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# Chemical analyses of coal and coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming

By

Joseph R. Hatch and Ronald H. Affolter



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## Introduction

As part of a continuing program by the U.S. Geological Survey to collect and analyze representative samples of U.S. coals, 26 coal and 5 coal-associated shale samples were collected from 13 core and rotary-drill holes in the lower part of the Paleocene Fort Union Formation in the Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming (fig. 1). The samples are briefly described in table 1. Twenty-six of the samples were collected from eight core holes that were drilled in connection with the Red Rim EMRIA (Energy Mineral Rehabilitation Inventory and Analyses) study (U.S. Department of the Interior, 1976). The locations of these eight holes and five other drill holes are shown in figure 2.

Detailed geologic mapping of part of the sample collection area was done by Sanders (1974) in his work on the Riner quadrangle. Seven of the core holes (index map locations 1-7) are located in this quadrangle. In his discussion, Sanders (1974) describes the coal beds in the lower part of the Fort Union Formation as being thin, discontinuous, and generally lenticular. Few beds attain a thickness of more than five feet. In the Riner quadrangle coal beds in the lower part of the Fort Union Formation dip 12° to 24° northwestward.

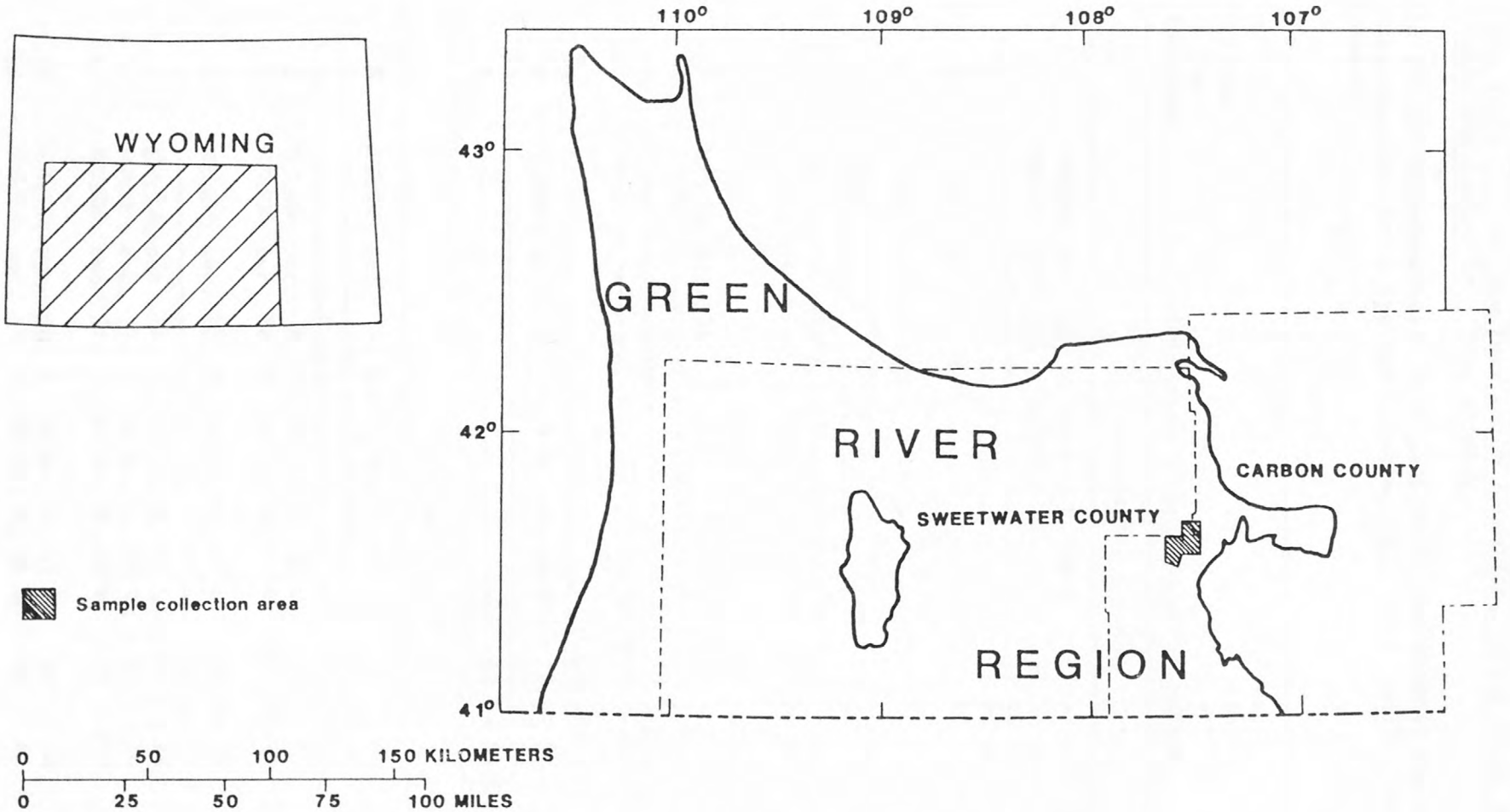


Figure 1.--Map of southwestern Wyoming showing the location of the sample collection area and an outline of the Green River coal region. Map modified from Averitt (1942)

Table 1.--U.S. Geological Survey sample numbers, index map locations, locations, depth intervals represented, and descriptions for 26 coal and 5 coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming

[All coals are of Paleocene age. Samples D180032 and D180035 through D180038 are from rotary drill cuttings from above the water table. All other samples are from cores. One foot = 0.3048 meter]

| USGS sample number | Index map location | Location | Depth interval represented in feet | Description |
|---|---|---|---|---|
| | | Sweetwater County | | |
| D178449 | 1 | SE¼SE¼ sec. 28, T. 20 N., R. 90 W. | 81.3- 87.7 | Coal D1 bed. |
| D178458 | 2 | NW¼NW¼ sec. 34, T. 20 N., R. 90 W. | 36.3- 37.9 | Shale, coaly, E coal zone. |
| D178457 | 2 | ----------do---------- | 37.9- 38.9 | Coal, E coal zone. |
| D178477 | 2 | ----------do---------- | 38.9- 39.2 | Shale, coaly, E coal zone. |
| D178456 | 2 | ----------do---------- | 39.2- 41.0 | Coal, E coal zone. |
| D178459 | 2 | ----------do---------- | 41.7- 43.9 | Do. |
| D178463 | 2 | ----------do---------- | 151.0-154.0 | Coal F1 bed. |
| D178462 | 2 | ----------do---------- | 154.0-158.0 | Coal, shaley, F1 bed. |
| D178461 | 2 | ----------do---------- | 158.0-163.3 | Coal, F1 bed. |
| D178478 | 2 | ----------do---------- | 163.3-164.7 | Shale, coaly, F1 bed. |
| D178460 | 2 | ----------do---------- | 164.7-167.0 | Coal, F1 bed. |
| D178452 | 3 | NW¼SW¼ sec. 34, T. 20 N., R. 90 W. | 125.3-126.8 | Coal, F2 bed rider. |
| D178453 | 3 | ----------do---------- | 129.5-130.5 | Coal F2 bed. |
| D178476 | 3 | ----------do---------- | 130.5-130.7 | Shale, coaly, F2 bed. |
| D178454 | 3 | ----------do---------- | 130.7-135.9 | Coal, F2 bed. |
| D178455 | 3 | ----------do---------- | 135.9-141.0 | Do. |
| D178465 | 4 | SE¼NW¼ sec. 4, T. 19 N., R. 90 W. | 77.8- 82.9 | Coal, F2 bed. |
| D178479 | 4 | ----------do---------- | 82.9- 83.4 | Shale, coaly, F2 bed. |
| D178464 | 4 | ----------do---------- | 83.4- 88.8 | Coal, F2 bed. |
| | | Carbon County | | |
| D178467 | 5 | SW¼SW¼ sec. 4, T. 19 N., R. 90 W. | 31.5- 36.0 | Coal, G coal zone. |
| D178468 | 5 | ----------do---------- | 42.0- 44.1 | Do. |
| D178469 | 5 | ----------do---------- | 137.0-138.5 | Coal, shaley, H coal zone. |
| D178471 | 6 | NE¼NW¼ sec. 8, T. 19 N., R. 90 W. | 40.2- 45.2 | Coal, F2 bed. |
| D176221 | 7 | NE¼NE¼ sec. 18, T. 19 N., R. 90 W. | 185.0-190.0 | Coal, shaley, G coal zone. |
| D178450 | 8 | NE¼NW¼ sec. 18, T. 19 N., R. 90 W. | 53.7- 57.7 | Coal, E coal zone. |
| D178451 | 8 | ----------do---------- | 82.2- 85.7 | Do. |
| D180032 | 9 | SW¼SW¼ sec. 14, T. 18 N., R. 91 W. | 74 - 78 | Coal, uncorrelated bed. |
| D180035 | 10 | NW¼NE¼ sec. 22, T. 18 N., R. 91 W. | 89 -110 | Do. |
| D180036 | 11 | NE¼SW¼ sec. 22, T. 18 N., R. 91 W. | 239 -243 | Do. |
| D180037 | 12 | NW¼NE¼ sec. 28, T. 18 N., R. 91 W. | 62 - 70 | Do. |
| D180038 | 13 | NE¼SW¼ sec. 28, T. 18 N., R. 91 W. | 46 - 63 | Do. |

