The Geological Survey of Wyoming
Gary B. Glass, State Geologist

Coal Fields and Coal Beds of Wyoming

by Gary B. Glass and Richard W. Jones

Reprint No. 47 • 1992

Laramie, Wyoming

Text printed on 50% recycled fiber paper.

Reprint of 500 copies by Pioneer Printing and Stationery Company, Cheyenne, Wyoming.

This and other publications available from:

The Geological Survey of Wyoming
Box 3008, University Station
Laramie, Wyoming 82071-3008
(307) 766-2286 • FAX (307) 766-2605

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Originally published in the Wyoming Geological Association, Forty-Second [Annual] Field Conference Guidebook, 1991.

COAL FIELDS AND COAL BEDS OF WYOMING

GARY B. GLASS[1] and RICHARD W. JONES[1]

COAL FIELD NOMENCLATURE

As defined by the U. S. Geological Survey, Wyoming's coal fields fall into two coal-bearing provinces. The coals in eastern Wyoming are within the Northern Great Plains Province, while all other coal deposits in the State are within the Rocky Mountain Province. Additionally, the U. S. Bureau of Mines designates Wyoming as coal-producing District 19. Beyond these national designations, the State's coal-bearing areas are divided into the following 10 coal fields (Jones, 1990, 1991) (**Figure 1**):

Bighorn Coal Field	Hanna Coal Field
Black Hills Coal Field	Jackson Hole Coal Field
Goshen Hole Coal Field	Powder River Coal Field
Green River Coal Field	Rock Creek Coal Field
Hams Fork Coal Field	Wind River Coal Field

These coal fields underlie more than 53,000 square miles or approximately 54% of the State and collectively contain in-place coal resources greater than 1.46 trillion tons (Wood and Bour, 1988). Although coal beds do occur in some of the areas between these named fields, these coal beds are either very local in extent or not thick enough to mine.

COAL-BEARING ROCKS

In Wyoming, coal beds occur in rock sequences deposited during either the Cretaceous Period (66.4-144 million years ago) or during a portion of the later Tertiary Period (36.6-66.4 million years ago) (**Figure 2**). In both these periods, depositional environments and climates were at least periodically well suited to the development of densely vegetated swamps. Peats that accumulated in these swamps have since been transformed into the numerous coal beds that underlie the State.

The geologic formations in which these coal beds occur are characteristically thick, each usually from 700 to 7,000 feet thick. While the Cretaceous formations normally exhibit gradual, regional thickening or thinning that can be correlated across the State, the thicknesses of the Tertiary formations vary from basin to basin. The thickness variations in the Tertiary formations are related more to the local tectonic and depositional events that affected each of the coal fields than to larger regional events.

[1]Geological Survey of Wyoming
P.O. Box 3008 University Station
Laramie, Wyoming 82071

The most widespread coal-bearing rocks in Wyoming are Cretaceous, but they are usually exposed only as narrow bands of upturned rock around the margins of the larger structural basins and uplifted areas of the State. They also crop out as irregularly exposed, linear bands in the Overthrust Belt of western Wyoming. Relatively flat-lying Tertiary rocks, on the other hand, occupy the central portions of most of the coal fields, where they overlie the older Cretaceous rocks. Even the Tertiary rocks often exhibit steeper dips along the margins of basins.

Cretaceous and Tertiary coal-bearing formations contain numerous coal beds that are separated from one another by as little as a few inches of shale or claystone to as much as hundreds of feet of rock that may vary from coarse sandstone or conglomerate to siltstone, claystone, and shale. Although the Cretaceous coal beds interspersed in these rocks are generally less than 10 feet thick, in westernmost Wyoming a few Cretaceous coal beds are 30 to 100 feet thick.

The Tertiary coal beds, which were deposited during the Eocene and Paleocene Epochs, often exceed 10 feet thick with 30- to 100-foot-thick beds common. Locally, some Tertiary coal beds exceed 200 feet thick.

Lower Cretaceous

The oldest coal-bearing formation in Wyoming is the Lower Cretaceous Lakota Formation (**Figure 2**). This formation contains at least one minable coal bed in the Black Hills Coal Field and may be coal bearing at depth on the eastern side of the Powder River Coal Field. The Lakota is not coal-bearing in the other eight coal fields.

The Bear River Formation of Early Cretaceous age is the next younger coal-bearing rock unit. The coal beds in this formation are very local in extent and have only been reported in the Hams Fork Coal Field (Glass, 1977). Most coal beds in the Bear River Formation are probably not economically minable.

Upper Cretaceous

Separated from the Bear River Formation by a marine shale, the overlying Frontier Formation (also mapped as the lower part of the Blind Bull Formation) contains numerous fairly thick, persistent coal beds in western Wyoming (Glass, 1977). Throughout the rest of the State, the coal beds in the Frontier Formation are apparently thin, shaly, and of very limited extent.

The oldest widespread coal deposits in Wyoming are found in the Mesaverde Group and its western equivalent, the Adaville Formation. These rocks contain numerous thick to moderately thick coal beds in the Hams Fork and Green River Coal Fields. North and east of these two coal fields, Mesaverde coal beds are less numerous, thinner, and not as persistent. Because the Mesaverde Group (or formation) disappears northeastward across Wyoming, this group does not underlie the northeastern and northern portions of the Powder River Coal Field. The Mesaverde does, however, contain some thin coal beds on the southern flank of the Powder River field (Glass, 1976).

The Meeteetse Formation is recognized in the Wind River and Bighorn coal fields where it contains some minable coal beds. Most Meeteetse coal beds, however, are thin and discontinuous.

The Lance Formation contains the youngest Upper Cretaceous coal beds in Wyoming. Although Lance and equivalent aged rocks (**Figure 2**) contain coal beds throughout the State, coal beds in the Lance Formation are best developed in southern Wyoming. There they are numerous, but seldom reach more than 10 feet thick. Coal beds in the Lance Formation in the Goshen Hole Coal Field are apparently no more than 36 inches thick and are not economically minable.

Paleocene

Paleocene rocks (variously mapped as the Fort Union, Pinyon Conglomerate, Hanna, Ferris, or Evanston formations) crop out in all but the Black Hills and Goshen Hole Coal Fields. Paleocene rocks invariably contain coal beds although coal beds are

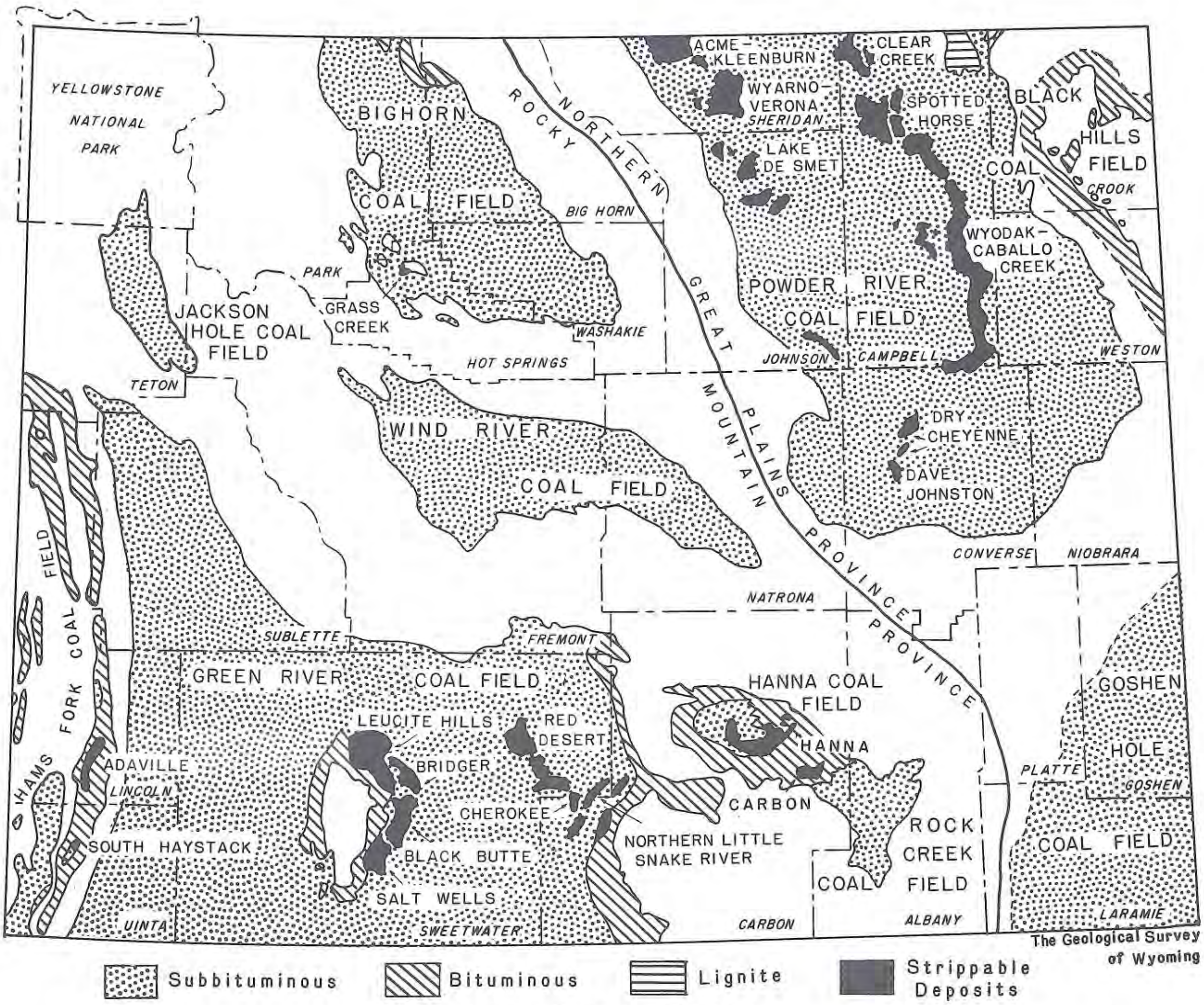

Figure 1. Wyoming coal fields.

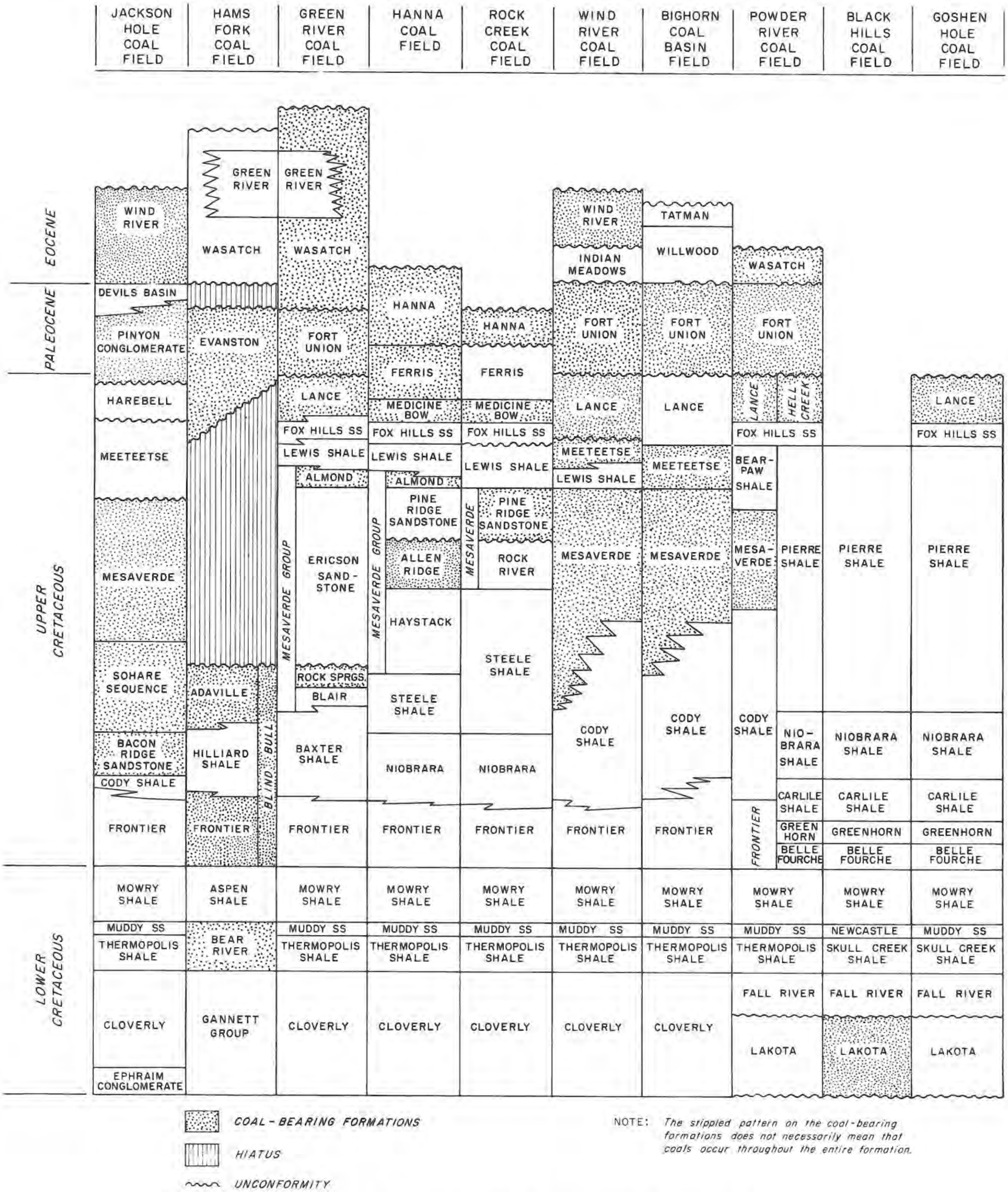

Figure 2. Major coal-bearing formations in Wyoming.

most abundant in the Powder River and Hanna Coal Fields. There are more Paleocene coal beds in the Ferris and Hanna formations of the Hanna Coal Field than in the Fort Union Formation of the Powder River Coal Field. The Paleocene coal beds in the Powder River field, however, are up to 200 feet thick, whereas the thickest coal bed in the Hanna Coal Field is only 60 feet (Glass and Roberts, 1980a).

Eocene

The Eocene Wasatch Formation is the youngest coal-bearing rock unit of economic importance in Wyoming. At least in the Powder River Coal Field, the Wasatch rivals the older Paleocene rocks in both the number of coal beds it contains and in their thicknesses. In fact, the Wasatch contains the thickest coal bed in Wyoming, the 250-foot-thick Lake De Smet bed (Obernyer, 1980). Equivalent aged coal beds are also abundant and moderately thick in the northeastern corner of the Green River Coal Field and in the Hanna Coal Field. Elsewhere in the State, Wasatch coal beds are thinner and less persistent than many older coal beds.

STRUCTURAL GEOLOGY OF THE COAL FIELDS

In general, Wyoming coal fields are situated in broad, asymmetrical, synclinal basins between various ranges of the Rocky Mountains. Except for those coal beds that are tilted against the Rock Springs uplift in the central portion of the Green River Coal Field, most of the State's coal beds are relatively flat-lying in the more central portions of the basins. Steeper dips and significant folding are common at some basin margins as well as on the flanks of mountain ranges.

The Hams Fork and Hanna Coal Fields exhibit the greatest structural complexity and the Powder River Coal Field shows the least. Faulting is most common in the southern and western coal fields, but it is not restricted to those fields.

CHARACTERIZATION OF COALS

Apparent rank

Except where coal beds are deeply buried, the apparent ranks of Wyoming coals are lignite to high volatile A bituminous. Although **Figure 1** shows lignites only in a small area in the northeastern corner of the Powder River Coal Field, the apparent ranks of many Tertiary-age coal beds have never been determined. Although it is possible that lignites are more widespread in the State than indicated by **Figure 1**, it is equally possible that there are no lignites at all.

Subbituminous coal beds, which are all either Tertiary or Late Cretaceous, are found in all coal fields of the State except the Black Hills. Usually, the subbituminous coal beds occupy the more central parts of the coal fields although, in the case of the Hams Fork Coal Field, subsequent erosion has relegated even the younger subbituminous coal-bearing rocks to narrow bands between faults and eroded folds.

Most of Wyoming's bituminous coal beds crop out in narrow bands in the Hams Fork Coal Field, around the Rock Springs uplift and along the eastern edge of the Green River Coal Field, and on the periphery and eastern half of the Hanna Coal Field. The Mesaverde coal beds in the north end of the Bighorn Coal Field and the Lower Cretaceous coal beds of the Black Hills Coal Field are also bituminous. Bituminous coals are actually much more widespread than these outcrops would suggest because a great portion of them lie deeply buried. Most bituminous coal beds are Cretaceous, but some Paleocene coal beds are also bituminous, i.e., some beds in both the Hanna and Bighorn coal fields.

While the older coal beds in any given coal field are generally higher in rank than the younger beds, the rank of individual beds in a coal field also increases downdip. Both of these variations in rank have been attributed to increases in depth of burial (Unfer, 1951). A recent report by Glass and Roberts (1980a) showed a marked regional increase in rank eastward across the Hanna Coal Field. It is not known if this regional variation is attributable to tectonic controls or to differences in depth of burial.

Proximate analyses and sulfur contents

Moisture, volatile matter, and fixed carbon contents of coal beds vary widely across the State in response to variations in rank. The bituminous and higher ranked subbituminous coal beds of the Cretaceous and Tertiary are very similar on an as-received basis. Moisture contents are less than 15%, volatile matter contents are between 30 and 40%, and fixed carbon contents are greater than 40%. In contrast, the lower ranked subbituminous Tertiary coal beds of the Green River and Powder River Coal Fields have as-received moisture contents between 20 and 30% and about equal volatile matter and fixed carbon contents.

Ash and sulfur contents are characteristically low and are more related to the depositional histories of the coal beds than to any differences in rank. Consequently, variation in ash contents, in particular, are quite irregular. As-received ash contents range from a few percent to more than 50% in response to the volume of inorganic debris entering the original peat swamp. Published analyses of various coal beds sampled across the State, however, suggest that a typical, persistent Wyoming coal bed of minable thickness contains less than 10% ash (**Table 1**).

Washability studies suggest that many Wyoming coal beds with higher than average ash contents are readily washed to a desirable ash level with minimum loss of yield (Deurbrouck, 1971; Jackson, 1978).

Although there have been published estimates of the average sulfur content of Wyoming's coal resources and reserves (Hamilton and others, 1975; Energy Information Administration, 1989), the data used for these estimates were incomplete, and it is recommended that they not be used (Glass, 1981; Glass and Jones, 1990). On an as-received basis, however, published analyses of Wyoming's Cretaceous coal beds usually show 0.40 to 2.0% sulfur compared to 0.3 to 0.9% sulfur in the State's Tertiary coal beds. Because of contract demands, sulfur contents of mined Wyoming coal beds seldom exceed 1.0% and average only 0.5% (**Table 1**).

