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1981 Summary of COAL RESOURCES in Colorado

by L. R. Ladwig

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Denver, Colorado / 1983

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SPECIAL PUBLICATION NO. 23

1981 SUMMARY

OF

COAL RESOURCES IN COLORADO

BY

L. R. LADWIG

COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
STATE OF COLORADO
DENVER, COLORADO

1983

$5.00

PREFACE

This coal summary initially was prepared for the 1979 Keystone Coal Industry Manual, by D. Keith Murray where it appeared as the Colorado Chapter. In 1983 it was revised to reflect the Colorado coal industry through 1981. Changes mainly occur in the area of historical data and additions to the bibliography.

This summary should serve as an excellent introduction to Colorado coal, with follow-up reading of the various Colorado Geological Survey publications that describe Colorado coal and coal bed methane in detail. A list of these publications are printed inside the front and rear covers.

The Colorado Geological Survey expresses its appreciation to George F. Nielsen, Editor and Chief, Mining Informational Services, McGraw Hill, Inc., publishers of the Keystone Coal Industry Manual for photo-ready copy that made it possible to reproduce this article in its entirety.

L. R. Ladwig
Chief-Mineral Fuels Section

ABSTRACT

Colorado, with 8 coal-bearing regions and 20 coal fields, contains at least 11 percent of the total remaining coal resources of the United States to a depth of 6000 feet. Colorado coals range from early Late Cretaceous to Eocene in age.

The higher rank bituminous coals and the largest reserves generally are found in the Upper Cretaceous Dakota and Mesa Verde Groups/Formations in western Colorado. The younger 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. Marginal and premium grades of coking coal are found in the Carbondale, Crested Butte, and Somerset fields, Uinta coal region; in the Trinidad field, Raton Mesa region; and in the Durango field, San Juan River region.

Colorado coals range in rank from lignite to anthracite; over 70 percent of the resource is bituminous, approximately 23 percent is subbituminous, 5 percent lignite, and less than one percent anthracite. Moisture, volatile matter, and fixed carbon contents of Colorado coals vary considerably with rank from region to region.

According to the U.S. Bureau of Mines (1977a), Colorado ranks seventh in the total U.S. demonstrated reserve base of coal (16.3 billion short tons) and fourth in the reserve base of bituminous coal. Furthermore, Colorado ranks first in the reserve base of underground-minable low sulphur bituminous coal.

The Green River region produced over 9.5 million tons of the total 1981 state-wide coal production of 19.7 million tons. Projections for Colorado coal production through 1985 is in the order of 21 million tons per year.

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Colorado

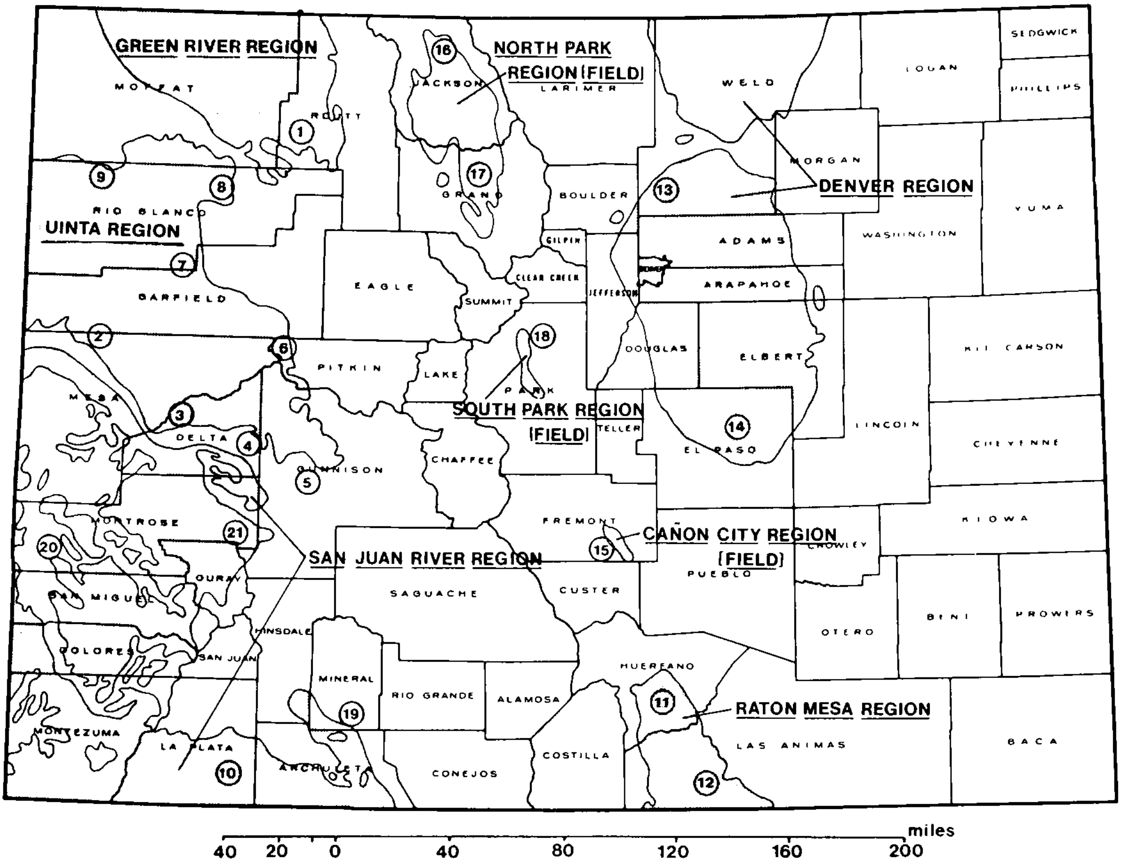


Figure 1. Coal-bearing regions and fields in Colorado.

1. Yampa
2. Book Cliffs
3. Grand Mesa
4. Somerset
5. Crested Butte
6. Carbondale
7. Grand Hogback
8. Danforth Hills
9. Lower White River
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

Introduction

The largest presently available source of energy in Colorado lies in its vast deposits of coal, which occur in an area encompassing nearly 30,000 sq. mi., or approximately 28 percent of the State. Over 434 billion tons of in-place coal resources are believed to remain in Colorado (Averitt, 1975, p. 14) above an overburden thickness of 6,000 ft.; this estimate is nearly 11 percent of the total resource in the entire United States and is the fourth largest of all the States. To a depth of 3,000 ft., Colorado's remaining identified coal resources are listed (Averitt, 1975) as nearly 129 billion tons. 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, p. 22). Most (over 80%) of the coal resources of the State are believed to be minable by underground methods.

