Special Publication 41

1995 Summary of COAL RESOURCES in Colorado

By C. M. Tremain,
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Department of Natural Resources
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INTRODUCTION

The largest available source of energy in Colorado is the coal that underlies nearly 30,000 square miles or 28% of the state (Fig. 1). Over 434 billion tons of in-place coal resources are estimated in Colorado above an overburden of 6,000 feet.[1] This resource is 11% of the total coal resources in the entire United States and is the fourth largest of all the states. To a depth of 3,000 feet, Colorado's remaining identified coal resources are nearly 129 billion tons.[1] In remaining identified bituminous coal resources, Colorado ranks second, behind Illinois, but is first in low-sulfur bituminous coal.[1] More than 80% of the coal resources of the state are minable by underground methods.

The coal resources of Colorado occur entirely within the Rocky Mountain coal province in Upper Cretaceous to Paleocene age formations (Fig. 2).

The state's eight named coal-bearing regions and 21 coal fields are located in the western part of the Great Plains within intermontane basins west of Denver and in the Colorado Plateau province.[3] Of the eight coal regions, the most important in terms of both total in-place resources and present annual production are the Green River and Uinta regions in the northwestern part of the state.

COAL PRODUCTION

Colorado mines have produced more than 942 million tons of coal since 1864. After establishing a record production of 12.658 million tons in 1918, Colorado's production began to decrease, declining markedly during the Depression. A slight increase in the state's coal production occurred during World War II, but mine output again

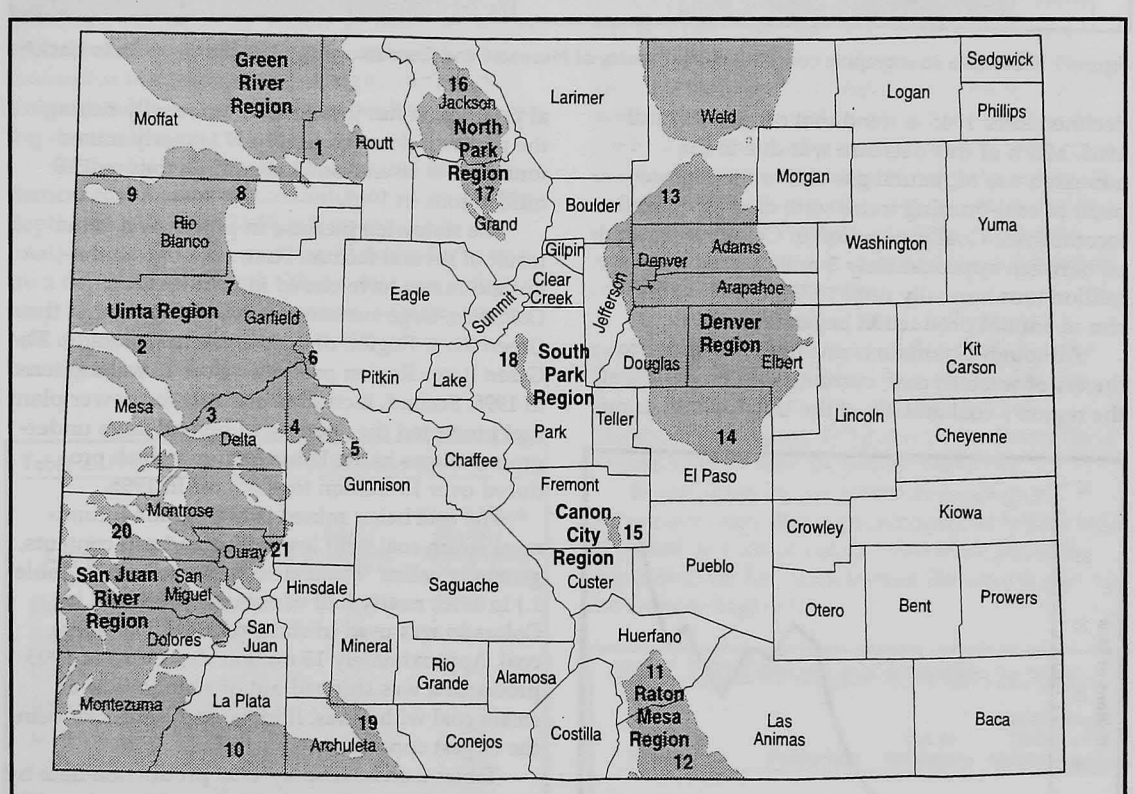

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Figure 1. Coal-bearing regions and fields in Colorado.

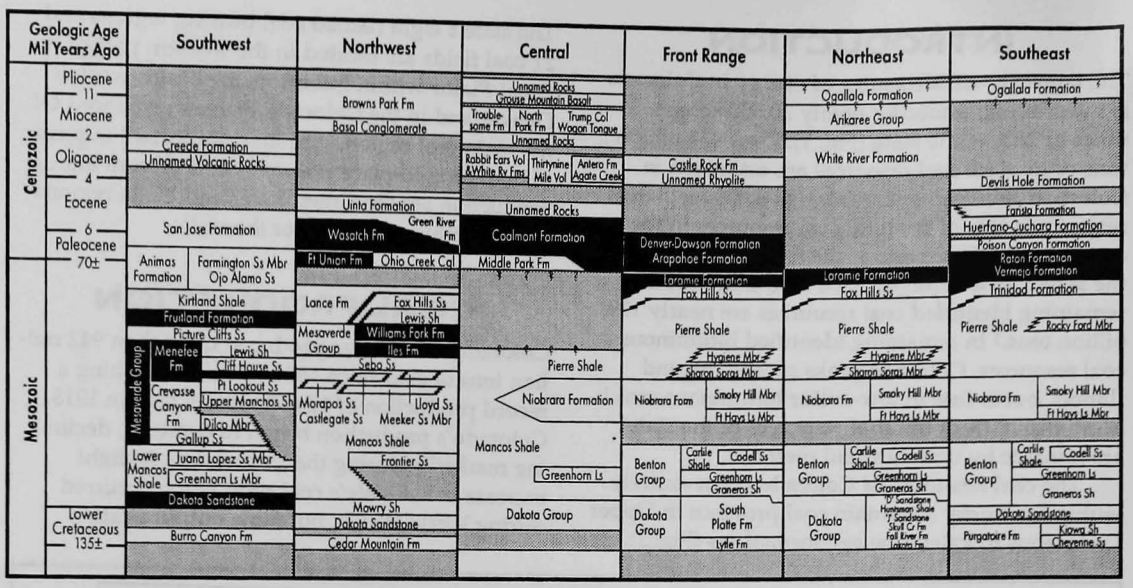

Figure 2. Colorado stratigraphic correlation chart, parts of Mesozoic and Cenozoic eras. Coal-bearing units in black.[2]

declined after 1945, a trend that continued until 1963. Much of this decrease was due to the increased use of natural gas and to the replacement of coal-burning trains with diesel-powered locomotives. Coal production in Colorado fluctuated between approximately 3 million tons and 6 million tons annually until 1973, when a strong rise in annual production began (Fig. 3).

Although Colorado is one of the smaller producers of western coal, currently producing 6% of the region's coal and 2% of the U.S. total, its annual production has increased dramatically during the past two decades. Since 1971, yearly mined tonnage has risen from 5.31 million tons to 25.9 million tons in 1995.

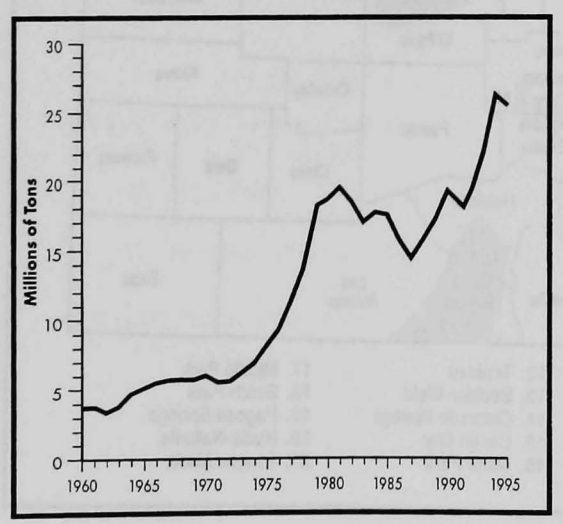

Figure 3. Colorado coal production, 1960–1995.

The statewide increase in production is the result of several factors. First, although underground mines have closed in southeastern Colorado, large surface mines have opened in the Green River Region of northwestern Colorado. The Green River Region produced over 10 million tons in 1995. Second, increased demand for power plant fuel prompted the opening of several large underground mines in the Uinta Region, which produced over 13 million tons of coal in 1995.

The coal being mined is high-grade bituminous steam coal with low sulfur and ash contents, generally called "clean air compliance coal" (Table 1.) In 1995, nearly half of the coal produced in Colorado was used in-state, primarily as steam coal. Approximately 13 million short tons of 1995 production was shipped out of state for use as steam coal with Texas, Illinois, and Kentucky being the largest consumers.