High-sulfur coal does occur in the Green River and Hanna Coal Fields. Although the high-sulfur Wasatch coal beds of the Green River Coal Field are not mined, exploration has shown sulfur contents as high as 7% (Smith and others, 1972). Some of the stratigraphically higher, unmined coal beds of the Carbon district of the Hanna Coal Field contain up to 8.7% sulfur (Glass, 1978; Glass and Roberts, 1979).

In Wyoming's lower sulfur coals, the sulfate form of sulfur averages less than 0.03% (3-5% of the total sulfur); the pyritic form averages less than 0.2% (25-29% of the total sulfur); and the organic form averages less than 0.47% (70-72% of the total sulfur) (Walker and Hartner, 1966). Because most of the sulfur in Wyoming coal is in the organic form, conventional mechanical cleaning or preparation processes cannot materially reduce the total sulfur content. Even if all the pyritic sulfur could be removed, total sulfur would only be reduced by a maximum of 30%. There are, however, indications that the combustion of some relatively high-calcium coal beds in Wyoming traps a portion of their sulfur contents in their ash, thereby reducing sulfur dioxide emissions when these coal beds are burned (Hamilton and others, 1975).

In very-high-sulfur Wyoming coal, the pyritic form of sulfur becomes the dominant form although organic sulfur contents as high as 3% has been noted in some coal beds of the Carbon district of the Hanna Coal Field (Glass, 1978). When the organic sulfur form in these high-sulfur coal beds is between 2 and 3%, the pyritic sulfur is always 2 to 3 times higher.

Heat values

Heat values of currently mined coal beds vary widely across Wyoming (**Table 1**). In the southern half of the State, as-received heat values average about 10,000 Btu/lb. Heat values are typically between 9,480 and 11,030 Btu/lb. While heat values of coal beds mined in western Wyoming average 9,570 Btu/lb., they are much lower in northeastern Wyoming. Average heat values for northeastern Wyoming coals vary from 9,410 Btu/lb. in the Sheridan area to 7,710 Btu/lb. in Converse County, and they average 8,580 Btu/lb.

Heat values of Wyoming coal beds are commensurate with their apparent ranks (ASTM, 1987). On a moist, mineral-matter-free basis, the heat value of bituminous coal is between 11,500 Btu/lb. and 14,000 Btu/lb. while the heat value of subbituminous coal is between 8,300 Btu/lb. and 11,500 Btu/lb.

At least for subbituminous and bituminous coal beds, heat values increase noticeably under greater increments of overburden. While Unfer (1951) reported an increase of 300 Btu/lb. per 110-foot increase in overburden for relatively shallow coal beds in the Hanna Coal Field, an analysis of similar analytical data from Glass (1977) suggests that heat values increase about 140 Btu/lb. per 100 feet for the Adaville coal beds in westernmost Wyoming. More recently, a 6,000-foot exploration well for coalbed methane in the Hanna Coal Field indicated that heat values of coal beds between 1,500 and 6,000 feet deep increase between 50-60 Btu/lb. per 100 feet. The apparent ranks of the analyzed coal beds in this well are high volatile B to high volatile A bituminous. Where these coal beds crop out, their apparent rank is high volatile C bituminous.

Major and minor elements

In Wyoming coals, the major elements, which make up more than 0.1% of coal by weight, are silicon, calcium, aluminum, iron, and magnesium, usually in that order of abundance. Common minor elements, which account for less than 0.1% of coal by weight, are potassium, sodium, titanium, phosphorous, chlorine, and manganese, in that order (**Table 2**).

Silicon, aluminum, calcium, and iron all can occur in concentrations greater than 2%. Silicon concentrations have exceeded 5% in some samples. The minor elements rarely exceed 0.1% and are best described in parts per million.

Based on some recent analyses, Wyoming's Cretaceous and Tertiary coal beds show similar concentrations of all the major and minor elements except calcium and sodium. The concentrations of calcium and sodium in the Tertiary coal beds are usually five to six times the concentrations normally reported in the Cretaceous coal beds of Wyoming (Glass, 1975).

Table 1. Characteristics of Wyoming coal beds that are currently mined.

Coal field	Apparent rank	Bed thickness (feet)	Moisture (%) (as-received basis)	Ash (%) (as-received basis)	Sulfur (%) (as-received basis)	Heat Value (Btu/pound) (as-received basis)	Hardgrove Grindability Index (HGI)
Powder River Coal Field							
Northwestern portion	Subbituminous	Range: 10-57 Average: 40	Range: 14.5-26.0 Average: 21.5	Range: 3.1-8.2 Average: 4.9	Range: 0.3-1.0 Average: 0.48	Range: 9,000-10,410 Average: 9,410	Range: 39-50 Average: 41
Eastern portion	Subbituminous	Range: 50-100 Average: 75	Range: 21.1-36.9 Average: 29.8	Range: 3.9-12.2 Average: 5.1	Range: 0.2-1.2 Average: 0.36	Range: 7,420-9,600 Average: 8,580	Range: 49-55 Average: 53
Southern portion	Subbituminous	Range: 17-38 Average: 35	Range: 19.5-29.3 Average: 22.2	Range: 6.6-15.7 Average: 10.3	Range: 0.4-0.7 Average: 0.47	Range: 7,610-8,870 Average: 7,710	Range: 30-35 Average: 35
Hanna Coal Field	Subbituminous and bituminous	Range: 5-38 Average: 12	Range: 6.0-20.8 Average: 11.9	Range: 3.8-21.3 Average: 6.3	Range: 0.2-2.1 Average: 0.6	Range: 8,310-12,600 Average: 11,030	Range: 43-110 Average: 55
Green River Coal Field	Subbituminous	Range: 5-30 Average: 15	Range: 17.0-20.5 Average: 20.5	Range: 5.9-10.0 Average: 8.8	Range: 0.4-0.8 Average: 0.5	Range: 9,270-10,000 Average: 9,480	Range: 79-82 Average: 80
Hams Fork Coal Field	Subbituminous	Range: 5-90 Average: 16.5	Range: 15.4-28.6 Average: 20.8	Range: 5.9-10.0 Average: 5.8	Range: 0.4-0.81 Average: 0.81	Range: 9,270-10,000 Average: 9,570	Range: 79-82 Average: 51
Bighorn Coal Field	Bituminous	Range: 8-38 Average: 20	Range: 10.7-12.8 Average: 12.3	Range: 5.0-9.4 Average: 7.4	Range: 0.3-0.6 Average: 0.4	Range: 10,730-11,245 Average: 10,970	Range: 50-55 Average: 51

Table 2: Major and minor elements in 48 Wyoming coal samples in % on a whole-coal basis (Glass, 1975). (U.S. average from Swanson and others, 1976).

Element	Wyoming range	Wyoming average	U.S. average
Silicon	0.41-5.50	1.70	2.60
Calcium	0.13-2.10	0.75	0.54
Aluminum	0.17-2.50	0.72	1.40
Iron	0.15-2.10	0.51	1.60
Magnesium	0.026-0.34	0.17	0.12
Potassium	0.005-0.37	0.063	0.18
Sodium	0.003-0.19	0.044	0.06
Titanium	<0.001-0.13	0.038	0.08
Phosphorous	<0.0021-0.044	<0.012	—
Chlorine	0.004-<0.026	<0.010	—
Manganese	<0.0007-0.0492	0.004	0.01

Trace elements

Of the 30 trace elements recognized in 48 analyses of Wyoming coal beds, concentrations of the various elements vary from a high of 1,000 parts per million to a low of 0.004 parts per million. If these elements are grouped according to their average concentrations on a whole-coal basis, six elements average less than 1 part per million, 12 elements vary between 1 and 5 parts per million, 11 elements vary between 5 and 100 parts per million, and only barium averages more than 300 parts per million (**Table 3**).

With the exception of zinc, which averages 17.9 parts per million, the more common metals (copper, cobalt, nickel, and lead) all occur in concentrations between 1 and 5 parts per million. While the potentially dangerous elements, arsenic and molybdenum, also average 1 to 5 parts per million, selenium, cadmium, and mercury normally occur in concentrations of less than one part per million.

Based on these 48 published analyses, Tertiary coal beds in Wyoming apparently contain higher concentrations of 26 of these trace elements than do Cretaceous coal beds. Only boron, beryllium, and fluorine are higher in the Cretaceous coal beds (Glass, 1975).

Low-temperature carbonizing properties

Although most Wyoming coal beds are nonagglomerating, they can be carbonized in fluidized systems. Chars produced at low temperatures contain 17 to 23% residual volatile matter and are easily ignited. On a moisture-free basis, char heating values lie between 10,500 and 14,200 Btu/lb. and appear suitable as power plant fuel. Lump chars can be produced from most Wyoming coal beds, but they are relatively weak. These lump chars are a suitable substitute for coke breeze used in phosphate ore reduction (Landers and others, 1961).

At low temperatures, the yield of tar from coal beds generally increases with increase in rank, but the variation in yield within ranks may be large. Tar-plus-light oil yields vary between 14 and 40 gallons/ton of raw coal processed (Landers, 1961).

COKING COAL

Coal beds with weak to moderate coking properties occur in the Kemmerer district of the Hams Fork

Table 3: Average trace element concentrations in 48 Wyoming coal samples in parts per million on a whole-coal basis (Glass, 1975). (U.S. average from Swanson and others, 1976.)

Element	Wyoming average	U.S. average
Barium	300	150
Strontium	100	100
Boron	70	50
Fluorine	70	74
Cerium	<20	—
Zinc	17.9	39
Vanadium	15	20
Zirconium	15	30
Neodymium	<15	3
Copper	8	19
Chromium	7	15
Lanthanum	7	—
Nickel	5	15
Yttrium	5	10
Lithium	4.6	20
Gallium	3	7
Arsenic	<3	15
Lead	<3	16
Thorium	2.7	4.7
Cobalt	2	7
Germanium	<2	—
Niobium	1.5	—
Scandium	1.5	3
Molybdenum	1.0	3
Uranium	<0.9	1.8
Selenium	<0.8	4.1
Ytterbium	0.5	1
Antimony	<0.4	1.1
Cadmium	<0.15	1.3
Mercury	0.10	0.18

Coal Field, the Rock Springs district of the Green River Coal Field, and the Cambria district of the Black Hills Coal Field. The Lower Cretaceous Cambria coal bed in the Cambria district possesses the best coking qualities, but there is little published information on the remaining resources of the Cambria coal bed (Berryhill and others, 1950; Rich and others, 1988).

The Willow Creek No. 5 or Middle Main bed in the Kemmerer district of the Hams Fork Coal Field is between 3.1 feet and 6.5 feet thick and yields a weak coke. Recoverable reserves of this Frontier Formation coal bed are 8,000,000 tons. Other coal beds in the Hams Fork Coal Field also have coking potential (Berryhill and others, 1950; Toenges and others, 1945).

In the Green River Coal Field, the Rock Springs No. 7 bed in the Rock Springs Formation is 2 to 10 feet thick. Although there are more than 200,000,000 tons of measured resources of this coal bed, it is of poor coking quality (Berryhill and others, 1950). This coal bed crops out on the flanks of the Rock Springs uplift.

Coke plants

Currently there are two coke plants in Wyoming. FMC Corporation's process coke plant near Kemmerer was built in the early 1960s and uses the Adaville No. 1 coal bed from the Hams Fork Coal Field. The Adaville No. 1 is subbituminous in apparent rank and noncoking by normal processes. The patented FMC process dries, carbonizes, and calcines raw noncoking coal into a uniform carbon product called calcinate. The calcinate is combined with a liquid binder and formed into small pillow-shaped briquets. The typical composition for FMC coke in 1963 was (Farr, 1966):

Moisture 1.9%
Moisture-free ash 4.5%
Moisture-free volatile matter 1.6%
Moisture-free fixed carbon 93.9%
Moisture-free sulfur 0.6%

Char produced in an early stage of the FMC process is a suitable fuel for producing power and steam as well as for injection into blast furnaces. The calcinate is suitable for sintering iron ore.

FMC makes two grades of coke: chemical and metallurgical. Chemical coke, which is the lower grade, is used for reducing phosphate rock in electric furnaces at FMC's plant at Pocatello, Idaho. Another use for this coke is in the production of calcium carbide. FMC's metallurgical-grade coke is a much higher temperature coke that is suitable for blast furnace use.

D.D. Converter operates a commercial-sized coke plant for Monsanto's subsidiary, Sweetwater Resources. The plant, which is near Rock Springs was formerly run by Columbine Mining Company and Gunn-Quealy Coal Company before that. Monsanto's process can use poorly coking to noncoking coal of any rank to produce a chemical coke suitable for reducing phosphate in electric furnaces. Bituminous coal from Utah is currently used in the plant, which employs a rabble-type rotary oven. Currently all production from D.D. Converter goes to Monsanto's phosphate plant in Idaho.

IN-SITU GASIFICATION

The U.S. Department of Energy's former Laramie Energy Technology Center (LETC) conducted research into the in- situ production of gas from the Hanna No. 1 coal bed in the Hanna Coal Field. In the fall of 1972, numerous boreholes were drilled into this 30-foot-thick high volatile C bituminous coal bed, which underlaid the test site at depths in excess of 350 feet. The coal bed was ignited and extinguished during various experiments in which the combustion and gasification of the bed was controlled by regulation of air fed through the boreholes.

During their early experiments, LETC researchers reported gas volumes between 75,000 to 2 million cubic feet per day. The heat value of the product gas varied from 30 to 475 Btu/cubic foot. Subsequent experiments maintained gas production rates at an average of 2.7 million cubic feet per day with a gas heating value of 152 Btu/cubic foot (Brandenburg and others, 1976). The main constituent of the gas was nitrogen, which accounted for the low heat values. In all, four experiments were conducted at this site. LETC's fourth and last experiment was in 1979. Some activity resumed at the site in the late 1980s.

In 1974, Lawrence Livermore Laboratory (LLL) started an in-situ gasification experiment on a 25-foot-thick coal bed (the Felix[2] bed) that was 125 feet below the surface at their site. Drilling and explosive fracturing at the Hoe Creek site in Campbell County was completed in 1975. Ignition of the Felix[2] coal bed, however, was postponed because measured permeabilities and air flows indicated that there was insufficient flow between wells for successful gasification (Stephens and Lentzner, 1976).

In late 1977 with more closely spaced holes, LLL successfully burned 2,500 tons of coal during a 14-day test. Produced gas flowed at rates between 3 and 6 million cubic feet per day. Also, oxygen was injected into the burn, raising the heat value of the produced gas to 270 Btu/cubic foot. A final test, which involved horizontal drilling, was completed in 1979.

In addition to these two projects, both Gulf Research and Development and Atlantic Richfield have conducted their own experiments. Like LLL, Atlantic Richfield's project was located in the Powder

River Coal Field. In this case, however, Atlantic Richfield's site was over the thick Wyodak coal bed.

In 1977, Gulf Resources and Development was awarded a $13.5-million cost-sharing contract with the U.S. Department of Energy. The contract called for a five-year study of the in-situ gasification of steeply dipping coal beds. Their project site was located near Rawlins in the eastern portion of the Green River Coal Field. Gulf's first burn occurred in 1979; their last test was in 1981. In 1987, Energy International, Inc. acquired some funding from the U.S. Department of Energy to resume the in-situ gasification tests of steeply dipping coal beds at the old Gulf site. They hope to have a commercial operation on line in the 1990s.

COAL MINING AND PRODUCTION

Except for an 11-year interval after World War I, Wyoming's annual coal production for the years 1910 through 1945 remained above 6 million tons. After 1945, the railroads' conversion from coal-fired, steam-driven locomotives to diesel engines caused production to fall. It reached a record low of 1.6 million tons in 1958.

Renewed interest in Wyoming's coal resources began in the late 1960s as power plant demands for inexpensive, low-sulfur coal increased. Because of this demand, the combined production from Wyoming's coal companies has set new records every year but one since 1972 (**Figure 3**). Production did decrease slightly in 1986.

Wyoming's 1990 tonnage was no exception. It increased to more than 184 million tons. With this tonnage, Wyoming remains the largest coal-producing state in the Nation.

Coal production in Wyoming was dominated by underground mining until 1954. In that year, tonnages from strip mining barely exceeded that from the underground mines. Since then, however, strip mining has become the dominant mining method and now accounts for more than 99% of Wyoming's annual production. Conversely, underground mining has slipped to less than 1% of the annual tonnage mined.

In 1989, 97.7% of the coal mined in Wyoming was used to fuel power plants in Wyoming and in 22 other states. In-state and out-of-state industrial users including the beet sugar, cement, trona, bentonite, synthetic coke, and phosphate industries used 2.2% of the State's production or 3.7 million tons of coal. Residential/commercial users within and outside Wyoming accounted for another 0.2% or 300,000 tons of coal (Energy Information Administration, 1990b). Markets for Wyoming coal were similar in 1990 although specific information is not yet available.

COALBED METHANE

Coalbed methane is a natural by-product of the coalification of plant materials through time. There are two kinds of coalbed methane, biogenic and thermogenic. Biogenic coalbed methane is derived from microbial action on low-rank coal that has not been deeply buried and that has not been subjected to elevated temperatures. Thermogenic coalbed methane, on the other hand, is derived from higher rank coal that has been more deeply buried. This higher rank coal has been subjected to higher temperatures, related either to its greater depth of burial or to higher geothermal gradients.

Commercial accumulations of biogenic coalbed methane occur in several Wyoming coal fields. The most significant quantity of biogenic methane exists in shallow Tertiary coal beds in the Powder River Coal Field. While the methane contents of individual coal beds are relatively low in this field (usually less

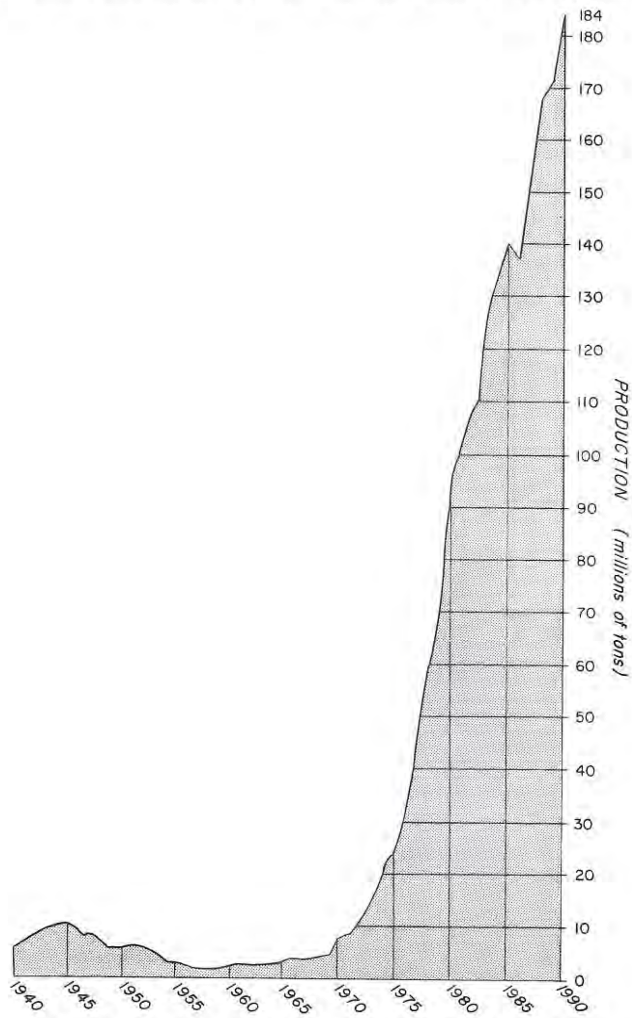

Figure 3. Wyoming coal production, 1940 to 1990.

than 100 cubic feet of gas per ton of coal), the great number of coal beds and the exceptional thickness of many of the coal beds account for the accumulation of large quantities of coalbed methane. In the Powder River Coal Field, biogenic coalbed methane is commercially produced from thick coal beds as well as from sandstone units that have been charged with methane from adjacent coal beds.

