THE GEOLOGICAL SURVEY OF WYOMING

Daniel N. Miller, Jr., State Geologist

PUBLIC INFORMATION CIRCULAR No. 9

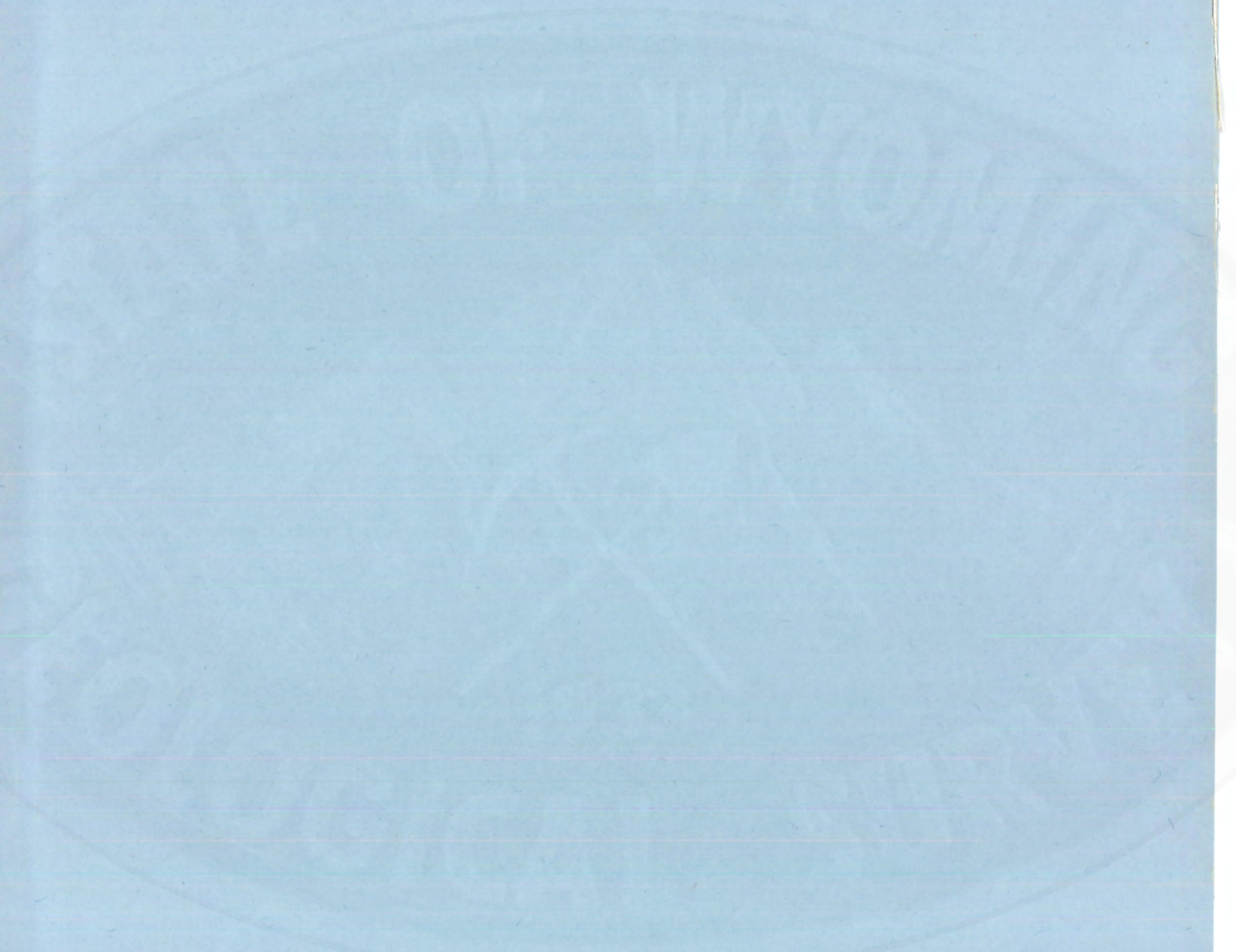
WYOMING COAL FIELDS, 1978

by

Gary B. Glass

LARAMIE, WYOMING

1978



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INTRODUCTION

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 Plains Province while all other coal deposits of the State are in the Rocky Mountain Province. Additionally, the United States Bureau of Mines designates Wyoming as coal-producing District 19. Beyond these national designations, the State's coal-bearing areas are divided into the following 10 major regions, basins, or fields, which underlie more than 40,000 square miles or approximately 41 percent of the state and which collectively contain about 24 percent of the nation's coal resources under less than 6000 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 eight are in the Bighorn Basin. The Wind River and Green River regions 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 regions are single coal fields. Revised boundaries for many of these fields are shown in Figure 2.

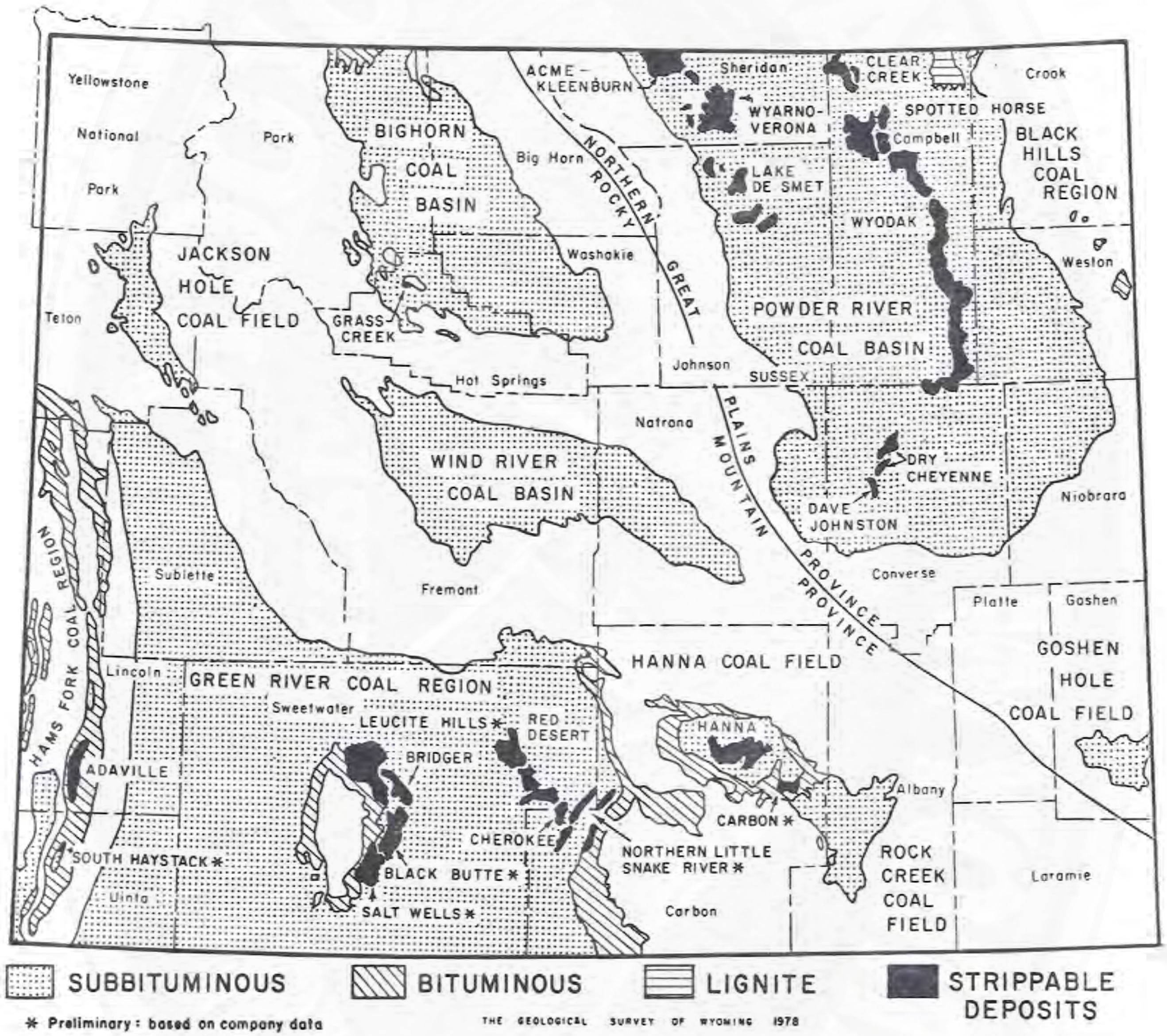
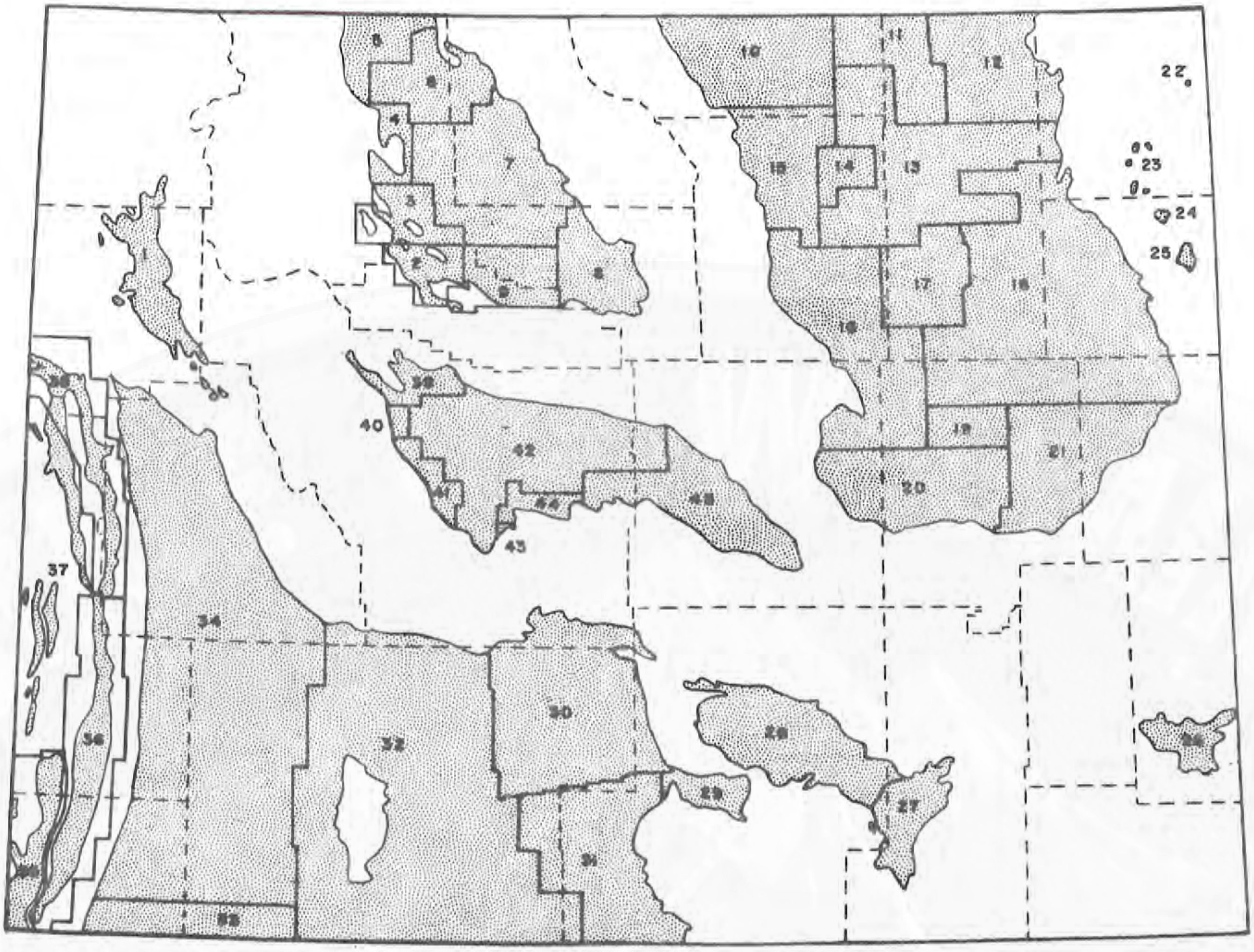


Figure 1. Wyoming Coal-Bearing Areas.



