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1990 Summary of COAL RESOURCES in Colorado

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INTRODUCTION

The largest currently available source of energy in Colorado is its vast deposits of coal, which underlie nearly 30,000 square miles, or approximately 28 percent of the state. Over 434 billion tons of coal resources above an overburden thickness of 6,000 feet are believed to remain in Colorado (Averitt, 1975); this estimate is nearly 11 percent 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 (Averitt, 1975). In terms of remaining identified bituminous coal resources, Colorado ranks second, behind Illinois, but is first in terms of low-sulfur bituminous coal (Averitt, 1975). Most (over 80 percent) of the coal resources of the state are believed to be minable by underground methods.

Colorado coals range in age from Late Cretaceous to Eocene; the largest and most widespread resources occur in the Mesaverde Group (Upper Cretaceous). Cretaceous coals, which are related to transgressions and regressions of the Late Cretaceous seaway, generally are of higher rank and better quality than are the non-marine (limnic) Tertiary coals found in the more restricted Laramide-age structural basins. Of the eight coal-bearing regions in Colorado, the most important from the standpoint of both total in-place resources and present annual production are the Green River and Uinta Coal Regions in the northwestern and west-central parts of the state, respectively.

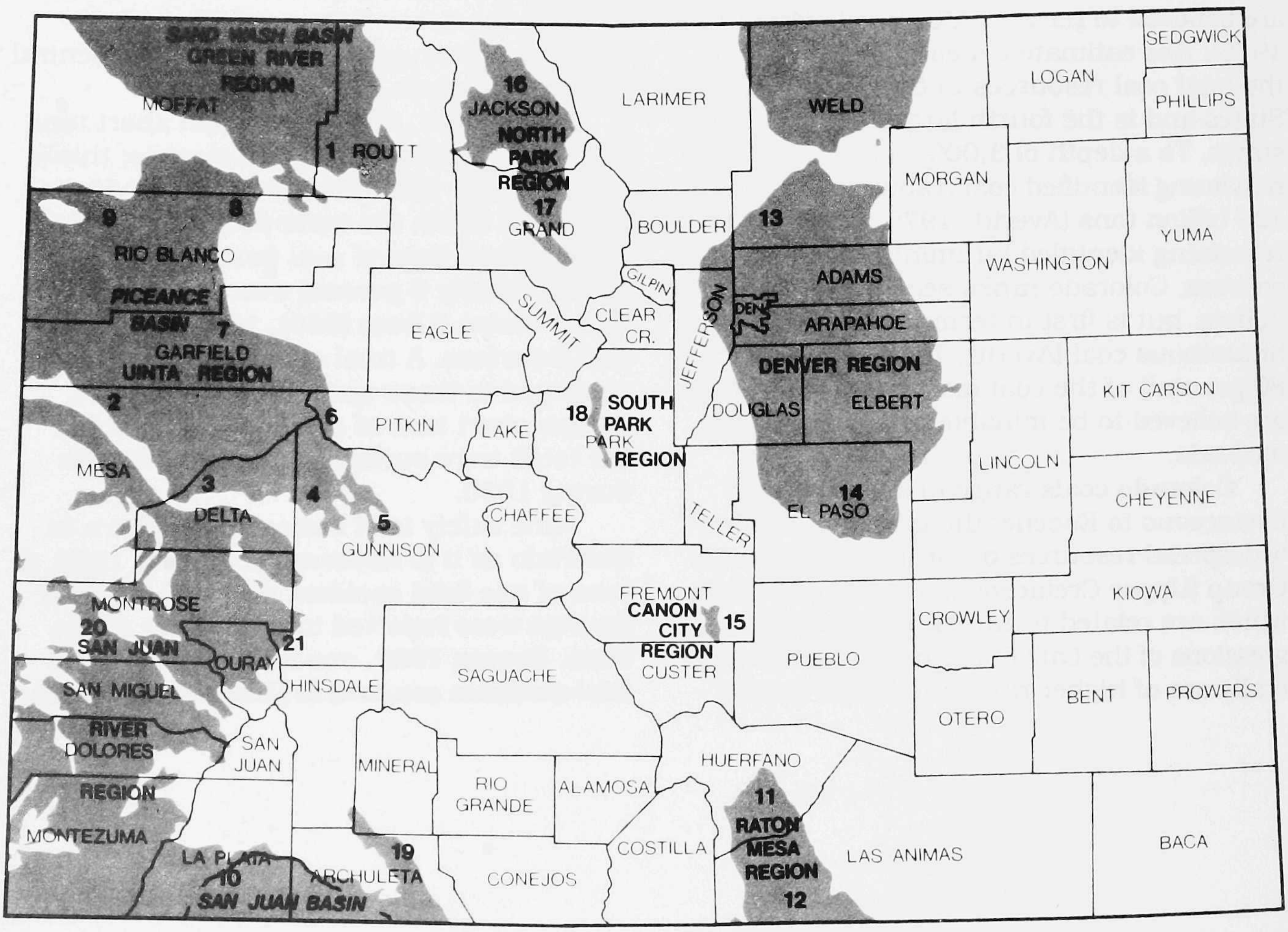
Since 1864, over 830 million short tons of coal have been mined in Colorado; this is less than the 1989 production of the United States. In 1990, the state produced 19.1 million short tons of coal (an increase of approximately 9 percent over 1989) from 20 mines (down 3 from 1989), 15 underground and 5 surface. A total of 2,141 persons were employed in these operations. Nearly 8.2 million short tons of coal (or 43 percent of the total) were surface-mined in Colorado during 1990.

Mine safety is of increasing concern in Colorado as it is nationwide. During 1990, a total of one fatal accident and 255 nonfatal injuries were reported in coal mines in the state. During 1989, one fatal and 256 nonfatal accidents occurred in Colorado coal mines.

COAL RESOURCES

COAL REGIONS

The coal resources in Colorado occur entirely within the Rocky Mountain coal province. The eight named coal regions and 21 coal fields (fig. 1) are located in the western part of the Great Plains; within intermontane basins west of Denver; and in the Colorado Plateau province, which extends westward into eastern Utah (see Averitt, 1972).



Coal Fields

1. Yampa
2. Book Cliffs
3. Grand Mesa
4. Somerset
5. Crested Butte
6. Carbondale
7. Grand Hogback
8. Danforth Hills
9. Lower White R.
10. Durango
11. Walsenburg
12. Trinidad
13. Boulder-Weld
14. Colorado Springs
15. Canon City
16. North Park
17. Middle Park
18. South Park
19. Pagosa Springs
20. Nucla-Naturita
21. Tongue Mesa

Figure 1. Coal regions and fields in Colorado.

COAL-BEARING FORMATIONS

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 Dakota and Mesaverde Groups/Formations (fig. 2) in western Colorado, especially in the region from Garfield County south to the New Mexico state line. The oldest coals in Colorado occur in the Dakota Sandstone (or Group) in the southwestern part of the state (northern San Juan Coal Region, Durango to Nucla-Naturita Coal Field areas). Successively younger coals were laid down as the Late Cretaceous Western Interior 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 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 Coal Region.

STRUCTURE OF COAL REGIONS

The San Juan River, Uinta, Green River, Raton Mesa, and Denver Coal Regions, for the most part, are located within Laramide-age structural basins. The interior areas of these basins appear to be relatively free from structural complications; the coal beds usually are not highly folded, faulted, or otherwise disturbed. However, some of the margins of these structural basins are moderately to severely folded and faulted; in places, Tertiary igneous activity has metamorphosed the coal to anthracite and 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-age basins.

Only a small part (possibly 5 percent) of the coal resources of Colorado today are considered to be surface-minable since only limited areas within the coal-bearing regions

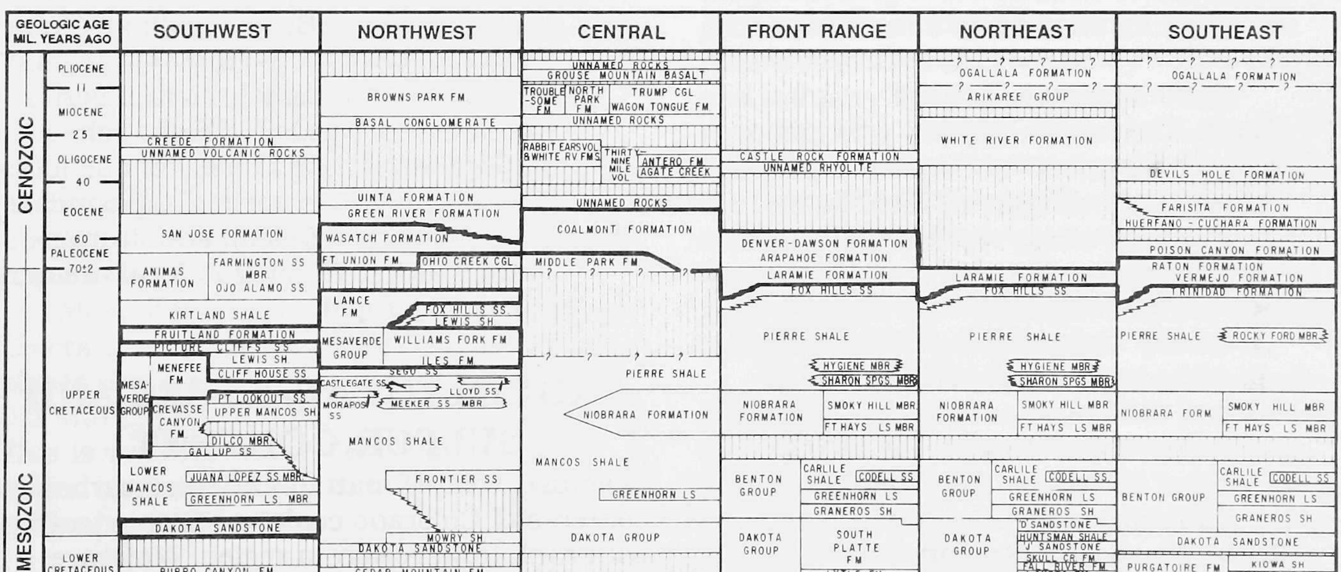


Figure 2. Colorado stratigraphic correlation chart, parts of Mesozoic and Cenozoic Eras. Coal-bearing units are outlined (from Pearl and Murray, 1974).

contain coal beds which are both of gentle dip and under "shallow" cover.

COAL RANK

Colorado coals range in rank from lignite to anthracite. However, over 70 percent of the state's coal resources are bituminous, approximately 23 percent subbituminous, 5 percent lignite, and less than 1 percent anthracite.

Generally, the older the coal, the higher the rank; however, geologic factors, such as higher geothermal gradient and deeper burial, can significantly increase the rank of even the youngest coals.

Most 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 Coal Regions (see discussion below).

The coal-bearing sequences and coal ranks, by region, can be generally described as follows (units currently being mined are italicized):

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

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

Green River Coal Region:
Wasatch (Eocene), Fort Union (Paleocene), and Lance (Upper Cretaceous) Formations—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 Coal Region (or Field):
Coalmont Formation (Paleocene-Eocene) subbituminous A and B

Raton Mesa Coal 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 Field):
Raton Formation (Paleocene-Upper Cretaceous) high-volatile A and B bituminous (generally of coking quality)
Vermejo Formation (Upper Cretaceous) high-volatile A and B bituminous (generally of coking quality)

San Juan River Coal 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 of coking quality)
Dakota Formation or Group (Upper Cretaceous) high-volatile B and C bituminous (may locally be of coking quality)

South Park Coal Region (or Field):
Laramie Formation (Upper Cretaceous) subbituminous A and B (not produced since 1932)

Uinta Coal 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 of Carbondale Field); high-volatile A, B, and C bituminous (of coking quality in parts of Carbondale and Somerset Fields); subbituminous A and B (?) (only in local areas near outcrops).