Thermogenic coalbed methane also exists in many Wyoming coal fields where Cretaceous and some Tertiary coal beds have been buried in structurally deep portions of sedimentary basins. Because these coal beds are usually higher in rank by virtue of their depth of burial, their methane content is generally higher (exceeding 500 cubic feet of gas per ton of coal in western Wyoming). Commercial accumulations of thermogenic coalbed methane have recently been documented in the Hanna Coal Field, in the southeastern part of the Green River Coal Field near the Wyoming-Colorado State Line, and in the central part of the Green River Coal Field on the northeastern flank of the Rock Springs uplift (Jones and DeBruin, 1990).

Based on the assumption that the gas contents of coal beds in the State are between 5 and 100 cubic feet per ton, Jones and DeBruin (1990) estimate that the in-place resources of coalbed methane in Wyoming are between 7.25 and 145.0 trillion cubic feet. Commercial production of this resource began in the Powder River Coal Field in 1986, from sandstones adjacent to coal beds in the Fort Union Formation. It wasn't until 1989 that coalbed methane was produced directly from a thick Fort Union coal bed north of Gillette. Cumulative production of coalbed methane, which has all come from the Powder River Coal Field to date, was more than 2 billion cubic feet through December 31, 1989.

COAL FIELD DESCRIPTIONS

Powder River Coal Field

The Powder River Coal Field of northeastern Wyoming includes Campbell County and portions of Sheridan, Crook, Weston, Niobrara, Converse, Natrona, and Johnson counties (**Figure 1**). This 14,700-square mile coal field, which is areally the second largest in the State, coincides with the topographic and structural basin of the same name. As defined, however, the coal field is limited to that portion of the Powder River Basin underlain by Mesaverde Formation or younger rocks. This definition was chosen because the Mesaverde Formation is the oldest coal-bearing formation in the field.

Structurally, the coal field is part of a broad asymmetric syncline bounded by the Bighorn Mountains to the west, the Black Hills to the east, and the Casper arch, Laramie Mountains, and Hartville uplift to the south. The syncline continues into Montana where it is separated from the Williston Basin by the Cedar Ridge anticline. Because the axis of this asymmetric syncline is west of its geographic center, the rocks in the eastern and central portions of the coal field have almost imperceptible dips compared to the steeper dips on the western side. In general, the Cretaceous rocks around the margins of the coal field dip more steeply than the Tertiary rocks, which are nearly flat-lying (2-3° dip) except on the west side where at least the Paleocene rocks steepen to 10 to more than 25°.

Although some faulting occurs in many areas of the coal field, faults are relatively rare except on the west margin, particularly in southern Johnson County. Most of the faults trend northeast-southwest with apparent maximum vertical displacements of 300 to 400 feet in the Sussex area.

At 1.03 trillion tons (Wood and Bour, 1988), this coal field has the largest in-place coal resources of any field in the conterminous United States. Although coal beds occur in the Upper Cretaceous Mesaverde and Lance formations, the thickest and most important coal beds are in the Paleocene Fort Union Formation and the Eocene Wasatch Formation (**Figure 2**).

The Fort Union Formation, which is between 2,000 and 3,000 feet thick, is perhaps the most prolific coal-bearing rock unit in Wyoming. Although the lower members of the formation contain coal beds, the most persistent and thickest coal beds occur in the 1,500 to 1,800 feet thick upper member, the Tongue River Member. Coal beds in the Tongue River Member are best developed in the northern and eastern portions of the Powder River Coal Field and consist of 8 to 12 persistent, subbituminous coal beds (Denson and Keefer, 1974).

The most important of these Paleocene coal beds, the Wyodak bed, is persistently 50 to 100 feet thick. The outcrop of this coal, though burned in many places, is mapped for more than 100 miles along the eastern side of the coal field. Regionally, the Wyodak splits into two or more separate beds (**Figure 4**). Several of these beds are correlative with coal beds in the Sheridan area, 60 miles across the field (Glass, 1976). A portion of the Wyodak coal is also correlative with the Big George bed, which is another thick coal bed in the Fort Union Formation. This coal bed, which occurs in the west-central portion of the field, averages 113 feet thick and lies at depths greater than 1,000 feet (Kent, 1986).

The Wasatch Formation, which is 1,000 to 2,000 feet thick, is another prolific coal-bearing formation rivaled in importance only by the Fort Union Formation. The Wasatch Formation crops out over much of the central portion of the Powder River Coal Field, and usually exhibits low dips (less than 4 °).

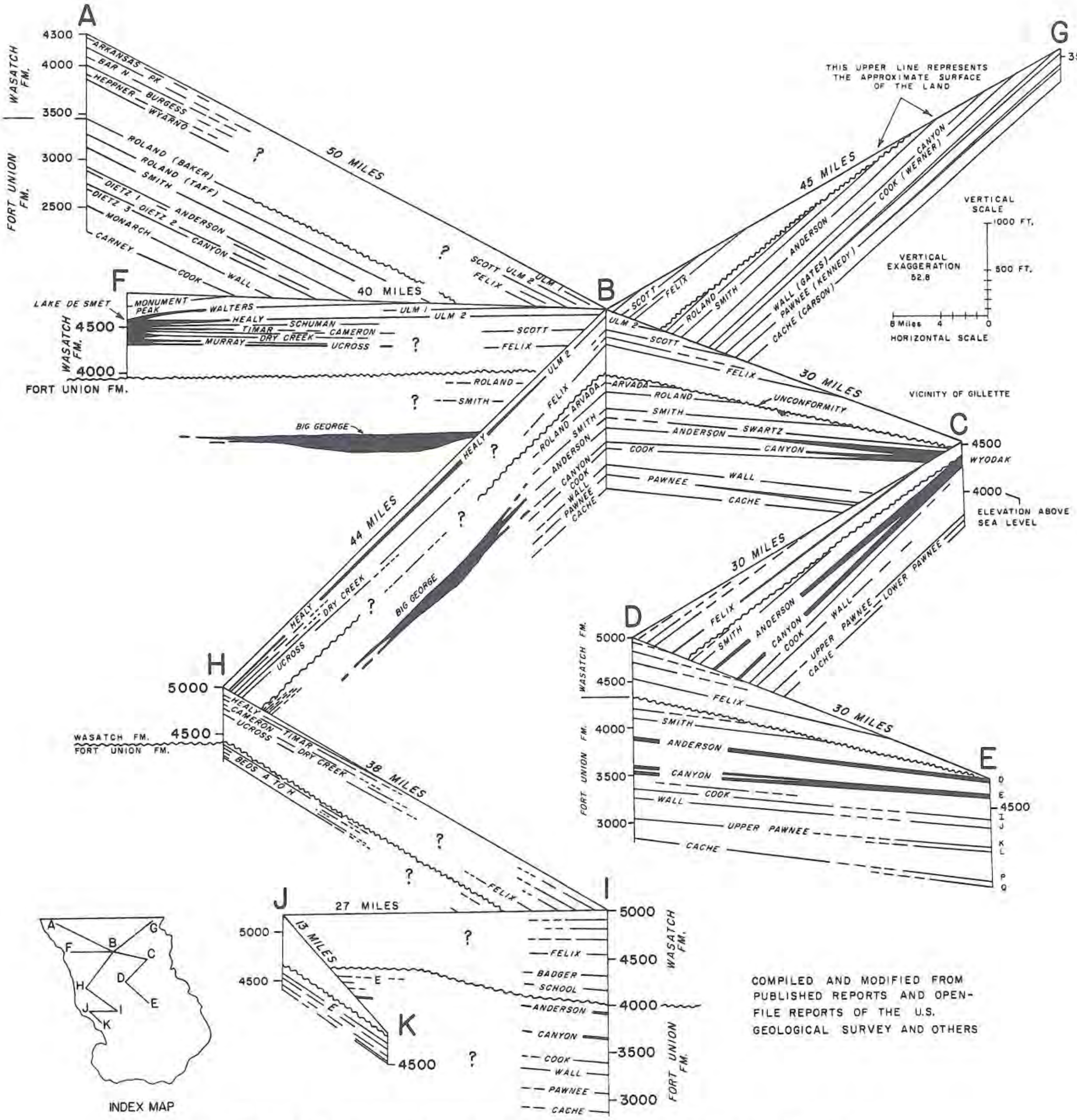

Figure 4. Correlation of coal beds in the Powder River Coal Field.

The Wasatch Formation contains as many as eight, thick, persistent coal beds (**Figure 4**). While these Wasatch coal beds are mapped and correlated for tens of miles along outcrop, they are thicker and more persistent in the western and central parts of the basin. The thickest Wasatch coal bed is the Lake De Smet bed on the west side of the field in northern Johnson County. The Lake De Smet coal bed locally exceeds 200 feet thick (Mapel, 1959).

Important coal beds in the Powder River Coal Field

Anderson coal bed: This Paleocene coal bed is well developed in most of the Powder River Coal Field. The Anderson coal bed coalesces with the Canyon coal bed in the Gillette area to form the 70- to 175-foot-thick Wyodak coal bed, which crops out on the eastern side of the field (Denson and others, 1978; Kent and others, 1980). Northward, westward, and southward from Gillette, the Anderson splits off the Wyodak bed and thins to 10 to 50 feet thick (**Figure 4**). Farther westward it again merges with the Canyon coal bed, forming the Big George bed discussed below.

In reports prior to the mid-1970s, the Anderson coal bed had been called the D coal bed, south of Gillette. At one time it was also incorrectly correlated with the Roland coal bed, which is stratigraphically higher.

The strippable reserve base for the Anderson coal bed is included in the 19 billion tons of reserve base calculated for the Wyodak coal bed (Smith and others, 1972). The Anderson coal bed is currently mined only where it is combined with the Canyon coal bed to form the Wyodak bed.

The apparent rank of this coal bed is subbituminous C. Nine core analyses of this bed are summarized below (U.S. Geological Survey and Montana Bureau of Mines and Geology, 1973, 1974):

As-received basis	*Range (9 analyses)*	*Average*
Moisture (%)	24.9-34.1	29.5
Volatile matter (%)	26.5-34.5	30.1
Fixed carbon (%)	29.0-38.0	33.9
Ash (%)	3.5-12.2	6.5
Sulfur (%)	0.17-1.13	0.52
Btu/lb.	7,130-8,740	7,900

Badger coal bed: This coal bed is best developed in the Dave Johnston deposit in the southern part of the coal field (**Figure 1**). The coal bed occurs near the base of the Wasatch Formation, between the School and Felix coal beds (Denson and others, 1978).

The Badger coal bed is 17 to 20 feet thick and is normally 110 to 180 feet above the School bed. The U.S. Bureau of Mines conservatively estimated that the original, in-place, strippable reserve base for this bed in Converse County was 9.5 million tons (Smith and others, 1972).

The Badger coal bed is mined in Glenrock Coal Company's Dave Johnston strip mine north of Glenrock for use in the Dave Johnston power plant at Glenrock. Its apparent rank is subbituminous C. Five analyses from that mine show the following composition:

As-received basis	*Range (5 analyses)*	*Average*
Moisture (%)	22.7-29.3	27.4
Volatile matter (%)	31.7-34.5	33.3
Fixed carbon (%)	28.5-32.6	31.4
Ash (%)	6.6-9.8	7.9
Sulfur (%)	0.4-0.5	0.45
Btu/lb.	7,610-8,290	7,950

Big George coal bed: The Big George coal bed is a relatively recently defined deposit of coalescing coal beds in the west-central part of the Powder River Coal Field (**Figure 4**). Kent (1986) reports the coal bed is up to 200 feet thick and averages 113 feet thick. This thick bed does not crop out, but only occurs in the subsurface at depths between 1,000 and 2,000 feet (Ayers, 1986). For this reason, the coal bed is not currently mined. There are, however, several coalbed methane projects testing this bed.

Because the Anderson and Canyon coal beds merge to form the Big George coal bed, Big George is correlative with the upper portion of the thick Wyodak coal bed of the Fort Union Formation in the Gillette area (Pierce and others, 1990). In the intervening distance between these two thick coal deposits, the Anderson and Canyon coal beds thin (Kent, 1986; Pierce and others, 1990). Pierce and others (1982) estimate that the Big George deposit contains a resource of 113 billion tons.

The apparent rank of this coal bed is subbituminous A. An average unweighted analysis is provided by Kent (1986). This average is derived from the analyses of 30 incremental samples of a 200-foot-thick cored portion of the bed:

As-received basis	*Average*
Moisture (%)	22.6
Volatile matter (%)	30.5
Fixed carbon (%)	43.3
Ash (%)	3.5
Sulfur (%)	0.25
Btu/lb.	9,750

C coal bed: See Wasatch coal beds.

Canyon coal bed: The Canyon coal bed is a persistent, 11- to 65-foot-thick bed in the Fort Union Formation over most if not all the coal field. In the Gillette area of Campbell County, the Canyon and other coal beds coalesce with the Anderson bed to form the thick Wyodak coal bed (70-175 feet), which crops out on the eastern side of the field (**Figure 4**). North of Gillette, the Canyon also locally merges with the Cook coal bed to form a 54-foot-thick bed (Kent and others, 1980). In western Campbell County and eastern Johnson County, the Canyon merges with the Anderson coal bed to form the thick Big George coal bed (Pierce and others, 1990).

The Canyon bed has been called the E coal bed, south of Gillette. While the Canyon is also correlative with the Monarch bed in the Sheridan area, it is not correlative with the stratigraphically higher Smith coal bed as previously reported (Culbertson and others, 1979).

Except for an estimated 184.9 million tons of strippable reserve base along Clear Creek in northwestern Campbell County, the strippable reserve base of the Canyon bed is reported with the Wyodak bed or with the Monarch and Dietz beds in the Acme-Kleenburn district in the northwestern corner of the field (**Figure 1**) (Smith and others, 1972).

The analyses of the Canyon coal bed, which are summarized below, are from Campbell County (U.S. Geological Survey and Montana Bureau of Mines and Geology, 1973, 1974). In this part of the field, the coal bed's apparent rank is subbituminous C. Analyses from Sheridan County are not averaged with these because the quality of the Canyon coal bed in the two counties is quite different (see Monarch coal bed).

As-received basis	*Range (9 core analyses)*	*Average*
Moisture (%)	26.5-31.5	29.6
Volatile matter (%)	28.7-33.3	30.7
Fixed carbon (%)	31.8-38.4	34.6
Ash (%)	3.1-7.4	5.1
Sulfur (%)	0.14-0.92	0.34
Btu/lb.	7,540-8,610	8,290

D coal bed: See Anderson coal bed.

Daly coal bed: see Wasatch coal beds.

Dietz No. 2 coal bed: This coal bed is locally important in the Acme-Kleenburn area in the northwestern corner of the Powder River Coal Field (**Figure 1**). Big Horn Coal Company is mining or has mined it as a rider bed above the Monarch and Dietz No. 3 coal beds. This Fort Union Formation coal bed averages 12 feet thick and was previously identified as the Armstrong coal bed in Big Horn's strip mine. Analytical data on the subbituminous Dietz No. 2 coal bed is summarized below:

As-received basis	*Range or typical analysis (5 analyses)*
Moisture (%)	21.7-23.8
Volatile matter (%)	33.6
Fixed carbon (%)	38.5
Ash (%)	5.6-6.6
Sulfur (%)	0.74-1.02
Btu/lb.	9,220-9,390

Dietz No. 3 coal bed: This coal bed is another important strippable bed in the northwestern corner of the coal field, where it was once extensively deep mined. It averages 10 to 25 feet thick. Locally, the Dietz No. 3 coalesces with the underlying Monarch (Canyon) coal bed to form a 40- to 45-foot-thick bed in the Acme-Kleenburn area of Sheridan County (**Figure 1**). The Dietz No. 3 also locally coalesces with the Dietz Nos. 1 and 2 coal beds, reaching a cumulative thickness of 75 feet (Law and others, 1979).

The estimated original, in-place, strippable reserve base for this Fort Union Formation coal bed is included with the estimate for the Monarch coal bed, which underlies it by a few inches to 60 feet. Collectively, the original strippable reserve base for the two coal beds exceeded 12.5 million tons (Smith and others, 1972).

The Dietz No. 3 is mined along with the Monarch coal bed in Big Horn Coal Company's strip mine north of Sheridan. A typical analysis of the Dietz No. 3 in this mine is provided below (Glass, 1975). Based on this analysis and analyses of the underlying Monarch coal bed, the Dietz No. 3 has an apparent rank of subbituminous B.

As-received basis	*Typical analysis*
Moisture (%)	19.1
Volatile matter (%)	34.8
Fixed carbon (%)	41.7
Ash (%)	4.4
Sulfur (%)	0.5
Btu/lb.	9,710

E coal bed: See Canyon coal bed.

F coal bed: This Wasatch coal bed occurs in the Dry Cheyenne deposit in the southern portion of the Powder River Coal Field in Converse County (**Figure 1**). Bed F has a maximum thickness of 11.6 feet, but averages only 7.5 feet (Smith and others, 1972). The strippable reserve base of this bed is estimated at 179.5 million tons (Smith and others, 1972). There are no published analyses of this coal, and it is not presently mined.

Felix coal bed: This is a persistent coal bed in the northern and central portions of the Powder River Coal Field. This Wasatch Formation coal bed is 5 to 21 feet thick in the northwestern part of Campbell County. It thickens to as much 50 feet in the central and southern parts of Campbell County. Partings are common and fairly persistent in places. In the Caballo Creek area south of Gillette (**Figure 1**), a parting up to 79 feet thick separates the Felix coal bed into an upper bed, the Felix[1] (5.5-12 feet thick), and a lower bed, the Felix[2] (15.4 to 31 feet thick) (Grazis, 1977 a-d).

Based on Smith and others, (1972), Kent and others (1977), Haddock and others (1976), Grazis (1977a-d), and Kent (1986), the strippable reserve base of the Felix coal bed in the northern and central portions of the coal field is at least 1,881.5 million tons. This coal bed is not currently mined. Lawrence Livermore Laboratory, however, conducted in-situ gasification experiments in this bed, south of Gillette.

