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COAL DEPOSITS OF WYOMING

by Gary B. Glass

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COAL DEPOSITS OF WYOMING

GARY B. GLASS[1]

COAL-BEARING AREAS

As defined by the United States Geological Survey, Wyoming's coal fields fall into two coal-bearing provinces. The coals in northeastern Wyoming are within the Northern Great Plains Province while all other coal deposits of the state are in the Rocky Mountain Province. Additionally, the United States Department of Energy designates Wyoming as coal-producing District 19. Beyond these national designations, Wyoming's coal-bearing areas are divided into the following 10 major regions, basins, or fields, which underlie more than 40,000 square miles or approximately 41 percent of the state and which collectively contain almost 24 percent of the nation's coal resources under less than 6,000 feet of overburden (Figure 1):

1. Powder River Coal Basin
2. Green River Coal Region
3. Hams Fork Coal Region
4. Hanna Coal Field
5. Wind River Coal Basin
6. Bighorn Coal Basin
7. Rock Creek Coal Field
8. Jackson Hole Coal Field
9. Black Hills Coal Region
10. Goshen Hole Coal Field

These major areas are further subdivided into 45 individual coal fields (Figure 2). Twelve fields are in the Powder River Basin while 8 are in the Bighorn Basin. The Wind River Basin and Green River Region consist of 7 and 6 fields respectively, while the Hams Fork Region and the Black Hills Region each have 4 fields. The remaining four major areas are single coal fields. Revised boundaries for many of these fields are shown in Figure 2. It is noteworthy that, at least locally, coals also occur outside the defined coal-bearing areas and coal fields.

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COAL-BEARING ROCKS

Wyoming's coals occur in rock sequences deposited during either the Cretaceous Period (some 66-135 million years ago) or during the younger Tertiary Period (38-66 million years ago). During 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 nearly trillion tons of coal that still underlie 41 percent of the state.

Geologic formations that contain these coals characteristically are thick; generally 700-7,000 feet in thickness. While the Cretaceous formations normally exhibit gradual, regional thickening or thinning across the state, the thicknesses of the various Tertiary formations vary from basin to basin. These variations are more a result of local tectonic and depositional events that affected each of the coal-bearing areas than they are related to the larger regional events that marked the Cretaceous Period.

The most widespread coal-bearing rocks in Wyoming are Cretaceous in age and these rocks usually crop out only as narrow bands of upturned strata along the margins of the larger structural basins and uplifted areas of the state. They also crop out as irregularly exposed, linear bands in the thrust belt of western Wyoming. Relatively flat-lying Tertiary rocks, on the other hand, occupy the central portions of most of the coal-bearing areas where they overlie the older Cretaceous rocks. Even the Tertiary rocks often exhibit steeper dips as they approach the margins of the coal-bearing basins and regions.

Cretaceous and Tertiary coal-bearing formations contain numerous coals that are separated from one another by as little as a few inches of shale or claystone to hundreds of feet of rock that may vary from coarse sandstone or conglomerate to siltstones, claystones, and shales. Although the Cretaceous coals interspersed in these rocks are generally less than ten feet in thickness, a few

Cretaceous coals are 30 to 100 feet thick in westernmost Wyoming.

The Tertiary coals, which were deposited during the Eocene and Paleocene Epochs, often exceed ten feet in thickness with 30 to 80 feet thick coals common. Locally, at least one Tertiary coal is 220 feet in thickness.

Correlation of individual coals across most of the coal-bearing areas or even across a coal field is seldom documented. For this reason, the correlation of a coal from one coal-bearing area to another is not yet possible. In fact, correlation of some coal-bearing formations from one basin or region to another is speculative.

Lower Cretaceous

The oldest coal-bearing formation in Wyoming is the Lower Cretaceous Lakota Conglomerate (Figure 3). This formation contains at least one minable coal in the Black Hills Coal Region.

The Bear River Formation of Lower Cretaceous age is the next younger coal-bearing rock unit above the Lakota. The coals in the Bear River Formation

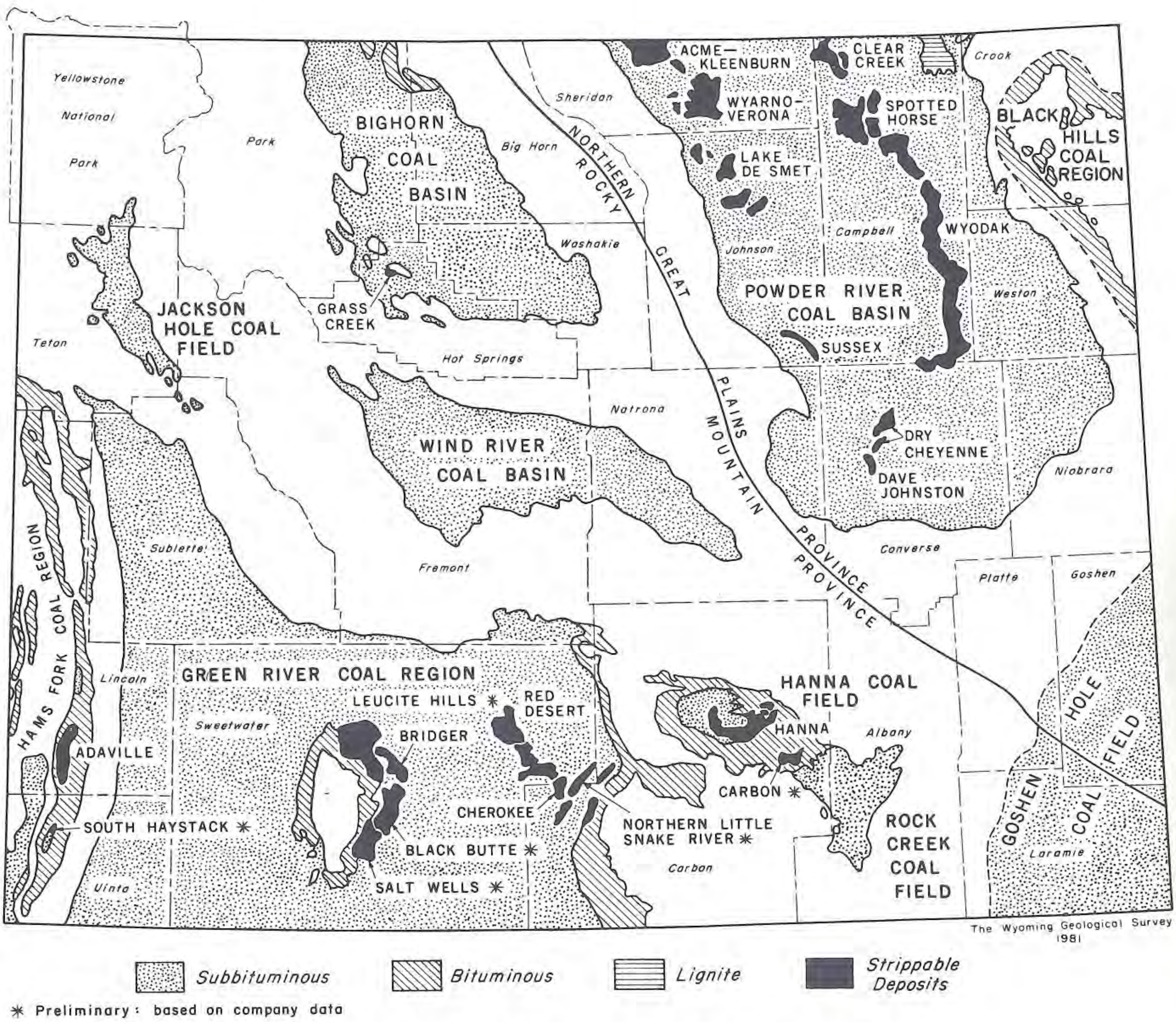
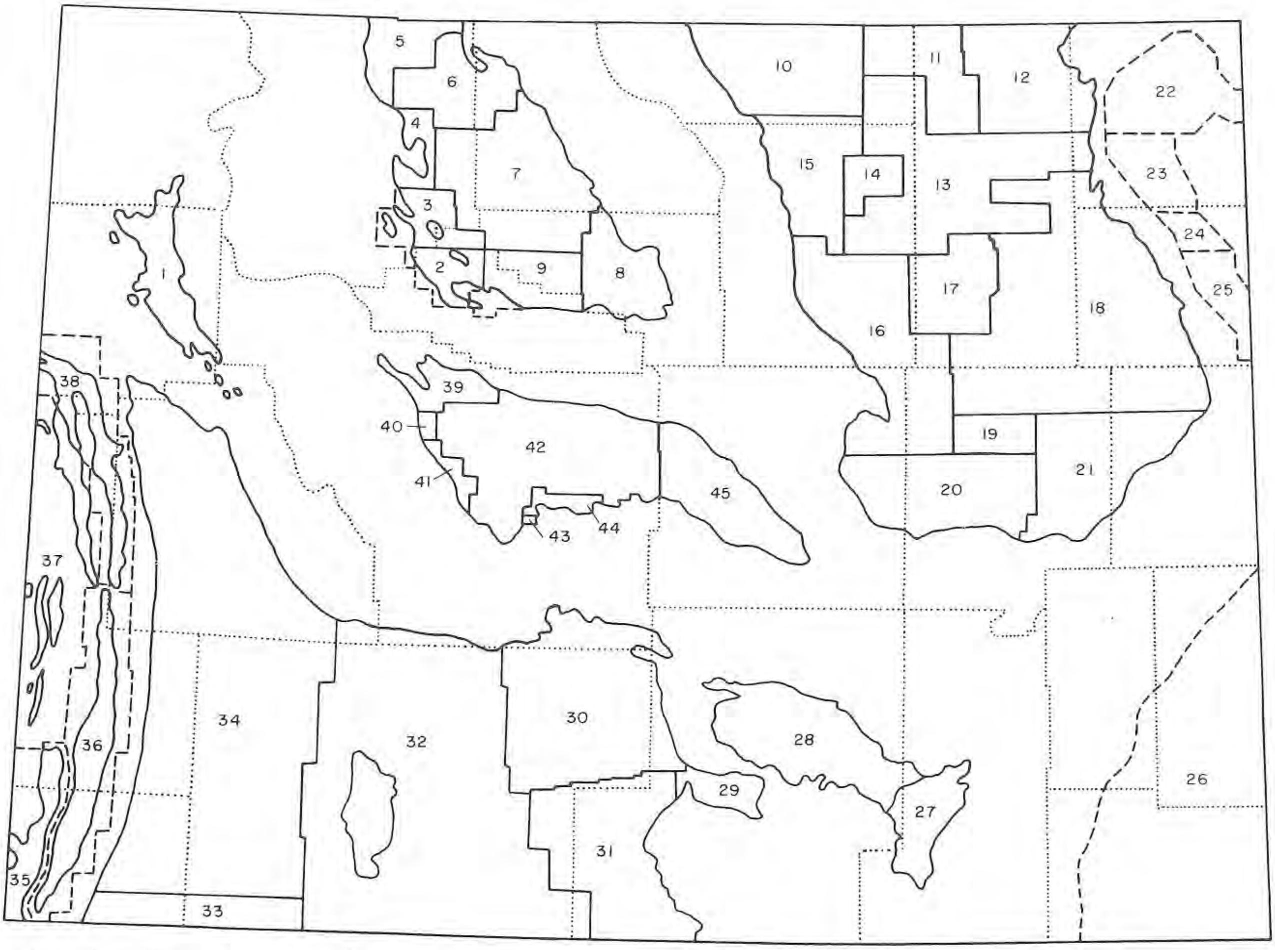


Figure 1: Wyoming coal-bearing areas (revised in 1981).



1. Jackson Hole
2. Grass Creek
3. Meeteetse
4. Oregon Basin
5. Silvertip
6. Garland
7. Basin
8. Southeastern
9. Gebo
10. Sheridan
11. Spotted Horse
12. Little Powder River
13. Powder River
14. Barber
15. Buffalo
16. Sussex
17. Pumpkin Buttes
18. Gillette
19. Dry Cheyenne
20. Glenrock
21. Lost Spring
22. Aladdin
23. Sundance
24. Skull Creek
25. Cambria
26. Goshen Hole
27. Rock Creek
28. Hanna
29. Kindt Basin
30. Great Divide Basin
31. Little Snake River
32. Rock Springs
33. Henry's Fork
34. Labarge Ridge
35. Evanston
36. Kemmerer
37. Greys River
38. McDougal
39. Muddy Creek
40. Pilot Butte
41. Hudson
42. Beaver Creek
43. Big Sand Draw
44. Alkali Butte
45. Arminto

Figure 2: Coal fields of Wyoming.

are very local in extent and have only been reported in the Hams Fork Coal Region (Glass, 1977).

Upper Cretaceous

Separated from the Bear River Formation by a marine shale, the overlying Upper Cretaceous Frontier Formation (variously mapped as the Blind Bull Formation) contains numerous fairly thick, persistent coals in western Wyoming (Glass, 1977). Elsewhere, the Frontier coals apparently are thin, shaly, and of very limited extent.

The oldest widespread coal deposits in Wyoming are found in the Upper Cretaceous Mesaverde Group or its western equivalent, the Adaville Formation. These rocks contain numerous thick to moderately thick coals in the Hams Fork and Green River regions. Mesaverde coals are less numerous and apparently thinner and more local in extent

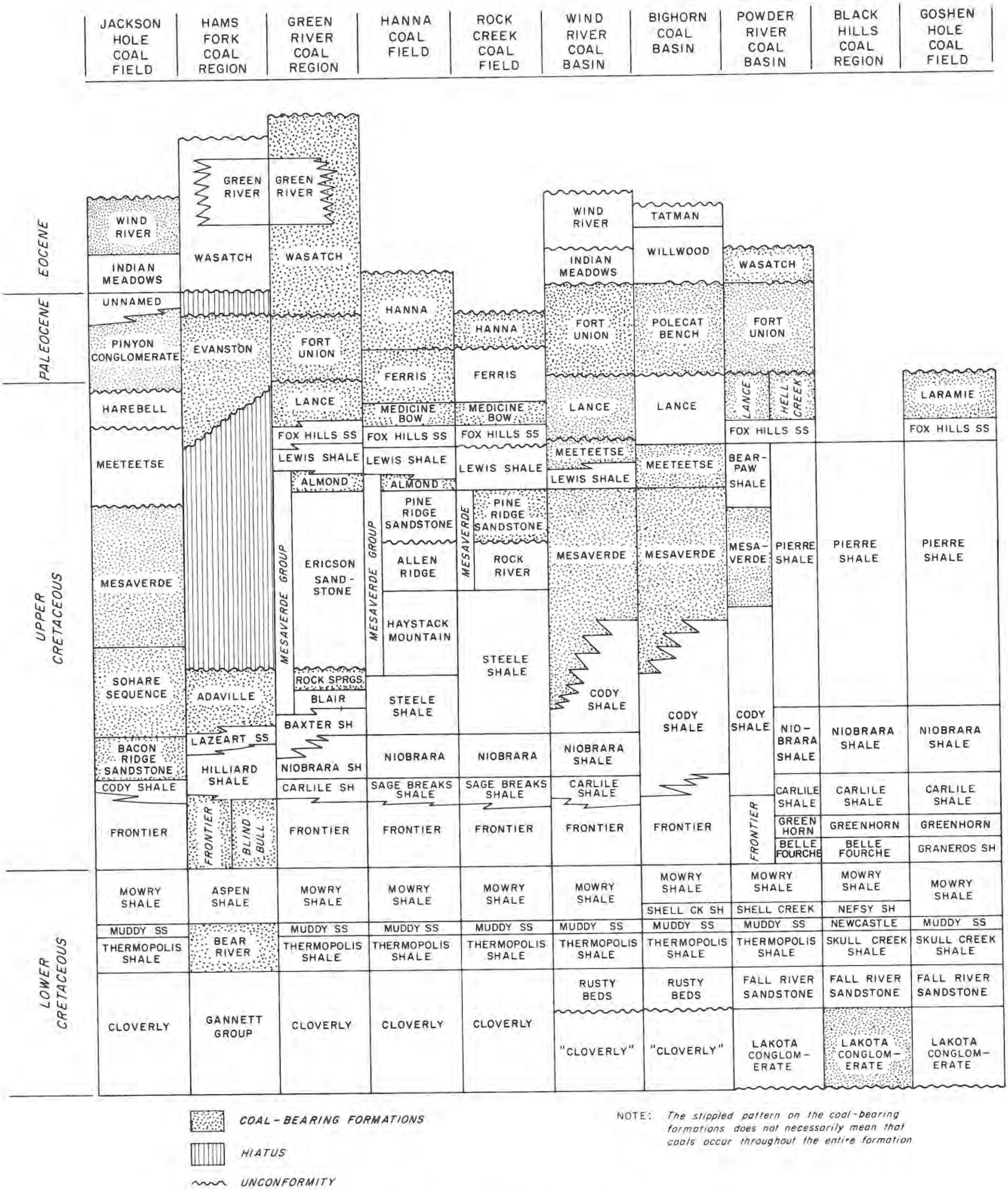


Figure 3: Major coal-bearing formations in Wyoming (adapted from Love and Christiansen, 1980 a Wyoming Geological Association's Stratigraphic Nomenclature Chart, 1969).

throughout the rest of the state. The Mesaverde disappears before it reaches half way across the Powder River Basin, and only contains very thin coals on the southern flank of that basin (Glass, 1976).

The Meeteetse Formation was deposited at about the same time as the Lewis Shale. This formation is recognized in the Wind River and Bighorn basins where it contains some coals, most of which are thin and discontinuous.

Lance Formation coals are the youngest Upper Cretaceous coals in Wyoming. Although the Lance and equivalent aged rocks contain coal throughout the state, Lance coals are best developed in southern Wyoming. There they are numerous, but seldom more than 10 feet in thickness.

Paleocene

Paleocene rocks (variously mapped as the Fort Union, Polecat Bench, Pinyon Conglomerate, or Evanston formations) crop out in all but the Black Hills Region and Goshen Hole Field. Paleocene rocks invariably contain coals although they are most prolific in the Powder River Basin and Hanna fields. While there are more Paleocene coals in the Ferris and Hanna formations of the Hanna Field, the Fort Union coals of the Powder River Basin are often two to three times as thick as the thickest coals in the Hanna Field, which are as thick as 36 feet.

Eocene

The Eocene Wasatch Formation is the youngest coal-bearing rock unit of economic importance in Wyoming. At least in the Powder River Basin, the Wasatch rivals the older Paleocene rocks in both the number of coals it contains and in their thickness. In fact, the Wasatch contains the thickest coal in Wyoming, the 220 feet thick Lake DeSmet coal. Wasatch or equivalent aged coals are also abundant and moderately thick in the Great Divide Basin of the Green River Region and in the Hanna Field. Elsewhere in the state, they are thinner and less persistent than many older coals.

STRUCTURAL GEOLOGY OF COAL-BEARING AREAS

In general, Wyoming coal measures 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 Region, most of the state's coals 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.

While the Hams Fork Region and Hanna Field exhibit the greatest structural complexity, the Powder River Basin shows the least. Faulting is most common in the southern and western coal regions, but it is not restricted to those areas.

RANK

The rank of Wyoming coal is lignite to high volatile A bituminous. Lignites, however, are restricted to a small area in the northeastern corner of the Powder River Basin. That occurrence represents a southern extension of the Tertiary lignite deposits of Montana and North Dakota (Figure 1).

Subbituminous coals which are all either Tertiary or Late Cretaceous in age, are found in all the coal-bearing areas of the state except the Black Hills Region. Usually, the subbituminous coals occupy the more central parts of the coal-bearing areas although, in the case of the Hams Fork Region, subsequent erosion has relegated even the younger subbituminous coal-bearing rocks to narrow bands between faults and eroded folds. In several basins the subbituminous coals are buried beneath great thicknesses of rock that do not contain coals.

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

While the older coal beds in any given field are generally higher in rank than the younger beds, the rank of individual beds in a field also seems to increase toward the troughs of the structural basins. Both of these variations in rank have been attributed to increases in depth of burial (Unfer, 1951).

In the Hanna Coal Field, however, Glass and Roberts (1980a) report that the rank of Tertiary age coals increases eastward across the coal field. As a result, Paleocene and Eocene coals of the Hanna Formation exhibit higher apparent ranks than the

Lower Cretaceous and Paleocene coals that crop out in the western half of the Hanna Field. Glass and Roberts (1980a) attribute this variation in rank more to variations in heat flow within the field than simply to greater depth of burial.

PROXIMATE ANALYSES AND SULFUR CONTENT

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

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

Washability studies suggest that most if not all Wyoming coals can be readily washed to a desirable ash level with minimal loss of yield (Deurbrock, 1971).