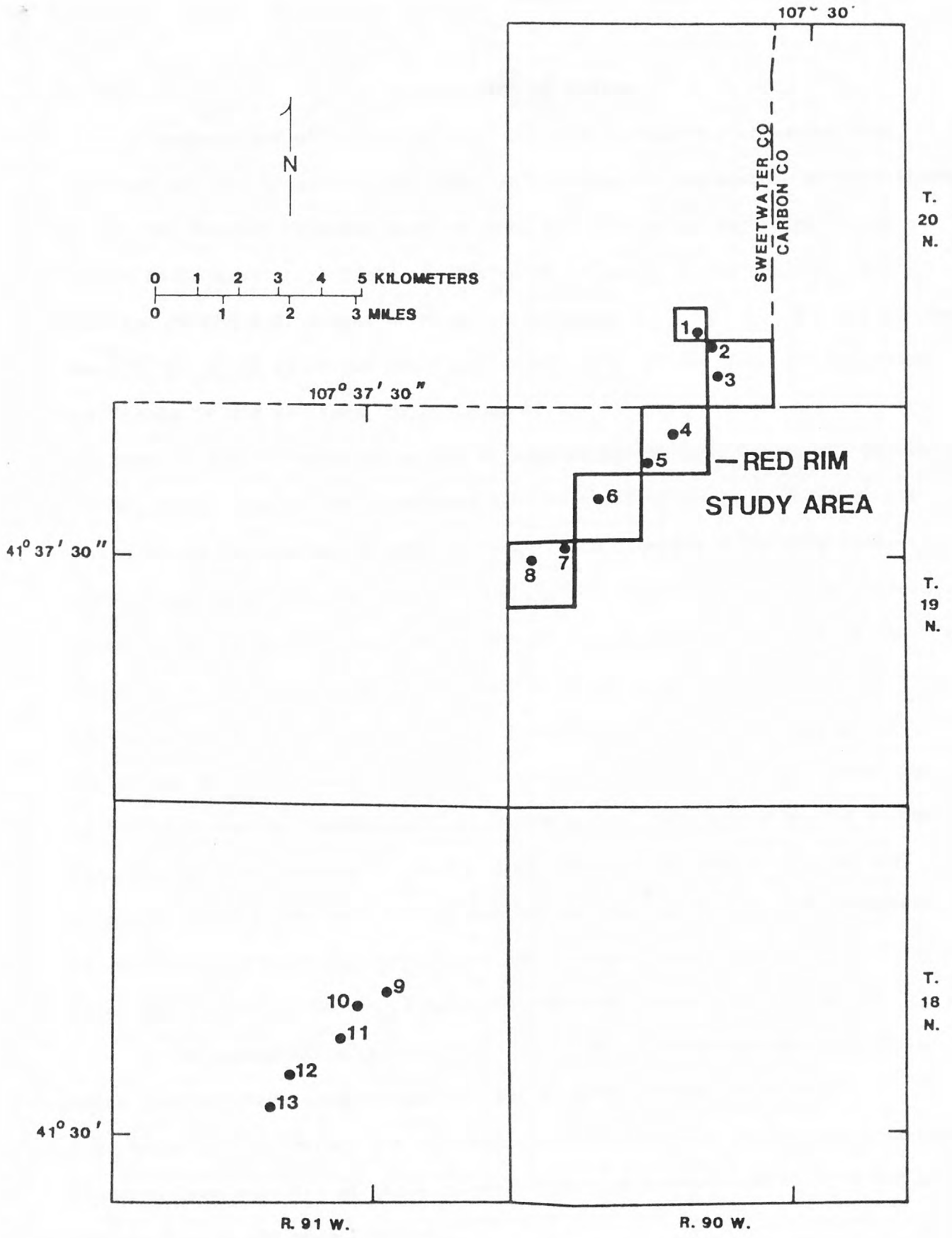


Figure 2.--Map of the sample collection area in Sweetwater and Carbon Counties Wyoming showing the locations of core and drill holes and an outline of the Red Rim EMRIA study area.

## Explanation of Tables

Proximate and ultimate analyses, heat-of-combustion, air-dried-loss, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations on 26 coal samples from the lower part of the Fort Union Formation in the Little Snake River coal field are listed in table 2. These analyses were provided by the U.S. Bureau of Mines, Pittsburgh, Pa. Analyses for ash content and content of 38 major and minor oxides and trace elements in the laboratory ash (table 3) and analyses for contents of seven trace elements in whole coal and shale (table 4) were run on all 31 samples 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 and whole-rock basis plus for completeness, the analyses listed in table 4. Twenty-two additional elements not listed in tables 3, 4, and 5 were looked for but not found in amounts greater than their lower limits of detection (table 6). Unweighted statistical summaries of analytical data for the 26 coal samples in tables 2, 3, and 5 are listed in tables 7, 8, and 9, respectively. For comparison, data summaries for Powder River region coal samples are included in tables 7, 8, and 9. Statistical summaries for $P_2O_5$ content in coal ash and for Ag, Ce, Ge, Nd, and P contents in coal were not included in tables 8 and 9 respectively as these were detected in an insufficient number of samples to calculate meaningful statistics.

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

## Explanation of statistical terms used in summary tables

In this report the geometric mean (GM) is used as the estimate of the most probable concentration (mode); the geometric mean is calculated by taking the logarithm of each analytical value, summing the logarithms, dividing the sum by the total number of values, and obtaining the antilogarithm of the result. The measure of scatter about the mode used here is the geometric deviation (GD), which is the antilog of the standard deviation of the logarithms of the analytical values. These statistics are used because the quantities of trace elements in natural materials commonly exhibit positively skewed frequency distributions; such distributions are normalized by analyzing and summarizing trace-element data on a logarithmic basis.

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

Although the geometric mean is, in general, an adequate estimate of the most common analytical value, it is, nevertheless, a biased estimate of the arithmetic mean. The estimates of the arithmetic means listed in the summary tables are Sichel's $\underline{t}$ 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 lower part of the Fort Union Formation, Little Snake River coal field, were calculated using the data in table 2 and the formulas in ASTM designation D-388-77 (American Society for Testing and Materials, 1978). The apparent ranks range from lignite A (1 sample), to subbituminous C coal (24 samples) to subbituminous B coal (1 sample). The subbituminous B coal sample (D178459) has a lower moisture content then the rest of the samples (17.9 percent vs an average of 24.0 percent for the other samples). This is due to drying of the sample because of incorrect storing procedures and probably accounts for the relatively higher apparent rank.

A statistical comparison (student's t test, 95-percent confidence level) of the geometric mean contents of the U.S. Bureau of Mines data for the 26 Fort Union Formation coal samples from the Little Snake River coal field with data for 33 Powder River region coal samples shows that the Little Snake River coal field samples have significantly higher contents of ash, sulfate, and organic sulfur, a significantly lower heat of combustion, and significantly lower contents of volatile matter, hydrogen, carbon, nitrogen, and pyritic sulfur. The contents of moisture, fixed carbon, oxygen, and total sulfur are not significantly different. When compared at the 99-percent confidence level, the contents of carbon and sulfate sulfur 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 26 Fort Union Formation coal samples from the Little Snake River coal field with analyses of ash from 410 Powder River region coal samples shows that the Little Snake River coal field samples have a significantly higher ash content, higher $SiO_2$, and $K_2O$ contents in ash and significantly lower CaO, MgO, and

$Na_2O$ contents in ash. The contents of $Al_2O_3$, $Fe_2O_3$, $TiO_2$, and $SO_3$ in ash are not significantly different.

A statistical comparison of the geometric mean contents of 36 elements in 26 Fort Union Formation coal samples from the Little Snake River coal field with analyses of 410 Powder River region coal samples shows that the Little Snake River coal field samples have significantly higher contents of Si, Al, Mg, K, Fe, Ti, B, Be, Cd, Cr, Ga, Li, Mn, Mo, Nb, Ni, Sb, U, V, Y, and Yb and significantly lower contents of Na and Ba. The contents of Ca, As, Co, Cu, F, Hg, Pb, Sc, Se, Sr, Th, Zn, and Zr are not significantly different.

Zinc contents of samples D180032 and D180035 - D180038 are relatively high; averaging 170 ppm Zn versus an average of 37 ppm Zn for all 26 samples. These five samples are of coal cuttings from holes drilled with air and we suspect zinc contamination from a zinc-based pipe dope, commonly used as a lubricant and sealer.

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 have been made for coal beds from the Little Snake River coal field.

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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 26 coal samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming

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

| Sample number | Proximate analysis | | | | Ultimate analysis | | | | | Heat of combustion | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | Moisture | Volatile matter | Fixed carbon | Ash | Hydrogen | Carbon | Nitrogen | Oxygen | Sulfur | Kcal/kg | Btu/lb |
| D178449 | 26.1 | 23.8 | 32.7 | 17.4 | 5.7 | 43.0 | 0.6 | 32.7 | 0.6 | 4,010 | 7,220 |
| | --- | 32.2 | 44.2 | 23.5 | 3.8 | 58.2 | .8 | 12.9 | .8 | 5,430 | 9,770 |
| | --- | 42.1 | 57.9 | --- | 5.0 | 76.1 | 1.1 | 16.8 | 1.1 | 7,100 | 12,780 |
| D178457 | 25.1 | 27.7 | 39.2 | 8.0 | 5.9 | 49.1 | .7 | 34.6 | 1.7 | 4,610 | 8,300 |
| | --- | 37.0 | 52.3 | 10.7 | 4.2 | 65.6 | .9 | 16.4 | 2.3 | 6,160 | 11,080 |
| | --- | 41.4 | 58.6 | --- | 4.7 | 73.4 | 1.0 | 18.4 | 2.5 | 6,890 | 12,410 |
| D178456 | 26.2 | 27.3 | 40.3 | 6.2 | 6.0 | 50.3 | .9 | 35.5 | 1.1 | 4,730 | 8,510 |
| | --- | 37.0 | 54.6 | 8.4 | 4.2 | 68.2 | 1.2 | 16.5 | 1.5 | 6,410 | 11,530 |
| | --- | 40.4 | 59.6 | --- | 4.6 | 74.4 | 1.3 | 18.1 | 1.6 | 6,990 | 12,590 |
| D178459 | 17.9 | 29.0 | 36.8 | 16.3 | 5.0 | 48.3 | .7 | 28.8 | .9 | 4,520 | 8,140 |
| | --- | 35.3 | 44.8 | 19.9 | 3.7 | 58.8 | .9 | 15.7 | 1.1 | 5,510 | 9,910 |
| | --- | 44.1 | 55.9 | --- | 4.6 | 73.4 | 1.1 | 19.6 | 1.4 | 6,870 | 12,370 |
| D178463 | 22.9 | 27.6 | 38.5 | 11.0 | 5.8 | 49.2 | .8 | 32.0 | 1.2 | 4,580 | 8,250 |
| | --- | 35.8 | 49.9 | 14.3 | 4.2 | 63.8 | 1.0 | 15.1 | 1.6 | 5,940 | 10,700 |
| | --- | 41.8 | 58.2 | --- | 4.9 | 74.4 | 1.2 | 17.6 | 1.8 | 6,930 | 12,480 |
| D178462 | 21.2 | 23.7 | 31.6 | 23.5 | 5.1 | 41.0 | .5 | 29.1 | .8 | 3,770 | 6,790 |
| | --- | 30.1 | 40.1 | 29.8 | 3.5 | 52.0 | .6 | 13.0 | 1.0 | 4,790 | 8,620 |
| | --- | 42.9 | 57.1 | --- | 5.0 | 74.1 | .9 | 18.5 | 1.4 | 6,820 | 12,280 |
| D178461 | 23.5 | 28.8 | 39.6 | 8.1 | 6.0 | 51.6 | .6 | 33.0 | .7 | 4,790 | 8,620 |
| | --- | 37.6 | 51.8 | 10.6 | 4.4 | 67.5 | .8 | 15.8 | .9 | 6,260 | 11,270 |
| | --- | 42.1 | 57.9 | --- | 5.0 | 75.4 | .9 | 17.7 | 1.0 | 7,000 | 12,600 |
| D178460 | 26.5 | 23.7 | 36.7 | 13.1 | 5.5 | 44.5 | .6 | 35.3 | 1.0 | 4,140 | 7,460 |
| | --- | 32.2 | 49.9 | 17.8 | 3.5 | 60.5 | .8 | 16.0 | 1.4 | 5,640 | 10,150 |
| | --- | 39.2 | 60.8 | --- | 4.2 | 73.7 | 1.0 | 19.4 | 1.7 | 6,860 | 12,350 |
| D178452 | 25.8 | 34.0 | 34.1 | 6.1 | 6.4 | 51.0 | .6 | 35.2 | .7 | 4,860 | 8,750 |
| | --- | 45.8 | 46.0 | 8.2 | 4.8 | 68.7 | .8 | 16.5 | .9 | 6,550 | 11,790 |
| | --- | 49.9 | 50.1 | --- | 5.2 | 74.9 | .9 | 18.0 | 1.0 | 7,140 | 12,850 |
| D178453 | 24.5 | 28.2 | 39.6 | 7.7 | 5.7 | 50.9 | .7 | 34.7 | .3 | 4,740 | 8,540 |
| | --- | 37.4 | 52.5 | 10.2 | 3.9 | 67.4 | .9 | 17.1 | .4 | 6,280 | 11,310 |
| | --- | 41.6 | 58.4 | --- | 4.4 | 75.1 | 1.0 | 19.1 | .4 | 7,000 | 12,600 |
| D178454 | 23.2 | 29.6 | 40.1 | 7.1 | 5.7 | 51.6 | .5 | 34.8 | .3 | 4,770 | 8,590 |
| | --- | 38.5 | 52.2 | 9.2 | 4.1 | 67.2 | .7 | 18.5 | .4 | 6,210 | 11,180 |
| | --- | 42.5 | 57.5 | --- | 4.5 | 74.0 | .7 | 20.3 | .4 | 6,850 | 12,320 |
| D178455 | 22.4 | 29.3 | 37.1 | 11.2 | 5.6 | 48.8 | .5 | 33.3 | .6 | 4,570 | 8,220 |
| | --- | 37.8 | 47.8 | 14.4 | 4.0 | 62.9 | .6 | 17.3 | .8 | 5,880 | 10,590 |
| | --- | 44.1 | 55.9 | --- | 4.7 | 73.5 | .8 | 20.2 | .9 | 6,880 | 12,380 |