The Felix coal bed has an apparent rank of subbituminous C. Analyses of 42 core samples of this bed are summarized below (U.S. Geological Survey and Montana Bureau of Mines and Geology, 1973, 1974):

As-received basis	*Range (42 core samples)*	*Average*
Moisture (%)	17.8-33.5	28.0
Volatile matter (%)	29.1-36.4	31.7
Fixed carbon (%)	28.4-39.4	32.5
Ash (%)	4.5-14.9	7.8
Sulfur (%)	0.32-3.26	0.89
Btu/lb.	7,180-9,535	8,050

Glenrock-Big Muddy zone coal beds; This coal zone is in the basal 200 to 300 feet of the Lance Formation and is restricted to the southernmost part of the coal field, extending from just east of Glenrock to northeast of Casper, 15 miles to the west (Glass, 1976). Coal beds are reportedly up to 6.8 feet thick and dip northeast at 3 to 7°.

Although none of these coal beds are currently mined, they were mined in the past. While the coal beds mined in the Glenrock area averaged about six feet thick, those mined near Big Muddy and Casper were all less than five feet thick. Their apparent rank is subbituminous C. Analyses of the coal beds in this zone are summarized below (Fieldner and others, 1931):

As-received basis	*Range (10 analyses)*	*Average*
Moisture (%)	19.9-27.2	23.4
Volatile matter (%)	29.7-49.3	35.9
Fixed carbon (%)	20.3-41.3	34.0
Ash (%)	4.8-10.6	6.8
Sulfur (%)	0.40-0.97	0.66
Btu/lb.	7,695-9,270	8,740

Lake De Smet coal bed: The Lake De Smet coal bed is the thickest known coal bed in the conterminous United States. The bed occurs in north-central Johnson County, where it is reportedly as much as 250 feet thick in some drill hole descriptions (Mapel, 1959; Obernyer, 1978; 1980). Upper portions of this Wasatch coal bed, however, are frequently burned over much of its area of occurrence. The Lake De Smet bed was originally correlated with the Healy coal bed to the north and east (Mapel, 1959; Culbertson and Mapel, 1976). Obernyer (1978, 1980), however, showed that the thick Lake De Smet coal bed at Lake De Smet represents the coalescing of five major coal beds, possibly in response to basin-margin faulting active in Eocene time. From oldest to youngest, these coal beds are the Ucross, Murray, Cameron, Healy, and Walters.

The strippable reserve base of the Lake De Smet coal bed is approximately one billion tons (Smith and others, 1972). Most of these reserves are in the vicinity of Lake De Smet or southeast of there (**Figure 1**). The coal bed is not currently mined.

The apparent rank of the Lake De Smet coal bed is subbituminous C. Fifteen analyses of the bed show the following range in quality (none represent more than a portion of the total bed):

As-received basis	*Range (5 to 15 analyses)*[1]	*Average (5 analyses)*
Moisture (%)	22.6-30.7	28.5
Volatile matter (%)	28.6-31.9	30.0
Fixed carbon (%)	32.8-34.8	33.9
Ash (%)	5.1-22.1	7.6
Sulfur (%)	0.26-3.00	0.6
Btu/lb.	6,480-8,270	7,880

[1]Ten of these analyses did not include volatile matter and fixed carbon.

Lower Ulm coal bed: See PK, Ulm 2, and Ulm 1 coal beds.

Mesaverde coal beds: Although several Mesaverde coal beds have been prospected in the southern end of the coal field between Casper and Glenrock, they have only been mined on a very local basis. These prospected coal beds were only 1.8 to 3 feet thick. While two published analyses from these prospects contained over 37% ash, another two analyses revealed fairly good coal as shown below (Shaw, 1909; Fieldner and others, 1918). Based on these two analyses, the apparent rank of these coal beds is subbituminous C.

As-received basis	*Range (2 analyses)*	*Average*
Moisture (%)	19.8-24.1	21.9
Volatile matter (%)	41.4-33.6	37.5
Fixed carbon (%)	26.2-36.8	31.5
Ash (%)	5.5-12.6	9.0
Sulfur (%)	0.70-0.72	0.71
Btu/lb.	8,250-8,710	8,480

Monarch coal bed: The Monarch coal bed is one of the most important Fort Union Formation coal beds in the Acme-Kleenburn area in the northwestern corner of the Powder River Coal Field (**Figure 1**). Although it is reportedly up to 57 feet thick, the thicker occurrences apparently equate to areas where the Monarch and Dietz No. 3 coal beds merge into a single bed. Where the Monarch is a single bed, it is between 5 and 25 feet thick. The Monarch coal bed is correlative with the Canyon coal bed on the eastern side of Powder River Coal Field (**Figure 4**) (Culbertson and others, 1979).

An estimate of the original strippable reserve base for this coal bed in the Acme-Kleenburn area was 125 million tons. This estimate included some Dietz No. 3 tonnage as well.

Currently, Big Horn Coal Company operates the only active mine on the Monarch coal bed. The Monarch bed is merged with the Dietz No. 3 over a large portion of Big Horn's strip mine, which is located near the former site of Acme, Wyoming. Collectively, the two beds are over 44 feet thick at this mine.

The apparent rank of the Monarch coal bed is subbituminous B. Analyses of the Monarch bed from various publications of the U.S. Bureau of Mines, U.S. Geological Survey, and the Geological Survey of Wyoming are summarized below. Some of these published analyses, like the reserve estimates, probably include the Dietz No. 3 coal bed:

As-received basis	*Range (203 analyses)*	*Average*
Moisture (%)	14.5-26.0	21.5
Volatile matter (%)	30.3-38.4	34.5
Fixed carbon (%)	34.9-44.0	39.6
Ash (%)	3.1-8.2	4.4
Sulfur (%)	0.3-0.7	0.4
Btu/lb.	9,000-10,410	9,600

Parnell coal bed: See Wasatch coal beds.

PK, Ulm 2, and Ulm 1 coal beds: These three Wasatch Formation coal beds are persistent in the Wyarno-Verona deposit in the central part of

Sheridan County where they are 4 to 52 feet thick (**Figure** 1). The Ulm 2 is also locally persistent in the Caballo Creek area south of Gillette (**Figure 1**), where it is called the lower Ulm (Grazis, 1977a-d).

In the central part of Sheridan County, the PK coal bed, which locally splits into at least three benches, is 4 to 18 feet thick and correlates with the Ucross bed in Johnson County (Culbertson and Mapel, 1976). The Ulm 2, which occurs about 300 feet above the PK coal zone, is 7 to 30 feet thick. Culbertson and Mapel (1976) correlate this coal bed to the Healy coal bed of the Lake De Smet deposit in Johnson County (**Figure** 4). The Ulm 1 lies 60 to 200 feet above the Ulm 2 and is believed to be correlative with the Walters coal bed of Johnson County (Culbertson and Mapel, 1976). The Ulm 1 in Johnson and Sheridan counties is 14 to 52 feet thick. It is thickest where it includes several thick shale partings. All three of these beds become part of the thick Lake De Smet bed in northern Johnson County (Obernyer, 1978, 1980).

A strippable reserve base of 1.8 billion tons has been estimated for these three coal beds in the Wyarno-Verona deposit of central Sheridan County (Culbertson and Mapel, 1976). This strippable reserve base includes 200 million tons of the PK coal bed, 990 million tons of the Ulm 2 coal bed, 543 million tons of the Ulm 1 coal bed, and 67 million tons of other thinner and less persistent Wasatch coal beds. All the coal beds included in this estimate, however, were greater than 10 feet thick and under less than 200 feet of cover.

Grazis (1977a-d) estimated another 43.8 million tons of strippable reserve base for the lower Ulm (Ulm 2) in the Caballo Creek area of Campbell County. All the coal beds included in Grazis' estimate were at least 5 feet thick and under less than 200 feet of cover. None of these Wasatch coal beds, in either area, are currently mined.

Analyses of these coal beds are few, and many were performed on badly weathered samples. Excluding all analyses where the heat values were below 6,500 Btu/lb., analyses of the Ulm 1, Ulm 2, and PK beds are averaged below. The apparent rank of these coal beds is subbituminous C.

As-received basis	*Range (5 analyses)*	*Average*
Moisture (%)	30.7-27.4	30.2
Volatile matter (%)	28.9-33.2	31.2
Fixed carbon (%)	31.0-38.4	34.3
Ash (%)	2.3-8.8	4.3
Sulfur (%)	0.3-3.2	1.5
Btu/lb.	7,640-8,320	8,000

School coal bed: In the southern portion of the coal field, the School bed is a thick, persistent coal bed in the Dave Johnston deposit north of Glenrock (**Figure 1**). The coal bed occurs near the base of the Wasatch between the Anderson coal bed of the underlying Fort Union Formation and the Badger coal bed of the Wasatch Formation (Denson and others,1978).

The School bed, which lies 110 to 180 feet below the Badger coal bed, is 22 to 38 feet thick, but averages 35 feet. The quality of the bed deteriorates to the south due to shaly partings. Northward its quality remains good, but the bed thins.

The original strippable reserve base of this coal in Converse County was 126.2 million tons (Smith and others, 1972). Since 1958, Glenrock Coal Company has been mining this coal at their Dave Johnston strip mine north of Glenrock. Three analyses from their mine are given below. The apparent rank of the School bed is subbituminous C.

As -received basis	*Range (3 analyses)*	*Average*
Moisture (%)	19.5-26.4	22.2
Volatile matter (%)	34.4-38.1	35.9
Fixed carbon (%)	28.3-33.6	30.5
Ash (%)	8.8-15.7	11.4
Sulfur (%)	0.5-0.7	0.6
Btu/lb.	7,830-8,870	8,180

Scott coal bed: See Wasatch coal beds.

Smith coal bed: The Smith bed is best developed in northwestern Campbell County (Olive, 1957). The bed occurs near the top of the Fort Union Formation when it has not been cut out by the Wasatch-Fort Union unconformity (**Figure 4**). The Smith coal bed is not correlative with the stratigraphically lower Canyon coal bed of the Gillette area (McLellan and others, 1990).

Where it is best developed, the Smith coal bed is 5 to 20 feet thick (Olive, 1957; Smith and others, 1972; and McLellan and others, 1990). In the vicinity of Spotted Horse, a local, 4.5- to 13-foot-thick, unnamed coal bed (possibly the Swartz coal bed) underlies the Smith coal bed by 30 feet. In that area, there are an estimated 178 million strippable tons of the Smith coal bed and another 58.3 million strippable tons of the local coal bed (Smith and others, 1972). Neither coal bed is mined at this time.

A single core analysis of the Smith coal bed is provided below (U.S. Geological Survey and Montana Bureau of Mines and Geology, 1974). Based on this analysis, the coal bed has an apparent rank of subbituminous C.

As-received basis	*Core analysis*
Moisture (%)	31.8
Volatile matter (%)	28.7
Fixed carbon (%)	34.8
Ash (%)	4.7
Sulfur (%)	0.63
Btu/lb.	7,990

Sussex district, "lower coal bed": A number of Fort Union Formation coal beds crop out in the southeastern corner of Johnson County, northeast of Lynch

(**Figure 1**). The outcrops occur in what has been called Sussex Basin No. 4. The "lower coal bed" in Basin No. 4 of the Sussex district averages 11.8 feet thick, but reaches a maximum of 50 feet in places. A preliminary estimate of the strippable reserve base of this Fort Union Formation coal bed is 13.6 million tons (Smith and others, 1972). This bed is not currently mined.

Based on the one analysis of the "lower coal bed" given below, this coal bed has an apparent rank of subbituminous B (Smith and others, 1972).

As-received basis	*One analysis*
Moisture (%)	23.5
Volatile matter (%)	35.6
Fixed carbon (%)	35.7
Ash (%)	5.2
Sulfur (%)	0.49
Btu/lb.	9,160

Truman coal bed: See Wasatch coal beds.

Ulm 1 coal bed: See PK coal bed.

Ulm 2 coal bed: See PK coal bed.

Walters coal bed: See PK coal bed and the Lake De Smet coal bed.

Wasatch coal beds: In the northwestern and central areas of Campbell County, there are a number of less well known but persistent Wasatch Formation coal beds. In northwestern Campbell County, these coal beds are, in descending order: the Truman, Parnell, Scott, and Daly beds. They all overlie the Felix coal bed. In the Caballo Creek area south of Gillette, the C bed is another persistent Wasatch coal bed, which lies 330 feet above the Felix coal bed.

All of these coal beds are locally 5 to 10 feet thick. The Truman coal bed exceeds 10 feet thick in the northwestern corner of the county; the C bed also is greater than 10 feet thick in the Caballo Creek area.

Kent and others (1977) and Haddock and others (1976) estimated the strippable reserve base at 74.5 million tons for the Truman bed, 30.6 million tons for the Parnell bed, 17.9 million tons for the Scott bed, and 11.2 million tons for the Daly bed. These same investigators tabulated another 4.8 million tons of strippable reserve base for a local coal bed below the Felix bed. Grazis (1977a-d) estimated the strippable reserve base for the C coal bed at 41.8 million tons. This coal bed is commonly 6 to 10 feet thick. None of these Wasatch Formation coal beds are currently mined. Although there are no analyses of these coal beds available, analyses of comparable coal beds indicate they are probably subbituminous.

Wyodak coal bed: Outcrops show this thick Fort Union Formation coal bed is persistent, though extensively burned, on the eastern side of Campbell County, especially in the Gillette area (**Figure 1**). The coal has been called the Roland-Smith, Wyodak-Anderson, and Anderson-Canyon coal bed. Recent geologic mapping by the U.S. Geological Survey, however, shows that this coal bed does not directly correlate with the stratigraphically higher Roland coal bed as previously reported (Kent and others, 1980; Kent, 1986).

This coal bed is 25 to 175 feet thick and averages 100 feet thick (U.S. Geological Survey and Montana Bureau of Mines, 1976). In the central part of the coal field, the Wyodak coal bed splits westward into an Upper Wyodak, comprised of the Anderson and Canyon coal beds, and a lower and less persistent Lower Wyodak. In this area, the Upper and the Lower Wyodak are each 10 to 65 feet thick. Farther west in the vicinity of the Campbell and Sheridan county line, the Upper Wyodak (Anderson and Canyon coal beds merged) becomes the Big George coal bed (Pierce and others, 1990). North of Gillette, the Wyodak splits into an Upper Wyodak and Lower Wyodak (McLellan and others, 1990). The Upper Wyodak then splits into the Smith, Swartz, and Anderson coal beds while the Lower Wyodak splits into the Canyon and Cook coal beds (Kent and others, 1980). When the Wyodak splits into five or more beds, the individual beds are 3 to 38 feet thick and separated by a few feet to 200 feet of claystone, shale, or sandstone. The Wyodak also splits into the Anderson coal bed (D bed) and the Canyon coal bed (E bed) in southern Campbell County (**Figure 4**).

The strippable reserve base of this Fort Union Formation coal bed is the largest for any single coal bed in Wyoming and perhaps even for any coal bed in the United States. Using a 200-foot cutoff for overburden, Smith and others, (1972) estimated the strippable reserves at 19 billion tons. Grazis (1977a-d) calculated about 1,360.7 million tons of strippable Wyodak reserve base in just the Caballo Creek area of Campbell County (**Figure 1**).

This is the only coal bed mined in the Gillette area. Its apparent rank is subbituminous C. Fifty-nine analyses of the Wyodak coal bed in the Gillette area are summarized below:

As-received basis	*Range (59 analyses)*	*Average*
Moisture (%)	21.1-36.9	29.8
Volatile matter (%)	26.5-35.5	30.7
Fixed carbon (%)	29.6-41.4	33.5
Ash (%)	3.9-12.2	6.0
Sulfur (%)	0.2-1.2	0.5
Btu/lb.	7,420-9,600	8,220

Green River Coal Field

The Green River Coal Field, which is the State's largest coal field, covers about 16,800 square miles of southwestern Wyoming (**Figure 1**). The field coincides with the Greater Green River Basin. The more important coal beds crop out on the flanks of the Rock Springs uplift in the central part of the field, on the eastern margin of the field, and in the Red Desert

Basin in the northeastern corner of the field. Dips in this coal field are low except around the Rock Springs uplift and along the field's eastern margin. Dips on the western side of the Rock Springs uplift are up to 20°, and on the eastern side of the uplift, 10°. Along the eastern margin of the coal field, dips are 20 to more than 50° in some areas.

The apparent ranks of outcropping coal beds are subbituminous B to high volatile C bituminous. The higher rank coal beds, which are Cretaceous, crop out on the eastern margins of the coal field as well as around the Rock Springs uplift.

Wood and Bour (1988) estimated the field's in-place coal resources at 237.11 billion tons. Coal beds in the field occur in the Mesaverde Group and Lance Formation of Late Cretaceous age, the Fort Union Formation of Paleocene age, and the Wasatch Formation of Eocene age (**Figure 2**). Coal beds of the Mesaverde Group (Rock Springs Formation) were historically the most important, but their importance has waned with the more recent mining of younger beds in the Lance, Fort Union, and Wasatch Formations. Coal-bearing rocks in the Green River Coal Field are largely concealed by younger rocks.

Figure 5 shows the bed designations for the coals in the Rock Springs Formation on the flanks of

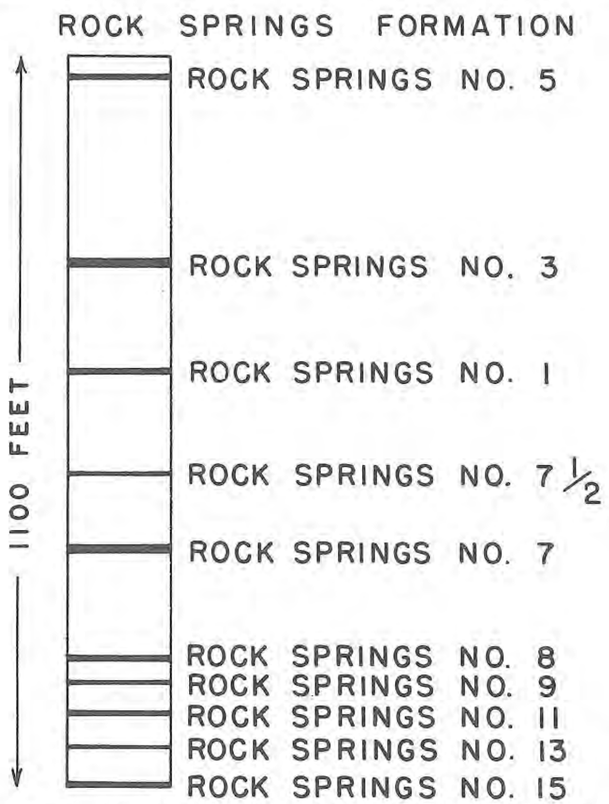

Figure 5. Coal-bed nomenclature for the Rock Springs Formation in the Green River Coal Field.

the Rock Springs uplift. Coal beds in the Rock Springs Formation are bituminous and are up to 13.8 feet thick.

Except on the southwestern side of the Rock Springs uplift, coal beds occur in the Almond Formation of the Mesaverde Group where it crops out around the uplift. These bituminous coal beds have not been extensively mined, but they are reportedly up to 13.1 feet thick on the east side of the uplift (Roehler, 1979c).

Although coal beds in the Fort Union Formation are some of the thicker and more persistent coal beds in the field, they were not extensively mined until 1974, when the Jim Bridger strip mine opened on the Deadman coal bed, which is up to 30 feet thick in that area. South of the Bridger mine, Roehler (1979a-c, 1983) has identified and mapped up to five Fort Union coal beds. In descending order, he named them the Leaf, Big Burn (Nuttal), Hail, Washout, and Little Valley (Deadman) beds. Each of these beds is locally greater than five feet thick. The Big Burn and Little Valley beds are up to 9 feet and 15 feet thick, respectively. All these coal beds are apparently subbituminous.