Colorado coals range in age from early Late Cretaceous to Eocene, the largest and most widespread resources oc-

Prepared by D. Keith Murray, Energetics, Inc., Englewood, CO 80112. Revised by L. R. [illegible] ary 1983.

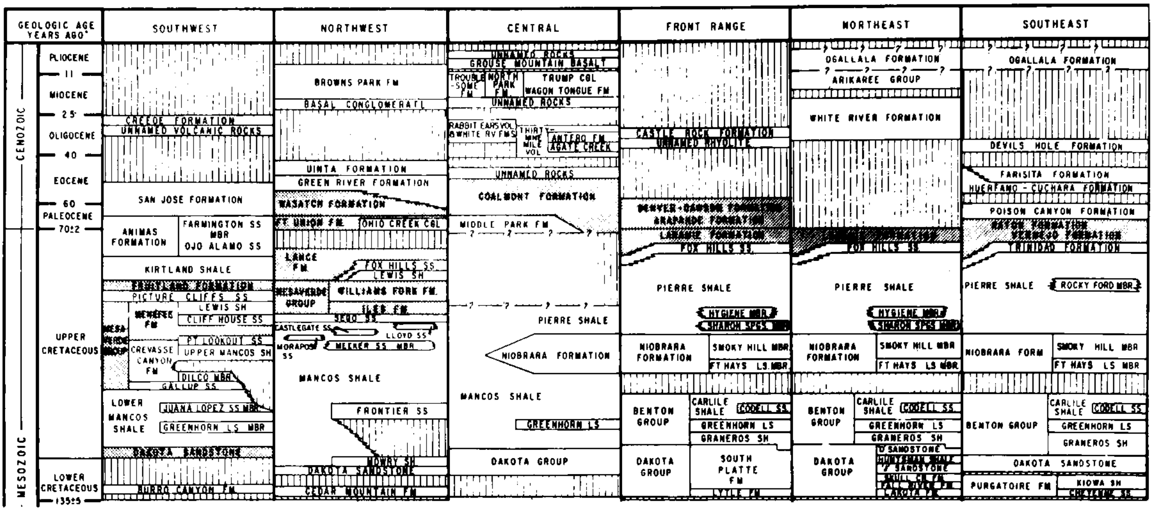


Figure 2. Colorado stratigraphic correlation chart, parts of Mesozoic and Cenozoic Eras. Coal-bearing units are shaded. (from Pearl, R.H., and Murray, D.K., 1974, Colorado Stratigraphic Correlation Chart: Colorado Geol. Survey, 1 plate).

curring 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 regions in the northwestern and west-central parts of the State, respectively.

The low sulfur, ash, and moisture content, together with generally high heating values, of Colorado coals affords a demand for both steam-quality and metallurgical-grade coals. Bituminous coal comprised 38 percent of Colorado's 1981 production; the balance was subbituminous in rank (mainly subbituminous A). Approximately 10 percent of the coal presently mined in the State is used for metallurgical purposes. Eighty-four percent of the coal now consumed in Colorado is utilized for steam-electric power generation, and this percentage is steadily increasing. Most of the remainder of the coal consumption is for metallurgical and industrial requirements. The rising demand for low-sulfur, high-Btu coal for power-generating and industrial purposes, together with the fact that perhaps 75 percent of the coal resources occur either on private or State-owned lands, assure a steady demand for Colorado coal.

Since 1864, over 678 million short tons of coal have been mined in Colorado; this is less than the present annual production of one year's current output of the United States. In 1981, Colorado produced more than 19.7 million tons, an all-time record. The State's previous coal production high, 12.658 million tons, occurred in 1918; this figure was surpassed during November 1978.

In 1981, the State produced 19.7 million short tons of coal (an increase of approximately 4.5 percent over 1980) from 57 mines (down 7 from 1980)—38 underground and 19 surface. A total of 4,675 persons were employed in these operations, 2,367 of them (or 50%) in underground mines. Nearly 11 million short tons (or 55% of the total) of coal were surface-mined in Colorado during 1981. In 1981, the number of days worked per mine averaged 201; daily production per miner averaged 21 short tons; and daily production from all mines averaged 98,017 short tons.

Colorado's coal production for 1982 is estimated at some 18.6 million short tons, or nearly a 6 percent decrease from 1981. At the end of October 1982, slightly more than 15.4 million short tons of coal had been produced for the year from a total of 60 operations—39 underground and 21 surface—that employed 3,260 workers, 487 fewer than in 1981. During October only 31 mines actually reported production, while 14 were idle.

Mine safety is of increasing concern in Colorado as it is nationwide. During the first ten months of 1982, a total of 23 fatal accidents and 234 non-fatal injuries were reported in coal mines in the State. During all of 1981, ten fatal and 406 non-fatal accidents occurred in Colorado coal mines.

Coal-Bearing Regions

The coal resources of Colorado occur entirely within the Rocky Mountain coal province. The eight named coal-bearing regions and 21 coal fields (Fig. 1) are located in the western three-fourths of the State: 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, Fig. 3). These coal-bearing regions encompass approximately 29,600 sq. mi. (or 28 percent of the total area of Colorado) and contain at least 11 percent of the total remaining coal resources of the United States to a depth of 6,000 ft.

Coal-Bearing Rocks

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 River region, Durango to Nucla-Naturita 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 upper part of the Denver Formation in the central Denver coal region.

Structure of Coal-Bearing 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 here probably 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 is located partially within the Piceance Creek basin, and the Green River region, the Colorado portion of which includes the Sand Wash basin, each contain significant coal resources to depths exceeding 10,000 ft.; these 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 due to the limited areas within the coal-bearing regions in which the coal beds are both of gentle dip and under "shallow" cover.

Coal Rank

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

In a general sense, 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.

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 (see discussion below).

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

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 (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 Region (or field):

Coalmont Formation (Paleocene-Eocene)—
subbituminous A and B.

Raton Mesa Region:

Northern part of region (Walsenburg coal field):
Raton Formation (Paleocene-Upper Cretaceous)—
high-volatile B and C bituminous (non-coking)

Veremjo 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 (generally of coking quality).