The sulfur content of Wyoming coals is quite variable. For example, relatively high sulfur coals occur in the Wasatch Formation in the Red Desert area of the Green River Coal Region and in the uppermost Hanna Formation coals of the Carbon Mining District of the Hanna Coal Field. Although none of these coals is mined, exploration has shown as-received sulfur contents as high as 7.2 percent in the Red Desert area (Masursky, 1961) and 8.7 percent in the Carbon Mining District (Glass, 1978).

Published analyses of Wyoming's coals generally highlight the lower sulfur coals. For instance, most published analyses of the state's Cretaceous coals show 0.9-2.0 percent sulfur on an as-received basis, compared to 0.3-0.9 percent sulfur in the state's Tertiary coals. In some cases, relatively low sulfur contents are the result of an old practice of removing impurities before analysis. In other cases, analyzed samples are coming from coal mines where contract specifications require the exclusive mining of low sulfur coals. For this reason, mined Wyoming coals now average 0.5 percent sulfur and rarely exceed 1.0 percent sulfur on an as-received basis.

Given these previous words of caution, there is still a vast quantity of coal in Wyoming that does contain less than one percent sulfur. No one, however, has satisfactorily estimated that quantity. Although the U.S. Bureau of Mines attempted such an estimate in 1975 (Hamilton et al., 1975), their estimate was not only based on inadequate data, but their treatment of that data was statistically incorrect. The Bureau's estimate is therefore not accurate (Glass, in press).

In studies of Wyoming's lower sulfur coals, the sulfate form of sulfur averages less than 0.03 percent (3-5% of the total sulfur); the pyritic form averages less than 0.2 percent (25-29% of the total sulfur); and the organic form averages less than 0.47 percent (70-72% of the total sulfur) (Walker and Hartner, 1966). Because most of the sulfur in Wyoming's lower sulfur coals is in the organic form, conventional mechanical cleaning or preparation processes are not going to 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 percent.

In contrast, pyritic sulfur generally accounts for more than 50 percent of the total sulfur in high sulfur Wyoming coals (Glass, 1978). In many of Wyoming's high sulfur coals, however, the organic form of sulfur also increases to as much as 2-3 percent of the total sulfur, again offsetting the potential benefits of simple mechanical cleaning.

HEAT VALUE

Heat values of currently mined coals, like moisture contents, vary widely across Wyoming. In the southern half of the state, as-received heat values average 10,500 Btu/lb. They typically are between 9,270 and 11,700 Btu/lb. Some younger coals, mined at the Jim Bridger strip mine in southwestern Wyoming, account for the lower heat values. These coals average only 9,350 Btu/lb. While heat values of coals mined in western Wyoming average 9,600

Table 1: Characteristics of Wyoming coals that are currently mined.

Coal-bearing Area	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
Powder River Coal Basin							
Northwestern portion	Subbituminous	Range: 10-57 Average: 40	Range: 14.5-26.0 Average: 21.5	Range: 3.1-8.2 Average: 4.4	Range: 0.3-1.0 Average: 0.4	Range: 9,000-10,410 Average: 9,600	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: 6.0	Range: 0.2-1.2 Average: 0.5	Range: 7,420-9,600 Average: 8,220	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: 11.4	Range: 0.4-0.7 Average: 0.6	Range: 7,610-8,870 Average: 8,180	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: 8.7	Range: 0.2-2.1 Average: 0.8	Range: 8,310-12,600 Average: 10,310	Range: 43-110 Average: 55
Green River Coal Region	Subbituminous	Range: 5-30 Average: 15	Range: 17.0-20.5 Average: 20.5	Range: 5.9-10.0 Average: 9.7	Range: 0.4-0.8 Average: 0.5	Range: 9,270-10,000 Average: 9,350	Range: 79-82 Average: 80
Hams Fork Coal Region	Subbituminous	Range: 5-90 Average: 16.5	Range: 15.4-28.6 Average: 20.8	Range: 1.5-8.9 Average: 3.4	Range: 0.2-1.8 Average: 0.6	Range: 7,920-10,530 Average: 9,860	Range: 41-87 Average: 51
Bighorn Coal Basin	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 AverageL 0.4	Range: 10,730-11,246 Average: 10,970	Range: - Average: -

Btu/lb., the heat values in northeastern Wyoming are much lower. Although heat values in northeastern Wyoming coals are from 9,300 Btu/lb. in the Sheridan area to 7,550 Btu/lb. in Converse County, they average only 8,300 Btu/lb.

Heat values of Wyoming coals are commensurate with their rank. On a moist mineral-matter-free basis, the bituminous coals are between 14,000 Btu/lb. and 11,500 Btu/lb. while the subbituminous coals are between 8,300 Btu/lb. and 11,500 Btu/lb.

For at least the subbituminous coals, the heat values increase noticeably under greater increments of overburden. An increase of 300 Btu/lb. per 110 feet increase in overburden has been reported in the Hanna Field (Unfer, 1951).

MAJOR AND MINOR ELEMENTS

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

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

Based on some recent analyses, Wyoming's Cretaceous and Tertiary coals show similar concentrations of all the major and minor elements except calcium and sodium. The concentrations of calcium and sodium in the Tertiary coals are usually four to five times the concentrations normally reported in the Cretaceous coals of Wyoming.

TRACE ELEMENTS

Of the 30 trace elements recognized in some 48 analyses of Wyoming coals, 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, 6 elements average less than 1 part per million, 12 elements are between 1-5 parts per million, 11 elements are between 5-100 parts per million, and one element, barium, averages more than 300 parts per million (Table 3).

Table 2: Major and minor elements in 48 Wyoming coal samples in percent on a whole-coal basis (Glass, 1975; Swanson, et. al., 1976).

	Wyoming Range	Wyoming Average	U.S. Average
Silicon	0.41-5.50	1.70	2.6
Calcium	0.13-2.10	0.75	.54
Aluminum	0.17-2.50	0.72	1.4
Iron	0.15-2.100	0.51	1.6
Magnesium	0.026-0.340	0.17	.12
Potassium	0.005-0.370	0.063	.18
Sodium	0.003-0.190	0.044	.06
Titanium	0.001L-0.130	0.038	.08
Phosphorous	0.0021L-0.044	0.0121	--
Chlorine	0.004-0.026L	0.010L	--
Manganese	0.0007L-0.0492	0.004	.01

Table 3: Average trace element concentrations in 48 Wyoming coal samples in parts per million on a whole-coal basis (Glass, 1975; Swanson, et. al., 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	--
Neobium	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	.18

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 from 1-5 parts per million. While the potentially dangerous elements, arsenic and molybdenum, also average 1-5 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 coals in Wyoming appear to contain higher concentrations of 26 of these trace elements than do the Cretaceous coals. Only boron, beryllium, fluorine, and germanium are higher in the Cretaceous coals (Glass, 1975).

CARBONIZING PROPERTIES

Most Wyoming coals are nonagglomerating and may be carbonized in fluidized systems. Chars produced at low temperatures contain about 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 coals, but they are relatively weak. These lump chars are a suitable substitute for coke breeze used in phosphate ore reduction (Landers, et. al., 1961).

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

COKING COAL

Coal with weak to moderate coking properties occurs in the Kemmerer Field of the Hams Fork Region, the Rock Springs Field of the Green River Region and the Cambria Field of the Black Hills Region. The Cambria coal in the Cambria Field possesses the best coking qualities. Unfortunately much of the recoverable Cambria coal has already been removed. Reserves of this bed are believed to be small (Berryhill et. al., 1950). The Middle Main bed in the Kemmerer Field is between 3.1 feet and 6.5 feet thick and yields a weak coke. Recoverable reserves of this bed are estimated at 8,000,000 tons. Other coals in the Hams Fork Region also have coking potential. The Rock Springs No. 7 bed of the Rock

Springs Field is between 2 feet and 10 feet in thickness. Although there are more than 200,000,000 tons of measured resources of this coal, it is of poor coking quality.

COKING OPERATIONS IN WYOMING

Currently there are two coking facilities in Wyoming. FMC Corporation's process coke plant near Kemmerer was built in the early 1960's and utilizes the Adaville No. 1 coal from the Kemmerer Coal Field. The Adaville No. 1 is subbituminous in 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 then combined with a liquid binder and formed into small pillow-shaped briquets. A typical composition for FMC coke in 1963 was as follows (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 suitable as a fuel to produce power and steam and can also be used for injection into blast furnaces. The calcinate is a suitable fuel for sintering iron ore.

FMC now 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. This plant is approximately three times larger than its prototype built in 1963. Monsanto's process can use poorly coking to noncoking coals 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.

An average analysis of the coke produced from this plant in 1966 was as follows (Fagnant, 1966):

Moisture	0.5%
Moisture-free volatile matter	1.17%
Moisture-free fixed carbon	91.6%

Currently all production from the plant goes to Monsanto's phosphate plant in Idaho.

IN SITU GASIFICATION

Since 1972, the U.S. Department of Energy's Laramie Energy Technology Center (LETC) has conducted research into the in situ production of gas from the Hanna No. 1 coal at Hanna, Wyoming. In the fall of 1972, numerous boreholes were drilled into a 30-foot thick subbituminous coal underlying the site at depths in excess of 350 feet. Since then, the coal has been ignited and extinguished during various experiments in which the combustion and gasification of the coal has been controlled by regulation of air fed through the boreholes. During their early experiments, LETC researchers reported gas volumes from 75,000 to 2 million cubic feet per day. The heat value of the product gas varied from 30 to 475 Btu per 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 per cubic foot. (Brandenburg, et. al., 1976). To date, the main constituent of the gas has been nitrogen, accounting for the low heat values. Future plans call for oxygen injection and possibly a small demonstration power plant fueled by the product gas.

In 1974, Lawrence Livermore Laboratory (LLL) started an independent in situ experiment on a 25-foot thick Wasatch Formation coal that lies 125 feet below the surface. Drilling and explosive fracturing at their Hoe Creek site in Campbell County was completed in 1975. Ignition of the Felix No. 2 coal, however, was postponed because measured permeabilities and air flows indicated that there would be 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 the coal during a 14 day test. Produced gas flowed at rates between 3-6 million cubic feet per day. Also, oxygen was injected into the burn, raising the heat value of the produced gas to 270 Btu per cubic foot.

In addition to these two ongoing projects, both

Gulf Research and Development and Atlantic Richfield are conducting independent experiments. In 1977, Gulf was awarded a $13.5 million cost-sharing contract with the Department of Energy. The contract called for a five year study of the in situ gasification of steeply dipping coal beds. Their project site is located near Rawlins in southcentral Wyoming. Their first burn occurred in 1979 on a Fort Union Formation coal, designated the "G" seam.

Atlantic Richfield conducted its own experiment on the 100-foot thick Wyodak coal bed near Reno Junction in northeastern Wyoming. Arco's first experiment was completed in 1979.

COAL MINING AND PRODUCTION

Except for an eleven-year interval after World War I, Wyoming's coal production for the years 1910 through 1945 remained above 6 million tons annually. After 1945, production fell to a record low of 1.6 million tons by 1958. This decline followed World War II, and more importantly, the railroad's change from steam locomotives to diesel engines.

Renewed interest in Wyoming's coal resources began in the late 1960's as power plant demands for inexpensive, low sulfur coals increased. Because of this demand, Wyoming's coal companies have set new production records every year since 1972 (Figure 4).

Wyoming's 1980 tonnage set yet another record at 95 million tons. With this tonnage, Wyoming remains the largest coal-producing state in the Rocky Mountains and the 3rd or 4th largest in the nation. In 1981 production will probably exceed 108 million tons. Present indications suggest annual tonnage will be about 157 million tons in 1985 and 176 million tons by 1990. These projected increases are principally to satisfy the electric power market and include no coal gasification plants. At these rates of increase, Wyoming's coal production in the 15-year period between 1971 and 1985 will be more than twice the production from 110 years of mining prior to these years or approximately one billion cumulative tons.

Coal production in Wyoming was dominated by underground mining until 1954. In that year strip mining tonnage barely exceeded that of the underground mines. Since then, however, strip mining has become the dominant mining method and now accounts for more than 98% of Wyoming's annual production. Conversely, underground mining has slipped to 2% of the annual tonnage mined. An estimate of the total coal production from Wyoming, to January 1, 1981, is 823.3 million tons of which 47% or 289.1 million tons came from underground mines and 53% or 434.2 million tons came from surface mines.

In 1980, twenty-one coal mining companies produced 95 million tons of coal. These companies operated 23 strip mines and 3 underground mines (Table 4). Two of the underground (deep) mines accounted for 86% of the underground tonnage of

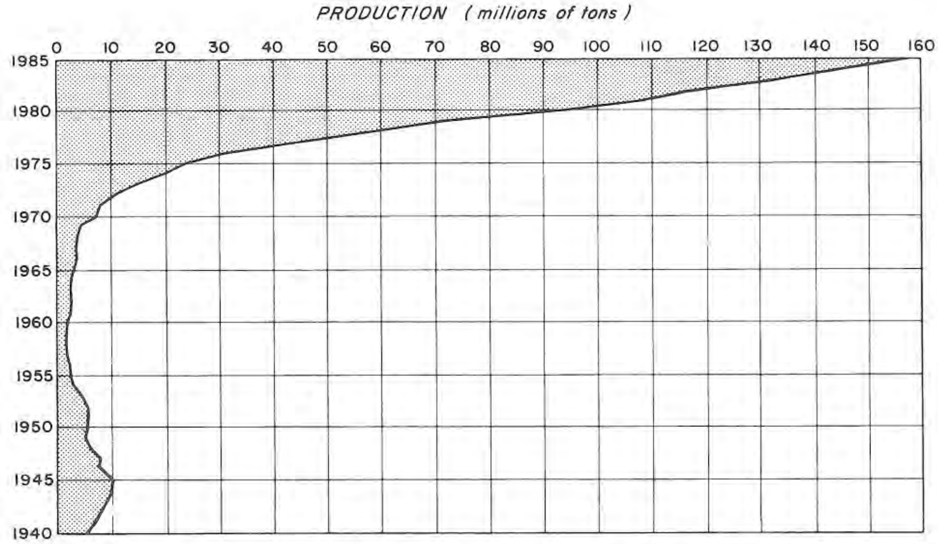


Figure 4: Wyoming coal production 1940-1980, with projections to 1985.

1.63 million tons. The eight strip mines that produced in excess of 4 million tons, accounted for 70% of the strip mine tonnage. Amax Coal Company's Belle Ayr strip mine remained the largest coal mine in the United States in 1980, producing 16.1 million tons, which is 2 million tons less than its record production of 18.1 million tons in 1978.

The coal-producing counties in Wyoming are now Campbell, Carbon, Converse, Hot Springs, Lincoln, Sheridan, and Sweetwater.

In 1979, about 75% or 54 million tons of the coal mined in Wyoming went to power plants in at least 14 other states, located as far south as Texas and Louisiana, and as far east as Indiana, Illinois, and Ohio (Figure 5). Another 20%, or 14.2 million tons was burned in Wyoming power plants. Industrial customers used the remaining 5%. The beet sugar, cement, and phosphate industries were the major out-of-state industrial users, with about 1.8 million tons shipped to various plants throughout the Pacific Northwest, Rocky Mountain, and Mid-continent regions. Another 1.7 million tons were used to manufacture trona, cement, bentonite, and synthetic coke in Wyoming. In-state and out-of-state retail sales of coal were each about 100,000 tons.

Table 4: Wyoming coal production by mine.

Company	Mine Name(s)	County	Coal Field	Employees (1980)	Production (1980)
Amax	Belle Ayr (strip)	Campbell	Gillette	404	16,106,093
	Eagle Butte (strip)	Campbell	Powder River	212	8,440,000
Arch Mineral	Seminoe # 1 (strip)	Carbon	Hanna	225	2,500,000
	Seminoe # 2 (strip	Carbon	Hanna	270	1,828,852
Atlantic Richfield	Coal Creek (strip)	Campbell	Gillette	13	Under Construction
Big Horn	Big Horn (strip)	Sheridan	Sheridan	298	4,287,000
Black Butte	Black Butte (strip)	Sweetwater	Rock Springs	879	3,719,106
Bridger	Jim Bridger (strip)	Sweetwater	Rock Springs	404	6,453,302
Carbon County	Carbon # 1 (deep)	Carbon	Hanna	256	527,273
Carter Mining	Caballo (strip)	Campbell	Powder River	112	1,974,164
	Rawhide (strip)	Campbell	Powder River	226	4,472,530
Cordero Mining (Sunedco)	Cordero (strip)	Campbell	Gillette	150	6,562,802
Delzer Construction	Fort Union (strip)	Campbell	Powder River	13	10,962
Energy Development	Vanguard # 2 (deep)	Carbon	Hanna	199	877,637
FMC Corporation	Skull Point (strip)	Lincoln	Kemmerer	100	845,884
Glenrock (Nerco)	Dave Johnston (strip)	Converse	Glenrock	202	3,803,932
Kemmerer	Elkol (strip)	Lincoln	Kemmerer	271	1,733,740
	Sorensen (strip)	Lincoln	Kemmerer	333	2,348,838
Kerr-McGee	Clovis Point (strip)	Campbell	Gillette	124	2,481,996
	Jacobs Ranch (strip)	Campbell	Gillette	298	8,246,072
Medicine Bow	Medicine Bow (strip)	Carbon	Hanna	231	1,819,622
Northwestern Resources	Grass Creek (strip)	Hot Springs	Grass Creek	4	18,284
Prospect Point	Commercial tipple-processed 502,470 tons[1]	Sweetwater	Rock Springs	10	
Resource Exploration & Mining	Energy pits (strip)	Carbon	Hanna	75	692,087
Rosebud Coal Sales	Rosebud pits (strip)	Carbon	Hanna	240	1,890,540
Shell Oil	Buckskin (strip)	Campbell	Powder River	32	Under Construction
Stansbury	Stansbury (deep)	Sweetwater	Rock Springs	168	228,110
Thunder Basin (Arco)	Black Thunder (strip)	Campbell	Gillette	410	10,548,996
Wyodak Resources	Wyodak (strip)	Campbell	Gillette	52	2,568,611
				6,211	94,986,433

Source: State Inspector of Mines

[1] This coal is included in the tonnage from the Jim Bridger mine

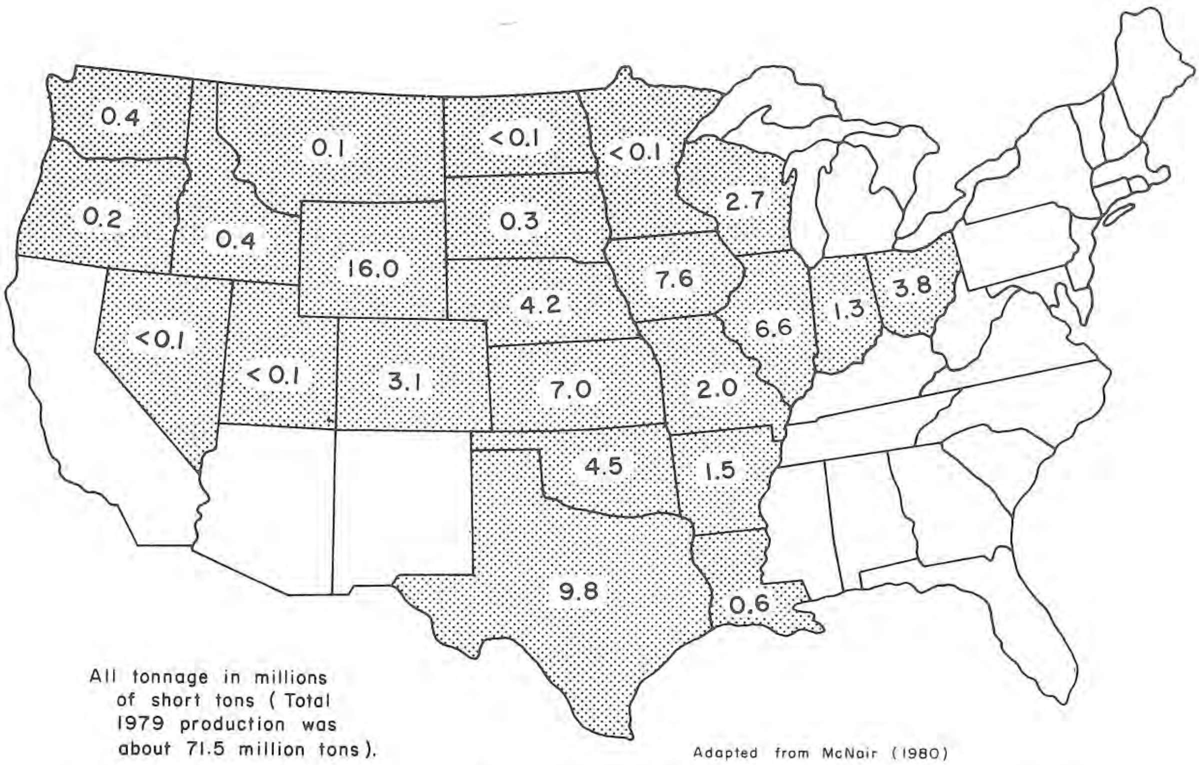


Figure 5: 1979 markets for Wyoming coal (adapted from McNair, 1980).