Wasatch coal beds of the Red Desert deposit (**Figure 1**) in the northeastern corner of the Green River Coal Field are designated, from youngest to oldest: Battle No. 3, Battle No. 2, Monument No. 1, Sourdough-Monument-Teirney seams, Hadsell No. 2, Creston No. 3, Creston No. 2, and Latham No. 3 (Pipiringos, 1961; Masursky, 1962). These coal beds are lenticular and grade into shale to the east and west. An average as-received analysis of these subbituminous coal beds shows a moisture content of 21%, an ash content of 16%, a sulfur content of 2.5% and a heat value of 7,900 Btu/lb. (Smith and others, 1972). Analyses of drill core samples of these beds show that they yield from 7.8 to 25.2 gallons of oil per ton by the Fischer assay method. Additionally, the uranium content of these coal beds is between 0.001% and 0.009% U_3O_8. These Wasatch coal beds contain over 55 million pounds of uranium with U_3O_8 contents 0.003% or greater (Pipiringos, 1961; Masursky, 1962).

Two Wasatch coal beds in the Cherokee deposit just south of the Red Desert deposit also reach minable thicknesses (**Figure 1**). These coal beds, called the Upper and Lower Cherokee beds, average 11 and 25 feet thick, respectively.

Important coal beds in the Green River Coal Field

Almond coal beds: Recent mapping shows as many as 18 relatively persistent, mappable coal beds in the Almond Formation on the southeastern flank of the Rock Springs uplift (Roehler, 1979b-c). In the northern part of his study area, Roehler (1979b, 1983) names these coal beds the Sparrow, Coot, Buzzard, Shrike, Eagle, Robin, Meadowlark, Magpie, and Mourning Dove beds in descending order. The Mourning Dove coal bed is apparently correlative with the Lebar coal bed of the Black Butte mine. In this area, the mining company has named four minable Almond Formation coal beds: the D, C, A1, and A beds, in descending order. By their nomenclature, the Lebar bed equates to a coal bed where the A1 and A beds come together into a single bed.

Farther south, Roehler (1979c) mapped and named some additional Almond coal beds. In descending order, the beds in that area are the Falcon, Golden Eye, Teal, Waxwing, Pintail, Finch, Gull, Sparrow, Coot, Mallard, Robin, Magpie, Upper Mourning Dove, Lower Mourning Dove, and Starling.

Of the coal beds mapped by Roehler, the Finch, Mallard, Robin, Meadowlark, Magpie, and Mourning Dove (Lebar) beds locally exceed 9 feet thick. The other beds are thinner, but each is more than 5 feet thick in places.

Roehler (1977a-b) estimated that there is 5.56 billion tons of coal in the Almond Formation along the flanks of the Rock Springs uplift. This coal resource only includes coal beds that are greater than 2.5 feet thick and under less than 3,000 feet of cover. He further estimated that 5 to 10% of that resource may be strippable. In two of his more recent publications, Roehler (1979b-c) provided detailed resource estimates for more than 828 million tons of Almond Formation coal of which almost 54 million tons are within strippable limits (under less than 200 feet of cover). These two publications, however, represent a very small portion of the total resource area that Roehler described in 1977.

The Black Butte and Salt Wells areas on **Figure 1** indicate where most of the potentially strippable reserves of these Almond coal beds occur. McClurg and others, (1983) provided the results of a nine-hole drilling project in this area.

Based on the analyses given below, the Almond Formation coal beds on the southeastern flank of the Rock Springs uplift have an apparent rank of high volatile C bituminous. A summary of available analyses is given below:

As-received basis	*Range (29 analyses)*	*Average*
Moisture (%)	9.6-18.0	12.6
Volatile matter (%)	26.4-33.3	30.6
Fixed carbon(%)	35.8-53.6	47.4
Ash (%)	2.1-27.9	9.5
Sulfur (%)	0.44-2.82	0.8
Btu/lb.	8,510-12,070	10,770

Northeast of the area mapped by Roehler, three of five Almond Formation coal beds are mined in the Leucite Hills deposit (**Figure 1**). These coals, designated A2, A3, and A4, average 6.5 feet, 3.7 feet, and 4.0 feet thick, respectively. The original, in-place, strippable reserves on the mine property were 5.1 million tons. The apparent ranks of these Almond coal beds are subbituminous A to high volatile C bituminous. The quality of these beds is summarized below:

As-received basis	*Range of all three beds*	*Average of all three beds*
Moisture (%)	15.5-28.0	18.5
Volatile matter (%)	28.7-32.5	30.8
Fixed carbon (%)	39.4-46.7	44.4
Ash (%)	3.27-13.4	6.4
Sulfur (%)	0.28-1.18	0.51
Btu/lb.	7,210-10,670	9,970

B and C coal beds: See Upper and Lower Cherokee coal beds.

Battle No. 1 and No. 2 coal beds: These two subbituminous B coal beds crop out in the Red Desert deposit in the northwestern corner of the coal field (**Figure 1**). They occur in the Wasatch Formation and average 6.4 and 8.6 feet thick, respectively. The strippable reserve base of these two beds is 38.1 million tons (Smith and others, 1972). A typical analysis of the Battle No. 1 bed is:

As-received basis	*Typical analysis*
Moisture (%)	21.9
Volatile matter (%)	29.9
Fixed carbon (%)	37.0
Ash (%)	11.2
Sulfur (%)	1.9
Btu/lb.	8,650

Creston No. 2 and No. 3 coal beds: These coal beds are in the Wasatch Formation. They crop out in the Red Desert deposit in the east-central part of the field where they average about 18 feet thick. Locally, the coals merge to form a 42-foot- thick bed. They are subbituminous B in apparent rank. The strippable reserve base of these beds is 125.6 million tons (Smith and others, 1972). A typical analysis of the Creston No. 2 bed is:

As-received basis	*Typical analysis*
Moisture (%)	20.7
Volatile matter (%)	32.2
Fixed carbon (%)	34.4
Ash (%)	12.7
Sulfur (%)	1.8
Btu/lb.	8,710

Deadman coal bed: The Deadman coal bed of the Fort Union Formation is exceptionally well developed in the Bridger deposit on the northeastern flank of the Rock Springs uplift (**Figure 1**). There the Deadman coal bed is 31.4 feet thick except where it splits into as many as five thinner beds (Glass, 1975). The Deadman coal bed can be traced southward into the Black Buttes area of the uplift (**Figure 1**), and is equivalent to the Little Valley bed of Roehler (1979a-c, 1983). In the Black Butte area, Roehler reports the Little Valley bed is as thick as 15 feet. It is unclear if Roehler's Little Valley bed is correlative with all five splits of the Deadman coal bed in the Jim Bridger deposit.

The strippable reserve base of the Deadman coal bed is approximately 250 million tons (Smith and others, 1972). The bed is now strip mined. Analyses of the Deadman coal bed, which has an apparent rank of subbituminous B, are summarized below:

As-received basis	*Range (4 analyses)*	*Typical analysis*
Moisture (%)	17.0-20.5	20.5
Volatile matter (%)	29.1-32.6	29.1
Fixed carbon (%)	40.7-42.0	40.7
Ash (%)	5.9-10.0	9.7
Sulfur (%)	0.36-0.77	0.47
Btu/lb.	9,270-10,000	9,350
HGI	79-82	

Fort Union Formation coal beds: As many as five relatively persistent, Fort Union coal beds crop out on the southeastern side of the Rock Springs uplift (Roehler, 1979a-c, 1983). These coal beds occur in an interval that has been termed the Black Rock Coal Group. In descending order, the coal beds are named the Leaf, Big Burn, Hail, Washout, and Little Valley beds. At least locally, all these beds exceed five feet thick. The Big Burn coal bed reaches 9 feet thick while the Little Valley is up to 15 feet thick. Northward, the Little Valley bed correlates with the Deadman bed of the Black Buttes and Bridger deposits (**Figure 1**). The Big Burn coal bed is tentatively correlated with the Nuttal bed of the Black Buttes deposit (Roehler, 1979c).

Roehler (1979a-c) provided detailed resource estimates for about 885 million tons of coal in the Fort Union Formation in a small area on the southeast side of the Rock Springs uplift. Again the resource is comprised of coal beds greater than 2.5 feet thick and under less than 3,000 feet of cover. He estimated that more than 40 million tons are under less than 200 feet of cover and would therefore qualify as a strippable resource.

Analyses of four, 5- to 10-foot thick, Fort Union Formation coal beds in this area are summarized below (McClurg and others, 1983). The apparent rank of these coal beds is high volatile C bituminous.

As-received basis	*Range (4 core analyses)*	*Average of 4 analyses*
Moisture (%)	10.9-15.9	13.4
Volatile matter (%)	28.0-31.2	30.3
Fixed carbon (%)	44.7-47.8	46.6
Ash (%)	8.0-12.1	9.7
Sulfur (%)	0.70-1.07	0.8
Btu/lb.	10,210-10,860	10,380

Hadsell No. 2 coal bed: This is another Wasatch coal bed that crops out in the Red Desert deposit in the northeastern part of the Green River Coal Field (**Figure 1**). It is subbituminous B in rank and averages 7.7 feet thick. There are 39.8 million tons of strippable reserve base estimated for this bed (Smith and others, 1972).

As-received basis	*Typical analysis*
Moisture (%)	21.0
Volatile matter (%)	31.0
Fixed carbon (%)	32.2
Ash (%)	13.8
Sulfur (%)	2.7
Btu/lb.	8,250

Lance Formation coal beds: Coal beds of the Lance Formation are known as the Black Buttes Coal Group. Where they crop out on the northeastern and eastern sides of the Rock Springs uplift, several small underground mines worked 4- to 9.6-foot-thick coal beds in the early 1900s. Mining has resumed on some Lance coal beds in the Black Butte strippable deposit (**Figure 1**) (VTN, 1974). In that deposit, the minable coal beds, in descending order, are the Overland, Gibraltar, Black Butte, Maxwell, and Hall beds. All five of these beds are 4 to 10 feet thick. Farther south, the French and Bluff beds of Roehler (1979a-b, 1983) reach 6.5 and 8.4 feet thick, respectively. Roehler's French and Bluff beds are correlative with the Maxwell and Hall beds.

In the Black Buttes area, the Overland coal bed is the highest minable coal bed in the Lance Formation. This bed, however, is seldom more than 4 feet thick. Locally the Overland bed contains shaly partings that raise its ash content as high as 31% and lower its heat value to less than 6,900 Btu/lb. More typically, the ash is in the 5 to 7% range and its heat value nearer 9,650 Btu/lb. The Gibraltar bed is usually only 4 to 5 feet beneath the Overland bed and has a maximum reported thickness of 8 feet.

The next lower bed is the Black Butte bed, which averages 5 to 6 feet thick except where it coalesces with the underlying Maxwell bed to form a coal bed that is 16 to 22 feet thick. The normal interval between these two beds is 25 feet. The Maxwell coal bed averages 5.5 feet thick when it isn't merged with the overlying Black Butte bed.

The Hall bed is the lowest minable bed in the Lance Formation in the Black Buttes deposit. It is up to 10 feet thick.

The Black Butte deposit contains an estimated 82.6 million tons of strippable reserve base when tonnages for the coal beds in the Almond, Lance, Fort Union, and Wasatch formations are combined. Roehler (1979a-b) delimits almost 268 million tons of in-place coal resources for the French and Bluff beds, south of the Black Buttes area. Roehler's resources only include coal beds under less than 3,000 feet of cover and over 2.5 feet thick. Almost seven million tons of Roehler's resource is strippable.

The Lance Formation coal beds on the southeast flank of the Rock Springs uplift have an apparent rank of subbituminous B. The available analyses of these coal beds show:

As-received basis	*Range (5 analyses)*	*Average (5 analyses)*
Moisture (%)	17.5-21.0	20.1
Ash (%)	4.1-6.0	4.9
Sulfur (%)	0.4-1.08 0.69	
Btu/lb.	9,650-10,110	9,850

Latham No. 3 and No. 4 coal beds: The Latham beds are best developed in the Red Desert deposit in the northeastern part of the coal field (**Figure 1**). These coal beds occur in the Wasatch Formation and are subbituminous B in apparent rank. Average thicknesses are 5.7 feet. The strippable reserve base of the two coal beds totals 70.7 million tons (Smith and others, 1972). A typical analysis of the Latham No. 3 bed is:

As-received basis	*Typical analysis*
Moisture (%)	22.6
Volatile matter (%)	30.9
Fixed carbon (%)	31.2
Ash (%)	15.3
Sulfur (%)	5.4
Btu/lb.	7,980

Lebar coal bed: This Almond Formation coal bed crops out in the Black Buttes area on the southeastern flank of the Rock Springs uplift where it averages 8 to 12 feet thick (**Figure 1**). There are plans to mine the Lebar bed along with the overlying C and D beds. The apparent ranks of these coal beds are subbituminous A to high volatile C bituminous. The Lebar bed correlates with Roehler's (1979c, 1983) Mourning Dove coal bed, which is discussed in the above section on Almond Formation coal beds. A typical analysis of the Lebar bed is:

As-received basis	*Typical analysis*
Moisture (%)	17.5
Ash (%)	7.6
Sulfur (%)	0.57
Btu/lb.	10,000

Little Valley coal bed: See Deadman coal bed.

Rock Springs No. 1 coal bed: This coal bed crops out on the west and north flanks of the Rock Springs uplift where it is still at least periodically mined underground (**Figures 1** and **5**). Analyses of this Rock Springs Formation coal, which include some recent analyses from Glass and Roberts (1988), are summarized below. The apparent rank of this coal bed is high volatile C bituminous.

As-received basis	*Range in analyses*
Moisture (%)	8.5-17.6
Volatile matter (%)	34.5-36.5
Fixed carbon (%)	43.9-50.4
Ash (%)	4.0-6.0
Sulfur (%)	0.8-1.0
Btu/lb.	10,480-11,830

Rock Springs No. 3 coal bed: This coal bed in the Upper Cretaceous Rock Springs Formation was extracted by underground mining near Rock Springs (**Figures 1** and **5**). The bed at least locally exceeds 11 feet thick and has an apparent rank of high volatile C bituminous. The following analysis is from Glass and Roberts (1988):

As-received basis	*One analysis*
Moisture (%)	16.7
Volatile matter (%)	35.7
Fixed carbon (%)	45.4
Ash (%)	2.2
Sulfur (%)	0.9
Btu/lb.	10,520
HGI	52

Rock Springs No. 7 coal bed: This coal bed averages 4.5 feet thick; is high volatile C bituminous in apparent rank (Glass and Roberts, 1988); and occurs in the Rock Springs Formation of the Mesaverde Group on the west and north flanks of the Rock Springs uplift (**Figures 1** and **5**). This bed also has some coking properties. The No. 7 bed is still intermittently mined by underground methods in Sweetwater County.

As-received basis	*Range (17 samples)*	*Average*
Moisture (%)	5.0-16.5	10.1
Volatile matter (%)	33.8-40.3	37.2
Fixed carbon (%)	44.3-52.6	48.1
Ash (%)	2.4-6.4	4.5
Sulfur (%)	0.6-1.1	0.8
Btu/lb.	10,640-13,110	11,660
HGI	48-54	51

Rock Springs No. 11 coal bed: The apparent rank of the No. 11 coal bed is high volatile C bituminous. This bed is 44 to 54 inches thick, and averages 4 feet thick. It is an important coal bed on the west and north flanks of the Rock Springs uplift (**Figures 1** and **5**). This bed, which is in the Rock Springs Formation, also has some coking properties. The following analytical data is available:

As-received basis	*Range in analyses*
Moisture (%)	6.56-8.46
Volatile matter (%)	38.42-39.74
Fixed carbon (%)	47.69-48.55
Ash (%)	4.57-6.69
Sulfur (%)	0.7
Btu/lb.	12,380-12,570

Sourdough-Monument-Tierney coal beds: This coal zone in the Red Desert deposit in the northeastern corner of the field (**Figure 1**) is comprised of up to five coal beds that all occur at about the same horizon in the Wasatch Formation. Because these beds sometimes coalesce with one another, separation of the coals into individual beds is not always possible. In places, each of these coal beds exceeds 5 feet thick. The strippable reserve base of these unmined beds is 458.9 million tons (Smith and others, 1972). The apparent rank of all these coal beds is subbituminous B. Below, is a typical analysis of the Sourdough No. 2 bed:

As-received basis	*Typical analysis*
Moisture (%)	23.2
Volatile matter (%)	33.6
Fixed carbon (%)	33.0
Ash (%)	10.2
Sulfur (%)	2.9
Btu/lb.	8,680

Upper and Lower Cherokee coal beds: These two unmined coal beds occur in the Wasatch Formation. They reach their maximum development in the Cherokee deposit in the east-central part of the coal field (**Figure 1**). The Upper Cherokee or B bed is 10 to 18 feet thick and normally has a 1- to 2-foot parting in it. The Lower Cherokee or C bed, which is 40 to 70 feet below the upper bed, is 20 to 32 feet thick. It has a 1- to 1.5-foot parting. In places these two coal beds coalesce into a single, 30 to 40 feet thick bed, which has a parting up to 4 feet thick. The apparent rank of these coal beds is subbituminous A. Collectively, the strippable reserve base of these coal beds is 200.9 million tons (Smith and others, 1972).

As-received basis	*Range in analyses*
Moisture (%)	15-25
Volatile matter (%)	28-36
Fixed carbon (%)	27-40
Ash (%)	10-25
Sulfur (%)	0.5-5.0
Btu/lb.	5,010-9,000

Ute coal bed: The Ute bed is a Fort Union Formation coal bed that occurs about 55 feet below the Deadman bed in the Black Buttes area of the Rock Springs uplift (**Figure 1**). It is up to 7 feet thick, and may be mined in the near future. The coal bed is subbituminous in rank.

Wasatch Formation coal beds (exclusive of the Red Desert and Cherokee deposits): Wasatch coal beds in the Black Buttes area of Sweetwater County (**Figure 1**) reportedly average 6 to 8 feet thick (VTN, 1974). The reserve base for these Wasatch Formation coal beds is included with the estimate given in the above discussion of Lance Formation coal beds. Analyses of the Wasatch coal beds that crop out on the flanks of the Rock Springs uplift are given below:

As-received basis	*Average or range*
Moisture (%)	19.3-19.6
Volatile matter (%)	33.0
Fixed carbon (%)	40.4
Ash (%)	7.2-8.1
Sulfur (%)	0.74-1.5
Btu/lb.	8,770-9,610

Hanna Coal Field

Coal-bearing rocks of the Hanna Coal Field crop out in a 1,300-square-mile area of Carbon County in south-central Wyoming (**Figure 1**). The Hanna Coal Field occupies a structural trough that is divided into two separate basins by a northeast-southwest trending anticline. The Hanna Basin lies to the northwest of the anticline while the Carbon Basin lies to the southeast. The Hanna Coal Field is bounded on the north, west, and south by mountain ranges. Faulting is common in the field.