PROXIMATE ANALYSES AND SULFUR CONTENT

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

The ash contents of coal beds in Colorado vary considerably as a result of different environments of deposition, even within the same coal "zone". The range typically is from 2 to 20 percent, averaging about 6 percent. Locally, however, ash contents may reach 25–30 percent, as-received.

Sulfur contents of most Colorado coal beds vary from 0.2–1.2 percent as received. More than 99 percent of the coals analyzed contain less than 1.0 percent; and more than 50 percent, less than 0.7 percent sulfur. The bulk of the coal being surface-mined in Colorado at present contains between 0.2 and 0.5 percent sulfur. On the other hand, much of the metallurgical-grade coal in Colorado contains 0.5–1.0 percent sulfur (still low in comparison with many Eastern coals).

Work by the U.S. Geological Survey and the Colorado Geological Survey (Boreck and others, 1977) indicates that organic sulfur usually predominates, followed by pyritic sulfur and sulfate. A typical coal in the Yampa Coal Field, Green River Coal Region, has the following forms of sulfur analysis: organic, 0.49 percent; pyritic, 0.03; and sulfate, 0.03; total sulfur, 0.55 percent. Abnormally high pyrite content can be reduced by conventional coal preparation techniques to 0.5 percent sulfur or less.

Most of the coal being surface-mined in Colorado is for use in steam-electric power plants and contains between approximately 0.2 and 0.5 lbs of sulfur per million Btu. This is well within the definition of low-sulfur coal: one which contains 0.6 lb or less sulfur per million Btu.

HEATING VALUES

Most of the subbituminous and bituminous steam coal being produced in Colorado ranges from about 10,000–13,600 Btu/lb; the coking coal ranges from 12,070 to over 14,000 Btu/lb as-received. 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.

CARBONIZING PROPERTIES

Many Colorado coals are nonagglomerating and may be carbonized in fluidized systems. Chars produced at relatively low temperatures (450-700 °F) contain about 8.5–14.4 percent residual volatile matter and are easily ignited. Char heating values on a moisture-free basis vary from 14,600–14,960 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.

OTHER ANALYSES

The Colorado Geological Survey and the U.S. Geological Survey have conducted cooperative projects to sample and analyze most of the producing coal mines in Colorado, together with coals likely to be mined in the future that have been cored by both Federal and industry drilling programs. Trace-elements and other geochemical analyses were done by the U.S. Geological Survey in the Denver area. Proximate, ultimate, and related analyses were performed by the U.S. Bureau of Mines laboratory (now under the jurisdiction of the U.S. Department of Energy) in Pittsburgh, Pennsylvania.

Results of this program have been published (Boreck and others, 1977; Khalsa and Ladwig, 1981). Included in the analyses resulting from this coal sampling program 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 for); and proximate and ultimate analyses, heating values, and forms of sulfur determinations, etc. Table 1 displays some of the results.

Although many of the analytical results of the sampling programs have not yet been fully tabulated and correlated, it appears certain that none of the Colorado coals 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 United States.

Table 1. Arithmetic mean of proximate and ultimate analyses for coal regions (from Khalsa and Ladwig, 1981, tables A5, B5, C11, C14, D5, E5, and F5).

	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	3.8
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
Sulfur %	0.3	0.6	0.5	0.7	0.8	0.6

COKING COAL

Significant reserves of marginal and premium grades of coking coal occur in the Carbondale, Crested Butte, and Somerset Coal Fields, Uinta Coal Region; in the Trinidad Field, Raton Mesa Region; and in the Durango Field, San Juan River Coal Region (fig. 1). The Colorado Geological Survey completed an evaluation of coking coals in Colorado (Goolsby and others, 1979) showing that original in-place identified coking-coal reserves in the state total more than 4.2 billion short tons.

According to Goolsby and others (1979), the Uinta Coal Region contains an estimated 0.5 billion short tons of coking-coal reserves, ranging from premium grade medium-volatile bituminous to marginal grade high-volatile bituminous; the Raton Mesa Region, approximately 2.0 billion tons of marginal grade high-volatile A and B bituminous; and the San Juan River Coal Region, 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 Coal Region contains coking coal of generally lower quality than that found in the other two regions; however, it is the most accessible. The San Juan River Coal Region is the least known of the three. It produces a medium quality bituminous coal. The thin nature of the coal beds and the lack of rail transportation in southwestern Colorado have hindered coal development in this region. The southeastern third of the Uinta Region produces the most desirable coke-oven feedstock in Colorado. Lack of transportation, depth of overburden (this is the deepest coal mined in Colorado), 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 3,000 feet in thickness. The portals 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.

SPECIFIC GRAVITY OF COAL

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 considered to be representative (Averitt, 1975):

Anthracite and semianthracite—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).

FEDERAL COAL IN COLORADO

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; on about 72 percent of this land, the Federal government controls both the coal and the surface rights (Dawson and Murray, 1978).

The BLM estimates that 60 billion tons of coal resources are under Federal ownership in Colorado. Of this amount, approximately 6.4 billion tons (over 10 percent) are surface-minable. Recoverable coal reserves in Colorado held under Federal lease are estimated to be 1.65 billion tons (of which 273 million tons are surface-minable).

COAL MINING AND PRODUCTION

Since 1864, Colorado mines have produced more than 830 million short tons of coal. Colorado's previous all-time record production (surpassed during November 1978) of 12.658 million tons occurred in 1918; production then declined markedly during the Depression years. A slight increase in the state's coal production took place during the period 1941–1945 (World War II). Colorado coal output declined drastically from 1945 to 1963, reaching a low of 2.9 million tons in 1954, the lowest since 1889. Much of this decrease was due to the increased use of natural gas (the price of which was fixed by action of the Federal Power Commission in the early 1950's) and to the replacement of coal burning trains with diesel-powered locomotives. Coal production in Colorado fluctuated between approximately 3 and 6 million tons per year until 1973, when a rise in the annual production began.

Even though Colorado is one of the smaller producers of western coal, at producing 6 percent of the total, and less than 2 percent of the U.S. total; nevertheless, its annual production has increased dramatically—over 360 percent since 1971, as shown by the following tabulation:

Year	Million short tons	Percent change
1971	5.31	
1972	5.53	+4
1973	6.23	+13
1974	6.96	+12
1975	8.27	+19
1976	9.46	+14
1977	11.97	+27
1978	14.36	+20
1979	18.13	+26
1980	18.77	+4
1981	19.70	+5
1982	18.93	-4
1983	16.74	-12
1984	17.68	+6
1985	17.30	-2
1986	15.30	-12
1987	14.39	-6
1988	15.82	+10
1989	17.43	+10
1990	19.12	+9

The statewide increase in production since the 1960's has been the result of several factors. First, a significant increase in the production of high-quality coking coal has occurred in Gunnison and Pitkin Counties.

Second, although most underground mines have been closed in southeastern Colorado, large surface mines have been opened in northwestern Colorado. The coal being mined is high-grade bituminous steam coal with low sulfur and ash contents, generally called "clean air compliance coal".

Third, the increased demand for coal-fired power plant fuel has prompted the opening of several large underground mines in the Uinta Coal Region (fig. 1), which produced nearly 8 million tons of coal in 1990.

The Green River Coal Region was the leading coal producing region in 1990; this region produced nearly 9 million tons of coal that year. Approximately two-thirds of the coal resources in this region are believed to be high-volatile C bituminous; and the remaining third subbituminous A, B, or C (Hornbaker and others, 1976).

In 1989, approximately 62 percent of the coal produced in Colorado was used in-state (fig. 3) principally as steam coal. Approximately 38 percent of 1989 production was shipped out of state for use as steam coal in Texas, California, Utah and Arizona.

The surface mining of coal in Colorado began in Jackson County in 1909 in the Coalmont district of western North Park Coal Field (fig. 1). By 1962, seven of the State's 177 operating mines were surface mines, producing 14 percent of the total

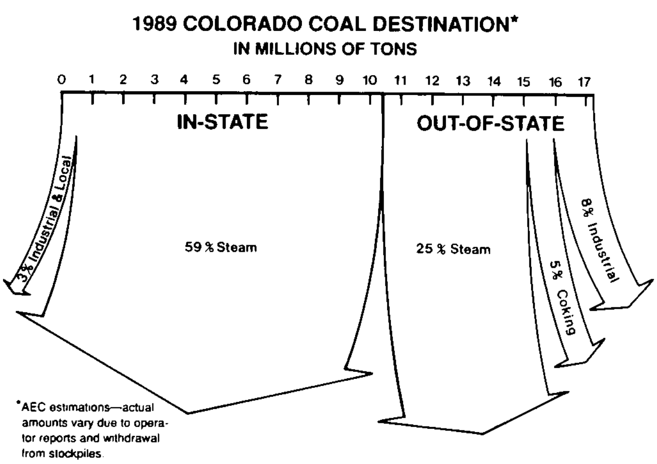


Figure 3. Colorado coal shipments—1989 in millions of tons.

State production of 3.39 million tons (figs. 4 and 5). Since 1962, between 5 and 26 surface mines have been licensed to operate in Colorado. Colorado's 1990 coal production amounted to 19.1 million short tons (MST), an increase of 9 percent over 1989.

Tables 2, 3, 4, 5, and 6 display production data by county and by coal-bearing region. Figures 5 and 6 graphically depict cumulative coal production by county to January 1, 1991 and annual coal production during 1990 respectively.

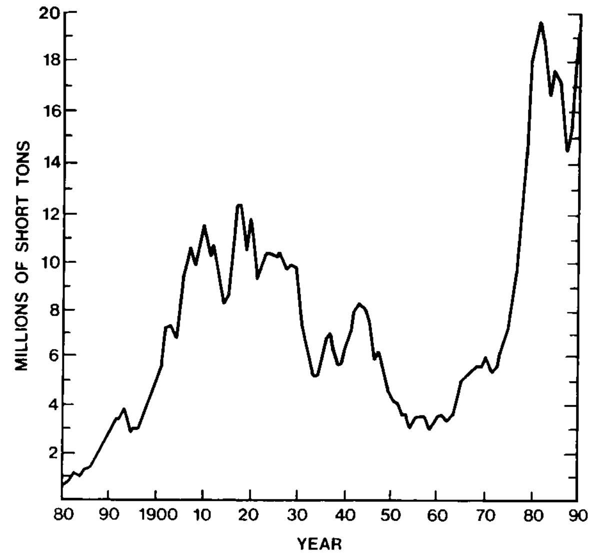


Figure 4. Colorado coal production (MST) 1880–1990.

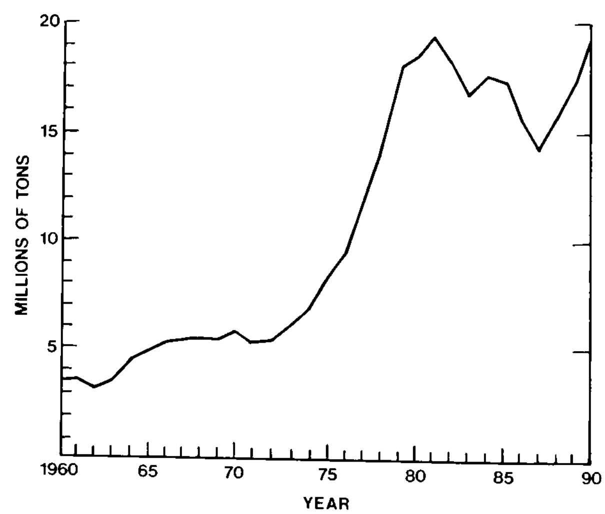


Figure 5. Colorado coal production 1960–1990.

