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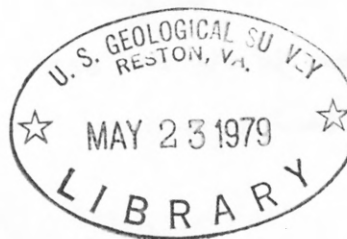


✓ UNITED STATES (DEPARTMENT OF THE INTERIOR)

GEOLOGICAL SURVEY

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Chemical analyses of coal  
from the Tongue River Member, Fort Union Formation,  
Decker coal deposit, Big Horn County, Montana



by

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## Introduction

As part of a continuing cooperative program between the U. S. Geological Survey and the Montana Bureau of Mines and Geology to collect and chemically analyze representative samples of Montana coals, 50 coal and 2 carbonaceous shale samples were collected from the Anderson, Dietz 1 and Dietz 2 coal beds in the Paleocene Tongue River Member of the Fort Union Formation. These samples were collected at six locations in sections 9 and 15, T. 9 S., R. 40 E., section 26, T. 8 S., R. 39 E., and section 29, T. 9 S., R. 39 E., Big Horn County, Montana. This area is part of the Decker coal deposit as described by Matson and Blumer (1973), and is in the southeastern Montana part of the Powder River coal region (fig. 1). Brief descriptions for all 52 samples are in table 1. Sample locations are shown in Figure 2. Bed names used in this report are those listed in Matson and Blumer (1973).

The coal deposits of this area were first discussed by Baker (1929) in his description of the Northward Extension of the Sheridan coal field, and more recently by Matson and Blumer (1973) in their work on the Decker coal deposit. For the Anderson, Dietz 1 and Dietz 2 beds in the Decker coal deposit, Matson and Blumer (1973) estimated at least 2.03 billion metric tons (2.28 billion short tons) of strippable coal resources.

In the area of the Decker coal deposit, the Anderson and Dietz 1 beds, Anderson, Dietz 1, and Dietz 2 beds, and Dietz 1 and 2 beds have locally coalesced to form single beds. Forty-two of the samples are from four locations (loc. 1, 2, 3, and 4, fig. 2) within the Decker mine where the Anderson and Dietz 1 beds have coalesced to form a single bed approximately 15.8 m (52 ft) thick. Seven samples (D192402 through D192408) are from a core hole located 7.2 km (4.5 mi) northwest of the Decker mine (loc. 5, fig. 2). At this location the Anderson, Dietz 1, and Dietz 2 beds have coalesced to

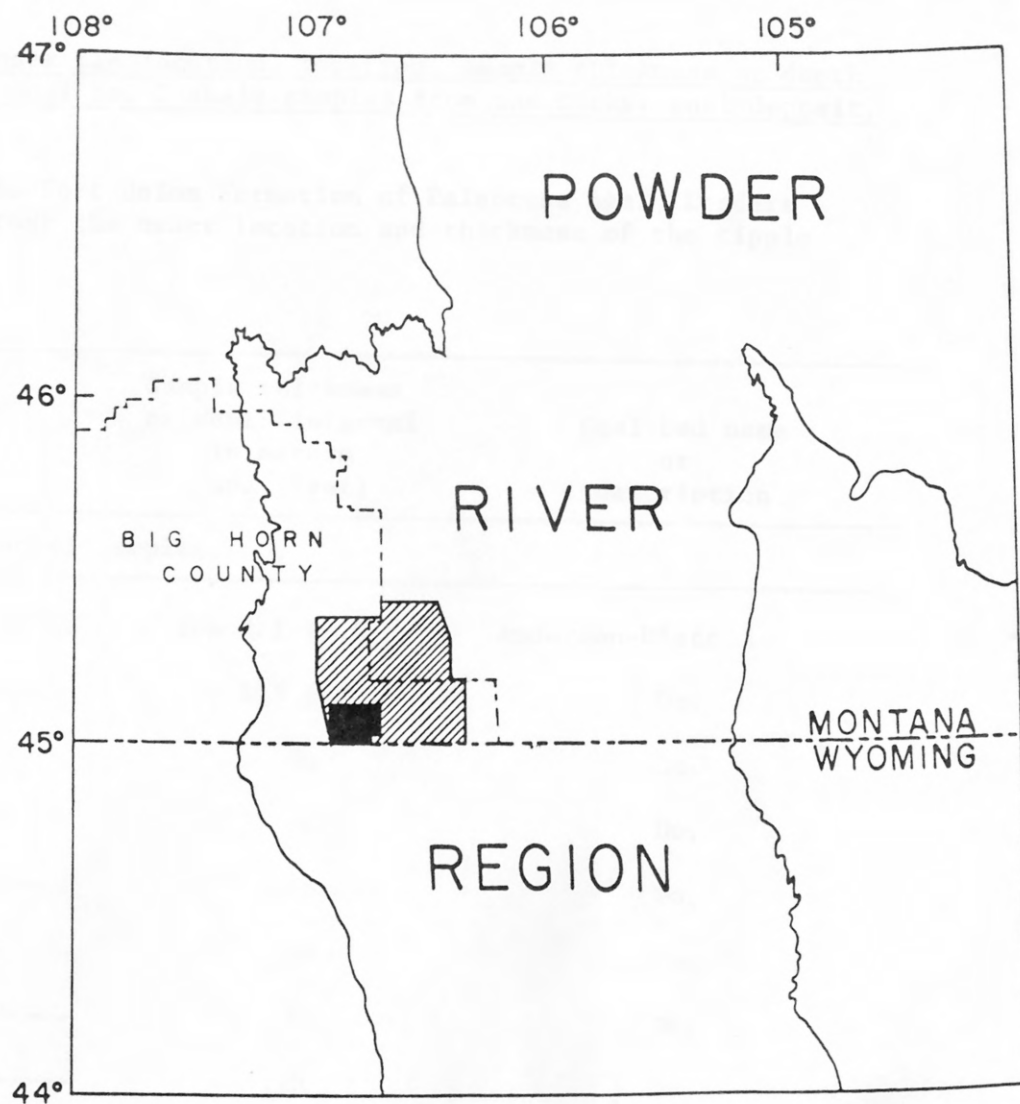
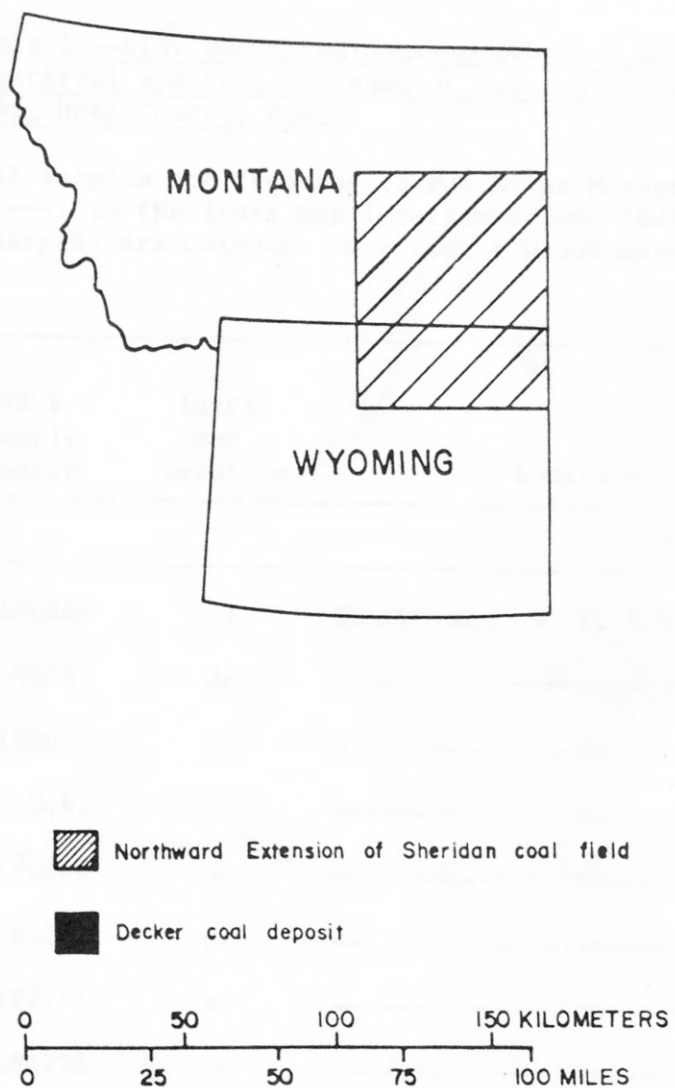


Figure 1.--Map of northeastern Wyoming and southeastern Montana showing locations of the Northward Extension of the Sheridan coal field, and the Decker coal deposit, Big Horn County, Montana, and an outline of the Powder River coal region. Map modified from Averitt (1942).

Table 1.--U.S. Geological Survey sample numbers, index map location, location, sample thickness or depth interval and coal bed name or description for 50 coal and 2 shale samples from the Decker coal deposit, Big Horn County, Mont.

[All samples are from the Tongue River Member of the Fort Union Formation of Paleocene age. Leaders (---) in the index map location column indicate that the exact location and thickness of the tipple samples are unknown. One foot = 0.305 meters.]

USGS sample number	Index map location	Location	Sample thickness or depth interval in meters and (feet)	Coal bed name or description
Bench channel samples				
D180068	1	SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 9, T. 9 S., R. 40 E.	Top 2.1 (7.0)	Anderson-Dietz 1
D180067	do	-----do-----	1.5 (5.0)	Do.
D180066	do	-----do-----	do	Do.
D180065	do	-----do-----	do	Do.
D180064	do	-----do-----	do	Do.
D180063	do	-----do-----	do	Do.
D182776	do	-----do-----	do	Do.
D182775	do	-----do-----	do	Do.
D182774	do	-----do-----	do	Do.
D182773	do	-----do-----	Bottom 1.5 (5.0)	Do.
D180056	2	NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 9, T. 9 S., R. 40 E.	Top 1.5 (5.0)	Do.



