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REVIEW OF WYOMING COAL FIELDS, 1976

SEPTEMBER 1976

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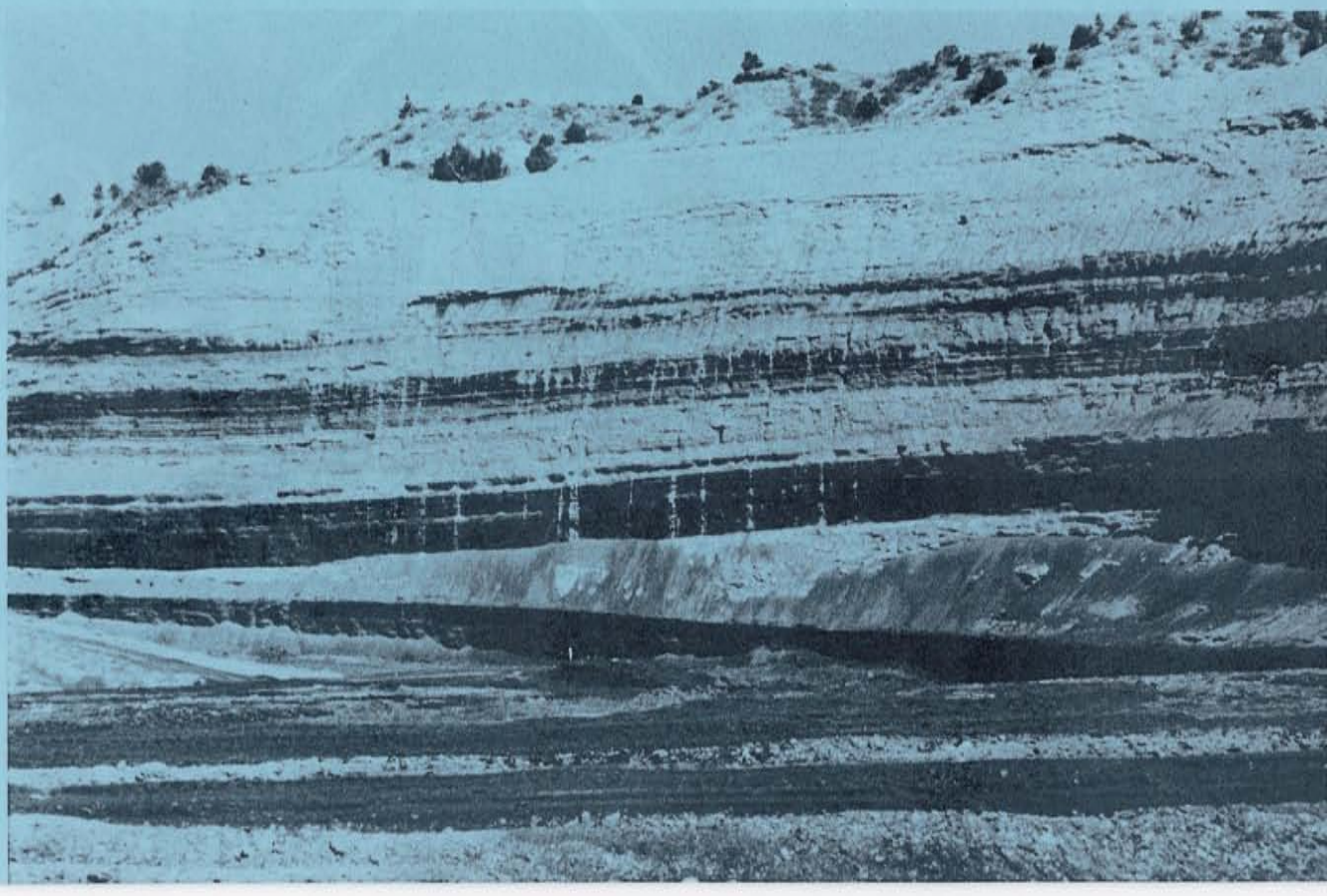

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BY GARY B. GLASS

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GEOLOGICAL SURVEY OF WYOMING

Daniel N. Miller, Jr., State Geologist

GEOLOGICAL SURVEY OF WYOMING
1933

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Photo on cover: Highwall of the Big Horn No. 1 strip mine in Sheridan County. The two major coals near the base of the highwall are each more than 20 feet thick.

STATE OF WYOMING
1933
GEOLOGICAL SURVEY

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Gary B. Glass
Staff Coal Geologist

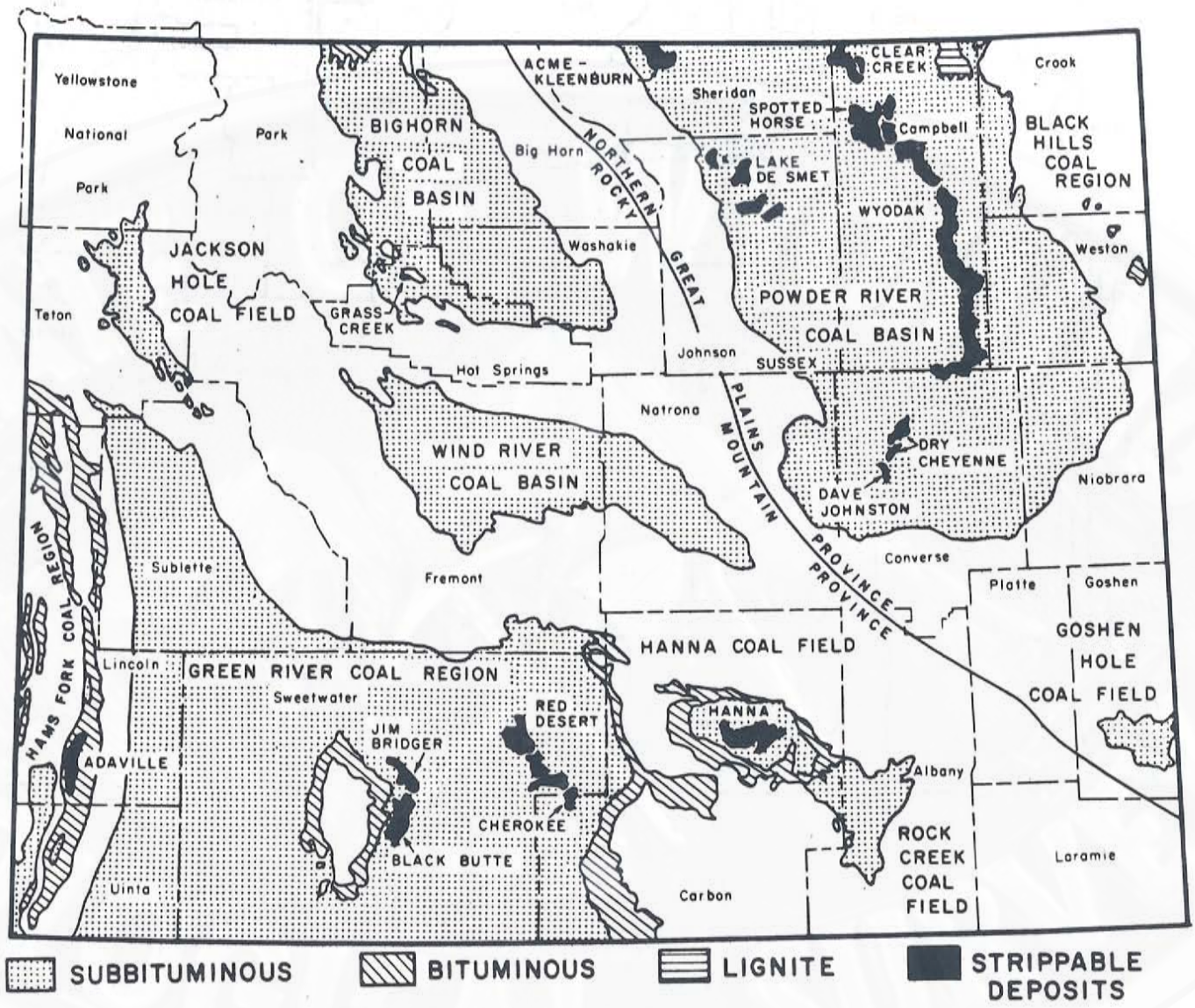

Figure 1: Coal-bearing areas of Wyoming

Coal-bearing Areas

As defined by the United States Geological Survey, Wyoming's coal fields fall into two coal-bearing provinces. The coals in northeastern Wyoming are within the Northern Great Plains Province while all other coal deposits of the state are in the Rocky Mountain Province. Additionally, the United States 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 almost 24 percent of the nation's coal resources under less than 6000 feet of overburden (Figure 1):