POWDER RIVER COAL BASIN

The Powder River Coal Basin of northeastern Wyoming includes Campbell County and portions of Sheridan, Crook, Weston, Niobrara, Converse, Natrona, and Johnson counties. This 12,000 square mile coal-bearing area, which is the second largest in the state, coincides with the topographic and structural basin of the same name. As defined, however, the coal basin is limited to that portion of the Powder River Basin underlain by Mesaverde or younger rocks. This definition was chosen because the Mesaverde Formation is the oldest coal-bearing formation in the basin.

Structurally, the basin is 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 basin continues into Montana where it is separated from the Williston Basin by the Miles City Arch-Cedar Ridge Anticline. Because the axis of the Powder River Basin is west of the basin's center, the rocks in the eastern and central portions of the basin have almost imperceptible dips compared to the steeper dips on the west flank. In general, the Cretaceous rocks around the flanks of the basin dip more steeply than the Tertiary rocks, which are nearly flat-lying (2-3 degree dip) except on the west flank where at least the Paleocene rocks steepen to 10-25 degrees.

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

Although coals are reported in the Upper Cretaceous Mesaverde and Lance formations, the thickest and most important coals are limited to the Paleocene Fort Union Formation and the Eocene Wasatch Formation.

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

One, the Wyodak coal, is frequently 50-100 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 basin. Although the Wyodak coal regionally splits into two or more separate beds, coals equivalent to these beds are tentatively correlated into the Sheridan area, 60 miles across the basin (Glass, 1976). Other coal beds, as well, have been correlated over slightly shorter distances (Figure 6).

The Wasatch Formation, which is 1,000-2,000 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 Basin, and usually exhibits shallow dips (less than 4 degrees).

The Wasatch Formation contains as many as eight, thick, persistent coals (Figure 6). The thickest Wasatch coal bed occurs at Lake DeSmet on the west side of the basin. There, the Lake DeSmet coal locally exceeds 200 feet in thickness (Mapel, 1959). Although many Wasatch coals have been mapped and correlated for tens of miles along outcrop, these coals are thicker and more persistent in the western and central parts of the basin.

Important Coal Beds

Anderson coal bed: This Paleocene coal is well developed in all but the western part of the Powder River Basin. The Anderson coal coalesces with the Canyon and other coals in the Gillette area to form the 70-175 feet thick Wyodak coal, which crops out on the eastern side of the basin (Denson, et. al., 1978; Kent, et. al., 1980). Northward, eastward, and southward, the Anderson splits off the Wyodak bed and thins to 10-50 feet thick (Figure 6).

The D coal bed of the southern part of the Gillette Field is correlative with the Anderson bed, but the Roland coal, which is stratigraphically higher, does not correlate with it as previously reported.

There are at least 250 million tons of strippable, subbituminous Anderson or D coal in the southern part of the Gillette Field (Smith, et. al., 1972). The Anderson coal, however, is only currently mined where it is combined with the Canyon coal to form the Wyodak bed.

Nine core analyses of the Anderson coal are summarized below (U.S. Geological Survey and Montana Bureau of Mines, 1973; 1974).

As-received basis	Range (9 samples)	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/pound	7,128-8,737	7,979

Badger coal bed: This is a subbituminous coal best dèveloped in the Glenrock Field. The coal occurs near the base of the Wasatch Formation, between the School and Felix coal beds (Denson, et. al., 1978).

The Badger coal is 17 to 20 feet in thickness and is normally 110-180 feet above the School bed. In 1972, the U.S. Bureau of Mines conservatively estimated that there were at least 9.5 million tons of strippable reserve base of this bed in Converse County (Smith, et. al., 1972). Since then, some of this reserve has been mined.

The Badger coal is strip mined in Pacific Power and Light Company's Dave Johnston mine north of Glenrock, and then burned in the Dave Johnston Power plant at Glenrock. Five analyses from that mine show the following composition:

As-received basis	Range (5 samples)	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/pound	7,606-8,290	7,951

Canyon coal bed: The subbituminous Canyon coal is a persistent bed in the Fort Union Formation over all but the southern and western flanks of the basin. In the Gillette area of Campbell County, the Canyon and other coals coalesce with the Anderson bed to form the thick Wyodak coal (70-175 feet), which crops out on the eastern side of the basin (Figure 6). North of Gillette, the Canyon also locally merges with the Cook coal to form a single bed up to 54 feet thick (Kent, et. al., 1980).

The Canyon coal is between 11 and 65 feet thick where it is not joined with the Anderson or Cook coals. The Canyon bed is correlated with the E coal bed of the southern part of the Gillette Field and with the Monarch bed of the Sheridan Field. The Canyon is not correlative with the stratigraphically higher Smith bed as previously reported (Culbertson, et. al., 1979).

Except for an estimated 250 million tons of strippable reserve base in the southern Gillette Field (E bed) and another 184.9 million tons along Clear Creek in the Spotted Horse Field (Smith, et. al., 1972), the strippable reserve base of the Canyon bed is reported with the Wyodak bed or with the Monarch and Dietz beds in the Sheridan area.

The nine Canyon core analyses summarized below are from Campbell County. Monarch analyses from Sheridan County are not averaged with these because the quality of the Canyon in the two counties is quite different (see also Monarch coal bed).

As-received basis	Range (9 core samples; U.S. Geol. Survey, et. al., 1973; 1974)	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/pound	7,537-8,609	8,386

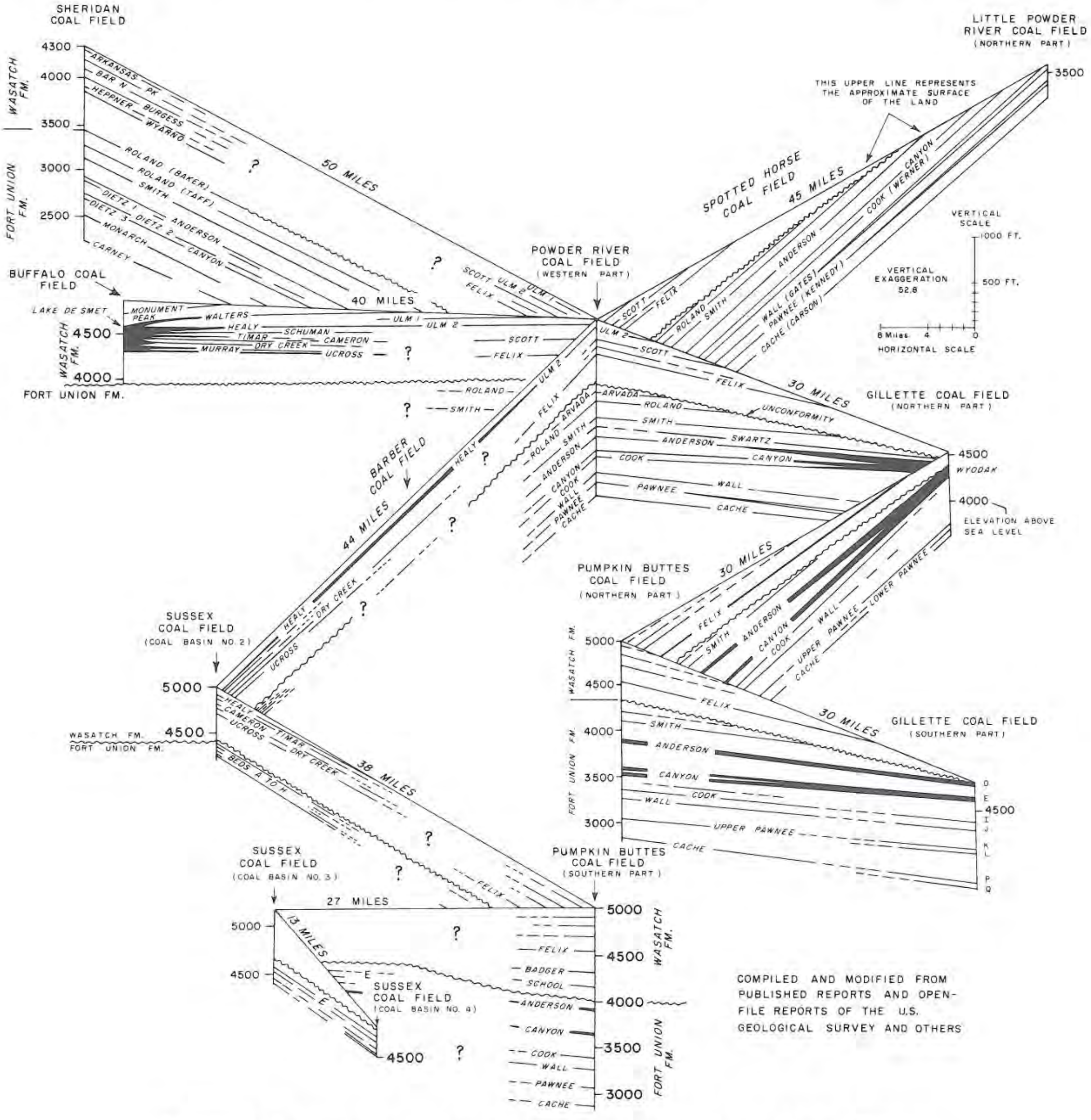


Figure 6: Correlation of coal beds in the Powder River Coal Basin.

D coal bed: See Anderson coal bed.

Dietz No. 2 coal bed: This coal is locally important in the Sheridan Field where Big Horn Coal Company currently mines it as a rider coal above the Monarch and Dietz No. 3 coals. This subbituminous Fort Union Formation coal averages 12 feet in thickness, and was previously identified as the Armstrong coal in Big Horn's strip mine.

Analytical data on the Dietz No. 2 coal is summarized below.

As-received basis	Range or typical analysis (5 samples)
Moisture (%)	21.7-23.8
Volatile Matter (%)	33.6
Fixed Carbon (%)	38.5
Ash (%)	5.6- 6.6
Sulfur (%)	0.74- 1.02
Btu/pound	9,220-9,387

Dietz No. 3 coal bed: This subbituminous coal is an important strippable bed in the Sheridan Field where it was once extensively deep mined. It averages 10-25 feet in thickness. Locally the Dietz No. 3 coalesces with the underlying Monarch (Canyon) coal bed to form a 40-57 feet thick coal in the Sheridan area. The Dietz No. 3 also locally coalesces with the Dietz Nos. 1 and 2 coals, reaching a cumulative thickness of 75 feet (Law, et. al., 1979).

The estimated strippable reserve base of this Fort Union Formation coal is included with the estimate for the Monarch coal, which underlies it by a few inches to 60 feet. Collectively, the strippable reserve base of the two coals originally exceeded 32 million tons.

The Dietz No. 3 is mined along with the Monarch coal in Big Horn Coal Company's Big Horn No. 1 strip mine near Acme. A typical analysis of the Dietz No. 3 in this mine is:

As-received basis	Typical analysis (Glass, 1975)
Moisture (%)	19.1
Volatile Matter (%)	34.8
Fixed Carbon (%)	41.7
Ash (%)	4.4
Sulfur (%)	0.5
Btu/pound	9,710

E coal bed: See Canyon coal bed.

F coal bed: Although this Wasatch coal is persistent in portions of the Dry Cheyenne, Sussex, and Gillette fields in Converse County, it is not presently mined. Bed F has a maximum thickness of 11.6 feet, but averages only 7.5 feet (Wegemann, et. al., 1928).

The strippable reserve base of this bed is estimated at 179.5 million tons (Smith, et. al., 1972). There are no published analyses of this coal.

Felix coal bed: This is an important coal bed in the northern and eastern portions of the Powder River Basin. This Wasatch Formation coal is from 5-21 feet thick in the Spotted Horse Field in the north to as thick as 50 feet in the southern part of the Gillette Field. Partings are common and fairly persistent in places.

Smith, et. al. (1972), estimates the strippable reserve base of the Felix coal is 480.7 million tons in the Spotted Horse Field. The coal is subbituminous in rank, and is not currently mined. The Lawrence Livermore Laboratories, however, have conducted in situ gasification experiments in this coal south of Gillette.

Analyses of 42 core samples are summarized below:

As-received basis	Range (42 Core samples U.S. Geol. Survey, et. al., 1973; 1974)	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/pound	7,180-9,535	8,053

Glenrock-Big Muddy Zone coals: This coal zone is in the basal 200-300 feet of the Lance Formation and extends from just east of Glenrock to just northeast of Casper some 15 miles to the west (Shaw, 1909). Coals are reportedly up to 6.8 feet thick and dip northeast at 3-7 degrees. The coals mined in the Glenrock area averaged about six feet thick. Although none of these coal beds are currently mined, they were mined for many years in the Glenrock area. Analyses of the subbituminous coals in this zone are summarized below (Fieldner, et. al., 1931).

As-received basis	Range (10 samples)	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/pound	7,695-9,270	8,742

Lake DeSmet coal field: The Lake DeSmet coal is locally the thickest coal bed in Wyoming or the

United States for that matter. In the Buffalo Field of Johnson County, this coal bed is reportedly as much as 250 feet thick in some dirll hole descriptions (Obernyer, 1978; Obernyer, 1980; Mapel, 1959). Upper portions of this Wasatch coal bed, however, are frequently burned over much of the Buffalo Field.

The Lake DeSmet bed of the Buffalo Field was originally correlated with the Healy coal to the north and east of that area (Mapel, 1959; and Culbertson and Mapel, 1976). Obernyer (1978; 1980), however, reported that the thick Lake DeSmet coal at Lake DeSmet represents the coalescing of five major coal beds in response to basin-margin faulting active in Eocene time (growth faulting). From oldest to youngest, these coals are the Ucross, Murray, Cameron, Healy, and Walters.

The strippable reserve base of the Lake DeSmet and other coals in the Lake DeSmet area approximates one billion tons according to Smith, et. al. (1972). These reserves include tonnages calculated for the Lake DeSmet, Walters, Healy, Cameron, Ucross, and Murray beds. The coals are not currently mined. Fifteen analyses of this subbituminous coal show the following range in quality (none of these analyses represent more than a portion of the total bed):

As-received basis	Range (5 to 15 samples)[1]	Average (5 samples)
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/pound	6,480-8,270	7,884

Mesaverde coal beds: Although several subbituminous Mesaverde coals have been prospected between Casper and Glenrock, they have never been mined except on a very local basis. These prospected coals were only 1.8-3 feet thick. Although two published analyses from these prospects contained over 37 percent ash, another two analyses revealed fairly good coal as shown below (Shaw, 1909; Fieldner, et. al., 1918).

As-received basis	Range (2 samples)	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/pound	8,246-8,712	8,479

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

Monarch coal bed: The subbituminous Monarch coal is one of the most important Fort Union Formation coals in the Sheridan Field. Although it reportedly is up to 57 feet thick, the thicker occurrences apparently equate to areas where the Monarch and Dietz No. 3 coals merge into a single bed. The Monarch's normal thickness is probably between 5 and 25 feet. Recent studies suggest that the Monarch coal correlates with the Canyon coal to the east of Sheridan (Culbertson, et. al., 1979).

The U.S. Bureau of Mines estimated that there were originally 32 million tons of strippable reserve base of this coal, but these reserves include some Dietz No. 3 tonnage as well (Smith, et. al., 1972).

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

A large number of Monarch analyses from various publications of the U.S. Bureau of Mines and U.S. Geological Survey are summarized below. Some of these published analyses, like the reserve estimates, probably include Dietz No. 3 coal.

As-received basis	Range (203 samples)	Average
Moisture (%)	14.5-26.0	21.5
Volatie 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/pound	9,000-10,410	9,600

PK, Ulm 2 and Ulm 1 coal beds: These three Wasatch Formation coals are at least persistent in the central part of Sheridan County where they are 4-52 feet thick.

The PK coal bed, which locally splits into at least three benches, averages 4-18 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, varies from 7-30 feet in thickness. Culbertson and Mapel (1976) equate this coal bed with the Healy coal of the Lake DeSmet area in Johnson County (Figure 6). The Ulm 1 lies 50-200 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 2, which occurs about 300 feet above the PK coal zone, varies from 7-30 feet in thickness. Culbertson and Mapel (1976) equate this coal bed with the Healy coal of the Lake DeSmet area in Johnson County (Figure 6). The Ulm 1 lies 50-200 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 14-52 feet thick where it still remains. Its thickest expression, however, includes several thick shale partings.

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

Although none of these coals is currently mined, at least one company has applied for a mining permit within the strippable deposit.

Analyses of these coals are few, and many were performed on badly weathered samples. Excluding all analyses where the heat value was below 6,500 Btu/pound, analyses of the Ulm 1, Ulm 2, and PK beds are averaged below:

As-received basis	Range (5 samples)	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/pound	7,640-8,320	8,000

School coal bed: The School coal or School House coal as it is sometimes called, is 110 to 180 feet below the Badger coal in the Glenrock Field. It is subbituminous in rank and occurs near the base of the Wasatch Formation between the Anderson and Badger beds (Denson, et. al., 1978) (Figure 6).

The coal is between 22 feet and 38 feet in thickness, 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.

In 1972, the U.S. Bureau of Mines estimated that there were at least 126.2 million tons of strippable reserve base of this coal in Converse County (Smith, et. al., 1972).

Pacific Power and Light Company has been mining this coal since 1958 at their Dave Johnston strip mine north of Glenrock. Three analyses from their mine show the following:

As-received basis	Range (3 samples)	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/pound	7,830-8,870	8,183

Smith coal bed: This bed is particularly well developed in the Spotted Horse Field and the western side of the Little Powder River Field. The bed is between 5 and 13 feet thick and is subbituminous. It is found near the top of the Fort Union Formation when it hasn't been cut out by the Wasatch-Fort Union unconformity (Figure 6).

In the southern part of the Spotted Horse Field, the Smith apparently splits (Kent, et. al., 1980). In this area the lower bench is also 4.5-13 feet thick and underlies the Smith coal by as much as 30 feet. There are an estimated 178 million strippable tons of the Smith coal bed and another 58.3 million strippable tons of the lower split in that area (Smith, et. al., 1972). Neither coal is mined at this time.

This Smith coal bed is not to be confused with the Canyon coal bed of the Gillette area which was miscorrelated with the Smith coal for many years. The Smith coal bed is stratigraphically higher in the Fort Union Formatin than the Canyon bed (Figure 6).

A single core analysis of the Smith coal bed is given below:

As-received basis	Core Analysis (U.S. Geol. Survey, et. al., 1974)
Moisture (%)	31.8
Volatile Matter (%)	28.7
Fixed carbon (%)	34.8
Ash (%)	4.7
Sulfur (%)	0.63
Btu/pound	7,991

Sussex Coal Field, "Lower coal bed": This "lower coal bed" in Basin No. 4 of the Sussex Field 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 is 13.6 million tons (Smith, et. al., 1972). This coal is not mined at this time.

An analysis of the "lower bed" shows:

As-received basis	One analysis (Smith, et. al., 1972)
Moisture (%)	23.5
Volatile Matter (%)	35.6
Fixed Carbon (%)	35.7
Ash (%)	5.2
Sulfur (%)	0.49
Btu/pound	9,160

Ulm No. 1 coal bed: See discussion under PK coal bed.

Ulm No. 2 coal bed: See discussions under the PK coal bed and the Healy coal bed.

Walters coal bed: See discussions under the PK coal bed and the Lake DeSmet coal bed.

Wyodak coal bed: Outcrops show this thick coal is persistent, though extensively burned, on the eastern flank of the Powder River Basin, especially in the Gillette area.

This subbituminous coal is 25 to 175 feet thick, and probably averages 70 feet in thickness (U.S. Geological Survey and Montana Bureau of Mines, 1976). The coal has variously been called the Wyodak-Anderson and Anderson-Canyon coal. Recent geologic mapping by the U.S. Geological Survey shows that this coal bed does not directly correlate with the stratigraphically higher Roland and Smith coals, as previously reported (Kent, et. al., 1980).

The Wyodak coal separates into the Anderson and Canyon coal beds to the west with the two beds each 10 to 65 feet in thickness. To the north of Gillette, the Wyodak splits into an Upper Wyodak and Lower Wyodak. The Upper Wyodak then splits into the Smith, Swartz, and Anderson coals while the Lower Wyodak splits into the Canyon and Cook coals (Kent, et. al., 1980). When the Wyodak splits into five or more beds, the individual coals 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 (D bed) and the Canyon coal (E bed) southward from Gillette (Figure 6).