Table 1.--U.S. Geological Survey sample numbers, index map location, location, sample thickness or depth interval and coal bed name or description for 50 coal and 2 shale samples from the Decker coal deposit, Big Horn County, Mont.--continued

USGS sample number	Index map location	Location	Sample thickness or depth interval in meters and (feet)	Coal bed name or description
Bench channel samples				
D180055	2	NW $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 9, T. 9 S., R. 40 E.	1.5 (5.0)	Anderson-Dietz 1
D180054	do	-----do-----	do	Do.
D180053	do	-----do-----	do	Do.
D180052	do	-----do-----	do	Do.
D182784	do	-----do-----	do	Do.
D182783	do	-----do-----	do	Do.
D182782	do	-----do-----	do	Do.
D182781	do	-----do-----	Bottom 1.5 (5.0)	Do.
D180062	3	-----do-----	Top 2.2 (7.3)	Do.
D180061	do	-----do-----	1.5 (5.0)	Do.
D180060	do	-----do-----	do	Do.
D180059	do	-----do-----	do	Do.
D180058	do	-----do-----	do	Do.

Table 1.--U.S. Geological Survey sample numbers, index map location, location, sample thickness or depth interval and coal bed name or description for 50 coal and 2 shale samples from the Decker coal deposit, Big Horn County, Mont.--continued

USGS sample number	Index map location	Location	Sample thickness or depth interval in meters and (feet)	Coal bed name or description
Bench channel samples				
D180057	3	NE $\frac{1}{4}$ SE $\frac{1}{4}$ sec. 9, T. 9 S., R. 40 E.	1.5 (5.0)	Anderson-Dietz 1
D182780	do	-----do-----	do	Do.
D182779	do	-----do-----	do	Do.
D182778	do	-----do-----	do	Do.
D182777	do	-----do-----	Bottom 1.5 (5.0)	Do.
D182794	4	SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 15, T. 9. S., R. 40 E.	Top .23 (.75)	Shale, carbonaceous
D182793	do	-----do-----	.91 (3.0)	Anderson-Dietz 1
D182792	do	-----do-----	.18 (.58)	Shale, carbonaceous
D182791	do	-----do-----	.84 (2.8)	Anderson-Dietz 1
D182790	do	-----do-----	1.2 (4.0)	Do.
D182789	do	-----do-----	1.5 (5.0)	Do.

Table 1.--U.S. Geological Survey sample numbers, index map location, location, sample thickness or depth interval and coal bed name or description for 50 coal and 2 shale samples from the Decker coal deposit, Big Horn County, Mont.--continued

USGS sample number	Index map location	Location	Sample thickness or depth interval in meters and (feet)	Coal bed name or description
Bench channel samples				
D182788	4	SW $\frac{1}{4}$ NW $\frac{1}{4}$ sec. 15, T. 9. S., R. 40 E.	1.5 (5.0)	Anderson - Dietz 1
D182787	do	-----do-----	do	Do.
D182786	do	-----do-----	do	Do.
D182785	do	-----do-----	Bottom 1.5 (5.0)	Do.
Core samples				
D192402	5	NE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 26, T. 8 S, R. 39 E.	38.7-40.4 (126-132)	Anderson - Dietz 1 - Dietz 2
D192403	do	-----do-----	40.4-44.5 (132-146)	Do.
D192404	do	-----do-----	44.5-48.6 (146-159)	Do.
D192405	do	-----do-----	48.6-49.5 (159-162)	Do.
D192406	do	-----do-----	49.5-53.1 (162-174)	Do.
D192407	do	-----do-----	53.1-56.4 (174-185)	Do.
D192408	do	-----do-----	56.4-59.8 (185-196)	Do.

Table 1.--U.S. Geological Survey sample numbers, index map location, location, sample thickness or depth interval and coal bed name or description for 50 coal and 2 shale samples from the Decker coal deposit, Big Horn County, Mont.--continued

USGS sample number	Index map location	Location	Sample thickness or depth interval in meters and (feet)	Coal bed name or description
Core samples				
D160668	6	SE $\frac{1}{4}$ SW $\frac{1}{4}$ sec. 29, T. 9 S., R. 39 E.	35.4-38.7 (116-127)	Anderson
D160669	do	-----do-----	38.7-41.8 (127-137)	Do.
D160670	do	-----do-----	41.8-42.7 (137-140)	Do.
Tipple samples				
D161317	---	Decker Mine Area	---	Anderson - Dietz 1
D161318	---	-----do-----	---	Do.
D161319	---	-----do-----	---	Do.

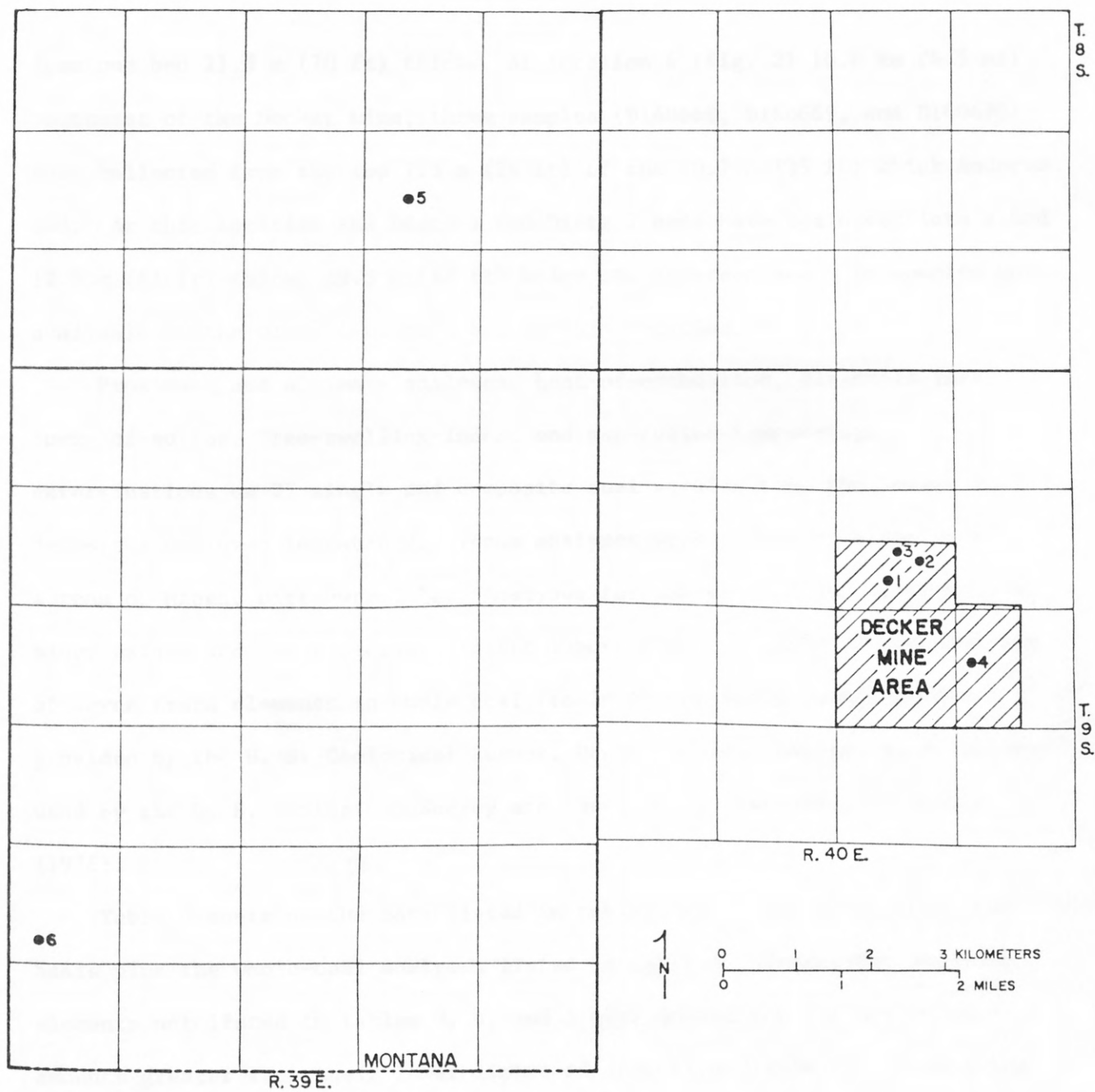


Figure 2.--Index map showing sample locations and the Decker Mine area, Decker coal deposit, Big Horn County, Montana. Detailed location descriptions are in table 1.

form one bed 21.3 m (70 ft) thick. At location 6 (fig. 2) 10.6 km (6.5 mi) southwest of the Decker mine, three samples (D160668, D160669, and D160670) were collected from the top 7.3 m (24 ft) of the 10.7 m (35 ft) thick Anderson bed. At this location the Dietz 1 and Dietz 2 beds have coalesced into a bed 12.5 m (41 ft) thick, 19.5 m (64 ft) below the Anderson bed. No samples were available of the Dietz 1-Dietz 2 bed at this location.

Proximate and ultimate analyses, heat-of-combustion, air-dried-loss, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations on 27 single and composite coal samples from the Decker 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 52 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. Twenty-two additional elements not listed in tables 3, 4, and 5 were looked for but not found in amounts greater than their lower limits of detection (table 6). Unweighted statistical summaries of the analytical data for 50 coal samples from the Decker coal deposit in tables 2, 3, and 4 are listed in tables 7, 8, and 9. For comparison, data summaries for other Powder River region coal samples are included. Data summaries for Ag, Ce, Ge, La, Nd, P, and Th contents in coal were not included in tables 8 and 9 because these elements were detected in an insufficient number of samples to calculate meaningful statistics.

Arsenic contents of the samples summarized in this report have been determined by three different analytical methods: samples D160668 through D160670 and samples D161317 through D161319 were analyzed spectrophotometrically (lower detection limit 1.0 ppm); samples D192402 through D192408 were analyzed by instrumental neutron activation analysis (lower detection limit 0.1 ppm); the remaining 39 samples were analyzed by the graphite furnace-atomic absorption method (lower detection limit 0.5 ppm).

Thorium contents of the samples were determined by two methods: samples D192402 through D192408 were analyzed by instrumental neutron activation analysis (lower detection limit 0.1 ppm); the remaining 45 samples were analyzed by delayed neutron activation analysis (lower detection limit 3.0 ppm).

$P_2O_5$  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 D160668 through D160670 and samples D161317 through D161319 is 0.1 percent; for all other samples it is 1.0 percent.