Tables 2 and 3 display 1995 production data by county and by coal-bearing region. Tables 4 and 5 display cumulative data by county and region.

COAL RESOURCES

According to the U.S. DOE's Energy Information Administration, Colorado ranks eighth in the total

Table 1. Arithmetic mean of proximate, ultimate analyses for regions.[4]

	Denver Region	Green River Region	North Park Region	Raton Mesa Region	San Juan River Region	Uinta Region
Moisture (%)	28.9	9.7	16.3	3.9	2.9	2.8
Volatile matter (%)	27.5	36.4	32.1	33.5	31.0	31.6
Fixed carbon (%)	33.1	46.8	39.4	46.6	53.6	58.6
Ash (%)	11.2	9.0	12.4	16.1	12.7	6.8
Hydrogen (%)	6.3	5.5	5.2	5.1	5.1	5.3
Carbon (%)	45.0	63.2	53.1	65.1	71.3	75.3
Nitrogen (%)	1.0	1.5	0.9	1.3	1.4	1.8
Oxygen (%)	36.7	20.2	27.8	11.7	8.0	10.8

U.S. demonstrated reserve base of coal (16.96 billion tons). Furthermore, Colorado ranks second in the reserve base of underground-minable, very low-sulfur bituminous coal. A significant part of Colorado's bituminous coal reserve base is of coking or metallurgical grade.[5]

Of the 434 billion tons of identified and hypothetical coal resources remaining in the ground to a depth of 6,000 feet, 128.95 billion tons (30% of the total) are classed as remaining identified resources (to a depth of 3,000 feet).[1] These data are preliminary, however; detailed or specific information on coal occurrence exists in about 25% of the coal-bearing areas of Colorado.[1]

Table 2. 1995 Colorado coal production by county.

County	Production	No. of Employees	No. of Mines (Surface / Underground)
Delta	522,384	84	0/1
Fremont	302,233	46	0/1
Garfield	375	0	0/1
Gunnison	6,844,648	349	0/3
La Plata	208,642	48	0/1
Las Animas	1,519,174	225	0/1
Mesa	589,064	67	0/1
Moffat	7,165,125	347	2/1
Montrose	374,266	20	1/0
Rio Blanco	760,255	114	0/1
Routt	7,614,673	394	2/1
Total	**25,900,839**	**1,694**	**5/12**

Of the demonstrated reserve base of 16.96 billion tons, only 4.8 billion tons or (28%) are surface-minable. The demonstrated reserve base includes coals, except lignite, that occur at depths above 1,000 feet, or deeper coals that are currently being mined. Bituminous coal and anthracite must be 28 inches or more in thickness and subbituminous coal and lignite, 60 inches or more in thickness, to be included. The Colorado Geological Survey estimates that more than 80% of the total coal resources of the state (maximum of 6,000 feet of overburden) will be minable only by underground methods.

Overall recovery of total resources probably will be much less than 50% of the coal in-place unless major breakthroughs in mining technology are achieved. Thick, multiple coal beds typical of many parts of Colorado may defy efficient recovery by even the most advanced mining methods. In some instances, recovery of naturally occurring coalbed methane or in situ combustion of deeply buried or steeply dipping coal beds may be the only way to recover the energy contained in much of the state's coal resources.[6]

According to Speltz,[7] most of Colorado's potentially surface-minable coal is located in the Denver coal region (75% of the total, mostly lignite), in the San Juan River Region (Nucla-Durango-Cortez area, 16%) and in the Green River Region (Oak Creek-Craig-Axial area, 5%).

Recent work by the Colorado Geological Survey indicates that approximately 34 billion tons of lignite, in beds at least 2.5 feet thick above a depth of 2,000 feet, may exist in the central part of the Denver Region.[8,9]

Table 3. 1995 Colorado coal production by region.

Coal Region	Production	No. of Employees	No. of Mines (Surface / Underground)
Canon City	302,233	46	0/1
Green River	10,383,933	512	3/2
Raton Mesa	1,519,174	225	0/1
San Juan River	582,908	68	1/1
Uinta	13,112,591	843	1/7
Total	**25,900,839**	**1,694**	**5/12**

Table 4. Cumulative Coal Production by County (1864 through 1995) in short tons.

Adams	37,112	La Plata	8,912,142
Arapahoe	36,259	Larimer	54,284
Archuleta	1,391,713	Las Animas	186,403,693
Boulder	43,321,306	Mesa	17,098,650
Delta	20,000,411	Moffat	129,392,599
Dolores	62,631	Montezuma	174,515
Douglas	27,367	Montrose	3,914,610
Elbert	108,948	Ouray	14,216
El Paso	15,251,246	Park	724,658
Fremont	46,952,294	Pitkin	29,548,497
Garfield	7,833,303	Rio Blanco	14,245,977
Gunnison	84,331,937	Routt	173,702,749
Huerfano	75,690,588	San Miguel	27,197
Jackson	7,067,310	Weld	68,660,774
Jefferson	6,697,939	**Total**	**941,684,925**

Coal Ownership

Preliminary compilations by the U.S. Bureau of Land Management (BLM) indicate that at least half of Colorado's coal resources lie on privately-owned land. The rights to the remainder appear to be split more or less equally between state and federal ownership.

Some 8.8 million acres of coal rights are owned by the federal government. The BLM estimates that these lands contain 60 billion tons of coal resources. Of this amount, about 6.4 billion tons (over 10%) are minable by surface methods. Recoverable coal reserves in Colorado held under federal lease are estimated to be 1.65 billion tons, of which 273 million tons are suitable for surface mining.

GENERAL COAL CHARACTERISTICS

Rank

Colorado coals range in rank from lignite to anthracite. More than 70% of the state's coal resources are bituminous, approximately 23% subbituminous, 5% lignite and less than 1% anthracite. Generally, the older the coal, the higher the rank; however, geologic factors such as higher geothermal gradient and deeper burial have significantly increased coal rank of even the youngest coals. For the most part, coals in Colorado are low-slacking. Many also are nonagglomerating, although significant resources of coking coal are found in parts of the Uinta, San Juan River and Raton Mesa regions.[5]

The coal-bearing sequences and coal ranks, by region, can be described as follows (units mined in 1995 are underlined):

Canon City Region (or field):
- Vermejo Formation (Upper Cretaceous) high-volatile C bituminous

Denver Region:
- Denver-Dawson Formations (Paleocene part) lignite A to subbituminous C
- Laramie Formation (Upper Cretaceous) subbituminous B and C

Green River Region:
- Wasatch (Eocene), Fort Union (Paleocene) and Lance Formation (Upper Cretaceous) — probably mostly subbituminous B and C
- Mesaverde Group (Upper Cretaceous) — mostly high-volatile C bituminous, some high-volatile B bituminous and subbituminous A

North Park Region (or field):
- Coalmont Formation (Paleocene-Eocene) subbituminous A and B

Table 5. Cumulative Colorado coal production by Coal Region to January 1, 1996.

Coal Region	County	Production (Millions of Tons)	Percent of State Total
Canon City	Fremont	46.95	4.99
Denver	Adams, Arapahoe, Boulder, Douglas, Elbert, El Paso, Jefferson, Larimer, Weld	134.20	14.25
Green River	Moffat, Routt	246.21	26.15
North Park	Jackson	7.07	0.75
Raton Mesa	Las Animas, Huerfano	262.09	27.83
San Juan River	Archuleta, Dolores, La Plata, Montezuma, Montrose, Ouray, & San Miguel	14.50	1.54
South Park	Park	0.72	0.08
Uinta	Delta, Garfield, Gunnison, Mesa, Moffat, Pitkin, & Rio Blanco	229.93	24.42
Total		**941.68**	

Raton Mesa Region:

Northern part of region (Walsenburg Coal Field):

Raton Formation (Paleocene-Upper Cretaceous) — high-volatile B and C bituminous (non-coking)

Vermejo Formation (Upper Cretaceous) — high-volatile B and C bituminous (non-coking)

Southern part of region (Trinidad Coal Field):

Raton Formation (Paleocene-Upper Cretaceous) — high-volatile A and B bituminous (coking)

Vermejo Formation (Upper Cretaceous) — High-volatile A and B bituminous (coking)

San Juan River Region:

Fruitland Formation (Upper Cretaceous) — high-volatile B and C bituminous

Menefee Formation of Mesaverde Group (Upper Cretaceous) — high-volatile A and B bituminous (locally coking)

Dakota Formation or Group (Upper Cretaceous) — high-volatile B and C bituminous (locally coking)

South Park Region (or field):

Laramie Formation (Upper Cretaceous) — subbituminous A and B (not produced since 1932)

Uinta Region:

Mesaverde Group (Upper Cretaceous) — anthracite and semianthracite (restricted to areas of igneous activity in southeastern part of area, especially in Crested Butte field); medium-volatile bituminous (high-grade coking coal, chiefly in Coal Basin area Carbondale field); high-volatile A, B and C bituminous (coking quality in parts of Carbondale and Somerset fields); subbituminous A and B (only in local areas near outcrops).