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 26 coal samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming--Continued

| Sample number | Air-dried loss | Forms of sulfur | | | Free swelling | Ash fusion temperature, °C | | |
|---|---|---|---|---|---|---|---|---|
| | | Sulfate | Pyritic | Organic | | Initial deformation | Softening | Fluid |
| D178449 | 9.2 | 0.02 | 0.05 | 0.55 | 0.0 | 1,130 | 1,230 | 1,355 |
| | --- | .03 | .07 | .74 | | | | |
| | --- | .04 | .09 | .97 | | | | |
| D178457 | 5.7 | .02 | .08 | 1.55 | .0 | 1,065 | 1,105 | 1,165 |
| | --- | .03 | .11 | 2.07 | | | | |
| | --- | .03 | .12 | 2.32 | | | | |
| D178456 | 7.4 | .02 | .05 | 1.05 | .0 | 1,105 | 1,150 | 1,160 |
| | --- | .03 | .07 | 1.42 | | | | |
| | --- | .03 | .07 | 1.55 | | | | |
| D178459 | 1.7 | .09 | .06 | .75 | .0 | 1,295 | 1,345 | 1,400 |
| | --- | .11 | .07 | .91 | | | | |
| | --- | .14 | .09 | 1.14 | | | | |
| D178463 | 3.6 | .06 | .03 | 1.11 | .0 | 1,155 | 1,195 | 1,215 |
| | --- | .08 | .04 | 1.44 | | | | |
| | --- | .09 | .05 | 1.68 | | | | |
| D178462 | 7.9 | .04 | .07 | .71 | .0 | 1,215 | 1,290 | 1,355 |
| | --- | .05 | .09 | .90 | | | | |
| | --- | .07 | .13 | 1.28 | | | | |
| D178461 | 5.1 | .07 | .13 | .51 | .0 | 1,140 | 1,180 | 1,210 |
| | --- | .09 | .17 | .67 | | | | |
| | --- | .10 | .19 | .75 | | | | |
| D178460 | 7.4 | .05 | .05 | .86 | .0 | 1,130 | 1,180 | 1,215 |
| | --- | .07 | .07 | 1.17 | | | | |
| | --- | .08 | .08 | 1.42 | | | | |
| D178452 | 6.1 | .07 | .13 | .51 | .0 | 1,115 | 1,140 | 1,160 |
| | --- | .09 | .18 | .69 | | | | |
| | --- | .10 | .19 | .75 | | | | |
| D178453 | 5.8 | .02 | .13 | .18 | .0 | 1,155 | 1,190 | 1,220 |
| | --- | .03 | .17 | .24 | | | | |
| | --- | .03 | .19 | .27 | | | | |
| D178454 | 4.3 | .02 | .06 | .21 | .0 | 1,190 | 1,240 | 1,260 |
| | --- | .03 | .08 | .27 | | | | |
| | --- | .03 | .09 | .30 | | | | |
| D178455 | 5.1 | .02 | .06 | .53 | .0 | 1,080 | 1,120 | 1,155 |
| | --- | .03 | .08 | .68 | | | | |
| | --- | .03 | .09 | .80 | | | | |

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 26 coal samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming--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 |
| D178465 | 24.7 | 27.5 | 39.7 | 8.1 | 6.0 | 49.9 | 0.7 | 34.9 | 0.4 | 4,600 | 8,280 |
| | --- | 36.5 | 52.7 | 10.8 | 4.3 | 66.3 | .9 | 17.2 | .5 | 6,110 | 11,000 |
| | --- | 40.9 | 59.1 | --- | 4.8 | 74.3 | 1.0 | 19.3 | .6 | 6,850 | 12,320 |
| D178464 | 23.2 | 29.8 | 38.9 | 8.1 | 5.9 | 50.4 | .6 | 34.3 | .7 | 4,680 | 8,430 |
| | --- | 38.8 | 50.7 | 10.5 | 4.3 | 65.6 | .8 | 17.8 | .9 | 6,100 | 10,980 |
| | --- | 43.4 | 56.6 | --- | 4.8 | 73.4 | .9 | 19.9 | 1.0 | 6,820 | 12,270 |
| D178467 | 30.0 | 24.2 | 33.2 | 12.6 | 6.3 | 42.5 | .6 | 37.1 | .9 | 3,980 | 7,160 |
| | --- | 34.6 | 47.4 | 18.0 | 4.2 | 60.7 | .9 | 14.9 | 1.3 | 5,680 | 10,230 |
| | --- | 42.2 | 57.8 | --- | 5.2 | 74.0 | 1.0 | 18.2 | 1.6 | 6,930 | 12,470 |
| D178468 | 23.7 | 26.5 | 37.1 | 12.7 | 5.7 | 47.2 | .6 | 32.6 | 1.2 | 4,390 | 7,910 |
| | --- | 34.7 | 48.6 | 16.6 | 4.0 | 61.9 | .8 | 15.1 | 1.6 | 5,760 | 10,370 |
| | --- | 41.7 | 58.3 | --- | 4.8 | 74.2 | .9 | 18.1 | 1.9 | 6,910 | 12,440 |
| D178469 | 29.7 | 21.6 | 30.7 | 18.0 | 5.9 | 39.0 | .5 | 36.2 | .4 | 3,600 | 6,480 |
| | --- | 30.7 | 43.7 | 25.6 | 3.7 | 55.5 | .7 | 13.9 | .6 | 5,120 | 9,220 |
| | --- | 41.3 | 58.7 | --- | 5.0 | 74.6 | 1.0 | 18.7 | .8 | 6,880 | 12,390 |
| D178471 | 25.6 | 25.8 | 36.8 | 11.8 | 5.9 | 45.6 | .5 | 35.8 | .4 | 4,220 | 7,590 |
| | --- | 34.7 | 49.5 | 15.9 | 4.1 | 61.3 | .7 | 17.5 | .5 | 5,670 | 10,200 |
| | --- | 41.2 | 58.8 | --- | 4.9 | 72.8 | .8 | 20.8 | .6 | 6,740 | 12,120 |
| D176221 | 20.5 | 24.8 | 24.2 | 30.5 | 4.7 | 35.0 | .5 | 28.9 | .4 | 3,180 | 5,720 |
| | --- | 31.2 | 30.4 | 38.4 | 3.0 | 44.0 | .6 | 13.4 | .5 | 4,000 | 7,190 |
| | --- | 50.6 | 49.4 | --- | 4.9 | 71.4 | 1.0 | 21.8 | .8 | 6,490 | 11,670 |
| D178450 | 24.5 | 29.2 | 39.1 | 7.2 | 5.6 | 50.4 | .7 | 35.3 | .8 | 4,680 | 8,420 |
| | --- | 38.7 | 51.8 | 9.5 | 3.8 | 66.8 | .9 | 17.9 | 1.1 | 6,200 | 11,150 |
| | --- | 42.8 | 57.2 | --- | 4.2 | 73.8 | 1.0 | 19.8 | 1.2 | 6,850 | 12,330 |
| D178451 | 23.5 | 26.5 | 31.9 | 18.1 | 5.1 | 42.0 | .7 | 32.4 | 1.7 | 3,950 | 7,110 |
| | --- | 34.6 | 41.7 | 23.7 | 3.3 | 54.9 | .9 | 15.0 | 2.2 | 5,160 | 9,290 |
| | --- | 45.4 | 54.6 | --- | 4.3 | 71.9 | 1.2 | 19.7 | 2.9 | 6,760 | 12,170 |
| D180032 | 25.2 | 27.9 | 36.9 | 10.0 | 5.9 | 46.9 | .7 | 36.0 | .5 | 4,340 | 7,810 |
| | --- | 37.3 | 49.3 | 13.4 | 4.1 | 62.7 | .9 | 18.2 | .7 | 5,800 | 10,440 |
| | --- | 43.1 | 56.9 | --- | 4.8 | 72.4 | 1.1 | 21.0 | .8 | 6,700 | 12,060 |
| D180035 | 23.4 | 29.2 | 36.8 | 10.6 | 5.6 | 48.1 | .7 | 34.5 | .6 | 4,450 | 8,010 |
| | --- | 38.1 | 48.0 | 13.8 | 3.9 | 62.8 | .9 | 17.9 | .8 | 5,810 | 10,460 |
| | --- | 44.2 | 55.8 | --- | 4.5 | 72.9 | 1.1 | 20.8 | .9 | 6,740 | 12,130 |
| D180036 | 20.5 | 30.0 | 38.2 | 11.3 | 5.5 | 49.5 | .8 | 31.5 | 1.4 | 4,550 | 8,200 |
| | --- | 37.7 | 48.1 | 14.2 | 4.1 | 62.3 | 1.0 | 16.7 | 1.8 | 5,730 | 10,310 |
| | --- | 44.0 | 56.0 | --- | 4.7 | 72.6 | 1.2 | 19.5 | 2.1 | 6,680 | 12,020 |