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

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, each usually ranging from 700 to 7000 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 usually crop out only as narrow bands of upturned rock around the margins of the larger structural basins and uplifted areas of the state. They also crop out as irregularly exposed, linear bands in the 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 reaches 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 cor-

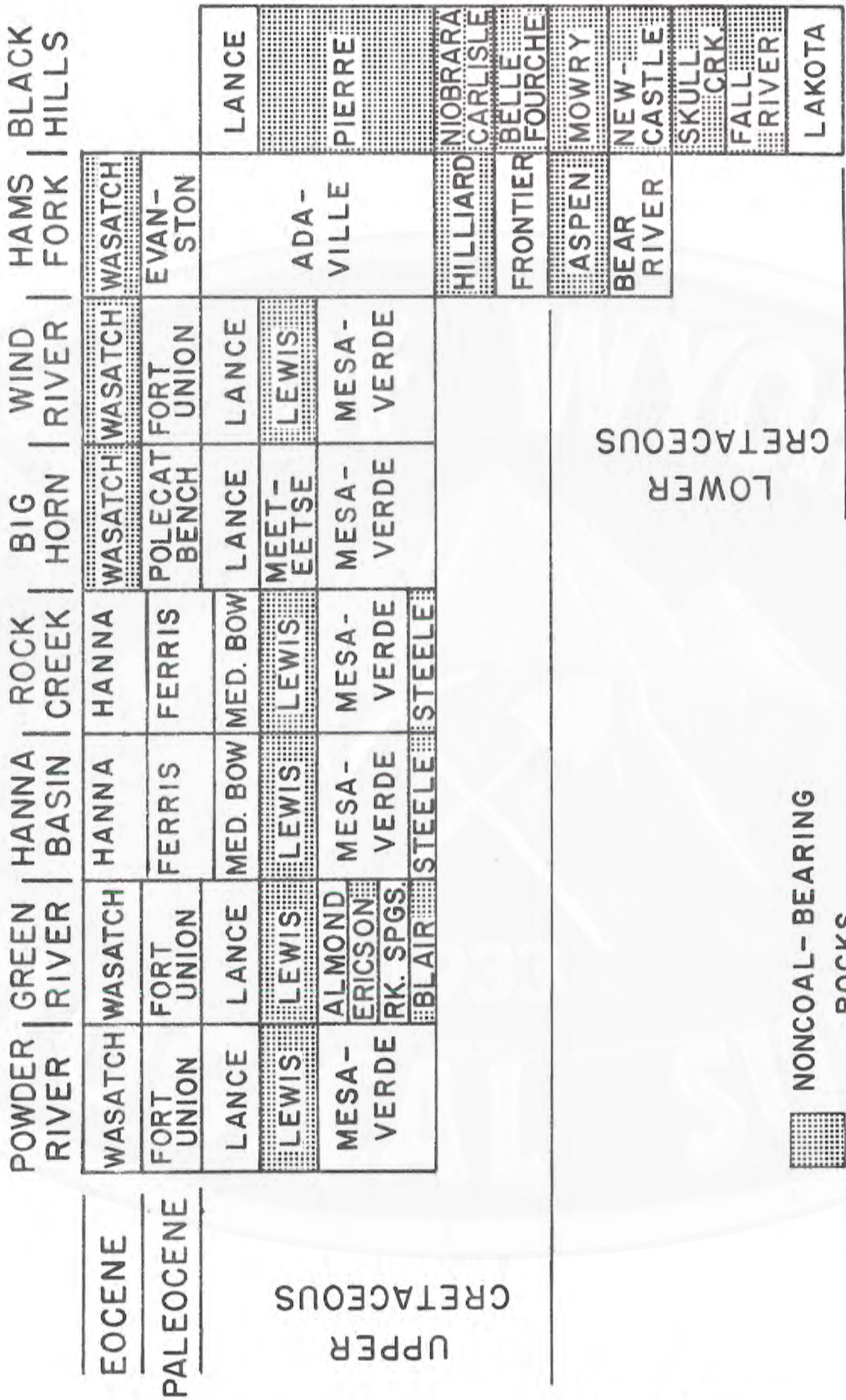


Figure 3. Major Coal-Bearing Formations in Wyoming.

relation 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: In review, 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 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 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 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 throughout the rest of the state. The Mesaverde disappears before it reaches half way across the Powder River Basin, and only exhibits very thin coals on the southern flank of the 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 (or its equivalent, the Medicine Bow Formation of the Hanna Field) contains coal throughout the state, Lance coals are best developed in southern Wyoming. There they are numerous, but seldom reach more than 10 feet in thickness.

Paleocene: Paleocene rocks (variously mapped as the Fort Union, Polecat Bench, or Evanston formations) crop out in all but the Black Hills Region and Goshen Hole Field. Paleocene rocks invariably contain coals, although these coals are most prolific in the Powder River Basin and Hanna Field. 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 three to four times as thick as the thickest coals in the Hanna Field, which run as high as 36 feet thick.

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 Healy coal. Wasatch or equivalent 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 ranges from 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 the Rock Springs Uplift, along the eastern edge of the Green River Region, and on the periphery of the Hanna Coal Field. The Mesaverde coals in the north end of the Bighorn Basin and the Lower Cretaceous coal 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 lies deeply buried. All known bituminous coals in Wyoming are Cretaceous in age.

While the older coal beds in any given field are generally higher in rank than the younger beds, the rank of individual beds 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).

Proximate Analysis 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 high rank 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 and 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 and 30 percent and about equal volatile matter and fixed carbon contents.

Ash and sulfur contents are characteristically low and are related to the depositional histories of the coals rather than to any differences in rank. Consequently, variation in ash content, in particular, is quite irregular. As-received ash content ranges from a few percent to more than 50 percent in response to the volume of inorganic debris entering the original peat swamp. Published analyses of various coals sampled across the state, however, sug-

TABLE 1: WYOMING COAL CHARACTERISTICS

Geographic Area	*Rank*	*Bed Thicknesses (Feet)*	*Moisture[1] (%) (AR)*	*(Ash[1] %) (AR)*	*Sulfur[1] (%)*	*Heat Value[1] (Btu/lb.) (AR)*	*Hardgrove Grindability Index[1]*
Northeastern Wyoming	Lignite Subbituminous[1] Bituminous	Max.: 220 Range[1]: 12-100 Avg.[1]: 70	Range 20.3-29.8 Average 26.3	Range 4.4-11.4 Average 7.9	Range 0.45-0.6 Average 0.54	Range 7550-8700 Average 8300	Range 30-53 Average 45
Southern Wyoming	Subbituminous[1] Bituminous[1]	Max.: 50 Range[1]: 4-35 Avg.[1]: 20	Range 10.2-20.5 Average 12.4	Range 4.2-12.2 Average 7.1	Range 0.4-0.9 Average 0.52	Range 9270-11,700 Average 10,500	Range 45-80 Average 49
Western Wyoming	Subbituminous[1] Bituminous	Max.: 110 Range[1]: 5-90 Avg.[1]: 16.5	Range 20.4-20.9 Average 20.8	Range 3.0-4.8 Average 4.5	Range 0.6-0.7 Average 0.6	Range 9500-10,200 Average 9600	Range 53-57 Average 54
Northcentral Wyoming	Subbituminous[1] Bituminous	Max.: 50 Range[1]: 15-20 Avg.[1]: 13	Range 10.7-12.8 Average 12.3	Range 5.0-9.4 Average 7.4	Range 0.3-0.6 Average 0.4	Range 10,730- 11,246 Average 10,970	Range 30-80 Average 49

[1]Beds currently mined. (Table compiled by Geological Survey of Wyoming, March 1978.)
(AR) = As Received

gest 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 (Deurbrouck, 1971).

More than 99 percent of Wyoming's total known coal resources contain less than 1 percent sulfur, and about one-half of that is less than 0.7 percent. Forty percent of Wyoming's reserve base contain less than 0.7 percent sulfur (Hamilton *et al.*, 1975).

In Wyoming coals the sulfate form of sulfur averages less than 0.03 percent (3-5 percent of the total sulfur); the pyritic form averages less than 0.2 percent (25-29 percent of the total sulfur); the organic form averages less than 0.47 percent (70-72 percent of the total sulfur) (Walker and Hartner, 1966). Because most of the sulfur in Wyoming's coal 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.

The state's highest sulfur coals occur in the Green River Coal Region. Although these Wasatch Formation coals are not being mined, exploration has shown sulfur contents as high as 7 percent. However, on an as-received basis, published analyses of Wyoming's Cretaceous coals usually show 0.9-2.0 percent sulfur compared to 0.3-0.9 percent sulfur in the state's Tertiary coals. Because of contract demands, the sulfur contents of mined coals average 0.5 percent and rarely exceed 1.0 percent (Table 1).

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 range 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 Btu/lb., the heat values in northeastern Wyoming are much lower. Although heat values in northeastern Wyoming coals range 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 range between 14,400 Btu/lb. and 11,000 Btu/lb., while the subbituminous coals range between 8,400 Btu/lb. and 13,000 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 foot 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.

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	<0.001-0.130	0.038	.08
Phosphorous	<0.0021-0.0440	0.0121	----
Chlorine	<0.004-0.026	<0.010	----
Manganese	<0.0007-0.0492	0.004	.01

Trace Elements

Of the 30 trace elements recognized in some 48 analyses of Wyoming coals, concentrations of the various elements range from a high of 1000 parts per million to a low of 0.004 parts per million. If these elements are grouped according to their average concentrations of a whole-coal basis, 6 elements average less than 1 part per million, 12 elements range between 1 and 5 parts per million, 11 elements range between 5 and 100 parts per million, and one element, barium, averages more than 300 parts per million (Table 3).

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

Based on these 48 published analyses, Tertiary 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).

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

Carbonizing Properties

Most Wyoming coals are nonagglomerating and may be carbonized in fluidized systems. Chars produced at low temperatures contain about 17 to 23 percent 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, 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 range from 14 to 40 gallons/ton of raw coal processed (Landers, 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 most of the recoverable Cambria coal has already been removed. Reserves of this bed are believed to be very small (Berryhill *et al.*, 1950). The Middle Main bed in the Kemmerer Field ranges 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 ranges 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 Pocatello, Idaho plant. 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-size 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	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 ranged 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/cubic foot (Brandenburg and others, 1976). Currently, the main constituent of the gas is 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 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 and 6 million cubic feet per day. Also, oxygen was injected into the burn, raising the heat value of the produced gas to 270 Btu/cubic foot.

In addition to these two ongoing projects, both Gulf Research and Development and Atlantic Richfield are planning 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. Gulf's test site is located near Rawlins in southcentral Wyoming.

Atlantic Richfield plans to conduct its own experiment on a 100-foot-thick coal bed near Reno Junction in northeastern Wyoming. Arco's experiment should commence in 1978.

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 1977 tonnage set yet another record at 44,046,842 tons. With this tonnage, Wyoming remains the largest coal-producing state in the Rocky Mountains and the 6th largest in the nation. In 1978 production will probably exceed 60 million tons. Present indications suggest annual tonnage will be about 70 million tons in 1979 and 100 million tons by 1980. 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 period 1971-1980 will almost equal 110 years of previous mining.

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 99 percent of Wyoming's annual production. Conversely, underground mining has slipped to 1 percent of the annual tonnage mined.

In 1977, eighteen coal mining companies produced 44 million tons of coal. These companies operated 17 strip mines and 3 underground mines. Two of the underground (deep) mines accounted for 99 percent of the underground tonnage of 624,313 tons. Six of the strip mines produced in excess of 2.5 million tons each thus accounting for 69 percent of the strip mine tonnage (43,422,529). Amax Coal Company's Belle Ayr strip mine became the largest coal mine in the United States in 1977, producing 13.3 million tons.

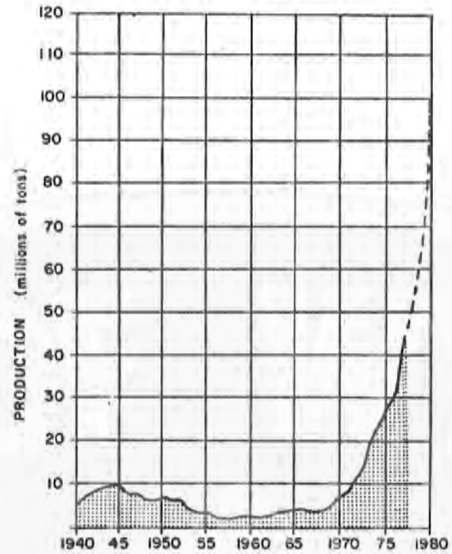


Figure 4. Wyoming Coal Production 1940-1977, With Projections to 1980.

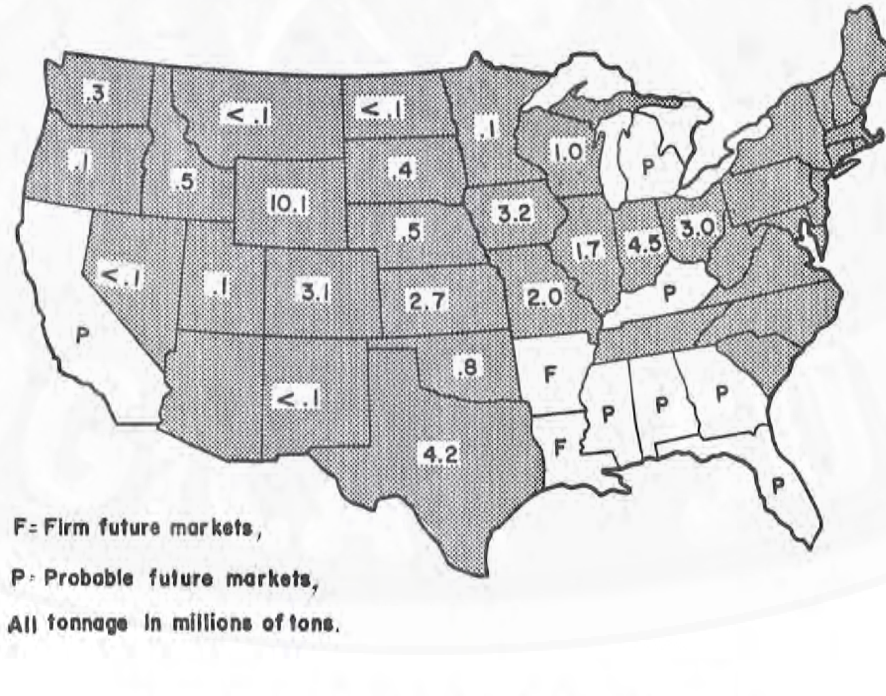


Figure 5. 1977 Markets for Wyoming Coal.
F = Firm Future Markets,
P = Probable Future Markets.
All tonnage in millions of tons.

