168883
D168884	70	700	.7	.11L	1	1.5	5.0	140	2	N	D168884
D168890	50	2,000	.7	.08L	1	2	5.3	20	2	N	D168890
D168891	70	100	N	.10L	N	2	5.5	40	2	N	D168891
D168897	50	20	.7	.16L	N	1.5	14	30	5	N	D168897
D168898	50	500	N	.08	.7L	1	5.1	20L	2	N	D168898
D168899	50	1,000	N	.14L	N	1.5	6.2	20	3	N	D168899
D168900	70	10	.2	.23	.7L	.7	2.4	25	2	N	D168900
D168901	30	20	1.5	.17L	2	2	8.8	20	5	N	D168901
D172035	70	150	.7	.08L	.7L	1.5	5.3	30	2	N	D172035
D172037	70	700	1	.10L	1.5	3	5.4	30	3	N	D172037
D172039	100	100	1.5	.09L	1.5	2	5.7	25	5	N	D172039
D172041	70	20	.7	.08L	1.5	2	4.6	25	2	N	D172041
D172043	70	50	1	.07L	1	2	5.5	20	2	N	D172043
D172045	70	15	.7	.09L	1.5	1.5	6.1	20L	3	N	D172045
D172047	150	20	.7	.08L	1.5	1.5	4.9	20	2	N	D172047
D172049	50	150	.5	.08L	1	2	5.9	20	2	N	D172049
D172051	70	300	.7	.10L	2	2	5.5	30	3	N	D172051

Table 5.--Major, minor-, and trace-element composition of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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
D163186	0.05	5	6.6	14	0.7	1	2	16L	5.4	2.7	D163186
D168877	.10	7	6.1	20	1	2L	1	43L	3.9	B	D168877
D168878	.11	N	3.0	12	1.5	N	2	36L	2.5	B	D168878
D168883	.05	N	6.8	9.0	.7L	N	1L	39L	3.6	B	D168883
D168884	.11	N	3.4	8.0	N	N	3	50L	3.4	1.0	D168884
D168890	.02	5	2.7	16	.7	1.5L	2	34L	2.7	B	D168890
D168891	.08	N	6.1	29	1	N	1L	43L	2.4	B	D168891
D168897	.19	N	9.8	24	1	3L	1.5L	69L	5.5	1.9	D168897
D168898	.06	N	6.7	24	N	1.5L	.7L	35L	4.8	B	D168898
D168899	.13	N	5.9	41	1.5	N	1.5L	59L	5.4	B	D168899
D168900	.05	N	2.6	23	.7	N	1.5	33L	2.7	B	D168900
D168901	.22	N	1.7	25	2	N	5	74L	4.2	2.5	D168901
D172035	.03	N	5.3	16	.7	1.5	1.5	81	2.4	1.0	D172035
D172037	.05	N	5.4	31	1.5	2	2	73	2.6L	1.7	D172037
D172039	.03	N	4.0	17	1.5	1.5L	2	68	2.2L	1.4	D172039
D172041	.03	N	3.4	16	1.5	1.5	1.5	75	2.9	1.7	D172041
D172043	.03	N	2.8	14	1	1.5L	2	84	1.8L	1.8	D172043
D172045	.03	N	2.4	19	1.5	2L	2	410L	2.3L	1.1	D172045
D172047	.02	7L	3.5	41	1.5	1.5L	1.5	85	2.0	1.0	D172047
D172049	.03	N	4.5	15	1	1.5L	1.5	71	2.7	1.0	D172049
D172051	.05	N	3.9	30	1.5	2	3	95	2.5	1.4	D172051