Vermejo Formation (Upper Cretaceous)—
high-volatile A and B bituminous (generally of coking quality).

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 of coking quality)

Dakota Formation or Group (Upper Cretaceous)—
high-volatile B and C bituminous (currently mined only in Nucla-Naturita field; may locally be of coking quality).

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 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 1-20 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 in 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 approximately 2-20 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 (over two-thirds of the State's production in 1980 was from surface mines) contains between 0.2 and 0.5 percent sulfur; on the other hand, much of the underground-mined metallurgical-grade coal in Colorado contains 0.5-1.0 percent sulfur, still low in comparison with many Eastern coals. Recent 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 field, Green River region, shows 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. In terms of pounds of sulfur per million Btu, most of the coal being surface-mined in Colorado today for use in steam-electric power plants contains between approximately 0.2 and 0.5 lbs/ million Btu, well within the definition of low-sulfur coal: namely, one which contains 0.6 lb or less sulfur per million Btu, and thus meets EPA regulations for fossil fuel-fired steam generating units when combusted without removal of any of the sulfur dioxide (SO_2) from the combustion effluents.

Washability

During 1980, only 13 percent (or 2.4 million tons) of the coal mined in Colorado was washed. Most Colorado coals do not require treatment other than sizing in order to meet market demands (generally 2.5 in. x 0 in.). Relatively high ash contents in some of the coals is the main reason for washing. Grindability indices of Colorado coals generally vary between 45 and 50.

Heating Values

Most of the subbituminous and bituminous steam coal being produced today in Colorado ranges from about 10,000-13,600 Btu/lb; and coking coal, 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. On a moisture- and ash-free basis, an average of approximately 14,000 Btu/lb is reasonable for most Colorado coals; and on an as-received basis, about 11,370 Btu/lb.

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.

Coal Analyses

Since 1975, 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 are done by the U.S.G.S. in the Denver area; and the proximate, ultimate, and related analyses are performed by the U.S. Bureau of Mines laboratory (now under the jurisdiction of the Department of Energy) in Pittsburgh, Pa.

Results of the first phases of this program have been published (Boreck and others, 1977; Khalsa and Ladwig, 1981). Included in the analyses resulting from this ongoing 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 of the first phase.

Although many of the analytical results of the sampling programs conducted since 1976 have not been fully tabulated and correlated, it appears certain that none of the Colorado coals sampled to date—and these include coals from all of the larger producing mines in the States—contains 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, Ultimate Value Analyses for Fields (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 fields, Uinta coal region; in the Trinidad field, Raton Mesa region; and in the Durango field, San Juan River region (Fig. 1). The Colorado Geological Survey recently completed an evaluation of coking coals in Colorado (Goolsby and others, 1979). This study shows 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 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 region, about 1.7 billion tons of premium grade high-volatile A bituminous to latent grade high-volatile B bituminous coking-coal reserves.

Colorado has been a leading producer of coking-coal in the West for many years, and contains two of the four major coal fields that produce good quality coal and account for most of the production of coking coal in the western U.S. (Averitt, 1966). In the 1960s, the American steel industry began relying more heavily upon quality blending coals to supplement the declining supplies of premium-grade coking coals for their coking operations. With the advent of a market for premium-quality as well as for blending-quality coals, and the continued depletion of readily available Eastern coal reserves, the Western States have assumed a role of increasing importance as a source of coking coal.

Today, Colorado, New Mexico, and Utah produce most of the coking coal consumed by the three steel mills operating in the West. These mills are located in Pueblo, Colorado, Provo, Utah, and Fontana, California, and they supply much of the West's demand for steel. Colorado produces approximately 40 percent of the marginal and premium grades; Utah, the balance of the premium grade; and New Mexico, the balance of the marginal grade coking coal (premium grade coking coal includes low-volatile, medium-volatile, and high-volatile A bituminous coals with 0-8.0% ash and 0-1.0% sulfur; and marginal grade includes low-volatile, medium-volatile, and high-volatile A bituminous coals with 8.1-12.0% ash and 1.1-1.8% sulfur).

CF&I Steel Corporation and United States Steel Corporation still maintain their own captive (i.e., company-owned) coal mines in Colorado. CF&I Steel ships coal from its Allen and Maxwell mines, in Las Animas County, to its Pueblo, Colorado steel mill. Likewise, U.S. Steel transports coal from its Somerset mine, in Gunnison County, to its

Table 2. Currently Producing Coking Coal Mines in Colorado (Colorado Division Mines, 1981).

Mine Name	*County*	*1981 Production (ST)*	*Overburden Thickness (feet)*
Bear	Gunnison	260,658	1200
Hawk's Nest East (#2)	Gunnison	618,531	1600
Hawk's Nest West (#3)	Gunnison	84,461	1600-2000
Somerset	Gunnison	668,622	200-2000
Allen	Las Animas	486,705	400-1100
Maxwell	Las Animas	175,184	400-1400
Coal Basin	Pitkin	92,999	1000-3000
Bear Creek	Pitkin	Idle	1000-3000
Dutch Creek #1	Pitkin	45,385	1000-2500
Dutch Creek #2	Pitkin	257,492	1000-3000
L.S. Wood	Pitkin	224,643	1000-3000
Thompson Creek #1	Pitkin	116,049	400-1300
Thompson Creek #2	Pitkin	3,605	400-1300

Geneva steel mill, located near Provo, Utah (Jones and Murray, 1977).

The Raton Mesa region contains coking coal of generally lower quality than that in the other two main areas of occurrence in Colorado; however, it is the most readily accessible region from the standpoint of transportation. The San Juan River region is the least known of the three; it produces a medium-quality bituminous coal. Problems involving the thinness 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; transportation problems, depth of overburden (this is the deepest coal mined in Colorado), and abnormally gassy 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 ft. of overburden. Consequently, such reserves have not been included in the "demonstrated coal reserve base" tabulated by the U.S. Bureau of Mines (1977a), which uses 1,000 ft. as the maximum minable depth criterion for all ranks of coal except lignite. In western Colorado, for example, virtually all of the major underground coal mines today are mining beneath cover ranging from 1,000-3,000 ft. 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 ft. in thickness within relatively short distances in from the portal. As shown on Table 2, much of the coking coal being mined today in Colorado comes from reserves that exist beneath greater than 1,000 ft. of overburden and, as a consequence, have not been included in the demonstrated coal reserve base computations of the Bureau of Mines (1977a).