TABLE 4. WYOMING COAL PRODUCTION BY MINE

Company	*Mine Name*	*Em-ploy-ees*	*Production 1976*	*Em-ploy-ees*	*Production 1977*
Amax	Belle Ayr (strip)	224	7,233,000	339	13,303,000
Arch Mineral	Seminoe No. 1 (strip)	160	2,715,723	174	2,242,137
	Seminoe No. 2 (strip)	100	2,660,931	232	2,543,900
Ash Creek Mining	PSO No. 1 (strip)	---	---------	23	Under Con-struction
Big Horn	Big Horn No. 1 (strip)	100	730,678	132	2,394,532
Black Butte	Black Butte (strip)	---	---------	16	Under De-velopment
Bridger	Jim Bridger (strip)	129	3,567,058	196	5,448,953
Carter Mining	Rawhide (strip)	191	Under Con-struction	131	1,096,240
	Caballo (strip)	---	---------	129	Under Con-struction
Columbine Mining	Rainbow No. 8 (deep)	94	119,086	102	6,377
Energy Development	Vanguard No. 2 (deep)	220	303,155	231	387,936
FMC	Skull Point (strip)	78	84,524	60	718,789
Glenrock Coal	Dave Johnston (strip)	132	2,714,326	133	3,236,616
Kemmerer	Elkol (strip)	169	1,845,658	183	1,654,409
	Sorenson (strip)	285	2,276,799	313	2,730,656
Kerr-McGee	Jacobs Ranch	---	---------	106	Under Con-struction
Medicine Bow	Medicine Bow (strip)	152	2,773,856	183	1,200,000
Northwestern Resources	Grass Creek (strip)	2	1,686	1	1,607
Prospect Point	Commercial stockpile and tipple	---	---------	12	Unknown
Resource Exploration	Section 25 (strip)	82	829,372	82	1,017,003
Rosebud Coal Sales	Rosebud (strips)	165	2,270,894	197	2,806,239
Stansbury	Stansbury (deep)	82	101,652	135	230,000
SUNEDCO	Cordero (strip)	66	10,338	56	2,128,545
Thunder Basin (ARCO)	Black Thunder (strip)	41	Under Con-struction	110	42,865
Welch	Welch (strip)	2	8,640	0	Closed
Wyodak Resources	Wyodak (strip)	37	838,216	38	857,038
		2,511	31,085,592	3,314	44,046,842

Source: State Inspector of Mines.

The locations of mines operational in 1977 are summarized below:

Powder River Coal Basin

Powder River Field: Wyodak Resources and Development (Wyodak strip--T.50N., R.71W.); Carter Mining Company (Rawhide strip--T.41N., R.72W.)

Gillette Field: Amax Coal Company (Belle Ayr strip--T.48N., R.71W.); Sunoco Energy Development Company (Cordero strip--T.47N., R.71W.); Thunder Basin Coal Company (Black Thunder strip--T.43N., R.70W.)

Sheridan Field: Big Horn Coal Company (Big Horn No. 1 strip--T.47N., R.84W.)

Glenrock Field: Glenrock Coal Company (Dave Johnston strip--T.36N., R.75W.)

Green River Coal Region

Rock Springs Field: Bridger Coal Company (Jim Bridger strip--T.21N., R.100W.); Columbine Mining Company (Rainbow No. 8 deep mine--T.18N., R.105W.); Stansbury Coal Company (Stansbury deep mine--T.20N., R.104W.)

Hanna Coal Field: Energy Development Company (Vanguard No. 2 deep mine--T.22N., R.82W.); Resource Exploration and Mining, Inc. (Section 24 strip--T.22N., R.82W.); Rosebud Coal Sales Company (Rosebud Pit Nos. 4, 4S, 5, 6, 7, 8, and 9--T.22-23N., R.80-81W.); Arch Mineral Corporation (Seminoe No. 1 strip--T.22N., R.83W.; Seminoe No. 2 strip--T.22N., R.81W., Seminoe No. 2 North strip or Simplot North--T.23N., R.82W.; Seminoe No. 2 West strip or Simplot West--T.22N., R.81W.); Medicine Bow Coal Company (Medicine Bow strip--T.23N., R.83W.)

Hams Fork Coal Region

Kemmerer Field: Kemmerer Coal Company (Sorenson strip--T.21N., R.116W.; Elkol strip--T.21N., R.116W.); FMC (Skull Point strip--T.20N., R.117W.)

Bighorn Coal Basin

Grass Creek Field: Northwestern Resources (Grass Creek strip--T.46N., R.116W.)

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

An estimate of the total coal production from Wyoming to January 1, 1978, is 596.66 million tons of which 65 percent or 386.05 million tons came from underground mines and 35 percent or 210.61 million tons came from surface mines.

In 1977, about 67 percent, or 29.9 million tons of the coal mined in Wyoming went to power plants in at least 19 other states, located as far west as Washington, as far south as Texas and Oklahoma, and as far east as Indiana, Illinois, and Ohio (Figure 5). Another 26 percent, or 11.3 million tons was burned in Wyoming power plants. Industrial customers used the remaining 7 percent. The beet sugar, cement, and phosphate industries were the major out-of-state industrial users, with about 1.4 million tons shipped to various plants throughout the Rocky Mountain region. Another 1.5 million tons were used to manufacture trona, cement, and synthetic coke in Wyoming.

By 1980, Wyoming coal will also be shipped to Arkansas, Louisiana, and perhaps Mississippi, Alabama, Florida, Georgia, Michigan, and California.

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 Cedar Ridge Anticline. Because the axis of this syncline 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 Creatceous 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 some 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 ranges between 2,000 and 3,000 feet thick, is perhaps the most prolific coal-bearing rock unit in Wyoming. Although the lower members of the formation contain 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-Anderson 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-Anderson 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 De Smet on the west side of the basin. There, the Healy 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.

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 coal in the Gillette area to form the 70-125 feet thick Wyodak-Anderson coal, which crops out on the eastern side of the basin (Denson and Keefer, 1974). Northward, eastward, and southward, the Anderson splits off the Wyodak-Anderson 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.

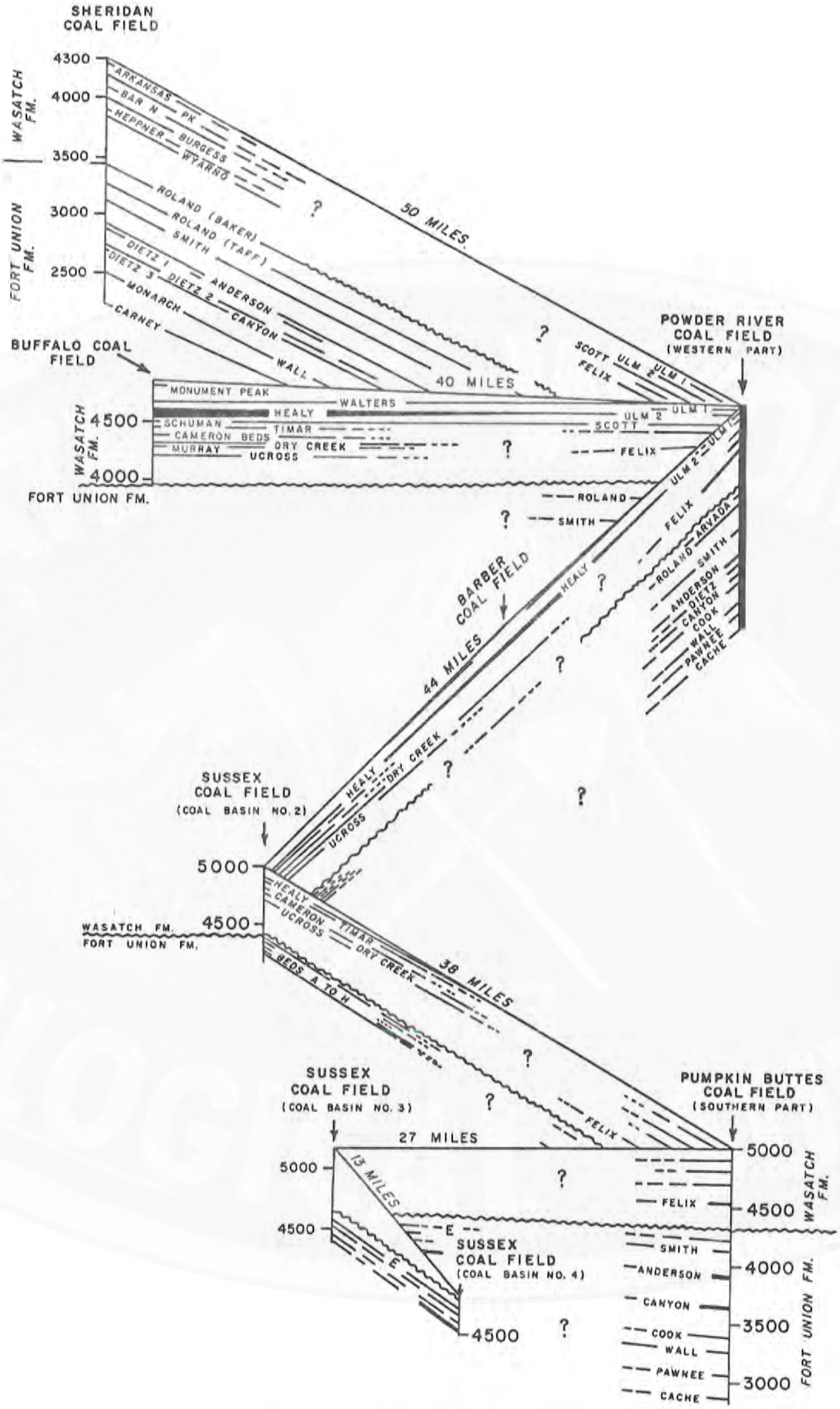
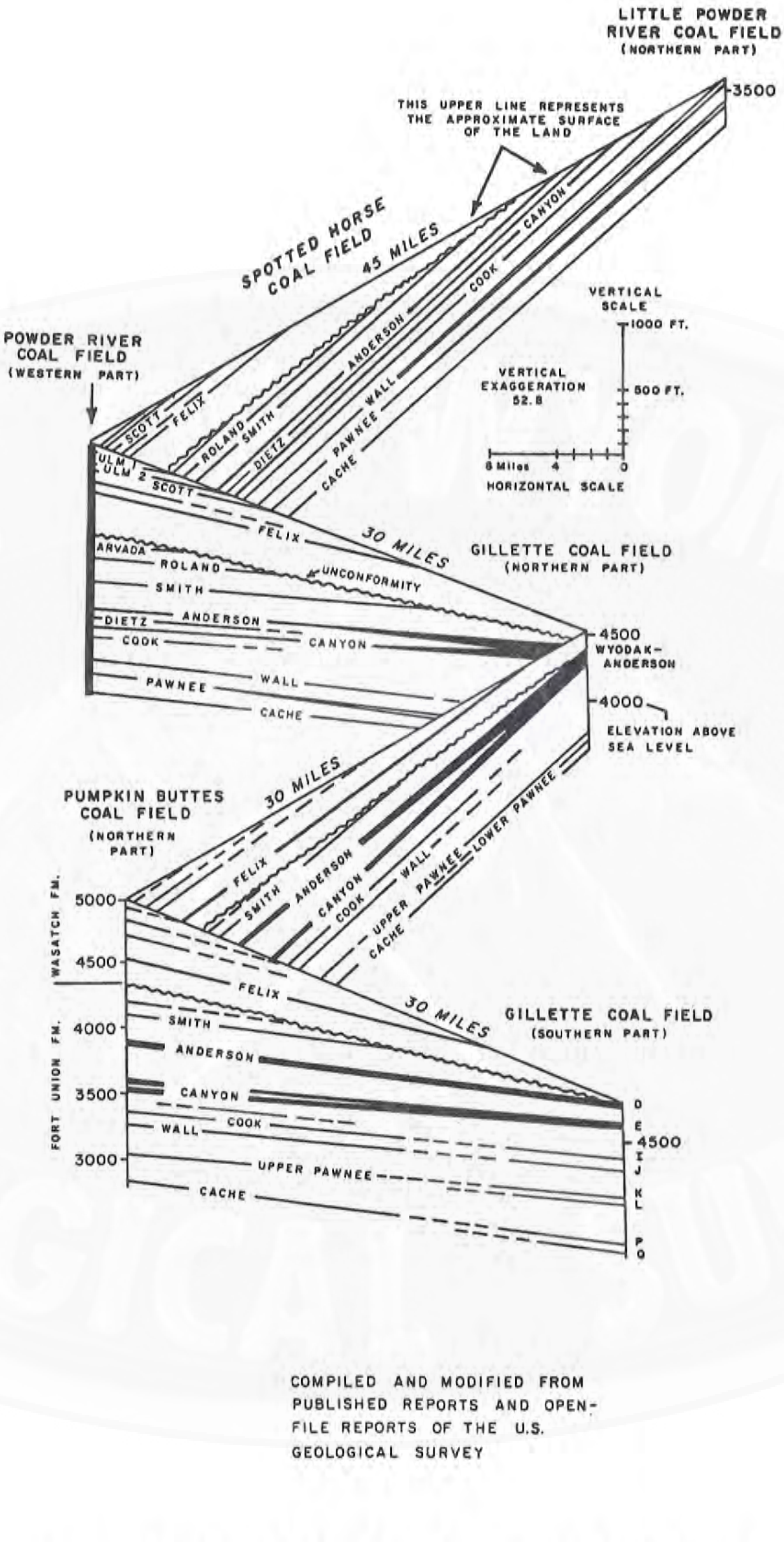


Figure 6. Correlation of Coal Beds in the Powder River Coal Basin.