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



## Explanation of statistical terms used in summary tables

In this report the geometric mean (GM) is used as the estimate of the most probable concentration (mode); the geometric mean is calculated by taking the logarithm of each analytical value, summing the logarithms, dividing the sum by the total number of values, and obtaining the antilogarithm of the result. The measure of scatter about the mode used here is the geometric deviation (GD), which is the antilog of the standard 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  $GM \cdot GD$ . 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  $\underline{t}$  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 Decker 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 range from subbituminous C (7 samples) to subbituminous B coal (20 samples).

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 27 coal samples from the Decker coal deposit with data for 33 other Powder River region coal samples shows that coal from the Decker deposit has significantly higher contents of fixed carbon and carbon, a significantly higher heat of combustion; and significantly lower contents of ash, and total and pyritic sulfur. Contents of moisture, volatile matter, hydrogen, nitrogen, oxygen, and sulfate and organic sulfur are not significantly different. When compared at the 99-percent confidence level, the carbon contents and heats of combustions 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 50 coal samples from the Decker coal deposit with analyses of ash from 410 other Powder River region coal samples shows that coal ash from the Decker deposit has significantly higher  $\text{Na}_2\text{O}$  and  $\text{TiO}_2$  contents, a significantly lower ash content, and significantly lower  $\text{SiO}_2$  and  $\text{Fe}_2\text{O}_3$  contents in ash. Contents of  $\text{Al}_2\text{O}_3$ ,  $\text{CaO}$ ,  $\text{MgO}$ ,  $\text{K}_2\text{O}$ , and  $\text{SO}_3$  in ash are not significantly different. When compared at the 99-percent confidence level, the  $\text{Fe}_2\text{O}_3$  contents in ash are not significantly different.

A statistical comparison of the geometric mean contents of 35 elements in 50 coal samples from the Decker coal deposit with analyses of 410 other Powder River region coal samples shows that coal from the Decker deposit has

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

Compared to other U.S. coals (Swanson and others, 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, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations for 27 coal samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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. °C = (°F-32) 5/9; Kcal/kg = 0.556 (Btu/lb), L, less than the value shown, B, not determined. Sample D180066\* is a composite of D180066 and B180067; D180064\* is a composite of D180064 and D180065; D182773\* is a composite of D182773, D182774, D182775 and D182776; D180053\* is a composite of D180053, D180054 and D180055; D182781\* is a composite of D182781, D182782, D182783 and D182784; D180060\* is a composite of D180060 and D180061; D180058\* is a composite of D180058 and D180059; D182777\* is a composite of D182777, D182778, D182779, and D182780; D182793\* is a composite of D182793 and D182794; and D182785\* is a composite of D182785, D182786, D182787, D182788, D182789, D182790, and D182791]

Sample number	Proximate analysis				Ultimate analysis					Heat of combustion	
	Moisture	Volatile matter	Fixed carbon	Ash	Hydrogen	Carbon	Nitrogen	Oxygen	Sulfur	Kcal/kg	Btu/lb
D180068	21.2 --- ---	32.7 41.5 43.7	42.2 53.6 56.3	3.9 4.9 ---	6.2 4.9 5.1	56.2 71.3 75.0	1.0 1.3 1.3	32.5 17.3 18.2	0.3 .4 .4	5,410 6,870 7,230	9,750 12,370 13,010
D180066*	22.8 --- ---	31.1 40.3 42.3	42.4 54.9 57.7	3.7 4.8 ---	6.1 4.6 4.9	55.9 72.4 76.1	.9 1.2 1.2	33.2 16.8 17.6	.2 .3 .3	5,340 6,920 7,270	9,610 12,450 13,080
D180064*	21.3 --- ---	32.2 40.9 42.9	42.9 54.5 57.1	3.6 4.6 ---	6.1 4.7 5.0	57.0 72.4 75.9	.8 1.0 1.1	32.3 17.0 17.8	.3 .4 .4	5,390 6,850 7,170	9,700 12,320 12,910
D180063	23.2 --- ---	30.2 39.3 41.9	41.8 54.4 58.1	4.8 6.2 ---	6.2 4.7 5.0	53.5 69.7 74.3	.9 1.2 1.2	33.6 16.9 18.0	1.1 1.4 1.5	5,160 6,710 7,160	9,280 12,090 12,890
D182773*	22.1 --- ---	32.6 41.8 43.9	41.7 53.5 56.1	3.6 4.6 ---	6.4 5.1 5.3	56.4 72.4 75.9	.8 1.0 1.1	32.4 16.4 17.2	.3 .4 .4	5,430 6,970 7,300	9,770 12,540 13,150
D180056	21.8 --- ---	32.7 41.8 43.6	42.3 54.1 56.4	3.2 4.1 ---	6.3 5.0 5.2	56.5 72.3 75.3	.9 1.2 1.2	32.0 16.1 16.8	1.1 1.4 1.5	5,400 6,910 7,200	9,720 12,430 12,960
D180053*	21.6 --- ---	32.0 40.8 42.4	43.4 55.4 57.6	3.0 3.8 ---	6.3 5.0 5.2	56.6 72.2 75.1	.8 1.0 1.1	32.2 16.6 17.2	1.1 1.4 1.5	5,390 6,870 7,150	9,700 12,370 12,860
D180052	22.6 --- ---	30.8 39.8 42.4	41.9 54.1 57.6	4.7 6.1 ---	6.1 4.6 4.9	54.2 70.0 74.6	.8 1.0 1.1	33.1 16.8 17.9	1.0 1.3 1.4	5,200 6,720 7,150	9,360 12,090 12,870
D182781*	22.8 --- ---	31.2 40.4 42.2	42.7 55.3 57.8	3.3 4.3 ---	6.4 5.0 5.2	56.0 72.5 75.8	.8 1.0 1.1	33.1 16.6 17.4	.3 .4 .4	5,380 6,970 7,280	9,690 12,550 13,110
D180062	21.6 --- ---	32.8 41.8 44.2	41.4 52.8 55.8	4.2 5.4 ---	6.3 5.0 5.3	55.8 71.2 75.2	1.0 1.3 1.3	32.4 16.8 17.8	.3 .4 .4	5,360 6,840 7,230	9,650 12,310 13,010
D180060*	22.3 --- ---	30.8 39.6 41.2	43.9 56.5 58.8	3.0 3.9 ---	6.2 4.8 5.0	56.1 72.2 75.1	.9 1.2 1.2	33.5 17.6 18.3	.2 .3 .3	5,350 6,880 7,160	9,620 12,390 12,880
D180058*	21.9 --- ---	31.7 40.6 42.2	43.5 55.7 57.8	2.9 3.7 ---	6.2 4.8 5.0	56.6 72.5 75.3	.8 1.0 1.1	33.3 17.7 18.4	.2 .3 .3	5,420 6,940 7,210	9,750 12,490 12,970



Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations of 27 coal samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn County, Mont.--continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D180068	11.9	0.01	0.03	0.27	0.0	1,120	1,175	1,240
	---	.01	.04	.34				
	---	.01	.04	.36				
D180066*	12.8	.01	.05	.18	.0	1,175	1,220	1,275
	---	.01	.06	.23				
	---	.01	.07	.24				
D180064*	13.3	.08	.05	.15	.0	1,180	1,230	1,285
	---	.10	.06	.19				
	---	.11	.07	.20				
D180063	15.7	.03	.08	1.01	.0	1,095	1,155	1,210
	---	.04	.10	1.32				
	---	.04	.11	1.40				
D182773*	16.2	.02	.13	.19	.0	1,180	1,245	1,295
	---	.03	.17	.24				
	---	.03	.17	.26				
D180056	12.1	.01	.22	.89	.0	1,155	1,205	1,270
	---	.01	.28	1.14				
	---	.01	.29	1.19				
D180053*	14.5	.01	.27	.81	.0	1,270	1,320	1,370
	---	.01	.34	1.03				
	---	.01	.36	1.07				
D180052	14.3	.15	.13	.68	.0	1,230	1,290	1,330
	---	.19	.17	.88				
	---	.21	.18	.94				
D182781*	17.2	.01L	.12	.20	.0	1,165	1,220	1,265
	---	.01L	.16	.26				
	---	.01L	.16	.27				
D180062	14.1	.01L	.06	.25	.0	1,145	1,190	1,240
	---	.01L	.08	.32				
	---	.01L	.08	.34				
D180060*	15.0	.01L	.03	.17	.0	1,155	1,215	1,270
	---	.01L	.04	.22				
	---	.01L	.04	.23				
D180058*	13.1	.01L	.06	.16	.0	1,170	1,230	1,290
	---	.01L	.08	.20				
	---	.01L	.08	.21				