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 26 coal samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming--Continued

| Sample number | Air-dried loss | Forms of sulfur | | | Free swelling | Ash fusion temperature, °C | | |
|---|---|---|---|---|---|---|---|---|
| | | Sulfate | Pyritic | Organic | | Initial deformation | Softening | Fluid |
| D178465 | 7.9 | 0.02 | 0.08 | 0.31 | 0.0 | 1,155 | 1,190 | 1,215 |
| | --- | .03 | .11 | .41 | | | | |
| | --- | .03 | .12 | .46 | | | | |
| D178464 | 7.1 | .02 | .07 | .56 | .0 | 1,065 | 1,120 | 1,140 |
| | --- | .03 | .09 | .73 | | | | |
| | --- | .03 | .10 | .82 | | | | |
| D178467 | 14.8 | .02 | .02 | .85 | .0 | 1,185 | 1,230 | 1,250 |
| | --- | .03 | .03 | 1.21 | | | | |
| | --- | .03 | .03 | 1.48 | | | | |
| D178468 | 7.1 | .03 | .10 | 1.12 | .0 | 1,105 | 1,145 | 1,155 |
| | --- | .04 | .13 | 1.47 | | | | |
| | --- | .05 | .16 | 1.76 | | | | |
| D178469 | 14.1 | .04 | .02 | .33 | .0 | 1,180 | 1,250 | 1,270 |
| | --- | .06 | .03 | .47 | | | | |
| | --- | .08 | .04 | .63 | | | | |
| D178471 | 6.9 | .02 | .02 | .37 | .0 | 1,195 | 1,235 | 1,255 |
| | --- | .03 | .03 | .50 | | | | |
| | --- | .03 | .03 | .59 | | | | |
| D176221 | 11.4 | .03 | .05 | .35 | .0 | 1,210 | 1,240 | 1,265 |
| | --- | .04 | .06 | .44 | | | | |
| | --- | .06 | .10 | .71 | | | | |
| D178450 | 6.8 | .02 | .42 | .37 | .0 | 1,150 | 1,175 | 1,195 |
| | --- | .03 | .56 | .49 | | | | |
| | --- | .03 | .61 | .54 | | | | |
| D178451 | 5.1 | .02 | .33 | 1.39 | .0 | 1,110 | 1,150 | 1,180 |
| | --- | .03 | .43 | 1.82 | | | | |
| | --- | .03 | .57 | 2.38 | | | | |
| D180032 | 18.1 | .06 | .11 | .33 | .0 | 1,190 | 1,220 | 1,255 |
| | --- | .08 | .15 | .44 | | | | |
| | --- | .09 | .17 | .51 | | | | |
| D180035 | 15.1 | .01 | .06 | .49 | .0 | 1,215 | 1,265 | 1,320 |
| | --- | .01 | .08 | .64 | | | | |
| | --- | .02 | .09 | .74 | | | | |
| D180036 | 11.9 | .01L | .23 | 1.16 | .0 | 1,175 | 1,235 | 1,275 |
| | --- | .01L | .29 | 1.46 | | | | |
| | --- | .01L | .34 | 1.70 | | | | |

Table 2.--Proximate and ultimate analyses, and heat-of-combustion, forms-of-sulfur, free-swelling-index, and ash-fusion-temperature determinations for 26 coal samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming--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 |
| D180037 | 22.4 | 30.3 | 40.4 | 6.9 | 5.7 | 51.8 | 0.8 | 34.4 | 0.4 | 4,770 | 8,590 |
| | --- | 39.0 | 52.1 | 8.9 | 4.1 | 66.8 | 1.0 | 18.7 | .5 | 6,150 | 11,070 |
| | --- | 42.9 | 57.1 | --- | 4.5 | 73.3 | 1.1 | 20.5 | .6 | 6,750 | 12,150 |
| D180038 | 21.6 | 28.6 | 37.6 | 12.2 | 5.4 | 48.7 | .8 | 32.4 | .5 | 4,470 | 8,040 |
| | --- | 36.5 | 48.0 | 15.6 | 3.8 | 62.1 | 1.0 | 16.8 | .6 | 5,700 | 10,250 |
| | --- | 43.2 | 56.8 | --- | 4.5 | 73.6 | 1.2 | 19.9 | .8 | 6,750 | 12,140 |

| Sample number | Air-dried loss | Forms of sulfur | | | Free swelling | Ash fusion temperature, °C | | |
|---|---|---|---|---|---|---|---|---|
| | | Sulfate | Pyritic | Organic | | Initial deformation | Softening | Fluid |
| D180037 | 14.3 | 0.01L | 0.03 | 0.39 | 0.0 | 1,165 | 1,205 | 1,270 |
| | --- | .01L | .04 | .50 | | | | |
| | --- | .01L | .04 | .55 | | | | |
| D180038 | 13.2 | .01 | .03 | .43 | .0 | 1,180 | 1,240 | 1,280 |
| | --- | .01 | .04 | .55 | | | | |
| | --- | .02 | .05 | .65 | | | | |

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 26 coal and 5 coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming

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

| Sample number | Ash (percent) | SiO2 (percent) | Al2O3 (percent) | CaO (percent) | MgO (percent) | Na2O (percent) | K2O (percent) | Fe2O3 (percent) | TiO2 (percent) | P2O5 (percent) | Sample number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D178449 | 21.8 | 61 | 13 | 5.4 | 2.48 | 0.19 | 1.8 | 4.0 | 0.57 | 1.0L | D178449 |
| D178458 | 52.0 | 63 | 18 | 1.1 | 1.68 | .14 | 2.5 | 3.6 | .59 | 1.0L | D178458 |
| D178457 | 11.1 | 27 | 13 | 11 | 3.58 | .22 | .29 | 14 | .65 | 1.0L | D178457 |
| D178477 | 77.0 | 69 | 17 | .75 | 1.58 | .09 | 2.9 | 3.6 | .53 | 1.0L | D178477 |
| D178456 | 9.1 | 23 | 13 | 13 | 4.58 | .26 | .55 | 11 | .50 | 1.0L | D178456 |
| D178459 | 17.4 | 43 | 17 | 5.8 | 2.78 | .19 | 2.2 | 5.9 | .61 | 1.0L | D178459 |
| D178463 | 13.3 | 37 | 15 | 8.4 | 3.38 | .18 | .81 | 7.2 | .54 | 1.0L | D178463 |
| D178462 | 19.2 | 45 | 21 | 8.6 | 2.33 | .16 | .83 | 2.6 | .77 | 1.0L | D178462 |
| D178461 | 10.4 | 23 | 14 | 20 | 3.85 | .19 | .35 | 5.2 | .54 | 1.0 | D178461 |
| D178478 | 66.5 | 68 | 18 | .90 | 1.29 | .09 | 2.1 | 2.9 | .57 | 1.0L | D178478 |
| D178460 | 29.2 | 66 | 14 | 3.4 | 1.71 | .15 | 1.7 | 3.1 | .80 | 1.0L | D178460 |
| D178452 | 8.9 | 28 | 14 | 13 | 3.20 | .34 | .67 | 9.3 | .57 | 1.0L | D178452 |
| D178453 | 10.2 | 37 | 16 | 13 | 3.28 | .27 | .75 | 4.9 | .65 | 1.0L | D178453 |
| D178476 | 71.4 | 79 | 14 | .99 | .71 | .09 | 1.4 | .81 | 1.1 | 1.0L | D178476 |
| D178454 | 9.2 | 14 | 13 | 17 | 3.35 | .24 | .33 | 21 | .36 | 1.0L | D178454 |
| D178455 | 13.7 | 36 | 15 | 9.7 | 2.43 | .21 | .90 | 14 | .68 | 1.0L | D178455 |
| D178465 | 10.4 | 43 | 13 | 13 | 3.10 | .28 | .39 | 4.8 | .74 | 1.0L | D178465 |
| D178479 | 77.0 | 84 | 12 | .91 | .78 | .09 | 1.2 | .99 | .86 | 1.0L | D178479 |
| D178464 | 10.2 | 30 | 10 | 17 | 2.60 | .29 | .44 | 9.1 | .53 | 1.0L | D178464 |
| D178467 | 16.9 | 45 | 16 | 6.9 | 1.49 | .13 | .65 | 5.6 | 1.3 | 1.0L | D178467 |
| D178468 | 15.7 | 38 | 12 | 9.6 | 1.95 | .12 | .67 | 12 | .92 | 1.0L | D178468 |
| D178469 | 25.2 | 60 | 17 | 5.5 | 1.81 | .16 | 1.4 | 3.9 | .75 | 1.0L | D178469 |
| D178471 | 13.9 | 49 | 20 | 9.1 | 2.31 | .22 | .76 | 4.2 | .79 | 1.0L | D178471 |
| D176221 | 37.4 | 54 | 17 | 7.8 | 1.59 | .18 | .84 | 3.3 | .74 | 1.0L | D176221 |
| D178450 | 10.1 | 21 | 6.3 | 20 | 3.68 | .19 | .54 | 11 | .40 | 1.0L | D178450 |
| D178451 | 24.3 | 48 | 15 | 5.5 | 2.08 | .15 | 1.7 | 6.3 | .53 | 1.0L | D178451 |
| D180032 | 13.3 | 52 | 9.2 | 11 | 3.75 | .34 | 1.6 | 6.2 | .41 | 1.0L | D180032 |
| D180035 | 10.8 | 37 | 12 | 16 | 3.63 | .26 | .84 | 4.4 | .50 | 1.0L | D180035 |
| D180036 | 12.5 | 43 | 11 | 12 | 4.28 | 1.15 | 1.5 | 6.0 | .41 | 1.0L | D180036 |
| D180037 | 7.6 | 26 | 8.8 | 21 | 5.20 | .31 | .58 | 4.8 | .31 | 1.0L | D180037 |
| D180038 | 12.7 | 46 | 11 | 15 | 3.40 | .18 | .56 | 3.0 | .57 | 1.0L | D180038 |