Compiled and Modified From Published Reports and Open-File Reports of the U.S. Geological Survey

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-Anderson bed.

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

As Received Basis	*Range (9 analyses)*	*Average*
Moisture (%)	24.9-34.1	29.5
Volatile Matter (%)	26.5-34.5	30.1
Fixed Carbon (%)	29.0-38.0	33.9
Ash (%)	3.5-12.2	6.5
Sulfur (%)	0.17-1.13	0.52
Btu/pound	7,128-8,737	7,979

Badger Coal Bed

This is a subbituminous coal best developed in the Glenrock Field. The coal occurs at the top of the Fort Union Formation, but has not yet been correlated with coals in other fields.

The Badger coal is 17 to 20 feet thick and is normally 110-180 feet above the School bed. The U.S. Bureau of Mines conservatively estimates that there are at least 9.5 million tons of strippable reserve base on this bed in Converse County (Smith *et al.*, 1972). To date, very little of this reserve has been mined.

The Badger coal is strip mined in Glenrock Coal Company's Dave Johnston strip 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 analyses)*	*Average*
Moisture (%)	22.7-29.3	27.4
Volatile Matter (%)	31.7-34.5	33.3
Fixed Carbon (%)	28.5-32.6	31.4
Ash (%)	6.6-9.8	7.9
Sulfur (%)	0.4-0.5	0.45
Btu/pound	7,606-8,290	7,951

Canyon Coal Bed

The subbituminous Canyon coal is a persistent bed over all but the southern and western flanks of the basin. In the Gillette area of Campbell County, the Canyon coalesces with the Anderson bed to form the thick Wyodak-Anderson coal (70-125 feet) which crops out on the eastern side of the basin (Figure 6).

Where it is not joined with the Anderson coal, the Canyon is 11 to 65 feet thick. The Canyon bed of the Fort Union Formation is correlated with the E coal bed of the southern part of the Gillette Field and with the Dietz No. 3 bed of the Sheridan Field. The Canyon is not correlative with the stratigraphically higher Smith bed as previously reported.

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-Anderson estimates. Currently, the Canyon coal is only mined near Gillette, where it is merged with the Anderson bed.

The nine Canyon core analyses summarized below are from Campbell County. Dietz No. 3 analyses from Sheridan County are not averaged with these because the quality of the Canyon in the two counties is quite different (see also Dietz No. 3).

As Received Basis	*Range (9 core analyses: U.S. Geological Survey, 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	8,286

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 analyses)*
Moisture (%)	21.7-23.8
Volatile Matter (%)	33.6
Fixed Carbon (%)	38.5
Ash (%)	5.6-6.6
Sulfur (%)	0.74-1.02
Btu/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, which is correlative with the Canyon coal of the eastern Powder River Basin, coalesces with the underlying Monarch (Wall) coal bed to form a 40-45 feet thick coal in the Sheridan area (Figure 6).

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 exceeds 32 million tons (Smith *et al.*, 1972).

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 (Glass, 1976).

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 bed.

Felix Coal Bed

This is an important coal bed in the northern and eastern portions of the Powder River Basin. This Wasatch Formation coal ranges from 5 to 21 feet in thickness 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. Lawrence Livermore Laboratory, however, is conducting an in situ gasification experiment in this coal south of Gillette.

Analyses of 42 core samples are summarized below.

As Received Basis	*Range (42 cores U.S. Geological Survey, 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 (Glass, 1976). 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. Coals mined near Big Muddy and Casper were all less than five 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 analyses)*	*Average*
Moisture (%)	19.9-27.2	23.4
Volatile Matter (%)	29.7-49.3	35.9
Fixed Carbon (%)	20.3-41.3	34.0
Ash (%)	4.8-10.6	6.8
Sulfur (%)	0.40-0.97	0.66
Btu/pound	7,695-9,270	8,742

Healy Coal Bed

The Healy coal is locally the thickest coal bed in Wyoming, or the United States for that matter. In the Buffalo Field of Johnson County, the Healy is 5-25 feet thick at outcrop, but is reportedly as much as 220 feet thick in some drill hole descriptions (Mapel, 1959). Upper portions of this Wasatch Formation coal bed, however, are frequently burned over much of the Buffalo Field.

Tentatively, the Healy bed of the Buffalo Field is correlated with the Ulm No. 2 coal in other fields to the north and east of that area (Culbertson and Mapel, 1976) (Figure 6).

The strippable reserve base of the Healy coal is approximately one billion tons according to Smith, *et. al.*, (1972). Most of these reserves are in the Lake De Smet area or southeast of there. The coal is 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 analyses)*[1]	*Average (5 analyses)*
Moisture (%)	22.6-30.7	28.5
Volatile Matter (%)	28.6-31.9	30.0
Fixed Carbon (%)	32.8-34.8	33.9
Ash (%)	5.1-22.1	7.6
Sulfur (%)	0.26-3.00	0.6
Btu/pound	6,480-8,270	7,884

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

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 only ranged from 1.8 to 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 analyses)*	*Average*
Moisture (%)	19.8-24.1	21.9
Volatile Matter (%)	33.6-41.4	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

Monarch Coal Bed

The subbituminous Monarch coal is one of the most important Fort Union Formation coals in the Sheridan Field. Although it reportedly ranges up to 57 feet in thickness, 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 Wall coal to the east of Sheridan (Figure 6).

The U.S. Bureau of Mines estimates that there are 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 the Dietz No. 3 coal.

As Received Basis	*Range (203 analyses)*	*Average*
Moisture (%)	14.5-26.0	21.5
Volatile Matter (%)	30.3-38.4	34.5
Fixed Carbon (%)	34.9-44.0	39.6
Ash (%)	3.1-8.2	4.4
Sulfur (%)	0.3-0.7	0.4
Btu/pound	9,000-10,410	9.600

PK, Ulm 2, 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 to 30 feet in thickness. Culbertson and Mapel (1976) equate this coal bed with the thick Healy coal of the Lake De Smet deposit in Johnson County (Figure 6). The Ulm 1 lies 60-200 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, though extensively burned in both Sheridan and Johnson 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 used 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 analyses)*	*Average*
Moisture (%)	27.4-30.7	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, which is 110 to 180 feet below the Badger coal in the Glenrock Field, is subbituminous in rank and occurs near the top of the Fort Union Formation. Its correlation with coals in the more northern fields remains problematic.

The coal ranges 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.

The U.S. Bureau of Mines estimates that there are at least 126.2 million tons of strippable reserve base of this coal in Converse County (Smith *et al.*, 1972).

NERCO's subsidiary, Glenrock Coal Co., 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 analyses)*	*Average*
Moisture (%)	19.5-26.4	22.2
Volatile Matter (%)	34.4-38.1	35.9
Fixed Carbon (%)	28.3-33.6	30.5
Ash (%)	8.8-15.7	11.4
Sulfur (%)	0.5-0.7	0.6
Btu/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 5-13 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, a local unnamed coal, which is 4.5-13 feet thick, underlies the Smith coal by 30 feet. There are an estimated 178 million strippable tons of the Smith coal bed and another 58.3 million strippable tons of the local coal 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 Formation than the Canyon bed.

A single core analysis of the Smith coal bed is below.

As Received Basis	*Core Analysis (U.S. Geological Survey, 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 1 Coal Bed: See discussion under PK coal bed.

Ulm 2 Coal Bed: See Healy coal bed and discussion under PK coal bed.

Wall Coal Bed: See Monarch coal bed.

Walters Coal Bed: See discussion under PK coal bed.

Wyodak-Anderson 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. Recent geologic mapping by the U.S. Geological Survey now shows that this coal bed does not correlate with the stratigraphically higher Roland and Smith coals, as previously reported (Figure 6). The Wyodak-Anderson is actually the Anderson and Canyon coals coalesced into one (Denson and Keefer, 1974).

The coal is subbituminous, ranges between 25 and 125 feet thick, and probably averages 70 feet in thickness. It commonly has an 8 inch parting 38 feet above its base, which marks the contact between the Anderson and Canyon coals.

The Wyodak-Anderson coal separates into the Anderson and Canyon coal beds to the west with the two beds each 10-65 feet thick. To the north, the Wyodak-Anderson splits into five or more beds varying from 5 to 31 feet in thickness and each separated by 4 to 33 feet of claystone and shale. The coal bed also splits into the D bed (Anderson coal) and the E bed (Canyon coal) southward from Gillette (Figure 6).

The strippable reserve base of this Fort Union Formation coal is the largest for any single 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 36.7 million tons of these original strippable reserves. A conservative estimate projects another 175 million tons of the Wyodak-Anderson coal will be strip mined by 1980. By 1985, an estimated 565 million tons will have been mined from 9 to 11 large strip mines in Campbell County.

Amax Coal Company's Belle Ayr mine, Wyodak Resources' South Pit, Sunedco's Cordero mine, Carter's Rawhide mine, Kerr-McGee's Jacobs Ranch mine, and Arco's Black Thunder mine are the only active strip mines on the Wyodak-Anderson coal. Kerr-McGee, Carter, Mobil-Consolidation, Amax, Arco, and others have additional strip mines planned on this bed. Most of these mines will be 5-20 million ton per year mines, and will be located in Campbell County.

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

As Received Basis	*Range (59 analyses)*	*Average*
Moisture (%)	21.1-36.9	29.8
Volatile Matter (%)	26.5-35.5	30.7
Fixed Carbon (%)	29.6-41.4	33.5
Ash (%)	3.9-12.2	6.0
Sulfur (%)	0.2-1.2	0.5
Btu/pound	7,420-9,600	8,244

GREEN RIVER 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 degrees; and on the eastern side, 10 degrees. Along the eastern margin of the region, dips range between 20 degrees and 50 degrees in some areas.

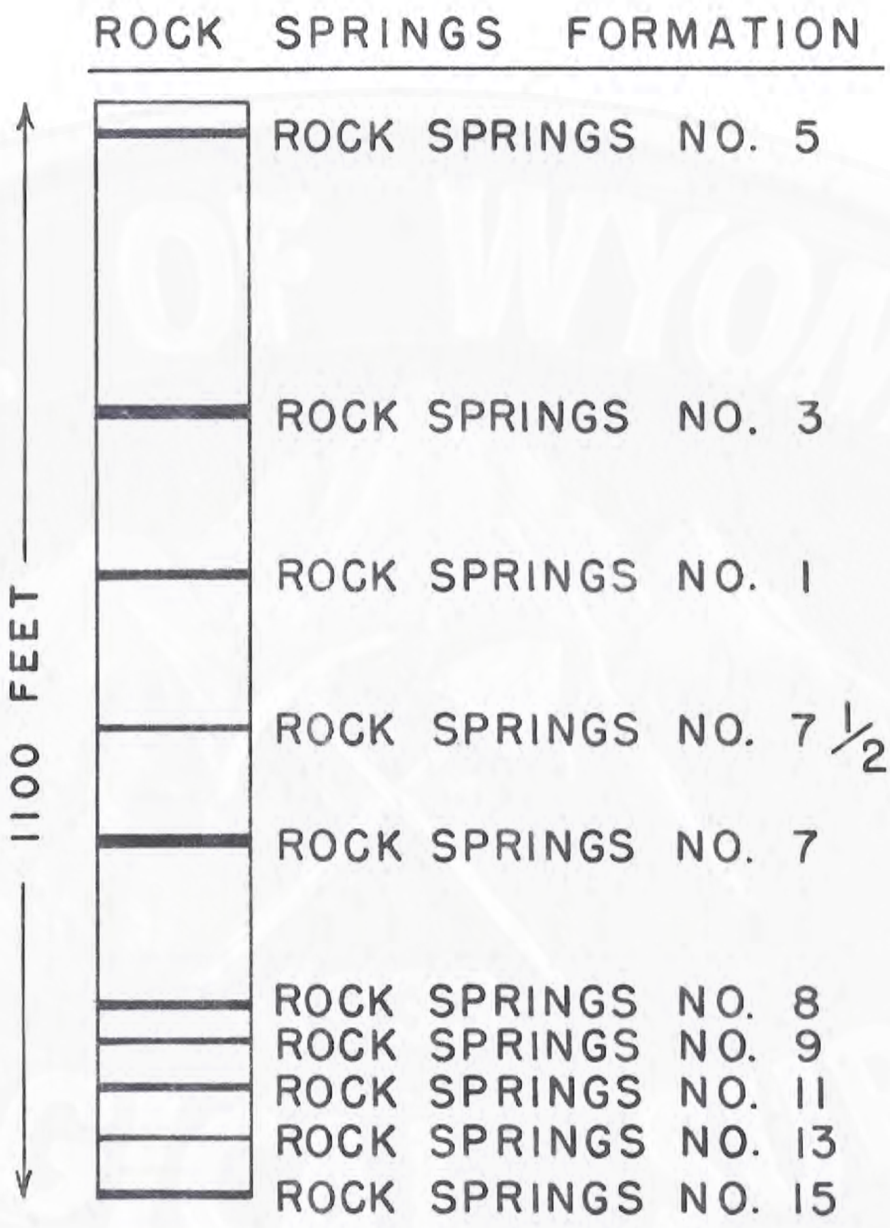


Figure 7. Coal Nomenclature for the Rock Springs Formation of the Green River Coal Region.