Moisture

Moisture, volatile matter and fixed carbon contents of Colorado coals vary considerably from region to region. Moisture contents generally are in the 1 to 20% range, as-received. However, some of the subbituminous coals and lignites in the Denver Region contain as much as 38% moisture. Overall, Colorado coals average about 12% moisture content. Statewide, volatile matter contents vary from 6.9% (in anthracite in Crested Butte field) to about 45%, with most coals being in the 31% to 40% range. Fixed carbon contents typically vary between 39 and 69%.

Ash

Ash contents vary considerably even within the same coal zone due to different depositional environments. The range typically is from 2 to 20%, averaging about 6%. Locally, however, ash contents may reach 25 to 30%, as-received.

Sulfur

Sulfur contents vary from 0.2 to 1.2%, as received. Ninety-nine percent of the coals contain less than 1.0% sulfur. More than 50% contain less than 0.7% sulfur. The bulk of the coal being surface-mined in Colorado at present contains between 0.2 and 0.5% sulfur. On the other hand, much of the metallurgical-grade coal in Colorado contains 0.5 to 1.0% sulfur, still low in comparison with many eastern coals. Work by the U.S. Geological Survey and the Colorado Geological Survey[4,10] indicates that organic sulfur usually predominates, followed by pyritic sulfur and sulfate. A typical coal in the Yampa field, Green River Region, has the following forms of sulfur: organic, 0.49%; pyritic, 0.03%; sulfate, 0.03%; total sulfur, 0.55%. Abnormally high pyrite content can be reduced by conventional coal preparation techniques to 0.5% sulfur or less.

Most of the coal being surface-mined in Colorado is used in steam-electric power plants. These coals contain between 0.2 and 0.5 pounds sulfur per million Btu, well within the definition of low-sulfur coal (0.6 pounds or less sulfur per million Btu).

Heating Values

The subbituminous and bituminous steam coal being produced in Colorado ranges from about 10,400 to 13,100 Btu/lb. On a dry, ash-free basis, most Colorado coals vary between 13,300 and 14,500 Btu/lb in heat content. Colorado coals average approximately 14,000 Btu/lb on a moisture and ash-free basis and 11,370 Btu/lb on an as-received basis.

Specific Gravity

Specific gravities of Colorado coals, based on available analyses, range from 1.280 for bituminous coal from the Farmers (old Paonia Farmers) mine (Somerset Coal Field, Delta County) to 1.468 for anthracite from Yampa Coal Field (Routt County). Average specific gravity for cleaned bituminous coal in Colorado is 1.332; for subbituminous coal, 1.291.

The specific gravity of coal varies considerably with rank and with ash content. For unbroken coal in the ground, the following values are representative:[1]

Anthracite and semianthracite coal— specific gravity (sp gr) 1.47 (2,000 tons/acre-foot)

Bituminous coal — sp gr 1.32 (1,800 tons /acre-foot)

Subbituminous coal — sp gr 1.30 (1,770 tons/acre-foot)

Lignite — sp gr 1.29 (1,750 tons/acre-foot)

Carbonizing Properties

Many Colorado coals are nonagglomerating and may be carbonized in fluidized systems. Chars produced at relatively low temperatures (450 to 700 degrees F) contain about 8.5 to 14.4% residual volatile matter and are easily ignited. Char heating values on a moisture-free basis vary from 14,600 to 14,960 Btu/lb and are suitable for boiler fuel. Lump chars can be produced from most Colorado coals but are relatively weak. Some of the lump chars might constitute suitable substitutes for coke breeze in special uses.

Coal Analyses

The Colorado Geological Survey and the U.S. Geological Survey have conducted cooperative projects to sample and analyze coal from most of the producing coal mines in Colorado, plus coals likely to be mined in the future. Trace elements and other geochemical analyses were done by the U.S. Geological Survey; the proximate, ultimate and related analyses were performed by the U.S. Bureau of Mines.

Results of this program have been published in hard copy by the Colorado Geological Survey[4,10] and on CD-ROM[11] by the U.S. Geological Survey. Included in the analyses are: trace element composition of the laboratory ash of coal samples, partings, roof rocks and floor rocks (31 trace elements are examined); major, minor and trace element composition of coals, on a whole-coal basis (42 elements are tested); and proximate and ultimate analyses, heating values and forms of sulfur determinations. Table 6 displays some of the results.

None of the Colorado coal samples (including coals from all of the larger producing mines in the state) contain significant quantities of toxic or radioactive elements such as arsenic, mercury, selenium, strontium, thorium and uranium. In fact, most appear to contain smaller amounts of these substances than do coals from other regions of the U.S.

COKING COAL

Significant reserves of marginal and premium grade coking coal occur in the Carbondale, Crested Butte and Somerset fields, Uinta Region; in the Trinidad field, Raton Mesa Region; and in the Durango field, San Juan River Region (Fig. 1). The Colorado Geological Survey completed an evaluation of coking coals in Colorado5 showing that original in-place identified coking coal reserves in the state total more than 4.2 billion tons.

According to Goolsby et al.,[5] the Uinta Region contains an estimated 0.5 billion tons of coking-coal reserves, ranging from premium grade medium-volatile bituminous to marginal grade high-volatile bituminous. The Raton Mesa Region contains about 2.0 billion tons of marginal grade high-volatile A and B bituminous; and the San Juan River Region contains about 1.7 billion tons of premium grade high-volatile A bituminous to latent grade high-volatile B bituminous coking coal reserves.

The Raton Mesa Region coking coals are of generally lower quality than that found in the other two regions; however, this region is the most accessible. The San Juan River Region is the least known of the three. It produces a medium quality bituminous coal. The thinness of the coal beds and the lack of rail transportation in southwestern Colorado have hindered coal development, but coalbed methane production is significant.

The southeastern third of the Uinta Region has produced the most desirable coke-oven feedstock in Colorado. Depth of overburden and the abnormally gassy nature of the coals have tended to retard development of the resource in this area.

A significant percentage of the bituminous coal reserves of Colorado lie beneath more than 1,000 feet of overburden. In western Colorado, for example, virtually all of the major underground coal mines are mining beneath cover ranging from 1,000 to 2,000 feet in thickness. The portals of most of these mines are in the sides of steep-walled valleys, and the coal is mined by means of drift- or slope-mining techniques. Because of the rugged topography in these areas, overburden rapidly increases as mining progresses, often attaining 1,000 feet in thickness within relatively short distances from the portal.

GENERAL GEOLOGY OF THE COAL FIELDS

Colorado coals range in age from early Late Cretaceous to Eocene. The higher rank bituminous coals, and the largest reserves, generally are found in the Upper Cretaceous-age Dakota and Mesaverde groups/formations (Fig. 2) in western Colorado, especially in the region from Garfield County south to the New Mexico state line. Cretaceous coals, which are related to transgressions and regressions of the Late Cretaceous-age

Table 6. Range of analyses of Colorado coals.