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 26 coal and 5 coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming--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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D178449 | 8.1 | 2 | 300 | 3,000 | 10 | 1.0L | N | 7 | 70 | 67 | D178449 |
| D178458 | 1.7 | N | 150 | 700 | 5 | 1.5 | N | 10 | 150 | 86 | D178458 |
| D178457 | 26 | N | 700 | 700 | 15 | 2.0 | N | 15 | 70 | 131 | D178457 |
| D178477 | 1.3 | N | 100 | 700 | N | 1.0L | N | 10 | 100 | 64 | D178477 |
| D178456 | 26 | N | 700 | 700 | 15 | 4.0 | N | 15 | 70 | 210 | D178456 |
| D178459 | 13 | N | 300 | 3,000 | 3 | 1.0L | N | 7 | 70 | 87 | D178459 |
| D178463 | 19 | N | 500 | 1,500 | 15 | 1.5 | N | 7 | 70 | 74 | D178463 |
| D178462 | 8.7 | N | 300 | 3,000 | 7 | 1.5 | N | 10 | 150 | 99 | D178462 |
| D178461 | 18 | N | 700 | 1,500 | N | 1.0L | N | 7 | 50 | 54 | D178461 |
| D178478 | 1.0 | N | 150 | 500 | N | 1.0 | N | 7 | 100 | 87 | D178478 |
| D178460 | 6.4 | N | 300 | 700 | 7 | 1.0L | N | 15 | 70 | 44 | D178460 |
| D178452 | 22 | N | 700 | 1,000 | 30 | 1.0L | 300 | 70 | 100 | 116 | D178452 |
| D178453 | 10 | N | 700 | 3,000 | 15 | 1.0L | 300 | 30 | 70 | 67 | D178453 |
| D178476 | .27 | N | 150 | 500 | N | 1.0L | N | N | 100 | 48 | D178476 |
| D178454 | 8.6 | N | 700 | 3,000 | N | 1.0L | N | 7 | 30 | 49 | D178454 |
| D178455 | 13 | N | 300 | 1,500 | 3 | 1.0L | N | 7 | 70 | 84 | D178455 |
| D178465 | 12 | N | 700 | 5,000 | 30 | 1.0L | N | 15 | 70 | 51 | D178465 |
| D178479 | .20L | N | 100 | 500 | N | 1.0L | N | N | 70 | 49 | D178479 |
| D178464 | 15 | N | 700 | 1,500 | N | 1.0L | N | 7 | 30 | 72 | D178464 |
| D178467 | 15 | N | 300 | 1,500 | 15 | 1.0L | N | 15 | 150 | 152 | D178467 |
| D178468 | 22 | N | 300 | 300 | 15 | 1.0L | N | 20 | 70 | 108 | D178468 |
| D178469 | 5.2 | N | 200 | 500 | 20 | 1.0L | N | 70 | 70 | 84 | D178469 |
| D178471 | 9.0 | N | 700 | 1,000 | 7 | 1.0L | N | 15 | 70 | 81 | D178471 |
| D176221 | 3.1 | N | 150 | 500 | 5 | 1.0 | 500L | 15 | 70 | 68 | D176221 |
| D178450 | 24 | N | 700 | 3,000 | 20 | 1.0L | N | 15 | 70 | 47 | D178450 |
| D178451 | 13 | N | 300 | 1,000 | 15 | 1.0 | N | 15 | 70 | 92 | D178451 |
| D180032 | 9.3 | N | 700 | 2,000 | 10 | 1.0L | N | 20 | 50 | 56 | D180032 |
| D180035 | 12 | N | 1,000 | 5,000 | N | 1.0L | N | 7 | 50 | 39 | D180035 |
| D180036 | 9.0 | N | 1,000 | 2,000 | N | 1.0L | N | 10 | 50 | 48 | D180036 |
| D180037 | 13 | N | 1,000 | 3,000 | N | 2.0 | N | 7 | 50 | 45 | D180037 |
| D180038 | 8.6 | N | 500 | 1,000 | N | 1.0L | N | 7 | 70 | 51 | D180038 |

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 26 coal and 5 coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming--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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D178449 | 30 | N | 70 | 88 | 330 | 15 | N | N | 30 | 30 | D178449 |
| D178458 | 50 | N | 70 | 84 | 80 | 20 | N | N | 30 | 55 | D178458 |
| D178457 | 30 | N | 100 | 37 | 170 | 70 | 20 | N | 70 | 40 | D178457 |
| D178477 | 30 | N | N | 73 | 70 | 7 | 20L | B | 30 | 25L | D178477 |
| D178456 | 30 | 20L | N | 21 | 130 | 70 | 20 | B | 70 | 45 | D178456 |
| D178459 | 30 | N | N | 50 | 290 | 30 | N | B | 30 | 35 | D178459 |
| D178463 | 50 | N | N | 73 | 340 | 70 | N | B | 30 | 30 | D178463 |
| D178462 | 50 | N | 100 | 118 | 900 | 50 | N | N | 50 | 45 | D178462 |
| D178461 | 30 | N | N | 53 | 1,700 | 15 | N | B | 30 | 25 | D178461 |
| D178478 | 30 | N | N | 256 | 65 | 10 | 20L | B | 20 | 45 | D178478 |
| D178460 | 70 | N | N | 67 | 120 | 20 | 20 | B | 20 | 35 | D178460 |
| D178452 | 70 | N | 200 | 27 | 185 | 70 | 20 | 200 | 150 | 35 | D178452 |
| D178453 | 50 | N | 150 | 52 | 280 | 20 | 20 | N | 30 | 40 | D178453 |
| D178476 | 30 | N | N | 49 | 45 | N | 20 | B | 7 | 25L | D178476 |
| D178454 | 30 | N | N | 80 | 1,450 | 20 | N | B | 50 | 30 | D178454 |
| D178455 | 30 | N | N | 56 | 630 | 20 | 20 | B | 20 | 30 | D178455 |
| D178465 | 30 | 70 | N | 44 | 405 | 10 | N | B | 30 | 35 | D178465 |
| D178479 | 30 | N | N | 37 | 35 | N | 20 | B | N | 25L | D178479 |
| D178464 | 30 | N | N | 33 | 570 | 50 | 20 | B | 15 | 30 | D178464 |
| D178467 | 70 | N | 150 | 58 | 655 | 30 | 30 | 150 | 30 | 60 | D178467 |
| D178468 | 70 | N | N | 44 | 570 | 30 | 20 | B | 50 | 55 | D178468 |
| D178469 | 70 | N | 70 | 82 | 210 | 10 | 20 | N | 30 | 40 | D178469 |
| D178471 | 70 | N | 70 | 105 | 125 | 20 | 20 | N | 30 | 45 | D178471 |
| D176221 | 30 | N | 100L | 54 | 1,210 | 10 | 20 | 150L | 30 | 50 | D176221 |
| D178450 | 30 | 20 | N | 10 | 1,710 | 20 | N | B | 30 | 25 | D178450 |
| D178451 | 30 | N | 70 | 63 | 260 | 30 | 20 | N | 50 | 40 | D178451 |
| D180032 | 15 | N | N | 17 | 1,210 | 15 | N | B | 30 | 25L | D180032 |
| D180035 | 20 | N | N | 37 | 605 | 15 | 20 | B | 15 | 25L | D180035 |
| D180036 | 15 | N | N | 17 | 805 | 7 | N | B | 20 | 25L | D180036 |
| D180037 | 15 | N | N | 15 | 415 | 15 | N | B | 15 | 35 | D180037 |
| D180038 | 15 | N | N | 39 | 290 | 15 | 20 | B | 15 | 30 | D180038 |

Table 3.--Major- and minor-oxide and trace element composition of the laboratory ash of 26 coal and 5 coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming--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 |
|---|---|---|---|---|---|---|---|---|
| D178449 | 15 | 700 | 1,500 | 70 | 7 | 68 | 100 | D178449 |
| D178458 | 15 | 300 | 300 | 70 | 7 | 217 | 100 | D178458 |
| D178457 | 15 | 2,000 | 200 | 100 | 7 | 61 | 100 | D178457 |
| D178477 | 15 | 200 | 150 | 20 | 3 | 134 | 100 | D178477 |
| D178456 | 30 | 5,000 | 300 | 150 | 15 | 189 | 150 | D178456 |
| D178459 | 10 | 2,000 | 150 | 50 | 5 | 74 | 70 | D178459 |
| D178463 | 15 | 1,500 | 150 | 70 | 7 | 112 | 100 | D178463 |
| D178462 | 15 | 1,000 | 300 | 70 | 7 | 96 | 100 | D178462 |
| D178461 | 10 | 2,000 | 150 | 70 | 7 | 36 | 150 | D178461 |
| D178478 | 15 | 200 | 200 | 20 | 3 | 77 | 150 | D178478 |
| D178460 | 15 | 700 | 150 | 70 | 7 | 74 | 150 | D178460 |
| D178452 | 30 | 5,000 | 300 | 300 | 30 | 174 | 150 | D178452 |
| D178453 | 15 | 5,000 | 150 | 100 | 7 | 151 | 150 | D178453 |
| D178476 | 15 | 300 | 150 | 20 | 3 | 26 | 200 | D178476 |
| D178454 | 7 | 7,000 | 70 | 30 | 3 | 55 | 100 | D178454 |
| D178455 | 15 | 3,000 | 150 | 70 | 7 | 125 | 100 | D178455 |
| D178465 | 15 | 2,000 | 150 | 70 | 7 | 45 | 150 | D178465 |
| D178479 | 10 | 300 | 100 | N | 2 | 27 | 200 | D178479 |
| D178464 | 7 | 3,000 | 70 | 50 | 5 | 39 | 100 | D178464 |
| D178467 | 30 | 700 | 300 | 150 | 15 | 31 | 200 | D178467 |
| D178468 | 15 | 700 | 300 | 150 | 10 | 56 | 150 | D178468 |
| D178469 | 15 | 300 | 200 | 100 | 7 | 100 | 150 | D178469 |
| D178471 | 15 | 1,500 | 150 | 70 | 7 | 55 | 150 | D178471 |
| D176221 | 15 | 700 | 150 | 30 | 3 | 82 | 150 | D176221 |
| D178450 | 15 | 1,500 | 1,000 | 70 | 7 | 29 | 100 | D178450 |
| D178451 | 15 | 1,500 | 300 | 70 | 7 | 108 | 100 | D178451 |
| D180032 | 5 | 700 | 70 | 30 | 3 | 2,500 | 100 | D180032 |
| D180035 | 5 | 5,000 | 70 | 20 | 2 | 1,200 | 150 | D180035 |
| D180036 | 5 | 3,000 | 70 | 20 | 2 | 260 | 100 | D180036 |
| D180037 | 5 | 10,000 | 70 | 30 | 3 | 3,000 | 100 | D180037 |
| D180038 | 7 | 3,000 | 100 | 30 | 3 | 1,100 | 200 | D180038 |