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 they are surpassed in importance by younger beds of the 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. 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 12 feet thick on the east side of the uplift (VTN, 1974).

Lance Formation coals reportedly average 5 to 10 feet thick, at least on the east flank of the uplift (VTN, 1974). Five minable coals within the Black Butte area are designated from youngest to oldest: Overland, Gibraltar, Black Butte, Maxwell, and Hall. Collectively, these Lance coals average 20.8 percent moisture, 5.5 percent ash, 0.77 percent sulfur, and 9780 Btu/lb. on an as-received basis. These coals vary from less than 5 feet thick to as much as 22 feet thick.

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 officially opened. Up to 30 feet of coal is exposed in that area. South of the Bridger mine, Fort Union Formation coals average 10-26 feet thick in the Black Buttes area (VTN, 1974). In both cases the coals are subbituminous in rank.

Wasatch coals in the Red Desert part of the 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. 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 percent, an ash content of 16 percent, a sulfur content of 2.5 percent and a heat value of 7900 Btu/lb. (Smith *et al.*, 1972). Analyses of drill core samples of these beds show that they yield from 7.8 to 26.2 gallons of oil per ton by the Fisher assay method. Additionally, the uranium content of these coals is between 0.001 percent and 0.009 percent U_3O_8. These Wasatch coals are estimated to contain over 55 million pounds of uranium with U_3O_8 contents 0.003 percent 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.

Almond Coal Beds

Recent mapping shows at least thirteen persistent Almond coals crop out on the southeastern flank of the Rock Springs Uplift (Roehler, 1976a; 1977). In descending order, these subbituminous coals are named the Falcon, Golden Eye, Pintail, Finch, Gull, Sparrow, Coot, Mallard, Shrike, Meadow Lark, Robin, Magpie and Mourning Dove. Of these beds, the Mallard, Meadow Lark, Robin, Magpie and Mourning Dove coals each locally exceeds nine feet in thickness. The other beds are at least five feet thick. None of these coals is currently mined. Correlation northward into the Black Buttes mine area suggests the Magpie bed is possibly equivalent to the Lebar bed.

Although analyses of these specific beds are not available, published analyses of Almond coals in the Rock Springs area are probably similar. These other analyses are averaged below. See also the Lebar bed in the Black Buttes area.

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. 2 and Battle No. 3 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. They average between 6.4 and 8.6 feet in thickness. 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. 3 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 and 22 feet thick. 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*
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 of 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. 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 southward into the Black Buttes area of the uplift. It is probably equivalent to the Little Valley bed of Roehler (1977).

As Received Basis	*Range (4 Analyses)*	*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
HGI	79-82	——

Fort Union Formation Coal Beds

Recent mapping has shown that three persistent subbituminous Fort Union coals and several thick local beds crop out on the southeastern side of the Rock Springs Uplift (Roehler, 1976a, 1976b, 1977). These coals occur in what has been termed the Black Rock Coal Group. In descending order, the Big Burn, Hail, and Little Valley beds all exceed six feet in thickness. The Big Burn coal reaches 9 feet thick while the Little Valley bed is up to 15 feet thick. Northward the Little Valley bed correlates with the Deadman bed of the Black Buttes and Bridger deposits. In the Black Buttes area uncorrelated Fort Union Formation coals average 10-26 feet thick. At least the Ute bed of that area will be mined in the near future (VTN, 1974).

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 area 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 area 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 Bluff and French beds of Roehler (1976a, 1976b) reach 8.5 and 6.5 feet thick, respectively. In the Black Buttes area, 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).

As Received Basis	*Average (Root, 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 unnamed 4.8-6 feet thick coal about 60 feet above it. Both coals are probably subbituminous. The Lebar bed may correlate with Roehler's (1977) Magpie bed.

As Received Basis	*Typical Analysis*
Moisture (%)	17.5
Ash (%)	7.6
Sulfur (%)	0.57
Btu/pound	10,000

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 area of the Rock Springs Field. Although the coal is not yet mined, it will probably be mined within several years. This coal may be equivalent to Roehler's (1977) Big Burn bed.

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. This coal, however, is seldom more than four feet thick. Locally the Overland bed contains shaly partings that raise its ash content as high as 31 percent, and lower its heat value to less than 6900 Btu/lb. More typically, the ash is in the 5-7 percent 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 is currently mining this coal. 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
HGI	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
HGI	48-54	51

Rock Springs No. 11 Coal Bed

The No. 11 bed is high volatile C bituminous coal, ranges from 44 to 54 inches in thickness, and averages 4 feet thick. It is an important coal in the Rock Springs Field. This bed is in the Rock Springs Formation. The 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
Sulfur (%)	0.7
Btu/pound	12,379-12,572

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 these 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 five 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 ranges from 10 to 18 feet in thickness and normally has a 1 to 2 foot 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 foot 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.

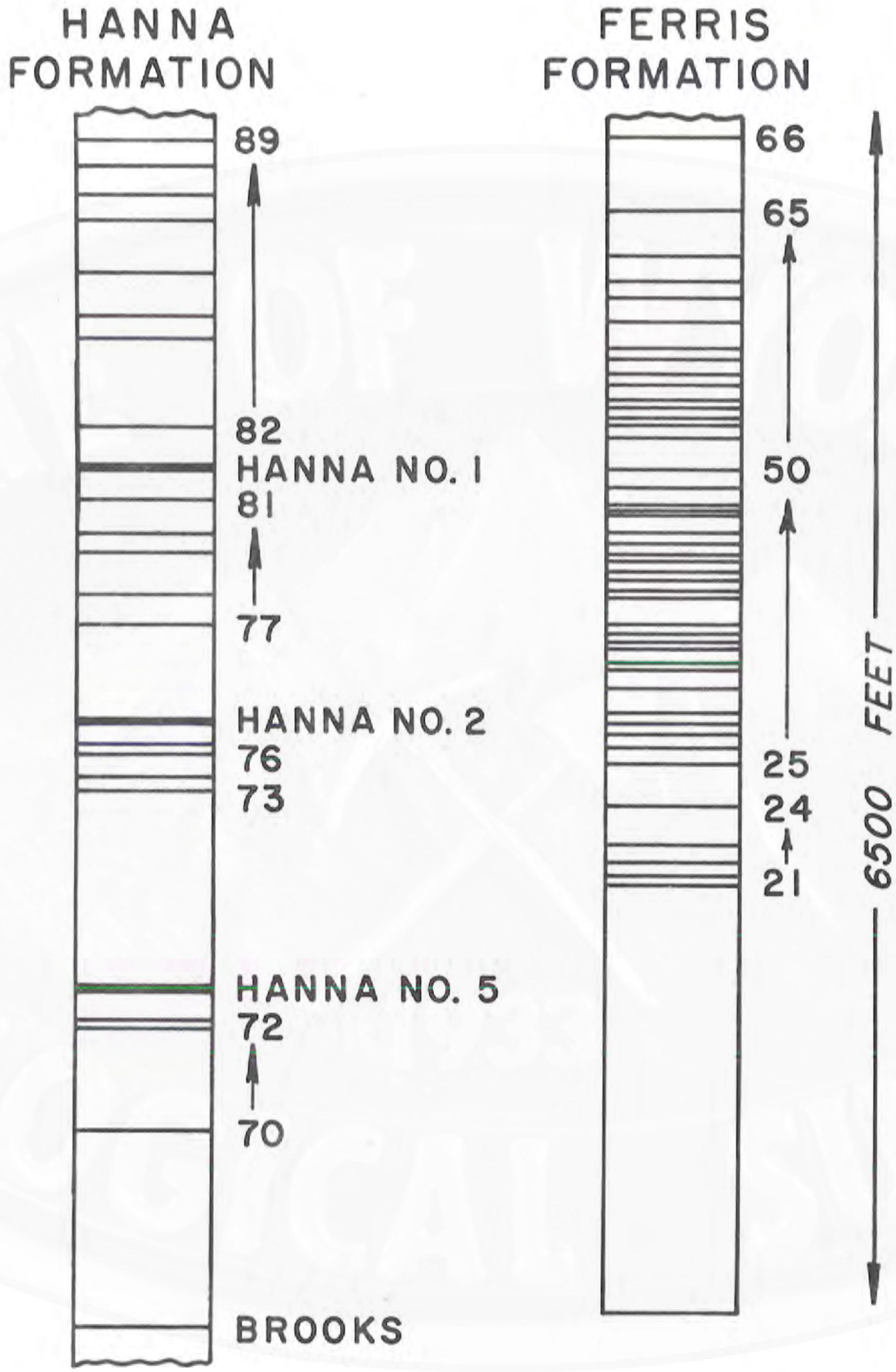


Figure 8. Coal Nomenclature for the Hanna and Ferris Formations of the Hanna Coal Field.

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 FIELD

Coal-bearing rocks of the Hanna Field crop out in a 750 square mile area of Carbon County in southcentral Wyoming. Most simply, the Hanna Field occupies a structural trough that is divided into two separate basins by a northeast-southwest trending anticline. The Hanna Basin lies to the northwest of the anticline while the Carbon Basin lies to the southeast. The Hanna Field is bounded on the north, west and south by mountain ranges. Faulting is common in the field.

Coal beds occur in the Mesaverde Group and Medicine Bow Formations of Upper Cretaceous age, the Ferris Formation of Upper Cretaceous and Paleocene age, and the Hanna Formation of Paleocene and Eocene age. The rank of the coals in the Hanna Field ranges from subbituminous C to high volatile C bituminous. The highest ranked coal, high volatile C bituminous, occurs in the Mesaverde Group. Collectively, coals of this Group and the Medicine Bow Formation range downward in rank to subbituminous B. The Hanna Formation and Ferris Formation coals (Figure 8) are predominantly subbituminous although the Hanna No. 2 bed of the Hanna Formation has reportedly been ranked as high as high volatile C bituminous (Glass, 1972).

The U.S. Bureau of Mines has estimated that there are at least 10 million tons of strippable resources in just the Hanna Formation of the field. This figure was calculated on 8 coals of the formation. The total strippable reserve base in the Hanna Field is approximately 313 million tons (Glass, 1972).

Bed No. 24

This subbituminous Ferris Formation coal averages 18-20 feet thick. It is presently strip mined on the west side of the Hanna Field. A typical analysis is:

As Received Basis	*Range or Typical*
Moisture (%)	14.0-16.0
Volatile Matter (%)	34.3
Fixed Carbon (%)	45.8
Ash (%)	3.9-8.4
Sulfur (%)	0.3-0.4
Btu/lb.	10,050-10,180
HGI	47

Bed No. 25

Bed No. 25 is a subbituminous coal in the lower third of the Ferris Formation and is best developed on the west side of the Hanna Field. This coal averages up to 22 feet thick except where it splits into as many as three thinner benches, designated Seam 1, 2, and 3 from the top down. Seam 1, or the upper bench, averages 4 feet thick; seam 2 averages 5.5 feet; seam 3, or the lower bench, averages 7.2-8.3 feet thick. The coal is currently strip mined.

As Received Basis	*Range-4 samples*	*Average*
Moisture (%)	11.5-18.9	14.6
Volatile Matter (%)	32.5-34.5	33.6
Fixed Carbon (%)	39.3-44.3	42.0
Ash (%)	6.6-16.7	9.8
Sulfur (%)	0.3-0.7	0.5
Btu/lb.	8,340-9,940	9,327
HGI	41-66	51

Bed No. 50

This coal occurs near the middle of the Ferris Formation and is subbituminous in rank. The bed is best developed west of the town of Hanna where it is currently mined. It varies between 15-19 feet in thickness.