REGION Field Formation (Coal Bed)	Moisture (%)	Volatile Matter (%)	Ash (%)	Sulfur (%)	Heating Value (Btu/lb)	Ash Fusion Temperature (°F)	FSI
CANON CITY (and field)							
Vermejo Fm. (7 beds)	5.4–11.9	31.4–42.9	4.6–14.8	0.3–1.7	10,400–11,390	2,030–2,720	0
DENVER							
Boulder–Weld							
Laramie Fm. (beds 1–7)	13.7–29.1	27.3–43.6	3.5–12.7	0.2–0.9	8,250–10,810	1,990–2,470	0
Colorado Springs							
Laramie Fm. (beds A, B, C)	19.0–26.2	31.4–45.1	5.6–20.8	0.3–0.7	8,440–9,280	2,150–2,470	0
Southeast and South–Central							
Denver Fm. (Bijou, Kiowa,Comanche)	26.4–39.6	19.3–42.7	9.8–44.6	0.2–0.6	3,636–6,803	2,480–2,530	0
Laramie Fm.	33.1–35.0	30.8–44.2	7.8–15.7	0.4–1.1	6,150–7,340	2,140–2,400	0
GREEN RIVER							
Yampa							
Fort Union Fm. (Seymour)	20.7–23.0	——	3.9–7.8	0.2–0.4	8,250–8,710	——	0
Lance Fm. (Lorella, Kimberly)	19.6–21.8	——	4.1–6.5	0.5–0.7	9,660–9,720	2,010–2,260	0
Williams Fork Fm., Upper coal gp.							
(Dry Creek, Crawford, Fish Creek)	9.8–16.9	34.9–39.2	4.1–17.2	0.4–1.8	9,800–11,680	2,070–2,480	0
Williams Fork Fm., Middle coal gp.							
(Lennox, Wadge)	6.4–11.8	33.8–39.0	3.0–20.2	0.3–0.9	9,871–12,440	2,140–2,890	0–0.5
Iles Fm., Lower coal gp.							
(E, D, C, B, A or Pinnacle)	6.3–12.2	——	4.3–11.3	0.3–0.9	11,090–12,560	2,250–2,780	0
RATON MESA							
Trinidad							
Raton Fm. (11 beds)	1.8–4.5	34.4–40.3	5.3–16.4	0.4–1.1	10,169–13,871	2,055–2,800	0–8.5
Vermejo Fm. (14 beds)	1.6–7.5	32.2–39.1	7.7–21.8	0.5–1.0	11,430–13,510	2,290–2,910	0–6.5
Walsenburg							
Raton Fm.	2.5–4.2	——	5.3–13.5	0.4–1.0	12,660–13,340	2,230–2,730	0
Vermejo Fm.	5.3–10.2	36.4–38.0	7.2–14.4	0.4–1.3	11,050–12,880	2,210–2,840	0
SAN JUAN RIVER							
Durango							
Fruitland Fm.	0.9–2.3	20.8–23.6	19.5–26.6	0.7–0.8	11,230–12,140	——	——
Menefee Fm. (9 beds)	1.6–10.7	36.2–42.1	3.4–16.6	0.6–1.3	10,860–14,700	2,020–3,000	0–5.5
Nucla–Naturita							
Dakota Ss. (Fm.) (3 beds)	2.5–13.5	32.6–36.1	6.1–12.8	0.5–1.1	10,010–13,380	2,620–2,910	0–1.5
Tongue Mesa							
Fruitland Fm. (Cimarron)	14.2–16.0	36.0–47.3	6.7–8.4	0.5–0.9	9,350–10,200	2,450–2,480	0
NORTH PARK (and field)							
Coalmont District							
Coalmont Fm. (Riach; beds 1–4; (Monahan)	14.5–20.2	29.3–37.3	5.5–13.1	0.6–1.0	6,520–9,570	2,060–2,570	0
McCallum Anticline District							
Coalmont Fm. (Hill, Winscom, Sudduth)	12.0–16.1	27.4–37.3	2.1–19.2	0.2–0.3	8,580–11,280	2,040–2,680	0
SOUTH PARK (and field)							
Laramie Fm. (3 beds)	6.3–15.5	——	1.3–6.4	0.47–0.53	9,780	2,700	——
UINTA							
Book Cliffs							
Mt. Garfield Fm. (Mesaverde Gp.)							
(Carbonera, Cameo, Palisade, Thomas, Anchor Mine)	3.3–14.0	29.8–35.4	4.9–23.3	0.4–1.7	9,833–13,560	2,130–2,960	0–1.0
Carbondale							
Willaims Fork Fm. , (South Canon Gp.,							
Dutch Creek, Allen, Anderson)	0.8–3.4	22.0–28.1	3.4–10.0	0.3–1.3	12,470–15,190	2,140–2,505	8.5–9.0
Fairfield Gp. or A, B, C, D, Coal Basin A–B	0.8–4.0	21.8–39.3	3.4–6.7	0.4–1.5	12,609–15,088	2,180–2,455	1–9
Crested Butte							
Williams Fork Fm., Paonia Mbr. (6 beds)	2.5–13.3	——	3.2–9.1	0.4–1.9	11,400–14,170	2,130–2,480	0
Danforth Hills							
Williams Fork Fm. (Lion Canyon., Goff, Fairfield gps.)	8.9–15.5	——	2.2–9.6	0.3–1.4	10,140–11,790	2,210–2,910	——
Iles Fm. (Black Diamond Gp.)	9.2–13.4	——	3.7–10.0	0.4–0.6	11,200–11,970	2,210–2,990	——
Grand Hogback							
Williams Fork Fm. (E, Sunnyridge)	4.0–4.8	37.2–39.8	6.1–10.4	0.6–0.7	12,060–12,581	2,230–2,910	1.0–1.5
Grand Mesa							
Mt. Garfield Fm. (Mesaverde Gp.) (6–8 beds)	3.1–19.5	30.4–35.0	2.1–17.9	0.5–2.2	8,298–13,489	2,060–2,970	——
Lower White River							
Williams Fork Fm.	11.2–14.1	——	4.4–8.5	0.4–0.5	10,800–11,230	2,060–2,910	0–1.5
Somerset							
Williams Fork Fm. (F, E, D, C, B, A beds)	3.2–13.6	35.3–37.7	3.2–11.4	0.5–0.8	10,040–13,453	2,145–2,810	0–3.0

Western Interior seaway, generally are of higher rank and better quality than are the non-marine Tertiary coals found in the more restricted Laramide-age structural basins.

The oldest coals in Colorado occur in the Dakota Sandstone in the southwestern part of the state (northern San Juan Region, Durango to Nucla-Naturita field areas). Successively younger coals were laid down as the Late Cretaceous seaway retreated eastward and northeastward from the region.

The youngest coals, generally of lower rank (subbituminous A to lignite), are found in latest Cretaceous and early Tertiary rocks in the Green River, North and South Park, Raton Mesa and Denver coal regions. Subbituminous coals occur in the Cretaceous-age Lance, Laramie and Vermejo formations; in the Paleocene Fort Union and Raton formations; and in the Paleocene-Eocene Wasatch and Coalmont formations. Lignite is restricted to the Paleocene-age Denver Formation in the central Denver Region.

The San Juan River, Uinta, Green River, Raton Mesa and Denver coal regions are located principally within Laramide-age structural basins. The interior areas of these basins are relatively free from structural complications; the coal beds usually are not highly folded, faulted or otherwise disturbed. Some of the margins of these structural basins, however, are moderately to severely folded and faulted. In places, Tertiary igneous activity has metamorphosed the coal to anthracite, or even to coke. The Uinta Region (which includes the Piceance Creek Basin) and the Green River Region (which includes the Sand Wash Basin) each contain significant coal resources to depths exceeding 10,000 feet. These two basins are the deepest structural basins in the state. The Canon City, North Park and South Park coal regions occur in smaller, generally more structurally complex Laramide basins.

The coal-bearing regions and coal fields of Colorado are discussed below, region by region, in alphabetical order. Representative analyses of many of the most important coal beds or coal zones of the state, also listed in alphabetical order by coal region, are found in Table 6.

The stratigraphic columns for most of the currently producing coal fields[12] display the relative vertical distribution of the major coal-bearing intervals (or zones) together with the names of the coal beds that have been mined. Unlike coals in many eastern states, the coal beds in Colorado have been only tentatively correlated; thus, care should be used in assigning coal quality characterizations to a specific named coal bed.

Colorado coals are variable in both chemical and physical character and in thickness and in areal extent. Although recent coalbed methane studies have found some coals that extend up to 30 miles, correlation of individual coals from basin to basin, or from region to region, is rarely possible. For these and other reasons, many workers prefer to delineate coal-bearing sequences, or zones, when mapping coal beds. The stratigraphic columns included herein are preliminary attempts to address the problem of coal bed correlation and should be used with care.

CANON CITY REGION

The Canon City Region (or field) (Fig. 1) of Fremont County, lies within the Laramide-age Canon City Basin, a downfaulted, synclinal, structural embayment located at the southwest extremity of the Denver structural basin of similar age. The Canon City embayment is bounded on the north by the Front Range uplift, on the southwest by the Wet Mountains uplift and on the south by the Apishapa Uplift, which separates the Canon City and Denver basins from the Raton Basin to the south. Geologically, the Canon City Basin is more analogous to the Raton Basin than to the Denver Basin, and the coals in the Canon City Region are similar to those in the northern part of the Raton Mesa Region (Walsenburg field). The geologic structure in the Canon City Region is asymmetric, with gentle dips on the east and moderately steep dips on the west. Some faulting occurs along the east flank of the Wet Mountains uplift. This is the smallest coal region in Colorado, covering an area of only about 50 square miles.

The coals in the Canon City Region (or field) occur in the lower part of the Vermejo Formation (Upper Cretaceous). Seven main coal beds have been mined commercially in the area (Fig. 4); another eight or 10 beds have been reported.

Canon City coals typically are high-volatile C bituminous in rank, relatively low in sulfur content, non-weathering, non-agglomerating and non-coking.