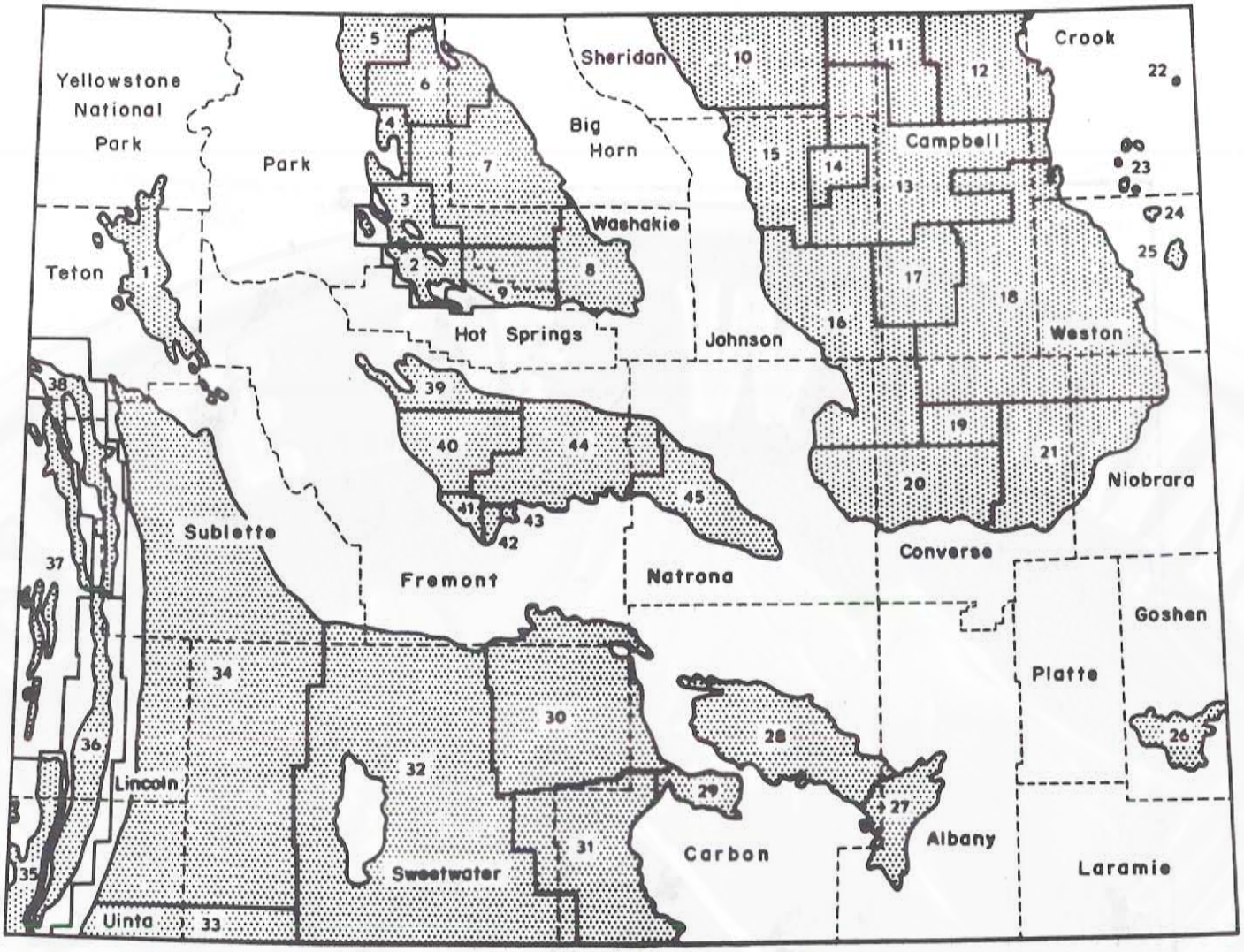

Figure 2. List of the coal fields in Wyoming, marked by number on map:

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. *La Barge 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 (Powder River)*

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 seven and six fields respectively, while the Hams Fork Region and the Black Hills Region each have four fields. The remaining four major areas are single coal fields. Revised boundaries for many of these fields are shown in Figure 2.

Coal-bearing Rocks

Coal-bearing rocks of Wyoming range in age from Lower Cretaceous to Eocene; however, Upper Cretaceous and younger rocks contain most of the calculated coal resources. Lower Cretaceous coals are restricted to the Black Hills and Hams Fork Regions. Upper Cretaceous coals are the most widespread and are found in all the major regions except the Black Hills Region. Paleocene coals are found in all but the Black Hills Region and the Goshen Hole Field. Eocene coals are the youngest and crop out in the Powder River Basin, the Green River Region, the Hanna Field and the Rock Creek Field.

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 coal beds are relatively flat-lying in the more central portions of the basins. Steeper dips and significant folding are common at some basin margins as well as on the flanks of mountain ranges. 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. Lignite occupies a very small area in the northeastern part of the Powder River Basin. Bituminous is restricted to the Black Hills Region, portions of the Hanna Field, Green River Region, Hams Fork Region and Bighorn Basin. High volatile B and A bituminous coal is reported only in the Hams Fork Region. With few exceptions, the bituminous coals are all of Cretaceous age; however, the Cretaceous coals are not all bituminous. Many are subbituminous rank.

Subbituminous coals are found in all the major coal areas of the state except the Black Hills Region. Figure 1 shows the geographic distribution of lignite, subbituminous and bituminous coals in Wyoming.

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

Coal Moisture, Ash and Sulfur Content

With one exception, the as received moisture contents of currently mined coals average 12.5 percent in the southern half of the state and in the Bighorn Basin (Table 1). The exception is the Jim

Table 1: Wyoming coal characteristics

Geographic Area	Rank	Bed Thicknesses (Feet)	Moisture[1] (%) (AR)	Ash[1] (%) (AR)	Sulfur[1] (%) (AR)	Heat Value[1] (Btu/lb.) (AR)	Hardgrove[1] Grindability Index
Northeastern Wyoming	Lignite Subbituminous[1] Bituminous	Max.: 220 Range[1]: 12-125 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 7550-9700 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 9350-11,700 Average 10,500	Range 45-80 Average 49
Western Wyoming	Subbituminous[1] Bituminous	Max.: 110 Range[1]: 5-110 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]: 7-20 Avg.[1]: 13	Range 12.1-12.8 Average 12.5	Range 3.7-9.0 Average 6.3	Range 0.4-0.55 Average 0.48	Range 10,800-11,400 Average 11,100	Range 30-80 Average 49

[1]Beds currently mined. (Table compiled by Geological Survey of Wyoming, February 1975.)

Bridger strip mine in southwestern Wyoming. The younger coals mined there average 20.5 percent moisture. Coals in the western and northeastern portions of the state average 21 percent and 26 percent moisture (as received), respectively.

Currently, the average as received ash content of Wyoming coals is 7.2 percent. Reported as received ash values normally range between four and ten percent (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).

Sulfur contents on an as received basis now average 0.55 percent and rarely exceed 0.9 percent (Table 1). The highest known sulfur contents occur in some Wasatch coals in the Green River Coal Region. Although these coals are not being mined, exploration has shown sulfur contents as high as seven percent. More than 99 percent of Wyoming's total known coal resources, however, contain less than one percent sulfur and about one-half of that is less than 0.7 percent. Ninety-six percent of Wyoming's known strippable resources contain less than two percent sulfur (USBM, 1971).

The sulfate form of sulfur in Wyoming coals averages less than 0.3 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, 1966). Because most of the sulfur in Wyoming's coal is in the organic form, conventional mechanical cleaning or preparation processes do not materially reduce the total sulfur content. Even if all pyritic sulfur could be removed, total sulfur would only be reduced by a maximum of 30 percent.

Heat Value

Heat values of presently mined coals, like moisture contents, vary widely across Wyoming (Table 1). In the southern half of the state and the Bighorn Basin, as received heat values average between 10,800 and 11,100 Btu/lb. Again, the younger coals at the Jim Bridger mine in southwestern Wyoming are a notable exception. Those coals average only 9350 Btu/lb. While heat values of coals mined in western Wyoming average 9600 Btu/lb., the heat values in northeastern Wyoming are generally lower. Although northeastern Wyoming coals range from 9300 Btu/lb. in the Sheridan area to 8000 Btu/lb. in Converse County, their overall average is only 8300 Btu/lb. By weighting average heat values with mined tonnages, mined Wyoming coal currently averages 9400 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 8400 Btu/lb. and 13,000 Btu/lb.

At least for 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).

Grindability and Friability

Because Wyoming coals have low Hardgrove Grindability Indices, averaging only 50 (Table 1), they are harder to grind or crush than many coals. Additionally, Wyoming coals tend to cake during pulverization. This caking tendency, which is a result of high moisture contents, retards pulverization.