The strippable reserve base of this Fort Union Formation coal is the largest for any single coal bed in Wyoming and perhaps even for any coal bed in the United States. These reserves are estimated at 19 billion tons (Smith, et. al., 1972). Since this estimate was made, strip mining has removed 203.1 million tons of these original strippable reserves. By the end of 1985, an estimated 600 million tons of the Wyodak coal will have been strip mined from 9-11 large strip mines in Campbell County (Glass, 1980).

Amax Coal Company's Belle Ayr and Eagle Butte mines, Wyodak Resources' South Pit, Sunedco's Cordero mine, Carter's Caballo and Rawhide mines, Kerr-McGee's Clovis Point and Jacobs Ranch mines, Delzer's Fort Union mine, and Arco's Black Thunder mine are the only active strip mines on the Wyodak coal bed. Kerr-McGee, Carter, Mobil, Gulf, Peabody, Cities Service, Nerco, Consol, Arco, and others have additional strip mines planned on that bed. Most of these mines will produce 5-20 million tons per year, and will be located in Campbell County (Hausel, et. al., 1979).

Fifty-nine analyses of the Wyodak coal in the Gillette area are summarized below:

As-received basis	Range (59 samples)	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/pound	7,420-9,600	8,224

GREEN RIVER COAL REGION

The Green River Coal Region which is the state's largest coal-bearing area, covers about 15,400 square miles of southwestern Wyoming. It is divided into two major structural basins by the Rock Springs anticline: the Green River Basin to the west and the Great Divide Basin to the east. Dips in this region are small except around the Rock Springs Uplift and the eastern margin. Dips on the western side of the Rock Springs Uplift go up to 20°; and on the eastern side 10°. Along the eastern margin of the region, dips are between 20° and 50° in some areas.

Coals are subbituminous C to high volatile C bituminous in rank. The higher rank coals occur on the eastern margins of the region as well as around the Rock Springs Uplift. The higher rank coals are of Cretaceous age.

Coal-bearing rocks in the Green River Region are largely concealed by younger rocks and very little is known about the total coal resources in the area. Coal beds in the region occur in the Mesaverde Group and the Lance Formation of Upper Cretaceous age, the Fort Union Formation of Paleocene age, and the Wasatch Formation of Eocene age. Coals of the Rock Springs Formation of the Mesaverde Group have historically been the most important. It may not be long, however, before their importance is surpassed by younger beds of the Almond, Lance, Fort Union, and Wasatch formations.

Rock Springs Formation coals are high volatile C bituminous and are up to 13.8 feet thick. Although they are designated by numbers, the numbers are not arranged consecutively. From the top down, some of the more important beds are No. 3, No. 1, No. 7½, No. 7, No. 8, No. 9, No. 11 and No. 15 (Figure 7).

Almond Formation coals encircle all but the southwestern side of the Rock Springs uplift area. These subbituminous coals of the Mesaverde Group have not been extensively mined, but they are reportedly up to 13.1 feet thick on the east side of the uplift (Roehler, 1979c).

Lance Formation coals apparently are locally minable at least on the east flank of the uplift. Five minable coals within the Black Butte strippable deposit are designated from youngest to oldest: Overland, Gibralter, Black Butte, Maxwell, and Hall. Collectively, these Lance coals average 20.8% moisture, 5.5% ash, 0.77% sulfur, and 9,780 Btu/lb. on an as-received basis. These coals vary from less than 5 feet thick to as much as 22 feet thick (VTN, 1974). Roehler (1979a; 1979b) also mapped two Lance Formation coals in the Black Buttes area which he called the French and Bluff beds. These coals are up to 5 feet and 8.4 feet thick, respectively.

Although Fort Union Formation coals are some of the thicker and more persistent coals in the region, they were not extensively mined until 1974 when the Jim Bridger strip mine opened on the Deadman coal, which is up to 30 feet thick in that area. South of the Bridger mine, Roehler (1979a; 1979b; 1979c) has identified and mapped up to five Fort Union coals. In descending order, they are named the Leaf, Big Burn (Nuttal), Hail, Washout, and Little Valley (Deadman) beds. Each of these coals 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 coals are subbituminous in rank.

Wasatch coals in the Red Desert part of the

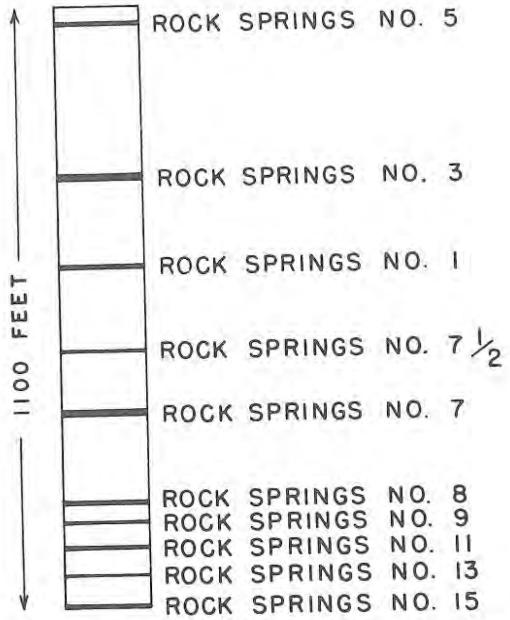


Figure 7: Coal nomenclature for the Rock Springs Formation of the Green River Coal Region.

Great Divide Basin Field are designated from youngest to oldest: Battle No. 3, Battle No. 2, Monument No. 1, Sourdough-Monument-Tierney seams, Hadsell No. 2, Creston No. 3, Creston No. 2, and Latham No. 3 (Masursky, 1962). These coal beds are lenticular and grade into shale to the east and west. The average, as-received analysis of these coals 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, et. al., 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 coals is between 0.001% and 0.009% U_3O_8. These Wasatch coals are estimated to contain over 55 million pounds of uranium with U_3O_8 contents o.003% or greater (Masursky, 1962).

Two Wasatch coals in the Creston-Cherokee Deposit just south of the Red Desert also reach minable thicknesses. These coals, called the Upper and Lower Cherokee coal beds, average 11 feet and 25 feet thick, respectively.

Important Coal Beds

Almond coal beds: Recent mapping shows as many as eighteen relatively persistent, mappable, subbituminous coals in the Almond Formation on the southeastern flank of the Rock Springs Uplift

(Roehler, 1979b; 1979c). In the northern part of his study area Roehler (1979b) names these coals the Sparrow, Coot, Buzzard, Shrike, Eagle, Robin, Meadowlark, Magpie, and Mourning Dove beds in descending order. The Mourning Dove coal is apparently correlative with the Lebar coal of the Black Butte mine. Further south, Roehler (1979c) mapped and named some additional Almond coals. In descending order, the coals 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 coals mapped by Roehler, the Finch, Mallard, Robin, Meadowlark, Magpie, and Mourning Dove (Lebar) beds locally exceed nine feet in thickness. The other beds are thinner, but each is more than five feet thick in places.

Roehler (1977) estimates that in the Rock Springs area there is 5,650 million tons of coal in the Almond Formation. This coal resource only includes coals that are (1) greater than 2.5 feet thick and (2) under less than 3,000 feet of cover. He further estimates that 5-10 percent of that resource may be strippable. In two of his later publications, Roehler (1979b; 1979c) provides 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 mentioned in 1977.

Although analyses of fresh, unweathered samples of these coals are not available, some older, published analyses from the Rock Springs area are believed similar. These older analyses are averaged below. See also the Lebar bed.

Although none of these coals is currently mined, the Mourning Dove or Lebar bed may be strip mined in the near future.

As-received basis	Average (Root, et. al., 1973)
Moisture (%)	16.4
Volatile Matter (%)	31.0
Fixed Carbon (%)	47.7
Ash (%)	5.0
Sulfur (%)	0.6
Btu/pound	9,727

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

Battle No. 1 and Battle No. 2 coal beds: These two subbituminous B coals crop out in the southeastern part of the Great Divide Basin Field. They occur in the Wasatch Formation and average 6.4 and 8.6 feet in thickness, respectively. The strippable reserve base of these two beds is estimated at 38.1 million tons (Smith, et. al., 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/pound	8,650

Black Butte coal bed: The Black Butte bed is a Lance Formation coal in the Black Buttes area of the Rock Springs uplift (east flank). This coal averages 5-6 feet thick except where it coalesces with the underlying Maxwell bed to form a coal that is between 16-22 feet thick (VTN, 1974). The normal interval between these two subbituminous beds is 25 feet. Although this coal has been mined in the past, it is not presently mined.

As-received basis	Typical Analysis
Moisture (%)	20.7
Ash (%)	5.0
Sulfur (%)	0.61
Btu/pound	9,650

Creston No. 2 and No. 3 coal beds: These coals are in the Wasatch Formation in the Great Divide Basin Field. They crop out in the southeastern part of the field where they average about 18 feet in thickness. They are subbituminous B in rank. The strippable reserve base of these beds is 125.6 million tons (Smith, et. al., 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/pound	8,710

Deadman coal bed: The Deadman coal of the Fort Union Formation is exceptionally well developed on the western edge of the Great Divide Basin Field. There the bed has been referred to as the Jim Bridger Deposit. The Deadman coal is 30 feet thick except where it splits into as many as five thinner beds. In the Black Butte strippable deposit, the Deadman is 16-22 feet thick (VTN, 1974). It is subbituminous in rank. Its strippable reserve base is approximately 250 million tons (Smith, et. al., 1972). The bed is now strip mined. This coal can be traced south of the Black Buttes area. It is probably equivalent to the Little Valley bed of Roehler (1979a; 1979b; 1979c). In this area, Roehler reports the Little Valley bed as thick as 15 feet.

As-received basis	Range (4 samples)	Typical
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/pound	9,270-10,000	9,350
Hardgrove grindability index	79-82	—

Fort Union Formation coal beds: As many as five relatively persistent, subbituminous, Fort Union coals crop out on the southeastern side of the Rock Springs Uplift (Roehler, 1979a; 1979b; 1979c). These coals occur in an interval that has been termed the Black Rock Coal Group. In descending order, the coals are named the Leaf, Big Burn, Hail, Washout, and Little Valley beds. At least locally, all these beds exceed five feet in thickness. The Big Burn Coal 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. The Big Burn coal is tentatively correlated with the Nuttal bed of the Black Buttes deposit. See Ute coal bed also.

Roehler (1979a; 1979b; 1979c) provides 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 coals greater than 2.5 feet thick and under less than 3,000 feet of cover. He estimates that more than 40 million tons of that resource is under less than 200 feet of cover and would therefore qualify as a strippable resource.

Published analyses of Fort Union Formation coals in these areas are summarized below:

As-received basis	Average (Root, et. al., 1973)
Moisture (%)	17.69
Volatile Matter (%)	30.93
Fixed Carbon (%)	43.85
Ash (%)	8.48
Sulfur (%)	0.41
Btu/pound	9,728

Gibraltar coal bed: This subbituminous coal is one of at least five minable Lance Formation coals that crop out in the Black Buttes deposit of the Rock Springs Field. The Gibraltar bed is usually only 4-5 feet beneath the Overland bed and has a maximum reported thickness of 8 feet. Plans to strip mine this coal have been announced.

As-received basis	Typical
Moisture (%)	20.6
Ash (%)	4.7
Sulfur (%)	0.53
Btu/pound	9,900

Hadsell No. 2 coal bed: This is another Wasatch coal that crops out in the southeastern part of the Great Divide Basin Field. 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, et. al., 1972).

As-received basis	Typical Analysis
Moisture (%)	23.0
Volatile Matter (%)	31.0
Fixed Carbon (%)	32.2
Ash (%)	13.8
Sulfur (%)	2.7
Btu/pound	8,250

Hall coal bed: This coal is the lowest minable bed in the Lance Formation of the Black Buttes strippable deposit of the Rock Springs Field. The Hall bed is subbituminous in rank, and up to 10 feet thick. Mining is expected to resume on this bed in the near future.

As-received basis	Typical
Moisture (%)	20.8
Ash (%)	4.6
Sulfur (%)	1.08
Btu/pound	9,900

Lance Formation coal beds: Subbituminous coals 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 4-9.6 feet thick coals in the early 1900's. The French and Bluff beds of Roehler (1979a; 1979b) reach 6.5 and 8.4 feet thick, respectively. In the Black Buttes strippable deposit, Lance coals averaging 5-10 feet thick may be strip mined in the near future (VTN, 1974) (See Black Butte, Gibraltar, Hall, Maxwell, and Overland beds).

Roehler (1979a; 1979b) delimits almost 268 million tons of coal resource from the French and Bluff beds in the Black Buttes area. The tabulated resources only include coals under less than 3,000 feet of cover and over 2.5 feet thick. Roehler lists almost seven million tons of that resource as strippable.

As-received basis	Average (Root, et. al., 1973)
Moisture (%)	17.5
Volatile Matter (%)	29.8
Fixed Carbon (%)	48.6
Ash (%)	4.1
Sulfur (%)	0.4
Btu/pound	10,110

Latham No. 3 and No. 4 coal beds: The Latham beds are best developed in the southeastern part of the Great Divide Basin Field. They occur in the Wasatch Formation and are subbituminous B coals. Average thicknesses are 5.7 feet. The strippable reserve base of the two coals totals 70.7 million tons (Smith, et. al., 1972). A typical analysis of the Latham No. 3 coal is:

As-received basis	Typical Analysis
Moisture (%)	22.6
Volatile Matter (%)	30.9
Fixed Carbon (%)	31.2
Ash (%)	15.3
Sulfur (%)	5.4
Btu/pound	7,980

Lebar coal bed: This Almond Formation coal crops out in the Black Buttes area on the southeastern flank of the Rock Springs Uplift where it averages 8-12 feet thick. The Lebar bed will probably be mined within the next several years along with an unnamed 4.8-6 feet thick coal about 60 feet above it. Both coals are probably subbituminous. The Lebar bed correlates with Roehler's (1979c) Mourning Dove coal. See Almond Formation coals.

As-received basis	Typical Analysis
Moisture (%)	17.5
Ash (%)	7.6
Sulfur (%)	0.57
Btu/pound	10,000

Little Valley coal bed: See Deadman coal bed.

Maxwell coal bed: This Lance coal frequently occurs less than 25 feet below the Black Butte coal in the Black Buttes area of the Rock Springs Field. The Maxwell coal bed averages 5.5 feet thick when it isn't merged with the overlying Black Butte bed. Where the two beds coalesce, they are locally 16-22 feet thick. The coal is probably subbituminous in rank, and will be mined in the near future.

As-received basis	Typical Analysis
Moisture (%)	21.0
Ash (%)	6.0
Sulfur (%)	0.84
Btu/pound	9,670

Nuttal coal bed: This subbituminous Wasatch coal is up to 8 feet thick in the Black Buttes deposit of the Rock Springs Field. Although the coal is not yet mined, it will probably be mined within several years. This coal is probably equivalent to Roehler's (1979c) Big Burn bed. See Fort Union Formation coals.

Overland coal bed: In the Black Buttes area of the Rock Springs Field, the Overland coal is the highest minable coal in the Lance Formation (VTN, 1974). This coal, 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 5-7% range and its heat value nearer 9,650 Btu/lb. The rank is probably subbituminous. Plans to mine this coal have been announced.

Rock Springs No. 1 coal bed: Although this bituminous coal was extensively deep mined in the past only the reopened Stansbury No. 1 underground mine recently mined this coal. Even that mine is now closed. Analyses of this Rock Springs Formation coal are summarized below:

As-received basis	Range Analysis
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/pound	10,480-11,830

Rock Springs No. 3 coal bed: This bituminous coal in the Cretaceous Rock Springs Formation is deep mined near Rock Springs. The bed at least locally exceeds 11 feet in thickness.

As-received basis	One Analysis
Moisture (%)	16.7
Volatile Matter (%)	35.7
Fixed Carbon (%)	45.4
Ash (%)	2.2
Sulfur (%)	0.9
Btu/pound	10,520
Hardgrove grind-ability index	52

Rock Springs No. 7 coal bed: This coal averages 4.5 feet in thickness; is high volatile C bituminous in rank; and occurs in the Rock Springs Formation of the Mesaverde Group in the Rock Springs Field. This bed has some coking properties. The No. 7 bed was recently deep mined in Sweetwater County and used, in part, for making chemical grade coke suitable for reducing phosphate in electric furnaces. It is no longer mined.

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/pound	10,640-13,110	11,664
Hardgrove grindability index	48-54	51

Rock Springs No. 11 coal bed: The No. 11 bed is high volatile C bituminous coal, from 44 to 54 inches in thickness, and averages 4 feet thick. It is an important coal in the Rock Springs Field. The bed is in the Rock Springs Formation. This No. 11 bed has some coking properties:

As-received basis	Range Analysis
Moisture (%)	6.56- 8.46
Volatile Matter (%)	38.42-39.74
Fixed Carbon (%)	47.69-48.55
Ash (%)	4.57- 6.69
Btu/pound	12,379-12,572
Sulfur (%)	0.7

Sourdough-Monument-Tierney coal beds: This coal zone is comprised of up to five coals that occur at about the same horizon in the Wasatch Formation in the southeastern part of the Great Divide Basin Field. Because at times the beds coalesce with one another, separation of the coals into individual beds is not always possible. In places, each of these subbituminous B coals exceeds 5 feet in thickness. The strippable reserve base of these unmined beds is 458.9 million tons (Smith, et. al., 1972). 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/pound	8,680

Upper and Lower Cherokee coal beds: These two unmined coals are subbituminous A coals of the Wasatch Formation and reach their maximum development in the Creston-Cherokee Deposit in the northern part of the Little Snake River Field. The Upper Cherokee or B bed is 10 to 18 feet in thickness and normally has a 1 to 2 feet thick rock parting in it. The Lower Cherokee or C bed which is 40-70 feet below the upper bed is 20-32 feet in thickness. It has a 1 to 1½ feet thick parting. In places these two coals coalesce into a single bed of 30 to 40 feet in thickness, which has a parting up to 4 feet thick. The strippable reserve base of these coals collectively reaches 200.9 million tons (Smith, et. al., 1972).

As-received basis	Range Analysis
Moisture (%)	15-25
Volatile Matter (%)	28-36
Fixed Carbon (%)	27-40
Ash (%)	10-25
Sulfur (%)	0.5-5.0
Btu/pound	5,009-9,000

Ute coal bed: The Ute bed is a Fort Union Formation coal that occurs about 55 feet below the Deadman bed in the Black Buttes area of the Rock Springs Field. It is up to 7 feet thick, and will probably be mined in the near future. The coal is subbituminous in rank.

Wasatch Formation coal beds (undifferentiated): Unnamed Wasatch coals in the Black Buttes area of Sweetwater County reportedly average 6-8 feet thick (VTN, 1974). These coals are subbituminous in rank, but are not presently mined. Analyses of the Wasatch coals that crop out on the flanks of the Rock Springs uplift are as follows:

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/pound	8,770-9,610

HANNA COAL FIELD

Most of the Hanna Coal Field of southcentral Wyoming lies in Carbon County with a small portion extending eastward into Albany County (Figure 1). This 750 square mile coal-bearing area coincides with the Hanna and Carbon topographic and structural basins and is considered part of th

U.S. Geological Survey's Rocky Mountain Coal Province. As defined, the coal field is limited to those portions of the basins that are underlain by rocks of the Mesaverde Group, thus all the coal-bearing rocks of the Hanna Coal Field occur within the outcrop of the Mesaverde. The boundary between this field and the Rock Creek Coal Field to the east is usually drawn to coincide with the alluvial deposits associated with Rock Creek.

Most simply, the Hanna Coal Field coincides with two sediment-filled intermontane basins between uplifted areas. These basins are separated from one another by the Saddleback Hills Anticline with the Hanna Basin lying to the north and the Carbon Basin to the south. The Hanna Basin is itself separated into two synclines whose axes are nearly perpendicular to one another. A low northwest-southeast trending ridge separates the two synclines about three miles northeast of Hanna. The southernmost of these synclines is called the Hanna Syncline; the northernmost syncline is unnamed.

Like other intermontane basins of Wyoming, these depressions formed during the Laramide Orogeny, some 38-65 million years ago. The Hanna Basin, however, is rather atypical in that it is not only extremely deep for its size (Knight, 1951, estimated that more than 30,000 feet of sedimentary rock overlie its crystalline basement), but a good portion of its sedimentary rocks are tightly folded and faulted. Even some younger coal-bearing rocks (Paleocene age) steepen to vertical or overturn on the northern flank of the basin as they approach the major fault that separated the basin from the ranges to the north. Elsewhere in the coal field, rocks that crop out on the flanks of the basin are folded and steeply dipping (greater than 25 degrees dip). In contrast, dips are much flatter in the central portions of the three major synclines, averaging 3-15 degrees.