Table 4.--Content of seven trace elements in 26 coal and 5 coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming

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

| Sample number | As (ppm) | F (ppm) | Hg (ppm) | Sb (ppm) | Se (ppm) | Th (ppm) | U (ppm) | Sample number |
|---|---|---|---|---|---|---|---|---|
| D178449 | 2.5 | 70 | 0.06 | 1.4 | 0.9 | 3.0L | 4.4 | D178449 |
| D178458 | 4.5 | 345 | .21 | 3.6 | 2.5 | 8.0 | 10 | D178458 |
| D178457 | 17 | 20L | .29 | 1.5 | 1.7 | 3.0L | 3.7 | D178457 |
| D178477 | 9.5 | 710 | .17 | 1.6 | 3.3 | 15 | 9.4 | D178477 |
| D178456 | 12 | 25 | .17 | 1.5 | 1.4 | 3.0L | 2.6 | D178456 |
| D178459 | 3.5 | 100 | .07 | 1.0 | .7 | 5.5 | 3.6 | D178459 |
| D178463 | 2.0 | 30 | .12 | .8 | 1.0 | 3.0L | 3.9 | D178463 |
| D178462 | 1.5 | 50 | .06 | .8 | 1.1 | 5.8 | 3.9 | D178462 |
| D178461 | 1.0 | 20 | .05 | .6 | .6 | 3.0L | 1.5 | D178461 |
| D178478 | 6.5 | 360 | .21 | 3.2 | 2.9 | 17 | 9.0 | D178478 |
| D178460 | 2.0 | 135 | .12 | 2.0 | .6 | 3.0L | 4.9 | D178460 |
| D178452 | 3.0 | 45 | .11 | 1.5 | .6 | 3.0L | 2.4 | D178452 |
| D178453 | 1.0 | 30 | .04 | .6 | .6 | 3.0L | 1.3 | D178453 |
| D178476 | 1.0 | 200 | .05 | 1.0 | .9 | 10 | 3.9 | D178476 |
| D178454 | .5 | 40 | .03 | .3 | .3 | 3.0L | .7 | D178454 |
| D178455 | 1.0 | 55 | .14 | .5 | .5 | 3.0L | 1.4 | D178455 |
| D178465 | 1.0 | 30 | .04 | .3 | .4 | 3.0L | .7 | D178465 |
| D178479 | 1.0 | 250 | .03 | .8 | .9 | 14 | 2.8 | D178479 |
| D178464 | 1.0 | 30 | .08 | .4 | .7 | 3.0L | .8 | D178464 |
| D178467 | 3.0 | 55 | .07 | 2.2 | 1.5 | 9.4 | 5.3 | D178467 |
| D178468 | 7.5 | 30 | .10 | 2.2 | 1.5 | 5.6 | 2.2 | D178468 |
| D178469 | 1.5 | 125 | .04 | 1.5 | 1.0 | 5.0 | 1.9 | D178469 |
| D178471 | 1.5 | 20 | .06 | .5 | .1 | 4.1 | 1.4 | D178471 |
| D176221 | 3.0 | 250 | .10 | 1.1 | 2.0 | 10 | 3.8 | D176221 |
| D178450 | 3.0 | 20 | .09 | .5 | .3 | 3.0L | .4 | D178450 |
| D178451 | 15 | 115 | .16 | 2.6 | 1.8 | 5.9 | 5.4 | D178451 |
| D180032 | 4.5 | 80 | .06 | .3 | 4.3 | 3.0L | 2.1 | D180032 |
| D180035 | 1.5 | 30 | .17 | .3 | .6 | 3.0L | .5 | D180035 |
| D180036 | 2.0 | 50 | .05 | .3 | .4 | 3.0L | .5 | D180036 |
| D180037 | 1.5 | 35 | .06 | .2 | .5 | 3.0L | .2L | D180037 |
| D180038 | 1.5 | 40 | .06 | .2 | 1.1 | 3.0L | 1.3 | D180038 |

Table 5.--Major-, minor-, and trace-element composition of 26 coal and 5 coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming

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

| Sample number | Si (percent) | Al (percent) | Ca (percent) | Mg (percent) | Na (percent) | K (percent) | Fe (percent) | Ti (percent) | Ag-S (ppm) | As (ppm) | Sample number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D178449 | 6.2 | 1.5 | 0.84 | 0.33 | 0.031 | 0.33 | 0.61 | 0.074 | 0.5 | 2.5 | D178449 |
| D178458 | 15 | 5.0 | .41 | .53 | .054 | 1.1 | 1.3 | .18 | N | 4.5 | D178458 |
| D178457 | 1.4 | .76 | .87 | .24 | .018 | .027 | 1.1 | .043 | N | 17 | D178457 |
| D178477 | 25 | 6.8 | .41 | .73 | .051 | 1.9 | 1.9 | .24 | N | 9.5 | D178477 |
| D178456 | .98 | .63 | .84 | .25 | .018 | .042 | .70 | .027 | N | 12 | D178456 |
| D178459 | 3.5 | 1.6 | .72 | .29 | .025 | .32 | .72 | .064 | N | 3.5 | D178459 |
| D178463 | 2.3 | 1.0 | .80 | .27 | .018 | .090 | .67 | .043 | N | 2.0 | D178463 |
| D178462 | 4.0 | 2.1 | 1.2 | .27 | .023 | .13 | .35 | .089 | N | 1.5 | D178462 |
| D178461 | 1.1 | .77 | 1.5 | .24 | .015 | .030 | .38 | .034 | N | 1.0 | D178461 |
| D178478 | 21 | 6.4 | .43 | .52 | .044 | 1.2 | 1.3 | .23 | N | 6.5 | D178478 |
| D178460 | 9.0 | 2.2 | .71 | .30 | .032 | .41 | .63 | .14 | N | 2.0 | D178460 |
| D178452 | 1.2 | .66 | .83 | .17 | .022 | .050 | .58 | .030 | N | 3.0 | D178452 |
| D178453 | 1.8 | .86 | .95 | .20 | .020 | .064 | .35 | .040 | N | 1.0 | D178453 |
| D178476 | 26 | 5.4 | .50 | .31 | .048 | .84 | .40 | .45 | N | 1.0 | D178476 |
| D178454 | .60 | .63 | 1.1 | .19 | .016 | .025 | 1.4 | .020 | N | .5 | D178454 |
| D178455 | 2.3 | 1.1 | .95 | .20 | .021 | .10 | 1.3 | .056 | N | 1.0 | D178455 |
| D178465 | 2.1 | .72 | .96 | .19 | .022 | .034 | .35 | .046 | N | 1.0 | D178465 |
| D178479 | 30 | 4.9 | .50 | .36 | .051 | .80 | .53 | .40 | N | 1.0 | D178479 |
| D178464 | 1.4 | .54 | 1.2 | .16 | .022 | .037 | .65 | .032 | N | 1.0 | D178464 |
| D178467 | 3.5 | 1.4 | .83 | .15 | .016 | .092 | .66 | .13 | N | 3.0 | D178467 |
| D178468 | 2.8 | 1.0 | 1.1 | .18 | .014 | .088 | 1.3 | .087 | N | 7.5 | D178468 |
| D178469 | 7.1 | 2.3 | .99 | .27 | .030 | .29 | .69 | .11 | N | 1.5 | D178469 |
| D178471 | 3.2 | 1.5 | .90 | .19 | .023 | .088 | .41 | .066 | N | 1.5 | D178471 |
| D176221 | 9.4 | 3.4 | 2.1 | .36 | .050 | .26 | .86 | .17 | N | 3.0 | D176221 |
| D178450 | .99 | .34 | 1.4 | .22 | .014 | .045 | .78 | .024 | N | 3.0 | D178450 |
| D178451 | 5.4 | 1.9 | .95 | .30 | .027 | .34 | 1.1 | .077 | N | 15 | D178451 |
| D180032 | 3.2 | .65 | 1.0 | .30 | .034 | .18 | .58 | .033 | N | 4.5 | D180032 |
| D180035 | 1.9 | .67 | 1.3 | .24 | .021 | .076 | .33 | .032 | N | 1.5 | D180035 |
| D180036 | 2.5 | .73 | 1.0 | .32 | .11 | .16 | .52 | .031 | N | 2.0 | D180036 |
| D180037 | .91 | .35 | 1.2 | .24 | .017 | .037 | .25 | .014 | N | 1.5 | D180037 |
| D180038 | 2.7 | .77 | 1.3 | .26 | .017 | .059 | .26 | .043 | N | 1.5 | D180038 |