The friability of Wyoming coals, on the other hand, equates with their rank. The higher rank coals shatter during handling while the lower rank coals slack readily upon exposure to air.

Fusibility of Ash

The ash in Wyoming coals softens and fuses at comparatively low temperatures, averaging 2140° for its softening temperature under reducing conditions. Because of this, they can be very troublesome in many types of burning equipment. Clinker and slag formation as well as a tendency to stick in ash hoppers are common problems. However, burning equipment designed for low-fusing ash minimizes or eliminates these problems.

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, et al., 1961).

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

Coking Coal

Coal with weak to moderate coking properties occurs in the Kemmerer Field of the Hams Fork Region, the Rock Springs Field of the Green River Region and the Cambria Field of the Black Hills Region. The Cambria coal in the Cambria Field possesses the best coking qualities. Unfortunately 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 coal 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 coal of the Rock Springs Field ranges between two feet and ten 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. The FMC Corporation's experimental 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 state of the FMC process is suitable as a fuel to produce power and steam and can also be used for injection into blast furnaces. The calcinate is a suitable fuel for sintering iron ore.

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

Columbine Mining Company operates a new commercial-sized coke plant near Rock Springs. This plant is approximately three times larger than its prototype built in 1963. Columbine's process uses poorly coking to noncoking bituminous coals to produce a chemical coke suitable for reducing phosphate in electric furnaces. The Rock Springs No. 7 coal of the Rock Springs Coal Field is currently used in the plant, which employs a rabble-type rotary oven. Columbine's process can also use subbituminous coal. An average analysis of the coke produced from this plant in 1966 was (Fagnant, 1966):

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

Currently, Columbine ships all its coke to Monsanto's phosphate plant in Idaho.

In Situ Gasification,

Since 1972, the Energy Research and Development Administration's Laramie Energy Research Center (formerly U.S. Bureau of Mines) has conducted research on in situ production of gas from coal at Hanna, Wyoming. The site in southern Wyoming was provided by Rocky Mountain Energy Company. In the fall of 1972, the Bureau drilled numerous 400-foot holes into a 30-foot thick subbituminous coal underlying the site. Since the coal's ignition in 1973, the combustion and gasification has been controlled by regulation of air fed through the boreholes. According to ERDA researchers, although gas volumes and heat values have ranged from 75,000 to two million cubic feet per day and from 30 to 475 Btu per cubic foot, both are now remaining on the high side of those ranges. Currently, the main fuel constituent of the gas is carbon monoxide, accounting for the low heat values. Future plans call for oxygen injection and the drilling of directional horizontal holes.

In 1975, the Lawrence Livermore Laboratories chose the Hoe Creek Site south of Gillette in Campbell County to begin Wyoming's second in situ coal gasification experiment. In the summer of 1975 several boreholes were drilled on the site. By fall, LLL researchers advanced far enough to detonate some high explosives to fracture the coal at the bottom of the boreholes. Ignition of the fractured coal is tentatively planned for the summer of 1976.

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 six million tons annually. After 1945, production plummeted 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. Low-sulfur fuel demands revived the state's coal industry in the 1960's. Production increased, first slowly, and then more than doubled between 1969 and 1972 to a record 10,920,468 tons (Figure 3).

Wyoming's 1975 tonnage set yet another record at 23.8 million tons. This tonnage ranked Wyoming as the largest coal producing state in the Rocky Mountains and the eighth largest in the nation. In 1976, production will probably exceed 30 million tons (Glass, 1976).

Coal production in Wyoming was dominated by underground mining until 1954. In that year production from strip mines barely exceeded that of the underground mines. Since then, however, strip mining has become the dominant mining method and accounts for more than 97 percent of Wyoming's annual production. Conversely, underground mining has slipped to less than three percent of the annual tonnage mined.

During 1975, there were five underground and 15 strip mines operational. The 16 companies that operated these mines produced an estimated 23.8 million tons.

The locations of mines operational in 1975 are summarized below:

Powder River Coal Basin

Powder River Field: Wyodak Resources and Development (Wyodak strip - T.50N., R.71W.)

Gillette Field: Amax Coal Company (Belle Ayr strip - T.48N., R.71W.)

Sheridan Field: Big Horn Coal Company (Big Horn No. 1 strip - T.57N., R.84W.), Welch Coal Company (Welch strip - T.57N., R.85W.)

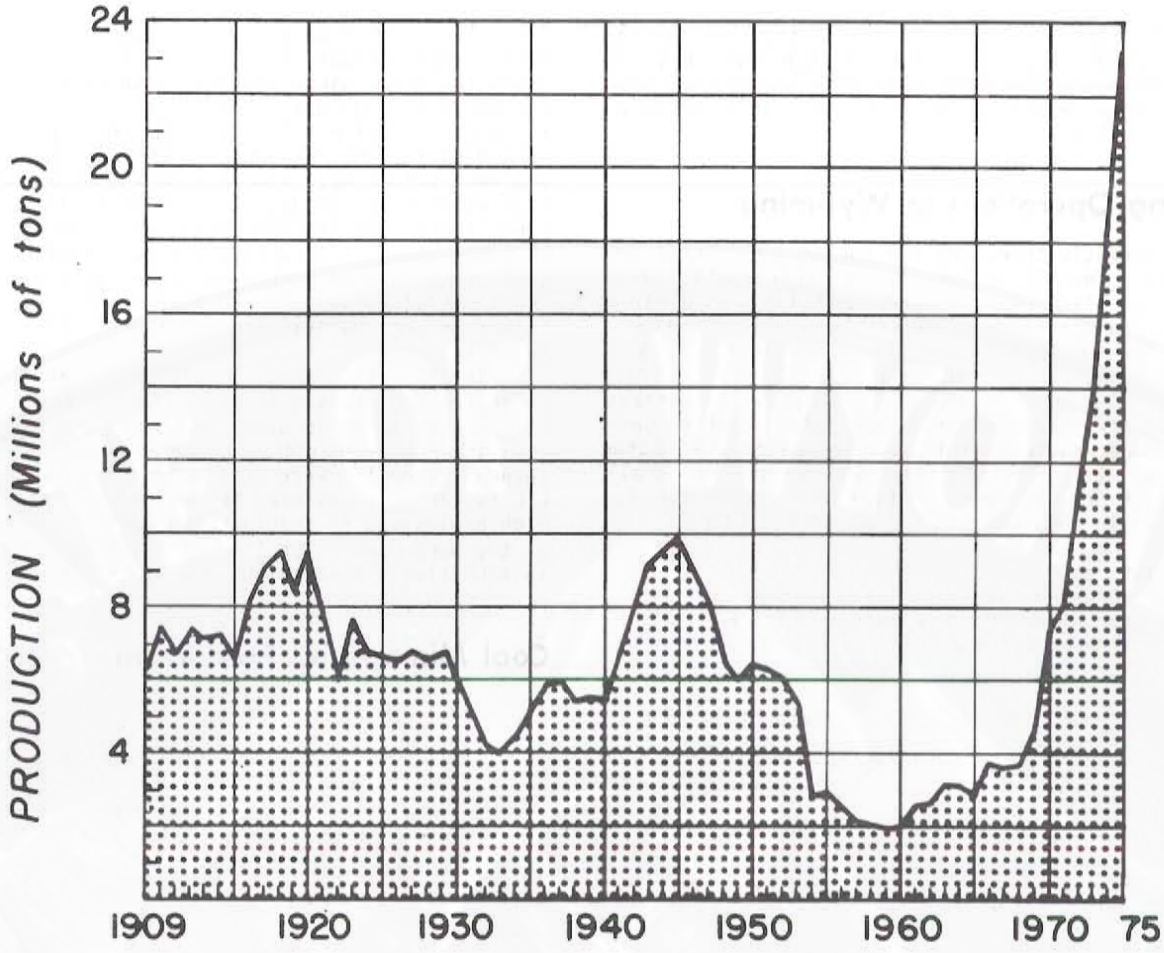

Figure 3. Wyoming coal production 1940-1975

Glenrock Field: Pacific Power and Light (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.18 N., R.105W.)

Hanna Coal Field

Hanna Field: Energy Development (Vanguard No. 2 deep mine - T.22N., R.82W., Vanguard No. 3 deep mine - T.22N., R.82W.), Resource Exploration and Mining, Inc. (Rimrock strips - T.23N., R.82W.), Rosebud Coal Sales Company (Pit No. 4 - T.22N., R.82W., Pit No. 5 - T.23N., R.81W., Pit No. 9 - T.23N., R.81W.), Arch Mineral Corporation (Seminoe No. 1 strip - T.22N., R.83W., Seminoe No. 2 strip - T.22N., R.81W.), Medicine Bow Coal Company (Medicine Bow strip - T.23N., R.83W.)