Table 2. 1990 Coal production in Colorado by county.

County	Production (Tons)	No. of Employees	No. Mines Surface/ Underground
Delta	600,952	62	0/1
Fremont	331,366	76	0/2
Garfield	196,803	16	0/1
Gunnison	949,888	121	0/3
Jackson	61,145	9	1/0
La Plata	165,516	42	0/1
Las Animas	1,572,122	175	0/2
Mesa	183,212	29	0/1
Moffat	8,668,000	664	2/1
Pitkin	477,927	397	0/1
Rio Blanco	1,498,739	236	0/1
Routt	4,414,772	314	3/1

Table 3. Cumulative coal production of top 10 counties, 1864–1990.

1.	Las Animas	180,742,062
2.	Routt	143,125,959
3.	Moffat	92,023,359
4.	Huerfano	75,690,588
5.	Weld	68,660,774
6.	Gunnison	63,824,543
7.	Fremont	45,315,891
8.	Boulder	43,321,306
9.	Pitkin	29,548,497
10.	Delta	15,610,749
	TOTAL	757,863,728

Table 4. Cumulative Colorado coal production by county 1864–1990.

Adams	37,112
Arapahoe	36,259
Archuleta	1,391,713
Boulder	43,321,306
Delta	15,610,749
Dolores	62,631
Douglas	27,367
Elbert	108,948
El Paso	15,251,246
Fremont	45,315,891
Garfield	7,637,905
Gunnison	63,824,543
Huerfano	75,690,588
Jackson	6,952,697
Jefferson	6,697,939
La Plata	7,946,750
Larimer	54,284
Las Animas	180,742,062
Mesa	15,321,927
Moffat	92,023,359
Montezuma	174,515
Montrose	2,634,272
Ouray	14,216
Park	724,658
Pitkin	29,548,497
Rio Blanco	7,732,689
Routt	143,125,959
San Miguel	27,197
Weld	68,660,774

Table 5. Cumulative Colorado coal production by coal region to January 1, 1990 (millions of tons).

Coal Region	*County*	*Production*	*% of State Total*
Canon City	Fremont	45.32	5.45
Denver	Adams, Arapahoe, Boulder, Douglas, Elbert, El Paso, Jefferson, Larimer, Weld	134.20	16.15
Green River	Moffat, Routt	201.00	24.19
North Park	Jackson	6.95	0.84
Raton Mesa	Huerfano, Las Animas	256.43	30.86
San Juan River	Archuleta, Dolores, La Plata, Montezuma, Montrose, Ouray, San Miguel	12.25	1.47
South Park	Park	0.72	0.09
Uinta	Delta, Garfield, Gunnison, Mesa, Moffat, Pitkin, Rio Blanco	174.11	20.95

Table 6. 1990 Colorado coal production by coal region .

Coal Region	*Production*	*% of Total*	*No. of Employees*	*No. of Mines*	*No. Mines Surface/ Underground*
Green River	8,997,272	47.06	669	6	4/2
Uinta	7,993,021	41.80	1170	9	1/8
Raton Mesa	1,572,122	8.22	175	2	0/2
North Park	61,145	0.32	9	1	1/0
San Juan River	165,516	0.87	42	1	0/1
Canon City	331,366	1.73	76	2	0/2
Denver	0	0.00	0	0	0/0
South Park	0	0.00	0	0	0/0

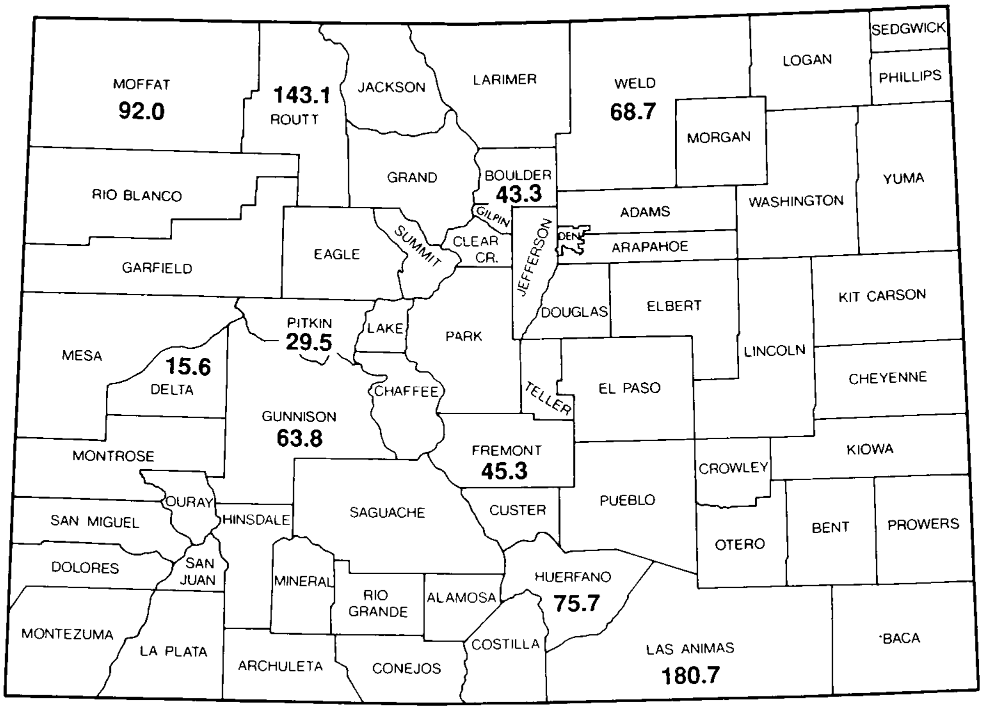


Figure 6. Top ten county Colorado cumulative coal production (MST) through 1990.

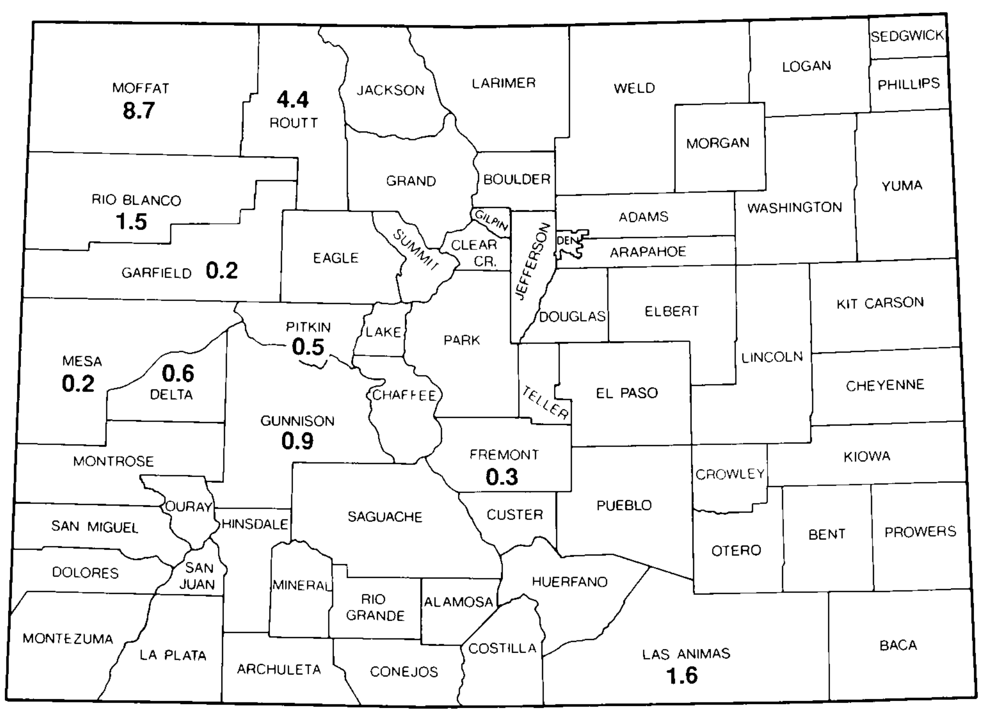


Figure 7. Top ten county Colorado coal production (MST) in 1990 .

COAL REGIONS AND FIELDS

INTRODUCTION

The coal-bearing regions and coal fields of Colorado (fig. 1) are discussed, 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 7.

The series of stratigraphic columns constructed for most of the coal regions and areas (from Boreck and Murray, 1979) display the relative vertical distribution of the major coal-bearing intervals, or "zones," placed within their geologic or stratigraphic framework, together with the names of the coal beds that have been mined.

Unlike coals in many eastern states, the coal beds in Colorado (and elsewhere in the Rockies) have been only tentatively correlated, for the most part, and care should be used in assigning coal quality characterizations to a named coal "bed." Colorado coals are highly variable in both chemical and physical character and in thickness and in areal extent; individual beds rarely persist for more than .5 to 1 mile.

Correlation of individual coals from basin to basin, or from region to region, often is virtually impossible. For these and other reasons, many workers prefer to delineate coal-bearing sequences, or "zones," when mapping coal beds. The stratigraphic columns included herein represent only preliminary attempts at this perplexing problem of coal bed correlation (historic records often are very confusing and inaccurate, at best) and should be used with care.

Additional details on the coal fields of Colorado may be found in the references listed at the end of this article.

CANON CITY COAL REGION (OR FIELD)

Canon City Coal Region(or Field), (fig. 1) of Fremont County, lies within the Laramide-age Canon City Basin, a downfaulted, synclinal, 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 (and Coal Regions) from the Raton Basin (and Raton Mesa Region), located to the south.

Geologically, the Canon City Basin is more analogous to the Raton Basin than to the Denver Basin; as a result, the coals in the Canon City Region are similar in many respects 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.

The Canon City Region can be considered to be a northern extension of the Raton Mesa Region. These two regions are now separated by uplift and faulting which caused the removal of the coal-bearing sequences once deposited in the area between them. The Canon City Region is the smallest coal region in Colorado, covering an area of only 50 square miles.

As shown in figure 8, the coals in the Canon City Region (or Field) occur in the lower part of the Vermejo Formation (Upper Cretaceous in age). Seven main coal beds have been mined commercially in the area;

Table 7. Range of analyses of Colorado coals (as received) by coal region and field.

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. (7beds)	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
S.E. & So.-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
NORTH PARK (and field)							
Coalmont District							
Coalmont Fm., (Riach; Beds 4,3,2,1; Monahan)	14.5-20.2	29.3-37.3	5.5-13.1	0.6-1.0	6,250-9,570	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
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							
Furitland 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
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							
Williams 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 Cyn., 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

another 8 or 10 beds have been reported but may be too thin to mine at this time.

Canon City coals typically are high-volatile C bituminous in rank, relatively low in sulfur content, nonweathering, nonagglomerating, and noncoking.

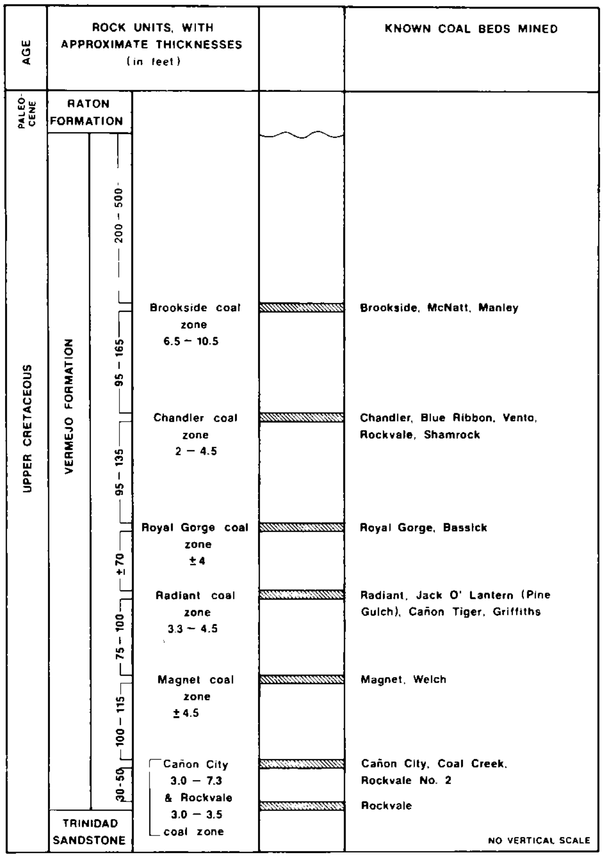


Figure 8. Stratigraphic column, coal-bearing sequence, Canon City Coal Field (no vertical scale) (from Boreck and Murray, 1979).