Table 5.--Major, minor-, and trace-element composition of 61 coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud 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
D163186	1	0.4	200	3.0L	0.8	5	3	0.3	2.5	10	D163186
D168877	1L	.4	300	2.8	.8	3	2	B	36	15	D168877
D168878	1L	.3	200	2.5	.3	2	2	B	42	7	D168878
D168883	N	.3	200	3.0L	1.0	2	2L	.2L	21	10	D168883
D168884	N	.4	200	3.0L	.7	2	2	B	34	7	D168884
D168890	1	.1	500	3.0L	.8	5	5	B	36	7	D168890
D168891	1L	.1L	300	2.3	1.0	3	N	B	46	15	D168891
D168897	N	.6	300	6.1	1.8	5	5	B	58	30	D168897
D168898	.7L	1.1	200	3.0L	1.5	1.5	1.5	.15	78	10	D168898
D168899	N	2.1	200	2.6	.6	3	N	B	130	10	D168899
D168900	N	.6	150	3.0L	.3	2	1.5	B	190	3	D168900
D168901	1.5	1.0	200	1.9	1.1	3	10	B	85	10	D168901
D172035	.7	2.6	150	3.0L	.7	7	2	.2	32	15	D172035
D172037	1.5	.1L	100	3.0L	.8	7	5	.3	20	15	D172037
D172039	1.5	.3	150	3.0L	.7	7	2	.2	37	15	D172039
D172041	.7	3.4	150	1.9	.7	5	2	.2	72	15	D172041
D172043	1	1.1	150	3.0L	.6	3	3	.2	45	10	D172043
D172045	1L	1.8	200	3.0L	.6	5	5	B	56	15	D172045
D172047	.7	.3	150	3.0L	.7	7	5	B	34	15	D172047
D172049	.7L	.1L	100	3.0L	.4	5	2	B	59	10	D172049
D172051	1.5	2.2	150	3.0L	1.0	7	3	B	35	15	D172051

Table 6.--Elements looked for but not detected in coal and coal-associated rock samples from the Rosebud and McKay beds, Tongue River Member of the Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.

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

Element name	Symbol	Lower limit of detection (ppm) in coal ash
Gold	Au	50
Bismuth	Bi	20
Europium	Eu	200
Hafnium	Hf	200
Indium	In	20
Palladium	Pd	5
Praseodymium	Pr	200
Platinum	Pt	100
Rhenium	Re	100
Samarium	Sm	200
Tin	Sn	20
Tantalum	Ta	1,000
Tellurium	Te	5,000
Thallium	Tl	100
Tungsten	W	200

Table 7.--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion and forms of sulfur for 11 coal samples from the Rosebud bed, Tongue River Member, Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.

[For comparison, geometric means from 33 Powder River region, Wyoming, coal samples (Swanson and others, 1976, tables 31b and 32b) are included. All values are in percent except Kcal/kg, Btu/lb, and geometric deviation and are reported on the as-received basis. °F = (°C x 1.8) + 32. 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	22.1	16.4	26.4	21.9	1.2	23.1
Volatile matter	29.3	27.1	31.4	29.3	1.0	32
Fixed carbon	39.8	33.3	43.5	39.7	1.1	36
Ash	8.8	4.3	15.5	8.4	1.4	7.5
Hydrogen	6.0	5.6	6.4	6.0	1.0	6.2
Carbon	52.6	44.4	56.5	52.5	1.1	50.3
Nitrogen	.8	.7	.9	.8	1.1	.9
Oxygen	30.7	26.5	34.3	30.6	1.1	32.9
Sulfur	1.1	.5	4.1	.9	1.9	.8
Heat of combustion						
Kcal/kg	5,060	4,340	5,400	5,050	1.1	4,860
Btu/lb	9,100	7,810	9,720	9,080	1.1	8,740
Forms of sulfur						
Sulfate	0.01	0.01	0.02	0.01	1.2	0.02
Pyritic	.77	.11	3.98	.46	2.8	.29
Organic	.30	.13	.38	.28	1.4	.31

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 35 coal samples from the Rosebud bed, Tongue River Member, Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.