Hams Fork Coal Region

Kemmerer Field: Kemmerer Coal Company (Sorensen strip - T.21N., R.116W., Elkol strip - T.21N., R.116W.)

Bighorn Coal Basin

Grass Creek Field: Northwestern Resources (Grass Creek strip mine - T.46N., R.99W.)

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, 1975 is 497,677,344, tons of which 77.2 percent or 384,397,712 tons came from underground mines and 22.8 percent or 113,279,632 tons from strip mines.

In 1976, an estimated 94 percent or 29.2 million tons of Wyoming's production will be used in coal-fired power plants with approximately 33 percent or 9.7 million tons of that used in-state. The remaining six percent of Wyoming's annual tonnage will be used by the beet sugar industry, cement industry, trona industry, synthetic coke industry, railroads, governments, domestic and other miscellaneous users. Power plant coal is currently shipped out of Wyoming to Colorado, Illinois, Indiana, Iowa, Ohio, Missouri, Nebraska, South Dakota and Wisconsin. Smaller volumes go to users in Idaho, Kansas, Minnesota, Montana, Nevada, North Dakota, Oregon, Utah and Washington. By 1980, coal will also be shipped to Arkansas, Louisiana, New Mexico, Oklahoma and Texas (Figure 4). By then coal may also be going to Mississippi, Florida, Alabama, Georgia, Kentucky, Tennessee, Michigan and California.

Table 2: Wyoming Coal Production 1974[1]

Company	Mine Name	Employees	Production[2]
Amax	Belle Ayr (strip)	51	3,301,472
Arch Mineral	Seminoe #1 (strip)	101	3,142,400
	Seminoe #2 (strip)	70	2,589,752
Best	East Antelope (strip)	0	Closed
Big Horn	Big Horn #1 (strip)	69	997,274
Bridger Coal Co.	Jim Bridger (strip)	50	735,349
Carter Mining Co.	Rawhide (strip)	50	Construction
Dusky Diamond	Dusky Diamond (deep)	3	3,877
Energy Development	Vanguard #1 (deep)		
	Vanguard #2 (deep)	120	417,605
Medicine Bow	Medicine Bow (strip)	85	Development
Muddy Creek Mines	Muddy Creek (strip)	0	Closed
Gunn-Quealy	Rainbow #7 (deep)	0	Closed
	Rainbow #8 (deep)	70	103,019
Kemmerer	Elkol (strip)	48	916,322
	Sorenson (strip)	352	2,436,835
Pacific Power & Light	Dave Johnston (strip)	109	2,687,045
Resource Exploration	Rimrock #1 and #2 (strip)	63	594,070
Roncco	Roncco (deep)	3	2,830
Rosebud Coal Sales	Rosebud pits (strip)	135	1,963,316
Welch	Welch (strip)	2	20,340
Wyodak Resources	Wyodak (strip)	28	738,248
		1,411	20,649,754

[1]Wyoming State Inspector of Mines, Rock Springs, Wyoming
[2]In tons per year

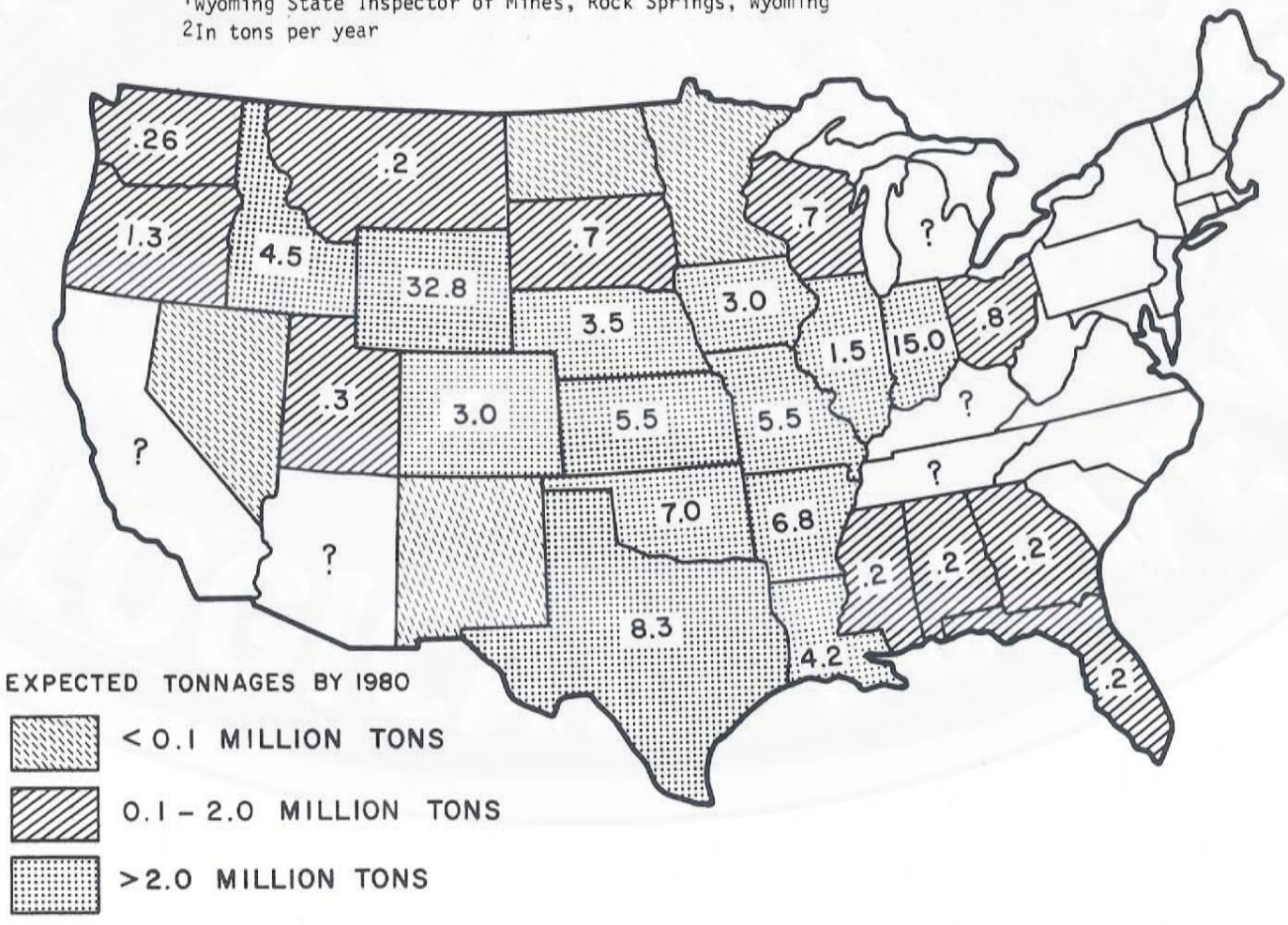

Figure 4. Current and announced markets for Wyoming coal

Wyoming's coal production is expected to increase 13 to 26 million tons per year throughout this decade. This is an average annual increase of 16.5 million tons. At these rates, annual tonnage will be 106-180 million tons by 1980; 118-281 million tons by 1985 (Figure 5). These projected increases are principally to satisfy the electric power market and include the requirements of only one to perhaps seven coal gasification plants (Glass, 1976).

If only the most probable forecast materializes, Wyoming coal companies will have to mine twice as much coal in the 13 years between 1973 and 1985 as their predecessors produced in the previous 108 years of recorded coal mining in the state (Glass, 1975b).

In regard to mine size, most Wyoming strip mines are slated to be very large--in excess of five million tons per year and several as high as 20 million tons. For examples, Amax, Carter Oil, Kerr-McGee, Atlantic Richfield, Pacific Power & Light, Kemmerer and Peabody each expect to have one or more strip mines producing between five and 20 million tons per year by 1980. For comparison, the Decker mine in Montana, which is currently the largest surface mine in the nation, produces nine million tons per year.

Bed Thickness

Currently, mined coals range from 4-110 feet thick, but average 13-70 feet thick (Table 1). The thickest beds are restricted to the Powder River Basin in northeastern Wyoming and the Hams Fork Coal Region in westernmost Wyoming. The thickest coal in the state occurs on the western side of the Powder River Coal Basin. There, the Healy coal is reportedly 220 feet thick, but is not presently mined.

The maximum coal thicknesses in southern, northwestern and central portions of Wyoming are 50 feet although the mined average is currently less than 20 feet. The thinnest coal mined in the state is four feet (southern Wyoming). This bed, incidentally, is the only bituminous coal mined in Wyoming. All other mined coals are subbituminous in rank.