The in-place coal resources in the Hanna Coal Field are an estimated 23.27 billion tons (Wood and Bour, 1988). Coal beds occur in the Mesaverde Group and Medicine Bow Formations of Late Cretaceous age, the Ferris Formation of Late Cretaceous and Paleocene age, and the Hanna Formation of Paleocene and Eocene age (**Figure 2**). **Figure 6** provides the coal bed names for the Hanna and Ferris formations.

The apparent ranks of outcropping coal beds in the Mesaverde Group and the Medicine Bow Formation are subbituminous C to high volatile C bituminous. While Ferris Formation coal beds are subbituminous A to high volatile C bituminous, outcropping coal beds of the Hanna Formation have apparent ranks as high as high volatile C bituminous (Glass and Roberts, 1979, 1980a-b, 1984).

Glass and Roberts (1979) estimated a remaining strippable reserve base of 648.29 million tons in the Hanna Coal Field, through January 1, 1978. Of that reserve base, Hanna coal beds accounted for 392.74 million tons, Ferris coal beds another 238.74 million tons, and Mesaverde and Medicine Bow coal beds another 17.08 million tons.

Important coal beds in the Hanna Coal Field

Bed No. 25: This Ferris Formation coal bed is 5 to 12 feet thick (**Figure 6**). It was strip mined on the west side of the coal field, where it was called "Bed No. 21" by the mining company. The bed is of Paleocene age and has an apparent rank of subbituminous A to high volatile C bituminous.

As-received basis	*Range (10 samples)*	*Average*
Moisture (%)	11.05-16.77	14.1
Volatile matter (%)	31.50-34.39	32.8
Fixed carbon(%)	43.88-45.58	44.6
Ash (%)	6.07-13.09	8.5
Sulfur (%)	0.21-0.74	0.4
Btu/lb.	9,095-10,290	9,750

Bed No. 28: This Paleocene Ferris Formation coal bed is 4.5 to 18 feet thick (**Figure 6**). Where it was mined in the western part of the field, it was called "Bed No. 24". The bed has an apparent rank of subbituminous A to high volatile C bituminous.

As-received basis	*Range (9 samples)*	*Average*
Moisture (%)	9.52-16.00	11.53
Volatile matter (%)	33.82-36.54	34.95
Fixed carbon (%)	45.80-49.59	47.57
Ash (%)	3.90-17.85	5.95
Sulfur (%)	0.21-0.74	0.31
Btu/lb.	8,570-11,480	10,080
HGI	47 (1 sample)	

30 Series Beds: Beds 30, 31, and 32 are Paleocene in age. These coal beds occur in the lower third of the Ferris Formation and were mined togeth-

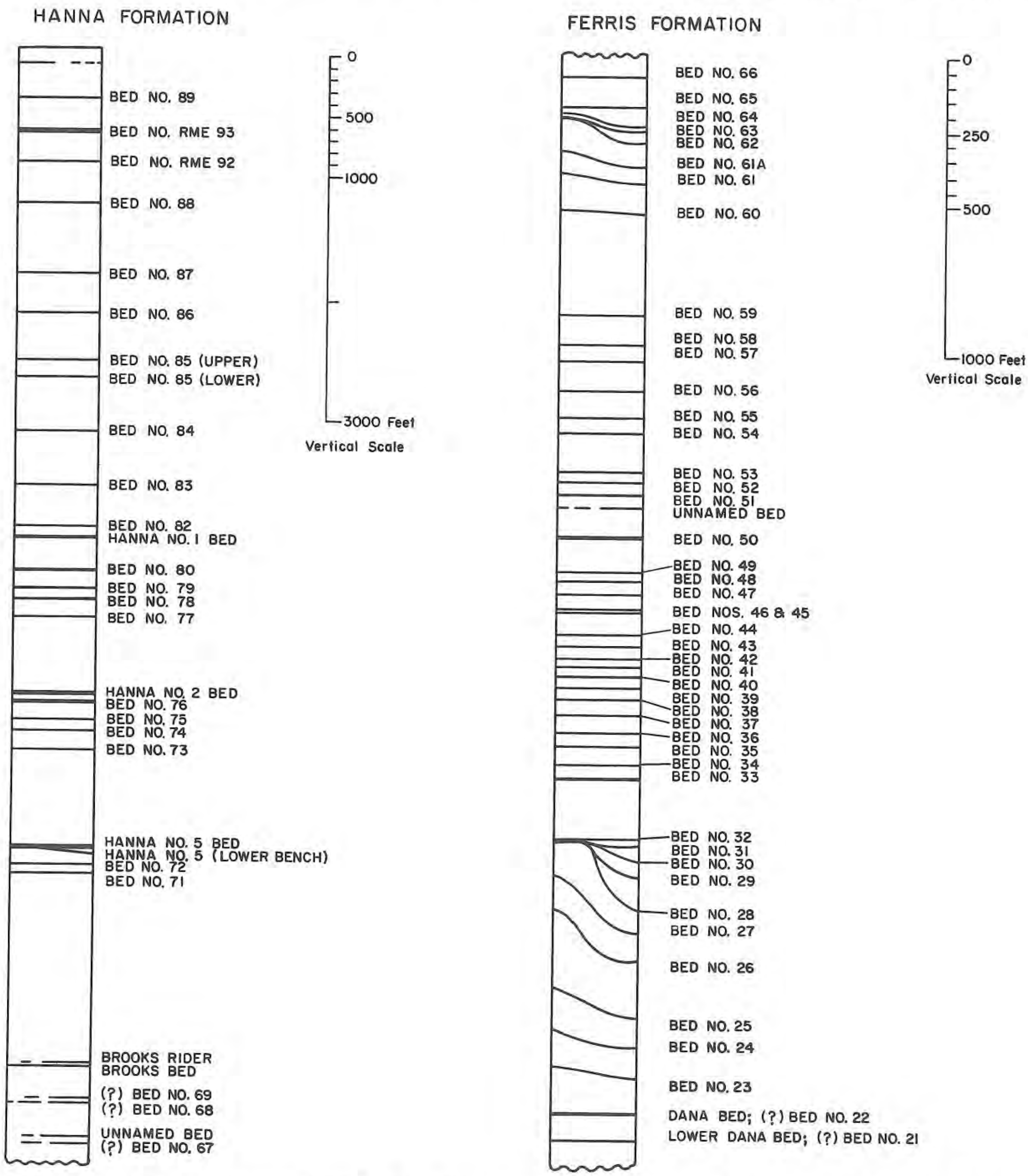

Figure 6. Coal-bed nomenclature for the Hanna and Ferris formations of the Hanna Coal Field.

er on the west side of the coal field (**Figure 6**). Locally they coalesce with one another. Bed No. 30, the lowermost bed, is 5 to 8 feet thick; Bed No. 31, the middle bed, is 5 to 18 feet thick; and Bed No. 32, the uppermost bed, is usually less than 4 feet thick. These coal beds were called benches of "Bed No. 25" by the mining company. The apparent ranks of these coal beds are subbituminous A to high volatile C bituminous.

As-received basis	*Range (17 samples)*	*Average*
Moisture (%)	10.92-18.90	14.03
Volatile matter (%)	31.99-37.69	34.53
Fixed carbon (%)	40.65-50.31	45.48
Ash (%)	3.95-15.68	5.96
Sulfur (%)	0.22-0.58	0.45
Btu/lb.	8,340-10,650	10,180
HGI	50-66 (2 samples)	

Bed No. 50: This Paleocene coal bed occurs near the middle of the Ferris Formation (**Figure 6**). The bed was mined west of Hanna, where it is 5 to 22 feet thick. The apparent rank of Bed No. 50 is subbituminous A to high volatile C bituminous.

As-received basis	*Range (4 samples)*	*Average*
Moisture (%)	11.30-15.73	12.50
Volatile matter (%)	31.72-35.75	33.93
Fixed carbon (%)	41.97-48.45	44.29
Ash (%)	6.74-15.20	9.29
Sulfur (%)	0.30-0.63	0.42
Btu/lb.	8,460-10,540	9,640
HGI	45 (1 sample)	

50 Series beds (exclusive of Bed No. 50): Bed Nos. 51 and 54 were mined in the western part of the field, where they are 5 to 10 feet thick and 5 to 15 feet thick, respectively (**Figure 6**). Bed No. 51 is called "Bed No. 53" by the mining company. The apparent ranks of these Paleocene-age coal beds are subbituminous A to high volatile C bituminous.

As-received basis	*Range (14 samples)*	*Average*
Moisture (%)	9.38-17.84	12.06
Volatile matter (%)	31.10-36.67	34.40
Fixed carbon (%)	39.20-48.14	45.89
Ash (%)	5.60-17.20	7.67
Sulfur (%)	0.47-1.30	0.52
Btu/lb.	8,310-10,930	10,230

60 Series Beds (exclusive of Bed No. 65): Beds 60, 61, 62, 63, and 64 are all mined in the western portion of the field (**Figure 6**). These Paleocene coal beds are 4 to 11 feet thick. Beds 62, 63, and 64 were usually called "Beds 63, 64, and 65" by the mining company in this area. These Ferris Formation coal beds are high volatile C bituminous in apparent rank.

As-received basis	*Range (16 samples)*	*Average*
Moisture (%)	8.2-12.9	10.8
Volatile matter (%)	33.5-39.3	35.4
Fixed carbon (%)	37.5-46.9	44.2
Ash (%)	6.5-20.8	9.6
Sulfur (%)	0.28-0.73	0.57
Btu/lb.	9,140-11,750	10,400

Bed No. 65: This Paleocene bed is subbituminous A to high volatile C bituminous in apparent rank. It is mined in the western part of the Hanna Coal Field where it is 5 to 12 feet thick. One mining company refers to it as "Bed No. 66". It occurs in the Ferris Formation (**Figure 6**).

As-received basis	*Range (11 samples)*	*Averages*
Moisture (%)	8.96-15.44	11.98
Volatile matter (%)	33.58-39.69	35.55
Fixed carbon (%)	36.86-49.04	46.29
Ash (%)	4.55-10.69	6.18
Sulfur (%)	0.29-0.79	0.55
Btu/lb.	9,770-11,280	10,670

70 Series Beds: Beds 74, 76, and 79 are mined in the central part of the field. These Paleocene coal beds occur in the Hanna Formation (**Figure 6**). They are 5 to 11 feet, 7 to 28 feet, and 5 to 23 feet thick, respectively. The apparent rank of the 70 series beds is high volatile C bituminous.

As-received basis	*Range (7 samples)*	*Average*
Moisture (%)	8.14-16.51	10.73
Volatile matter (%)	34.29-39.70	36.74
Fixed carbon (%)	26.24-47.30	41.79
Ash (%)	5.73-21.33	10.74
Sulfur (%)	0.6-2.29	1.18
Btu/lb.	9,680-11,105	10,500

Bed No. 80: Bed No. 80 is a Paleocene coal bed of the Hanna Formation (**Figure 6**). The apparent rank is high volatile C bituminous. This bed is 5 to 26 feet thick. The No. 80 bed generally has a 1- to 1.5-foot-thick parting 2 to 5 feet above its base. It is extracted by underground and strip mining this coal field.

As-received basis	*Range (17 samples)*	*Average*
Moisture (%)	5.97-15.44	10.83
Volatile matter (%)	35.03-47.34	39.23
Fixed carbon (%)	35.65-50.92	43.68
Ash (%)	4.40-15.83	6.27
Sulfur (%)	0.48-1.24	0.98
Btu/lb.	9,940-12,600	11,000
HGI	47-50	

Bed No. 82: This is an Eocene coal bed in the Hanna Formation (**Figure 6**). Its apparent rank is high volatile C bituminous, and it averages 9 feet thick. Bed No. 82 is strip mined.

As-received basis	*Range (15 samples)*	*Average*
Moisture (%)	6.51-20.75	11.90
Volatile matter (%)	31.28-43.78	37.08
Fixed carbon (%)	36.56-48.08	42.46
Ash (%)	4.29-13.20	8.56
Sulfur (%)	0.35-1.94	1.35
Btu/lb.	9,105-12,150	10,620
HGI	50	

Brooks coal bed: This is a Paleocene coal bed near the base of the Hanna Formation (**Figure 6**). It is between 5 feet and 8 feet thick, and has been strip mined. The apparent rank of the Brooks bed is high volatile C bituminous.

As-received basis	*Range (7 samples)*	*Average*
Moisture (%)	8.89-13.67	12.34
Volatile matter (%)	32.45-36.74	34.02
Fixed carbon (%)	46.46-49.92	48.10
Ash (%)	4.29-7.00	5.54
Sulfur (%)	0.25-0.70	0.60
Btu/lb.	10,395-11,180	10,860
HGI	48-51	49

Hanna No. 1 coal bed: Although this Hanna Formation coal bed is not now mined, it has been extensively mined underground (**Figure 6**). The bed is 4 to 27 feet thick and has been converted into a low-Btu gas at an in-situ gasification site south of Hanna. The apparent rank of the coal bed is high volatile C bituminous.

As-received basis	*Range (20 samples)*	*Average*
Moisture (%)	6.30-15.65	12.05
Volatile matter (%)	32.65-43.39	39.33
Fixed carbon (%)	34.09-45.26	41.71
Ash (%)	4.17-23.76	6.90
Sulfur (%)	0.29-1.02	0.50
Btu/lb.	8,660-11,480	10,740

Hanna No. 2 coal bed: This Paleocene coal bed has an apparent rank of high volatile C bituminous. Although it was extensively mined underground in the past, it is now strip mined near Hanna, Wyoming. The Hanna No. 2 bed is 5 to 38 feet thick and occurs in the Hanna Formation (**Figure 6**).

As-received basis	*Range (20 samples)*	*Average*
Moisture (%)	9.10-17.2	11.58
Volatile matter (%)	33.20-42.58	39.26
Fixed carbon (%)	39.33-44.90	42.61
Ash (%)	3.80-16.33	6.65
Sulfur (%)	0.21-0.80	0.48
Btu/lb.	9,990-11,390	10,910
HGI	48	

Hanna No. 5 coal bed: This Paleocene coal bed in the Hanna Formation is 5 to 31 feet thick and splits into a number of benches (**Figure 6**). It is strip mined in the central part of the field. It has an apparent rank of subbituminous A to high volatile C bituminous.

As-received basis	*Range (4 samples)*	*Average*
Moisture (%)	10.30-20.56	13.82
Volatile matter (%)	36.30-38.90	37.45
Fixed carbon (%)	37.20-47.30	42.70
Ash (%)	5.60-6.70	6.04
Sulfur (%)	0.34-0.60	0.47
Btu/lb.	8,880-11,190	10,540

Hams Fork Coal Field

The Hams Fork Coal Field of western Wyoming includes portions of Lincoln, Teton, and Uinta counties and is the third largest coal field in the State. As defined, the Hams Fork Coal Field is limited to those portions of the Thrust Belt that are underlain by coal-bearing rocks of the Bear River, Frontier, Adaville, Blind Bull, and Evanston formations (Glass, 1977). **Figure 1** shows the approximate location of these coal-bearing rocks, but geological and structural complexities prevent a more accurate depiction at this scale.

Structurally, the Hams Fork Coal Field is very complex. Folded Paleozoic and Mesozoic rocks are thrust eastward over folded Cretaceous rocks with the younger Cretaceous and Tertiary rocks of the area resting unconformably on these older rocks. The coal-bearing rocks of the Hams Fork Coal Field now crop out in long narrow belts bounded by major thrust faults or eroded limbs of folds. These same faults and folds form the Salt River and Wyoming Ranges of western Wyoming.

For the most part, coal-bearing rocks crop out between the north-south trending ranges common to this field. The coal-bearing rocks usually dip westward at 16 to 80°, averaging closer to 25 to 30°. The southwestern portion of the field occurs within Fossil Basin, which is bounded by the Absaroka Thrust to the east and the Medicine Butte Thrust on the west. Coal-bearing rocks in this part of the field are generally buried beneath younger rocks that are barren of coal beds. In the vicinity of Almy, minable coal beds crop out with east dips of 10 to 20°.

Faults are common in the Hams Fork Coal Field, particularly thrust faults. The rocks are thrust eastward and faults usually strike north-south although they do locally change direction. The Absaroka and Darby thrusts are the largest. These thrust faults each extend nearly the entire 170-mile length of the coal field. In the southern third of the Hams Fork Coal Field, these two faults are often covered by younger unfaulted rocks. Stratigraphic throw on the thrust faults in the Overthrust Belt is generally 10,000 to 20,000 feet.

High-angle faults are also common, particularly in the western part of the field. Both normal and reverse faults occur with stratigraphic throws between a few hundred feet to several thousand feet (Rubey and others, 1975).

Collectively, coal-bearing rocks account for over 9,000 feet of the estimated 20,000 feet of post-Jurassic rocks in the Hams Fork Coal Field. Wood and Bour (1988) estimate that there are 49.61 billion tons of in-place coal resources within these coal-bearing rocks. The most important coal beds occur in the Upper Cretaceous Frontier and Adaville Formations. In a few places, minable coal beds also occur in the Paleocene Evanston Formation and the Lower Cretaceous Bear River Formation (**Figure 2**).

In Uinta and southern Lincoln County, Bear River coal beds locally reach minable thicknesses, and they were prospected and mined on a very small scale in the late 1800s. Veatch (1907) referred to bituminous coal beds in the Bear River Formation as thin and dirty. The economic value of coal beds in the Bear River Formation cannot be evaluated from the sparse data that are available. No coal analyses are reported in published references, and the coal bed outcrops have not been mapped. Additionally, the existence of Bear River coal beds in northern Lincoln County and southernmost Teton County is not documented.

The 2,000- to 2,200-foot-thick Frontier Formation is the oldest significant coal-bearing unit in the Hams Fork Coal Field. The formation consists of alternating shale, sandstone, clay, and coal. The apparent ranks of Frontier Formation coal beds are high volatile C bituminous to high volatile A bituminous. Although coal bed thicknesses do not compare with some of the thicker coal beds in the Adaville Formation, Frontier coal beds in southern Lincoln and Uinta counties are persistent and higher in rank. The Main Kemmerer coal bed is up to 20 feet thick, but most Frontier coal beds are less than 6 feet thick. Minable coal beds occur throughout most of the Frontier Formation (Veatch, 1907; Berryhill and others, 1950).

In the southeastern portion of the coal field, the Kemmerer, Willow Creek, and Spring Valley Coal Groups are traceable along outcrop for more than 60 miles. Correlation of individual coal beds within these zones, however, is somewhat questionable. Collectively, these coal groups contain as many as nine minable coal beds (**Figure 7**). A fourth coal group, the Lower Carter Group, occurs near the base of the Frontier Formation and is locally important at least several miles south and east of Kemmerer. This lowermost zone is apparently characterized by a single coal bed.

To date, most coal production from the Frontier Formation has come from the east-central part of the coal field near Kemmerer. Although Frontier coal beds have been extensively deep mined in this field, there are no active mines on Frontier beds. The last coal mine in the Frontier Formation was Kemmerer Coal Company's Brilliant No. 8 underground mine on the Main Kemmerer coal bed. This mine closed in 1964.