[For comparison, geometric means for 410 Powder River region coal samples (Hatch and Swanson, 1977, table 6b) are included. 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)	12.6	5.0	24.7	12.0	1.4	9.0
SiO_2	38	11	54	36	1.3	28
Al_2O_3	16	6.5	24	15	1.2	14
CaO	11	3.3	49	10	1.5	15
MgO	3.6	1.7	6.0	3.5	1.3	3.6
Na_2O	.24	.070	.62	.21	1.6	.93
K_2O	.61	.030L	2.0	.14	5.9	.28
Fe_2O_3	7.3	.39	21	5.2	2.3	5.8
TiO_2	.56	.15	.91	.52	1.5	.61
SO_3	15	6.3	23	14	1.4	14
P_2O_5	.14	.10L	.67	.082	2.8	---

Table 9.--Arithmetic mean, observed range, geometric mean, and geometric deviation of 37 elements in 35 coal samples from the Rosebud bed, Tongue River Member, Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.

[For comparison, geometric means for 410 Powder River region coal samples (Hatch and Swanson, 1977, Table 6b) are included. 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	2.3	0.51	5.1	2.0	1.6	1.2
Al	1.0	.40	2.2	1.0	1.4	.66
Ca	.97	.46	6.5	.87	1.6	.98
Mg	.25	.18	.32	.25	1.1	.20
Na	.021	.008	.041	.019	1.6	.063
K	.095	.002	.36	.012	8.1	.022
Fe	.69	.051	3.6	.43	2.6	.37
Ti	.043	.009	.076	.037	1.8	.035
P	.007	.004L	.030	.003	3.7	---
			Parts per million			
As	2.7	1.0L	45	1.7	2.6	2
B	70	30	100	70	1.4	50
Ba	500	20	2,000	300	2.5	300
Be	.5	.15L	1.5	.2	3.7	.5
Co	.3	.5L	2	.2	4.5	2
Cr	5	1.5	15	3	1.8	5
Cu	7.7	3.6	16	7.4	1.3	9.5
F	65	20L	160	53	1.9	40
Ga	3	1.5	7	3	1.5	2
Hg	.11	.01	.64	.08	2.2	.08
La	5	5	15	5	2.1	---
Li	13	3.7	21	12	1.4	3.9
Mn	59	25	370	52	1.6	34
Mo	2	.7L	10	1.5	2.2	1.5
Nb	1.5	1.5L	5	1	2.2	1
Ni	1.5	1L	5	1.5	1.6	3
Pb	4.7	2.9L	9.9	4.4	1.4	5.1
Sb	.7	.3	1.5	.6	1.7	4
Sc	1.5	1L	3	1.5	1.6	1.5
Se	.7	.2	1.6	.6	1.9	7
Sr	150	30	500	150	1.8	150
Th	2.3	1.9L	6.0	1.8	1.9	3.3
U	1.1	.4	2.1	1.0	1.6	.6
V	7	3	15	7	1.4	10
Y	3	1.5L	7	3	1.7	3
Yb	.3	.2L	.7	.2	1.7	.3
Zn	48	1.9	90	24	3.3	12.5
Zr	20	10	30	20	1.3	15

Table 10.--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, and forms of sulfur for 5 coal samples from the McKay bed, Tongue River Member, Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.

[For comparison, geometric means from 33 Powder River region, Wyoming, coal samples (Swanson and others, 1976, tables 31b and 32b) are included. All values are in percent except Kcal/kg, Btu/lb, geometric deviation and are reported on the as-received basis. °F = (°C x 1.8) + 32; 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	25.0	19.7	27.0	24.8	1.1	23.1
Volatile matter	27.1	26.3	28.3	27.1	1.0	32
Fixed carbon	40.0	37.5	46.3	39.9	1.1	36
Ash	8.0	6.5	9.9	7.8	1.2	7.5
Hydrogen	6.0	5.5	6.3	6.0	1.1	6.2
Carbon	50.5	46.8	56.4	50.4	1.1	50.3
Nitrogen	.7	.7	.8	.7	1.1	.9
Oxygen	33.0	30.4	34.9	32.9	1.1	32.9
Sulfur	2.1	.4	4.2	1.4	2.6	.8
Heat of combustion						
Kcal/kg	4,810	4,590	5,215	4,810	1.1	4,860
Btu/lb	8,660	8,250	9,380	8,650	1.1	8,740
Forms of sulfur						
Sulfate	0.01	0.01	0.03	0.01	1.6	0.02
Pyritic	2.29	.09	4.10	.88	4.4	.29
Organic	.28	.15	.42	.26	1.5	.31