This region has produced nearly 47 million tons of coal, ranking fifth in the state. Historically, more than 175 mines have operated in this region; in 1995, one underground mine was producing coal. Much of the coal mined in the Canon City

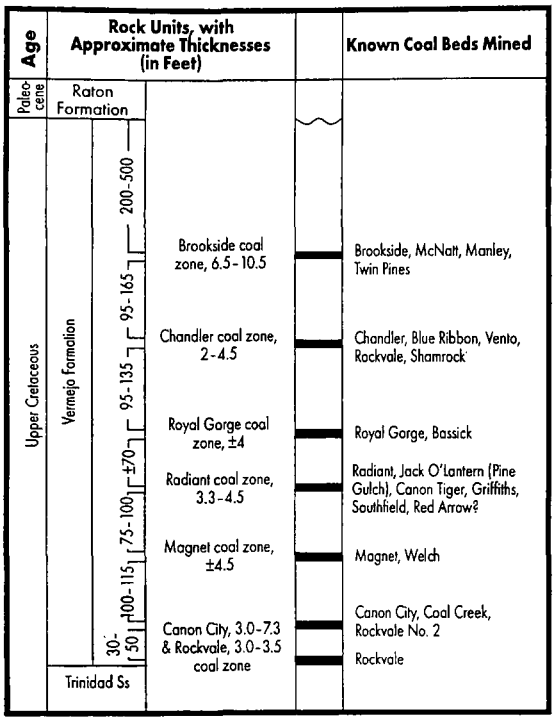

Figure 4. Stratigraphic column, coal-bearing rocks, Vermejo Formation, Canon City field, Canon City Region (no vertical scale).[12]

Region is used in nearby steam-electric power plants located in Canon City and by local domestic purchasers.

Of the estimated original in-place coal resource of 295 million tons,[13] about 248 million tons are believed to remain in the Canon City Region above a depth of 1,000 feet.

DENVER REGION

The Denver Coal Region encompasses an area of some 7,500 square miles east of the Front Range. It extends from the Wyoming state line south nearly to Colorado Springs (Fig. 1). The city of Denver is located in the west-central part of the region. The coal region lies within the larger Laramide Denver structural basin, the synclinal axis of which is located near its western edge. This region contains large resources of subbituminous coal and lignite within 3,000 feet of the surface.

Within the Denver Region are two separate coal-bearing sub-basins, the Denver Basin to the south and the Cheyenne Basin to the north. These basins are separated by a structural high, the Greeley arch, from which the coal-bearing sequences have been eroded.[14] The "sub-basins" are defined by the outcrop of the Upper Cretaceous Laramie Formation coal-bearing interval. The lower part of the Laramie in both sub-basins contains subbituminous to lignite coal beds. The overlying Denver Formation (Upper Cretaceous to Paleocene in age) occurs only in the Denver sub-basin and contains multiple beds of lignite only in the central part of the sub-basin.

LARAMIE COALS

Laramie Formation coals are exposed in hogbacks and road cuts along the foothills of the Front Range from Colorado Springs to Boulder. The Laramie coals are almost vertical in the Foothills district,[14] but their dips decrease rapidly eastward to 5 degrees or less. Laramie coal beds occur in a 50- to 275-foot-thick zone in the lower part of the formation. These coals were deposited on a delta plain in poorly-drained swamps.

Laramie coals are lenticular and generally thicker and more persistent in the Denver Basin than in the Cheyenne Basin. They are typically 5 to 10 feet thick and locally 20 feet thick in the former, but only 3 to 7 feet thick in the latter. In approximately 1,850 square miles of the Denver coal region, Laramie coal beds are surface minable (i.e., within 200 feet of the surface). Another 2,000-plus square miles contain Laramie coal beds from 500 to 1,500 feet in depth; these coals may be candidates for in situ gasification.[14]

Laramie coal beds vary significantly in rank in the Denver Region, from subbituminous B to lignite A. The higher rank coals, which average 8,500 to 10,000 Btu/lb, as-received, occur along the west side of the Denver Basin in the Foothills district and in the Boulder-Weld field (Fig. 1). Lower quality coals, ranging from 5,000 to 7,300 Btu/lb, as received, are typical of the eastern flank of the Denver Region.[14]

DENVER COALS

Thick lignite beds of early Paleocene age occur in the upper 300 to 500 feet of the Denver Formation immediately below the Dawson Arkose, in the Denver sub-basin. The lignite beds were apparently deposited in two separate swamps in an alluvial plain east of the Front Range piedmont. The northern lignite area contains individual beds typically 10 to 30 feet thick, with a maximum observed thickness of 55 feet. The southern lignite area con-

tains generally thinner beds, averaging 5 to 10 feet, with a maximum thickness of about 30 feet. Most of the known lignite beds occur in the central and eastern parts of the Denver Basin and are potentially surface-minable, beneath less than 200 feet of cover. To the west, in the deeper parts of the basin, the Denver Formation lignites pinch out.14

Denver Formation lignites exhibit the following properties, based on as-received analyses: heating value, 4,000 to 7,000 Btu/lb; ash content, 8 to 30%; moisture content, 22 to 40%; and sulfur content, 0.2 to 0.6%. Variations in quality are primarily a function of the number and thickness of partings—chiefly kaolinite—within a given bed. These kaolinite-rich partings, which may comprise 5 to 30% of the total thickness of a bed, are high in alumina content and offer the potential for dual-resource (lignite and alumina) recovery.14

Since the late 1800s, the Denver coal region has produced more than 134 million tons of coal, equivalent to more than 14% of the statewide total (Table 5), from about 385 mostly underground mines. Approximately 15 million tons of all the production in the region (or 11%) came from the Colorado Springs field in Douglas, El Paso and Elbert counties. The balance was mined in the Boulder–Weld field, principally from Boulder and Weld counties. This is the only coal region in Colorado in which shaft mining predominated over drift or slope mining. Shaft depths ranged from about 250 to 500 feet. No mines currently operate in this region.

According to the last resource estimates, coal resources in the Denver Region are approximately 38 billion tons of subbituminous coal in the Laramie Formation, and 34 billion tons of lignite in the Denver Formation, all at depths of less than 3,000 feet of overburden.8,9

GREEN RIVER REGION

The southeast arm of the large Green River coal region is located in Moffat and Routt counties of northwest Colorado (Fig. 1). The larger part of this important coal region covers most of southwest Wyoming.3 The Colorado part of this region is comprised of the Sand Wash structural basin of Laramide age, together with the north flank of the Axial Basin uplift, which bounds the basin to the south. The perimeter of the Green River coal region is defined (except where faulted) by the base of the Upper Cretaceous Mesaverde Group. The oldest coals in the region are found in the Iles Formation, part of the lower Mesaverde Group (Fig. 2).

Coal-bearing Upper Cretaceous, Paleocene and Eocene rocks crop out along the Yampa River-Williams Fork Mountains area in the southeastern part of the region. This area is the Yampa coal field, the only named field in the region. The south flank of the Sand Wash Basin consists of gently northward-dipping sediments that are locally folded (especially in the southeast part of the basin) and complicated by faulting and igneous intrusives of late Tertiary age. The intrusives have upgraded some of the coals to anthracite.

Nearly all of the coals mined in the Green River Region have come from the Iles and Williams Fork (Fig. 5) formations of the Mesaverde Group. Younger coal-bearing rocks (Lance, Fort Union and Wasatch formations) are preserved toward the interior of the basin, away from outcrops of the Mesaverde. A major part of the region contains multiple coal beds in several formations below a depth of 3,000 feet. In the central part of the Sand Wash Basin, coals are present to depths in excess of 10,000 feet.

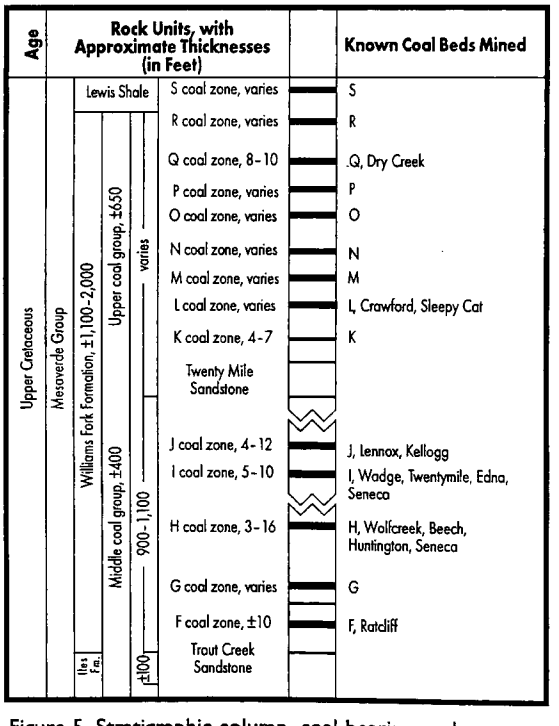

Figure 5. Stratigraphic column, coal-bearing rocks, Williams Fork Formation, Mesaverde Group, Green River Region (no vertical scale).12

The Mesaverde coals in the Green River region are principally high-volatile C bituminous in rank at the outcrop and vary in thickness from approximately 3 to 20 feet. The younger Lance Formation coals, which have been mined locally in the past, appear to be subbituminous B or C and range up to 10 feet in thickness. The overlying Fort Union coals are as thick as 20–50 feet, as shown by geophysical logs of oil wells drilled in the Sand Wash Basin. Where sampled near the surface, the coals appear to be subbituminous B or C in rank.