Faulting is not limited to the major reverse fault that separates the basin from uplifted areas to the north or to the faulting that is common to the western and southwestern flanks of the basin. Normal faults occur within the more gently folded coal-bearing synclines as well. In these synclinal areas, the frequency of mapped faulting shows a direct correlation with the intensity of coal mining. This observation suggests that many faults probably remain undetected until an area is mined.

Typically, vertical displacements on the normal faults in the Hanna and Carbon basins are less than 200 feet, although some greater displacements occur. Displacements on the order of tens of feet are most common.

Although coal beds occur in the Upper Cretaceous Mesaverde Group and the Medicine Bow Formation, the most significant beds are in the Ferris Formation of Upper Cretaceous and Paleocene age and in the Hanna Formation of Paleocene and Eocene age. In general, the older Mesaverde and Medicine Bow formations crop out on the flanks of the coal field while the younger Ferris and Hanna formations occupy the more central portions of the coal field.

Coal beds occur in a rock interval that has been estimated to be up to 24,000 feet thick. Coal, of course, accounts for only a minor portion of this great thickness of rock, probably less than 2 percent. Coals are most numerous in the upper 12,000 feet of rock, which comprise the Hanna Formation and the upper portion of the Ferris Formation. These Tertiary age coals are the youngest in the field (38-65 million years old) and also the most exploited. Mining of Tertiary coals in the Hanna Coal Field, which dates back to the 1860's is still occurring today. In fact, all the active mining in the coal field is in coals of the Hanna or Ferris formations.

Although the 2,400- to 8,000-foot thick Hanna Formation apparently contains at least 32 coals greater than five feet thick, correlation problems could account for some duplication among the beds, i.e., two names applied to the same coal in separated areas. While the thicker coals of the Hanna Formation are 20 to 60 feet thick, most coals in this formation are much thinner, probably better characterized as 5 to 11 feet thick (Figure 8). At least on the basis of strippable coal resources, the weighted average thickness of Hanna Formation coals is 14.22 feet in the Hanna Basin and 11.14 feet in the Carbon Basin (Glass and Roberts, 1979).

Beneath the Hanna Formation, the upper, or Paleocene, portion of the Ferris Formation contains at least 28 minable coal beds. Extensive faulting in the western third of the field, where these coals are mined, makes correlation difficult and accounts for more than one name being given to the same coal. Most minable coals in the Ferris Formation are thinner than those in the Hanna Formation (Figure 8). In fact, the majority of the coals in the Ferris Formation are only 5-10 feet thick. Based on strippable resources, Glass and Roberts (1979) report that the weighted average thickness of Ferris coals is 9.79 feet, compared to 11.14-14.22 feet for Hanna Formation coals. Thicker Ferris Formation coals are Bed No. 50, which is up to 22 feet thick, Bed No.

33, which is up to 25 feet thick, and Bed No. 123, which at least locally is over 40 feet thick (Glass and Roberts, 1980a). In the case of Bed No. 123, its thickest expression may coincide with an area where an underlying coal (Bed No. 122) has coalesced with it. According to a local mining company, as much as 60 feet of coal is found locally in this horizon. Other coals also coalesce and become quite thick in places.

The next older coal-bearing unit below the Ferris Formation is the Upper Cretaceous Medicine Bow Formation. Persistant coals greater than five feet thick are fewer in number than the coals of the Hanna and Ferris formations. Medicine Bow coal beds are usually limited to the lower 900-2,600 feet of that formation (Glass and Roberts, 1980a). Although as many as thirty Medicine Bow Formation coals are mapped in the western one-

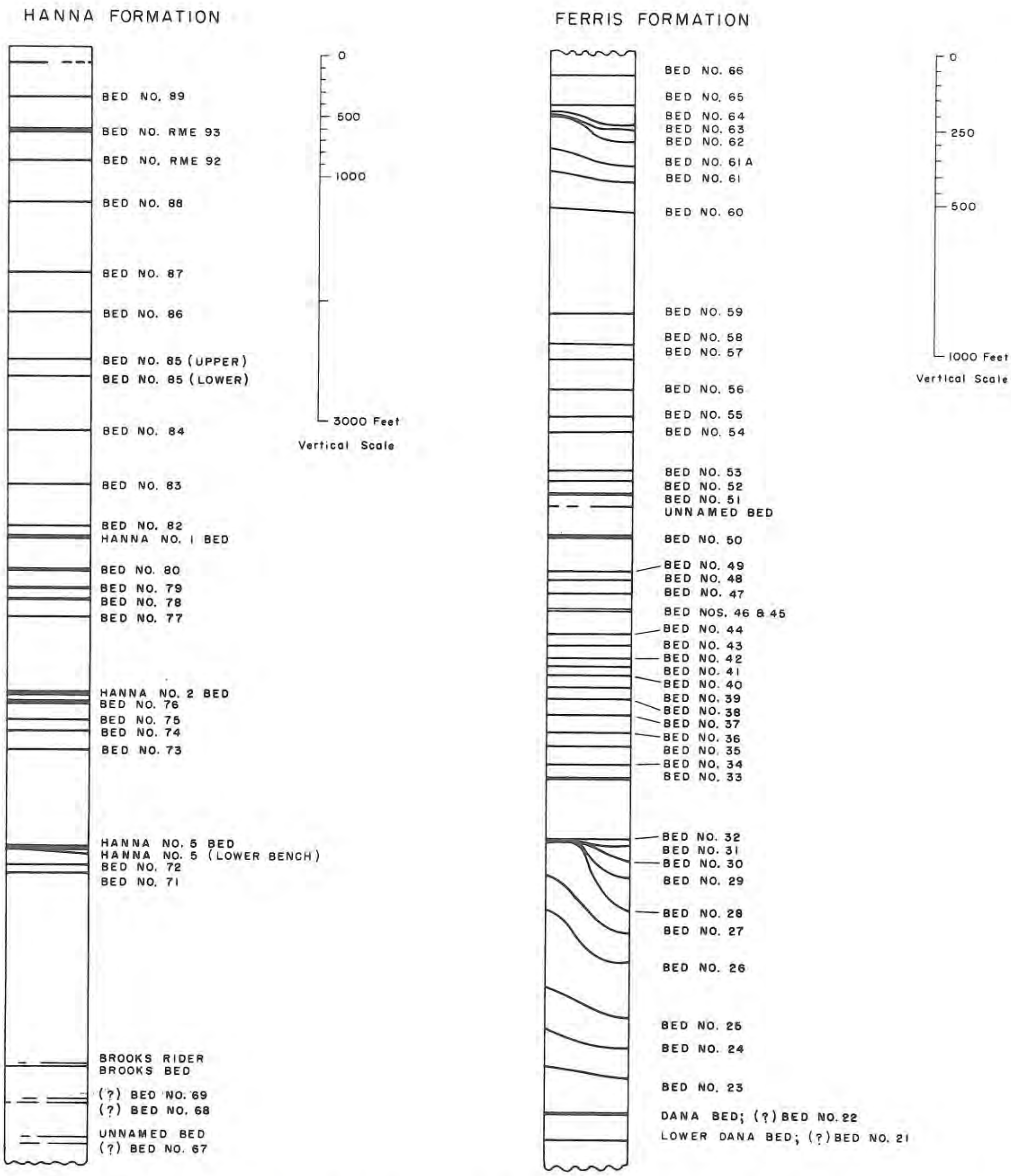


Figure 8: Coal nomenclature for the Hanna and Ferris formations of the Hanna Coal Field.

third of the field, only three are five feet or thicker. These coals also dip less than 25 degrees. The thickest of the three coals is the Penn-Wyoming coal bed, which is up to nine feet thick. The other two coal beds are unnamed and only 5 to 6 feet thick. Steeply dipping Medicine Bow coals occur in other areas of the field.

The oldest coals in the Hanna Coal Field are found in the Upper Cretaceous rocks of the Mesaverde Group. Thicker, potentially minable coals, however, are only reported in the uppermost formation of that group, the Almond Formation. The Almond Formation has as many as seven persistent coal beds that reach minable thickness (5 feet or greater). With the exception of the Almond coals in the western part of the field, Almond Formation coals dip at very steep angles. In the west part of the coal field, however, Almond Formation coal beds occur in two separated areas at shallow enough dips for strip mining (less than 25 degrees). In those areas, several unnamed Almond coals vary between 5-10 feet in thickness, averaging closer to 6 feet thick (Glass & Roberts, 1979). Because the two areas are isolated from one another, correlation between them is impossible at this time. There is every likelihood, however, that some of the coal beds in these two areas are correlative with one another.

The apparent rank of the coals in the Hanna Field is generally subbituminous A to high volatile C bituminous. While the rank of the Mesaverde coals is high volatile C bituminous, the coals of the Medicine Bow and Ferris formations are of subbituminous rank. Hanna Formation coals, however, are high volatile C bituminous in rank. Because Hanna Formation coals show a regional, eastward increase in rank, the highest rank coals of that formation occur in the Carbon Basin (Glass & Roberts, 1979; 1980a; 1980b). The overall anomalously high rank for the young Hanna coals is also a function of that regional increase in rank since Hanna coals only occur in the eastern two-thirds of the field.

Glass and Roberts (1979) estimated a strippable reserve base of 648.29 million tons remained in the field on January 1, 1978. Of that reserve base, Hanna coals accounted for 392.74 million tons, Ferris coals another 238.74 million tons, and Mesaverde and Medicine Bow coals another 17.08 million tons.

Important Coal Beds

Bed No. 25: This subbituminous Ferris Formation coal is 5-12.5 feet thick. It is presently strip mined on the west side of the Hanna Field where it is called "Bed No. 21" by the mining company. The bed is of Paleocene age.

As-received basis	Range Analysis (1-17 samples)	Average Proximate (10 samples)	Ultimate (1 sample)
Moisture (%)	11.05-16.77	14.1	
Volatile Matter (%)	31.5-34.39	32.8	
Fixed Carbon (%)	43.48-45.58	44.6	
Ash (%)	6.07-13.09	8.5	8.8
Sulfur (%)	0.21- 0.74		0.4
Hydrogen (%)	5.3		5.3
Carbon (%)	57.4		57.4
Nitrogen (%)	0.9		0.9
Oxygen (%)	27.1		27.1
Btu/pound	9,095-10,290	9,750 (17 samples)	
Ash softening temperature (°F)	2,265 (1 sample)		

Bed No. 28: This subbituminous Ferris Formation coal is 4.5-18 feet thick where it is mined in the western part of the field. It is called "Bed No. 24" in the mine, and is of Paleocene age.

As-received basis	Range Analysis (5-17 samples)	Average Proximate (9 samples)	Average Ultimate (5 samples)
Moisture (%)	9.52-16.0	11.53	
Volatile Matter (%)	33.82-36.54	34.95	
Fixed Carbon (%)	45.8-49.59	47.57	
Ash (%)	3.9-17.85	5.95	5.72
Sulfur (%)	0.21- 0.74		0.31
Hydrogen (%)	4.94- 5.8		5.20
Carbon (%)	60.0-63.54		61.81
Nitrogen (%)	0.69- 0.91		0.82
Oxygen (%)	23.99-29.1		26.13
Btu/pound	8,571-11,480	10,080 (16 samples)	
Ash softening temperature (°F)	2,430 (1 sample)		
Hardgrove grindabilty index	47 (1 sample)		

30 Series Beds: Beds 30, 31, and 32 are Paleocene in age. These subbituminous coals occur in the lower third of the Ferris Formation and are mined together on the west side of the Hanna Field. Locally they coalesce with one another. Bed No. 30, the lowermost bed, is 5-8 feet thick; Bed No. 31, the middle bed, is 5-18 feet thick; Bed No. 32, the uppermost bed, is usually less than 4 feet thick. These coals are called benches of "Bed No. 25" by the mining company.

As-received basis	Range Analysis (2-30 samples)	Average Proximate (17 samples)	Average Ultimate (2 samples)
Moisture (%)	10.92-18.9	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	7.6
Sulfur (%)	0.22- 0.5		0.45
Hydrogen (%)	5.2- 5.4		5.3
Carbon (%)	52.2-55.1		55.1
Nitrogen (%)	0.8- 0.9		0.85
Oxygen (%)	24.6-34.6		30.70
Btu/pound	8,340-10,650	10,180 (30 samples)	
Ash softening temperature (°F)	2,120- 2,390	2,255 (2 samples)	
Hardgrove grindability index	50-66	58 (2 samples)	

Bed No. 50: This Paleocene coal occurs near the middle of the Ferris Formation and is subbituminous in rank. The bed is strip mined and deep mined west of Hanna where it is 5-22 feet thick.

As-received basis	Range Analysis (2-11 samples)	Average Proximate (4 samples)	Average Ultimate (2 samples)
Moisture (%)	11.3 -15.73	12.50	
Volatile Matter (%)	31.72-35.75	33.93	
Fixed Carbon (%)	41.97-48.45	44.29	
Ash (%)	6.74-15.2	9.29	12.25
Sulfur (%)	0.3 - 0.63		0.42
Hydrogen (%)	5.3 - 5.43		5.37
Carbon (%)	55.39-58.9		57.14
Nitrogen (%)	1.11- 1.4		1.26
Oxygen (%)	23.1 24.1		23.60
Btu/pound	8,460-10,540	9,640 (11 samples)	
Ash softening temperature (°*F)*	2,150- 2,350	2,250 (2 samples)	
Hardgrove grindability index	45	45 (2 samples)	

Bed No. 51: This Paleocene coal is mined in the western part of the field where it is 5-10 feet thick. Bed No. 51 is apparently subbituminous B to high volatile C bituminous in rank. This coal is called "Bed No. 53" by the mining company.

As-received basis	Range Analysis (4-17 samples)	Average Proximate (13 samples)	Average Ultimate (4 samples)
Moisture (%)	9.38-17.84	12.06	
Volatile Matter (%)	31.9 -36.67	34.40	
Fixed Carbon (%)	44.82-48.14	45.89	
Ash (%)	5.6 -13.95	7.67	7.19
Sulfur (%)	0.47- 0.89		0.52
Hydrogen (%)	4.58- 5.4		5.03
Carbon (%)	57.5 -65.85		61.80
Nitrogen (%)	0.83- 1.3		1.00
Oxygen (%)	22.45-27.1		24.37
Btu/pound	8,310-10,930	10,230 (17 samples)	
Ash softening temperature (°F)	2,250- 2,260	2,255 (2 samples)	

Bed No. 54: This coal is 5-15 feet thick and subbituminous A to subbituminous B in rank. It is a Paleocene coal that has occasionally been mined in the western part of the field.

As-received basis	Range Analysis (1-5 samples)	Average Proximate (3 samples)	Average Ultimate (1 sample)
Moisture (%)	11.26-13.81	12.52	
Volatile Matter (%)	31.1 -33.51	32.26	
Fixed Carbon (%)	39.2 -44.9	42.26	
Ash (%)	7.78-17.2	12.96	17.2
Sulfur (%)	0.55- 1.3		1.3
Hydrogen (%)	5.1		5.1
Carbon (%)	51.2		51.2
Nitrogen (%)	1.2		1.2
Oxygen (%)	24.0		24.0
Btu/pound	8,825-10,140	9,380 (5 samples)	
Ash softening temperature (°F)		2,180 (1 sample)	

60 Series Beds: Beds 60, 61, 62, 63, and 64 are all mined in the western portion of the field. These Paleocene coals are 4-11 feet thick. Beds 62, 63, and 64 are usually called "Beds 63, 64, and 65" by the mining company in this area. These Ferris Formation coals are subbituminous A to high volatile C bituminous in rank.

As-received basis	Range Analysis (5-16 samples)	Average Proximate (16 samples)	Average Ultimate (5 samples)
Moisture (%)	8.2 -12.87	10.80	
Volatile Matter (%)	33.5 -39.3	35.41	
Fixed Carbon (%)	37.5 -46.9	44.19	
Ash (%)	6.51-20.8	9.56	10.30
Sulfur (%)	0.28- 0.7		0.57
Hydrogen (%)	5.0 - 5.6		5.4
Carbon (%)	51.0 -62.8		60.0
Nitrogen (%)	1.1 - 1.3		1.2
Oxygen (%)	21.2 -23.6		22.8
Btu/pound	9,140-11,750	10,400 (16 samples)	
Ash softening temperature (°F)	2,120- 2,400	2,180 (5 samples)	
Hardgrove grindability index	43-53	47 (3 samples)	

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

As-received basis	Range Analysis (2-17 samples)	Average Proximate (11 samples)	Average Ultimate (2 samples)
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	5.9
Sulfur (%)	0.29- 0.79		0.55
Hydrogen (%)	5.5 - 5.6		5.55
Carbon (%)	60.8 -64.4		62.60
Nitrogen (%)	1.3 - 1.6		1.45
Oxygen (%)	21.5 -26.4		23.95
Btu/pound	9,770-11,280	(10,670 (17 samples)	
Ash softening temperature (°F)	2,130- 2,170	2,150 (3 samples)	
Hardgrove grindability index	50-52	51 (2 samples)	

Bed No. 74: This Paleocene bed is 5-11 feet thick and occurs in the Hanna Formation. It is high volatile C bituminous in rank and mined in the central part of the field.

As-received basis	Proximate (1 sample)	Ultimate (1 sample)
Moisture (%)	8.14	
Volatile Matter (%)	34.29	
Fixed Carbon (%)	26.24	
Ash (%)	21.33	
Sulfur (%)		2.29
Hydrogen (%)		—
Carbon (%)		—
Nitrogen (%)		—
Oxygen (%)		—
Btu/pound	9,680 (1 sample)	

Bed No. 76: Bed No. 76 is high volatile C bituminous in rank and 7-28 feet thick where it is mined in the central part of the field. The coal is in the Paleocene portion of the Hanna Formation.

As-received basis	Range Analysis (1-2 samples)	Proximate (1 sample)	Ultimate (1 sample)
Moisture (%)	10.3-10.5	10.3	
Volatile Matter (%)	39.4	39.4	
Fixed Carbon (%)	40.5	40.5	
Ash (%)	9.8-16.0	9.8	9.8
Sulfur (%)	0.6- 0.7		0.7
Hydrogen (%)	5.7		5.7
Carbon (%)	61.0		61.0
Nitrogen (%)	1.4		1.4
Oxygen (%)	21.4		21.4
Btu/pound	9,760-10,690	10,255 (2 samples)	

Bed No. 79: This coal is a 5-23 feet thick, high volatile C bituminous bed in the Hanna Formation. It is Paleocene in age and strip mined in the central part of the basin.

As-received basis	Range Analysis (2-5 samples)	Average Proximate (5 samples)	Average Ultimate (2 samples)
Moisture (%)	8.94-16.51	11.33	
Volatile Matter (%)	34.4 -39.7	36.70	
Fixed Carbon (%)	41.41-47.3	43.16	
Ash (%)	5.73-12.26	8.81	7.55
Sulfur (%)	0.94- 2.05		1.05
Hydrogen (%)	5.6 - 5.7		5.65
Carbon (%)	61.4 -62.2		61.80
Nitrogen (%)	1.3 - 1.4		1.35
Oxygen (%)	20.4 -24.7		22.55
Btu/pound	10,390-11,105	10,724 (5 samples)	
Ash softening temperature (°F)	2,130- 2,320	2,230 (3 samples)	

Bed No. 80: Bed No. 80 is a Paleocene coal of the Hanna Formation. Its rank is high volatile C bituminous. This bed is well developed in the Hanna Basin where it is 5 to 26 feet in thickness. The No. 80 bed generally has a parting, 1 to 1½ fe thick, 2 to 5 feet above its base. It is both strip min and deep mined in the Hanna Field.

As-received basis	Range Analysis (7-32 samples)	Average Proximate (17 samples)	Average Ultimate (7 samples)
Moisture (%)	5.97-15.44	10.83	
Volatile Matter (%)	35.03-47.34	39.23	
Fixed Carbon (%)	35.65-50.92	43.68	
Ash (%)	4.4 -15.83	6.27	7.09
Sulfur (%)	0.48- 1.24		0.98
Hydrogen (%)	5.7 - 6.16		5.90
Carbon (%)	58.66-65.6		60.66
Nitrogen (%)	0.45 - 1.5		1.13
Oxygen (%)	21.9 -25.59		24.23
Btu/pound	9,940-12,600	11,000 (26 samples)	
Ash softening temperature (°F)	2,080- 2,430	2,250 (11 samples)	
Hardgrove grindability index	47-50 (4 samples)		

Bed no. 82: This bed is an Eocene coal in the Hanna Formation. It is a high volatile C bituminous coal and averages 9 feet thick and is best developed in the Hanna Basin where it is strip mined.