Powder River Coal Basin

The Powder River Coal Basin covers more than 12,000 square miles in northeastern Wyoming. The basin forms a gentle, asymmetrical syncline between mountain ranges on the east and west. The axis of the syncline is west of the center of the basin. Dips which are usually less than two degrees on the eastern side of the basin steepen against the Bighorn Mountains on the western side.

Although some subbituminous coals occur in the Cretaceous Mesaverde and Lance Formations, the most persistent and thickest coals occur in the Tertiary Fort Union and Wasatch Formations. In fact, these two formations are probably the most prolific coal-bearing formations in Wyoming. The Fort Union Formation coals, which are best developed on the north and east sides of the basin, consist of eight to 12 thick, subbituminous coals. One, the Wyodak-Anderson coal, frequently ranges between 70 and 125

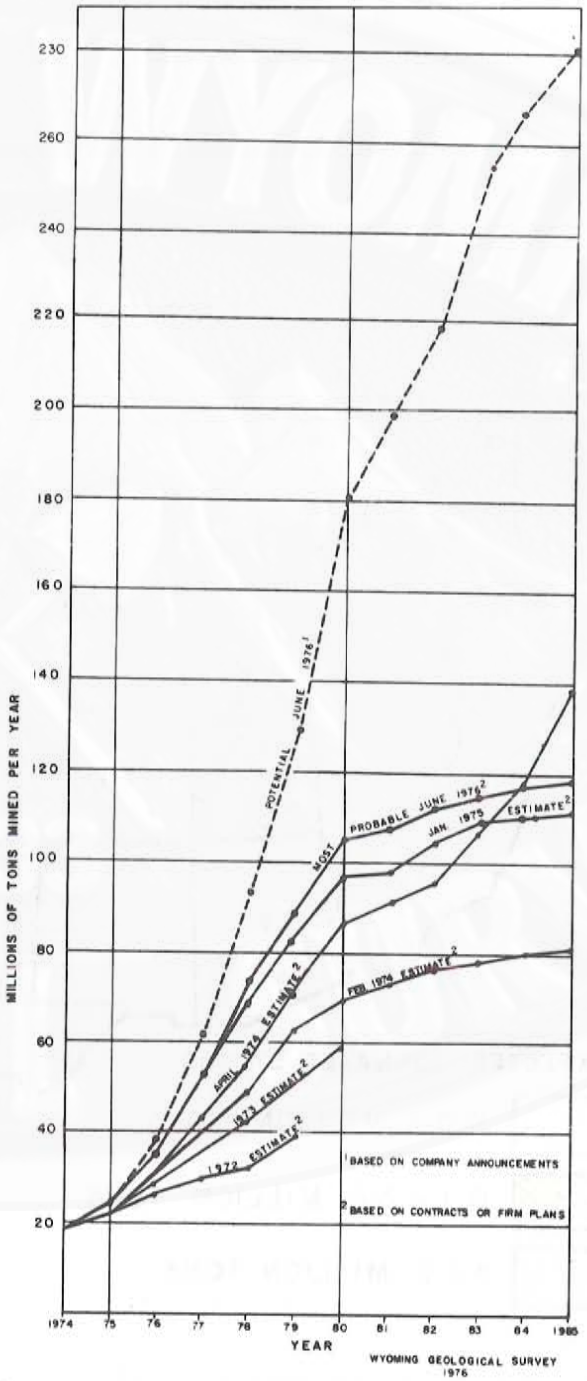

Figure 5. Forecasts of Wyoming coal production

feet thick. The Wasatch Formation, on the other hand, contains as many as eight persistent coals. The thickest Wasatch coal occurs at Lake De Smet on the west side of the basin. There, the Healy coal bed locally exceeds 220 feet in thickness.

Important coal beds in the Powder River Coal Basin are as follows:

Anderson Coal Bed: This Paleocene Fort Union Formation 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 foot 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.

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.

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.G.S., Montana Bureau of Mines and Geology, 1973; 1974).

As Received Basis	Range (9 analyses)	Ave.
Moisture (%)	24.9-34.1	29.5
Volatile Matter (%)	26.5-34.5	30.1
Fixed Carbon (%)	29.0-38.0	33.9
Ash (%)	3.5-12.2	6.5
Sulfur (%)	0.17-1.13	0.52
Btu/lb	7,128-8,737	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 ranges between 17 and 20 feet in thickness 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 reserves of 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 Pacific Power and Light Company's Dave Johnston mine north of Glenrock and burned in the Dave Johnston power plant at Glenrock. Five analyses from that mine show the following compositions:

As Received Basis	Range (5 analyses)	Ave.
Moisture (%)	22.7-29.3	27.4
Volatile Matter (%)	31.7-34.5	33.3
Fixed Carbon (%)	28.5-32.6	31.4
Ash (%)	6.6-9.8	7.9
Sulfur (%)	0.4-0.5	0.45
Btu/lb.	7,606-8,290	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.

Where it is not joined with the Anderson coal, the Canyon ranges between 11 and 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 the Dietz No. 3 bed of the Sheridan Field. The Canyon is not correlative with the stratigraphically higher Smith bed.

Except for an estimated 250 million tons of strippable reserves 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), strippable reserves of the Canyon bed are reported with the Wyodak-Anderson estimates. Currently, the Canyon coal is only mined at two sites 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 analyses)*	Ave.
Moisture (%)	26.5-31.5	29.6
Volatile Matter (%)	28.7-33.3	30.7
Fixed Carbon (%)	31.8-38.4	34.6
Ash (%)	3.1-7.4	5.1
Sulfur (%)	0.14-0.92	0.34
Btu/lb.	7,537-8,609	8,286

*U.S.G.S. and Montana Bureau of Mines and Geology, 1973, 1974

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 (1-5 analyses)
Moisture (%)	21.7-23.8
Volatile Matter (%)	33.6
Fixed Carbon (%)	38.5
Ash (%)	5.6-6.6
Sulfur (%)	0.74-1.02
Btu/lb.	9,220-9,387

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 to the Canyon coal of the eastern Powder River Basin, coalesces with the underlying Monarch (Wall) coal bed to form a 40-45 foot thick coal in the Sheridan area.

The strippable resource estimate 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

reserves of the two coals exceed 32 million tons (Smith, et al., 1972). Since this estimate was made, some 2.5 million tons of the reserve have been mined.

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 (Glass, 1975a)
Moisture (%)	19.1
Volatile Matter (%)	34.8
Fixed Carbon (%)	41.7
Ash (%)	4.4
Sulfur (%)	0.5
Btu/lb.	9,710

E Coal Bed: See Canyon Coal Bed.

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

Strippable reserves of this bed are estimated at 179.5 million tons (Smith, et al., 1972). There are no published analyses of this 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 5-21 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 strippable reserves of the Felix coal are 480.7 million tons in the Spotted Horse Field. The coal is subbituminous in rank and is not currently mined. The Lawrence Livermore Laboratories, however, are conducting an *in situ* gasification experiment in this coal south of Gillette.

Analyses of 42 core samples are summarized below:

Asreceived Basis	Range (42 cores)*	Ave.
Moisture (%)	17.8-33.5	28.0
Volatile Matter (%)	29.1-36.4	31.7
Fixed Carbon (%)	28.4-39.4	32.5
Ash (%)	4.5-14.9	7.8
Sulfur (%)	0.32-3.26	0.89
Btu/lb.	7,180-9,535	8,053

*U.S.G.S. and Montana Bureau of Mines and Geology, 1973; 1974

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 ranges between five and 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 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 (Mapel, 1958; Mapel 1959). The coal occurs in the Wasatch Formation.

Strippable reserves of the Healy coal approximate one billion tons according to Smith, et al. (1972). Most of this resource is 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 5-15 analyses[1]	Average 5 analyses
Moisture (%)	22.6-30.7	28.5
Volatile Matter (%)	28.6-31.9	30.0
Fixed Carbon (%)	32.8-34.8	33.9
Ash (%)	5.1-22.1	7.6
Sulfur (%)	0.26-3.00	0.6
Btu/lb.	6,480-8,270	7,884

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

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

The U.S. Bureau of Mines estimates that there are 32 million tons of strippable reserves of this coal, but these reserves include some Dietz No. 3 tonnage as well (Smith, et al., 1972). Since this estimate, mining has removed an estimated 2.5 million tons of the Monarch reserves.

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

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

As Received Basis	Range (203 analyses)	Ave.
Moisture (%)	14.5-26.0	21.5
Volatile Matter (%)	30.3-38.4	34.5
Fixed Carbon (%)	34.9-44.0	39.6
Ash (%)	3.1-8.2	4.4
Sulfur (%)	0.3-0.7	0.4
Btu/lb.	9,000-10,410	9,600

School Coal Bed: The School coal, which is 110 to 180 feet below the Badger coal in the Glenrock Field, is of subbituminous 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 thick, but averages 35 feet. Shaley partings deteriorate the quality of the bed to the south. 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 reserves of this coal in Converse County (Smith, et

al., 1972). Since this estimate was made, 11.5 million tons of this reserve have been mined.