In the northern part of the Hams Fork Coal Field, minable coal beds occur in the Upper Cretaceous Blind Bull Formation (Rubey, 1973). In the northern half of the field, the basal portion of this formation is equivalent in age to the Frontier Formation. The Vail coal bed in the Blind Bull Formation is over 10 feet thick and has an apparent rank of high volatile B bituminous.

The Upper Cretaceous Adaville Formation is without question the most important coal-bearing formation in the Hams Fork Coal Field. Ranging from 2,900-4,500 feet thick, the basal 1,200 feet of interbedded shale, claystone, and sandstone of this formation contain up to 32 subbituminous coal beds, many of which are much thicker than other Upper Cretaceous coal beds in Wyoming (Glass, 1977). Lawrence (1982) provided a possible explanation for the atypical thicknesses exhibited by these nearshore coals.

Adaville Formation coal beds crop out in three elongate basins in the southeastern and east-central portions of the field over a combined distance of more than 60 miles. Dips in these three basins are generally westward at 17 to 45°. Because all the Adaville coal beds in this area thicken, thin, split, and coalesce over very short distances, correlation of individual beds within the formation is extremely difficult (Glass, 1977). The apparent ranks of Adaville Formation coal beds are subbituminous C to subbituminous A.

The thickest and greatest numbers of Adaville coal beds occur in the central basin west of Kemmerer (**Figure 1**). In that deposit, at least eight coal beds exceed 10 feet thick while another seven beds are between 4 feet and 8 feet thick (**Figure 8**). The thickest bed, the Adaville No. 1, is locally 118 feet thick (Fagnant, 1962).

In the northernmost basin, the Adaville coal beds evidently thin and decrease in number. Little information is available for that area or for the southernmost basin, which also apparently has fewer coal beds

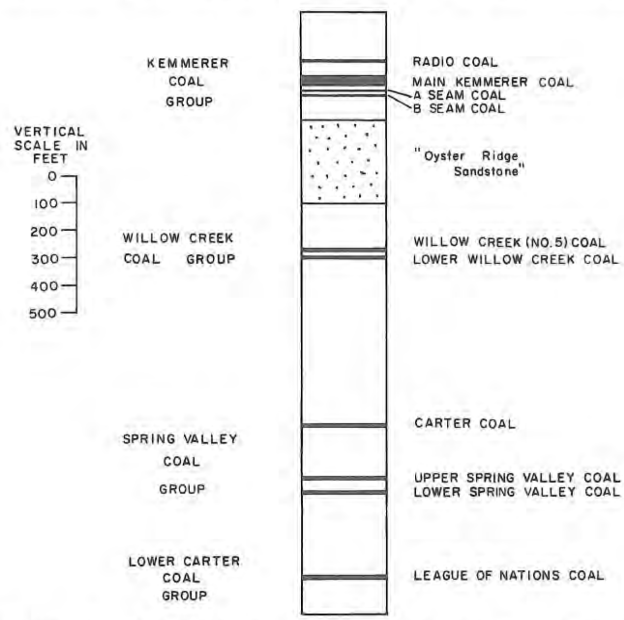

Figure 7. Coal-bed nomenclature for the Frontier Formation of the Hams Fork Coal Field.

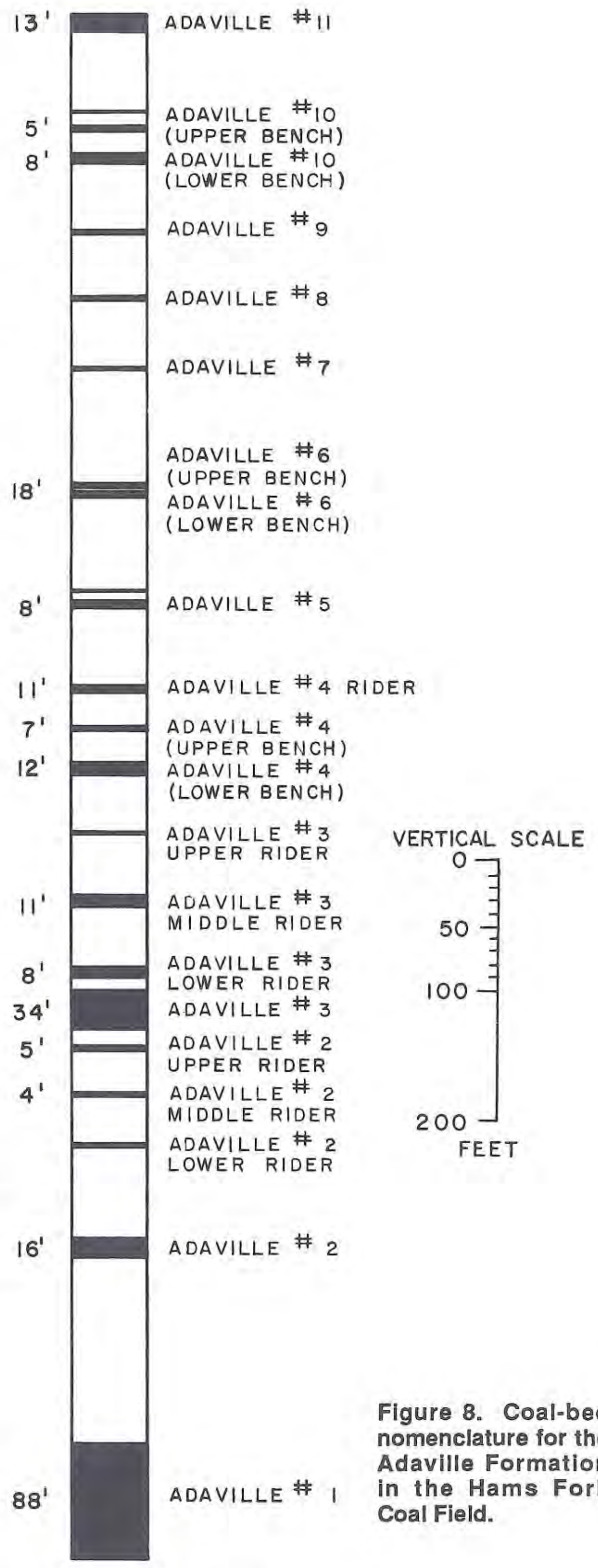

Figure 8. Coal-bed nomenclature for the Adaville Formation in the Hams Fork Coal Field.

than the central basin. Coal beds in the southern basin reportedly are 7 to 30 feet thick in places (Veatch, 1907; Schroeder, 1976).

To date, nearly all the Adaville coal production has come from the central basin west of Kemmerer. Although the Adaville coal beds have been deep mined in the past, most Adaville production came from Kemmerer Coal Company's open pit mine, which opened on the Adaville No. 1 bed in 1950 and on stratigraphically higher Adaville coal beds in 1963. Presently, there are two active open pit coal mines on the Adaville coals: Pittsburg & Midway's Kemmerer mine (formerly owned by Kemmerer Coal Company), and FMC Corporation's Skull Point mine. These two mines are the only active coal mines in the Hams Fork Coal Field.

Although Veatch (1907) states that the Evanston Formation underlies most of Fossil Basin, Evanston coal beds reportedly only crop out in fault blocks near Almy north of Evanston. The upper few hundred feet of the Evanston Formation in that area contains at least five subbituminous coal beds that are 6 to 18 feet thick. According to Veatch (1907), all but the Almy coal bed contained too many rock partings for efficient mining. Portions of the thick Almy coal bed were clean enough that at least 2.7 million tons were deep mined between 1869 and 1950 when the last mine closed. The apparent rank of the Almy coal bed is subbituminous A to high volatile C bituminous.

Important coal beds in the Hams Fork Coal Field

Adaville No. 1 coal bed: This coal bed is the lowermost Adaville Formation coal bed (**Figure 8**) and generally sits almost on top of the underlying Lazeart Sandstone . Although it varies in thickness and is locally split, the Adaville No. 1 apparently is the most persistent and thickest of the Adaville coal beds. Fagnant (1962) reported it locally reaches 118 feet thick. Commonly, it averages 74 to 84 feet thick in the central basin where it is best developed. If the Adaville No. 1 is correlative with the lowest Adaville coal bed in the southern basin, it is still 30 feet thick in that area (Schroeder, 1976). Presently, Pittsburg & Midway's Kemmerer and FMC Corporation's Skull Point mines are mining this coal bed.

Twenty-five published analyses of the Adaville No. 1 coal bed are summarized below. While six of these analyses were performed on channel samples (only one channel represents the entire bed thickness), the other 19 were performed on tipple samples. While the apparent ranks of the overlying Adaville coal beds vary between subbituminous C and B, the apparent rank of this basal Adaville coal is subbituminous A. None of the analyzed channel samples showed any agglomerating properties.

As-received basis	Range	Average Proximate (25 analyses) [1]	Average Ultimate (7 analyses) [2]
Moisture (%)	16.7-22.7	20.4	
Volatile matter (%)	33.0-36.6	34.5	
Fixed carbon (%)	38.8-44.7	42.1	
Ash (%)	1.5-5.3	3.0	3.7
Sulfur (%)	0.5-1.3	0.6	0.7
Hydrogen (%)	6.1-1.1		6.3
Carbon (%)	56.0-60.1		58.1
Nitrogen (%)	0.9-1.0		0.9
Oxygen (%)	27.5-33.6		30.2
Btu/lb.	9,720-10,530	10,190	
Ash softening temperature (°F)	2,150-2,660	2,370	

[1]Includes six underground mine samples
[2]Includes three underground mine samples

Adaville coal beds (undifferentiated beds, excluding the Adaville No. 1 bed): At least in the Kemmerer area of the coal field, Adaville coal beds are numbered consecutively from the lowermost bed upward (**Figure 8**). These numerical designations, however, have little meaning beyond the boundaries of Pittsburg & Midway Coal Mining Company's mine. For this reason, all Adaville coal beds above the Adaville No. 1 bed are discussed collectively. Glass (1975, 1977) provided a description of each numbered bed in the Kemmerer mine.

The coal beds above the Adaville No. 1 coal bed vary from a few inches to as much as 50 feet thick. In the central basin (Kemmerer area), at least seven of these coal beds are more than 10 feet thick. Another seven are between 4 and 8 feet thick (Glass, 1975). The rock intervals between these coals change considerably over very short distances (Glass, 1977). Correlation of these beds is extremely difficult without very close control or continuous exposures.

The strippable reserve base of the Adaville No. 1 and the other Adaville coal beds is estimated at more than one billion tons (Smith and others, 1972). Pittsburg & Midway's Kemmerer mine is currently mining as many as 21 of the coals above the Adaville No. 1, as well as the Adaville No. 1. Production from this mine is about 4 million tons per year.

Twenty analyses of various Adaville coal beds that occur above the Adaville No. 1, are summarized below. The apparent ranks of these coal beds increase down section, going from subbituminous C for the uppermost coal beds to subbituminous B for the lower coal beds. All but two of these analyses were performed on channel samples of the Adaville No. 2 through No. 11 coal beds, which were collected in the Kemmerer mine (Glass, 1975). The other two analyses were performed on tipple samples, one of which came from an underground mine.

As-received basis	Range	Average Proximate (20 analyses)	Average Ultimate (18 analyses)
Moisture (%)	15.4-28.6	21.2	
Volatile matter (%)	31.1-36.1	33.9	
Fixed carbon (%)	36.1-44.7	41.3	
Ash (%)	3.2-8.9	3.8	4.9
Sulfur (%)	0.2-1.8	0.6	0.6
Hydrogen (%)	5.9-6.5		6.1
Carbon(%)	47.2-60.0		55.1
Nitrogen (%)	0.8-1.5 1.4		
Oxygen (%)	28.2-39.4		31.8
Btu/lb.	7,920-10,510	9,520	
Ash softening temperature (°F)	1,980-2,340	2,100	

Almy coal bed: This is the only named bed in the Evanston Formation. Between 1869 and 1950, more than 2.7 million tons of the Almy bed were mined near Almy, just north of Evanston. Where it was mined, the Almy coal bed reached 28 feet thick, but it was characterized by numerous thin partings near the top and middle (Veatch, 1907). An upper 8-foot-thick bench, which splits off the main mined bed in places, evidently was never mined, possibly because it was of poor quality or because it aided roof support.

The two published analyses of this bed represent only a 43-inch cut and the lower 8 feet of a 24-foot expression of the coal (Lord and others, 1913). Based on these analyses, the apparent rank of the Almy coal bed is subbituminous A to high volatile C bituminous.

As-received analysis	Range (2 analyses)	Average (2 analyses)
Moisture (%)	14.1-14.4	14.3
Volatile matter (%)	35.3-36.8	36.1
Fixed carbon(%)	34.4-41.6	38.0
Ash (%)	7.2-16.2	11.7
Sulfur (%)	0.2-4.5	2.35
Hydrogen(%)	5.3-5.4	5.35
Carbon (%)	48.9-60.0	54.5
Nitrogen (%)	0.8-1.2	1.0
Oxygen (%)	24.4-26.0	25.2
Btu/lb.	8,820-10,450	9,635

"A" Seam coal bed: This coal bed lies 15 to 40 feet below the Main Kemmerer bed (**Figure 7**). Also called the Lower Kemmerer bed, the "A" Seam was mined in the central basin near Kemmerer where the bed reached a maximum thickness of 6.5 feet (Hunter, 1950). All mining on this Frontier Formation coal bed has been underground. Based on the single analysis below, the apparent rank of this coal bed is high volatile C bituminous (Veatch, 1907):

As-received basis	
Moisture (%)	5.9
Volatile matter (%)	39.5

Fixed carbon (%)	51.0
Ash (%)	3.6
Sulfur (%)	1.1
Hydrogen (%)	5.6
Carbon (%)	73.0
Nitrogen (%)	1.1
Oxygen (%)	15.7
Btu/lb.	12,780

Blind Bull coal bed: See Vail coal bed.

Frontier No. 1 coal bed: See Main Kemmerer coal bed.

Kemmerer No. 1: See Main Kemmerer coal bed.

Kemmerer No. 5 coal bed: See Willow Creek No. 5 coal bed.

Lower Kemmerer coal bed: See "A" Seam coal bed.

Lower Spring Valley coal bed: The Lower Spring Valley coal bed is a Frontier Formation coal bed that is best developed in the south-central portion of Lincoln County (**Figure 7**). In that area, this coal bed locally exceeded 5 feet thick, and was deep mined in the past (Veatch, 1907). The Lower Spring Valley coal bed may be equivalent to one or more coal beds of the Spring Valley Group to the south in Uinta County. Two analyses of the Lower Spring Valley coal bed are provided below (Townsend, 1960). The apparent rank of this coal bed is high volatile B bituminous.

As-received basis	*Typical analysis*	*Tipple sample*
Moisture (%)	5.9	4.9
Volatile matter (%)	34.4	37.1
Fixed carbon (%)	48.1	52.6
Ash (%)	11.6	5.4
Sulfur (%)	0.4	0.4
Btu/lb.	11,890	12,340
Ash softening temperature (°F)	2,590	2,330

Lower Willow Creek coal bed: In the south-central part of Lincoln County, this Frontier coal bed often underlies the Willow Creek No. 5 bed north of Kemmerer (**Figure 7**). The interval between the two beds is 5 to 20 feet. Frequently, the Lower Willow Creek coal bed is less than 2 feet thick, but locally it reaches 4 feet thick. Although the Lower Willow Creek bed has not been mined, the coal bed is weakly coking and has an apparent rank of high volatile A bituminous. The quality of 20 core analyses from Toenges and others (1945) are summarized below:

As-received basis	*Range (20 analyses)*	*Average (20 analyses)*
Moisture (%)	2.0-7.9	3.0
Volatile matter (%)	35.0-41.5	38.6
Fixed carbon(%)	45.8-52.7	49.7
Ash (%)	5.4-14.3	8.7
Sulfur (%)	0.9-1.4	1.1
Hydrogen (%)	5.2-5.7	5.4
Carbon (%)	65.3-74.8	71.7
Nitrogen (%)	1.0-1.4	1.3
Oxygen (%)	11.0-15.6	11.8
Btu/lb.	11,650-13,410	12,820
Ash softening temperature (°F)	2,340-2,720	2,480

Main Kemmerer coal bed: This coal bed, variously called Kemmerer No. 1 or Frontier No. 1, is the thickest and most persistent coal bed in the Kemmerer Coal Group. Stratigraphically, the Main Kemmerer bed lies 200 to 250 feet below the top of the Frontier Formation at least in the south-central portion of the coal field (**Figure 7**).

This bed, which is reportedly up to 20 feet thick in the southern part of Lincoln County, is typically split into two benches by a 6-inch-thick rock parting. While the top bench is usually 10 to 16 feet thick, the lower bench is closer to 4 or 5 feet. The rock parting reportedly thickens to 30 feet north and south of Kemmerer, and the two benches thin to 5 and 3 feet thick, respectively (Hunter, 1950). Occasionally, the Main Kemmerer bed exceeds 7 feet thick even in northern Uinta County.

Most underground mining in the Hams Fork Coal Field has been on this coal bed with extensive mining near Kemmerer and Diamondville in the east-central part of the field. This coal bed was mined in the Brilliant No. 8 deep mine, which was the last operating underground mine in the field (closed in 1964).

The apparent rank of the Main Kemmerer coal bed varies from high volatile B to high volatile C bituminous, possibly due to different depths of burial. Twenty-three analyses of this bed are summarized below. Of these analyses, nine were made on channel samples, eleven on tipple samples, one on a delivered sample, and two on unspecified sample types.

		Average	
As-received basis	*Range*	*Proximate (23 analyses)*	*Ultimate (10 analyses)*
Moisture (%)	3.9-6.8		5.9
Volatile matter (%)	35.0-42.0	39.6	
Fixed carbon (%)	44.3-51.3	47.6	
Ash (%)	3.5-10.5	6.9	5.9
Sulfur (%)	0.4-2.7	0.9	1.1
Hydrogen (%)	5.3-5.7		5.5
Carbon (%)	68.1-75.9		70.5
Nitrogen (%)	1.0-1.3		1.1
Oxygen (%)	13.5-17.9		16.0
Btu/lb.	11,980-12,690	12,380	
Ash softening temperature (°F)	2,060-2,270	2,170	

Middle Main coal bed: See Willow Creek No. 5 coal bed.

Upper Spring Valley coal bed: The Upper Spring Valley coal bed is a persistent Frontier coal bed in the southern part of Lincoln County where it has been deep mined on a small scale (Veatch, 1907). In this area, the Upper Spring Valley coal bed locally exceeds 6 feet thick, although it averages less. This bed may be correlative with one or more coal beds at about the same stratigraphic position in the Spring Valley area of Unita County (**Figure 7**). Correlation of individual beds between these two areas, however, is not documented. Schroeder (1976) reported that some Spring Valley coal beds in the Ragan Quadrangle just north of Spring Valley are 3 to 6.5 feet thick.

Townsend (1960) provided the following typical analysis of the Upper Spring Valley coal bed from the Kemmerer area. Based on this analysis, the bed's apparent rank is high volatile B bituminous.