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 the 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 (Averett, 1975, p. 21):

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

Bituminous coal—sp gr 1.32 (1,800 tons/ac-ft.)

Subbituminous coal—sp gr 1.30 (1,770 tons/ac-ft.)

Lignite—sp gr 1.29 (1,750 tons/ac-ft.)

Coal Transportation

In 1981 an estimated 50 percent of Colorado coal was shipped out of state, except for that produced in the San Juan Coal Region, most coal was ultimately shipped via rail, but a large portion was initially trucked to the railheads.

Most of the current coal developments are located in western Colorado, while the greatest demands are coming largely from eastern Colorado. There are three train routes across the Continental Divide, all on the Denver and Rio Grande Western Railroad. The trackage used for unit train coal transport often suffers greatly from heavy weights and frequent usage. The Union Pacific line from the Walden area, in Jackson County, northward into Wyoming will not accommodate unit train traffic at all. The Colorado & Southern Railway, Burlington Northern and AT & SF railroads haul unit train loads of coal along the Front Range Corridor, from Wyoming to New Mexico. Map Series 9 (Jones and others, 1978), published by the Colorado Geological Survey, shows the railroads of Colorado and the routes and directions travelled by coal trains in the State.

The lack of a major railroad in all of southwestern Colorado severely limits the potential market for coal produced in that region. Options available to the mine operators include (1) producing for a limited local domestic market, or (2) trucking the coal some 150 miles east to the nearest railhead (which adds approximately $7 per ton to the price of the coal).

State Coal Lands

In June 1981, a total of 161,733 acres of state lands were leased for coal.

From 1908 to July 1, 1981, over 31.9 million short tons of coal were produced from State lands. During FY 1980–1981, 2,471,227 short tons of coal were produced from State lands (Colorado State Board of Land Commissioners, 1981, p. 26). From 1908 to July 1, 1981, more than $13.4 million in royalties, rentals, and bonuses has been paid to the State Land Board by coal lessees.

During FY 1980–1981, $3,906,507 in cash receipts was received by the State Land Board—$129,468 from annual rentals of coal leases and $3,537,217 in royalties from coal production and $239,822 from lease bonuses. Table 3 shows this breakdown.

Table 3. Colorado State Board of Land Commissioners' Receipts from Coal Leases, July 1, 1980–June 30, 1981

Coal Production Royalties	$3,537,217
Coal Lease Rentals	$ 129,468
Coal Bonuses	$ 239,822

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 in the State 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).

Federal coal lands cannot be claimed under the Mining Law of 1872; therefore, all Federal coal land is administered by the BLM, and all mining operations are supervised by the U.S. Geological Survey Conservation Division under provisions of the Mineral Leasing Act of 1920. 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%) 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). Recoverable coal reserves held under Federal Preference Right Coal Lease Applications are estimated at 890 million tons. From April 23, 1925, when the first Federal lease was issued, to the June 6, 1973 Federal Coal Leasing Moratorium, the U.S. Government issued 56 competitive bid leases, aggregating 44,234 acres, and 56 preferential right leases (resulting from prospecting permits) aggregating 77,631 acres (Speltz, 1976, p. 11).

Historically, only 5 percent of the State's total coal production has come from Federal leases, and less than 4 percent from State-owned lands. However, in 1976, 30 percent of Colorado's coal was obtained from leased Federal lands and approximately two-thirds from privately held lands, while coal production from State lands remained at 5 percent of the total.

The Mineral Leasing Act of 1920 designates that royalties collected by the Federal government for coal produced on leased Federal coal land be shared with State governments. As a result, Colorado has received the revenues shown on Table 4.

Table 4. Colorado's Share of Federal Coal Lease Revenues (Ladwig-CGS)

FY 1977-78	$ 452,009
FY 1978-79	$ 904,283
FY 1979-80	$2,898,767
FY 1980-81	$6,998,200

Imports and Exports of Colorado Coal

The 10.0 million tons of coal that were shipped out-of-State in 1981 represent an increase of 112 percent over that exported during 1976. The large demand for Colorado coal in Utah and California came from steel plants (Fig. 3). In Illinois, Iowa, and Nebraska, both utilities and industry bought significant amounts of Colorado coal, while in Indiana the demand came entirely from utilities. However, Colorado power plants required imports of coal totalling 2.5 million tons. The imported coal was used by eastern Colorado electric power generating plants. These imports came from the Powder River basin of northeastern Wyoming. Some coking coal was imported from Oklahoma.

Colorado was a net exporter of coal in 1981, as shown on Table 5 (Colorado Division of Mines and Colorado Geological Survey). The same situation is believed to have prevailed in 1980, as well.

Table 5. Imports and Exports of Colorado Coal, 1981

Year	*Imports/Exports*
1981	Imports 2.8 million short tons Exports 10.0 million short tons

Coal Mining and Production

Since 1864, Colorado mines have produced more than 689 million short tons of coal (Fig. 4), nearly equal to the annual production of the United States. 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 three and six million tons per year until 1973, when the present rise in annual production began.

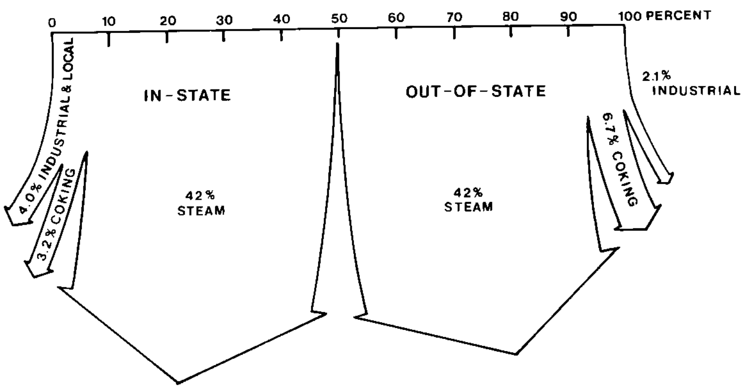
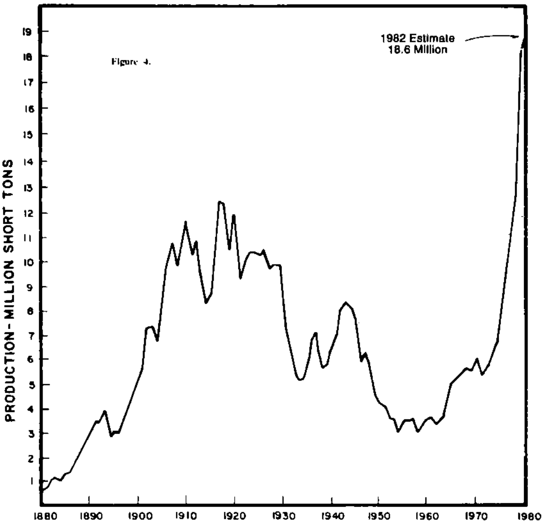