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 21 coal samples from the McKay bed, Tongue River Member, Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.

[For comparison, geometric means for 410 Powder River region coal samples (Hatch and Swanson, 1977, table 6b) are included. 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)	9.6	7.1	16.9	9.4	1.3	9.0
SiO_2	22	12	33	21	1.3	28
Al_2O_3	13	4.3	19	12	1.4	14
CaO	10	4.4	14	10	1.3	15
MgO	3.1	1.8	5.4	3.0	1.3	3.6
Na_2O	1.2	.22	4.2	.82	2.3	.93
K_2O	.18	.020L	.57	.10	3.0	.28
Fe_2O_3	20	6.7	55	17	1.7	5.8
TiO_2	.35	.080	.68	.30	1.8	.61
SO_3	21	12	31	21	1.3	14
P_2O_5	.16	.16L	.27	.15	1.4	---

Table 12.--Arithmetic mean, observed range, geometric mean, and geometric deviation of 36 elements in 21 coal samples from the McKay bed, Tongue River Member, Fort Union Formation, Colstrip coal deposit, Rosebud County, Mont.

[For comparison, geometric means for 410 Powder River region coal samples (Hatch and Swanson, 1977, Table 6b) are included. 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
		Maximum	Minimum			
			Percent			
Si	.99	0.46	2.3	0.94	1.4	1.2
Al	.64	.39	1.2	.62	1.3	.66
Ca	.67	.53	.83	.67	1.1	.98
Mg	.17	.12	.23	.17	1.2	.2
Na	.077	.020	.26	.057	2.2	.063
K	.015	.001L	.049	.008	3.2	.022
Fe	1.4	.34	6.5	1.1	2.1	.37
Ti	.020	.004	.064	.017	1.9	.035
P	.006	.006L	.009	.006	1.2	---
			Parts per million			
As	3.0	1.0	20	2.2	2.3	2
B	70	30	150	70	1.4	50
Ba	500	10	2,000	150	4.8	300
Be	.7	.2L	1.5	.5	2.2	.5
Co	1	1L	2	1	1.5	2
Cr	1.5	.7	3	1.5	1.4	5
Cu	5.6	2.4	14	5.3	1.4	9.5
F	35	20	140	30	1.8	40
Ga	3	2	5	2	1.4	2
Hg	.07	.02	.22	.05	2.0	.08
Li	4.6	1.7	9.8	4.2	1.6	3.9
Mn	21	8	41	19	1.5	34
Mo	1	.7L	2	1	1.5	1.5
Nb	.7	1L	2	.7	2.0	1
Ni	2	1L	5	1.5	1.7	3
Pb	3.1	2.0L	5.5	2.9	1.5	5.1
Sb	1.6	1.0	2.7	1.5	1.4	4
Sc	.7	.7L	1.5	.7	1.7	1.5
Se	1.0	.1	3.4	.5	3.5	7
Sr	200	100	500	200	1.5	150
Th	1.7	1.9	6.1	1.4	1.9	3.3
U	.8	.3	1.8	.7	1.6	.6
V	5	1.5	7	5	1.7	10
Y	3	1.5L	10	2	1.9	3
Yb	.2	.2L	.3	.2	1.3	.3
Zn	60	2.5	190	42	2.3	12.5
Zr	15	3	30	10	1.6	15