As Received Basis	*Range or Typical*
Moisture (%)	11.3-14.3
Volatile Matter (%)	34.1
Fixed Carbon (%)	43.7
Ash (%)	10.9-13.6
Sulfur (%)	0.4-0.43
Btu/lb.	9,410-10,700
HGI	45

Bed No. 62

This Paleocene Ferris Formation coal is subbituminous in rank, and is an important bed in the westcentral portion of the basin near Seminoe Reservoir. This coal is over 9 feet thick where it is strip mined.

As Received Basis	*One Analysis*
Moisture (%)	10.2
Volatile Matter (%)	36.2
Fixed Carbon (%)	46.9
Ash (%)	6.7
Sulfur (%)	0.6
Btu/lb.	10,860
HGI	53

Bed No. 63

This is another important Ferris Formation coal in the Seminoe Reservoir area. This subbituminous coal is of Paleocene age and ranges up to 5.2 feet thick where it is strip mined with other 60 series beds.

As Received Basis	*One Analysis*
Moisture (%)	9.5
Volatile Matter (%)	39.9
Fixed Carbon (%)	43.5
Ash (%)	7.1
Sulfur (%)	0.6
Btu/lb.	10,940
HGI	48

Bed No. 64

This Paleocene coal also occurs in the Ferris Formation near Seminoe Reservoir. It is a subbituminous coal strip mined with other 60 series beds. Bed No. 64 exceeds 6 feet in thickness.

As Received Basis	*One Analysis*
Moisture (%)	10.8
Volatile Matter (%)	38.5
Fixed Carbon (%)	44.1
Ash (%)	6.6
Sulfur (%)	0.4
Btu/lb.	10,880
HGI	43

Bed No. 65

This Ferris Formation coal is of Paleocene age. It is subbituminous in rank, and is currently deep mined in the field. The bed is important west of the town of Hanna where it ranges from 6 feet to 8 feet thick.

As Received Basis	*Range-3 samples*	*Average*
Moisture (%)	9.0-11.6	9.6
Volatile Matter (%)	36.8-37.2	37.0
Fixed Carbon (%)	46.4-49.0	47.7
Ash (%)	5.2-7.1	5.7
Sulfur (%)	0.6-0.7	0.65
Btu/lb.	11,020-11,277	11,213
HGI	50-54	52

Bed No. 66

This subbituminous Ferris Formation (Paleocene) coal is strip mined near Seminoe Reservoir where it reaches 10 feet in thickness.

As Received Basis	*One Analysis*
Moisture (%)	13.9
Volatile Matter (%)	34.6
Fixed Carbon (%)	46.0
Ash (%)	5.5
Sulfur (%)	0.5
Btu/lb.	10,330
HGI	52

Bed No. 76

This subbituminous coal in the Paleocene portion of the Hanna Formation is strip mined north of Hanna. The bed is up to 11.2 feet thick with several partings up to one foot thick. Because the partings are removed during mining, they were also excluded before analysis.

As Received Basis	*One Analysis*
Moisture (%)	10.3
Volatile Matter (%)	39.4
Fixed Carbon (%)	40.5
Ash (%)	9.8
Sulfur (%)	0.7
Btu/lb.	10,690
HGI	52

Bed No. 80

Bed No. 80 is a Paleocene coal of the Hanna Formation. The rank is subbituminous. This bed is well developed in the Hanna Basin where it ranges from 15.5 to 24 feet in thickness. The No. 80 bed generally has a 1 to 1½ foot parting 2 to 5 feet above its base. It is strip mined in Carbon County.

As Received Basis	*Range-10 samples*	*Average*
Moisture (%)	10.6-14.5	11.5
Volatile Matter (%)	37.4-39.2	38.3
Fixed Carbon (%)	39.6-47.6	43.6
Ash (%)	4.4-9.3	6.6
Sulfur (%)	0.6-1.2	0.9
Btu/lb.	10,307-11,510	10,665
HGI	47-49	48

Bed No. 82

This bed is an Eocene coal in the Hanna Formation. It is a subbituminous coal, averages 9 feet thick, and is best developed in the Hanna Basin. It is stripped in Carbon County.

As Received Basis	*Range-8 samples*
Moisture (%)	11.2-13.5
Volatile Matter (%)	40.9
Fixed Carbon (%)	40.6
Ash (%)	6.9-10.7
Sulfur (%)	0.73-1.0
Btu/lb.	10,140-10,870
HGI	50

Brooks Coal Bed

This bed is a subbituminous Paleocene coal near the base of the Hanna Formation. It ranges between 7.5 feet and 15 feet in thickness, and is strip mined in Carbon County.

As Received Basis	*Range-3 samples*	*Average*
Moisture (%)	8.9-13.7	10.6
Volatile Matter (%)	33.5-36.7	35.1
Fixed Carbon (%)	47.2-47.5	47.4
Ash (%)	6.5-7.0	6.9
Sulfur (%)	0.45-0.7	0.55
Btu/lb.	10,806-11,179	10,935
HGI	48-51	49

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 ranges between 15 and 30 feet thick, and is presently being converted into a low Btu gas at a Bureau of Mines in-situ gasification site south of Hanna. The coal is subbituminous in rank.

As Received Basis	*Range-3 samples*	*Average*
Moisture (%)	6.3-11.7	10.6
Volatile Matter (%)	32.6-41.1	36.9
Fixed Carbon (%)	34.1-41.7	37.9
Ash (%)	5.6-23.8	14.7
Sulfur (%)	0.26-0.68	0.47
Btu/lb.	8,660-9,633	9,831

Hanna No. 2 Coal Bed

This coal is normally of subbituminous A rank, but in places it 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 ranges between 30 and 36 feet thick.

As Received Basis	*Range (6 samples)*	*Average*
Moisture (%)	7.5-11.7	10.2
Volatile Matter (%)	38.4-40.5	39.6
Fixed Carbon (%)	42.9-46.7	44.4
Ash(%)	5.0-7.3	5.8
Sulfur (%)	0.26-0.45	0.37
Btu/lb.	11,180-11,600	11,350
HGI	----	48

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, 1975).

Structurally, the Hams Fork Region is very complex. Folded Paleozoic and Mesozoic rocks are thrust eastward over folded Cretaceous rocks with the younger Cretaceous and Tertiary rocks of the area resting unconformably on 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 coal. 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 ranges 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 ranging between a few hundred feet and 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 County and southern Lincoln County, Bear River coals locally reach minable thicknesses, and they were prospected and mined on a very small scale in the late 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

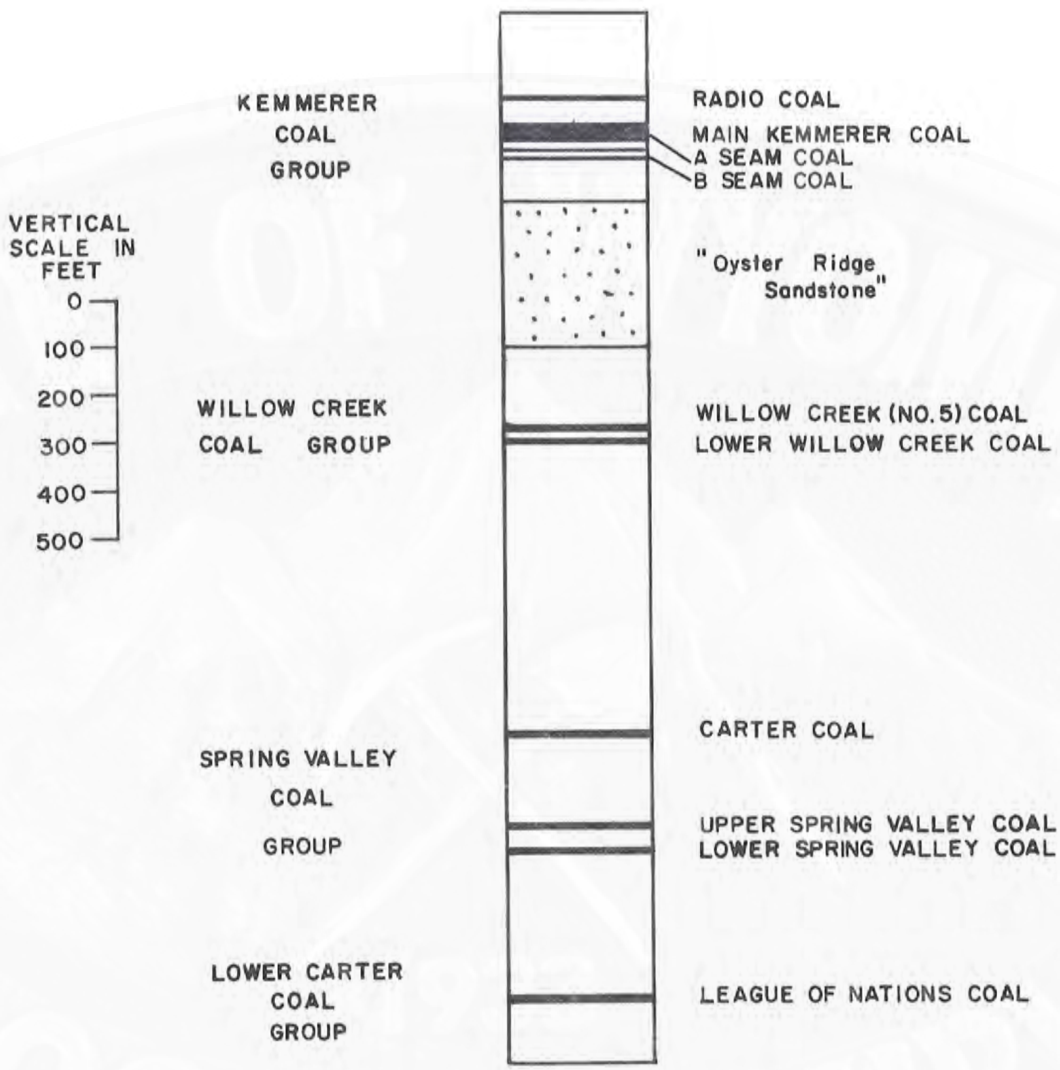


Figure 9. Coal Nomenclature for the Frontier Formation of the Hams Fork Coal Region.

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 County and Uinta County 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 in 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 possibly 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. Ranging from 2,900 to 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, 1975). Adaville Formation coals crop out in three

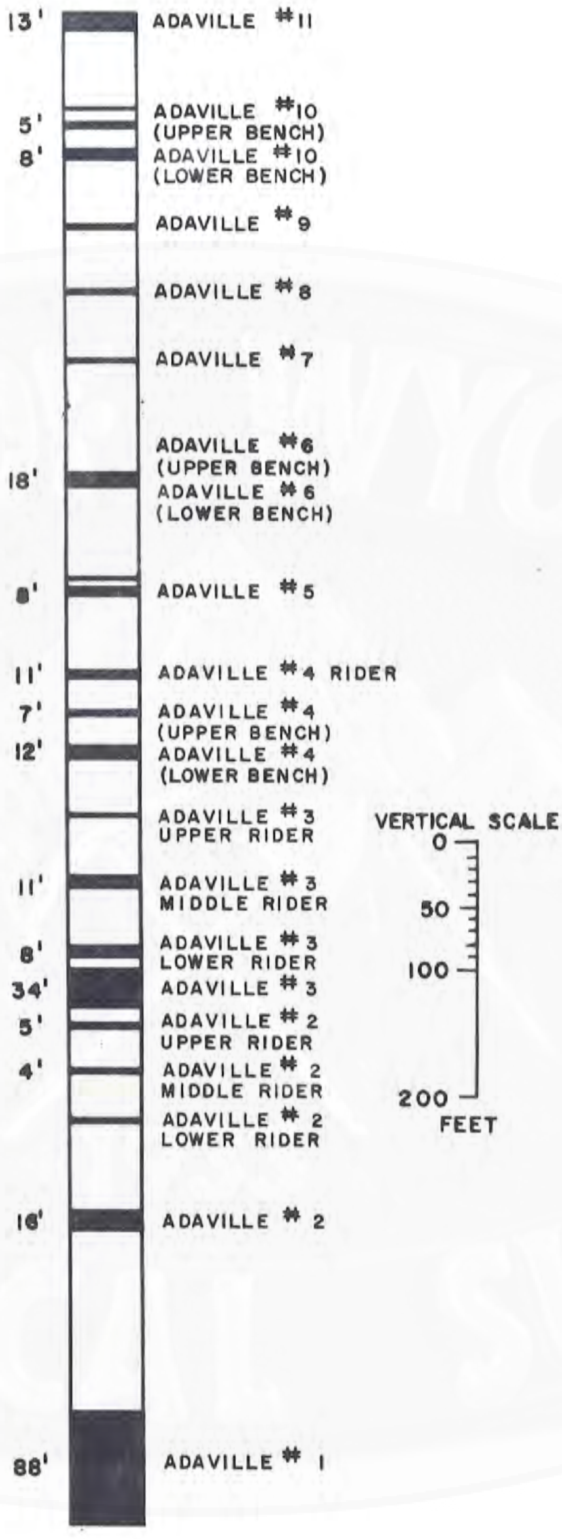


Figure 10. Coal Nomenclature for the Adaville
Formation of the Hams Fork Coal Region.