Table 5.--Major-, minor-, and trace-element composition of 26 coal and 5 coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming--Continued

| Sample number | B-S (ppm) | Ba-S (ppm) | Be-S (ppm) | Cd (ppm) | Ce-S (ppm) | Co-S (ppm) | Cr-S (ppm) | Cu (ppm) | F (ppm) | Ga-S (ppm) | Sample number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D178449 | 70 | 700 | 2 | 0.22L | N | 1.5 | 15 | 15 | 70 | 7 | D178449 |
| D178458 | 70 | 300 | 2 | .78 | N | 5 | 70 | 45 | 345 | 20 | D178458 |
| D178457 | 70 | 70 | 1.5 | .22 | N | 1.5 | 7 | 15 | 20L | 3 | D178457 |
| D178477 | 70 | 500 | N | .77L | N | 7 | 70 | 49 | 710 | 20 | D178477 |
| D178456 | 70 | 70 | 1.5 | .36 | N | 1.5 | 7 | 19 | 25 | 3 | D178456 |
| D178459 | 50 | 500 | .5 | .17L | N | 1.5 | 15 | 15 | 100 | 5 | D178459 |
| D178463 | 70 | 200 | 2 | .20 | N | 1 | 10 | 9.8 | 30 | 7 | D178463 |
| D178462 | 70 | 700 | 1.5 | .29 | N | 2 | 30 | 19 | 50 | 10 | D178462 |
| D178461 | 70 | 150 | N | .10L | N | .7 | 5 | 5.6 | 20 | 3 | D178461 |
| D178478 | 100 | 300 | N | .67 | N | 5 | 70 | 58 | 360 | 20 | D178478 |
| D178460 | 100 | 200 | 2 | .29L | N | 5 | 20 | 13 | 135 | 20 | D178460 |
| D178452 | 70 | 100 | 3 | .09L | 30 | 7 | 10 | 10 | 45 | 7 | D178452 |
| D178453 | 70 | 300 | 1.5 | .10L | 30 | 3 | 7 | 6.8 | 30 | 5 | D178453 |
| D178476 | 100 | 300 | N | .71L | N | N | 70 | 34 | 200 | 20 | D178476 |
| D178454 | 70 | 300 | N | .09L | N | .7 | 3 | 4.5 | 40 | 3 | D178454 |
| D178455 | 50 | 200 | .5 | .14L | N | 1 | 10 | 12 | 55 | 5 | D178455 |
| D178465 | 70 | 500 | 3 | .10L | N | 1.5 | 7 | 5.3 | 30 | 3 | D178465 |
| D178479 | 70 | 500 | N | .77L | N | N | 50 | 38 | 250 | 20 | D178479 |
| D178464 | 70 | 150 | N | .10L | N | .7 | 3 | 7.3 | 30 | 3 | D178464 |
| D178467 | 50 | 200 | 2 | .17L | N | 2 | 20 | 26 | 55 | 10 | D178467 |
| D178468 | 50 | 50 | 2 | .16L | N | 3 | 10 | 17 | 30 | 10 | D178468 |
| D178469 | 50 | 150 | 5 | .25L | N | 15 | 15 | 21 | 125 | 15 | D178469 |
| D178471 | 100 | 150 | 1 | .14L | N | 2 | 10 | 11 | 20 | 10 | D178471 |
| D176221 | 50 | 200 | 2 | .37 | 200L | 5 | 30 | 25 | 250 | 10 | D176221 |
| D178450 | 70 | 300 | 2 | .10L | N | 1.5 | 7 | 4.7 | 20 | 3 | D178450 |
| D178451 | 70 | 200 | 3 | .24 | N | 3 | 15 | 22 | 115 | 7 | D178451 |
| D180032 | 100 | 300 | 1.5 | .13L | N | 3 | 7 | 7.4 | 80 | 2 | D180032 |
| D180035 | 100 | 500 | N | .11L | N | .7 | 5 | 4.2 | 30 | 2 | D180035 |
| D180036 | 150 | 200 | N | .13L | N | 1.5 | 7 | 6.0 | 50 | 2 | D180036 |
| D180037 | 70 | 200 | N | .15 | N | .5 | 3 | 3.4 | 35 | 1 | D180037 |
| D180038 | 70 | 150 | N | .13L | N | 1 | 10 | 6.5 | 40 | 2 | D180038 |

Table 5.--Major-, minor-, and trace-element composition of 26 coal and 5 coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming--Continued

| Sample number | Ge-S (ppm) | Hg (ppm) | La-S (ppm) | Li (ppm) | Mn (ppm) | Mo-S (ppm) | Nb-S (ppm) | Nd-S (ppm) | Ni-S (ppm) | P (ppm) | Sample number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D178449 | N | 0.06 | 15 | 19 | 72 | 3 | N | N | 7 | 950L | D178449 |
| D178458 | N | .21 | 30 | 44 | 42 | 10 | N | N | 15 | 2,300L | D178458 |
| D178457 | N | .29 | 10 | 4.1 | 19 | 7 | 2 | N | 7 | 490L | D178457 |
| D178477 | N | .17 | N | 56 | 54 | 5 | 15L | B | 20 | 3,400L | D178477 |
| D178456 | 2L | .17 | N | 1.9 | 12 | 7 | 2 | B | 7 | 400L | D178456 |
| D178459 | N | .07 | N | 8.7 | 50 | 5 | N | B | 5 | 760L | D178459 |
| D178463 | N | .12 | N | 9.7 | 45 | 10 | N | B | 5 | 580L | D178463 |
| D178462 | N | .06 | 20 | 23 | 170 | 10 | N | N | 10 | 840L | D178462 |
| D178461 | N | .05 | N | 5.5 | 180 | 1.5 | N | B | 3 | 450 | D178461 |
| D178478 | N | .21 | N | 170 | 43 | 7 | 15L | B | 15 | 2,900L | D178478 |
| D178460 | N | .12 | N | 20 | 35 | 7 | 7 | B | 7 | 1,300L | D178460 |
| D178452 | N | .11 | 20 | 2.4 | 16 | 7 | 2 | 20 | 15 | 390L | D178452 |
| D178453 | N | .04 | 15 | 5.3 | 29 | 2 | 2 | N | 3 | 450L | D178453 |
| D178476 | N | .05 | N | 35 | 32 | N | 15 | B | 5 | 3,100L | D178476 |
| D178454 | N | .03 | N | 7.4 | 130 | 2 | N | B | 5 | 400L | D178454 |
| D178455 | N | .14 | N | 7.7 | 86 | 3 | 3 | B | 3 | 600L | D178455 |
| D178465 | 7 | .04 | N | 4.6 | 42 | 1 | N | B | 3 | 450L | D178465 |
| D178479 | N | .03 | N | 28 | 27 | N | 15 | B | N | 3,400L | D178479 |
| D178464 | N | .08 | N | 3.4 | 58 | 5 | 2 | B | 1.5 | 450L | D178464 |
| D178467 | N | .07 | 20 | 9.8 | 110 | 5 | 5 | 20 | 5 | 740L | D178467 |
| D178468 | N | .10 | N | 6.9 | 89 | 5 | 3 | B | 7 | 690L | D178468 |
| D178469 | N | .04 | 15 | 21 | 53 | 2 | 5 | N | 7 | 1,100L | D178469 |
| D178471 | N | .06 | 10 | 15 | 17 | 3 | 3 | N | 5 | 610L | D178471 |
| D176221 | N | .10 | 30L | 20 | 450 | 3 | 7 | 50L | 10 | 1,600L | D176221 |
| D178450 | 2 | .09 | N | 1.0 | 170 | 2 | N | B | 3 | 440L | D178450 |
| D178451 | N | .16 | 15 | 15 | 63 | 7 | 5 | N | 15 | 1,100L | D178451 |
| D180032 | N | .06 | N | 2.3 | 160 | 2 | N | B | 5 | 580L | D180032 |
| D180035 | N | .17 | N | 4.0 | 65 | 1.5 | 2 | B | 1.5 | 470L | D180035 |
| D180036 | N | .05 | N | 2.1 | 100 | 1 | N | B | 2 | 550L | D180036 |
| D180037 | N | .06 | N | 1.1 | 32 | 1 | N | B | 1 | 330L | D180037 |
| D180038 | N | .06 | N | 5.0 | 37 | 2 | 2 | B | 2 | 550L | D180038 |

Table 5.--Major-, minor-, and trace-element composition of 26 coal and 5 coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming--Continued

| Sample number | Pb (ppm) | Sb (ppm) | Sc-S (ppm) | Se (ppm) | Sr-S (ppm) | Th (ppm) | U (ppm) | V-S (ppm) | Y-S (ppm) | Yb-S (ppm) | Sample number |
|---|---|---|---|---|---|---|---|---|---|---|---|
| D178449 | 6.5 | 1.4 | 3 | 0.9 | 150 | 3.0L | 4.4 | 300 | 15 | 1.5 | D178449 |
| D178458 | 29 | 3.6 | 7 | 2.5 | 150 | 8.0 | 10 | 150 | 30 | 3 | D178458 |
| D178457 | 4.4 | 1.5 | 1.5 | 1.7 | 200 | 3.0L | 3.7 | 20 | 10 | .7 | D178457 |
| D178477 | 19L | 1.6 | 10 | 3.3 | 150 | 15.0 | 9.4 | 100 | 15 | 2 | D178477 |
| D178456 | 4.1 | 1.5 | 3 | 1.4 | 500 | 3.0L | 2.6 | 30 | 15 | 1.5 | D178456 |
| D178459 | 6.1 | 1.0 | 1.5 | .7 | 300 | 5.5 | 3.6 | 20 | 10 | 1 | D178459 |
| D178463 | 4.0 | .8 | 2 | 1.0 | 200 | 3.0L | 3.9 | 20 | 10 | 1 | D178463 |
| D178462 | 8.6 | .8 | 3 | 1.1 | 200 | 5.8 | 3.9 | 70 | 15 | 1.5 | D178462 |
| D178461 | 2.6 | .6 | 1 | .6 | 200 | 3.0L | 1.5 | 15 | 7 | .7 | D178461 |
| D178478 | 30 | 3.2 | 10 | 2.9 | 150 | 17.0 | 9.0 | 150 | 15 | 2 | D178478 |
| D178460 | 10 | 2.0 | 5 | .6 | 200 | 3.0L | 4.9 | 50 | 20 | 2 | D178460 |
| D178452 | 3.1 | 1.5 | 3 | .6 | 500 | 3.0L | 2.4 | 30 | 30 | 3 | D178452 |
| D178453 | 4.1 | .6 | 1.5 | .6 | 500 | 3.0L | 1.3 | 15 | 10 | .7 | D178453 |
| D178476 | 18L | 1.0 | 10 | .9 | 200 | 10.0 | 3.9 | 100 | 15 | 2 | D178476 |
| D178454 | 2.8 | .3 | .7 | .3 | 700 | 3.0L | .7 | 7 | 3 | .3 | D178454 |
| D178455 | 4.1 | .5 | 2 | .5 | 500 | 3.0L | 1.4 | 20 | 10 | 1 | D178455 |
| D178465 | 3.6 | .3 | 1.5 | .4 | 200 | 3.0L | .7 | 15 | 7 | .7 | D178465 |
| D178479 | 19L | .8 | 7 | .9 | 200 | 14.0 | 2.8 | 70 | N | 1.5 | D178479 |
| D178464 | 3.1 | .4 | .7 | .7 | 300 | 3.0L | .8 | 7 | 5 | .5 | D178464 |
| D178467 | 10 | 2.2 | 5 | 1.5 | 100 | 9.4 | 5.3 | 50 | 20 | 2 | D178467 |
| D178468 | 8.6 | 2.2 | 2 | 1.5 | 100 | 5.6 | 2.2 | 50 | 20 | 1.5 | D178468 |
| D178469 | 10 | 1.5 | 3 | 1.0 | 70 | 5.0 | 1.9 | 50 | 20 | 1.5 | D178469 |
| D178471 | 6.3 | .5 | 2 | .1 | 200 | 4.1 | 1.4 | 20 | 10 | 1 | D178471 |
| D176221 | 19 | 1.1 | 5 | 2.0 | 300 | 10.0 | 3.8 | 50 | 10 | 1 | D176221 |
| D178450 | 2.5 | .5 | 1.5 | .3 | 150 | 3.0L | .4 | 100 | 7 | .7 | D178450 |
| D178451 | 9.7 | 2.6 | 3 | 1.8 | 300 | 5.9 | 5.4 | 70 | 15 | 1.5 | D178451 |
| D180032 | 3.3L | .3 | .7 | 4.3 | 100 | 3.0L | 2.1 | 10 | 5 | .5 | D180032 |
| D180035 | 2.7L | .3 | .5 | .6 | 500 | 3.0L | .5 | 7 | 2 | .2 | D180035 |
| D180036 | 3.1L | .3 | .7 | .4 | 300 | 3.0L | .5 | 10 | 2 | .2 | D180036 |
| D180037 | 2.7 | .2 | .3 | .5 | 700 | 3.0L | .2L | 5 | 2 | .2 | D180037 |
| D180038 | 3.8 | .2 | 1 | 1.1 | 300 | 3.0L | 1.3 | 15 | 3 | .3 | D180038 |