To date, this region has produced over 45 million tons of coal, ranking fifth in the state. This amount of production represents approximately 15 percent of the total estimated in-place resource in the Canon City Region. Historically, more than 175 mines have operated in this region. In 1990, two underground mines employing a total of 76 persons were in operation.

Much of the coal mined in the Canon City Region is used in nearby steam-electric power plants located in Canon City and by local domestic purchasers. The remainder is shipped to Texas and New Mexico.

Of the estimated original in-place coal resource of 295 million tons (Landis, 1959), approximately 250 million tons are believed to remain in the ground above a depth of 1,000 feet.

DENVER COAL REGION

The Denver Coal Region encompasses an area of some 7,500 square miles in the eastern half of Colorado 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 Denver Coal Region lies within the larger Laramide-age (and younger?) Denver structural basin, an assymetrical basin with as synclinal axis of which is located near its west 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 subbasins, the Denver subbasin to the south and the Cheyenne subbasin to the north. These basins are separated by a structural high, the Greeley Arch, from which the coal bearing sequences have been eroded (Kirkham and Ladwig, 1979). The subbasins are defined by the outcrop of the base of the Upper Cretaceous Laramie Formation coal-bearing interval. The lower part of the Laramie in both subbasins contains several beds of coal varying in rank from subbituminous coal to lignite (figs. 9 and 10). The overlying Denver Formation (Upper Cretaceous to Paleocene in age) occurs only in the Denver subbasin and contains multiple beds of lignite only in the central part of the Denver subbasin (fig. 11).

Beds of the Laramie Formation are exposed in hogbacks and road cuts along the foothills of the Front Range from near Colorado Springs to Boulder. The Laramie coal beds are almost vertical in the Foothills district (Landis, 1959, p. 164–165); however, their dips decrease rapidly eastward to 5 degrees or less. The Denver and Cheyenne subbasins are underlain by coals of the Laramie Formation, except for a few areas where coals are thin or absent.

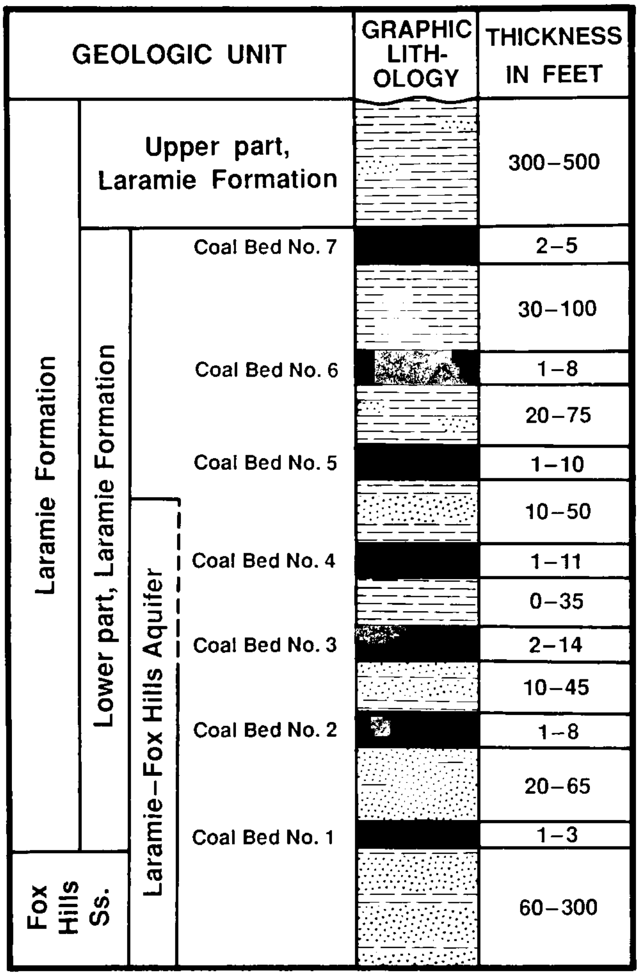


Figure 9. Stratigraphic column, coal-bearing part of Laramie Formation, Boulder-Weld Coal Field, Denver Coal Region (no vertical scale) (after Kirklam and Ladwig, 1979, fig. 12).

Laramie coal beds occur in a 50–275 feet thick zone within the lower part of the formation and were deposited on a delta plain in poorly-drained swamps. Laramie coals are lenticular, and they generally are thicker and more persistent in the Denver than in the Cheyenne subbasin. They are typically 5 to 10 feet thick and locally up to 20 feet thick in the former, but only 3 to 7 feet in thickness in the latter. Under approximately 1,850 square miles of the Denver Coal Region, Laramie coal beds are potentially surface minable (i.e., within 200 feet of the surface). Another 2,000-plus square miles contains Laramie coal beds from 500 to 1,500 feet in depth; these coals may someday be candidates for in-situ gassification (Kirkham and Ladwig, 1979).

Laramie coal beds vary significantly in rank in the Denver Region, from subbituminous B coal to lignite A. The higher rank coals, which average 8,500–10,000 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 5,000–7,300 Btu/lb as received, are typical of the eastern flank of the Denver Region (Kirkham and Ladwig, 1979).

Thick lignite beds of early Paleocene age occur in the upper 300-500 feet of the Denver Formation immediately below the Dawson Arkose, in the Denver subbasin (figs. 11 and 12). The lignite beds appear to

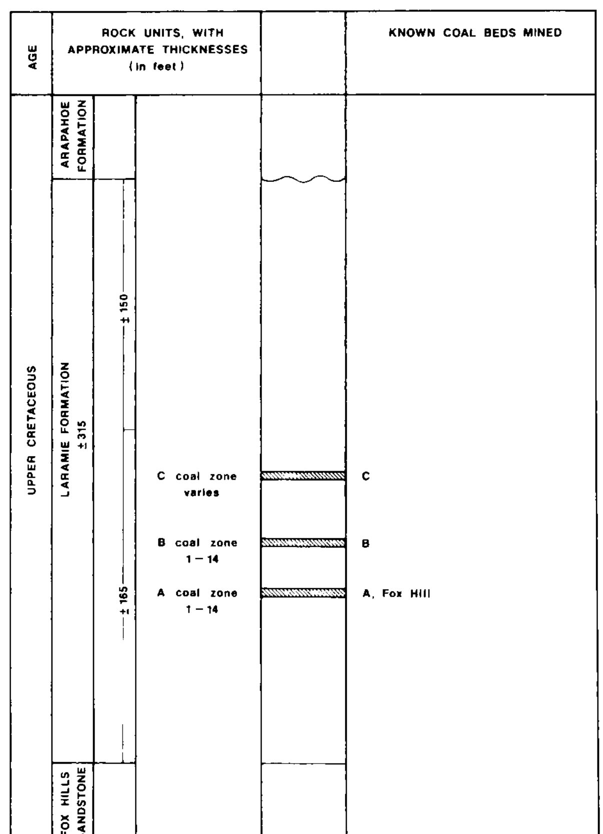


Figure 10. Stratigraphic column, coal-bearing part of Laramie Formation, Colorado Springs Coal Field, Denver Coal Region (no vertical scale) (from Boreck and Murray, 1979).

have been deposited within two separate early Paleocene swamps in an alluvial plain that existed east of the Front Range piedmont area. The northern lignite area contains individual lignite beds that typically are 10 to 30 feet in thickness, with a maximum observed thickness of 55 feet. The southern lignite area, on the other hand, contains generally thinner beds of lignite, averaging 5 to10 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, lying beneath less than 200 feet of cover. To the west, in the deeper parts of the basin, little is known about the Denver Formation lignites. They are believed to essentially pinch out westward near the axis of the Denver Basin (Kirkham and Ladwig, 1979).

PERIOD	DENVER BASIN	CHEYENNE BASIN
QUATERNARY	Undifferentiated	
PLIOCENE		? ?
MIOCENE		Ogallala Formation
		Arikaree Formation
OLIGOCENE	Castle Rock Conglomerate	White River Group
EOCENE	Dawson Arkose	
PALEOCENE	Denver Formation	
UPPER CRETACEOUS	Arapahoe Formation	
	Laramie Formation	
	Fox Hills Sandstone	
	Pierre Shale	
PRECAMBRIAN, PALEOZOIC, AND MESOZOIC FORMATIONS, UNDIFFERENTIATED		

Figure 12. Generalized stratigraphic correlation chart, Denver and Cheyenne sub-basins, Denver Coal Region (Kirkham and Ladwig, 1979, Fig. 10).

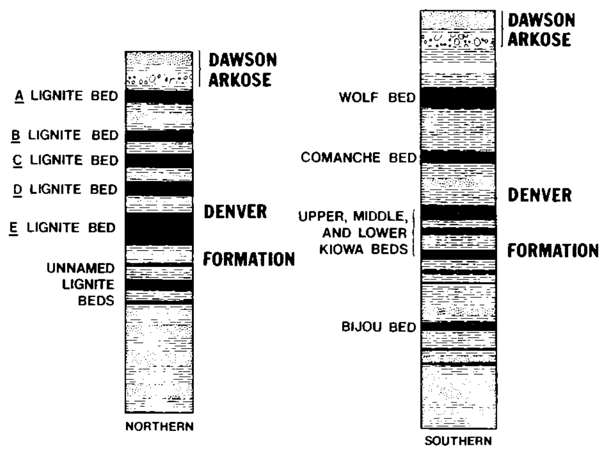


Figure 11. Generalized stratigraphic columns of Denver Formation lignites in the northern and southern lignite areas, Denver subbasin, Denver Coal Region (no vertical scale) (from Kirkham and Ladwig, 1979, Fig. 17).

Denver Formation lignites exhibit the following properties, based on as-received analyses: heating value, 4,000–7,000 Btu/lb; ash content, 8–30 percent; moisture content, 22–40 percent; and sulfur content, 0.2–0.6 percent. Variations in the quality of these lignites primarily is a function of the number and thickness of partings (chiefly kaolinite) within a given bed; such partings may comprise 5 to 30 percent of the total thickness of a lignite bed. These kaolinite-rich partings are high in alumina content and offer the potential for dual-resource (lignite and alumina) recovery (Kirkham and Ladwig, 1979).

Since the late 1800's, the Denver Coal Region has produced more than 134 million tons of coal or 16 percent of the statewide total (table 5) from approximately 385 mines, most of them underground. Approximately 15 million tons (or 11 percent) of all the production in the region 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 has predominated over drift or slope mining. Shaft depths here have ranged from about 250–500 feet.

According to the last resource estimates made of the region (Eakins and Ellis, 1987; Brand and Eakins, 1980), coal resources in the Denver Region amount to approximately 38 billion tons of subbituminous coal in the Laramie Formation, and 34 billion tons of lignite in the Denver Formation, all at depths above 3,000 feet.

GREEN RIVER COAL 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 (Averitt, 1972). 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, 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 constitutes 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.