As-received basis	Range Analysis (2-31 samples)	Average Proximate (15 samples)	Average Ultimate (2 samples)
Moisture (%)	6.51-20.75	11.90	
Volatile Matter (%)	31.28-43.78	37.08	
Fixed Carbon (%)	36.56-48.08	42.46	
Ash (%)	4.29-13.2	8.56	7.25
Sulfur (%)	0.35- 1.94		1.35
Hydrogen (%)	5.7 - 5.8		5.75
Carbon (%)	58.0 -61.3		59.65
Nitrogen (%)	0.9 - 1.6		1.25
Oxygen (%)	23.0 -26.6		24.80
Btu/pound	9,105-12,150	10,620 (21 samples)	
Ash softening temperature (°F)	2,140- 2,410	2,310 (1 sample)	
Hardgrove grindability index		50 (1 sample)	

Brooks coal bed: This bed is a high volatile C bituminous Paleocene coal near the base of the Hanna Formation. It is 5 feet to 8 feet in thickness where it is strip mined in Carbon County.

As-received basis	Range Analysis (2-8 samples)	Average Proximate (7 samples)	Average Ultimate (2 samples)
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- 7.0	5.54	6.92
Sulfur (%)	0.25- 0.70		0.60
Hydrogen (%)	5.60		5.60
Carbon (%)	62.5 -64.68		63.59
Nitrogen (%)	0.71- 1.1		0.91
Oxygen (%)	21.45-23.3		22.38
Btu/pound	10,395-11,180	10,860 (8 samples)	
Ash softening temperature (°F)	2,110- 2,160	2,135 (2 samples)	
Hardgrove grindability index	48-51	49.5 (2 samples)	

Hanna No. 1 coal bed: Although this Hanna Formation coal is not now mined, it has been extensively deep mined in the past. The bed is 4-27 feet thick, and has been converted into a low Btu gas at a U.S. Department of Energy's in situ gasification site south of Hanna. The coal is high volatile C bituminous in rank.

As-received basis	Range Analysis (4-22 samples)	Average Proximate (20 samples)	Average Ultimate (4 samples)
Moisture (%)	6.3 -15.65	12.05	
Volatile Matter (%)	32.64-43.39	39.33	
Fixed Carbon (%)	34.09-45.26	41.71	
Ash (%)	4.17-23.76	6.90	11.09
Sulfur (%)	0.29- 1.02		0.50
Hydrogen (%)	5.09- 5.79		5.48
Carbon (%)	49.6 -62.82		59.38
Nitrogen (%)	0.99- 1.31		1.21
Oxygen (%)	19.58-24.04		22.34
Btu/pound	8,660-11,480	10,740 (17 samples)	
Ash softening temperature (°F)	2,100- 2,310	2,190 (9 samples)	

Hanna No. 2 bed: This Paleocene coal is ranked as high volatile C bituminous. Although it was extensively deep mined in the past, it is now strip mined near Hanna, Wyoming. The Hanna No. 2 bed is 5-38 feet thick and occurs in the Hanna Formation.

As-received basis	Range Analysis (10-21 samples)	Average Proximate (20 samples)	Average Ultimate (10 samples)
Moisture (%)	9.1 -17.2	11.58	
Volatile Matter (%)	33.2 -42.58	39.16	
Fixed Carbon (%)	39.33-44.9	42.61	
Ash (%)	3.8 -16.33	6.65	7.62
Sulfur (%)	0.21- 0.8		0.48
Hydrogen (%)	5.11- 6.37		5.77
Carbon (%)	57.46-64.74		61.23
Nitrogen (%)	0.85- 1.4		1.05
Oxygen (%)	19.54-28.4		23.86
Btu/pound	9,990-11,390	10,910 (17 samples)	
Ash softening temperature (°F)	2,120- 2,350	2,260 (4 samples)	
Hardgrove grindability index		48 (1 sample)	

Hanna No. 5 Bed: This bed is a high volatile C bituminous Paleocene coal in the Hanna Formation. It is 5-31 feet thick and splits into a number of benches. It is strip mined in the central part of the field.

As-received basis	Range Analysis (2-4 samples)	Average Proximate (4 samples)	Average Ultimate (2 samples)
Moisture (%)	10.3 -20.56[1]	13.82	
Volatile Matter (%)	36.3 -38.9	37.45	
Fixed Carbon (%)	37.2 -47.3	42.70	
Ash (%)	5.6 - 6.7	6.04	5.92
Sulfur (%)	0.34- 0.6		0.47
Hydrogen (%)	4.78- 5.7		5.24
Carbon (%)	56.34-64.4		60.37
Nitrogen (%)	0.85- 1.3		1.08
Oxygen (%)	22.0 -31.95		26.98
Btu/pound	8,880-11,190	10,540 (4 samples)	
Ash softening temperature (°F)	2,130- 2,510	2,280 (3 samples)	
Hardgrove grindability index	50-110 (2 samples)		

HAMS FORK COAL REGION

The Hams Fork Coal Region of western Wyoming includes portions of Lincoln, Teton, and Uinta counties, and is the fifth largest coal-bearing area in the state. The region is unique from other coal-bearing areas in Wyoming because it falls within the Overthrust Belt. As defined, the Hams Fork Coal Region is limited to those portions of the Overthrust Belt that are underlain by coal-bearing rocks of the Bear River, Frontier, Adaville, Blind Bull, and Evanston Formations. Figure 1 shows the approximate location of these coal-bearing rocks, but geological and structural complexities prevent a more accurate depiction at this scale.

Based on early mining activity, the U.S. Geological Survey named four coal fields within the region: The Evanston, Greys River, Kemmerer, and McDougal coal fields (Figure 2). The field boundaries were recently revised so that the entire region is included within one or another field (Glass, 1977).

Structurally, the Hams Fork Region is very complex. Folded Paleozoic and Mesozoic rocks are thrust eastward overfolded Cretaceous rocks with the younger Cretaceous and Tertiary rocks of the area resting unconformably on top of these older rocks. The coal-bearing rocks of the Hams Fork Region 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 the region.

For the most part, the Kemmerer, Greys River, and McDougal coal fields are situated within synclinal areas between the various ranges of the region. Coal-bearing rocks within these fields usually dip westward at 16-80 degrees, averaging closer to 25-30 degrees. Much of the Evanston Coal Field underlies the 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 field are generally buried beneath younger rocks that are barren of coals. In the Almy District of the Evanston Coal Field, minable coals crop out with easterly dips of 10-20 degrees.

Faults are common in the Hams Fork Coal Region, particularly thrust faults. These faults are thrust westward and 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 region. In the southern third of the Hams Fork Region, these two faults are often covered by younger unfaulted rocks. Stratigraphic throw on the thrust faults in the Overthrust Belt generally is from 10,000 to 20,000 feet.

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

The more important coals in the region occur in the Upper Cretaceous Frontier and Adaville formations. Locally, minable coals also are found in the Lower Cretaceous Bear River Formation and the Paleocene Evanston Formation. Collectively, these coal-bearing rocks account for over 9,000 feet of the estimated 20,000 feet of post-Jurassic rocks in the Hams Fork Region.

In Uinta and southern Lincoln County, Bear River coals locally reach minable thicknesses, and they were prospected and mined on a very small scale in the 1800's. Veatch (1907) referred to bituminous coals in the Bear River Formation as thin and dirty.

Unfortunately, the economic value of coals in the Bear River Formation cannot be evaluated from the sparse data available on them. No coal analyses or mine locations are reported in published references, and the coal outcrops have not been mapped. Additionally, the existence of Bear River coals in northern Lincoln County and southernmost Teton County is not documented.

The 2,000-2,200 feet thick Frontier Formation is the oldest principal coal-bearing unit in the Hams Fork Coal Region. The formation consists of alternating shales, sandstones, clays, and coals. Although coal thicknesses don't compare with some of the thicker Adaville Formation coals, Frontier coals in southern Lincoln and Uinta counties are persistent and higher in rank. Although the Main Kemmerer coal bed is up to 20 feet thick, most Frontier coals are less than 6 feet thick. Minable coals occur throughout most of the formation (Veatch, 1907; Berryhill et. al., 1950).

In the southeastern quarter of the coal region, 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 beds (Figure 9). 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 Frontier coal production has come from the Kemmerer Coal Field. Although Frontier coals were traditionally deep mined from this region, there are no active mines on Frontier coal beds. The last coal mine in the Frontier Formation was Kemmerer Coal Company's Brilliant No. 8 deep mine on the Main Kemmerer coal bed. This mine closed in 1964.

In the northern part of the Hams Fork Coal Region, minable coals equivalent in age to the Frontier Formation crop out in the Upper Cretaceous Blind Bull Formation (Rubey, 1973).

The Upper Cretaceous Adaville Formation is without question the most important coal-bearing formation in the Hams Fork Coal Region. Varying from 2,900-4,500 feet thick, the basal 1,200 feet of interbedded shales, claystones, and sandstones of this formation in the Kemmerer Coal Field contain up to 32 subbituminous coals, many of which are much thicker than other Upper Cretaceous coals in Wyoming (Glass, 1977). Adaville Formation coals crop out in three elongate basins in the northern, central, and southern portions of the Kemmerer Field over a combined distance of more than 60 miles. Dips in these three basins are generally westward at 17-45 degrees. Because all the major and minor coals thicken, thin, split, and coalesce over very short distances, correlation of individual beds within the formation is extremely difficult (Glass, 1977).

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

In the northern basin, the Adaville coals evidently thin and decrease in number. Little information is available for that area or for the southernmost basin, which also apparently has fewer coals than the central basin. Coals in the southern basin reportedly are 7-30 feet thick in places (Veatch, 1907; Schroeder, 1976).

To date, most Adaville coal production has come from the Kemmerer District of the Kemmerer Coal Field where the Adaville coals were both deep mined and strip mined. Most of the Adaville production, however, has come from the Kemmerer Coal Company's open pit mines, which opened on the Adaville No. 1 bed in 1950 and on stratigraphically higher Adaville coals in 1963. By the end of 1980, these strip mines accounted for approximately 47.5 million tons of the coal produced in Lincoln County. Presently, there are three active open pit coal mines on the Adaville coals: Kemmerer's Elkol and Sorensen mines and FMC Corporation's Skull Point mine. These three mines are the only active coal mines in the Hams Fork Coal Region.

The youngest coal-bearing rocks in the Hams Fork Coal Region belong to the Paleocene Evanston Formation. This sequence of sandstones, conglomerates, shales, and coals has a maximum thickness of 1,600 feet in the Evanston Coal Field where at least one coal in the upper part of the formation was mined from the 1800's to the mid-1900's.

Although Veatch (1907) states that the Evanston Formation underlies most of the Fossil Syncline, Evanston coals reportedly only crop out in fault blocks of the Almy District north of Evanston. The

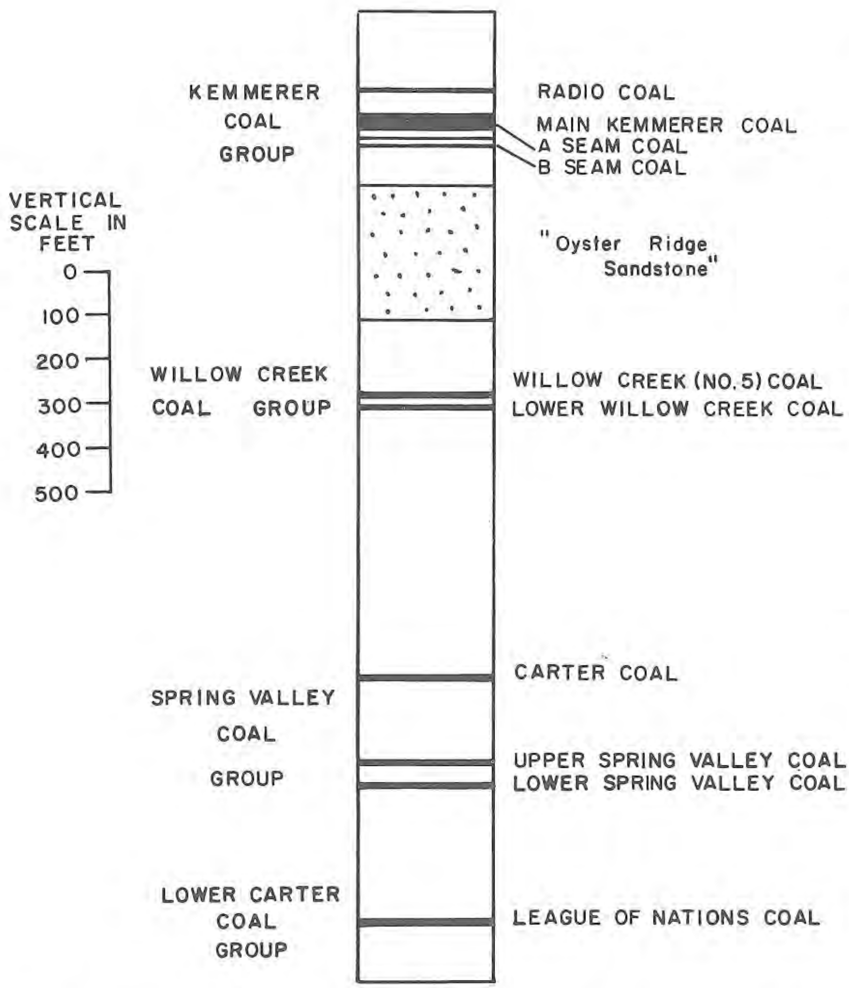


Figure 9: Coal nomenclature for the Frontier Formation of the Hams Fork Coal Region.

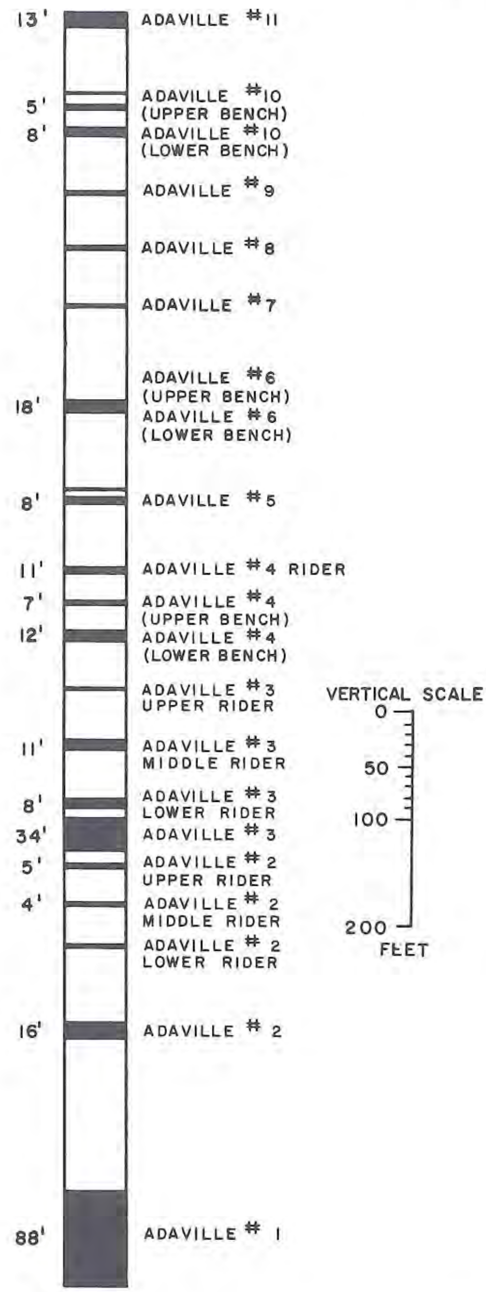


Figure 10: Coal nomenclature for the Adaville Formation of the Hams Fork Coal Region.

upper few hundred feet of the Evanston Formation in that area contains at least five subbituminous coals that are 6 to 18 feet thick. According to Veatch (1907), all but one of these beds contained too many rock partings for efficient mining. Portions of the thick Almy coal bed, however, were clean enough that at least 2.7 million tons were deep mined between 1869 and 1905 when the last mine closed.

Important Coal Beds

Adaville No. 1 coal bed: This subbituminous coal is the lowermost Adaville Formation coal 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 coals. Fagnant (1962) reports it is locally 118 feet in thickness. Commonly, it averages 74-84 feet thick in the Kemmerer District where it is best developed. If the Adaville No. 1 is correlative with the lowest Adaville coal in the southern basin, it is still 30 feet thick in that area (Schroeder, 1976). Presently, Kemmerer Coal Company's Elkol and FMC Corporation's Skull Point mines are mining about 3 million tons of this coal bed each year.

Twenty-five published analyses of the Adaville No. 1 coal bed were found and summarized. While 6 of these analyses were made on channel samples (only one channel represents the entire bed thickness), the other 19 were made on tipple samples. The apparent rank of the coal is as high as subbituminous A.

		Average	
As-received basis	Range Analysis	Proximate (25 samples)[1]	Ultimate (7 samples)[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- 6.6		6.3
Carbon (%)	56.0-60.1		58.1
Nitrogen (%)	0.9- 1.0		0.9
Oxygen (%)	27.5-33.6		30.2
Btu/pound	9,720-10,530	10,190	
Ash softening temperature (°F)	2,150- 2,660	2,370	

[1]Includes 6 deep mine samples
[2]Includes 3 deep mine samples

Adaville coal beds (undifferentiated): At least in the Kemmerer District of the Kemmerer Field, Adaville coals are numbered consecutively from the lowermost bed upward (Figure 10). These numerical designations, however, have little meaning beyond the boundaries of the Kemmerer Coal Company's mines. For this reason, all Adaville coal beds above the Adaville No. 1 bed are discussed collectively. For a description of each numbered bed in Kemmerer's Sorensen mine, the reader is referred to Glass (1975; 1977).

Subbituminous coal beds above the Adaville No. 1 coal vary from a few inches to as much as 50 feet in thickness. In the Kemmerer District, at least 7 of these coals are more than 10 feet thick. Another seven are between four and eight feet thick (Glass, 1975). The rock intervals between these coals are from a few inches to 140 feet thick, but average nearer to 50 feet. All these coals pinch and swell in thickness and split and coalesce over very short distances (Glass, 1977). Correlation of these beds is extremely difficult without very close control or continuous exposures.

Kemmerer Coal Company's Sorensen mine is currently mining as many as 21 of these upper Adaville coals. Production from this mine is about 2.4 million tons per year.

The remaining strippable reserve base of Adaville coals is presently estimated as more than one billion tons (Smith, et. al., 1972).

Twenty analyses of various Adaville coals, excluding the Adaville No. 1, are summarized below. The apparent rank of all these coals is subbituminous B to C. All but two of these analyses were made on channel samples of the Adaville No. 2 through No. 11 coal beds, which were collected in the Sorensen mine (Glass, 1975). The other two analyses were made on tipple samples, one of which came from an underground mine.

As-received basis	Range Analysis	Average Proximate (20 samples)	Average Ultimate (18 samples)
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
Oxygen (%)	28.2-39.4		31.8
Nitrogen (%)	0.8- 1.5		1.4
Btu/pound	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 1905, more than 2.7 million tons of the Almy bed were mined near Almy (T.16N., R.12W.). In mines, the Almy coal bed reached 28 feet in thickness, but it was characterized by numerous thin partings near the top and middle (Veatch, 1907). The upper eight feet, which splits off the main mined bed in places, evidently were never mined possibly because of poor quality or because it aided roof support.

The one published analysis of this coal only represents the lower 8 feet of the bed, which was 24 feet thick where it was sampled (Fieldner, et. al., 1931).

As-received analysis	
Moisture (%)	14.4
Volatile Matter (%)	36.8
Fixed Carbon (%)	41.6
Ash (%)	7.2
Sulfur (%)	0.2
Hydrogen (%)	5.4
Carbon (%)	60.0
Nitrogen (%)	1.2
Oxygen (%)	26.0
Btu/pound	10,450

"A" Seam coal bed: This high volatile C bituminous coal lies 15-40 feet below the Main Kemmerer bed. Also called the Lower Kemmerer bed, the "A" Seam was mined in the central part of the Kemmerer Coal Field where it had a maximum thickness of 6.5 feet (Hunter, 1950). All mining on this Frontier Formation coal bed has been underground. Veatch (1907) published a single analysis of the bed.

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/pound	12,780

Blind Bull coal bed: See Vail coal bed.