Very little is known about the Wasatch Formation coals in the Colorado part of the region, although they have been mined in limited quantities at several ranches on both sides of the Colorado-Wyoming state line. Like the older Fort Union and Lance coals, those in the Wasatch Formation probably are subbituminous B or C in rank, range from a few feet to 20 feet or more in thickness, and may be surface-minable in parts of the region.

The Green River Region has produced approximately 246 million tons of coal (about 26% of the state's coal) from some 200 mines. During 1995, over 10 million tons of coal were produced in Colorado's portion of the region; this was 40% of the coal produced in the state. Production from this region in 1995 was from three surface and two underground mines.

New in-place coal resource estimates in the Colorado part of the Green River Region exceed 300 billion tons above a depth of 6,000 feet.[15] Speltz[5] estimates that nearly 1 billion tons of potentially surface-minable coal exist in this part of the region.

Much of the coal (all of it low-sulfur) being mined in the Green River Region is burned in electric generating plants located within the region, at Craig and Hayden. The balance of the coal production is shipped mostly to Denver and Colorado Springs.

NORTH PARK REGION

The North Park coal region (or field), of Grand and Jackson counties (Fig. 1), lies in a high (elevation of 8,000 to 9,000 feet) intermontane structural basin in north-central Colorado. The North Park Basin, or syncline, of Laramide age, is bounded by the Medicine Bow-Front Range uplift to the east, the Park Range uplift to the west, the Independence Mountain thrust fault to the north (near the Wyoming state line) and the Williams River-Vasquez Mountains to the south. The North Park Region is comprised of two topographic basins, North Park and Middle Park, separated by the east-west-trending Rabbit Ears Range, a middle to late Tertiary volcanic field. Each basin contains a coal field: North Park Coal Field in North Park (Jackson County) and Middle Park Coal Field in Middle Park (Grand County).

All of the coals found in North Park Basin occur in the Coalmont (Middle Park) Formation of late Paleocene and early Eocene ages. The Coalmont consists of up to 12,000 feet of terrigenous clastics, carbonaceous shales and coals deposited in an alluvial basin that rapidly subsided as the Rocky Mountains uplifted in early Tertiary time. Coals formed in flood basins and swamps between the meandering streams. The Coalmont Formation unconformably overlies the marine Pierre Shale (Upper Cretaceous).

The North Park Region has produced over 7 million tons of coal from 35 mines since the early 1900s. The last mine in the region, the Marr surface mine on the east flank of McCallum anticline, ceased production in 1993.

NORTH PARK COAL FIELD

This coal field is the only part of the North Park Region ever mined—in the Coalmont District and the McCallum Anticline District. The coal beds mined in the region were (1) highly-folded—bed dips at McCallum Anticline exceed 45 degrees; (2) generally faulted; (3) very thick—50 to 60 feet—and lenticular; and (4) somewhat upgraded in rank due to a relatively high geothermal gradient in the area. North Park coals generally are subbituminous A to B in rank; most of the coal mined in recent years from McCallum anticline was subbituminous A (see Table 6).

MIDDLE PARK COAL FIELD

The Middle Park field has never produced coal, although some coal beds have been reported in lower Tertiary sediments probably correlative to the Coalmont Formation in North Park, a few miles to the north. An unknown amount of coal exists within this 250- to 300-square-mile southern extension of North Park Basin.

RATON MESA REGION

The Colorado portion of the Raton Mesa coal region extends northward from the Colorado-New Mexico state line to just north of the town of

Walsenburg, and from the prominent Sangre de Cristo and Culebra mountain ranges eastward to Interstate Highway 25 and the town of Trinidad (Fig. 1). This region lies within the Laramide Raton structural basin, an asymmetric syncline with a south-plunging axis near the west flank of the basin. Formation dips are gentle on the east flank, but are sharply up-turned to over-turned on the west flank, which is marked by the faulted east edge of the Sangre de Cristo uplift. The central part of the basin is penetrated by the twin Spanish Peaks (Tertiary-age igneous intrusions that rise to elevations exceeding 12,000 feet) and by many associated dikes, sills and laccoliths. The coals in this region have been upgraded—even coked in some areas—by abnormally high heat flow.

The perimeter of the Raton Mesa coal region is defined by the base of the Upper Cretaceous Vermejo Formation, the oldest coal-bearing sequence in the basin. Immediately above the Vermejo is the coal-bearing Raton Formation of Upper Cretaceous-Paleocene age (Fig. 6). The multiple, lenticular coal beds in both of these sequences generally are less than 10 feet thick.

Coals of both formations in the southern part of the region (Las Animas County) generally are of coking quality, whereas those in the north (Huerfano County) typically are non-coking.

The Colorado portion of the region has produced more than 262 million tons of coal from approximately 370 mines; this represents nearly 28% of all the coal produced in Colorado. This region has produced more coal than any other region in the state—nearly 16 million tons more than the second place Green River Region (Table 5). Despite the large volume of coal that has been removed from the Raton Mesa Region, more than 98% of the estimated in-place resource of 13.2 billion tons still remains.

Much of the mining in the region has been in the thicker, higher quality Vermejo coals. The mines have been located along the escarpment at the eastern edge of the basin and along the drainage of the eastward-flowing Purgatoire River, which dissects the area west of Trinidad. Only one Raton Formation mine was operating in the region in 1995 along the Purgatoire River.

Trinidad Coal Field

Las Animas County'js Trinidad field (Fig. 1) has produced considerable coal since the late 1800s, much of it coking quality. Over 185 million tons through 1995 (20% of the total for the entire state)

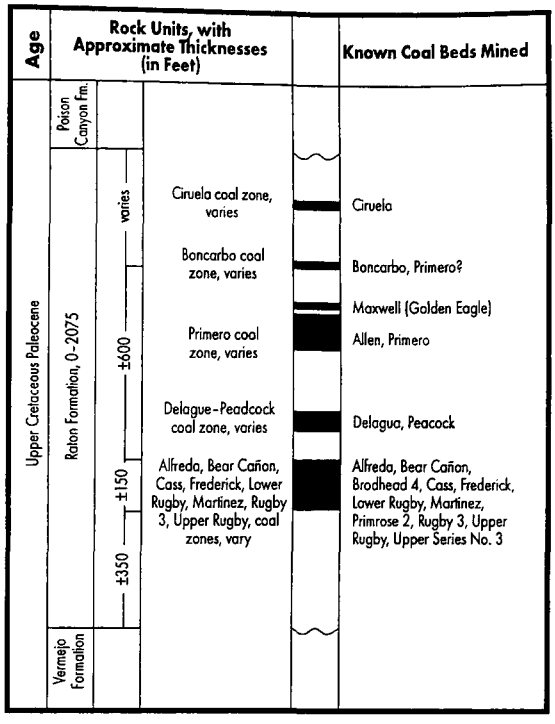

Figure 6. Stratigraphic column, coal-bearing rocks, Raton Formation, Raton Mesa Region (no vertical scale).[12]

came from more than 150 mines, most of them underground. Historically, this is the most important coal-producing county in Colorado. Table 6 summarizes the coal analyses from this field.

Walsenburg Coal Field

This coal field, located in Huerfano County (Fig. 1), has produced approximately 75.7 million tons of coal (mostly non-coking), which is about 8% of the cumulative production of Colorado. Most of this coal came from the lower part of the Vermejo Formation.

SAN JUAN RIVER REGION

The San Juan River Coal Region of Colorado and New Mexico covers part of southwest and west-central Colorado as far north as the Grand Valley-Grand Junction area (Fig. 1; references 3,16). This region includes the San Juan structural basin of Colorado and New Mexico, the Red Mesa-Mesa Verde platform, the Cortez saddle, and the eastern Paradox Basin. The region also includes parts of the Gunnison and Uncompahgre uplifts.

Since the late 1800s, the San Juan River Region has produced over 14.5 million tons of coal from nearly 200 mines, representing about 1.5% of the total production for Colorado (Table 5). In 1995, the region produced nearly 583 tons of bituminous coal from one underground mine and one surface mine. This volume represents only 2% of the state's total production.

To date, La Plata and Montrose counties have produced over 12.8 million tons of coal, 88% of the total for the entire San Juan River Region. Production during 1995 from the King underground mine in La Plata County totaled 208,642 tons. Production from the New Horizon surface mine in Montrose county was 374,266 tons.

Durango Coal Field

The Durango field (Fig. 1) includes the Colorado portion of the San Juan structural basin, the Hesperus-Red Mesa-Cortez area, and the Mesa Verde area, in La Plata and Montezuma counties. Coals are found in the Dakota Sandstone (or Formation), Menefee Formation and Fruitland Formation. The Dakota coals are relatively thin, discontinuous and of high ash content where they outcrop north and northeast of Durango. To the south and west, in the subsurface, Dakota coals have been mined to some extent at relatively shallow depths. A deeper resource exists to a depth of 8,000 feet or more in the Colorado portion of the San Juan Basin.