Virtually all of the coals mined to date in the Green River Region have come from the Iles (fig. 13) and Williams Fork (fig. 14) Formations of the Mesaverde Group. Younger coal-bearing rocks (Lance, Fort Union, and Wasatch Formations—fig. 2) 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.

The Mesaverde coals in the Green River Region are principally high-volatile C bituminous in rank 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 reach up to 10 feet in thickness. The overlying Fort Union coals appear to be as thick as 40 feet or more on geophysical logs of gas wells drilled in the Sand Wash Basin. Where sampled near the surface, they 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 to 20 feet or more in thickness, and may be surface-minable in parts of the Green River Region.

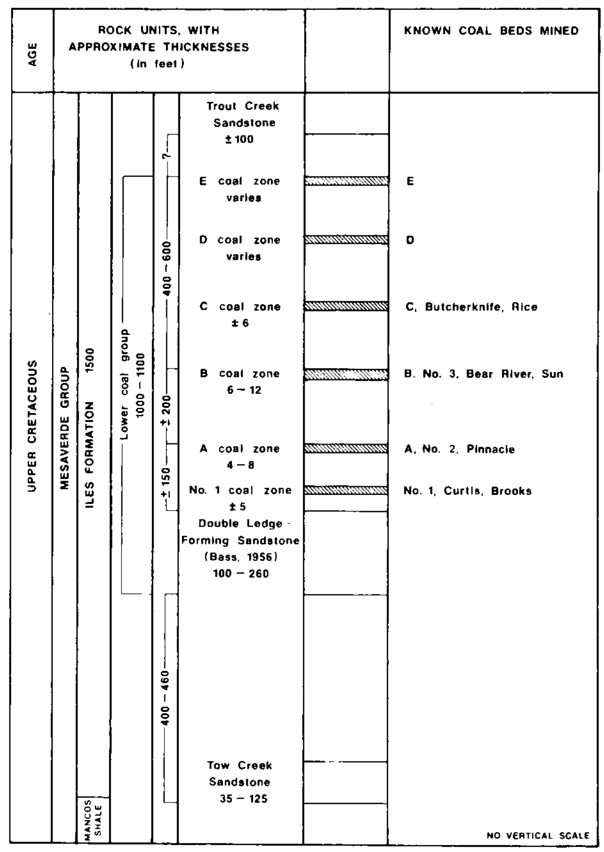


Figure 13. Stratigraphic column, coal-bearing Iles Formation, Lower Mesaverde Group, Green River Coal Region (no vertical scale) (from Boreck and Murray, 1979).

This region has produced approximately 201 million short tons of coal (or approximately 24 percent of the state total) from nearly 200 mines. During 1990, nearly 9 million tons of coal were produced in the Green River Region, Colorado; this was 47 percent of all of the coal produced in the state (table 6). Production from this region in 1990 was from four surface and two underground mines; 45 percent of the coal came from the surface mines.

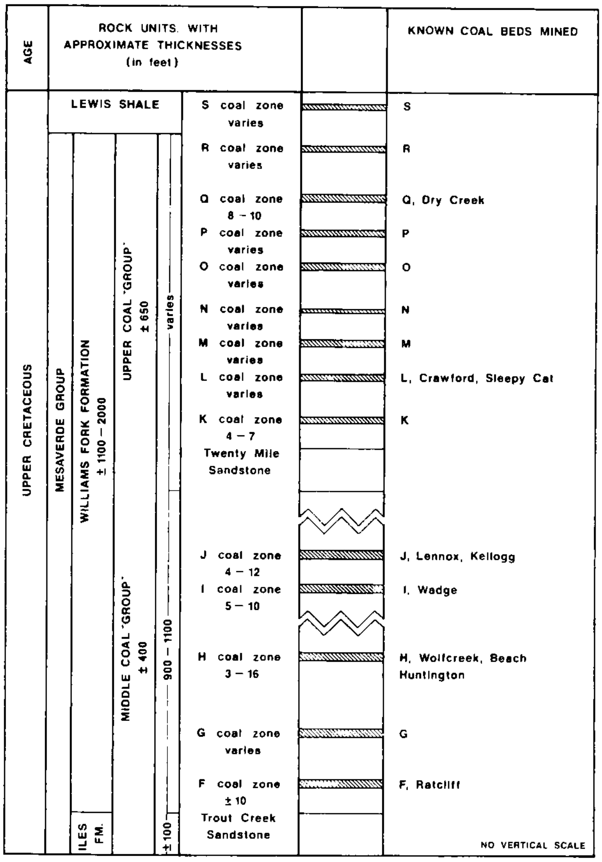


Figure 14. Stratigraphic column, coal-bearing Williams Fork Formation, Upper Mesaverde Group, Green River Coal Region (no vertical scale) (from Boreck and Murray, 1979).

Total in-place coal resources in the Colorado part of the Green River Region probably far exceed 60 billion tons above a depth of 6,000 feet although very little work has been done so far in evaluating the coals below "minable" depths. Speltz (1976) estimates that nearly 1 billion tons of potentially surface-minable coal may exist in this part of the region.

Most of the coal (all of it low-sulfur) being mined in the Green River Region is or will be burned in steam-electric generating plants located within the region, at Craig and Hayden; elsewhere in Colorado, mostly in Denver and Colorado Springs; or exported to states such as Illinois, Indiana, Iowa, Nebraska, and Texas.

NORTH PARK COAL REGION (OR FIELD)

North Park Coal Region, located in Grand and Jackson Counties (fig 1), lies in a high (8,000–9,000 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 on the east, the Park Range Uplift on the west, the Independence Mountain thrust fault on the north (near the Wyoming state line), and the Williams River-Vasquez Mountains on 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 of flows and intrusive bodies. 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, laid down in an alluvial basin that rapidly subsided as the Rocky Mountains were uplifted in early Tertiary time. Coals formed in flood basins and swamps between meandering streams. The Coalmont Formation unconformably overlies the marine Pierre Shale (Upper Cretaceous).

North Park Coal Field

North Park Coal Field is the only part of the region in which coal has been mined in both the Coalmont district (fig. 15) and the McCallum Anticline district (fig. 16). The coal beds in the region often are (1) highly-folded, with bed dips in areas like McCallum Anticline in excess of 45 degrees; (2) typically

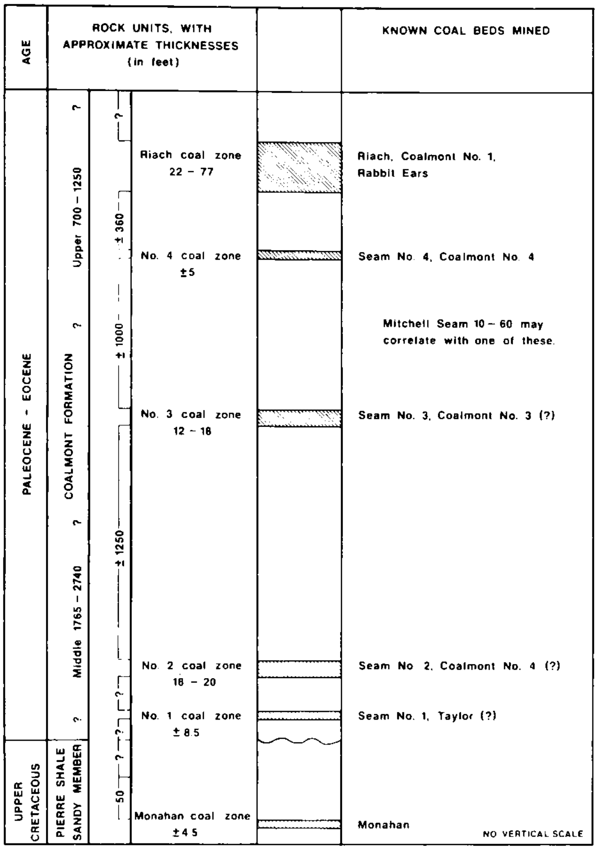


Figure 15. Stratigraphic column, coal-bearing part of Coalmont Formation, Coalmont district, North Park Coal Region (no vertical scale) (from Boreck and Murray, 1979).

faulted; (3) very lenticular; and (4) somewhat upgraded in rank due to the relatively high geothermal gradient in parts of the area. North Park coals generally are subbituminous A to B in rank; most of the coal mined in recent years from McCallum Anticline is subbituminous A (table 7).

The North Park Field has produced nearly 7 million tons of coal from 35 mines since the early 1900's. Most of the coal produced during the last few years has been shipped via a light duty railroad, operated by Union Pacific, which extends from just south of Walden (the Jackson County seat) to the Union Pacific Railroad main line at Laramie, Wyoming (see map by Jones and others, 1978).

During 1990, the North Park Field produced 61,145 short tons of steam coal from one surface mine, the Marr, located on the east flank of McCallum Anticline. This production represents about 3 percent of the total output for the state. The Marr Strip produces subbituminous A coal from a 50–60 foot bed (the "Sudduth") near the base of the Coalmont Formation (fig. 16). In the vicinity of the mine, the Sudduth bed dips from 45 to 60 degrees to the east, creating unique mining problems. This coal ranges up to 11,000-plus Btu/lb, with 0.2 to 0.7 percent sulfur, 2.1–10.8 percent ash, and 11.0–14.4 percent moisture, as received (Dawson and Murray, 1978).

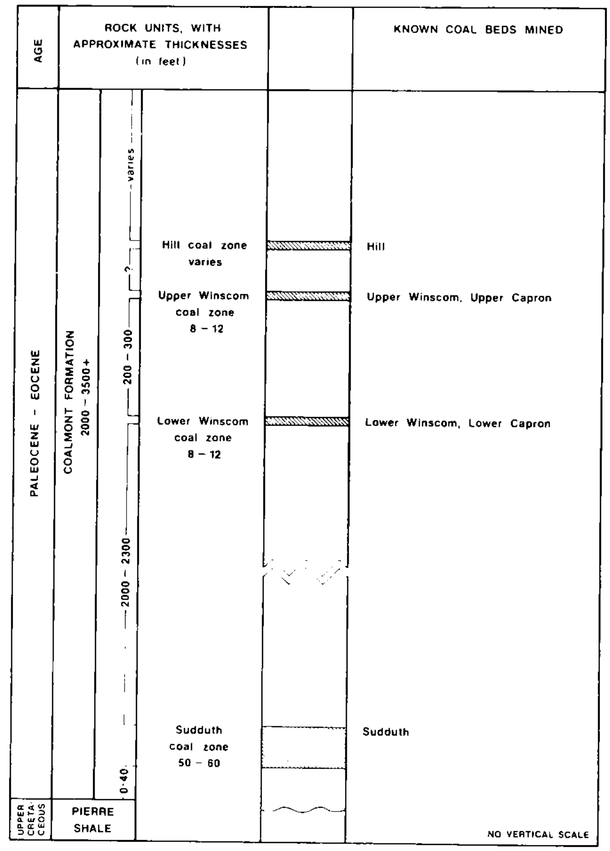


Figure 16. Stratigraphic column, coal-bearing part of Coalmont Formation, McCallum Anticline district, North Park Coal Region (no vertical scale) (from Boreck and Murray, 1979).

Middle Park Coal Field

Middle Park Coal Field never has produced coal, although some coal beds have been reported in lower Tertiary sediments that probably are correlative with the Coalmont Formation in North Park, a few miles to the north. An unknown amount of coal resources probably exist within this 250–300 square mile southern extension of North Park Basin.