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations of 27 coal samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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
D180057	22.6	30.6	39.7	7.1	6.1	52.3	0.8	32.5	1.1	5,050	9,090
	---	39.5	51.3	9.2	4.6	67.6	1.0	16.0	1.4	6,520	11,740
	---	43.5	56.5	---	5.1	74.4	1.1	17.7	1.6	7,180	12,920
D182777*	22.3	31.7	42.3	3.7	6.4	56.1	.8	32.6	.4	5,410	9,730
	---	40.8	54.4	4.8	5.0	72.2	1.0	16.4	.5	6,960	12,520
	---	42.8	57.2	---	5.3	75.8	1.1	17.3	.5	7,300	13,150
D182793*	18.1	26.0	28.4	27.5	5.0	38.4	.8	25.8	2.4	3,830	6,890
	---	31.7	34.7	33.6	3.6	46.9	1.0	11.9	2.9	4,680	8,420
	---	47.8	52.2	---	5.5	70.6	1.5	17.9	4.4	7,040	12,670
D182785*	22.0	31.5	42.8	3.7	6.3	56.1	1.0	32.5	.4	5,400	9,720
	---	40.4	54.9	4.7	4.9	71.9	1.3	16.6	.5	6,920	12,460
	---	42.4	57.6	---	5.2	75.5	1.3	17.4	.5	7,270	13,080
D192402	29.6	29.8	35.4	5.2	6.9	49.2	.8	37.3	.7	4,780	8,610
	---	42.3	50.3	7.4	5.1	69.9	1.1	15.6	1.0	6,790	12,230
	---	45.7	54.3	---	5.5	75.5	1.2	16.9	1.1	7,340	13,210
D192403	27.2	30.3	39.1	3.4	6.6	52.4	.7	36.8	.2	5,000	9,000
	---	41.6	53.7	4.7	4.9	72.0	1.0	17.3	.3	6,860	12,360
	---	43.7	56.3	---	5.2	75.5	1.0	18.2	.3	7,200	12,960
D192404	29.4	29.3	38.2	3.1	6.7	51.0	.6	38.4	.2	4,860	8,760
	---	41.5	54.1	4.4	4.9	72.2	.8	17.4	.3	6,890	12,400
	---	43.4	56.6	---	5.1	75.6	.9	18.2	.3	7,210	12,970
D192405	27.2	30.4	34.0	8.4	6.5	48.5	.6	34.5	1.5	4,710	8,470
	---	41.8	46.7	11.5	4.8	66.6	.8	14.2	2.1	6,470	11,640
	---	47.2	52.8	---	5.4	75.3	.9	16.0	2.3	7,310	13,160
D192406	25.0	32.2	38.1	4.7	6.5	53.9	.6	33.7	.6	5,170	9,300
	---	42.9	50.8	6.3	5.0	71.9	.8	15.3	.8	6,890	12,400
	---	45.8	54.2	---	5.3	76.7	.9	16.3	.9	7,350	13,230
D192407	25.1	31.6	39.1	4.2	6.7	54.1	.6	34.2	.2	5,190	9,340
	---	42.2	52.2	5.6	5.2	72.2	.8	15.9	.3	6,920	12,460
	---	44.7	55.3	---	5.5	76.5	.8	16.8	.3	7,340	13,200
D192408	27.3	29.1	38.0	5.6	6.5	51.5	.7	35.5	.2	4,890	8,800
	---	40.0	52.3	7.7	4.8	70.8	1.0	15.5	.3	6,720	12,100
	---	43.4	56.6	---	5.2	76.8	1.0	16.7	.3	7,280	13,110
D160668	24.0	30.8	41.3	3.9	B	B	B	B	.2	5,170	9,310
	---	40.5	54.3	5.1	---	---	---	---	.3	6,800	12,240
	---	42.7	57.3	---	---	---	---	---	.3	7,170	12,910

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations of 27 coal samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn County, Mont.--continued

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D180057	15.0	0.02	0.33	0.77	0.0	1,125	1,175	1,240
	---	.03	.43	.99				
	---	.03	.47	1.10				
D182777*	17.1	.01	.13	.25	.0	1,155	1,215	1,255
	---	.01	.17	.32				
	---	.01	.18	.34				
D182793*	13.6	.47	1.14	.76	.0	1,200	1,255	1,325
	---	.57	1.39	.93				
	---	.86	2.10	1.40				
D182785*	16.4	.02	.16	.20	.0	1,150	1,215	1,285
	---	.03	.21	.26				
	---	.03	.22	.27				
D192402	21.9	.01L	.07	.59	.0	1,155	1,165	1,180
	---	.01L	.10	.84				
	---	.01L	.11	.90				
D192403	17.9	.01L	.01	.16	.0	1,145	1,160	1,175
	---	.01L	.01	.22				
	---	.01L	.01	.23				
D192404	22.3	.01L	.01	.18	.0	1,140	1,155	1,170
	---	.01L	.01	.25				
	---	.01L	.01	.27				
D192405	19.9	.04	.63	.79	.0	1,060	1,080	1,110
	---	.05	.87	1.09				
	---	.06	.98	1.23				
D192406	17.6	.07	.10	.40	.0	1,170	1,190	1,205
	---	.09	.13	.53				
	---	.10	.14	.57				
D192407	15.8	.02	.01	.16	.0	1,160	1,175	1,195
	---	.03	.01	.21				
	---	.03	.01	.23				
D192408	20.6	.01	.02	.18	.0	1,145	1,160	1,175
	---	.01	.03	.25				
	---	.01	.03	.27				
D160668	18.2	.02	.04	.19	.0	B	B	B
	---	.03	.05	.25				
	---	.03	.06	.26				

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index and ash-fusion-temperature determinations of 27 coal samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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
D160669	25.2	30.5	41.4	2.9	B	B	B	B	0.2	5,120	9,210
	---	40.8	55.3	3.9	---	---	---	---	.3	6,840	12,320
	---	42.4	57.6	---	---	---	---	---	.3	7,120	12,810
D160670	25.3	29.2	39.3	6.2	B	B	B	B	.6	4,840	8,710
	---	39.1	52.6	8.3	---	---	---	---	.8	6,470	11,650
	---	42.6	57.4	---	---	---	---	---	.9	7,060	12,710
D161318	20.6	31.6	43.4	4.4	6.2	57.1	.9	30.9	.5	5,490	9,880
	---	39.8	54.7	5.5	4.9	71.9	1.1	15.9	.6	6,910	12,440
	---	42.1	57.9	---	5.2	76.1	1.2	16.8	.7	7,320	13,170

Sample number	Air-dried loss	Forms of sulfur			Free swelling	Ash fusion temperature, °C		
		Sulfate	Pyritic	Organic		Initial deformation	Softening	Fluid
D160669	19.3	0.02	0.03	0.18	0.0	B	B	B
	---	.03	.04	.24	---	---	---	---
	---	.03	.04	.25	---	---	---	---
D160670	19.6	.02	.08	.54	.0	B	B	B
	---	.03	.11	.72	---	---	---	---
	---	.03	.12	.79	---	---	---	---
D161318	B	.01	.20	.26	.0	B	B	B
	---	.01	.25	.33	---	---	---	---
	---	.01	.27	.35	---	---	---	---

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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)	SiO <sub>2</sub> (percent)	Al <sub>2</sub> O <sub>3</sub> (percent)	CaO (percent)	MgO (percent)	Na <sub>2</sub> O (percent)	K <sub>2</sub> O (percent)	Fe <sub>2</sub> O <sub>3</sub> (percent)	TiO <sub>2</sub> (percent)	P <sub>2</sub> O <sub>5</sub> (percent)	Sample number
D180068	4.7	29	13	13	3.13	8.55	0.15	2.4	1.8	1.0L	D180068
D180067	3.7	17	13	18	4.35	11.7	.18	3.3	1.1	1.0L	D180067
D180066	3.6	17	11	17	4.30	12.0	.18	3.3	1.1	1.0L	D180066
D180065	3.6	15	13	17	4.00	11.3	.16	3.3	1.2	1.0L	D180065
D180064	4.4	20	18	15	3.38	9.53	.17	3.2	1.5	1.0L	D180064
D180063	6.0	18	14	10	3.38	6.83	.29	9.5	1.0	1.0L	D180063
D182776	4.0	15	15	26	3.38	9.63	.16	5.0	1.9	1.0L	D182776
D182775	3.2	11	16	30	3.76	11.7	.27	5.5	1.9	1.0L	D182775
D182774	4.2	19	16	27	3.28	9.03	.20	4.6	2.0	1.0L	D182774
D182773	5.9	20	21	22	2.34	6.34	.33	3.7	2.1	5.3	D182773
D180056	3.9	18	13	17	4.00	11.6	.19	3.2	1.1	1.0L	D180056
D180055	3.2	15	10	17	4.08	13.5	.21	3.6	1.2	1.0L	D180055
D180054	3.4	13	10	18	4.33	12.7	.19	3.3	1.2	1.0L	D180054
D180053	4.2	21	18	15	3.45	10.3	.18	2.6	1.4	1.0L	D180053
D180052	6.1	19	13	9.8	2.55	6.75	.32	8.5	1.2	1.0L	D180052
D182784	6.0	28	15	17	2.37	6.48	.49	6.4	1.7	1.0L	D182784
D182783	3.8	14	15	27	3.33	9.58	.19	4.7	2.6	1.0L	D182783
D182782	3.5	13	14	25	3.12	10.1	.20	5.3	2.1	1.0L	D182782
D182781	4.2	19	13	23	3.23	8.88	.29	5.4	1.5	1.0L	D182781
D180062	5.0	29	14	14	2.60	8.28	.16	3.0	1.7	1.0L	D180062
D180061	3.6	17	13	17	3.20	11.1	.17	3.7	1.1	1.0L	D180061
D180060	3.7	25	9.7	16	4.08	11.1	.17	3.3	1.2	1.0L	D180060
D180059	3.5	14	13	17	4.33	11.7	.19	3.5	1.2	1.0L	D180059
D180058	3.9	19	19	15	3.45	10.3	.18	3.1	2.0	1.0L	D180058
D180057	8.6	32	16	7.0	2.18	4.83	.74	7.0	1.1	1.0L	D180057
D182780	3.4	26	18	18	2.45	6.55	.71	6.5	1.6	1.0L	D182780
D182779	3.3	13	15	28	3.66	11.4	.23	5.8	2.0	1.0L	D182779
D182778	4.4	21	15	26	3.33	8.48	.20	4.4	2.1	1.1	D182778
D182777	5.5	20	18	21	2.55	6.69	.34	3.6	1.9	3.6	D182777
D182794	79.7	60	14	1.6	1.24	.34	2.8	6.9	.62	1.0L	D182794
D182793	10.5	38	13	12	1.74	.76	1.3	13	.82	1.0L	D182793
D182792	93.0	89	3.6	.29	.24	.10	1.3	.090	.44	1.0L	D182792
D182791	9.9	55	11	12	1.76	2.75	.36	2.0	1.9	1.0L	D182791
D182790	4.6	27	11	23	2.99	8.16	.19	4.3	1.7	1.0L	D182790
D182789	3.7	18	11	27	3.38	10.2	.21	5.1	1.4	1.0L	D182789
D182788	3.9	31	8.6	22	2.99	9.38	.24	4.2	1.7	1.0L	D182788
D182787	3.4	15	12	27	3.53	10.9	.22	5.4	1.6	1.0L	D182787
D182786	4.0	17	15	26	3.08	9.18	.18	4.8	2.1	1.0L	D182786
D182785	5.9	16	11	13	1.97	6.15	.49	24	1.1	1.0L	D182785
D192402	7.3	41	12	9.8	2.63	5.50	.58	5.1	1.6	1.0L	D192402