Figure 3. Colorado coal shipments—1981 (Ladwig-CGS)



COLORADO COAL PRODUCTION 1880-1980

Figure 4

Even though Colorado is one of the smaller producers of Rocky Mountain coal, currently producing less than 10 percent of the region's coal, and only 1.5 percent of the U.S. total, nevertheless its annual production has increased dramatically—over 300 percent—since 1971, as shown by the following tabulation:

1971	5.31 million short tons (MST)	
1972	5.53 MST	(4% increase)
1973	6.23 MST	(13% increase)
1974	6.96 MST	(12% increase)
1975	8.27 MST	(19% increase)
1976	9.46 MST	(14% increase)
1977	11.97 MST	(27% increase)
1978	14.36 MST	(20% increase)
1979	18.13 MST	(26% increase)
1980	18.77 MST	(3.4% increase)
1981	19.70 MST	(5% increase)

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 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, and increasing coal development currently is underway in that region. 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 recent opening of several large underground mines in the Uinta coal region (Fig. 1), which region produced more than 4.1 million tons of coal in 1981.

The Green River region produced over 9.55 million tons of coal during 1981. Approximately two-thirds of the coal resources in this region are believed to be high-volatile C bituminous; and the remaining third A, B, or C subbituminous (Hornbaker and others, 1976, p. 10).

The more than 19.7 million tons of coal produced in Colorado in 1981 was worth an estimated $413 million dollars, assuming an average price of $21.00/short ton. This value represents over 14.7 percent of the total value of fuel and nonfuel minerals produced in Colorado during 1979—$3.9 billion dollars.

The surface mining of coal in Colorado began in 1909 in the Coalmont district, western North Park field, in Jackson County (Fig. 1). By 1962, seven of the State's 177 operating mines were surface mines, producing 14 percent of the total State production of 3.39 million tons (Figs. 4 and 5). Since 1962, between 6 and 26 surface mines have been licensed to operate in Colorado. To date, over 68 million tons of coal have been produced by surface-mining methods in Colorado, which is approximately 10 percent of the State's cumulative production.

Colorado's 1981 coal production amounted to 19.7 million short tons (MST), an increase over 1980 of 6 percent and the highest in Colorado history. Table 6 summarizes Colorado coal industry operations during 1981.

Table 6. Summary of 1981 Coal Production Operations in Colorado (Colorado Division Mines, 1981)

Total Mines	57	*Employees*	4,675
Underground	38	Underground	2,367
Strip	19	Surface	713
		Strip	1,595

Average Days Worked per Mine	201
Man-Hours Worked	7,507,086
Daily Production per Miner	21
Average Daily Production	98,017

Production (Tons)	19,701,496	*Method of Mining (Tons)*	
Bituminous	14,667,204	Underground	8,704,741
Subbituminous	5,034,292	Strip	10,996,755

Disposal (Tons)

	Shipped In State	*Shipped Out of State*	*Used At Mine*	*Stockpiled*
Archuleta	7,435	247,576	—	—
Delta	270,042	1,372,017	—	62,335
El Paso	—	—	—	—
Fremont	124,863	153,162	10	—
Garfield	22,721	31,667	—	1,905
Gunnison	272,598	1,407,086	100	8,605
Huerfano	35,492	506	—	485
Jackson	14,436	218,646	10	33,342
La Plata	9,310	133,450	—	200
Las Animas	669,741	65,038	—	—
Mesa	1,789	947,499	—	423
Moffat	683,231	2,929,125	—	307,889
Montrose	74,684	—	—	—
Pitkin	4,848	735,323	—	4,000
Rio Blanco	34,842	161,940	—	64,454
Routt	4,715,946	2,025,071	—	81,921
Weld	7,292	—	—	—
Totals	6,949,270	10,428,106	120	565,559

General Information

Openings to Mines:			
Shafts	9	Number of Mines on Railroads	17
Slopes	58	Tons of Washed Coal	2,322,794
Drift	43	Tons of Coal Chemically Treated or Oiled	40,656

Mining Machinery		Haulage Equipment	
Cutting Machines	6	Personnel Carriers	84
Continuous Miners	78	Hoists	8
Loading Machines	24	Locomotives:	
		Electric Trolley	32
		Battery	15

Mechanical Conveyors		Strip Machinery and Equipment	
Shakers	14	Bulldozers	91
Chains	4	Special Drills	57
Shuttle Cars	161	Trucks to Tipple	113
Belts:		Power Shovels	9
Mainline	66	Jackhammers	25
Secondary	66	Loaders	102
		Draglines	16
		Tractors	39
		Scarifiers	14

Safety Equipment	
Self Rescuers	3,315
Inhalators	62
Oxygen Breathers	498

Table 7. Coal Production in Colorado by County (Colorado Division of Mines, 1981)

County	Production (ST)	No. of Employees	No. Mines (Surface/ Underground)
Archuleta	255,011	52	1(1/0)
Delta	1,353,550	304	5(1/4)
El Paso	3,578	—	1(1/0)
Fremont	350,395	191	4(3/1)
Garfield	55,516	19	3(0/3)
Gunnison	1,634,757	1242	6(0/6)
Huerfano	37,016	7	1(1/0)
Jackson	523,212	60	3(3/0)
Las Animas	734,779	630	4(3/1)
La Plata	135,768	50	2(0/3)
Mesa	949,915	304	4(0/4)
Moffat	6,027,557	946	4(2/2)
Montrose	74,684	23	1(1/0)
Pitkin	740,173	603	7(0/7)
Rio Blanco	121,355	94	3(0/3)
Routt	6,696,938	722	7(6/1)
Weld	7,293	39	1(0/1)

Table 8. Cumulative Coal Production Top 10 Counties, 1981 (ST)