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

As Received Basis	Range (3 analyses)	Ave.
Moisture (%)	19.5-26.4	22.2
Volatile Matter (%)	34.4-38.1	35.9
Fixed Carbon (%)	28.3-33.6	30.9
Ash (%)	8.8-15.7	11.4
Sulfur (%)	0.5-0.7	0.6
Btu/lb.	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 coal ranges between five and 13 feet thick and is subbituminous. It is found near the top of the Fort Union Formation when it has not been cut out by the Wasatch-Fort Union unconformity.

In the southern part of the Spotted Horse Field, a local, unnamed coal, which ranges between 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 the area (Smith, et al., 1972). Neither coal is mined at this time.

The 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 (Figure 3).

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

As Received Basis	Core Analysis*
Moisture (%)	31.8
Volatile Matter (%)	28.7
Fixed Carbon (%)	34.8
Ash (%)	4.7
Sulfur (%)	0.63
Btu/lb.	7,991

*U.S.G.S. and Montana Bureau of Mines and Geology, 1974

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 reserves 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/lb.	9,160

Ulm No. 2 Coal Bed: See Healy Coal Bed.

Wall Coal Bed: See Monarch 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 the bed does not correlate with the stratigraphically higher Roland and Smith coals. 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 thick. It commonly has an eight 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 ranging between 10 and 65 feet in thickness. To the north, the Wyodak-Anderson splits into five or more beds varying from 5 to 31 feet in thickness and separated by four 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.

Strippable reserves of this Fort Union Formation coal are the largest for any single coal bed in Wyoming and perhaps even for any coal bed in the United States. These reserves are estimated at 19 billion tons (Smith, et al., 1972). Since this estimate was made, strip mining has removed 11.2 million tons of these original strippable reserves. A conservative estimate projects another 200 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 9-11 large strip mines in Campbell County (Glass, 1976).

Amax Coal Company's Belle Ayr mine and Wyodak Resources South Pit are the only two active strip mines on the Wyodak-Anderson coal. Sunoco Energy Development Company, Carter, Kerr-McGee, Atlantic Richfield and Rochelle Coal Company, however, are all planning to open one or two strip mines in the next ten years. Additionally, Amax is planning a second mine and Wyodak is expanding their present mine. 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)*	Ave.
Moisture (%)	21.1-36.9	29.8
Volatile Matter (%)	26.5-35.5	30.7
Fixed Carbon (%)	29.6-41.4	33.5
Ash (%)	3.9-12.2	6.0
Sulfur (%)	0.2-1.2	0.5
Btu/lb.	7,420-9,600	8,224

*U.S.G.S. and Montana Bureau of Mines and Geology, 1973, 1974 and others

Green River Coal Region

The Green River Coal Region 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 Up-

lift and the eastern margin. Dips on the western side of the Rock Springs Uplift go up to 20°; on the eastern side to 10°. Along the eastern margin of the region, dips range between 20° and 60° in some areas.

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

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

Rock Springs Formation coals are high volatile C bituminous and range 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. 10, No. 11 and No. 15.

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 reportedly average up to 12 feet thick on the east side of the uplift (VTN, 1974).

Lance Formation coals reportedly average 5-10 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 9,780 Btu/lb. on an as received basis. These coals range from less than five feet 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 ten to 26 feet thick in the Black Buttes area (VTN, 1974). In both cases the coal is subbituminous in rank.

Wasatch coals in the southern 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 coals, 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 7,900 Btu/lb. (Smith, et al., 1972). Analyses of drill core samples of these beds show that they yield from 7.8 to 25.2 gallons of oil per ton by the Fisher assay method. Additionally, the uranium content of these coals ranges 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).

Important coal beds in the Green River Region are as follows:

Almond Coal Beds: Although there are few formal names for these coals, at least one Almond coal averages 10-12 feet thick in the Black Buttes area east of Rock Springs (VTN, 1974). See Lebar coal bed for details.

As Received Basis	Undifferentiated Almond Coals Ave. (Root, et al., 1973)
Moisture (%)	16.4
Volatile Matter (%)	31.0
Fixed Carbon (%)	47.7
Ash (%)	5.0
Sulfur (%)	0.6
Btu/lb.	9,727

B and C Coal Beds: These two unmined coals are subbituminous A coals of the Wasatch Formation and reach their maximum development in the northern part of the Little Snake River Field. The B coal ranges from ten to 18 feet thick and normally has a one to two foot parting in it. The C bed, which is 40-70 feet below the B bed, ranges in thickness between 20 and 32 feet. It has a foot to a foot and a half parting. In places these two beds coalesce into a single coal 30 to 40 feet thick, which has a parting up to four feet thick. Strippable reserves of these coal beds collectively reach 200.9 million tons (Smith, et al., 1972).

As Received Basis	Range (Masursky, 1962)
Moisture (%)	15-25
Volatile Matter (%)	28-36
Fixed Carbon (%)	27-40
Ash (%)	10-25
Sulfur (%)	0.5-5.0
Btu/lb.	5,009-9,000

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 are coals of the Wasatch Formation, and average between 6.4 and 8.6 feet in thickness. Strippable reserves of these two beds are estimated at 38.1 million tons (Smith, et al., 1972). A typical analysis of the Battle No. 3 is:

As Received Basis	Typical (Masursky, 1962)
Moisture (%)	21.9
Volatile Matter (%)	29.9
Fixed Carbon (%)	37.0
Ash (%)	11.2
Sulfur (%)	1.9
Btu/lb.	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 five to six feet thick except where it coalesces with the underlying Maxwell bed to form a coal that ranges between 16-22 feet thick. The normal interval between these two subbituminous coal beds is 25 feet. Although this coal was mined in the past, it is not mined now.

As Received Basis	Typical
Moisture (%)	20.7
Ash (%)	5.0
Sulfur (%)	0.61
Btu/lb.	9,650

Creston No. 2 and Creston No. 3 Coal Beds: These coals are in the Wasatch Formation in the Great Divide Basin Field. They crop out in the southeastern part of the field where they average about 18 feet thick. They are subbituminous B in rank. Strippable reserves of these beds are 125.6 million tons (Smith, et al., 1972). A typical analysis of the Creston No. 2 is:

As Received Basis	Typical (Masursky, 1962)
Moisture (%)	20.7
Volatile Matter (%)	32.2
Fixed Carbon (%)	34.4
Ash (%)	12.7
Sulfur (%)	1.8
Btu/lb.	8,710

Deadman Coal Bed: The Deadman coal of the Fort Union Formation is exceptionally well developed on the western edge of the Great Divide Basin Field. There, the coal has been referred to as the Jim Bridger deposit. The Deadman coal is 30 feet thick except where it splits into two 15 foot beds. It is subbituminous in rank. Strippable reserves are approximately 250 million tons (Smith, et al., 1972). The coal is now strip mined by Bridger Coal Company, a subsidiary of Pacific Power and Light Company. This coal can be traced southward into the Black Buttes area of the uplift.

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/lb.	9,270-10,000	9,350
HGI	79-82	

Fort Union Formation Coal Beds (Undifferentiated): Subbituminous Fort Union coals are locally known as the Black Rock Coal Group (Root, et al., 1973). Although they crop out on both sides of the Rock Springs Uplift, they are best developed on the east side where they were occasionally mined underground in the early 1900's. In the Black Buttes area, these unnamed Fort Union Formation coals average 10-26 feet thick (VTN, 1974). They are not currently mined. See also Ute Coal Bed.

As Received Basis	Average (VTN, 1974)
Moisture (%)	17.69
Volatile Matter (%)	30.93
Fixed Carbon (%)	43.85
Ash (%)	8.48
Sulfur (%)	0.41
Btu/lb.	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 coal is usually only four to five feet beneath the Overland bed and has a maximum reported thickness of eight feet. Plans to strip mine this coal have been announced.

As Received Basis	Typical
Moisture (%)	20.6
Ash (%)	4.7
Sulfur (%)	0.53
Btu/lb.	9,900

Hadsell No. 2 Coal Bed: This is another Wasatch coal cropping 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 reserves estimated for this coal (Smith, et al., 1972).