RATON MESA COAL REGION

The Colorado part 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 Ranges eastward to Interstate Highway 25 and the town of Trinidad (fig. 1). This region lies within the Laramide-age 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 and 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 above 12,000 feet) and by many associated dikes, sills, and laccoliths. The coals in this region have been upgraded (and 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 (fig. 17). Immediately above the Vermejo is the coal-bearing Raton Formation, of Upper Cretaceous-Paleocene age (fig. 18). The multiple, lenticular coal beds in both of these sequences generally are less than 10 feet in thickness.

As described earlier, the coals of both formations in the southern part of the Colorado portion of the region (Las Animas County) generally are of coking quality, whereas those in the northern part (primarily in Huerfano County) typically are non-coking. The coal resources map by Jones and others (1978) shows the areas where coking coal has been mined, as well as the approximate extent of the "deep" part of the coal basin (where coals are presumed to be present at depths below 3,000 feet).

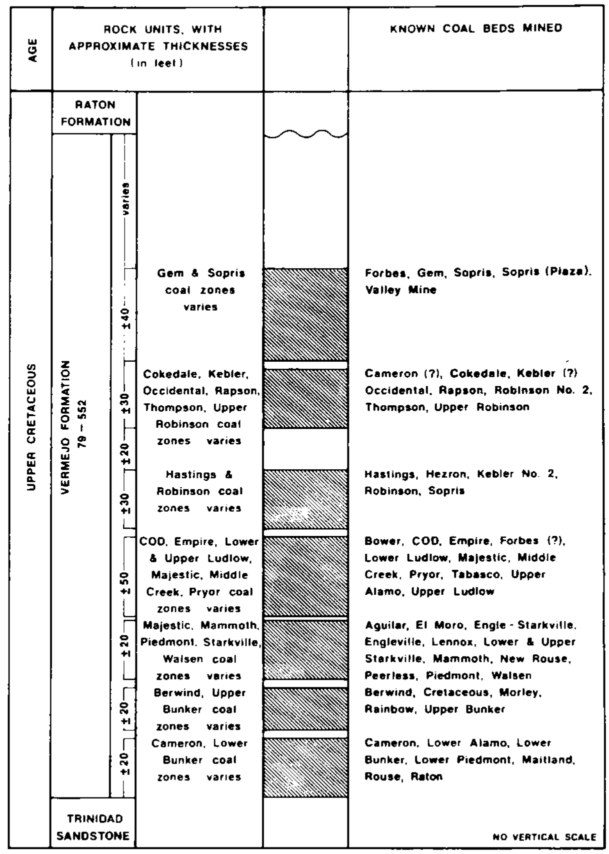


Figure 17. Stratigraphic column, coal-bearing Vermejo Formation, Raton Mesa Coal Region (no vertical scale) (from Boreck and Murray, 1979).

Trinidad Coal Field

Trinidad Coal Field (fig. 1) has produced considerable coal since the late 1800's, much of it coking quality. Nearly 181 million tons through 1990 or 22 percent of the total for the entire State came from more than 150 mines, most of them underground. Historically, this is the most important coal-producing county in Colorado (table 4). Table 7 summarizes the coal analyses from this field.

Walsenburg Coal Field

Walsenburg Coal Field (fig. 1) in Huerfano County has produced approximately 75.7 million tons of coal (mostly noncoking) which is about 9 percent of the cumulative production to date in Colorado. Most of this coal has been mined from the lower part of the Vermejo Formation (fig. 17).

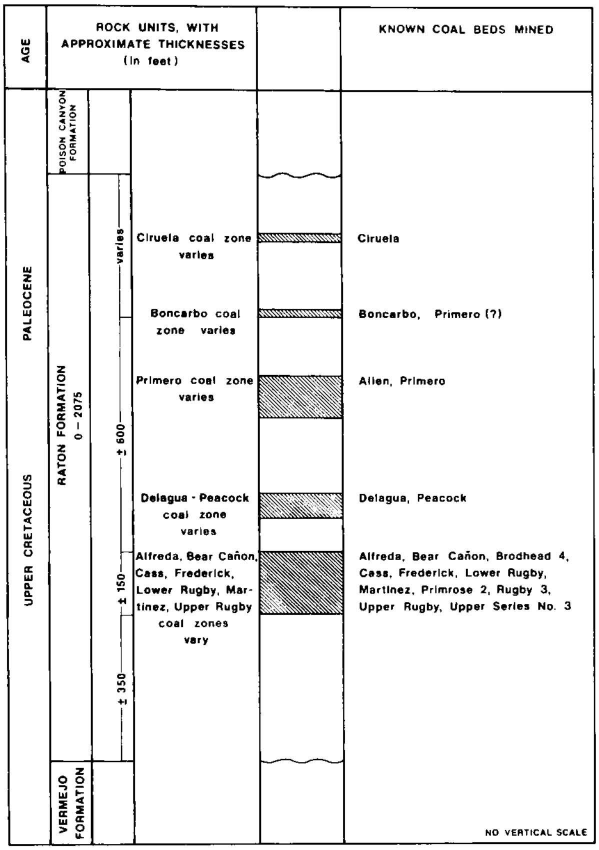


Figure 18. Stratigraphic column, coal-bearing Raton Formation, Raton Mesa Coal Region (no vertical scale) (from Boreck and Murray, 1979).

The Raton Mesa Coal Region (Colorado portion) has produced more than 256 million tons of coal to date from approximately 370 mines; this represents over 31 percent of all the coal produced in Colorado. This region has produced more coal than any other region in the state—at least 55 million tons more than the second place Green River Region (table 6, figs. 6 and 7). Despite the large volume of coal that has been removed from the Raton Mesa region, more than 98 percent of the estimated in-place resource of 13.2 billion tons still remains in the ground.

Much of the mining in the region to date 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.

SAN JUAN RIVER COAL REGION

San Juan River Coal Region of Colorado and New Mexico comprises a portion of southwest Colorado and part of west-central Colorado as far north as the Grand Valley-Grand Junction area (fig. 1; see also maps by Jones and others, 1978; Averitt, 1972). The larger part of this region lies in northwest New Mexico and includes the San Juan structural basin, the Red Mesa-Mesa Verde platform, the Cortez saddle, and the eastern part of the Paradox Basin, which extends into Utah. The region also includes parts of the Gunnison and Uncompahgre Uplifts in Colorado.

Durango Coal Field

Durango Coal 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 in the field are found in the Dakota Sandstone (or Formation), Menefee Formation, and Fruitland Formation (figs. 19, 20, 21).

The Dakota coals are relatively thin, discontinuous, and of high ash content in and near the areas of outcrop (the Hogback) 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 (fig. 20) comprise the most significant coal resource in the Durango field and are the only ones being mined at present. In local areas of structural complexity near Durango, they are of coking quality. Analyses of the coal beds in the Durango field are displayed in table 7.

To date, La Plata and Montezuma Counties have produced over 8 million tons of coal, 66 percent of the total for the entire San Juan River Region. Production during 1990 from one small underground mine in La Plata County totaled 165,516

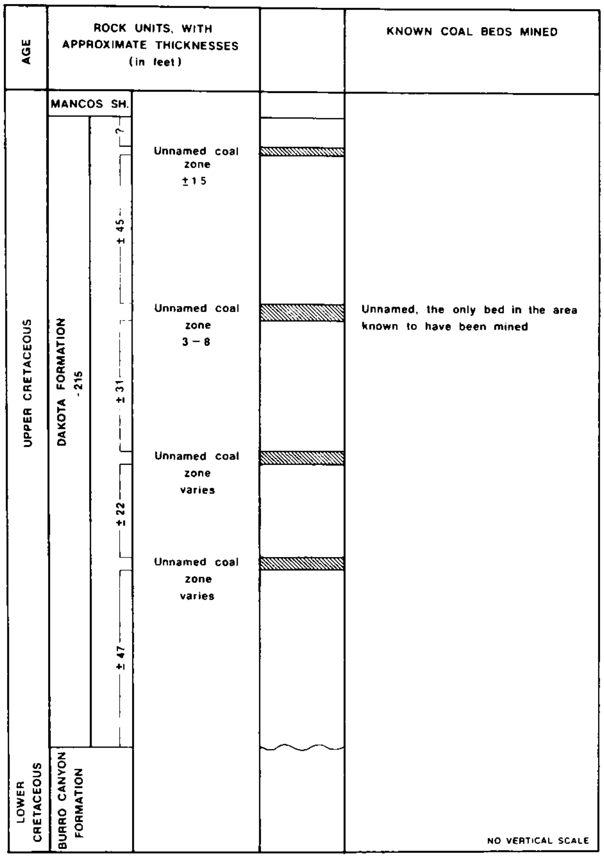


Figure 19. Stratigraphic column, coal-bearing member of Dakota Sandstone, Cortez area, Durango Coal Field, San Juan River Coal Region (no vertical scale) (from Boreck and Murray, 1979).

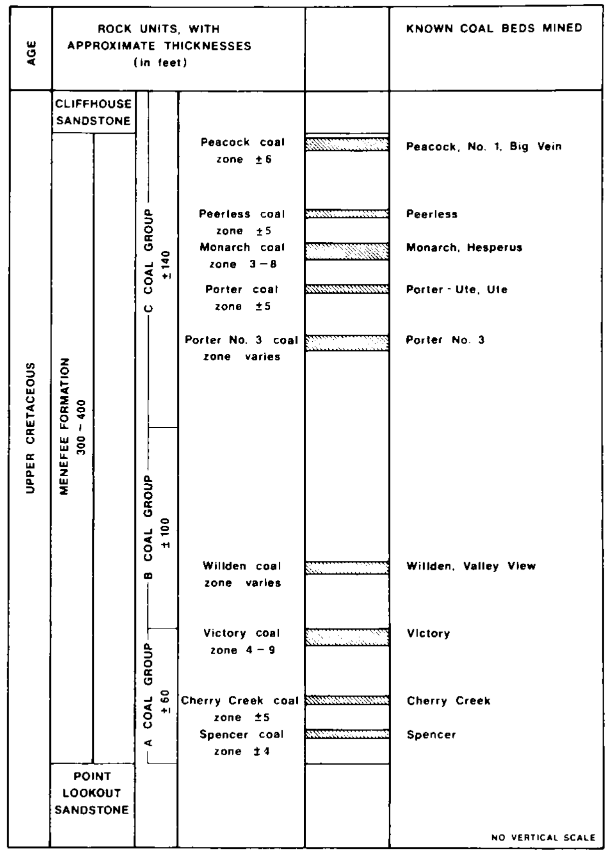


Figure 20. Stratigraphic column, coal-bearing Menefee Formation, Durango Coal Field, San Juan River Coal Region (no vertical scale) (from Boreck and Murray, 1979).

short tons. Most of this coal is shipped to Arizona, New Mexico, and Utah.

Nucla-Naturita Coal Field

Nucla-Naturita Coal Field (fig. 1), in the broad sense, extends from Dolores County northward to just south of the Colorado River in Mesa County. Throughout this large, highly dissected area (the "Dakota coal sub-region" of Hornbaker and others, 1976), most of the post Dakota coal-bearing rocks, and even much of the Dakota Sandstone itself, have been stripped away by erosion. Three minable coal beds, 3–5 feet in thickness, occur in the Dakota sequence in this area (table 7 and fig. 22).

Pagosa Springs Coal Field

Pagosa Springs Coal 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 Coal Field, which has been placed within the Uinta Coal Region in previous articles (Hornbaker and others, 1976), herein is included within the San Juan River Coal Region (fig. 1). Although not shown as such on recent maps (Jones and others, 1978, fig. 1), the Tongue Mesa Coal Field consists of an isolated erosional remnant of Upper Cretaceous sediments (equivalent to at least part of the Mesaverde Group) capped by volcanic rocks of the Late Cretaceous and early Tertiary ages. The field is located on Cimarron Ridge, about 20 miles southeast of the town of Montrose and 8 miles east of U.S. Highway 550, straddling the Montrose-Ouray County line. The coal-bearing

Mesaverde sequence has been eroded west of Tongue Mesa Field.