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn County, Mont.--continued

Sample number	SO <sub>3</sub> (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
D180068	12	N	700	20,000	N	1.0L	10	70	225	50	D180068
D180067	11	N	700	20,000	N	1.0L	15	50	82	30	D180067
D180066	12	N	700	20,000	N	1.0L	7	50	98	20	D180066
D180065	10	N	700	30,000	N	1.0L	10	50	102	30	D180065
D180064	11	N	500	20,000	N	1.0L	10	30	180	30	D180064
D180063	25	N	300	15,000	3	1.5	30	70	179	30	D180063
D182776	23	N	700	15,000	N	1.0L	30	50	198	20	D182776
D182775	16	N	1,000	15,000	N	1.0L	15	30	185	20	D182775
D182774	15	N	700	15,000	N	1.0L	15	30	210	30	D182774
D182773	20	N	700	15,000	15	1.0	30	70	188	70	D182773
D180056	11	N	700	30,000	N	1.0L	10	50	75	20	D180056
D180055	14	N	1,000	30,000	N	1.0L	10	70	97	20	D180055
D180054	12	N	700	30,000	N	1.0L	10	50	94	30	D180054
D180053	13	N	700	20,000	N	1.0L	15	50	134	50	D180053
D180052	24	N	300	10,000	3	1.0	20	70	192	30	D180052
D182784	21	N	500	10,000	N	1.0L	15	30	182	30	D182784
D182783	20	N	500	20,000	N	1.0L	20	50	295	30	D182783
D182782	22	N	700	20,000	N	1.0L	20	30	209	30	D182782
D182781	25	N	700	15,000	3	1.0L	20	50	144	30	D182781
D180062	12	N	700	20,000	N	1.0L	10	50	194	50	D180062
D180061	11	N	700	20,000	N	1.0L	10	50	91	30	D180061
D180060	9.5	N	700	20,000	N	1.0L	7	50	84	20	D180060
D180059	11	N	700	30,000	N	1.0L	10	50	119	30	D180059
D180058	11	N	500	20,000	N	1.0L	15	50	315	50	D180058
D180057	16	N	150	7,000	2	2.0	15	70	182	30	D180057
D182780	20	N	500	10,000	N	1.5	15	30	149	30	D182780
D182779	17	N	700	20,000	N	1.0L	20	30	210	20	D182779
D182778	15	N	500	15,000	N	1.0L	20	50	289	30	D182778
D182777	22	N	500	15,000	15	2.0	50	70	191	70	D182777
D182794	4.9	N	70	700	N	1.0L	15	70	41	20	D182794
D182793	17	7	500	5,000	7	1.0L	20	70	163	30	D182793
D182792	.20L	N	50	500	N	1.0L	N	20	20L	10	D182792
D182791	9.2	1	300	10,000	N	1.0L	10	70	185	30	D182791
D182790	15	N	700	20,000	N	1.0L	15	50	188	30	D182790
D182789	13	N	700	20,000	N	1.0L	15	70	72	30	D182789
D182788	12	N	700	20,000	N	1.0	15	70	150	20	D182788
D182787	16	N	700	20,000	N	1.0L	15	30	121	30	D182787
D182786	17	N	500	15,000	N	1.0L	20	30	250	50	D182786
D182785	28	N	500	10,000	3	1.0L	30	70	232	20	D182785
D192402	20	N	700	5,000	15	1.0L	15	70	201	70	D192402

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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
D180068	N	N	46	170	10	20	15	25L	30	15,000	D180068
D180067	N	N	35	235	7	20	20	25L	15	15,000	D180067
D180066	N	N	34	225	20	N	15	25L	10	15,000	D180066
D180065	N	N	44	195	10	20	20	25L	15	15,000	D180065
D180064	N	N	61	170	15	20	15	25L	20	10,000	D180064
D180063	N	N	91	155	70	N	70	25	30	7,000	D180063
D182776	N	100L	46	140	15	30	30	25L	30	5,000	D182776
D182775	N	100L	32	150	7	30	20	30	20	7,000	D182775
D182774	N	100L	34	120	7	50	30	25	30	7,000	D182774
D182773	70	100L	46	160	10	50	50	25L	50	7,000	D182773
D180056	N	N	43	250	7	N	20	25L	15	15,000	D180056
D180055	N	N	30	255	10	20	10	25L	10	15,000	D180055
D180054	N	N	34	285	10	N	20	25L	15	15,000	D180054
D180053	N	N	64	210	15	20	15	25	20	15,000	D180053
D180052	N	N	72	150	70	20	70	25	20	5,000	D180052
D182784	N	100L	107	115	20	30	30	25L	20	5,000	D182784
D182783	N	100L	44	165	10	30	30	25L	30	7,000	D182783
D182782	N	N	31	130	10	30	30	25L	30	7,000	D182782
D182781	N	N	32	155	7	30	50	25L	30	7,000	D182781
D180062	N	N	49	205	N	N	15	25L	20	10,000	D180062
D180061	N	N	37	220	7	N	15	25L	15	15,000	D180061
D180060	N	N	31	200	7	N	10	25L	10	10,000	D180060
D180059	N	N	42	215	7	N	15	25L	20	15,000	D180059
D180058	N	N	74	170	15	20	20	25L	30	10,000	D180058
D180057	N	N	171	145	70	N	70	25L	15	7,000	D180057
D182780	N	100L	85	155	20	30	50	25L	20	5,000	D182780
D182779	N	100L	48	180	15	50	30	25	30	7,000	D182779
D182778	N	100	34	160	15	30	30	35	30	7,000	D182778
D182777	100	100L	48	215	15	50	70	25L	50	7,000	D182777
D182794	N	100L	42	80	7	30	50	25	15	500	D182794
D182793	N	100L	47	190	30	30	100	25	30	2,000	D182793
D182792	N	N	22	20	N	30	10L	25L	N	100	D182792
D182791	N	N	69	115	7	30	20	25L	20	3,000	D182791
D182790	N	N	46	210	7	30	30	25L	30	7,000	D182790
D182789	N	100L	42	255	7	30	30	25L	30	7,000	D182789
D182788	N	100L	35	220	10	30	30	25L	15	7,000	D182788
D182787	N	N	52	270	7	30	30	25L	15	7,000	D182787
D182786	N	100L	69	255	15	30	30	25	30	7,000	D182786
D182785	N	100L	51	185	50	30	200	30	20	5,000	D182785
D192402	70	N	38	350	7	30	30	25L	50	2,000	D192402



Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn County, Mont.--continued

Sample number	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D180068	500	20	2	31	200
D180067	200	30	3	43	150
D180066	150	20	2	41	150
D180065	200	30	3	43	150
D180064	300	30	3	39	150
D180063	500	70	B	148	150
D182776	200	70	7	89	150
D182775	150	30	5	80	150
D182774	200	70	7	76	200
D182773	500	100	10	113	200
D180056	200	30	3	46	150
D180055	150	30	3	35	150
D180054	200	30	3	37	150
D180053	300	30	3	39	200
D180052	300	50	B	96	150
D182784	150	70	7	134	200
D182783	300	70	7	54	200
D182782	200	70	7	71	150
D182781	200	70	7	86	150
D180062	300	30	3	34	200
D180061	200	30	3	46	150
D180060	150	30	3	34	150
D180059	200	30	3	34	150
D180058	300	30	3	37	150
D180057	300	50	B	125	200
D182780	150	70	7	176	200
D182779	200	70	5	74	200
D182778	300	70	7	66	200
D182777	500	100	10	131	300
D182794	150	30	3	118	150
D182793	300	100	7	186	150
D182792	30	N	2	19	150
D182791	150	30	3	30	200
D182790	150	70	7	53	150
D182789	150	70	5	53	150
D182788	150	70	7	58	200
D182787	150	50	5	61	150
D182786	300	50	7	71	150
D182785	200	70	B	147	150
D192402	200	50	5	121	300

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn County, Mont.--continued

Sample number	Ash (percent)	SiO <sub>2</sub> (percent)	Al <sub>2</sub> O <sub>3</sub> (percent)	CaO (percent)	MgO (percent)	Na <sub>2</sub> O (percent)	K <sub>2</sub> O (percent)	Fe <sub>2</sub> O <sub>3</sub> (percent)	TiO <sub>2</sub> (percent)	P <sub>2</sub> O <sub>5</sub> (percent)	Sample number
D192403	4.7	36	14	14	4.00	9.20	0.45	2.9	1.1	1.0L	D192403
D192404	4.2	29	16	15	4.30	10.2	.47	2.8	1.5	1.0L	D192404
D192405	11.9	38	17	5.2	1.91	3.17	1.2	14	.91	1.0L	D192405
D192406	5.2	19	17	13	3.40	7.40	.39	5.3	1.4	1.0L	D192406
D192407	4.8	53	12	12	3.70	6.20	.30	2.5	1.3	1.0L	D192407
D192408	6.3	31	22	15	3.40	3.00	.58	3.0	2.1	1.0L	D192408
D160668	4.6	41	10	18	9.34	1.77	.28	3.9	B	.70	D160668
D160669	3.4	14	14	22	12.3	1.91	.39	5.5	B	4.4	D160669
D160670	7.1	25	18	11	5.70	.94	1.4	4.1	B	3.8	D160670
D161317	4.8	25	16	14	2.70	6.90	.53	7.1	B	1.1	D161317
D161318	4.9	25	15	14	2.65	6.70	.54	8.1	B	1.2	D161318
D161319	5.4	26	15	13	2.31	6.11	.60	8.3	B	1.3	D161319

Sample number	SO <sub>3</sub> (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
D192403	8.1	N	700	10,000	N	2.0	10	50	98	50	D192403
D192404	10	N	500	10,000	N	1.0L	15	50	125	70	D192404
D192405	15	N	150	5,000	3	4.0	70	70	219	50	D192405
D192406	27	N	300	10,000	N	1.0L	10	30	179	50	D192406
D192407	9.3	N	500	10,000	N	2.0	30	70	277	70	D192407
D192408	13	N	500	5,000	N	3.0	10	50	127	30	D192408
D160668	13	N	700	7,000	N	1.0L	15	50	245	20	D160668
D160669	16	N	700	10,000	N	1.0L	15	50	180	30	D160669
D160670	16	N	300	7,000	3	1.5	15	70	145	30	D160670
D161317	20	N	700	10,000	3	B	15	70	180	30	D161317
D161318	20	N	700	10,000	3	1.0	20	70	168	30	D161318
D161319	21	N	700	10,000	3	B	15	70	172	30	D161319

Table 3.--Major- and minor-oxide and trace-element composition of the laboratory ash of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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)	Sr-S (ppm)	Sr-S (ppm)	Sample number
D192403	N	N	47	370	N	N	20	25L	20	3,000	D192403
D192404	N	N	80	390	15	N	30	25	30	5,000	D192404
D192405	N	100L	189	285	70	20	150	35	30	2,000	D192405
D192406	N	N	90	350	15	N	20	25L	20	3,000	D192406
D192407	N	N	128	350	7	20	30	25L	50	5,000	D192407
D192408	N	N	45	270	N	20	20	25L	20	3,000	D192408
D160668	N	N	31	100	50	20	15	300	15	5,000	D160668
D160669	N	N	28	150	30	N	15	195	15	7,000	D160669
D160670	N	70	44	100	50	N	70	120	15	3,000	D160670
D161317	N	70	92	150	30	20	70	49	30	7,000	D161317
D161318	N	70	89	300	30	20	70	49	30	7,000	D161318
D161319	N	70	98	150	30	20	70	49	30	5,000	D161319

Sample number	V-S (ppm)	Y-S (ppm)	Yb-S (ppm)	Zn (ppm)	Zr-S (ppm)
D192403	100	30	3	303	150
D192404	150	30	3	331	150
D192405	300	70	B	188	150
D192406	150	30	3	151	150
D192407	300	50	5	124	200
D192408	100	30	3	168	300
D160668	150	30	3	83	200
D160669	150	20	2	93	100
D160670	150	50	3	240	100
D161317	200	50	3	80	200
D161318	300	70	3	92	200
D161319	200	50	3	108	200

Table 4.--Content of seven trace elements in 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn County, Mont.