1.	Las Animas	176,394,846
2.	Routt	104,923,203
3.	Huerfano	75,651,942
4.	Weld	67,036,596
5.	Gunnison	53,908,995
6.	Boulder	43,321,306
7.	Fremont	41,369,780
8.	Moffat	27,732,431
9.	Pitkin	22,074,168
10.	El Paso	15,251,246
		627,664,513

Table 9. Cumulative Coal Production by County 1864 through 1981 (ST)

Adams	37,112
Arapahoe	36,259
Archuleta	418,042
Boulder	43,321,306
Delta	8,727,937
Dolores	62,631
Douglas	27,367
Elbert	108,948
El Paso	15,251,246
Fremont	41,369,780
Garfield	7,207,736
Gunnison	53,908,995
Huerfano	75,651,942
Jackson	5,798,342
Jefferson	6,697,939
La Plata	6,916,567
Larimer	54,284
Las Animas	176,394,846
Mesa	10,575,560
Moffat	27,732,431
Montezuma	174,515
Montrose	2,366,049
Ouray	14,216
Park	724,658
Pitkin	22,074,168
Rio Blanco	1,086,693
Routt	104,923,203
San Miguel	27,197
Weld	67,036,596

Table 10. Cumulative Colorado Coal Production by Coal Region to January 1, 1982 (Colorado Geological Survey) (Millions of Tons)

Coal Region	(County)	Production	(% of State Total)
Raton Mesa	Huerfano & Las Animas	252.05	(37.14)
Denver	Adams, Arapahoe, Boulder, Douglas, Elbert, El Paso, Jefferson, Larimer & Weld	132.57	(19.53)
Green River	Moffat & Routt	129.49	(19.09)
Uinta*	Delta, Garfield, Gunnison, Mesa, Pitkin & Rio Blanco	106.75	(15.74)
Canon City	Fremont	41.37	(6.10)
San Juan River	Archuleta, Dolores, La Plata, Montezuma, Montrose, Ouray, & San Miguel	9.98	(1.47)
North Park	Jackson	5.80	(0.85)
South Park	Park	0.73	(0.11)

*Colowyo Mine included in Uinta Region although it is located in Moffat County.

Table 11. 1981 Colorado Coal Production by Coal Region (Colorado Geological Survey) (Short Tons)

Coal Region	Production	% of	No. of Employees	No. of Mines	No. Surface/ No. Underground
Green River	9,553,868	48.48	1,249	10	7/3
Uinta	8,025,893	40.73	2,374	29	2/27
Raton Mesa	771,795	3.92	637	5	2/3
North Park	523,212	2.66	60	3	3/0
San Juan River	465,463	2.36	125	4	2/2
Canon City	350,395	1.78	191	4	1/3
Denver	10,871	0.05	39	2	2/0
South Park	0	0.0	0	0	0/0

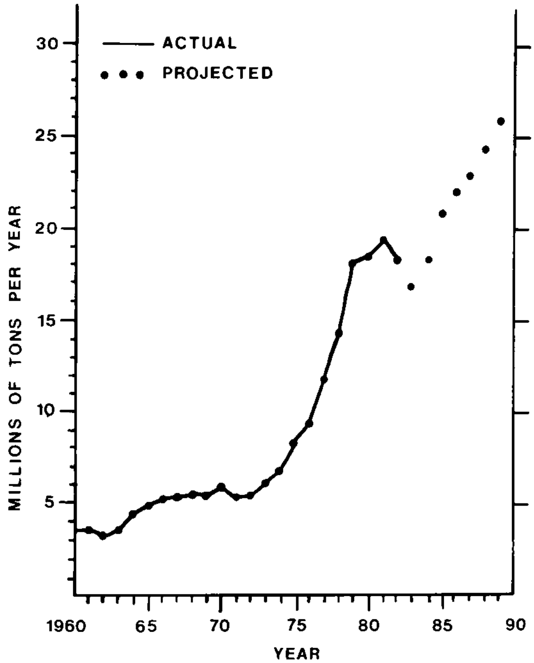


Figure 5. Production history and projections for Colorado coal production, 1960–1990 (Ladwig—CGS)

Table 12. Colorado Coal Production by Coal Region—1979-1981 (Ladwig-CGS)

Canon City		*North Park*	
1979	165,083	1979	785,437
1980	343,187	1980	806,915
1981	350,395	1981	523,212
Denver		*Raton Mesa*	
1979	0	1979	870,346
1980	38,778	1980	865,699
1981	10,871	1981	771,795
Green River		*San Juan*	
1979	9,736	1979	298,514
1980	9,914,724	1980	194,161
1981	9,553,868	1981	465,463
Uinta			
1979	6,015,610		
1980	6,605,854		
1981	8,025,893		

Tables 7, 8, 9, 10, 11, and 12 display production data by county and by coal-bearing region. Table 13 shows coal exported outside Colorado in 1981. Figures 6 and 7 graphically depict cumulative coal production by county to 1-1-82 and during 1981, respectively.

Table 13. 1981 Colorado Out of State Coal Exports by Use (Ladwig, CGS)

Steam Coal	8.2 MT
Met Coal	1.3 MT
Industrial Coal	.4 MT

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 on Table 14.

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, in thickness, and in areal extent; individual beds rarely persist for more than one-half to one 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 (refer to Murray, Fender, and Jones, 1977; and Fender and Murray, 1978, for examples of the use of geophysical well logs to correlate coal beds and "zones," determine coal depositional trends, estimate coal resources, etc.). 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 Region (or field)

The Canon City coal region, or field (Fig. 1), 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 (and coal regions) from the Raton basin (and Raton Mesa coal 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 norththern part of the Raton Mesa region (Walsenburg field). The geologic structure in the Canon City *region* (which coincides exactly with Canon City *field*) is asymmetric, with gentle dips on the east and moderately steep dips on the west, and with some complications due to faulting along the east flank of the Wet Mountains uplift.

The Canon City region can be considered, in many respects, to be a northern extension of the Raton Mesa region, separated by uplift and faulting which have resulted in the removal of the coal-bearing sequences that no doubt once were deposited in the area between these two regions. This is the smallest coal region in Colorado, covering an area of only about 50 sq. mi.

As shown on Figure 8, the coals in the Canon City region (or field) occur in the lower part of the Vermejo Formation (Upper Cretaceous-Paleocene? in age). Seven main coal beds have been mined commercially in the area; 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, non-weathering, non-agglomerating, and non-coking.