Coal beds in the Menefee Formation comprise the most significant coal resource in the Durango field and are the only ones being mined at present (Fig. 7). In local, structurally complex areas near Durango, they are of coking quality. Analyses of coal beds in the Durango field are displayed in Table 6.

Nucla-Naturita Coal Field

This coal field extends from Dolores County northward to just south of the Colorado River in Mesa County (Fig. 1). Throughout this large, highly dissected area, most of the post-Dakota coal-bearing rocks, and much of the Dakota itself, have been stripped away by erosion. Three minable coal beds (Fig 8), 3 to 5 feet in thickness, occur in the Dakota sequence in this area.[16]

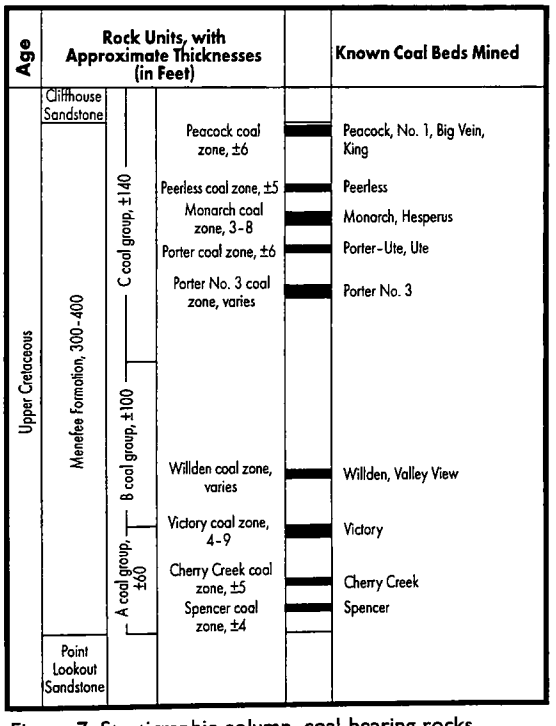

Figure 7. Stratigraphic column, coal-bearing rocks, Menefee Formation, Durango field, San Juan River Region (no vertical scale).[12]

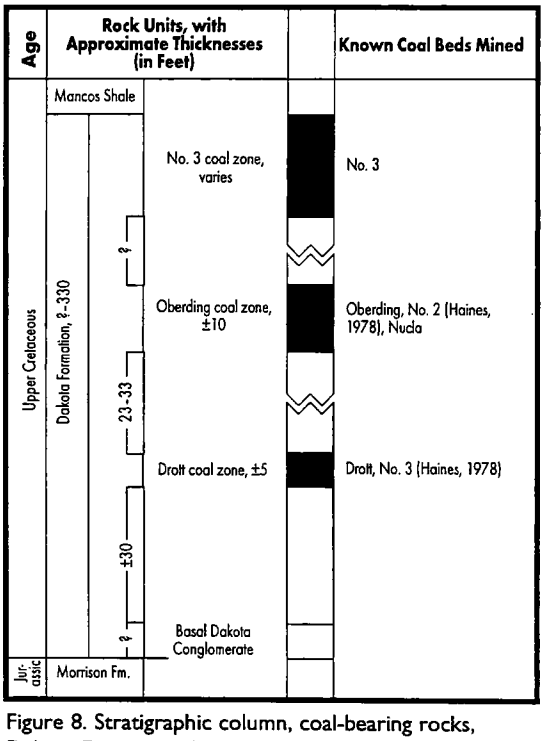

Figure 8. Stratigraphic column, coal-bearing rocks, Dakota Formation, Nucla-Naturita field, San Juan River Region (no vertical scale).[12]

Pagosa Springs Coal Field

This field, located in Archuleta County (Fig. 1), has produced more than 1,391,713 tons of bituminous coal over the years.

Tongue Mesa Coal Field

The Tongue Mesa field is an isolated erosional remnant of Upper Cretaceous sediments (equivalent to at least part of the Mesaverde Group) capped by volcanic rocks of Late Cretaceous and early Tertiary ages. The field is located on Cimarron Ridge, about 20 miles southeast of Montrose and 8 miles east of U.S. Highway 550, straddling the Montrose County-Ouray County line. The coal-bearing Mesaverde sequence has been eroded west of Tongue Mesa field. The coals occur within a 900-foot-thick sequence that correlates with the Kirtland-Fruitland-Pictured Cliffs formations in the San Juan Basin to the south (Fig. 2). At least four coal beds, ranging from 2 to more than 40 feet in thickness, occur on Tongue Mesa in the lower 200 feet of the Fruitland Formation. The most persistent and the thickest coal bed, the Cimarron (or Lou Creek), and several thinner coals were mined underground intermittently from the 1890s until the 1940s. No mines are active in the field.

Tongue Mesa coals generally are subbituminous B in rank and often are considerably oxidized and bony (Table 6).

SOUTH PARK REGION

South Park Coal Region (or field), in Park County, lies entirely within a small, high (9,000 to 10,000 feet elevation), intermontane structural and topographic basin of the same name (Fig. 1). The tightly folded and faulted South Park Basin originally may have contained 227 million tons of in-place coal resources above a depth of 6,000 feet.[17]

The coal-bearing Laramie Formation of Upper Cretaceous age crops out around parts of the Michigan Syncline at the north end of the basin, and in a few other places within South Park. Near the town of Como, several Laramie coal beds, dipping as much as 45 degrees, were mined between 1870 and 1905 in 14 underground mines. Only 725,000 tons of coal have been produced in the South Park Region, and no mining is occurring at present.

The Laramie coals near the surface in South Park probably are subbituminous A or B in rank (Table 6); however, no modern analyses are available.

UINTA REGION

Approximately one-half of the large Uinta coal region lies in west-central Colorado; the remainder is the main coal-bearing region of eastern Utah (Fig. 1).[3] Most of the Colorado portion of the Uinta Region coincides with the Piceance Creek structural basin of Laramide age and is located in the eastern part of the Colorado Plateau physiographic province. The Uinta Region in Colorado is bounded by the Grand Hogback monocline to the east, the Axial Basin uplift to the north (which separates this region from the Green River coal region), the Utah state line to the west, Grand Valley and the Colorado River to the southwest and the North Fork Valley and Gunnison uplift to the south and southeast.

The Piceance Creek Basin is the largest structural basin in western Colorado, covering an area exceeding 7,200 square miles as defined by the base of the Upper Cretaceous Mesaverde Group. The basin is asymmetric in shape, with the steep flank on the east and its long axis trending northwest. This is one of the deepest basins in the Rocky Mountain region, with an estimated 25,000-plus feet of sediments at the north end of the basin in Rio Blanco County.

The southeastern part of the region, in Gunnison and Pitkin counties, is marked by the Elk and West Elk Mountains igneous intrusive complexes of Tertiary-age sills, laccoliths, dikes and associated folds and faults. The high geothermal heat flow characteristic of this part of the region has increased the rank of much of the coal, producing large resources of coking coal. Much of this coking coal is of premium grade, high in methane content and commonly under more than 1,000 feet of overburden.[5]

The Uinta coal region produced over 13 million tons of coal in 1995, or half of the state's total output (Table 3). Since the late 1880s, this important region has produced nearly 230 million tons of coal from 300 mines; this production constitutes over 24% of the total for all of Colorado (Table 5). New resource estimates indicate the Piceance Basin portion of the region may contain 289 billion tons of coal (or 113 billion tons at less than 6000 feet of overburden).[18]

The eight coal fields that occupy the periphery of the Uinta Region are briefly discussed below. All of these fields are, or have been, productive from the Mesaverde Group (Fig. 2). Representative ranges of analyses for each field are given in Table 6.

Book Cliffs Coal Field

The Book Cliffs field contains a number of high-quality coal beds in the Mount Garfield Formation of the Mesaverde Group. These are mostly high-volatile C bituminous in rank, with some high-volatile B. Estimated total in-place resources in this field (in the 800-square-mile area considered) have been placed at approximately 7.2 billion tons to a depth of 6,000 feet.[17]

Grand Mesa Coal Field

Located primarily in Delta County, the Grand Mesa Coal Field is on the south flank of the prominent Grand Mesa, a very large, flat-topped feature capped by Tertiary volcanic flows 10,000 feet in elevation. The northwestern part of the field, on the west flank of Grand Mesa and south of the Colorado River, is located in Mesa County (Fig. 1). The Mesaverde coals in this field are in the Mt. Garfield Formation, much the same as in the Book Cliffs field to the west (Fig. 9). Coals in the Grand Mesa field range from high-volatile C bituminous to subbituminous A and are typically 4 to 14 feet in thickness. Original in-place resources to a depth of 6,000 feet in a 530-square-mile area probably exceed 8.6 billion tons.[17] One underground mine located in Mesa County, the Roadside Mine, produced 589,064 tons of bituminous steam coal in 1995.