As Received Basis	Typical (Masursky, 1962)
Moisture (%)	23.0
Volatile Matter (%)	31.0
Fixed Carbon	32.2
Ash (%)	13.8
Sulfur (%)	2.7
Btu/lb.	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 ten 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/lb.	9,900

Lance Formation Coal Beds (Undifferentiated): Subbituminous coals of the Lance Formation are known as the Black Buttes Coal Group (Root, et al., 1973). Where they crop out on the northeastern and eastern sides of the Rock Springs Uplift, several small underground mines worked 4-9.6 foot thick coals in the early 1900's. Lance coals averaging five to ten feet thick are reported in the Black Buttes area by VTN, (1974) and may be strip mined in the near future. See Black Butte, Gibraltar, Hall, Maxwell and Overland coal beds.

As Received Basis	Ave. (Root, et al., 1973)
Moisture (%)	17.5
Volatile Matter (%)	29.8
Fixed Carbon (%)	48.6
Ash (%)	4.1
Sulfur (%)	0.4
Btu/lb.	10,110

Latham No. 3 and Latham No. 4 Coal Beds: The Latham coals 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 thickness is 5.7 feet. Strippable reserves of these two coals total 70.7 million tons (Smith, et al., 1972). A typical analysis of the Latham No. 3 coal is as follows:

As Received Basis	Typical (Masursky, 1962)
Moisture (%)	22.6
Volatile Matter (%)	30.9
Fixed Carbon (%)	31.2
Ash (%)	15.3

Sulfur (%)	5.4
Btu/lb.	7,980

Lebar Coal Bed: This Almond Formation coal 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 coal will probably be mined within the next several years along with an unnamed 4.8-6 foot coal about 60 feet above it. Both coals are probably subbituminous. A typical analysis of the Lebar coal bed follows.

As Received Basis	Typical
Moisture (%)	17.5
Ash (%)	7.6
Sulfur (%)	0.57
Btu/lb.	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 bed averages 5.5 feet thick when it isn't merged with the overlying Black Butte bed. Where the two beds coalesce, they locally range between 16-22 feet in thickness. The coal is probably subbituminous in rank, and will be mined in the near future.

As Received Basis	Typical
Moisture (%)	21.0
Ash (%)	6.0
Sulfur (%)	0.84
Btu/lb.	9,670

Nuttal Coal Bed: This subbituminous Wasatch coal ranges up to eight 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.

Overland Coal Bed: In the Black Buttes area of the Rock Springs Field, the Overland Coal Bed is the highest minable coal in the Lance Formation. This coal, however, is seldom more than four feet thick. Locally, the Overland bed contains shaley 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 five to seven 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: This bituminous coal was deep mined extensively in the past. Plans to reopen the Stansbury No. 1 underground mine on this bed are now complete and some coal was mined in 1976. A run-of-the-mine analysis of this Rock Springs Formation coal, taken at Stansbury in 1952, showed:

As Received Basis	One Tipple Sample
Moisture (%)	17.6
Volatile Matter (%)	34.5
Fixed Carbon (%)	43.9
Ash (%)	4.0
Sulfur (%)	0.99
Btu/lb.	10,480

Rock Springs No. 7 Coal Bed: This coal bed 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. The coal has some coking properties. The No. 7 coal is mined in Columbine's Rainbow No. 8 underground mine in Sweetwater County and used for making chemical grade coke suitable for reducing phosphate in electric furnaces.

As Received Basis	Range (14 Samples)	Ave.
Moisture (%)	5.0-16.5	11.4
Volatile Matter (%)	33.8-40.3	37.7
Fixed Carbon (%)	44.3-52.6	46.7
Ash (%)	2.4-5.4	4.2
Sulfur (%)	0.6-1.1	0.9
Btu/lb.	10,640-13,110	11,695
HGI		48

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

As Received Basis	Range
Moisture (%)	6.56-8.46
Volatile Matter (%)	38.42-39.74
Fixed Carbon (%)	47.69-48.55
Ash (%)	4.57-6.69
Sulfur (%)	0.7
Btu/lb.	12,379-12,572

This bed is not currently mined.

Sourdough - Monument - Tierney Coal Beds: This group of coals is actually five beds that occur at about the same horizon in the Wasatch Formation in the southeastern part of the Great Divide Basin Field. Because these coals at times 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. Strippable reserves for these unmined coals are 458.9 million tons (Smith, et al., 1972). Below is a typical analysis of the Sourdough No. 2 bed:

As Received Basis	Typical (Masursky, 1962)
Moisture (%)	23.2
Volatile Matter (%)	33.6
Fixed Carbon (%)	33.0
Ash (%)	10.2
Sulfur (%)	2.9
Btu/lb.	8,680

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

Wasatch Formation Coal Beds (Undifferentiated): Unnamed Wasatch coals in the Black Buttes area of Sweetwater County reportedly average six to eight feet thick (VTN, 1974). These coals are subbituminous in rank, but 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/lb.	8,770-9,610

Hanna Coal Field

Coal-bearing rocks of the Hanna Field crop out in a 750 square mile area of Carbon County in south-central 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.

Coals 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 are predominantly subbituminous although the Hanna No. 2 bed of the Hanna Formation has reportedly been ranked as high volatile C bituminous (Glass, 1972).

Total strippable reserves in the Hanna Field are approximately 313 million tons (Glass, 1972).

The following coals are important in the Hanna Field:

Bed No. 24: This subbituminous Ferris Formation coal averages 18-20 feet thick. Arch Mineral presently strip mines it on the west side of the Hanna Field in their Seminoe No. 1 mine. A typical analysis is:

As Received Basis	Range or Typical
Moisture (%)	14.0-16.0
Volatile Matter (%)	34.3
Fixed Carbon (%)	45.8
Ash (%)	3.9-0.4
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 1, 2 and 3 from the top down. The upper bench averages four feet thick; Bench 2 averages 5.5 feet; Bench 3, or the lower bench, averages 7.2-8.3 feet thick. The coal is currently mined in Arch Mineral's Seminoe No. 1 strip mine.

As Received Basis	Range (4 Samples)	Ave.
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 of subbituminous rank. The bed is best developed west of the town of Hanna where it is presently mined in Energy Development's Vanguard No. 2 deep mine. It varies between 15 and 19 feet thick.

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.	9,410-10,070
HGI	45

Bed No. 65: This Ferris Formation coal is of Paleocene age. It is subbituminous in rank and is now mined in Energy Development's Vanguard No. 3 deep mine. The coal is important west of the town of Hanna where it ranges from six feet to eight feet thick.

As Received Basis	Range (3 Samples)	Ave.
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 (%)	0.60-0.7	0.65
Btu/lb.	11,020-11,277	11,213
HGI	50-54	52

Bed No. 80: Bed No. 80 is a Paleocene coal of the Hanna Formation. The rank is subbituminous. This coal is well developed in the Hanna Basin where it ranges from 15.5 to 24 feet thick. The No. 80 bed generally has a foot to a foot and a half parting two to five feet above its base. Rosebud Coal Sales strip mines it in Carbon County.

As Received Basis	Range (10 Samples)	Ave.
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 coal bed is an Eocene coal in the Hanna Formation. It is a subbituminous coal averaging nine feet thick and is best developed in the Hanna Basin. It is stripped in Carbon County by Rosebud Coal Sales Company.

As Received Basis	Range (1-8 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 coal 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 mined in Resource Exploration's Rimrock strip pits in Carbon County.

As Received Basis	Range (3 Samples)	Ave.
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 coal ranges between 15 and 30 feet in thickness and is presently being converted into a low Btu gas at an ERDA in situ gasification site south of Hanna. The coal is subbituminous in rank.

As Received Basis	Range (3 Samples)	Ave.
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, Arch Mineral strip mines it now in their Seminoe No. 2 mine near Hanna, Wyoming. The Hanna No. 2 coal ranges between 30 and 36 feet thick.

As Received Basis	Range (6 Samples)	Ave.
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.	11,180-11,660	11,350
HGI		48

Hams Fork Coal Region

This region is the westernmost of the coal-bearing areas. Because it is highly folded and thrust faulted, the coal-bearing rocks crop out in long narrow belts. The coal-bearing rocks of this region are the Bear River, Frontier and Adaville Formations of Cretaceous age and the Evanston Formation of Paleocene age. Coals in this region range between high volatile A bituminous and subbituminous B. Coals up to 20 feet thick occur in the Frontier Formation and are the higher ranking beds. The Adaville Formation coals are subbituminous in the southern part of the region and bituminous in the north. In the southern half of the region near Kemmerer at least one Adaville coal attains a thickness over 100 feet.

Adaville Coal Beds: These coals are the most important coals in the region and are best developed in the Kemmerer Field. At least seventeen coals in this formation exceed six feet in thickness. The Adaville No. 1 coal bed is the thickest and attains thicknesses in excess of 100 feet. Some production of the No. 1 coal is used to make chemical coke for the phosphorous industry as well as experimental metallurgical grade coke. All the coals have partings which range from one inch to 15 feet in thickness. These coals are all subbituminous B in rank, where they are currently mined. Reserves calculated on 13 of the Adaville coals are greater than one billion tons (Smith, et al., 1972). All active mining on these coals is by surface methods. Kemmerer Coal Company currently operates both the Sorensen and Elkol mines. FMC Coal Company and Rocky Mountain Energy Company also plan to open strip mines on these coal beds.