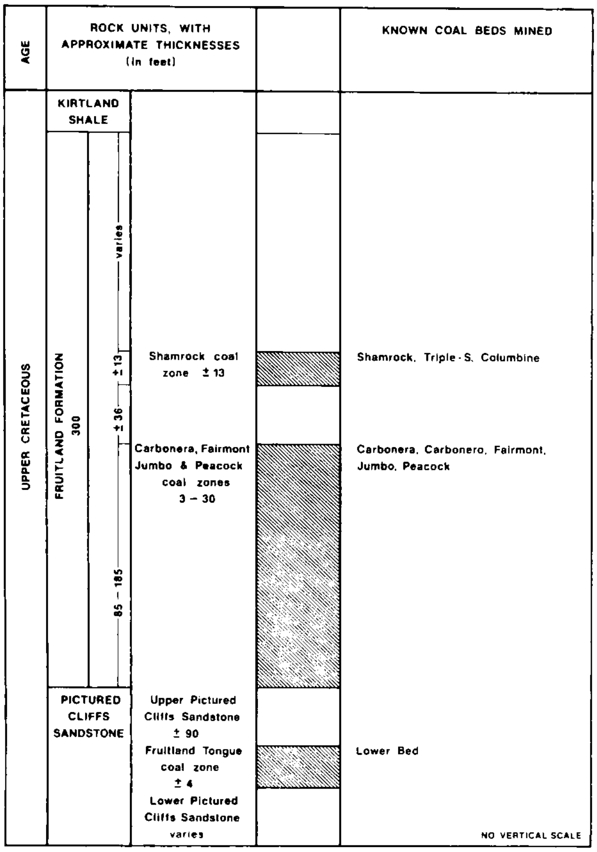


Figure 21. Stratigraphic column, coal-bearing Fruitland Formation, Durango Field, San Juan River Coal Region (no vertical scale) (from Boreck and Murray, 1979).

The coals in this field 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 underground-mined intermittently from the 1890's until the 1940's. No mines are presently active in the field.

Tongue Mesa coals generally are subbituminous B in rank and often are considerably oxidized and bony (table 7).

Since the late 1800's, the San Juan River Region has produced over 12.2 million tons of coal (from nearly 200 mines), which represents about 1.5 percent of the total production for Colorado (table 5). In 1990, the region produced 165,516 short tons of bituminous coal from one underground mine. This volume represents only 9 percent of the state's total production.

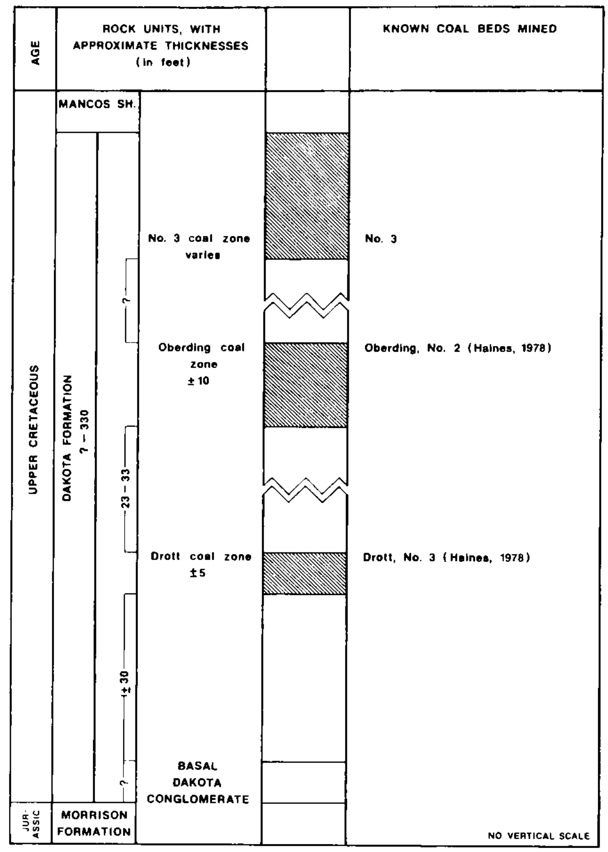


Figure 22. Stratigraphic column, coal-bearing part of Dakota Formation, Nucla-Naturita Coal Field, San Juan River Coal Region (no vertical scale) (from Boreck and Murray, 1979).

SOUTH PARK COAL REGION (FIELD)

South Park Coal Region, in Park County, lies entirely within a small, high (9,000–10,000 feet in elevation), intermontane structural and topographic basin of the same name (fig. 1).

The coal-bearing Laramie Formation of Upper Cretaceous age (fig. 23) 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. A total of only 725,000 tons of coal has been produced in the South Park Region. No mining is taking place at the present.

The Laramie coals near the surface in South Park probably are subbituminous A or B in rank (table 7); however, no modern analyses are available.

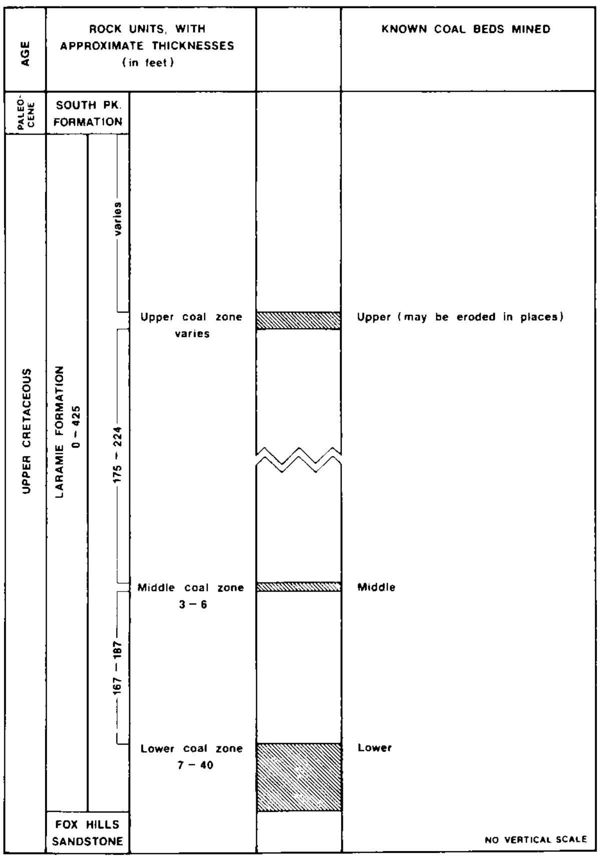


Figure 23. Stratigraphic column, coal-bearing Laramie Formation, Como area, South Park Coal Region (no vertical scale) (from Boreck and Murray, 1979).

The tightly folded and faulted South Park Basin originally may have contained approximately 227 million tons of in-place coal resources above a depth of 6,000 feet (Hornbaker and others, 1976).

UINTA COAL REGION

Approximately one-half of the large Uinta Coal Region lies in west-central Colorado; the remainder constitutes the main coal-bearing region of eastern Utah (fig. 1; Averitt, 1972). Most of the Colorado portion of the 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 on the east, Axial Basin Uplift on the north (which separate this region from the Green River Coal Region), the Utah state line on the west, Grand Valley and the Colorado River on the southwest, and the North Fork Valley and Gunnison Uplift on 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; its long axis trends northwest. This is one of the deepest basins in the Rocky Mountain region, with an estimated over 25,000 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, etc., and associated folds and faulting. 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 (Murray, Fender, and Jones, 1977).

The eight coal fields that exist around the periphery of the Uinta Region are briefly discussed below (fig. 1). 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 7. Production figures by county and for the region are shown in tables 3 through 6.

Book Cliffs Coal Field

Book Cliffs Coal Field of Garfield and Mesa Counties, contains a number of high-quality coal beds in the Mount Garfield Formation of the Mesaverde Group (fig. 24). These coals are mostly high-volatile C bituminous in rank, with some high-volatile B. Hornbaker and others (1976) have estimated total in-place resources in this field (in the 800 square mile area considered) at approximately 7.2 billion tons to a depth of 6,000 feet. During 1990, 196,803 tons of coal were produced from the Book Cliffs Field from one underground mine in Garfield County.

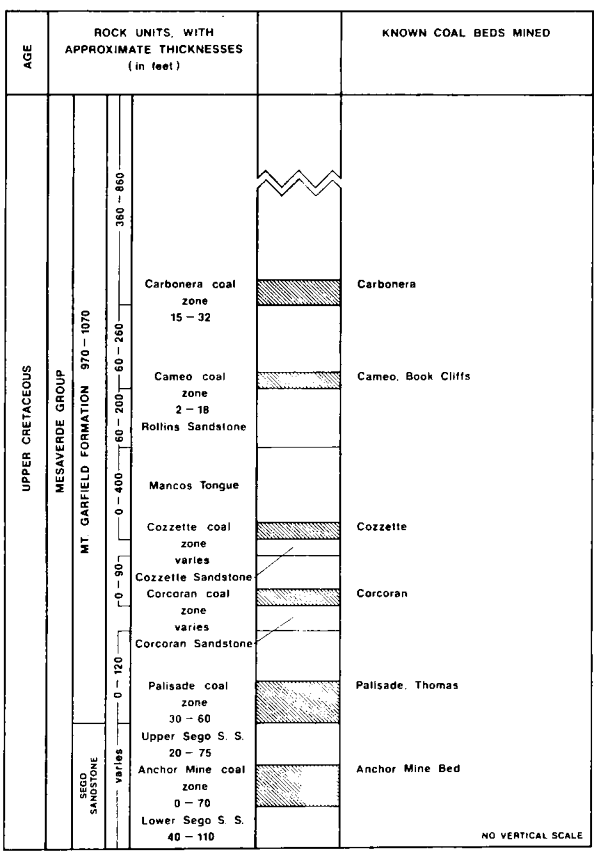


Figure 24. Stratigraphic column, coal-bearing Mesaverde Group, Book Cliffs Coal Field, Uinta Coal Region (no vertical scale) (from Boreck and Murray, 1979).

Grand Mesa Coal Field

To the east of Book Cliffs Coal Field lies Grand Mesa Coal Field, located primarily in Delta County. This field is situated 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 (fig. 24) to the west. The coal beds in 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 the 530 square mile area for which the estimate was made, probably exceed 8.6 billion tons (Hornbaker and others, 1976). One underground mine located in Delta County produced 600,952 tons of bituminous steam coal in 1990 and one in Mesa County produced 183,212 tons.

Somerset Coal Field

East of Grand Mesa Field lies the Somerset Coal Field, located in the valley cut by the North Fork of the Gunnison River and its tributaries, in Delta and Gunnison Counties. The coals in this area occur in the Bowie and Paonia Members of the Williams Fork Formation (fig. 25), are high-volatile B and C bituminous, and range up to 25 to 30 feet in thickness. The eastern part of the field, near the settlement of Somerset, contains coking coal of relatively good quality. Two underground mines in this field produced 949,888 tons of coal during 1990. 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 (Hornbaker and others, 1976).