[Analyses in 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
D180068	0.5L	45	0.04	0.2	0.7	3.0L	0.2L	D180068
D180067	.5L	40	.03	.2	.2	3.0L	.2L	D180067
D180066	.5L	20L	.04	.1	.3	3.0L	.2L	D180066
D180065	.5L	40	.04	.1	.1	3.0L	.3	D180065
D180064	.5L	40	.03	.2	.1	3.0L	.3	D180064
D180063	7.0	25	.30	.6	1.1	3.0L	1.1	D180063
D182776	.5L	30	.05	.2	.5	3.0L	.4	D182776
D182775	.5L	35	.03	.1	.3	3.0L	.3	D182775
D182774	.5L	40	.03	.2	.3	3.0L	.4	D182774
D182773	.5	60	.09	.2	.1	3.0L	.6	D182773
D180056	.5L	50	.04	.2	.1	3.0L	.2L	D180056
D180055	.5L	35	.03	.2	.1L	3.0L	.2L	D180055
D180054	.5L	30	.03	.2	.2	3.0L	.2L	D180054
D180053	.5L	55	.04	.2	.2	3.0L	.3	D180053
D180052	3.5	40	.15	.4	.8	3.0L	1.0	D180052
D182784	1.5	45	.18	.4	.6	3.0L	.7	D182784
D182783	.5	40	.03	.1	.5	3.0L	.2L	D182783
D182782	.5L	45	.03	.2	.5	3.0L	.2L	D182782
D182781	1.5	45	.11	.2	.4	3.0L	.2L	D182781
D180062	.5L	50	.03	.2	.3	3.0L	.2L	D180062
D180061	.5L	40	.03	.1	.1L	3.0L	.2L	D180061
D180060	.5L	30	.04	.1L	.2	3.0L	.2L	D180060
D180059	.5L	35	.03	.3	.1L	3.0L	.2L	D180059
D180058	.5L	35	.03	.3	.2	3.0L	.2L	D180058
D180057	4.0	90	.19	.7	.8	3.0L	1.7	D180057
D182780	6.5	55	.22	.4	1.3	3.0L	.5	D182780
D182779	.5L	45	.03	.3	.6	3.0L	.2L	D182779
D182778	.5L	55	.03	.2	.5	4.4	.2L	D182778
D182777	.5	60	.08	.3	.2	3.0L	.5	D182777
D182794	160	660	.49	2.0	4.9	9.9	6.4	D182794
D182793	4.0	60	.24	1.0	1.6	3.0L	3.3	D182793
D182792	1.0	180	.02	.2	.8	3.5	2.0	D182792
D182791	.5	55	.04	.2	1.1	3.4	.4	D182791
D182790	.5L	45	.04	.2	.5	3.0L	.2L	D182790
D182789	.5L	45	.03	.1L	.3	3.0L	.2L	D182789
D182788	.5L	35	.03	.1L	.4	3.0L	.2	D182788
D182787	.5L	30	.02	.2	.5	3.0L	.2L	D182787
D182786	.5L	40	.03	.2	.4	3.0L	.2L	D182786
D182785	6.5	35	.17	.8	1.6	3.0L	2.3	D182785
D192402	3.7	30	.13	.6	.1L	.7	.6	D192402

Table 4.--Content of seven trace elements in 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn County, Mont.--continued

Sample number	As (ppm)	F (ppm)	Hg (ppm)	Sb (ppm)	Se (ppm)	Th (ppm)	U (ppm)	Sample number
D192403	0.5	25	0.01	0.1	0.3	0.4	0.6	D192403
D192404	.3	25	.01	.1	.3	.5	.9	D192404
D192405	21	65	.62	2.1	5.6	2.3	6.7	D192405
D192406	1.5	25	.18	.1	1.0	.6	.8	D192406
D192407	.4	20	.02	.1	.3	.5	.2L	D192407
D192408	.4	20	.02	.1	.4	.7	.7	D192408
D160668	1.0	30	.04	3.8	.2	3.0L	.2L	D160668
D160669	1.0	20	.03	1.9	.1L	3.0L	.2L	D160669
D160670	3.0	30	.11	1.8	.6	3.0L	1.2	D160670
D161317	3.0	B	.10	B	.4	3.0L	.6	D161317
D161318	4.0	50	.11	.3	.6	3.0L	.6	D161318
D161319	5.0	B	.11	B	.9	3.0L	.8	D161319

Table 5.--Major-, minor-, and trace-element composition of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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)	Hg (percent)	Na (percent)	K (percent)	Fe (percent)	Ti (percent)	Ag-S (ppm)	As (ppm)	Sample number
D180068	0.64	0.31	0.43	0.089	0.30	0.006	0.079	0.051	N	0.5L	D180068
D180067	.30	.25	.46	.097	.32	.006	.085	.024	N	.5L	D180067
D180066	.29	.22	.44	.093	.32	.005	.083	.023	N	.5L	D180066
D180065	.25	.24	.44	.087	.30	.005	.083	.025	N	.5L	D180065
D180064	.41	.41	.47	.090	.31	.006	.099	.040	N	.5L	D180064
D180063	.51	.46	.43	.12	.30	.014	.40	.037	N	7.0	D180063
D182776	.28	.32	.74	.081	.29	.005	.14	.046	N	.5L	D182776
D182775	.16	.27	.69	.072	.28	.007	.12	.036	N	.5L	D182775
D182774	.37	.36	.81	.083	.28	.007	.14	.050	N	.5L	D182774
D182773	.55	.66	.93	.083	.28	.016	.15	.074	N	.5	D182773
D180056	.32	.27	.47	.094	.34	.006	.086	.025	N	.5L	D180056
D180055	.22	.18	.40	.079	.32	.006	.080	.022	N	.5L	D180055
D180054	.20	.19	.43	.089	.32	.005	.078	.024	N	.5L	D180054
D180053	.40	.40	.44	.087	.32	.006	.075	.036	N	.5L	D180053
D180052	.55	.43	.43	.094	.31	.016	.36	.043	N	3.5	D180052
D182784	.78	.48	.73	.086	.29	.024	.27	.061	N	1.5	D182784
D182783	.25	.30	.73	.076	.27	.006	.12	.059	N	.5	D182783
D182782	.21	.26	.62	.066	.26	.006	.13	.044	N	.5L	D182782
D182781	.37	.29	.69	.082	.28	.010	.16	.038	N	1.5	D182781
D180062	.68	.38	.48	.078	.31	.007	.10	.051	N	.5L	D180062
D180061	.28	.25	.44	.069	.30	.005	.093	.023	N	.5L	D180061
D180060	.44	.19	.41	.091	.30	.005	.085	.027	N	.5L	D180060
D180059	.23	.23	.43	.091	.30	.006	.086	.026	N	.5L	D180059
D180058	.35	.38	.41	.081	.30	.006	.085	.047	N	.5L	D180058
D180057	1.3	.72	.43	.11	.31	.053	.42	.057	N	4.0	D180057
D182780	.41	.32	.44	.050	.17	.020	.15	.033	N	6.5	D182780
D182779	.20	.26	.66	.073	.28	.006	.13	.040	N	.5L	D182779
D182778	.43	.35	.82	.088	.28	.007	.14	.055	N	.5L	D182778
D182777	.51	.52	.82	.084	.27	.016	.14	.063	N	.5	D182777
D182794	22	5.9	.91	.59	.20	1.9	3.8	.30	N	160	D182794
D182793	1.9	.72	.90	.11	.059	.11	.95	.052	.7	4.0	D182793
D182792	39	1.8	.19	.13	.069	1.0	.059	.25	N	1.0	D182792
D182791	2.5	.58	.85	.10	.20	.030	.14	.11	.1	.5	D182791
D182790	.58	.27	.76	.083	.28	.007	.14	.047	N	.5L	D182790
D182789	.31	.22	.71	.075	.28	.006	.13	.031	N	.5L	D182789
D182788	.56	.18	.61	.070	.27	.008	.11	.040	N	.5L	D182788
D182787	.24	.22	.66	.072	.27	.006	.13	.033	N	.5L	D182787
D182786	.32	.32	.74	.074	.27	.006	.13	.050	N	.5L	D182786
D182785	.44	.34	.55	.070	.27	.024	.99	.039	N	6.5	D182785
D192402	1.4	.46	.51	.12	.30	.035	.26	.070	N	3.7	D192402