Frontier No. 1 coal bed: 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 another high volatile C bituminous Frontier Formation coal best developed in the Kemmerer District of the Kemmerer Coal Field. In that district, this coal locally exceeded five feet in thickness, and was deep mined in the past (Veatch, 1907). The Lower Spring Valley coal may be equivalent to one or more coals of the Spring Valley Group to the south in Uinta County.

Two analyses of the Lower Spring Valley coal bed are:

As-received basis	Tipple Sample	Typical Analysis (Townsend, 1960)
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
Hydrogen (%)		5.4
Carbon (%)		73.6
Nitrogen (%)		1.2
Oxygen (%)		14.0
Btu/pound	11,890	12,340
Ash softening temperature (°F)	2,590	2,330

Lower Willow Creek coal bed: In the Kemmerer Coal Field, this high volatile C bituminous Frontier coal often underlies the Willow Creek No. 5 bed north of Kemmerer. The interval between the two beds is 5-20 feet thick. Frequently, the Lower Willow Creek coal is less than two feet thick, but locally it reaches four feet in thickness.

Although the Lower Willow Creek bed has not been mined, the coal is weakly coking (Toenges, et. al., 1945). In regard to quality, 20 core analyses from Toenges, et. al., (1945) are summarized below.

As-received basis	Range (20 samples)	Average Proximate and Ultimate) (20 samples)
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
Oxgyen (%)	11.0-15.6	11.8
Btu/pound	11,650-13,410	12,820
Ash softening temperature (°F)	2,340- 2,720	2,480

Main Kemmerer coal bed: This coal, variously called Kemmerer No. 1 or Frontier No. 1, is the thickest and most persistent coal in the Kemmerer Coal Group. Stratigraphically, the Main Kemmerer bed lies 200-250 feet below the top of the Frontier Formation at least in the Kemmerer Field (Figure 9).

This bed, which is reportedly up to 20 feet thick in the Kemmerer District of the Kemmerer Coal Field, is typically split into two benches by a six-inch-thick rock parting. While the top bench is usually 10-16 feet thick, the lower bench is closer to four or five feet. The rock parting reportedly thickens to 30 feet north and south of Kemmerer, and the two benches thin to five and three feet thick, respectively (Hunter, 1950). Occasionally, the Main Kemmerer bed exceeds seven feet in thickness even in the southern portion of the Kemmerer Coal Field.

Most deep mining in the Hams Fork Region has been on this coal bed with extensive mining near Kemmerer and Diamondville. This coal was mined in the Brilliant No. 8 deep mine, which was the last operating deep mine in the region (closed in 1964).

The rank of the Main Kemmerer coal bed apparently varies from high volatile B to high volatile C bituminous. 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.

As-received basis	Range Analysis	Average Proximate (23 samples)	Average Ultimate (10 samples)
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/pound	11,980-12,960	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 in the Kemmerer District of the Kemmerer Coal Field where it has been deep mined on a rather small scale (Veatch, 1907). In this area the Upper Spring Valley coal locally exceeds six feet in thickness although it averages less. This bed may be correlative with one or more coals at about the same stratigraphic position in the Spring Valley area (T. 15 N., R. 118 W.) of Uinta County. Correlation of individual beds between these two areas, however, is not documented. Schroeder (1976) reports that some Spring Valley coals in the Ragan Quadrangle just north of Spring Valley are 3-6.5 feet thick.

Townsend (1960) provided the following typical analysis of the high volatile C bituminous Upper Spring Valley coal bed from the Kemmerer area.

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/pound	12,340
Ash softening temperature (°F)	2,560

Vail coal bed: In the McDougal Coal Field, this high volatile bituminous Blind Bull Formation coal bed is reportedly up to 10.2 feet thick. Most mines on the Vail or Blind Bull coal bed, however, mined only 6-7.5 feet of low ash, low sulfur coal (Veatch, 1907). The outcrop of the Vail bed is apparently traceable for more than 10 miles in the Blind Bull District of the McDougal Coal Field.

Analyses of nine coals, 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, but no new mining has begun.

As-received basis	Range Analysis	Average Proximate (9 samples)	Average Ultimate (3 samples)
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/pound	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, 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 coals in the Willow Creek Group (Glass, 1977). Although the Willow Creek No. 5 coal is 3-11.2 feet thick where it was mined, it thins to less than two feet in places and is not even recognized in the southern portion of the Kemmerer Coal Field (Schroeder, 1976).

Toenges, et. al., (1945) found that the Willow Creek No. 5 coal exhibited 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 coals tested, the Willow Creek No. 5

bed did offer the most promise for development.

Berryhill, et. al., (1950) estimated that in five townships where the Willow Creek No. 5 bed is 28-42 inches thick, the measured and indicated original 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 2,000-3,000 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 was in the central part of the Kemmerer Coal Field 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 high volatile A or B bituminous coal are the lowest of any analyzed Willow Creek Group coal. Thirty-five published analyses of the Willow Creek No. 5 bed are summarized below.

As-received basis	Range Analysis	Average Proximate (35 samples)[1]	Average Ultimate (24 samples)[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/pound	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 BASIN

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

Based on early mining activity, the U.S. Geological Survey named eight coal fields within the basin. The exact boundaries of the fields were not defined, and beds were not correlated between them. Areas barren of coal mining serve to roughly delimit one field from the other. Since the coal-bearing formations are only exposed along the flanks of the coal basin, the coal fields also lie within this peripheral zone. Clockwise from the Montana border, the eight fields are: Silvertip, Garland, Basin, Southeastern, Gebo, Grass Creek, Meeteetse, and Oregon Basin (Cody) coal fields (Figure 2).

Structurally, these eight coal fields are on the flanks of 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 Basin continues into Montana and narrows where it is flanked by the Beartooth and Pryor Mountains before it merges with the Crazy Mountains syncline. Local folding characterizes the marginal areas of the basin where the coal fields are located. These small anticlines and synclines create local dips at various angles to the overall synclinal structure of the basin. Dips from 15 to 50 degrees are common in these borders. There are also numerous normal faults on the flanks of the syncline, especially in the northern half of the basin.

Most of these faults trend northeast-southwest with vertical displacements up to 250 feet reported.

Although coals are reported 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 Polecat Bench Formation.

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 basin, eight feet of Cloverly Formation coal was mined.

Only thin coals have been found in the Upper Cretaceous Frontier Formation of the Bighorn Basin. Thicknesses over a few inches are seldom mentioned.

Although Upper Cretaceous Mesaverde coals occur throughout the basin, they are thin in the southeastern corner where they seldom exceed 14 inches in thickness. The thickest and most persistent Mesaverde coals are in the southern and southwestern portions of the basin where bed thicknesses are up to 12 feet. More commonly, Mesaverde coals are only 4-6 feet thick. The coals in the Mesaverde Formation have historically been the most important coals in the basin, and have been mined in all but the Basin and Southeastern coal fields. The minable coals of the Mesaverde are normally found in the basal portion of the formation, but are not limited to there. Splitting and rapid thinning of Mesaverde coals are common.

At least in the Gebo Coal Field, the apparent rank of these Mesaverde coals is high volatile C bituminous. This is a higher rank than previously reported and may be a local phenomenon or regional in extent. If it is regional, the higher rank may be the result of the post-1950 change in the American Society of Testing and Materials classification system. That change revised the distinction between subbituminous A and high volatile C bituminous coals (Glass, in press). Consequently, many coals classified as subbituminous A in the older classification, are classified as high volatile C bituminous under the new one. This is also why many of the coals in the Hanna Coal Field are now called high volatile C bituminous rather than subbituminous A.

Apparently coals are distributed throughout the Upper Cretaceous Meeteetse Formation everywhere in the basin, but they are not as thick nor as persistent as the older Mesaverde coals. The thicker Meeteetse coal beds coincide with areas where numerous thin coals coalesce into interbedded shale and coal units. These thicker coals commonly are 4 to 6 feet thick, although 8- to 11-foot beds have been reported. Meeteetse coals have been mined in all but the Silvertip, Gebo, and Grass Creek coal fields. Because the Meeteetse and Lance Formations in the Bighorn Basin are not always mapped separately, the distinction between upper Meeteetse coals and basal Lance coals is often not possible. Of the two formations, however, the Meeteetse Formation normally contains the thicker and more persistent beds of coal. The apparent rank of Meeteetse coals is subbituminous A to high volatile C bituminous.

Where the Upper Cretaceous Lance can be separated from the Meeteetse, it contains only thin coals. These thin coals are usually reported in the top of the formation and are less than 6 inches in thickness. Separation of the Lance from the overlying Polecat Bench Formation is difficult, therefore, the age of the coals near that contact is not always correctly identified. Because there are no analyses, the rank of these coals is unknown.

Polecat Bench (formerly Fort Union) Formation coals are found in all the coal fields of the basin except the Silvertip Coal Field. These Paleocene coals reach their maximum reported thickness in the Grass Creek and Southeastern coal fields where they are as thick as 38 feet and 10 feet, respectively. The maximums in the other fields are 3.5 to 8.8 feet thick. In all cases the thicker and more important coals occur in the lower part of the formation. Interest in the coals of the Polecat Bench Formation has hightened recently as the search for thick, low sulfur coals continues. The shallower dips exhibited by these younger Paleocene coals complement their greater thicknesses.

At least in the Grass Creek Coal Field, the apparent rank of the thick Mayfield coal bed is high volatile C bituminous. This again, is a higher rank than previously reported. See the above discussion under Mesaverde coals for an explanation of this phenomenon.

The Eocene Willwood Formation reportedly contains a few low quality coals. Rohrer (1966) reports thicknesses up to 2 feet and gives an analysis of one Willwood coal with a heat value of only 4,110 Btu/pound.

Rohrer (1966) also found a 19-inch coal in the Eocene Tatman Formation. He reports the coals in the Tatman are typically less than 8 inches in thickness and very low in quality.

Important Coal Beds

Gebo coal bed: The Mesaverde Formation Gebo bed of the Gebo Coal Field is 6-11 feet in thickness, but averages only 7 feet. The bed has recently been mined by conventional underground methods (Glass, Westvelt, and Oviatt, 1975). Where mined, the bed dipped 17-45 degrees. The apparent rank of this coal is high volatile C bituminous.

As-received basis	Range (69 samples)	Average
Moisture (%)	12.4-17.8	15.5
Volatile Matter (%)	31.1-40.3	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/pound	10,080-11,780	10,970

Mayfield coal bed: This Polecat Bench (Ft. Union) Formation coal in the Grass Creek Field is currently strip mined. The bed is 8-38 feet thick and has been deep mined in the past. A preliminary estimate of the strippable reserve base for this bed is in excess of 15 million tons (Stewart, 1975). The apparent rank of this coal 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/pound	10,730-11,246	10,970

Meeteetse Formation coal beds (undifferentiated): See the general discussion above for details. The apparent rank of these Upper Cretaceous coals is subbituminous A to high volatile C bituminous. These coals are not presently mined.

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/pound	7,773-10,965	9,800

WIND RIVER COAL BASIN

The Wind River Coal Basin of central Wyoming includes portions of Fremont and Natrona counties as well as a major part of the south eastern corner of the Wind River Indian Reservation (Figure 1). This coal-bearing area, which is areally the fourth largest in the State, coincides with the topographic and structural basin of the same name as defined, however, the coal basin is limited to that portion of the Wind River Basin underlain by Mesaverde or younger rocks. This definition was chosen because the Mesaverde Formation is the oldest important coal-bearing formation in the basin. The coal basin is divided into seven coal fields (Figure 2). Counterclockwise from the northwestern corner of the basin, the seven fields are: Muddy Creek, Pilot Butte, Hudson (Lander), Beaver Creek, Big Sand Draw, Alkali Butte, and Arminto (Powder River).

Structurally, these seven fields lie on the flanks of or within a large, asymmetrical, west-northwest trending syncline, which is 125 miles long and 45 miles wide. The Wind River Basin is bounded by the Absaroka Mountains, the Owl Creek Mountains, and the Bighorn Mountains to the north, by the Wind River Mountains to the west and southwest, by Beaver Rim (a north-facing erosional escarpment) to the south, and by the Rattlesnake Hills to the southeast. Local folding characterizes the flanks of the basin where most of the coal fields are located. These small anticlines and synclines create local dips at various angles to the overall synclinal structure of the basin. Dips from 15 to 40 degrees are common along the southern flank of the basin. Dips along the northern flank are steeper, between 40 and 85 degrees, but are overturned in places. Although faulting occurs in all the fields, it is most pronounced in the Muddy Creek Field. Both normal and reverse faults occur.

Although coals are reported in the Frontier, Cody, Lance, Fort Union and Wind River formations, the thicker and more important coals are limited to the Upper Cretaceous Mesaverde and Meeteetse formations. The older formations crop out beyond the margins of the coal basin. The younger Wind River Formation rocks occur in the more central portions of the basin where they overlie the major coal-bearing rocks.

Upper Cretaceous Frontier coals were prospected about eight miles southeast of Lander beyond the defined boundary of the coal basin (Glass and Roberts, 1978). Two coals separated by about 69 feet of rock were examined in the early 1900's. The upper coal was reportedly 17 inches thick. The lower bed was only 15 inches thick.

Various older publications (Woodruff and Winchester, 1912) refer to thin discontinuous coals in the Upper Cretaceous Cody Shale. It is conceivable that most, if not all, of these coals actually occur in rocks now mapped as the Mesaverde Formation. A three feet thick Cody coal, however, is reported in at least one drill hole in the Beaver Creek Coal Field (Thompson and White, 1952).

Although Upper Cretaceous Mesaverde coals are present throughout the basin, they only crop out on the basin's flanks. Mesaverde coals occur at substantial depths along much of the northern flank and more central portions of the basin where they are buried under thick sequences of younger rocks.

Where the Mesaverde coals crop out, they are apparently thinnest and least numerous in the Pilot Butte Coal Field. Only one coal, the Kinnear bed, is mapped in that field, and it is less than three feet thick. Mesaverde coals in the northwestern, southwestern, and southeastern flanks of the Wind River Basin are locally 7-8.8 feet thick, but average only two feet. Most mined coals in these areas were three to five feet thick, and seldom maintained those thicknesses for more than a mile or two along outcrop.

The thickest and most persistent Mesaverde coals crop out in the Alkali Butte and Big Sand Draw Fields along the southcentral flank of the basin. The Downey coal bed in that area is 28 feet thick; another, the Signor bed, reaches 16.5 feet in thickness. Additionally, the Signor bed remains of minable thickness for more than six miles along strike. Although some other coals in these fields reach four to five and a half feet in thickness, there are many coals less than two feet thick.

In the Beaver Creek field, Mesaverde coals are only known from the subsurface. One oil well log in the southernmost part of that field shows 29 coal beds in the Mesaverde. The coals are two to fifteen feet thick with an aggregate thickness of about 165 feet in a 1,200 feet interval. Coal resources identified from drill holes in this field are probably indicative of the deeper coal resources underlying the rest of the Wind River Coal Basin.

The Upper Cretaceous Meeteetse Formation is only recognized in the Muddy Creek Coal Field in the northwestern corner of the basin. Meeteetse coals common to that area are nearly as well developed as the Mesaverde coals of the Alkali Butte Field. Meeteetse coals are reportedly up to 16 feet thick, although they average less than four feet (Woodruff and Winchester, 1912). The thickest expressions of Meeteetse coals occur in persistent shaly carbonaceous zones where numerous thin coals coalesce into interbedded shale and coal units (Keefer and Troyer, 1964).

Coals are documented in the Upper Cretaceous Lance Formation only in the Alkali Butte Coal Field. Most of these coals are very thin and shaly. Because of the lack of recent detailed mapping in the Arminto Coal Field of the easternmost Wind River Basin, some of the coals identified as Mesaverde in that field could be Lance coals, but that cannot be documented at this time.

Only one potentially minable Lance coal has been identified in the Alkali Butte Coal Field. Thompson and White (1952) calculated resources on a Lance coal that was 3 to 6 feet thick for more than two miles along its outcrop. They estimated there were 5.78 million tons of that coal under less than 1,000 feet of cover.

No analyses of Lance coals were found for the Wind River Basin.

The Paleocene Fort Union Formation is a minor coal-bearing formation in the Wind River Coal Basin. Fort Union coals are only documented in the southcentral and eastern portions of the basin. Even in those areas, Fort Union coals are uncommon and thin, seldom reaching three feet in thickness. In the southernmost part of the Beaver Creek Field, drill holes show as many as three coals in the Fort Union Formation, but they are only two to three feet thick (Thompson and White, 1952). One prospect in the Arminto field exposed four and a half feet of Paleocene coal (Woodruff and Winchester, 1912).

The Eocene Wind River Formation is not a major coal-bearing formation in the Wind River Basin. Drilling in the southernmost part of the Beaver Creek Coal Field, however, documents a few two to three feet thick coals (Thompson and White, 1952). Most Wind River Formation coals are only a few inches thick and of little economic value.

Coals in the Mesaverde, Meeteetse, Lance, and Fort Union Formations are all reportedly subbituminous in rank. As mentioned earlier, however, there are no analyses of the Lance and Fort Union coals to verify their rank. It is probable that Frontier coals, southeast of Lander, could be bituminous, and that Eocene Wind River Formation coals could be lignitic instead of subbituminous, Again, the lack of any analyses of the coals in the Frontier or Wind River formations precludes any firm determination of rank.

As-received moisture contents of mined

Mesaverde and Meeteetse coals in the basin were between 12.1-34.1 percent, and averaged 21.6 percent (Glass and Roberts, 1978). The one Meeteetse coal in these analyses had a moisture content of only 15.7 percent, but a single analysis prevents any meaningful comparisons.

Ash contents were between 1.8-12.0 percent and averaged 6.4 percent. Since many of the analyses in this average were conducted on channel samples, one should remember that it was customary to remove all partings over one centimeter thick from these samples while sampling. This procedure provided a relatively clean coal for analysis, similar to a coal run through a cleaning plant.

The Mesaverde and Meeteetse coals exhibited sulfur contents between 0.3-1.3 percent. The average sulfur content was 0.6 percent. Again, the channel sampling procedures used to collect many of the analyzed samples also required the collector to pick out all pyritic material found during sampling. This lowered the sulfur content below what an uncleaned coal might yield.

The heat values of Mesaverde and Meeteetse coal beds averaged 9,210 Btu/pound. While the lowest value of 6,080 Btu/pound was reported in the Alkali Butte Field, the highest heat value was 11,120 Btu/pound for a Mesaverde coal in the Muddy Creek Field. There is some suggestion that the coals from the western fields of the basin have higher heat values than more eastern coal fields (Glass and Roberts, 1978). In fact, the average heat values in the Muddy Creek, Pilot Butte, and Hudson fields are 980 to 2,600 Btu/pound higher than average values in the Alkali Butte and Arminto fields. Although biased statistics probably account for a good percentage of this difference, the observation requires further investigation for confirmation or denial.

Important Coal Beds

Lander coal bed: The Lander coal bed refers to the lowest of three Mesaverde coals that were mined or prospected in the Hudson Coal Field north and south of the Popo Agie River. Most mining in this areas was on the lowermost bed, the Lander coal bed, which was by far the thickest and most persistent coal in the area (Woodruff and Winchester, 1912). Dips in the area are only 12 to 15 degrees to the northeast. Although correlation of the Lander bed north and south of the Popo Agie River is not confirmed, the stratigraphic position makes the correlation likely.

According to Berryhill, et. al., (1950), at least 58.97 million tons of Mesaverde coal underlies the Hudson Coal Field between zero and 3,000 feet of cover. Because most of this resource is calculated on the Lander coal bed, most of the reserve base of 13.85 million tons is also on this bed. The resources partially lie within the Wind River Indian Reservation.

Analyzed samples were a mixture of channel, tipple, and delivered samples. Usually the entire bed thickness was not sampled and many samples were cleaned or screened before analysis. The apparent rank of the Lander coal bed is subbituminous B.

As-received basis	Range	Average Proximate (37 samples)	Average Ultimate (7 samples)
Moisture (%)	16.0-24.7	21.2	
Volatile Matter (%)	29.1-38.1	32.9	
Fixed Carbon (%)	33.2-45.0	39.8	
Ash (%)	2.8-11.8	6.1	4.6
Sulfur (%)	0.3- 1.3	0.6	0.6
Hydrogen (%)			6.2
Carbon (%)			55.2
Nitrogen (%)			1.2
Oxygen (%)			32.2
Btu/pound	8,870-10,510	9,480	

Welton coal bed: The Welton coal bed is the thickest Meeteetse coal described in the Wind River Coal Basin. It is up to 16 feet thick although a thin shale parting commonly separates the basal two feet of the bed from the upper part (Keefer and Troyer, 1964).