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 occurs in the central basin west of Kemmerer. In that basin, at least eight coals exceed 10 feet in thickness while another seven beds range 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 have been both deep mined and strip mined. Most of the Adaville production 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 1976, these strip mines had accounted for approximately 28.5 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 Sorenson 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 in the 1800'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 upper few hundred feet of the

Evanston Formation in that area contain 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 1900 when the last mine closed.

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 that it locally reaches 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 this coal bed.

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 analyses)*[1]	*Ultimate (7 analyses)*[2]
Moisture (%)	16.7-22.7	20.4	
Volatile Matter (%)	33.0-36.6	34.5	
Fixed Carbon (%)	38.8-44.7	42.1	
Ash (%)	1.5-5.3	3.0	3.7
Sulfur (%)	0.5-1.3	0.6	0.7
Hydrogen (%)	6.1-6.6		6.3
Carbon (%)	56.0-60.1		58.1
Nitrogen (%)	0.9-1.0		.09
Oxygen (%)	27.5-33.6		30.2
Btu/pound	9,720-10,530	10,190	
Ash softening Temperature (^{o}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 Sorenson mine, the reader is referred to Glass (1975).

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 vary from a few inches to 140 feet, 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 Sorenson mine is currently mining as many as 21 of these upper Adaville coals. Production from this mine is about 2.7 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 Sorenson 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 analyses)	Average Ultimate (18 analyses)
Moisture (%)	15.4-28.6	21.2	
Volatile Matter (%)	31.1-36.1	33.9	
Fixed Carbon (%)	36.1-44.7	41.3	
Ash (%)	3.2-8.9	3.8	4.9
Sulfur (%)	0.2-1.8	0.6	0.6
Hydrogen (%)	5.9-6.5		6.1
Carbon (%)	47.2-60.0		55.1
Nitrogen (%)	0.8-1.5		1.4
Oxygen (%)	28.2-39.4		31.8
Btu/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 1900, more than 2.7 million tons of the Almy bed were mined near Almy (T. 16 N., R. 120 W.). In those 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 split 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 bed represents only the lower 8 feet of a 24-feet expression of the coal (U.S. Bureau of Mines, 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 reached 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 bituminous Frontier coal often underlies the Willow Creek No. 5 bed north of Kemmerer. The interval between the two beds varies from 5 to 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 analyses)*	*Average Proximate and Ultimate (20 analyses)*
Moisture (%)	2.0-7.9	3.0
Volatile Matter (%)	35.0-41.5	38.6
Fixed Carbon (%)	45.8-52.7	49.7
Ash (%)	5.4-14.3	8.7
Sulfur (%)	0.9-1.4	1.1
Hydrogen (%)	5.2-5.7	5.4
Carbon (%)	65.3-74.8	71.7
Nitrogen (%)	1.0-1.4	1.3
Oxygen (%)	11.0-15.6	11.8
Btu/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 Mining District.

Most deep mining in the Hams Fork Region has been on this coal bed, with extensive mining near Kemmerer and Diamondville in the Kemmerer Mining District. 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.

		Average	
As Received Basis	*Range (23 analyses)*	*Proximate (23 analyses)*	*Ultimate (10 analyses)*
Moisture (%)	3.9-6.8	5.9	
Volatile Matter (%)	35.0-42.0	39.6	
Fixed Carbon (%)	44.3-51.3	47.6	
Ash (%)	3.5-10.5	6.9	5.9
Sulfur (%)	0.4-2.7	0.9	1.1
Hydrogen (%)	5.3-5.7		5.5
Carbon (%)	68.1-72.9		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.

As Received Basis	Range Analysis	Average Proximate (9 analyses)	Average Ultimate (3 analyses)
Moisture (%)	5.5-10.0	7.4	
Volatile Matter (%)	36.8-43.9	39.4	
Fixed Carbon (%)	44.5-50.3	47.5	
Ash (%)	2.2-9.7	5.7	4.6
Sulfur (%)	0.3-1.0	0.6	0.4
Hydrogen (%)	5.7-5.9		5.8
Carbon (%)	68.0-72.8		69.9
Nitrogen (%)	1.3-1.6		1.5
Oxygen (%)	16.2-19.8		17.8
Btu/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 ranged from 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 was estimated between 2,000 and 3,000 feet of cover. Because of steep dips and depth of cover, most if not all of this 144,620,000 tons of coal are underground reserve base rather than strippable reserve base.

Most mining on the Willow Creek No. 5 coal was in the central part of the Kemmerer Coal Field although the coal bed crops out for more than 50 miles along the 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 are summarized below.

		Average	
As Received	*Range Analysis*	*Proximate (35 analyses)*[1]	*Ultimate (24 analyses)*[2]
Moisture (%)	2.0-7.7	3.4	
Volatile Matter (%)	34.7-42.7	37.2	
Fixed Carbon (%)	46.0-55.1	51.8	
Ash (%)	4.3-15.3	7.7	8.0
Sulfur (%)	0.4-2.1	0.9	0.9
Hydrogen (%)	4.9-5.6		5.3
Carbon (%)	66.3-76.4		72.8
Nitrogen (%)	1.0-1.3		1.2
Oxygen (%)	10.5-17.3		11.8
Btu/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 region, 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 others. Since the coal-bearing formations are only exposed along the flanks of the coal basin, the coal fields also lie within the 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 border areas. 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, 8 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 range 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.

Apparently coals are distributed throughout the Upper Cretaceous Meeteetse Formation everywhere in the basin, but they are not as thick or 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 range from 4 to 6 feet, 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, 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.

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.

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 range from 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 heightened recently as the search for thick, low sulfur coals continues. The shallower dips exhibited by these younger Paleocene coals compliment their greater thicknesses.

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 4110 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.

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 was recently mined by conventional underground methods (Glass, Westervelt, and Oviatt, 1975). Where mined, the bed dipped 17-45 degrees.

As Received Basis	*Range (69 samples)*	*Average*
Moisture (%)	12.4-17.8	15.5
Voaltile 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 (Fort 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).

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)

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 southeastern 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.

Based on early reports of the U.S. Geological Survey, Berryhill *et al.* (1950) described five coal fields within the basin: the Muddy Creek, Pilot Butte, Hudson, Alkali Butte, and Powder River fields. Since Berryhill *et al.*'s (1950) report, Thompson and White (1952) have identified two additional coal fields, the Beaver Creek and Big Sand Draw fields. The exact boundaries of these seven fields were not defined, and coal beds were not correlated between them. Areas barren of coal mining served to roughly delimit one field from another.

To aid in their description, Glass (1976a) assigned the first preliminary boundaries to these coal fields. Also, the Powder River Field was changed to the Arminto Field to avoid confusion with the Powder River Field in the Powder River Basin. In 1978, Glass and Roberts again revised the coal field boundaries, but retained the Arminto change. The major difference between the boundaries is that the Beaver Creek Coal Field now includes most of the central and northern portions of the Wind River Basin, which were formerly assigned to the Pilot Butte and Alkali Butte fields (Glass and Roberts, 1978). 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 of 15-40 degrees are common along the southern flank of the basin. Dips along the northern flank are steeper, averaging 40-85 degrees, and are even 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.

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-foot-thick Cody coal, however, is reported in at least one drill hole in the Beaver Creek Coal Field (Thompson and White, 1952).

Woodruff (1907) and Woodruff and Winchester (1912) refer to early prospecting of Upper Cretaceous Frontier coals in section 6, T.32N., R.98W. This area lies outside the defined basin and about eight miles southeast of Lander. 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.

Although Upper Cretaceous Mesaverde coals are present throughout the basin, they crop out only 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 3-5 feet thick coals, which 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 6 miles along strike. Although some other coals in these fields reach 4-5.5 feet in thickness, there are many coals less than two feet thick.

In the Beaver Creek field, Mesaverde coals are known only from the subsurface. One oil well log in the southernmost part of that field shows 29 coal beds in the Mesaverde. The coals are 2-15 feet thick with an aggregate thickness of about 165 feet in a 1,200-foot 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 3-6 feet thick for more than two miles along its outcrop. They estimated that 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 south-central 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 2-3 feet thick (Thompson and White, 1952). One prospect in the Arminto field exposed 4.5 feet of Paleocene coal (Woodruff and Winchester, 1912).

The Eocene Wind River Formation is also a minor coal-bearing formation in the Wind River Basin. Drilling in the southernmost part of the Beaver Creek Coal Field, however, documents a few 2-3 feet thick coals (Thompson and White, 1952). Most Wind River coals are only a few inches thick and of little economic value.

Beaver Coal Bed

The Beaver coal bed is a subbituminous Mesaverde coal that crops out in the Alkali Butte Coal Field. This is a fairly persistent coal, occurring about 430 feet above the Signor bed. The coal maintains a thickness of three feet for more than a mile along its outcrop. Thompson and White (1952) estimated that there were 2.96 million tons of this coal under less than 1,000 feet of cover. Unfortunately, none of this resource can be termed reserve base because the coal is too thin. They estimated another .51 million tons lay between 1,000 and 2,000 feet of cover. The coal dips 18-28 degrees and has been prospected in the past. There are no analyses of this coal bed. All calculated resources of this coal lie within the Wind River Indian Reservation.

Downey Coal Bed

The Downey coal bed is the thickest known Mesaverde coal in the Wind River Coal Basin. This coal was typically 28 feet thick where it was mined in the Big Sand Draw Coal Field. The coal generally has a two feet thick shale parting six feet above its base. There is some possibility that the lower six feet of the Downey coal bed may be correlative with the Signor bed to the northeast in the Alkali Butte Coal Field (Thompson and White, 1952). There are no coal analyses of this bed.

Thompson and White (1952) estimated that there were 71.83 million tons of this coal between 0 and 3,000 feet of ocver. Of this resource, 13.82 million tons can be termed reserve base. Along the two miles of outcrop for which resources were calculated, the Downey coal dipped 22-25 degrees.

Kinnear Coal Bed

This thin Mesaverde coal crops out for about one mile in the Pilot Butte Coal Field where it was once deep mined. The Kinnear coal has a maximum reported thickness of 2.8 feet although two feet is a better average thickness (Woodruff and Winchester, 1912). The bed dips 29-30 degrees northeast, and is the only coal identified in the Pilot Butte Coal Field.

Berryhill *et al.* (1950) estimated about 360,000 tons of this coal underlies the Pilot Butte Coal Field. All of this resource falls within the Wind River Indian Reservation.

A single analysis of a channel sample of this bed was published by Lord *et al.* (1913). The coal was 2.75 feet thick where sampled.

As Received Basis	*Single Analysis*
Moisture (%)	14.8
Volatile Matter (%)	34.0
Fixed Carbon (%)	42.6
Ash (%)	8.6
Sulfur (%)	0.9
Heat Value (Btu/lb)	10,193

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 area 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 12-15 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 underlie the Hudson Coal Field beneath 0-3,000 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. Analyses of the Lander coal bed are summarized below:

		Average	
As Received Basis	*Range (37 analyses)*[1]	*Proximate (37 analyses)*	*Ultimate (7 analyses)*
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
Heat Value (Btu/lb)	8,870-10,510	9,480	

[1]These analyses came from the Poposia, Poposia No. 2, Rogers, George, Big Dunne, Dunne Little, Schroeder, Wyoming Central, Hickey, McKinley, Indian, and Mitchell No. 2 deep mines. 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. Analyses were done by the U.S. Bureau of Mines and published in various reports listed in the references at the end of this paper.

Shipton Coal Bed

The Shipton coal bed is a fairly persistent Mesaverde coal in the Alkali Butte Coal Field. It overlies the Beaver coal by about 65 feet, and the Signor coal bed by about 495 feet. It crops out for more than three miles with a maximum thickness of 9.5 feet. It averages close to five feet thick and has been deep mined in the past. It dips 18-25 degrees to the north or west.

Thompson and White (1952) estimated that 17.29 million tons of the Shipton coal occurs under less than 1,000 feet of cover. Of this resource, 13.63 million tons is considered reserve base. They estimate that another 23.23 million tons lies between 1,000 and 3,000 feet of cover for a total resource of 40.52 million tons. Most of these calculated resources lie within the Wind River Indian Reservation.

A single analysis of a channel sample from an underground mine (Shipton Mine) was published by Lord *et al.* (1913). Only 5.5 feet of a 7.5 feet thick expression of the coal was included in the analysis.

	As Received Basis[1]	*Moisture-Free Basis*
Moisture (%)	34.1	
Volatile Matter (%)	30.4	46.2
Fixed Carbon (%)	29.3	44.4
Ash (%)	6.2	9.4
Sulfur (%)	0.6	0.9
Heat Value (Btu/lb)	6,080	9,230

[1]The sample was probably badly weathered as it was only 45 feet from the outcrop.

Signor Coal Bed

With the possible exception of the Lander coal bed, the Signor coal bed is probably the most persistent Mesaverde coal yet identified in the Wind River Coal Basin. The Signor bed is traceable for more than 10 miles in the Alkali Butte Coal Field. Its maximum reported thickness is 16.5 feet. Although it is 7-10 feet thick over much of its outcrop, it does thin to less than 2 feet thick in places. The coal has been deep mined, and dips at 13-31 degrees. Both a small deep mine and small strip mine have recently been permitted to mine this coal, but neither of the mines is yet operational.