Somerset Coal Field

The Somerset field in Delta and Gunnison counties lies in a valley cut by the North Fork of the Gunnison River and its tributaries. The coals in this area occur in the lower Williams Fork Formation (Fig. 10), are high-volatile B and C bituminous, and reach up to 25 to 30 feet in thickness. The eastern part of the field, near the town of Somerset, contains coking coal of relatively good quality. Four underground mines in this field produced 7,367,032 tons of coal during 1995. In-place coal resources to a depth of 6,000 feet in the 320-square-mile area investigated are conservatively estimated at more than 8 billion tons.[17]

Crested Butte Coal Field

This Gunnison County field forms the southeastern tip of the Uinta Region, near the Crested Butte

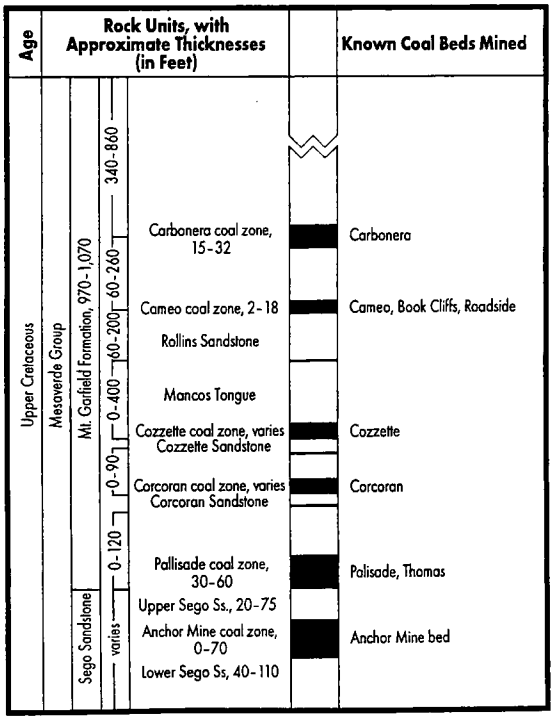

Figure 9. Stratigraphic column, coal-bearing rocks, Mesaverde Group, Book Cliffs and Grand Mesa fields, Uinta Region (no vertical scale).[12]

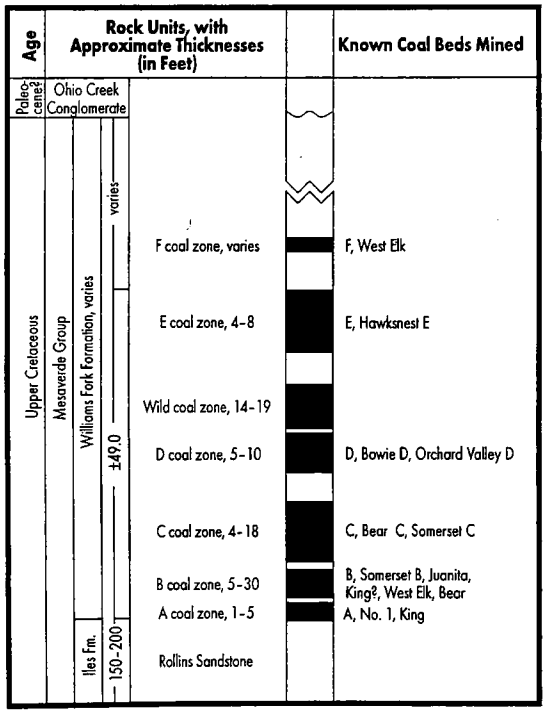

Figure 10. Stratigraphic column, coal-bearing rocks, Williams Fork Formation, Somerset Field, Uinta Region (no vertical scale).[12]

ski resort. Much of the field lies at elevations above 10,000 feet. Coal-bearing Mesaverde strata in this area have been folded, faulted and intruded by igneous rocks. The coals here range from high-volatile C bituminous to anthracite; some are of good coking quality. Coal beds vary from 2 to 14 feet in thickness. Original in-place coal resources to a depth of 1,000 feet in the 240-square-mile area surveyed are estimated at some 1.56 billion tons.[17] No coal was produced in the field during 1995.

Carbondale Coal Field

Located at the eastern edge of the region in Garfield and Pitkin counties, the Carbondale field is a source of high-quality coking coal from the Mesaverde Group. In the Coal Basin area of Pitkin County, in the southern part of the field, some of the coals have been metamorphosed to high-volatile A and medium-volatile bituminous and, locally, to semianthracite and anthracite. Original in-place coal resources, to a depth of 6,000 feet in the 165-square-mile area considered, have been estimated at more than 5.2 billion tons.[17] No mines were operating in 1995.

Grand Hogback Coal Field

This coal field is located along the eastern rim of the Piceance Creek Basin, which is sharply upturned into the prominent Grand Hogback monocline. This feature extends southward from Meeker for some 40 miles to just north of Rifle. There the hogback makes an abrupt bend to the southeast, passes through New Castle where it is cut by the Colorado River, then proceeds to Glenwood Springs where the structure again turns southward. Coals crop out along the length of the Grand Hogback and were mined for many years.

The Mesaverde coals in the northern part of the Grand Hogback field are mainly high-volatile C bituminous; these grade southward toward Glenwood Springs to high-volatile B bituminous. The major part of the coal mined from this field has come from the Fairfield and South Canon coal groups or zones in the lower part of the Williams Fork Formation. The Black Diamond coal group in the upper part of the Iles Formation also has been mined in this area, as has the Keystone coal group in the upper part of the Williams Fork. The numerous coal beds in this sequence range from approximately 3 feet to more than 18 feet in thickness. Original in-place resources to a depth of 6,000 feet in the 160-square-mile area considered are estimated at more than 3 billion tons.[17] During 1995, 375 tons of coal were produced from one underground mine in the field, the Eastside mine.

Danforth Hills Coal Field

The Danforth Hills field, which extends from Axial south to Meeker, forms the northeast limit of the Uinta Region, in Rio Blanco and southern Moffat counties. This field is separated from the Yampa field of the Green River Region to the north by the Axial Basin, a topographic low in which the coal-bearing Mesaverde Group has been stripped away. Both subdivisions of the Mesaverde Group here, the Iles and Williams Fork (Fig. 11) formations, contain numerous good-quality bituminous coal beds, chiefly high-volatile C in rank. Some of these beds exceed 20 feet in thickness. Original in-place coal resources to a depth of 6,000 feet in the approximately 400-square-mile area surveyed total more than 10.5 billion tons.[17] Approximately 4.4 million tons of coal were produced from this field in 1995 from the Colowyo surface mine.

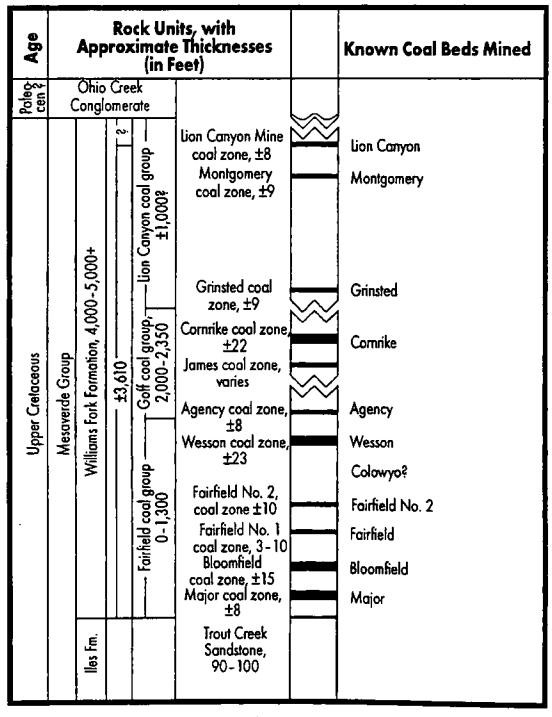

Figure 11. Stratigraphic column, coal-bearing rocks, Williams Fork Formation, Danforth Hills Field, Uinta Region (no vertical scale).[12]

Lower White River Coal Field

This coal field covers a large area that includes the western Piceance Creek Basin and much of the Douglas Creek arch, westward to the Utah state line (Fig. 1). Most of the field lies in Rio Blanco County; a small part, a few miles north of the giant Rangely oil field, is in southern Moffat County. Coals in the Lower White River field are in both the Williams Fork and Iles formations. Most of the mining has been near Rangely above the Mesaverde rimrock that flanks the large, breached Rangely Anticline. Coal seams here vary from 8 to 12 feet or more in thickness. The coals are high-volatile C bituminous in rank. In the 930-square-mile area surveyed, 11.76 billion tons of in-place coal resources have been estimated to a depth of 6,000 feet.[17] In 1995, Western Fuels-Utah, Inc.'s Deserado underground mine produced 760,255 million tons of coal in the field.

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