The coal crops out for more than two miles where it dips eastward at 19 to 28 degrees. It apparently splits and thins northward. It has been deep mined in the past. More recently, a small strip mine (Muddy Creek strip mine) has occasionally removed a few tens of tons for local use. This mine, incidentally, is the only active mine in the Wind River Basin. It apparently is not operated every year.

Keefer and Troyer (1964) estimated at least 1.82 million tons of the Welton and less persistent coals remain in the vicinity of the Welton coal outcrop. All this tonnage lies under less than 1,000 feet of cover, and most of it is calculated on the Welton coal bed. Of this resource, 1.65 million tons occurs in beds greater than five feet thick, and qualifies to be termed reserve base. Although this entire resource lies within the boundary of the Wind River Indian Reservation, not all the coal rights are retained by the Indians.

In 1913, an analysis of a single channel sample of the Welton coal was made. Only 3.8 feet of the 12.2 feet thick coal, however, were analyzed (Lord, et. al., 1913). The apparent rank of this coal is subbituminous A.

	As-received basis
Moisture (%)	15.7
Volatile Matter (%)	28.5
Fixed Carbon (%)	47.7
Ash (%)	8.1
Sulfur (%)	0.35
Btu/pound	9,920

JACKSON HOLE COAL FIELD

The Jackson Hole Field in northwestern Wyoming is underlain by coal-bearing rocks over an area of about 700 square miles. This coal-bearing area is bounded by the Teton Mountains to the west, the Gros Ventre Mountains and Wind River Range to the south, and volcanics of the Absaroka Range and Yellowstone Plateau to the east and north (Figure 1).

Coals of minable thickness occur in the Upper Cretaceous Bacon Ridge Sandstone and Sohare sequence (Love and Christiansen, 1980; Love, 1973); the Paleocene Pinyon Conglomerate (Love, 1973; Love, et. al., 1951; Love, et. al., 1948), and the Wind River Formation (Berryhill, et. al., 1950).

In the southern half of the field, Love, et. al., (1948) report several coals near the base of the 1,000 feet thick Upper Cretaceous Bacon Ridge Sandstone. Where these coals coalesce, they form a single bed about 11.2 feet thick. This coal contains numerous noncoaly interbeds. The coals between these rock partings do not exceed 3.5 feet in thickness.

The Upper Cretaceous Sohare Sequence is a new name given to a previously unnamed coal-bearing sequence above the Bacon Ridge Sandstone (Love and Christiansen, 1980). This sequence is also about 1,000 feet thick and contains thirteen coal beds 2.5-5 feet thick and five beds 5-10 feet thick. The thickest coal is reportedly 8.3 feet in thickness (Berryhill, et. al., 1950). Love, et. al., (1948) described these coals from exposures in the southeastern part of the Jackson Hole Field.

According to Love, et. al., (1948) several thin coals also occur in Upper Cretaceous rocks above the Sohare sequence. Although these coals are up to 3 feet thick, 1-2 feet thick coals are more common. These coals are probably in the Mesaverde Formation.

The Paleocene Pinyon Conglomerate sometimes has a basal 50-140 feet thick coal-bearing member (Love, 1973). In the southern part of the coal field, Love, et. al., (1948) describe a 12.2 feet thick coal within the Pinyon. However, this thick coal is comprised of three benches of coal (2.8, 4.0, and 2.5 feet thick, respectively) separated by noncoaly rock interbeds.

The youngest coal in the Jackson Hole Field occurs at about the middle of the Wind River Formation (Love, 1947). A 63 feet thick coal was described by Love at that interval in the southeastern part of the field. The coal contains numerous shaly partings and has been prospected.

Because there are no published coal analyses from the Jackson Hole Field, the rank and quality of the coals are unknown. Berryhill, et. al., (1950) indicate, however, that the coals in this field look and weather similar to subbituminous coals. There is no active mining in the Jackson Hole Field.

BLACK HILLS COAL REGION

The Black Hills Coal Region is in the extreme northeastern corner of the state. The only minable coal bed in the region is apparently confined to the base of the Lower Cretaceous Lakota Conglomerate (Berryhill, et. al., 1950). To the east and north, the Lakota crops out on the flanks of the Black Hills Uplift. Downdip or north and westward, the Lakota Conglomerate extends beneath the Powder River Basin. The boundaries for this coal region are revised for this report (Figure 1). The downdip boundary in particular is drawn rather arbitrarily and could be altered as future drilling proves the presence or absence of the Lakota coal bed.

The region is divided into four coal fields originally defined on the bases of isolated coal-bearing Lakota outcrops. Some mining has occurred in each of the fields. All this mining has been underground. Revised boundaries for the Alladin, Sundance, Skull Creek, and Cambria fields are shown on Figure 2. There is no active mining in the coal region.

According to Berryhill, et. al., (1950), the unnamed Lower Cretaceous coal bed is up to ten feet thick. The coal is relatively persistent, but not present everywhere. One analysis of the coal shows 16.6 percent ash, 4.9 percent sulfur, and a heat value of 10,247 Btu/pound (Berryhill, et. al., (1950). The coal is reportedly high volatile C bituminous in rank and possesses some coking properties.

Although much of the coal is "mined out," there is undoubtedly some coal remaining. The remaining coal resources in this region are likely to be relatively deep and minable only by underground methods.

ROCK CREEK COAL FIELD

This relatively small field (450 square miles) lies in the north-central part of the Laramie Basin between the Laramie and Medicine Bow mountains. Although the field was last described in detail by Dobbin, et. al., (1929b) more recent geologic mapping in the area has been published by both the U.S. Geological Survey and the Geological Survey of Wyoming (Blackstone, 1970, 1973, and 1976; Hyden, 1965, 1966a, 1966b, 1966c; Hyden, King, and Houston, 1967; McAndrews, 1965a, 1965b, and 1966).

Coals occur in the Upper Cretaceous Mesaverde and Medicine Bow formations and in the Tertiary Hanna Formation. The Mesaverde coals are found in the basal part of the Pine Ridge Sandstone Member at the top of the Mesaverde. Although these coal beds are reportedly up to 18.5 feet thick (Fieldner, et. al., 1918), most average less than 5 feet. Up to four coals have been mapped in this member of the Mesaverde Formation.

Coals are also reported in the overlying Upper Cretaceous Medicine Bow Formation. Where these coals are mined, they were usually 3.5-5 feet thick. At one mine, a 15-foot thick Medicine Bow coal was described (Hyden, 19661). Most Medicine Bow coals, however, are described as thin and discontinuous.

Berryhill, et. al., (1950) refer to a 9.4 feet thick coal in the Hanna Formation. Most references to the coals in this Tertiary formation, however, suggest that beds seldom are more than 2-3 feet thick.

Limited analytical data, most of which is quite old, suggest as-received heat values of 8,400-9,600 Btu/pound might be expected at least for coals in the Mesaverde and Medicine Bow formations. At this time, reports show a subbituminous rank for the coals in the Rock Creek Coal Field, but there are not enough good analyses to substantiate coal rank.

There has never been any large scale coal mining in this field, and resumption of coal mining in the Rock Creek area is not anticipated in the near future.

GOSHEN HOLE COAL FIELD

The Goshen Hole Coal Field is located in the Denver Basin of southeastern Wyoming. As depicted on many maps, the field was originally limited to the outcrop of Laramie (Lance) Formation rocks in this area (Berryhill, et. al., 1951). Because the Laramie Formation underlies much of the Denver Basin, the boundaries of this field have been extended to include more deeply buried Laramie rocks as well (Figure 1). The coal-bearing rocks of this field also extend southward into Colorado and westward into Nebraska.

Very little has been published on the Goshen Hole Coal Field. Berryhill, et. al., (1950), summarized the information available for the area. Their summary documented that thin coals (2.5 to perhaps 5 feet thick) occur in the Laramie Formation of southeastern Wyoming. To the south in the Cheyenne Basin portion of the Denver Coal Region of Colorado, Laramie Formation coals occur in a 50-275 feet zone within the lower part of the Laramie (Kirkham and Ladwig, 1979). Individual coal beds in that area are typically 3-5 feet thick. The coals of the Laramie Formation, at least in Colorado, are subbituminous B to lignite A in rank. There is no analytical data on the coals in the Goshen Hole Field, and there is no active coal mining.

Table 5: Estimated original in-place coal resources in Wyoming by county and rank (modified after Berryhill, et. al., 1950) (millions of short tons).

County	Bituminous	Subbituminous	Total
Albany		293.59	293.59
Big Horn		17.90	17.90
Campbell[1]		69,033.84	69,033.84
Carbon[2]	2,193.94	2,749.58	4,943.52
Converse		4,153.97	4,153.97
Crook	1.15	8.64	9.79
Fremont[1]		883.89	883.89
Hot Springs		261.08	261.08
Johnson[1]		12,235.66	12,235.66
Lincoln	1,670.07	1,154.65	2,824.72
Natrona		192.88	192.88
Niobrara		14.31	14.31
Park	17.90	196.59	214.49
Sheridan[1]		24,461.42	24,461.42
Sublette	1.60	5.21	6.81
Sweetwater[1]	9,878.04	6,187.23	16,065.27
Teton	.26	121.91	122.17
Uinta	1,525.75	523.23	2,048.98
Washakie		88.21	88.21
Weston	39.94	285.37	325.31
Total	15,328.65	122,869.16	138,197.81[3]

[1]These figures have been changed to reflect resources delimited after Berryhill, et. al., (1950). See Culbertson and Mapel (1976); Glass and Roberts (1978); Hose (1955); Keefer and Troyer (1964); Mapel (1959); Masursky (1962); Olive (1957); Pipiringos (1961); Roehler (1979a, 1979b, 1979c); Smith, et. al., (1972); Thompson and White (1952).

[2]These figures reflect changes caused by a revision of the ASTM classification of coal rank since Berryhill, et. al., (1950). There are subbituminous resources in other counties that should also be changed to bituminous resources, but estimates of these resources have not been made.

[3]All these resources occur between 0-3,000 feet of cover.

COAL RESOURCES, PRODUCTION AND RESERVES

Wyoming's original in-place coal resources between 0 and 3,000 feet of overburden are now estimated at 138,197,810,000 short tons (modified from Berryhill, et. al., 1950). Approximately 11% of these resources are bituminous coal and 89% subbituminous coal. These resources, however, are based on only 47% of the known or probable coal-bearing land in Wyoming as they are limited to mapped and explored areas. When an estimate of the resources of the previously omitted 53% of the State's coal-bearing land is added to the mapped and explored estimate, the U.S. Geological Survey estimates that Wyoming's original resources under less than 3,000 feet of overburden increase to 838,197,810,000 tons. Wyoming's original resource figure becomes 938,197,819,000 tons when the overburden category is extended to 6,000 feet (modified from Averitt, 1975). In the 0 to 6,000 feet overburden category, Wyoming has the largest in-place coal resources in the nation at approximately one trillion tons.

Estimates of Wyoming's original in-place coal resources by major coal-bearing region and by county are given in Tables 5 and 6. The original resources in these two tables include mapped and explored bituminous coals 14 inches or greater in thickness and subbituminous coals 2.5 feet and thicker. Measured, indicated, and inferred categories are combined; overburden limits for these figures are 0 to 3,000 feet.

Table 6: Estimated original in-place coal resources in Wyoming by major coal-bearing area and rank (modified after Berryhill, et. al., 1950) (millions of short tons).

Coal-Bearing Area	Bituminous	Subbituminous	Total
Powder River Coal Basin[1]		110,218.95	110,218.95
Green River Coal Region[1]	9,904.84	7,207.29	17,112.13
Hams Fork Coal Region	3,197.68	1,676.86	4,874.54
Hanna Coal Field[2]	2,167.14	1,749.82	3,916.96
Wind River Coal Basin[1]		1,025.79	1,025.79
Bighorn Coal Basin	17.90	563.78	581.68
Rock Creek Coal Field		305.18	305.18
Jackson Hole Coal Field		121.49	121.49
Black Hills Coal Region	41.09		41.09
Total	15,328.65	122,869.16	138,197.81[3]

[1]These figures have been changed to reflect resources delimited after Berryhill, et. al., (1950). See references under Table 5.

[2]These figures reflect changes caused by a revision of the ASTM classification of coal rank since Berryhill, et. al., (1950). There are subbituminous resources in other coal-bearing areas that should also be changed to bituminous resources, but estimates of these resources have not been made.

[3]All these resources occur between 0-3,000 feet of cover.

NOTE: There has never been an estimate of the coal resources of the Goshen Hole Coal Field.

Table 7: Reported Wyoming coal production by county to January 1, 1981 (millions of short tons).

County	1980 Production[1]	Cumulative Production[2]	Estimated 1981 Production[3]
Albany	0	0.01	-
Big Horn	0	0.38	-
Campbell	61.41	180.33	73.7
Carbon	10.14	139.67	11.0
Converse	3.80	45.35	3.8
Crook	0	0.06	-
Fremont	0	3.81	-
Hot Springs	0.02	11.89	-
Johnson	0	0.46	-
Lincoln	4.93	94.11	5.0
Natrona	0	0.03	-
Niobrara	0	0	-
Park	0	0.04	-
Sheridan	4.29	74.48	4.0
Sublette	0	0.02	-
Sweetwater	10.40	236.73	10.5
Teton	0	0.01	-
Uinta	0	22.42	-
Washakie	0	L[4]	-
Weston	0	12.43	-
Tonnage reported by County	94.99	822.23	108.0
Miscellaneous tonnage not reported by County[5]	0	1.05	0
Grand Total	94.99	823.28	931.23

[1]Source: Wyoming State Inspector of Mines.

[2]Sources: U.S. Geological Survey, U.S. Bureau of Mines, and Wyoming State Inspector of Mines.

[3]Wyoming Geological Survey preliminary estimate (May, 1981).

[4]L means less than 200 tons.

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

Table 7 shows reported coal production by county.

Table 8 shows the total original resources of the state, production and mining losses, and remaining resources. Wyoming's coal reserve base is also shown as approximately 56 billion tons.[1] Wyoming's known strippable reserve base is shown in Table 9. This 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. Approximately 586 million tons of the remaining strippable reserve base is bituminous in rank.

[1]The U.S. Department of Energy (1981) lists Wyoming's reserve base at 70 billion tons. Broken down by rank, they show 4.5 billion tons is bituminous and 65.5 billion tons is subbituminous. On the basis of recovery methods, their reserve base estimate contains 42.6 billion tons potentially recoverable by underground mining and 27.4 billion tons potentially recoverable by surface mining. The inconsistency of these estimates with those shown in Tables 5, 6, 8, and 9 of this report have not yet been reconciled.

Table 8: Estimate of remaining coal resources and reserve base of Wyoming to January 1, 1981 (millions of short tons).

Categories of Original Resources, Production and Mining Losses	Mapped and Explored Areas (0-3000 Ft. Of Cover)	Mapped and Estimate of Unexplored Areas (0-6000 Ft. of Cover)
Original resources[1]	138,197.81	938,197.81
Production from strip mining[2]	434.18	
Production from deep mining[2]	389.12	
Total production	823.30	823.30
Losses due to strip mining (20% lost)	86.84	
Losses due to deep mining (equals production)	389.12	
Total production and mining losses	1,299.26	1,299.26
Remaining resources	136,898.55	936,898.55
Strippable reserve base[3]	26,332.40	
Underground reserve base[3]	29,483.54	
Total reserve base[3]	55,815.94	

[1]Sources: Modified from Berryhill, et. al., (1950). See Table 5 also.

[2]Sources: U.S. Geological Survey, U.S. Bureau of Mines, and Wyoming State Inspector of Mines.

[3]Sources: U.S. Geological Survey, U.S. Bureau of Mines, and Wyoming Geological Survey (Includes some new strippable reserve base).

Table 9: Remaining strippable coal reserve base of Wyoming to January 1, 1981 (modified from Smith, et. al., 1972).

Coal-Bearing Region Strippable Deposit	Apparent Rank	Coal Bed(s) (Average thickness in feet)	Acreage Estimate	Original Estimated Reserves to Jan. 1, 1979	Production and Mining Losses Since Jan. 1, 1969	Remaining Strippable Reserves to Jan. 1, 1981
Powder River Coal Basin						
Acme-Kleenburn[1]	Subbituminous	Monarch and Dietz No. 3 (23')	2,029.0	39,300,000	24,800,000	14,500,000
Clear Creek	Subbituminous	Canyon (11.2')	9,337.6	184,900,000	-	184,900,000
Dave Johnston	Subbituminous	School (38") Badger (16')	2,418.0 390.0	126,200,000 9,500,000	40,000,000	95,700,000
Dry Cheyenne	Subbituminous	F (7.6')	13,260.8	179,500,000	-	179,500,000
Lake DeSmet	Subbituminous	Lake DeSmet (163') Other Wasatch coals	3,520.0	1,000,000,000	-	1,000,000,000
Spotted Horse	Subbituminous	Felix (12.5') Smith (10.0') Local (10.0')	36,736.0	480,700,000 178,000,000 58,300,000	- - -	480,700,000 178,000,000 58,300,000
Sussex	Subbituminous	Fort Union Fm. coal (11.8')	651.0	13,600,000	-	13,600,000
Wyarno-Verona	Subbituminous	PK (11') Ulm 2 (20') Ulm 1 (30') Other Wasatch coals (10'+)	28,000.0+	200,000,000 990,000,000 543,000,000 67,000,000	- - - -	200,000,000 990,000,000 543,000,000 67,000,000
Wyodak	Subbituminous	Wyodak (71') Anderson (D) Canyon (E)	155,282.0	19,000,000,000	203,100,000	18,796,900,000
		Subtotal	251,624.4+	23,070,000,000	267,900,000	22,802,100,000
Green River Coal Region						
Black Buttes	Subbituminous	Almond, Lance, Ft. Union, and Wasatch Fm. coals (12')	3,889.0	82,600,000	5,900,000	76,700,000
Creston-Cherokee[1]	Subbituminous	Upper Cherokee (B) (11') Lower Cherokee (C) (25') Other Ft. Union Fm. coals	4,204.0+	360,000,000	-	360,000,000
Jim Bridger	Subbituminous	Deadman (30')	4,708.0	250,000,000	34,700,000	215,300,000
Leucite Hills[1]	Subbituminous	Ft. Union Fm. coals		168,000,000	-	168,000,000
Northern Little Snake River[1]	Subbituminous	Ft. Union Fm. Coals (15'); Lance Fm. coals (8')	12,661.0	223,600,000	-	223,600,000
	Bituminous	Mesaverde Fm. coals (6')	3,240.0	46,000,000	-	46,000,000
Red Desert	Subbituminous	Battle 2 & 3 (7') Sourdough, Monument, and Tierney (6.8') Hadsell 2 (7.7') Creston 2 & 3 (14') Latham 3 & 4 (5.7')	2,938.0 27,469.0 2,874.0 3,846.0 6,893.0	38,100,000 458,900,000 39,800,000 125,600,000 70,700,000	- - - - -	38,100,000 458,900,000 39,800,000 125,600,000 70,700,000
Salt Wells[1]	Subbituminous	Almond Fm. coals (6'+)		60,000,000		60,000,000
		Subtotal	72,722.0+	1,923,300,000	40,600,000	1,882,700,000

Table 9 (continued)

Hams Fork Coal Region						
Adaville	Subbituminous	Adaville Fm. coals (44')	12,800.0	1,000,000,000	46,900,000	953,100,000
South Haystack[1]	Subbituminous	Adaville Fm. coals (40')	1,544.0	64,800,000	-	64,800,000
		Subtotal	14,344.0	1,064,800,000	46,900,000	1,017,900,000
Hanna Coal Field						
Carbon Basin[1]	Bituminous	Finch (10') Johnson (10') Other Hanna Fm. coals	2,725.0+	118,900,000[2]	-	118,900,000
Hanna Basin[1]	Bituminous	Hanna Fm. coals (14')		273,900,000[2]	18,400,000[3]	255,500,000
	Subbituminous	Ferris Fm. coals (10')	8,400.0+	238,500,000[2]	18,900,000[3]	219,600,000
	Subbituminous	Medicine Bow Fm. coals (6')		1,100,000[2]	-	1,100,000
	Bituminous	Mesaverde Fm. coals (6')		16,000,000[2]	-	16,000,000
		Subtotal	11,125.0	648,400,000[2]	37,300,000[3]	611,100,000
Bighorn Coal Basin						
Grass Creek	Bituminous	Mayfield (25')	420.30	18,600,000	-	18,600,000
		Subtotal	420.30	18,600,000	-	18,600,000
		GRAND TOTAL	350,235.70+	26,725,100,000	392,700,000	26,322,400,000

[1] Includes new reserve base derived from company reports and/or government publications.

[2] Original estimated reserves to January 1, 1978.

[3] Production and mining losses since January 1, 1978.

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