Table 5.--Major-, minor-, and trace-element composition of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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
D180068	30	1,000	N	0.05L	0.5	3	11	45	2	N	D180068
D180067	20	700	N	.04L	.5	2	3.0	40	1	N	D180067
D180066	20	700	N	.04L	.2	2	3.5	20L	.7	N	D180066
D180065	20	1,000	N	.04L	.3	2	3.7	40	1	N	D180065
D180064	20	1,000	N	.04L	.5	1.5	7.9	40	1.5	N	D180064
D180063	20	1,000	.2	.09	2	5	11	25	2	N	D180063
D182776	30	700	N	.04L	1	2	7.9	30	.7	N	D182776
D182775	30	500	N	.03L	.5	1	5.9	35	.7	N	D182775
D182774	30	700	N	.04L	.7	1.5	8.8	40	1.5	N	D182774
D182773	50	1,000	1	.06	1.5	5	11	60	5	5	D182773
D180056	30	1,000	N	.04L	.5	2	2.9	50	.7	N	D180056
D180055	30	1,000	N	.03L	.3	2	3.1	35	.7	N	D180055
D180054	20	1,000	N	.03L	.3	1.5	3.2	30	1	N	D180054
D180053	30	1,000	N	.04L	.7	2	5.6	55	2	N	D180053
D180052	20	700	.2	.06	1.5	5	12	40	2	N	D180052
D182784	30	700	N	.06L	1	2	11	45	2	N	D182784
D182783	20	700	N	.04L	.7	2	11	40	1	N	D182783
D182782	20	700	N	.04L	.7	1	7.3	45	1	N	D182782
D182781	30	700	.15	.04L	1	2	6.0	45	1.5	N	D182781
D180062	30	1,000	N	.05L	.5	2	9.7	50	2	N	D180062
D180061	20	700	N	.04L	.3	2	3.3	40	1	N	D180061
D180060	20	700	N	.04L	.2	2	3.1	30	.7	N	D180060
D180059	20	1,000	N	.04L	.3	1.5	4.2	35	1	N	D180059
D180058	20	700	N	.04L	.7	2	12	35	2	N	D180058
D180057	15	700	.15	.17	1.5	7	16	90	2	N	D180057
D182780	15	300	N	.05	.5	1	5.1	55	1	N	D182780
D182779	20	700	N	.03L	.7	1	6.9	45	.7	N	D182779
D182778	20	700	N	.04L	1	2	13	55	1.5	N	D182778
D182777	30	700	.7	.11	3	5	11	60	5	5	D182777
D182794	50	500	N	.80L	10	50	33	660	15	N	D182794
D182793	50	500	.7	.11L	2	7	17	60	3	N	D182793
D182792	50	500	N	.93L	N	20	19L	180	10	N	D182792
D182791	30	1,000	N	.10L	1	7	18	55	3	N	D182791
D182790	30	1,000	N	.05L	.7	2	8.6	45	1.5	N	D182790
D182789	20	700	N	.04L	.5	2	2.7	45	1	N	D182789
D182788	30	700	N	.04	.7	3	5.9	35	.7	N	D182788
D182787	20	700	N	.03L	.5	1	4.1	30	1	N	D182787
D182786	20	700	N	.04L	.7	1	10	40	2	N	D182786
D182785	30	700	.15	.06L	1.5	5	14	35	1	N	D182785
D192402	50	300	1	.07L	1	5	15	30	5	5	D192402



Table 5.--Major-, minor-, and trace-element composition of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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
D180068	0.04	N	2.2	8.0	0.5	1	0.7	210L	1.2L	0.2	D180068
D180067	.03	N	1.3	8.7	.2	1.7	.7	160L	.9L	.2	D180067
D180066	.04	N	1.2	8.1	.7	N	.5	160L	.9L	.1	D180066
D180065	.04	N	1.6	7.0	.3	.7	.7	160L	.9L	.1	D180065
D180064	.03	N	2.7	7.5	.7	1	.7	190L	1.1L	.2	D180064
D180063	.30	N	5.5	9.3	5	N	5	260L	1.5	.6	D180063
D182776	.05	5L	1.8	5.6	.7	1	1	170L	1.0L	.2	D182776
D182775	.03	3L	1.0	4.8	.2	1	.7	140L	1.0	.1	D182775
D182774	.03	5L	1.4	5.0	.3	2	1.5	180L	1.1	.2	D182774
D182773	.09	7L	2.7	9.4	.7	3	3	1,400	1.5L	.2	D182773
D180056	.04	N	1.7	9.8	.3	N	.7	170L	1.0L	.2	D180056
D180055	.03	N	1.0	8.2	.3	.7	.3	140L	.8L	.2	D180055
D180054	.03	N	1.2	9.7	.3	N	.7	150L	.9L	.2	D180054
D180053	.04	N	2.7	8.8	.7	1	.7	180L	1.1	.2	D180053
D180052	.15	N	4.4	9.2	5	1.5	5	270L	1.5	.4	D180052
D182784	.18	7L	6.4	6.9	1	2	2	260L	1.5L	.4	D182784
D182783	.03	3L	1.7	6.3	.3	1	1	170L	1.0L	.1	D182783
D182782	.03	N	1.1	4.6	.3	1	1	150L	.9L	.2	D182782
D182781	.11	N	1.3	6.5	.3	1.5	2	180L	1.1L	.2	D182781
D180062	.03	N	2.5	10	N	N	.7	220L	1.3L	.2	D180062
D180061	.03	N	1.3	7.9	.2	N	.5	160L	.9L	.1	D180061
D180060	.04	N	1.1	7.4	.2	N	.3	160L	.9L	.1L	D180060
D180059	.03	N	1.5	7.5	.2	N	.5	150L	.9L	.3	D180059
D180058	.03	N	2.9	6.6	.7	.7	.7	170L	1.0L	.3	D180058
D180057	.19	N	15	12	7	N	7	380L	2.2L	.7	D180057
D182780	.22	3L	2.9	5.3	.7	1	1.5	150L	.9L	.4	D182780
D182779	.03	3L	1.6	5.9	.5	1.5	1	140L	.8	.3	D182779
D182778	.03	5	1.5	7.0	.7	1.5	1.5	210	1.5	.2	D182778
D182777	.08	5L	2.6	12	.7	3	5	870	1.4L	.3	D182777
D182794	.49	70L	33	64	5	20	50	3,500L	20	2.0	D182794
D182793	.24	10L	4.9	20	3	3	10	460L	2.6	1.0	D182793
D182792	.02	N	20	19	N	30	10L	4,100L	23L	.2	D182792
D182791	.04	N	6.8	11	.7	3	2	430L	2.5L	.2	D182791
D182790	.04	N	2.1	9.7	.3	1.5	1.5	200L	1.2L	.2	D182790
D182789	.03	3L	1.6	9.4	.2	1	1	160L	.9L	.1L	D182789
D182788	.03	5L	1.4	8.6	.5	1	1	170L	1.0L	.1L	D182788
D182787	.02	N	1.8	9.2	.2	1	1	150L	.9L	.2	D182787
D182786	.03	5L	2.8	10	.7	1	1	170L	1.0	.2	D182786
D182785	.17	7L	3.0	11	3	1.5	10	260L	1.8	.8	D182785
D192402	.13	N	2.8	26	.5	2	2	320L	1.8L	.6	D192402

Table 5.--Major-, minor-, and trace-element composition of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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
D180068	1.5	0.7	700	3.0L	0.2L	20	1	0.1	1.5	10	D180068
D180067	.5	.2	500	3.0L	.2L	7	1	.1	1.6	5	D180067
D180066	.3	.3	500	3.0L	.2L	5	.7	.07	1.5	5	D180066
D180065	.5	.1	500	3.0L	.3	7	1	.1	1.5	5	D180065
D180064	1	.1	500	3.0L	.3	15	1.5	.15	1.7	7	D180064
D180063	2	1.1	500	3.0L	1.1	30	5	B	8.9	10	D180063
D182776	1	.5	200	3.0L	.4	7	3	.3	3.6	7	D182776
D182775	.7	.3	200	3.0L	.3	5	1	.15	2.6	5	D182775
D182774	1.5	.3	300	3.0L	.4	10	3	.3	3.2	10	D182774
D182773	3	.1	500	3.0L	.6	30	7	.7	6.7	10	D182773
D180056	.7	.1	700	3.0L	.2L	7	1	.1	1.8	7	D180056
D180055	.3	.1L	500	3.0L	.2L	5	1	.1	1.1	5	D180055
D180054	.5	.2	500	3.0L	.2L	7	1	.1	1.3	5	D180054
D180053	1	.2	700	3.0L	.3	15	1.5	.15	1.6	10	D180053
D180052	1.5	.8	300	3.0L	1.0	20	3	B	5.9	10	D180052
D182784	1	.6	300	3.0L	.7	10	5	.5	8.0	10	D182784
D182783	1	.5	300	3.0L	.2L	10	3	.3	2.1	7	D182783
D182782	1	.5	200	3.0L	.2L	7	2	.2	2.5	5	D182782
D182781	1.5	.4	300	3.0L	.2L	10	3	.3	3.6	7	D182781
D180062	1	.3	500	3.0L	.2L	15	1.5	.15	1.7	10	D180062
D180061	.5	.1L	500	3.0L	.2L	7	1	.1	1.7	5	D180061
D180060	.3	.2	300	3.0L	.2L	5	1	.1	1.3	5	D180060
D180059	.7	.1L	500	3.0L	.2L	7	1	.1	1.2	5	D180059
D180058	1	.2	500	3.0L	.2L	10	1	.1	1.4	7	D180058
D180057	1.5	.8	700	3.0L	1.7	20	5	B	11	15	D180057
D182780	.7	1.3	150	3.0L	.5	5	2	.2	6.0	7	D182780
D182779	1	.6	200	3.0L	.2L	7	2	.15	2.4	7	D182779
D182778	1.5	.5	300	4.4	.2L	15	3	.3	2.9	10	D182778
D182777	3	.2	500	3.0L	.5	30	5	.5	7.2	15	D182777
D182794	10	4.9	500	9.9	6.4	100	20	2	94	100	D182794
D182793	3	1.6	200	3.0L	3.3	30	10	.7	20	15	D182793
D182792	N	1.8	100	3.5	2.0	30	N	2	18	150	D182792
D182791	2	1.1	300	3.4	.4	15	3	.3	3.0	20	D182791
D182790	1.5	.5	300	3.0L	.2L	7	3	.3	2.4	7	D182790
D182789	1	.3	200	3.0L	.2L	5	2	.2	2.0	5	D182789
D182788	.7	.4	300	3.0L	.2	7	3	.3	2.3	7	D182788
D182787	.5	.5	200	3.0L	.2L	5	1.5	.15	2.1	5	D182787
D182786	1	.4	300	3.0L	.2L	10	2	.3	2.8	7	D182786
D182785	1	1.6	300	3.0L	2.3	10	5	B	8.7	10	D182785
D192402	3	.1L	150	.7	.6	15	3	.3	8.8	20	D192402