The Unita Coal Region produced nearly 8 million tons of coal in 1990, 42 percent of the state's total output (table 7). Since the late 1880's this important region has produced more than 174 million tons of coal

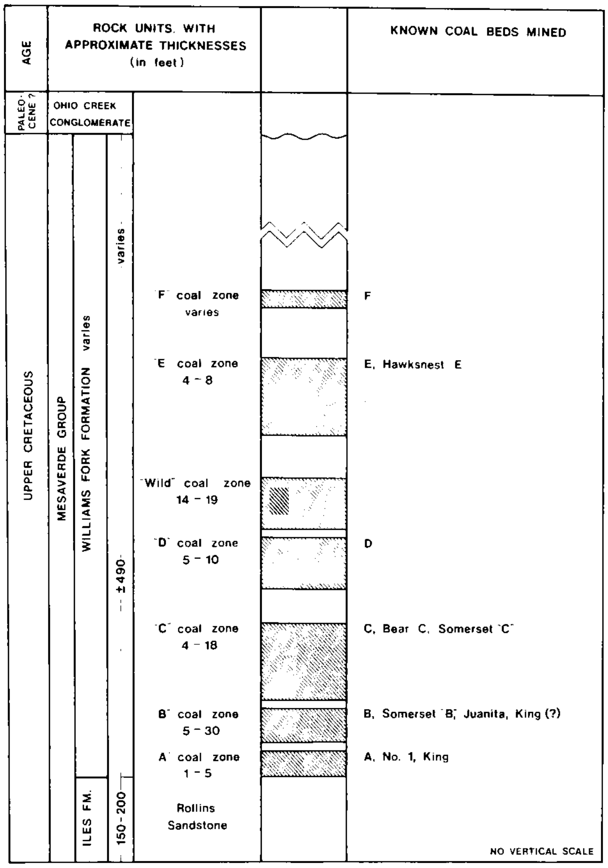


Figure 25. Stratigraphic column, coal-bearing Williams Fork Formation, Upper Mesaverde Group, Somerset Coal Field, Uinta Coal Region (no vertical scale). (from Boreck and Murray, 1979).

from nearly 300 mines; this production constitutes nearly 21 percent of the total for all of Colorado (table 5).

Crested Butte Coal Field

East of Grand Mesa Field lies the Crested Butte Coal Field, located at the southeastern tip of the Uinta Region, in Gunnison County, near the Crested Butte 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 in the field vary from 2–14 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 (Hornbaker and others, 1976). Only 4,784 tons of coal were produced from one mine in the field during 1990.

Carbondale Coal Field

Carbondale Coal Field, located at the eastern edge of the Uinta Coal Region in Garfield and Pitkin Counties, produces high quality coking coal from the Mesaverde Group (fig. 26). 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 miles area considered, have been estimated at more than 5.2 billion tons. One underground mine, Coal Basin, produced 477,927 tons of coal in 1990.

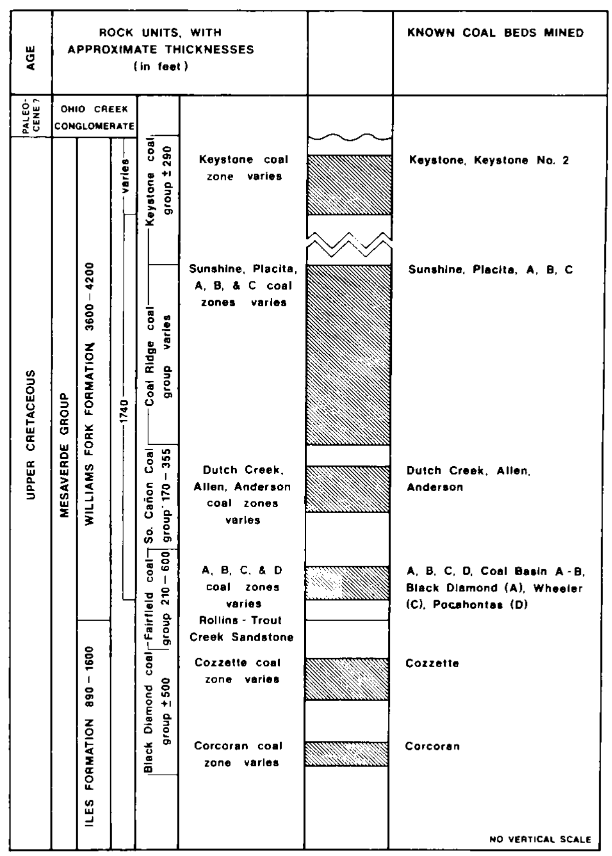


Figure 26. Stratigraphic column, coal-bearing part of Mesaverde Group, Grand Hogback and Carbondale Coal Fields, Uinta Coal Region (no vertical scale) (from Boreck and Murray, 1979).

Grand Hogback Field

Grand Hogback Field, northwest of Carbondale Field, is also located along the east rim of the Piceance Creek basin. The edge of the basin here is sharply upturned to form the prominent Grand Hogback Monocline. This feature extends south from Meeker for some 40 miles to just north of Rifle. There it makes an abrupt bend to the southeast and passes through New Castle (where it is cut through by the Colorado River) proceeds to Glenwood Springs, then again turns south.

Coals crop out along the length of the Grand Hogback (with its 40-degree to near-vertical dips) and have been 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 (fig. 26). 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 (Hornbaker and others, 1976). During 1990, 2,909 tons of coal were produced from one underground mine in the field.

Danforth Hills Coal Field

Danforth Hills Coal Field, which extends from Axial south to Meeker, is situated at the northeast limit of the Uinta Coal Region, in Rio Blanco and southern Moffat Counties. This field is separated from the Yampa Coal Field of the Green River Coal 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 (fig. 27) and Williams Fork (fig. 28) Formations, contain numerous good-quality bituminous coalbeds, 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 miles for which the estimate was made, total more than 10.5 billion tons (Hornbaker and others, 1976). More than 4 million tons of coal were produced from this field in 1990 from the multibench Colowyo surface mine.

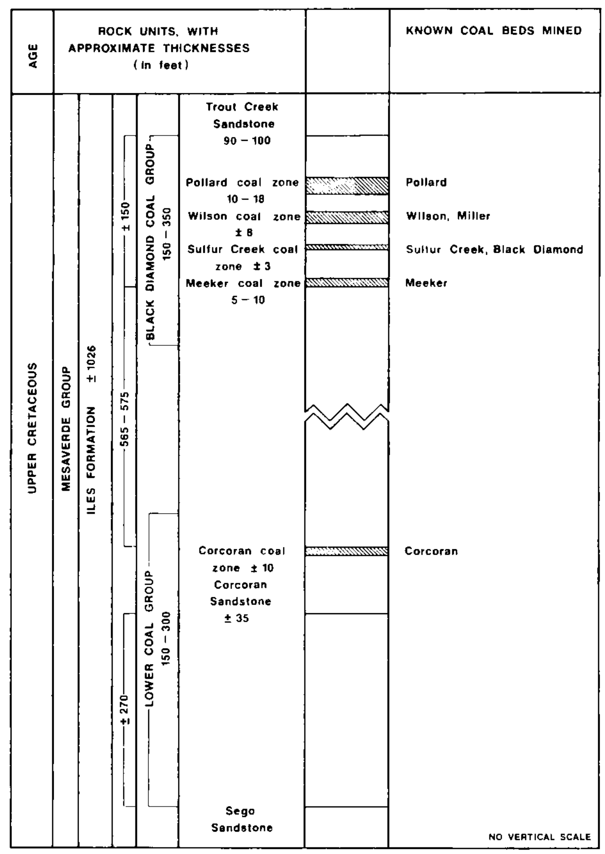


Figure 27. Stratigraphic column, coal-bearing Iles Formation, Lower Mesaverde Group, Danforth Hills Coal Field, Uinta Coal Region (no vertical scale) (from Boreck and Murray, 1979).

Lower White River Coal Field

Lower White River Coal Field, west of the Danforth Hills 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

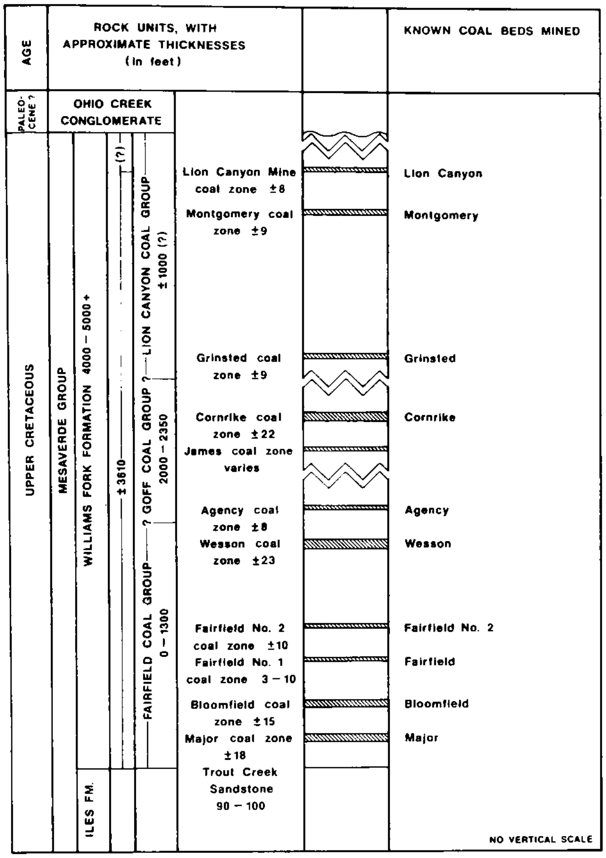


Figure 28. Stratigraphic column, coal-bearing Williams Fork Formation, Upper Mesaverde Group, Danforth Hills Coal Field, Uinta Coal Region (no vertical scale) (from Boreck and Murray, 1979).

part, a few miles north of the giant Rangely Oil Field (the largest oil field in Colorado), is located in southern Moffat County. Coals in Lower White River Field are in both the Williams Fork and Iles Formations (figs. 27 and 28). Most of the mining to date has taken place in the Rangely area, in the Mesaverde rimrock that defines the flanks of the large, breached Rangely Anticline. Coalbeds here vary from about 8 to 12 feet or more in thickness and 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. In 1990, Western Fuels— Utah, Inc.'s Deserado Mine (on the site of the old Staley Gordon Mine), underground mined 1,498,739 tons of coal in the field.

SUMMARY

According to the U.S. Energy Information Administration (1989), Colorado ranks eighth in the total U.S. demonstrated reserve base of coal (17.1 billion short tons). Furthermore, Colorado ranks first in the reserve base of underground-minable, low-sulfur bituminous coal. A significant part of Colorado's bituminous coal reserve base is of coking or metallurgical grade (Goolsby and others, 1979).

Of the 434.21 billion short tons of identified and hypothetical coal resources estimated to be remaining in the ground of Colorado to a depth of 6,000 feet, only 128.95 billion short tons (29.7 percent of the total) are classed as remaining identified resources (to a depth of 3,000 feet) (Averitt, 1975). However, these data are very preliminary; detailed or specific information on coal occurrence exists in only about 25 percent of the coal-bearing areas of Colorado (Averitt, 1975).

The U.S. Energy Information Administration (1989) estimates the demonstrated reserve base of Colorado coals (as of January 1, 1988) to be about 17.1 billion short tons, of which only 4.9 billion short tons (29 percent of the total) 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 over 80 percent of the total coal resources of the state (0 to6,000 feet of overburden) will be minable only by underground methods. Overall recovery of the total coal resources of Colorado probably will be much less than 50 percent of the coal in-place, unless major breakthroughs in mining technology are achieved. Even then, the thick, multiple coal beds typical of many parts of Colorado may defy efficient overall recovery. In some instances, in-situ combustion of deeply buried or steeply dipping coal beds may be the only means by which to recover the energy contained in a large part of the state's coal resources (Murray, Fender, and Jones, 1977).

According to Speltz (1976), most of Colorado's potentially surface-minable coal is located in the Denver Coal Region (75 percent of the total, mostly lignite), in the San Juan River Coal Region (Nucla-Durango-Cortez area, 16 percent), and in the Green River Region (Oak Creek-Craig-Axial area, 5 percent).

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