As-received basis	*Typical analysis*
Moisture (%)	5.2
Volatile matter (%)	37.6
Fixed carbon (%)	48.5
Ash (%)	8.8
Sulfur (%)	0.4
Hydrogen (%)	5.3
Carbon (%)	69.6
Nitrogen (%)	1.2
Oxygen (%)	14.8
Btu/lb.	12,340
Ash softening temperature (°F)	2,560

Vail coal bed: In the northeastern portion of the Hams Fork Coal Field, this coal bed, which occurs in the Blind Bull Formation, is reportedly up to 10.2 feet thick. Most mines on the Vail or Blind Bull coal bed, however, mined only 6 to 7.5 feet of low-ash, low-sulfur coal (Veatch, 1907). The outcrop of the Vail bed is apparently traceable for more than 10 miles in this area of the coal field.

Nine coal bed analyses, presumably all correlative with the Vail coal bed, are summarized below. All these analyses were performed on tipple samples. In 1979, a test pit was opened on this bed. The apparent rank of the Vail coal bed is high volatile B bituminous.

		Average	
As-received basis	*Range*	*Proximate (9 analyses)*	*Ultimate (3 analyses)*
Moisture (%)	5.5-10.0	7.4	
Volatile matter (%)	36.8-43.9	39.4	
Fixed carbon (%)	44.5-50.3	47.5	
Ash (%)	2.2-9.7	5.7	4.6
Sulfur (%)	0.3-1.0	0.6	0.4
Hydrogen (%)	5.7-5.9		5.8
Carbon (%)	68.0-72.8		69.9
Nitrogen (%)	1.3-1.6		1.5
Oxygen (%)	16.2-19.8		17.8
Btu/lb.	11,640-12,800	12,210	
Ash softening temperature(°F)	2,180-2,370	2,250	

Willow Creek coal bed: See Willow Creek No. 5 coal bed.

Willow Creek No. 5 coal bed: The Willow Creek No. 5 coal bed, which has also been called the Willow Creek, Middle Main, or Kemmerer No. 5 coal bed, is the thickest and most persistent of the Frontier coal beds in the Willow Creek Group (**Figure 7**) (Glass, 1977). Although the Willow Creek No. 5 coal bed was 3 to 11.2 feet thick where it was mined, it thins to less than 2 feet in places and is not even recognized in the southernmost portion of the coal field (Schroeder, 1976).

Toenges and others, (1945) found that the Willow Creek No. 5 coal bed had weak coking properties that improved if the coal was cleaned before coking. They concluded, however, that it was not useful for metallurgical grade coke unless it was blended with high quality coking coal. Of the three Willow Creek Group coal beds tested, the Willow Creek No. 5 bed did offer the most promise for development.

Berryhill and others, (1950) estimated that in five townships where the Willow Creek No. 5 bed is 28 to 42 inches thick, the measured and indicated resources of this bed total 96,640,000 tons to a depth of 2,000 feet. An additional 47,980,000 tons were estimated between 2,000 and 3,000 feet of cover. Because of steep dips and depth of cover, most if not all of this 144,620,000 tons of coal are underground reserve base rather than strippable reserve base. Most mining on the Willow Creek No. 5 coal bed was in the southern part of Lincoln County although the coal bed crops out for more than 50 miles along strike. To date all mining has been underground.

Both the ash and sulfur contents of this coal bed are the lowest of any analyzed Willow Creek Group bed. Thirty-five published analyses of the Willow Creek No. 5 bed are summarized below. These analyses indicate an apparent rank of high volatile A bituminous.

		Average	
As-received basis	*Range*	*Proximate (35 analyses)* [1]	*Ultimate (24 analyses)* [2]
Moisture (%)	2.0-7.7	3.4	
Volatile matter (%)	34.7-42.7	37.2	
Fixed carbon (%)	46.0-55.1	51.8	
Ash (%)	4.3-15.3	7.7	8.0
Sulfur (%)	0.4-2.1	0.9	0.9
Hydrogen (%)	4.9-5.6		5.3
Carbon (%)	66.3-76.4		72.8
Nitrogen (%)	1.0-1.3		1.2
Oxygen (%)	10.5-17.3		11.8
Btu/lb.	11,850-13,610	12,930	
Ash softening) temperature (°F)	2,150-2,520	2,300	

[1] 19 core samples: 10 channel samples; 4 tipple samples; 1 delivered sample; 1 unspecified sample.

[2] 19 core samples; 4 channel samples; 1 unspecified sample

Bighorn Coal Field

The Bighorn Coal Field of northwestern Wyoming includes portions of Park, Hot Springs, Washakie, and Big Horn counties (**Figure 1**). This coal field, which is the fourth largest in the State, coincides with the topographic and structural basin of the same name. As defined, however, the coal field is limited to that portion of the Bighorn Basin underlain by Mesaverde or younger rocks (Luhr and Jones, 1985). This definition was chosen because the Mesaverde Formation is the oldest important coal-bearing formation in the field (Glass and others, 1975).

Structurally, this coal field coincides with a broad syncline bounded on the east by the Bighorn Mountains, on the south by the Owl Creek Mountains, and on the west by the Absaroka Plateau and Beartooth Mountains. To the north, the Bighorn Coal Field continues into Montana and narrows where it is flanked by the Beartooth and Pryor Mountains. Local folding characterizes the marginal areas of the field where the coal beds crop out. These small anticlines and synclines create local dips at various angles to the overall synclinal structure of the Bighorn Basin. Dips from 15 to 50° are common in these border areas. There are also numerous normal faults on the margins of the coal field, especially in the northern half of the field. Most of these faults trend northeast-southwest with some vertical displacements up to 250 feet.

Although coal beds occur in the Cloverly, Frontier, Lance, Willwood, and Tatman Formations, the thicker and more important beds are limited to the Upper Cretaceous Mesaverde and Meeteetse formations and the Paleocene Fort Union Formation (**Figure 2**). These latter formations crop out around the margins of the coal field but are deeply buried in the central portions of the field. In-place coal resources are estimated at 23.5 billion tons (Wood and Bour, 1988).

Coaly shale and coal are sometimes found associated with the basal sandstones of the Lower Cretaceous Cloverly Formation. Just outside the boundary of the defined coal field, an 8-foot Cloverly Formation coal bed was mined.

Only thin coal beds have been found in the Upper Cretaceous Frontier Formation of the Bighorn Coal Field. Thicknesses over a few inches are seldom mentioned.

Although Upper Cretaceous Mesaverde coal beds occur throughout the field, they are thin in the southeastern corner, where they seldom exceed 14 inches thick. The thickest and most persistent Mesaverde coal beds are in the south-central and southwestern portions of the field, where at least one bed is up to 12 feet thick. More commonly, Mesaverde coal beds are only 4 to 6 feet thick. The coal beds in the Mesaverde Formation have historically been the most important beds in the field, and they have been mined in all but the central and southeastern portions of the coal field. The minable coal beds of the Mesaverde are normally found in the basal portion of the formation. Taucher and others (1990) provided some recent analytical data on coal beds in the Mesaverde Formation. The apparent ranks of Mesaverde coal beds are subbituminous A to high volatile C bituminous.

Apparently, coal beds are distributed throughout the Upper Cretaceous Meeteetse Formation everywhere in the field, but they are neither as thick nor as persistent as the older Mesaverde coal beds. The thicker Meeteetse coal beds coincide with areas where numerous thin coals coalesce into interbedded shale and coal units. These thicker coal beds are commonly 4 to 6 feet thick although 8- to 11-foot beds have been reported.

Meeteetse coal beds have been mined in all but the central, northern, and southwestern portions of the field. Because the Meeteetse and Lance formations in the Bighorn Coal Field are not always mapped separately, the distinction between upper Meeteetse coal beds and basal Lance coal beds is often not possible. Of the two formations, however, the Meeteetse Formation normally contains the thicker and more persistent beds of coal. The apparent ranks of Meeteetse coal beds are subbituminous A to high volatile C bituminous.

Where the Upper Cretaceous Lance Formation is separable from the Meeteetse, it contains only thin coal beds. These thin coal beds are usually found near the top of the formation and are less than 6 inches thick. Because separation of the Lance from the overlying Fort Union Formation is also difficult, some of these uppermost Lance coal beds may be part of the Fort Union Formation.

Paleocene Fort Union Formation coal beds are found in all but the northern end of the Wyoming portion of the coal field. They reach their maximum reported thicknesses in the southern end of the coal field where they are as thick as 38 and 10 feet, respectively. Elsewhere, Fort Union Formation coal beds are up to 8.8 feet thick. In all cases, the thicker and more important coal beds occur in the lower part of the formation. The shallower dips exhibited by these younger Paleocene coal beds compliment their greater thicknesses. Coal beds in the Fort Union Formation have apparent ranks between subbituminous A and high volatile C bituminous.

The Eocene Willwood Formation reportedly contains a few low-quality coal beds. Rohrer (1966) reported thicknesses up to 2 feet and gives an analysis of one Willwood coal bed with a heat value of only 4,119 Btu/lb., suggesting the sample might have been extremely weathered or a coaly shale rather than a coal. Rohrer (1966) also found a 19-inch coal bed in the Eocene Tatman Formation. He reported, however, that coal beds in the Tatman are typically less than 8 inches thick and of very low quality.

Important coal beds in the Bighorn Coal Field

Gebo coal bed: In the south-central portion of the field, the Gebo coal bed of the Mesaverde Formation is 6 to 11 feet thick, but averages only 7 feet. The bed was recently mined by conventional underground methods (Glass and others, 1975). Where mined, the bed dipped 17 to 45°. The coal bed's apparent rank is high volatile C bituminous.

As-received basis	*Range (69 samples)*	*Average*
Moisture (%)	12.4-17.8	15.5
Volatile matter (%)	31.3-40.3	34.2
Fixed carbon (%)	43.0-49.7	46.0
Ash (%)	2.3-9.1	4.3
Sulfur (%)	0.4-0.8	0.6
Btu/lb.	10,080-11,780	10,970

Mayfield coal bed: This Fort Union Formation coal bed occurs in the southwestern corner of the field where it is currently strip mined near Grass Creek. The bed is 8 to 38 feet thick and has been deep mined in the past. A preliminary estimate of the strippable reserve base for this bed was in excess of 15 million tons in 1975 (Stewart, 1975). The apparent rank of this coal bed is high volatile C bituminous.

As-received basis	*Range (6 samples)*	*Average*
Moisture (%)	10.7-12.8	12.3
Volatile matter (%)	34.0-38.0	35.6
Fixed carbon (%)	42.2-48.1	44.7
Ash (%)	5.0-9.4	7.4
Sulfur (%)	0.3-0.6	0.4
Btu/lb.	10,730-11,250	10,970

Meeteetse Formation coal beds (undifferentiated): The apparent ranks of these coal beds are subbituminous A to high volatile C bituminous.

As-received basis	*Range (10 samples)*	*Average*
Moisture (%)	12.8-15.2	13.8
Volatile matter (%)	32.1-49.7	38.0
Fixed carbon (%)	23.7-45.4	37.3
Ash (%)	6.5-16.6	10.9
Sulfur (%)	0.3-0.7	0.5
Btu/lb.	7,770-10,965	9,800

Wind River Coal Field

The Wind River Coal Field coincides with a large asymmetrical syncline in central Wyoming (**Figure 1**). Dips are steeper on the northern side than on the southern. Many minor folds and a number of faults also occur in the field.

Although coal beds occur in the Frontier, Cody, Mesaverde, Meeteetse, Lance, Fort Union, and Wind River formations, the thicker and more important coal beds are in the Upper Cretaceous Mesaverde and Meeteetse formations (**Figure 2**). Coal beds in the Mesaverde and Meeteetse formations are deeply buried in the central part of the Wind River Coal Field and only crop out around the margins of the field.

Summaries of this field are found in Glass and Roberts (1978), Groff and Jones (1986), and Gregory and others (1991). In addition, Wood and Bour (1988) estimated there are 81.01 billion tons of in-place coal resources in this field.

The apparent ranks of minable Mesaverde Formation coal beds in the Wind River Coal Field are subbituminous C to high volatile C bituminous. Available analyses of Meeteetse coal beds indicate an apparent rank of subbituminous A.

Jackson Hole Coal Field

The Jackson Hole Coal Field in northwestern Wyoming is underlain by coal-bearing rocks over an area of nearly 700 square miles (**Figure 1**). In-place coal resources are an estimated 6.34 billion tons (Wood and Bour, 1988). Minable coal beds occur in Upper Cretaceous, Paleocene, and Eocene age rocks (**Figure 2**). All the coal beds are probably subbituminous in rank. This field is summarized by Jones (1982).

Black Hills Coal Field

The Black Hills Coal Field is in the extreme northeastern part of the State (**Figure 1**). Coal beds crop out in a narrow, discontinuous belt through the field. Minable coal beds are apparently confined to the base of the Lakota Sandstone of Early Cretaceous age (**Figure 2**). The coal beds in this field have moderately good coking properties and have an apparent rank of high volatile C bituminous. The field contains an in-place coal resource of 7.89 billion tons (Wood and Bour, 1988).

Rock Creek Coal Field

The Rock Creek Coal Field is a small field southeast of the Hanna Coal Field (**Figure 1**). Coal-bearing rocks occur in the Mesaverde and Medicine Bow formations of Late Cretaceous age and the Hanna Formation of Paleocene age (**Figure 2**). The thickest and best-exposed coal beds are in the northwestern part of the field. At least some of the coal beds in the field are subbituminous. Wood and Bour (1988) estimated the in-place coal resources in this field at 3.4 billion tons.

Goshen Hole Coal Field

Much of the Goshen Hole Coal Field, which is in the southeastern part of the State, is covered by relatively young rocks that do not contain coal beds (**Figure 1**). In this field, coal beds only occur in the Lance Formation of late Cretaceous age (**Figure 2**). These coal beds are probably subbituminous in rank. Wood and Bour (1988) estimate that this field contains about 230 million tons of in-place coal resources.

Although Lance coal beds are relatively thick to the south in Colorado, no coal beds over 3 feet thick are documented in this part of Wyoming. For this reason, it is very unlikely that any economically minable coal beds occur in this field.

Table 4. Wyoming's in-place coal resources.[1, 2]

Coal fields	Identified, hypothetical coal-in-place[3]	Onshore speculative coal-in-place[4]	Total coal-in-place
Bighorn	23,500	0	23,500
Black Hills	4,150	3,740	7,890
Goshen Hole	230	0	230
Green River	237,110	0	237,110
Hams Fork	22,080	27,530	49,610
Hanna	23,270	0	23,270
Jackson Hole	6,340	0	6,340
Powder River	1,030,340	255	1,030,595
Rock Creek	3,400	0	3,400
Wind River	81,010	0	81,010
Totals	1,431,430	31,525	1,462,955

[1]Modified from Table 1 of Wood and Bour (1988).

[2]All figures are in millions of tons.

[3]Identified, hypothetical coal-in-place is defined as "discovered coal whose location, rank, quality, and quantity are known or estimated from specific geologic evidence. Such evidence is based on coal beds penetrated to any depth and which thickness of coal measurements are not extended more than 3 miles from point of measurement" (Wood and Bour, 1988).

[4]Onshore speculative coal-in-place is defined as "undiscovered coal that may be in favorable geologic settings. All onshore speculative coal-in-place shown on the map is vaguely supported, as to existence, by very widely spaced (more than 25 miles apart) outcrop measurements and(or) by drill holes that have penetrated coal beds, is beyond the extent of known coal fields and their hypothetical extension, or is located beneath known coal fields in rocks of ages previously not reported..." (Wood and Bour, 1988)

COAL RESOURCES, PRODUCTION, AND RESERVES

Wyoming's original in-place coal resources are more than 1.46 trillion short tons (Wood and Bour, 1988). **Table 4** provides a summary of Wyoming's coal resources by coal field. This resource estimate is for coal-in-place, which is defined as "naturally occurring concentrations or deposits of coal at all depths in the Earth's crust, in all forms and amounts, regardless of whether economic extraction may be currently or potentially feasible" (Wood and Bour, 1988).

Table 5. Reported coal production by county through December 31, 1989.[1]

County	1989 production[2]	Cumulative production[2]
Albany	0	0.01
Big Horn	0	0.38
Campbell	143.85	1,155.51
Carbon	4.27	179.37
Converse	6.12	83.63
Crook	0	0.06
Fremont	0	3.81
Hot Springs	0.05	12.26
Johnson	0	0.46
Lincoln	4.78	133.11
Natrona	0	0.03
Niobrara	0	0
Park	0	0.04
Sheridan	0.11	91.71
Sublette	0	0.02
Sweetwater	11.97	339.35
Teton	0	0.01
Uinta	0	22.42
Washakie	0	L[3]
Weston	0	12.43
Tonnage reported by county	171.15	2,034.61
Miscellaneous tonnage not reportedby county[4]		1.05
Grand total		2,035.66

[1] Production statistics from the U.S. Geological Survey, the U.S. Bureau of Mines, and the Wyoming State Inspector of Mines.

[2] Production is in millions of tons.

[3] L means less than 200 tons.

[4] Most of this tonnage was reported during various years in the 1800s and early 1900s, but was not recorded by county.

This new estimate of the coal resources in Wyoming differs from previous estimates in that coal beds of any thickness and to all depths are included. Previous estimates were restricted to coal beds that were less than 6,000 feet below the surface, to anthracite and bituminous coal beds that were more than 14 inches thick, and to subbituminous coal beds and lignites that were more than 30 inches thick (Berryhill and others, 1950, 1975).

Wyoming's in-place coal resources are more than twice the in-place resources of any other state in the conterminous United States. Only Alaska has more in-place-coal than Wyoming.

Table 5 shows reported coal production by county. **Table 6** shows the original in-place resources of the State, production and mining losses, and remaining resources. Wyoming's coal reserve base is also shown as approximately 64.99 billion tons. The U.S. Energy Information Administration (1990a) lists Wyoming's reserve base at 68.2 billion tons. On the basis of recovery methods, their reserve base estimate contains 42.5 billion tons potentially recoverable by underground mining and 25.7 billion tons potentially recoverable by surface mining. Wyoming's known strippable reserve base is limited to a few mapped and explored areas and is only a small portion of Wyoming's potentially strippable coal, which could easily total ten times the known reserve base.

Table 6. Remaining coal resources and reserve base for Wyoming on January 1, 1990[1]

Original resources[2]	1,462,955.00
Cumulative production from strip mining[3]	1,638.00
Cumulative production from deep mining[3]	397.66
Total cumulative production	2,035.66
Cumulative losses due to strip mining (10-20% loss)	392.43
Cumulative losses due to deep mining (equal to production)	397.66
Total cumulative production and mining losses	2,825.75
Remaining resources	1,460,129.25
Remaining strippable reserve base[4]	26,651.85
Remaining underground reserve base[5]	38,342.48
Total remaining reserve base	64,994.33

[1]All figures are in millions of tons.
[2]Wood and Bour (1988).
[3]Production statistics from the U.S. Geological Survey, the U.S. Bureau of Mines, and the Wyoming State Inspector of Mines.
[4]Modified from Smith and others (1972).
[5]Modified from Berryhill and others (1950).

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