Adaville No. 1 Coal Bed (Kemmerer area)

As Received Basis	Range (9 Samples)	Ave.
Moisture (%)	16.7-22.7	20.4
Volatile Matter (%)	33.0-36.5	34.5
Fixed Carbon (%)	40.8-42.8	42.1
Ash (%)	1.5-4.0	3.0
Sulfur (%)	0.5-1.3	0.7
Btu/lb.	9,720-10,530	10,193
HGI	55-59	57

Adaville Coal Beds (Kemmerer area)
(Exclusive of Adaville No. 1)

As Received Basis	Range (19 Samples)	Ave.
Moisture (%)	15.4-28.6	20.9
Volatile Matter (%)	31.1-36.1	33.8
Fixed Carbon (%)	33.5-44.7	40.4
Ash (%)	3.2-6.9	4.8
Sulfur (%)	0.2-1.8	0.6
Btu/lb.	7,920-10,400	9,472
HGI	41-87	53

Bighorn Coal Basin

The Bighorn Coal Basin is a broad structural basin bounded on the east, south and west by mountain ranges. Coal-bearing rocks, which underlie about 4,400 square miles of the basin, are exposed in the folded rocks around the margin. In these folded edges of the Bighorn Basin, dips as steep as 50° are common.

Coal-bearing rocks are the Mesaverde, Meeteetse and Lance Formations of Upper Cretaceous age and the Polecat Bench (Fort Union) Formation of Paleocene age. These rocks crop out in a three to five mile wide zone around the basin. Coals in the more central portion of the basin are under deep cover and little is known about them. Most of the coals are lenticular and of limited extent, especially along the eastern side. Thicker and more extensive coal beds occur on the southern and western sides.

Coal in the northernmost part of the Bighorn Basin is high volatile C bituminous in rank while the remaining part of the basin contains subbituminous A and B coals.

Gebo Coal Bed: This Mesaverde Formation coal was mined in the Gebo Field. The Gebo coal ranges between seven and nine feet thick, but averages only seven. Roncco Coal Company mined it underground by conventional methods in 1974.

As Received Basis	Range (69 Samples) *	Ave.
Moisture (%)	12.4-17.8	15.5
Volatile Matter (%)	31.1-40.3	34.2
Fixed Carbon (%)	43.0-49.7	46.0
Ash (%)	2.3-9.1	4.3
Sulfur (%)	0.4-0.8	0.6
Btu/lb.	10,080-11,780	10,970

*Glass, Westervelt, et al., 1975

Mayfield Coal Bed: This Polecat Bench Formation coal in the Grass Creek Field is now strip mined by Northwestern Resources. The coal ranges from eight to 38 feet thick and has been deep mined in the past. A preliminary and very conservative strippable reserve estimate for this bed is 18.6 million tons (Glass, Westervelt, et al., 1975).

As Received Basis	Range (6 Samples)*	Ave.
Moisture (%)	10.7-12.8	12.3
Volatile Matter (%)	34.0-38.0	35.6
Fixed Carbon (%)	42.2-48.1	44.7
Ash (%)	5.0-9.4	7.4
Sulfur (%)	0.3-0.6	0.4
Btu/lb.	10,730-11,246	10,970

*Glass, Westervelt, et al., 1975

Wind River Coal Basin

The Wind River Coal Basin is a large asymmetrical syncline in central Wyoming. Dips are steeper on the northern side than on the southern. Many minor folds and a number of faults complicate the basin. Coal-bearing rocks are the Mesaverde, Meeteetse and Lance Formations of Upper Cretaceous age and the Fort Union of Paleocene age. Coal-bearing rocks crop out around the margins of the basin. Coals in the central part of the basin are under considerable cover and are believed to be subbituminous.

Jackson Hole Coal Field

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

Black Hills Coal Region

The Black Hills Coal Region is in the extreme northeastern part of the state. Coals crop out in a narrow, discontinuous belt through the region. Minable coal is confined to the base of the Lakota Sandstone of Lower Cretaceous age. The field as a whole is usually considered "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 in rank.

Goshen Hole Coal Field

The Goshen Hole Field is in the southeastern part of the state. There are coals in the Lance Formation of Upper Cretaceous age, but little is known about their quality or thicknesses. While published reports only mention 2.5 foot thick subbituminous coals, oil and gas well logs suggest there may be some thicker coals. Additionally, much of this field is covered by younger noncoal-bearing rocks.

Coal Resources, Production and Reserves

Wyoming's remaining original in-place coal resources between zero and 3000 feet of overburden are estimated to be 136 billion short tons (modified from Berryhill, et al., 1950). Approximately two percent of these resources are lignite, four percent bituminous and 94 percent subbituminous coal. The estimates, 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 remaining original resources under 3000 feet of overburden increase to 836 billion tons. Figure 6 shows that Wyoming's remaining original resource figure becomes 936 billion tons when the overburden category is extended to 6000 feet (Averitt, 1975). In the zero to 6000 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 3 and 4. The original resources in these two tables only include mapped and explored bituminous beds 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 zero to 3000 feet.

Table 5 shows the total original resources of the state, production and mining losses and remaining resources. Coal reserves, which must be based on such factors as transportation and mining costs, are also tabulated. County production is shown in Table 6.

Disturbed Surface Land and Reclamation

In 1969, it was estimated that a total of 3078 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

Table 7: Remaining strippable subbituminous coal reserves of Wyoming to January 1, 1975 (modified from Smith, et al., 1972)

Coal-Bearing Area	Strippable Deposit	Coal Bed(s) (Average thickness in feet)	Acreage Estimate	Original Estimated Reserves to Jan. 1, 1968	Production and Mining Losses Since Jan. 1, 1968	Remaining Strippable Reserves to Jan. 1, 1975
Powder River Coal Basin	Acme-Kleenburn	Monarch and Dietz No. 3 (23')	786.0	32,000,000		
	Clear Creek	Canyon (11.2')	9,337.6	184,900,000		
	Dave Johnston	School (38')	2,418.0	126,200,000		
		Badger (16')	390.0	9,500,000		
	Dry Cheyenne	F (7.6')	13,260.8	179,500,000		
	Lake De Smet	Healy (163')	3,520.0	1,000,000,000		
	Spotted Horse	Felix (12.5')		480,700,000		
		Smith (10.0')	36,736.0	178,000,000		
		Local (10.0')		58,300,000		
	Sussex	Fort Union Fm., Lowermost coal (11.8')	651.0	13,600,000		
	Wyodak	Wyodak-Anderson (71'); Anderson (D) and Canyon (E)	155,282.0	19,000,000,000		
		Subtotal	222,381.4	21,262,700,000	34,000,000	21,228,700,000
Green River Coal Region	Black Buttes	Almond, Lance, Ft. Union, and Wasatch Fm. coals (12')	3,889.0	82,600,000[3]		
	Cherokee	B (10') C (17')	4,204.0	200,900,000		
	Jim Bridger	Deadman (30')	4,708.0	250,000,000		
	Red Desert	Battle 2 & 3 (7')	2,938.0	38,100,000		
		Sourdough, Monument and Tierney (6.8')	27,469.0	458,900,000		
		Hadsell 2 (7.7')	2,874.0	39,800,000		
		Creston 2 & 3 (14')	3,846.0	125,600,000		
		Latham 3 & 4 (5.7')	6,893.0	70,700,000		
		Subtotal	56,821.0	1,266,600,000	800,000	1,265,800,000
Ham's Fork Coal Region	Adaville	Adaville Fm. coals (44')	12,800.0	1,000,000,000		
		Subtotal	12,800.0	1,000,000,000	17,300,000	982,700,000
Hanna Coalfield	Hanna	Hanna, Ferris, and Medicine Bow Fm. coals (21')	8,400.0	313,000,000[1]		
		Subtotal	8,400.0	313,000,000	39,300,000[2]	273,700,000
Bighorn Coal Basin	Grass Creek	Mayfield (35')	97.0	18,600,000[4]		
		Subtotal	97.0	18,600,000	0	18,600,000
		GRAND TOTAL	301,372.4	23,860,900,000	91,400,000	23,761,500,000

[1]This approximation is based on Berryhill's 1950 original resources estimate (Glass, 1972).
[2]This is strip mine production and mining losses since 1950.
[3]This is based on a report by (VTN, 1974).
[4]This is based on an unpublished report by the U. S. Geological Survey.

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1933
GEOLOGICAL SURVEY