Table 5.--Major-, minor-, and trace-element composition of 26 coal and 5 coal-associated shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming--Continued

| Sample number | Zn (ppm) | Zr-S (ppm) |
|---|---|---|
| D178449 | 15 | 20 |
| D178458 | 110 | 50 |
| D178457 | 6.8 | 10 |
| D178477 | 100 | 70 |
| D178456 | 17 | 15 |
| D178459 | 13 | 15 |
| D178463 | 15 | 15 |
| D178462 | 18 | 20 |
| D178461 | 3.7 | 15 |
| D178478 | 51 | 100 |
| D178460 | 22 | 50 |
| D178452 | 15 | 15 |
| D178453 | 15 | 15 |
| D178476 | 19 | 150 |
| D178454 | 5.1 | 10 |
| D178455 | 17 | 15 |
| D178465 | 4.7 | 15 |
| D178479 | 21 | 150 |
| D178464 | 4.0 | 10 |
| D178467 | 5.2 | 30 |
| D178468 | 8.8 | 20 |
| D178469 | 25 | 30 |
| D178471 | 7.6 | 20 |
| D176221 | 31 | 50 |
| D178450 | 2.9 | 10 |
| D178451 | 26 | 20 |
| D180032 | 330 | 15 |
| D180035 | 130 | 15 |
| D180036 | 33 | 15 |
| D180037 | 230 | 7 |
| D180038 | 140 | 20 |

Table 6.--Elements looked for, but not detected, in coal and shale samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming.

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

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

Table 7.--Arithmetic mean, observed range, geometric mean, and geometric deviation of proximate and ultimate analyses, heat of combustion, forms of sulfur, and ash-fusion temperatures of 26 coal samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming

[For comparison geometric means from 33 Powder River region coal samples are included, (Swanson and others, 1976, tables 31b and 32b). All values are in percent except Kcal/kg, Btu/lb, ash-fusion, temperatures, and geometric deviations, and are reported on the as-received basis. L, less than the value shown. Leaders (---) indicate no data. Kcal/kg = 0.556 (Btu/lb). °F = (°C x 1.8) + 32]

| | Arithmetic mean | Minimum | Maximum | Geometric mean | Geometric deviation | Powder River region geometric mean |
|---|---|---|---|---|---|---|
| **Proximate and ultimate analyses** | | | | | | |
| oisture | 24.0 | 17.9 | 30.0 | 23.8 | 1.1 | 23.1 |
| olatile matter | 27.5 | 21.6 | 34.0 | 27.4 | 1.1 | 32 |
| ixed carbon | 36.5 | 24.2 | 40.4 | 36.2 | 1.1 | 36 |
| sh | 12.0 | 6.1 | 30.5 | 11.0 | 1.5 | 7.5 |
| ydrogen | 5.7 | 4.7 | 6.4 | 5.7 | 1.1 | 6.2 |
| arbon | 47.2 | 35.0 | 51.8 | 47.0 | 1.1 | 50.3 |
| itrogen | .7 | .5 | .9 | .6 | 1.2 | .9 |
| xygen | 33.7 | 28.8 | 37.1 | 33.6 | 1.1 | 32.9 |
| ulfur | .8 | .3 | 1.7 | .7 | 1.7 | .8 |
| **Heat of combustion** | | | | | | |
| cal/kg | 4,390 | 3,180 | 4,865 | 4,365 | 1.1 | 4,860 |
| tu/lb | 7,890 | 5,720 | 8,750 | 7,850 | 1.1 | 8,740 |
| **Forms of sulfur** | | | | | | |
| ulfate | 0.03 | 0.01L | 0.09 | 0.03 | 1.8 | 0.02 |
| yritic | .09 | .02 | .42 | .07 | 2.2 | .29 |
| rganic | .66 | .18 | 1.55 | .57 | 1.8 | .31 |
| **Ash-fusion temperatures, °C** | | | | | | |
| itial deformation | 1,160 | 1,060 | 1,290 | 1,150 | 1.0 | --- |
| ftening temperature | 1,200 | 1,100 | 1,340 | 1,200 | 1.0 | --- |
| uid temperature | 1,240 | 1,140 | 1,400 | 1,240 | 1.1 | --- |

Table 8.--Arithmetic mean, observed range, geometric mean, and geometric deviation of ash content and contents of nine major and minor oxides in the laboratory ash of 26 coal samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming

[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]

| Oxide | Arithmetic mean | Observed range | | Geometric mean | Geometric deviation | Powder River region geometric mean |
|---|---|---|---|---|---|---|
| | | Minimum | Maximum | | | |
| (Ash) | 15.1 | 7.6 | 37.4 | 13.9 | 1.5 | 9.0 |
| $SiO_2$ | 40 | 14 | 66 | 37 | 1.5 | 28 |
| $Al_2O_3$ | 14 | 6.3 | 21 | 13 | 1.3 | 14 |
| CaO | 12 | 3.4 | 21 | 10 | 1.6 | 15 |
| MgO | 3.0 | 1.5 | 5.2 | 2.8 | 1.4 | 3.6 |
| $Na_2O$ | .24 | .12 | 1.15 | .22 | 1.6 | .93 |
| $K_2O$ | .91 | .29 | 2.2 | .78 | 1.7 | .28 |
| $Fe_2O_3$ | 7.2 | 2.6 | 21 | 6.2 | 1.7 | 5.8 |
| $TiO_2$ | .62 | .31 | 1.3 | .59 | 1.4 | .61 |
| $SO_3$ | 14 | 3.1 | 26 | 12 | 1.7 | 14 |

able 9.--Arithmetic mean, observed range, geometric mean, and geometric deviation of 37 elements in 26 coal samples from the lower part of the Fort Union Formation, Little Snake River coal field, Sweetwater and Carbon Counties, Wyoming

For comparison geometric means for 410 Powder River region coal samples are included (Hatch and Swanson, 1977, table 6b). All analyses except geometric deviation are in percent or parts per million and are reported on a whole coal basis. As, F, Hg, Sb, Se, Th, and U values used to calculate the statistics were determined directly on whole coal. All other values used were calculated from determinations made on coal ash. L, less than the value shown. Leaders (---) indicate no data]

| Element | Arithmetic mean | Observed range | | Geometric mean | Geometric deviation | Powder River region geometric mean |
|---|---|---|---|---|---|---|
| | | Minimum | Maximum | | | |
| | | | Percent | | | |
| Si | 3.2 | 0.60 | 9.4 | 2.4 | 2.1 | 1.2 |
| Al | 1.2 | .34 | 3.4 | .97 | 1.8 | .66 |
| Ca | 1.0 | .71 | 2.0 | 1.0 | 1.2 | .98 |
| Mg | .24 | .15 | .35 | .24 | 1.3 | .20 |
| Na | .025 | .014 | .11 | .023 | 1.5 | .063 |
| K | .13 | .025 | .40 | .090 | 2.4 | .022 |
| Fe | .68 | .25 | 1.3 | .60 | 1.6 | .37 |
| Ti | .06 | .014 | .16 | .049 | 1.9 | .035 |
| | | | Parts per million | | | |
| As | 3.4 | 0.5 | 17 | 2.3 | 2.4 | 2 |
| B | 70 | 50 | 150 | 70 | 1.3 | 50 |
| Ba | 300 | 50 | 700 | 200 | 2.0 | 300 |
| Be | 1.5 | .5 | 5 | 1 | 2.6 | .5 |
| Cd | .12 | .15L | .37 | .09 | 2.1 | .04 |
| Co | 2 | .5 | 15 | 2 | 2.2 | 2 |
| Cr | 10 | 3 | 30 | 10 | 1.9 | 5 |
| Cu | 12 | 3.4 | 25 | 10 | 1.8 | 9.5 |
| F | 57 | 20L | 250 | 45 | 2.0 | 40 |
| Ga | 7 | 1 | 20 | 5 | 2.1 | 2 |
| Hg | .09 | .03 | .29 | .08 | 1.7 | .08 |
| La | 10 | 10L | 20 | 7 | 1.8 | --- |
| Li | 9.2 | 1 | 23 | 7 | 2.5 | 3.9 |
| Mn | 89 | 12 | 450 | 61 | 2.4 | 34 |
| Mo | 5 | 1 | 10 | 3 | 2.1 | 1.5 |
| Nb | 2 | 2 | 7 | 2 | 1.9 | 1 |
| Ni | 7 | 1 | 15 | 5 | 2.0 | 3 |
| Pb | 5.6 | 2.5L | 19 | 4.6 | 1.9 | 5.1 |
| Sb | 1 | .2 | 2.6 | .7 | 2.2 | .4 |
| Sc | 2 | .3 | 5 | 1.5 | 2.1 | 1.5 |
| Se | 1 | 1 | 4.2 | .8 | 2.1 | .7 |
| Sr | 300 | 70 | 700 | 200 | 1.9 | 150 |
| Th | 3.6 | 4.1L | 10 | 3 | 1.9 | 3.3 |
| U | 2.5 | .4L | 5.4 | 1.7 | 2.4 | .6 |
| V | 50 | 5 | 300 | 20 | 2.6 | 10 |
| Y | 10 | 2 | 30 | 10 | 2.2 | 3 |
| Yb | 1 | .2 | 3 | .7 | 2.1 | .3 |
| Zn | 37 | 2.9 | 330 | 17 | 3.5 | 12.5 |
| Zr | 20 | 7 | 50 | 15 | 1.6 | 15 |