Table 5.--Major-, minor-, and trace-element composition of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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
D192403	0.79	0.35	0.47	0.11	0.32	0.018	0.095	0.031	N	0.5	D192403
D192404	.57	.36	.45	.11	.32	.016	.082	.038	N	.3	D192404
D192405	2.1	1.1	.44	.14	.28	.12	1.2	.065	N	21	D192405
D192406	.46	.47	.48	.11	.29	.017	.19	.044	N	1.5	D192406
D192407	1.2	.30	.41	.11	.22	.012	.084	.037	N	.4	D192407
D192408	.91	.73	.67	.13	.14	.030	.13	.079	N	.4	D192408
D160668	.87	.24	.59	.26	.060	.011	.12	B	N	1.0	D160668
D160669	.22	.26	.55	.25	.049	.011	.13	B	N	1.0	D160669
D160670	.82	.68	.54	.24	.050	.080	.20	B	N	3.0	D160670
D161317	.57	.40	.48	.077	.24	.021	.24	B	N	3.0	D161317
D161318	.58	.40	.49	.078	.24	.022	.28	B	N	4.0	D161318
D161319	.66	.44	.49	.075	.24	.027	.31	B	N	5.0	D161319

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
D192403	30	500	N	0.09	0.5	2	4.6	25	2	N	D192403
D192404	20	500	N	.04L	.7	2	5.3	25	3	N	D192404
D192405	20	700	.3	.48	10	10	26	65	7	N	D192405
D192406	15	500	N	.05L	.5	1.5	9.3	25	2	N	D192406
D192407	20	500	N	.10	1.5	3	13	20	3	N	D192407
D192408	30	300	N	.19	.7	3	8.0	20	2	N	D192408
D160668	30	300	N	.05L	.7	2	11	30	1	N	D160668
D160669	20	300	N	.03L	.5	1.5	6.2	20	1	N	D160669
D160670	20	500	.2	.11	1	5	10	30	2	N	D160670
D161317	30	500	.15	B	.7	3	8.6	B	1.5	N	D161317
D161318	30	500	.15	.05	1	3	8.2	50	1.5	N	D161318
D161319	30	500	.15	B	.7	3	9.2	B	1.5	N	D161319

Table 5.--Major-, minor-, and trace-element composition of 50 coal and 2 shale samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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
D192403	0.01	N	2.2	17	N	N	1	210L	1.2L	0.1	D192403
D192404	.01	N	3.4	16	.7	N	1.5	180L	1.1	.1	D192404
D192405	.62	10L	22	34	10	2	20	520L	4.2	2.1	D192405
D192406	.18	N	4.7	18	.7	N	1	230L	1.3L	.1	D192406
D192407	.02	N	6.1	17	.3	1	1.5	210L	1.2L	.1	D192407
D192408	.02	N	2.8	17	N	1.5	1.5	280L	1.6L	.1	D192408
D160668	.04	N	1.4	4.6	2	1	.7	140	14	3.8	D160668
D160669	.03	N	1.0	5.1	1	N	.5	650	6.7	1.9	D160669
D160670	.11	5	3.1	7.1	3	N	5	1,200	8.5	1.8	D160670
D161317	.10	3	4.4	7.1	1.5	1	3	230	2.3	B	D161317
D161318	.11	3	4.4	15	1.5	1	3	260	2.4	.3	D161318
D161319	.11	3	5.3	8.0	1.5	1	3	310	2.6	B	D161319

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
D192403	1	0.3	150	0.4	0.6	5	1.5	0.15	14	7	D192403
D192404	1.5	.3	200	.5	.9	7	1.5	.15	14	7	D192404
D192405	3	5.6	200	2.3	6.7	30	10	B	22	20	D192405
D192406	1	1.0	150	.6	.8	7	1.5	.15	7.9	7	D192406
D192407	2	.3	200	.5	.2L	15	2	.2	6.0	10	D192407
D192408	1.5	.4	200	.7	.7	7	2	.2	11	20	D192408
D160668	.7	.2	200	3.0L	.2L	7	1.5	.15	3.8	10	D160668
D160669	.5	.1L	200	3.0L	.2L	5	.7	.07	3.2	3	D160669
D160670	1	.6	200	3.0L	1.2	10	3	.2	17	7	D160670
D161317	1.5	.4	300	3.0L	.6	10	2	.15	3.8	10	D161317
D161318	1.5	.6	300	3.0L	.6	15	3	.15	4.5	10	D161318
D161319	1.5	.9	300	3.0L	.8	10	3	.15	5.8	10	D161319

Table 6.--Elements looked for, but not detected, in coal and shale samples from Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn 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
Dy	100
Er	100
Eu	200
Gd	100
Hf	200
Ho	50
In	20
Lu	70
Pd	5
Pr	200
Pt	100
Re	100
Sm	200
Sn	20
Ta	1,000
Tb	700
Te	5,000
Tl	100
Tm	50
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 27 coal samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn County, Mont.

[For comparison geometric means from 33 Powder River region Montana and Wyoming coal 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.  $^{\circ}\text{C} = (^{\circ}\text{F}-32)5/9$ ;  $\text{Kcal/kg} = 0.556(\text{Btu/lb})$ . Leaders (---) indicate no data. L, less than the value shown.]

	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
Proximate and ultimate analyses						
Moisture	23.6	18.1	29.6	23.4	1.1	23.1
Volatile matter	30.9	26.0	32.8	30.9	1.1	32.0
Fixed carbon	40.4	28.4	43.9	40.2	1.1	36.0
Ash	4.9	2.9	27.5	4.4	1.6	7.5
Hydrogen	6.3	5.0	6.9	6.3	1.1	6.2
Carbon	53.8	38.4	57.1	53.6	1.1	50.3
Nitrogen	.8	.6	1.0	.8	1.2	.9
Oxygen	33.3	25.8	38.4	33.2	1.1	32.9
Sulfur	.57	.2	2.4	.43	2.1	.8
Heat of combustion						
Kcal/kg	5,160	3,830	5,490	5,140	1.1	4,860
Btu/lb	9,280	6,890	9,880	9,250	1.1	8,740
Forms of sulfur						
Sulfate	0.04	0.01L	0.47	0.02	2.8	0.02
Pyritic	.16	.01	1.14	.08	3.3	.29
Organic	.39	.15	1.01	.31	2.0	.31
Ash-fusion temperatures, °C						
Initial deformation	1,160	1,060	1,270	1,160	1.0	---
Softening temperature	1,200	1,080	1,320	1,200	1.0	---
Fluid temperature	1,250	1,110	1,370	1,240	1.1	---

Table 8.--Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of 10 major and minor oxides in the laboratory ash of 50 coal samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn County, Mont.

[For comparison geometric means for 410 Powder River region coal 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 means could not be calculated owing to an insufficient number of analyses above the lower detection limit.]

Oxide	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
(Ash)	4.9	3.2	12.0	4.7	1.4	9.0
SiO <sub>2</sub>	24	11	55	22	1.5	28
Al <sub>2</sub> O <sub>3</sub>	14	8.6	22	14	1.2	14
CaO	18	5.2	30	17	1.4	15
MgO	3.5	1.7	12	3.3	1.4	3.6
Na <sub>2</sub> O	8.6	.76	14	7.0	1.9	.93
K <sub>2</sub> O	.36	.15	1.4	.30	1.8	.28
Fe <sub>2</sub> O <sub>3</sub>	5.2	2.0	24	4.6	1.6	5.8
TiO <sub>2</sub>	1.5	.82	2.6	1.5	1.3	.61
SO <sub>3</sub>	16	8.1	28	15	1.4	14
P <sub>2</sub> O <sub>5</sub>	---	.7L	5.3	---	---	---

Table 9.--Arithmetic mean, observed range, geometric mean and geometric deviation of 35 elements in 50 coal samples from the Tongue River Member, Fort Union Formation, Decker coal deposit, Big Horn County, Mont.

[For comparison geometric means for 410 Powder River region, Montana and Wyoming coal 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 means could not be calculated owing to an insufficient number of analyses above the lower detection limit.]

Element	Arithmetic mean	Observed range		Geometric mean	Geometric deviation	Powder River region geometric mean
		Minimum	Maximum			
		Percent				
Si	0.58	0.16	2.5	0.48	1.9	1.2
Al	.38	.18	1.1	.35	1.5	.66
Ca	.57	.40	.93	.55	1.3	.98
Mg	.10	.050	.26	.093	1.4	.20
Na	.27	.050	.34	.24	1.6	.063
K	.02	.005	.12	.012	2.3	.022
Fe	.19	.075	1.2	.15	1.9	.37
Ti	.04	.023	.11	.041	1.5	.035
P	---	.01L	.14	---	---	---
Parts per million						
As	2.4	0.3L	21	0.3	8.1	2
B	20	15	50	20	1.3	50
Ba	700	300	1,000	700	1.4	300
Be	.15	.15L	1	.07	3.3	.5
Cd	.04	.04L	.48	.02	4.1	.04
Co	1	.2	10	.7	2.0	2
Cr	3	1	10	2	1.8	5
Cu	8.8	2.7	26	7.5	1.7	9.5
F	41	20L	90	38	1.4	40
Ga	2	.7	7	1.5	1.8	2
Hg	.08	.01	.62	.05	2.4	.08
Li	3.1	1	23	2.5	2.0	3.9
Mn	10	4.6	34	9.1	1.6	34
Mo	1	.2L	10	.7	3.0	1.5
Nb	1	.7L	3	1	1.8	1
Ni	2	.3	20	1.5	2.5	3
Pb	1.3	.8L	14	.5	4.2	5.1
Sb	.4	.1L	3.8	.3	2.6	.4
Sc	1.5	.3	3	1	1.8	1.5
Se	.6	.1L	5.6	.4	2.6	.7
Sr	300	150	700	300	1.6	150
Th	---	.4L	4.4	---	---	3.3
U	.6	.2L	6.7	.3	3.8	.6
V	10	5	30	10	1.7	10
Y	3	.7	10	2	1.9	3
Yb	.2	.07	.7	.2	1.8	.3
Zn	5.1	1.1	22	3.7	2.3	12.5
Zr	10	3	20	7	1.5	15



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