To date, this region has produced more than 40.3 million tons of coal, ranking sixth in the State. This amount of production represents approximately 14 percent of the total estimated in-place resource in the Canon City region (*see* Table 10). Historically, more than 175 mines have operated in this region. In 1980, three underground and one surface mines, employing a total of 115 persons (up from 1979), were in operation in this region, located in Fremont County.

Most of the coal mined in the Canon City region is used in nearby steam-electric power plants, located in Canon City and Colorado Springs; by the State Penitentiary in Canon City, by the State Hospital in Pueblo; and by local domestic purchasers.

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 in the Canon City region above a depth of 1,000 ft.

Denver Region

The Denver coal-bearing region encompasses an area of some 7,500 sq mi east of the Front Range in the eastern half of Colorado. It extends from the Wyoming State line south to near 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, the synclinal axis of which is located near its west edge. This region contains large resources of subbituminous coal and lignite within 3,000 ft of the surface.

Within the Denver region are two separate coal-bearing sub-basins, termed the Denver Basin and, to the north, the Cheyenne Basin, separated by a structural high, termed the Greeley arch. The coal-bearing sequences have been removed by erosion from the Greeley arch (Kirkham and Ladwig, 1979). Thse "sub-basins" 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 sub-basins 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) contains multiple beds of lignite only in the central part of the Denver sub-basin (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 near-vertical in the Foothills district (Landis, 1959, p. 164-165); however, their dips decrease rapidly eastward to 5 degrees or less. Most of the Denver and Cheyenne sub-basins are underlain by coals of the Laramie Formation, although coals may be thin or absent in a few areas. Laramie coal beds occur in a

Table 14
(Colorado Geological Survey)

RANGE OF ANALYSES OF COLORADO COALS (AS RECEIVED)

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
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	6,520- 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
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
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 Cañon 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

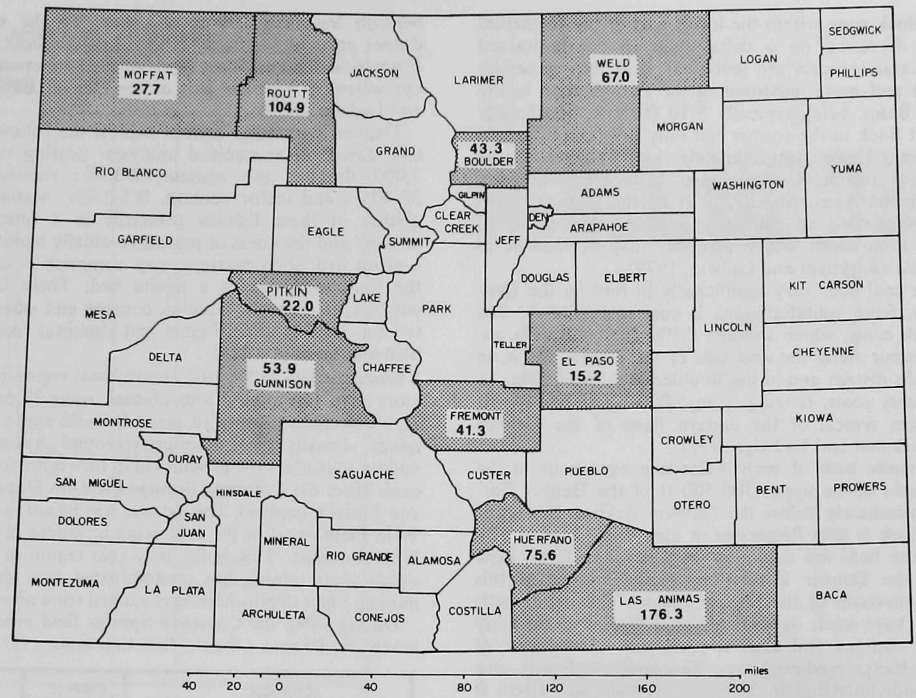


Figure 6. Top Ten Counties—Cumulative Coal Production in Colorado to 1982 (MST) (Ladwig—CGS)

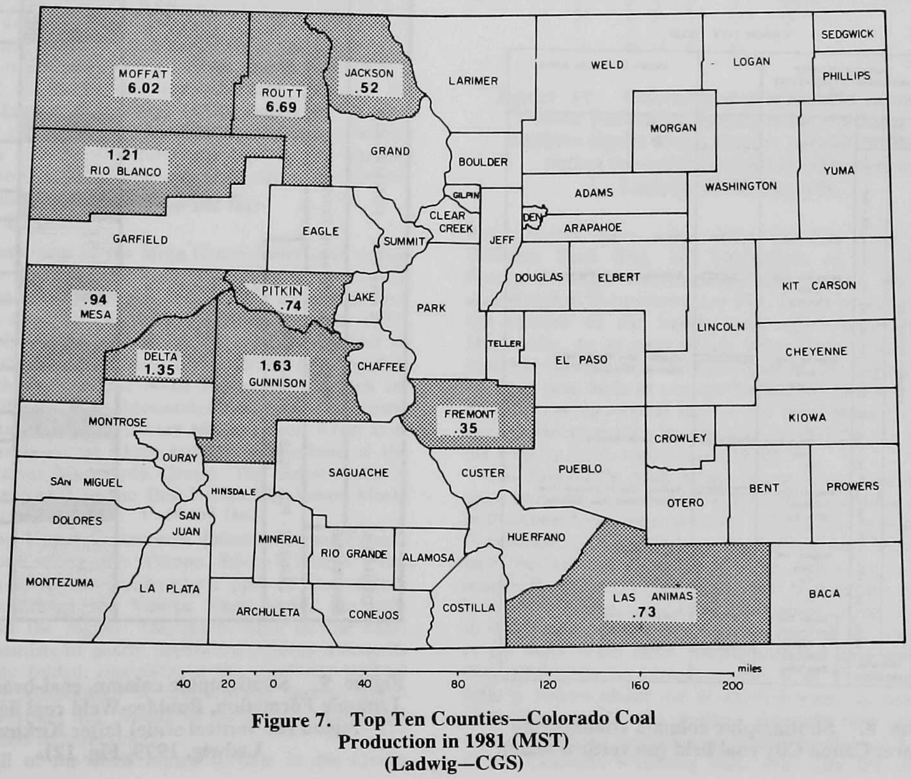


Figure 7. Top Ten Counties—Colorado Coal Production in 1981 (MST) (Ladwig—CGS)