Thompson and White (1952) calculated that 27.62 million tons of the Signor bed lie under less than 1,000 feet of cover. At least 25.72 million tons of this resource can be regarded as reserve base. Another 31.16 million tons lie beneath 1,000 and 3,000 feet of cover. Total resources of the Signor bed stand at 58.78 million tons. A portion of these resources lie within the Wind River Indian Reservation.

Lord *et al.* (1913) published an analysis of a single channel sample of the Signor coal bed. Only the lower 4.2 feet of the 7.9 feet thick coal was analyzed.

As Received Basis	*Single Analysis*
Moisture (%)	26.0
Volatile Matter (%)	30.7
Fixed Carbon (%)	38.1
Ash (%)	5.1
Sulfur (%)	0.6
Heat Value (Btu/lb)	8,760

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 19-28 degrees. It apparently splits and thins northward. It has been deep mined in the past. Currently, a small strip mine (Muddy Creek strip mine) occasionally removes a few tens of tons for local use. This mine, incidentally, was the last active mine in the Wind River Basin. Although this mine is within the Wind River Indian Reservation, it lies on private, not Indian land.

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 a 12.2 feet thick expression of the coal, however, was analyzed (Lord *et al.*, 1913).

As Received Basis	*Single Analysis*
Moisture (%)	15.7
Volatile Matter (%)	28.5
Fixed Carbon (%)	47.7
Ash (%)	8.1
Sulfur (%)	0.35
Heat Value (Btu/lb)	9,920

JACKSON HOLE COAL FIELD

The Jackson Hole Field in northwestern Wyoming is underlain by minable beds over an area of 700 square miles. Minable coals occur in Upper Cretaceous, Paleocene, and Eocene age rocks. The coals are probably subbituminous rank.

BLACK HILLS COAL REGION

The Black Hills Region is in the extreme northeastern part of the state. Coals crop out in a narrow, discontinuous belt through the region. The only minable coal bed is confined to the base of the Lakota Sandstone of Lower Cretaceous age. The field as a whole is usually considered to be "mined out." The coal in this field is high volatile C bituminous and is a moderately good coking coal.

ROCK CREEK COAL FIELD

The Rock Creek Field is a small field southeast of the Hanna Field. Coal-bearing rocks occur in the Mesaverde Group of Upper Cretaceous age and the Hanna Formation of Paleocene and Eocene age. The thickest and best exposed coals are in the northwestern part of the field. Coal in the field is subbituminous B rank.

GOSHEN HOLE COAL FIELD

The Goshen Hole Field is in the southeastern part of the state. Coals in the field occur in the Lance Formation of Upper Cretaceous age. No coal more than 2.5 feet thick is known to exist in this field. Much of the field is covered by younger rocks which do not contain coals. The coal is probably of subbituminous rank.

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*		69,033.84	69,033.84
Carbon	100.24	4,843.28	4,943.52
Converse		4,153.97	4,153.97
Crook	1.15	8.64	9.79
Fremont		733.76	733.76
Hot Springs		261.08	261.08
Johnson*		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

TABLE 5, continued

County	*Bituminous*	*Subbituminous*	*Total*
Park	17.90	196.59	214.49
Sheridan*		24,461.42	24,461.42
Sublette	1.60	5.21	6.81
Sweetwater	9,878.04	5,030.98	14,909.02
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	13,234.95	123,656.48	136,891.43

*This figure has been changed to reflect resources delimited after Berryhill's 1950 calculations (Doss White, U.S. Bureau of Mines, personal communication). All these resources occur between 0 and 3000 feet of cover.

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 Region	*Bituminous*	*Subbituminous*	*Total*
Powder River Coal Basin*		110,218.95	110,218.95
Green River Coal Region	9,904.84	6,051.04	15,955.88
Hams Fork Coal Region	3,197.68	1,676.86	4,874.54
Hanna Coal Field	73.44	3,843.52	3,916.96
Wind River Basin		875.66	875.66
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	13,234.95	123,656.48	136,891.43

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

*This figure has been changed to reflect resources delimited since Berryhill's figures were calculated in 1950 (Doss White, U.S. Bureau of Mines, personal communication). All these resources occur between 0 and 3000 feet of cover.

TABLE 7: REPORTED COAL PRODUCTION BY COUNTY TO JANUARY 1, 1978 (MILLIONS OF TONS)

County	*1977 Production*[1]	*Cumulative Production*[2]	*Estimated 1978 Production*[3]
Albany	0	0.01	0
Big Horn	0	17.90	0
Campbell	17.43	48.78	28.90
Carbon	10.20	104.23	11.00
Converse	3.24	34.36	3.25
Crook	0	0.06	0
Fremont	0	3.81	0
Hot Springs	.002	11.86	.002
Johnson	0	0.46	0
Lincoln	5.10	79.13	5.10
Natrona	0	0.03	0
Niobrara	0	0	0
Park	0	0.04	0
Sheridan	2.39	63.80	2.40
Sublette	0	0.02	0
Sweetwater	5.69	213.78	5.80
Teton	0	0.01	0
Uinta	0	22.42	0
Washakie	0	L[4]	0
Weston	0	12.43	0
Tonnage reported by County	44.05	613.13	56.45
Miscellaneous tonnage not reported by County[5]	0	1.05	0
Grand Total	44.05	614.18	56.45

[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 (March 1978).

[4]L means less than 200 tons.

[5]Most of this tonnage was reported during various years in the 1880's and early 1900's, but was not recorded by county.

Table 8: ESTIMATE OF REMAINING COAL RESOURCES AND RESERVE BASE OF WYOMING TO JANUARY 1, 1978 (MILLIONS OF 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]	136,891.43	936,891.43
Production from strip mining[2]	210.62	
Production from deep mining[2]	386.06	
Total production	596.68	596.68
Losses due to strip mining (20% lost)	42.12	
Losses due to deep mining (equals production)	386.06	
Total production and mining losses	1,024.86	1,024.86
Remaining resources	135,866.57	935,866.57
Strippable reserve base[3]	26,275.40	
Underground reserve base[3]	29,488.26	
Total reserve base[3]	55,763.66	

[1]Sources: U.S. Geological Survey and U.S. Bureau of Mines.

[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, 1978 (MODIFIED FROM SMITH *ET AL.*, 1972).

Coal-Bearing Region	*Strippable Deposit*	*Coal Bed(s) (Average thickness in feet)*	*Acreage Estimate*	*Original Estimated Reserves to Jan. 1, 1978*	*Production and Mining Losses Since Jan. 1, 1969*	*Remaining Strippable Reserves to Jan. 1, 1978*
Powder River Coal Basin	Acme-Kleenburn*	Monarch and Dietz No. 3 (23')	2,029.0	39,300,000	12,000,000	27,300,000
	Clear Creek	Canyon (11.2')	9,337.6	184,900,000	--	184,900,000
	Dave Johnston	School (38')	2,418.0	126,200,000		
		Badger (16')	390.0	9,500,000	26,900,000	108,800,000
	Dry Cheyenne	F(7.6')	13,260.8	179,500,000	--	179,500,000
	Lake DeSmet	Healy (163')	3,520.0	1,000,000,000	--	1,000,000,000
	Spotted Horse	Felix (12.5')		480,700,000	--	480,700,000
		Smith (10.0')	36,736.0	178,000,000	--	178,000,000
		Local (10.0')		58,300,000	--	58,300,000
	Sussex	Wasatch Fm. coal (11.8')	651.0	13,600,000	--	13,600,000
	Wyarno-Verona*	PK (11')	?	200,000,000	--	200,000,000
		Ulm 2 (20')	?	990,000,000	--	990,000,000
		Ulm 1 (30')	?	543,000,000	--	543,000,000
		Other Wasatch coals (10'+)	?	67,000,000	--	67,000,000
	Wyodak	Wyodak-Anderson (71'); Anderson (D) and Canyon (E)	115,282.0	19,000,000,000	45,300,000	18,954,700,000
		Subtotal	223,624.4+	23,070,000,000	84,200,000	22,985,800,000
Green River Coal Region	Black Buttes	Almond, Lance, Ft. Union, Wasatch Fm. coals (12')	3,889.0	82,600,000	--	82,600,000

TABLE 9, continued

Coal-Bearing Region	*Strippable Deposit*	*Coal Bed (s) (Average thickness in feet)*	*Acreage Estimate*	*Original Estimated Reserves to Jan. 1, 1978*	*Production and Mining Losses Since Jan. 1 1969*	*Remaining Strippable Reserves to Jan. 1, 1978*
Green River Coal Region, continued	Creston-Cherokee*	Upper Cherokee (B) (11') Lower Cherokee (C) (25') Other Ft. Union Fm. coals	4,204.0+	360,000,000	--	360,000,000
	Jim Bridger	Deadman (30')	4,708.0	250,000,000	14,000,000	236,000,000
	Leucite Hills*	Ft. Union Fm. coals	?	168,000,000	--	168,000,000
	Northern Little Snake River*	Ft. Union Fm. coals (15'); Lance Fm. coals (8'); Mesaverde Fm. coals (6')	15,901.0+	269,600,000	--	269,600,000
	Red Desert	Battle 2 & 3 (7')	2,938.0	38,100,000	--	38,100,000
		Sourdough, Monument, & Tierney (6.8')	27,469.0	458,900,000	--	458,900,000
		Hadsell 2 (7.7')	2,874.0	39,800,000	--	39,800,000
		Creston 2 & 3 (14')	3,846.0	125,600,000	--	125,600,000
		Latham 3 & 4 (5.7')	6,893.0	70,700,000	--	70,700,000
	Salt Wells*	Mesaverde Group coals	?	60,000,000		60,000,000
		Subtotal	72,722.0+	1,923,300,000	14,000,000	1,909,300,000

TABLE 9, continued

Coal-Bearing Region	*Strippable Deposit*	*Coal Bed(s) (Average thickness in feet)*	*Acreage Estimate*	*Original Estimated Reserves to Jan. 1, 1978*	*Production and Mining Losses Since Jan. 1, 1969*	*Remaining Strippable Reserves to Jan. 1, 1978*
Hams Fork Coal Region	Adaville	Adaville Fm. coals (44')	12,800.0	1,000,000,000	30,000,000	970,000,000
	South Haystack*	Adaville Fm. coals (40')	1,544.0	64,800,000	--	64,800,000
		Subtotal	14,344.0	1,064,800,000	30,000,000	1,034,800,000
Hanna Coal Field	Carbon Basin*	Finch (10') Johnson (20') Other Hanna Fm. coals	2,725.0+	79,000,000	--	79,000,000
	Hanna Basin	Hanna, Ferris & Medicine Bow Fm. coals (21')	8,400.0	313,000,000	65,100,000	247,900,000
		Subtotal	11,125.0	392,000,000	65,100,000	326,900,000
Bighorn Coal Basin	Grass Creek	Mayfield (35')	97.0	18,600,000	--	18,600,000
		Subtotal	97.0	18,600,000	--	18,600,000
		GRAND TOTAL	321,912.4+	26,468,700,000	193,300,000	26,275,400,000

*Includes new reserve base derived from company reports and/or government publications.

COAL RESOURCES, PRODUCTION, AND RESERVES

Wyoming's original in-place coal resources between 0 and 3,000 feet of overburden were estimated at 136,891,430,000 short tons (modified Berryhill *et al.*, 1950). Approximately 2 percent of these resources were lignite, 4 percent bituminous coal, and 94 percent subbituminous coal. These resources, however, were based on only 46.54 percent of the known or probable coal-bearing land in Wyoming as they were limited to mapped and explored areas. When an estimate of the resources of the previously omitted 53.46 percent 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 836,891,430,000 tons. Wyoming's original resource figure becomes 936,891,430,000 tons when the overburden category is extended to 6000 feet (Averitt, 1975). In the 0 to 6,000 feet overburden category, Wyoming has the largest in-place coal resources in the nation.

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 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. Wyoming's known strippable reserve base of subbituminous coal 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.

DISTURBED SURFACE LAND

In 1969, it was estimated that a total of 3,078 acres of surface land in Wyoming was disturbed by surface coal mining in five counties: Campbell, Converse, Carbon, Lincoln and Sheridan (Kovats, 1969). Disturbed lands in this estimate not only included the open pit acreage but also the spoil (waste) piles, roads and building acreages. A conservative estimate, which adds acreage not included in the 1969 estimate as well as acreage disturbed since

1969, would be 9,000 acres to January 1, 1978. This area is less than 14.1 square miles or a little less than 4/10 of a township. It is also estimated that surface land disturbed by coal strip mining is currently increasing at a rate of 500-1000 acres per year.

Between August 1969 and June 30, 1973, strip mined land was reclaimed under Wyoming's Open Cut Land Reclamation Act. In July 1973 this law was rescinded and replaced by Wyoming's new Environmental Quality Act. The Act established a Division of Land Quality, which regulates and enforces reclamation of all mined lands within the State excepting Indian lands (Dept. of Environmental Quality, 1973).

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