50-275-ft-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 Basin, being typically 5-10 ft thick, and locally up to 20 ft thick in the former but only 3-7 ft in thickness in the latter. Under approximately 1,850 sq mi of the Denver coal region, Laramie coal beds are potentially surface minable (i.e., within 200 ft of the surface). Another 2,000-plus sq mi contains Laramie coal beds from 500-1,500 ft in depth, which someday may be feasible to gasify *in situ* (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 Denver Basin in the upper 300-500 ft of the Denver Formation immediately below the Dawson Arkose, the lower part of which is also Paleocene in age (Figs. 11 and 12). These lignite beds are absent in the Cheyenne Basin inasmuch as the Denver Formation is not present in this northern sub-basin of the Denver region. The lignite beds appear to have been deposited within two separate early Paleocene swamps and alluvial plain that existed east of the Front Range piedmont area. The northern lignite area contains individual lignite beds that typically are 10-30 ft in thickness, with a maximum observed thickness of 55 ft. The southern lignite area, on the other hand, contains generally thinner beds of lignite, averaging 5-10 ft, with a maximum thickness of about 30 ft. 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 ft of cover. To the west, in the deeper parts of the basis, 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).

Denver Formation lignites exhibit the following properties, based on as-received analyses: heating value, 4,000-7,000 Btu/lb.; ash content, 8-30%; moisture content, 22-40%; and sulfur content, 0.2-0.6%. 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 5-30 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 130 million tons of coal, some 20 percent of the Statewide total (Tables 10 and 11), from approximately 385 mines, virtually all of them underground. Approximately 15 million tons of all the production in the region (or 12 percent) came from the **Colorado Springs Field** (in Douglas, El Paso and Elbert Counties). The balance was mined in the **Boulder-Weld Field,** most of the coal being produced in 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 ft.

During 1980, the Colorado Springs field produced coal—nearly 39,000 tons—for the first time since 1957 from a strip

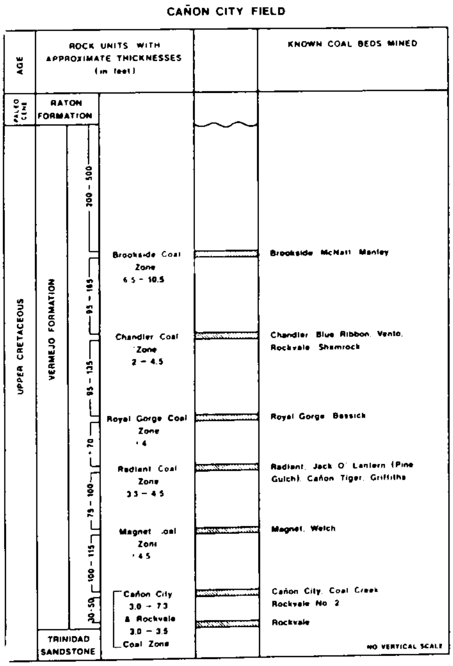


Figure 8. Stratigraphic column, coal-bearing sequence, Canon City coal field (no vertical scale).

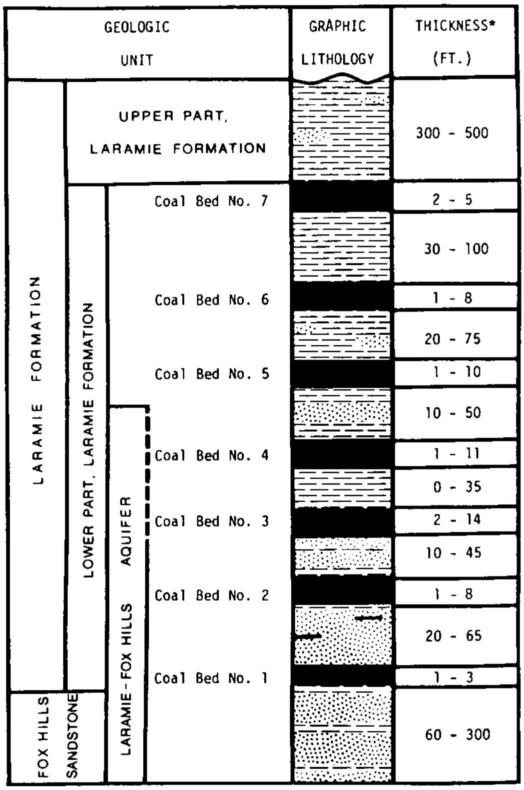


Figure 9. Stratigraphic column, coal-bearing part of Laramie Formation, Boulder-Weld coal field, Denver region (no vertical scale) (after Kirkham and Ladwig, 1979, Fig. 12).

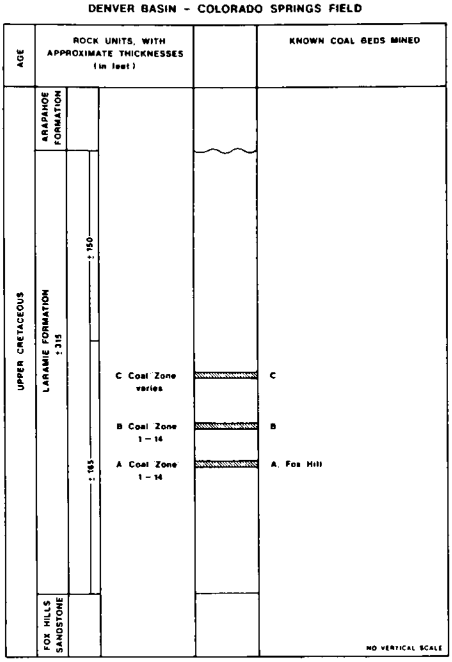


Figure 10. Stratigraphic column, coal-bearing part of Laramie Formation, Colorado Springs coal field, Denver region (no vertical scale).

mine located near the City of Colorado Springs, in El Paso County. This represented the entire production in the Denver region for the year 1980. In Weld County, Coors Energy Co. (part of the Adolph Coors Co.) was constructing a new surface mine near Keenesburg, situated northeast of Denver.

No coal was produced in the Denver region during 1979.

According to recent resource estimates made of the region (Kirkham and Ladwig, 1979), remaining in-place resources in the Denver region amount to approximately 20-25 billion tons of subbituminous coal in the Laramie Formation, and 10-15 billion tons of lignite in the Denver Formation, all at depths above 3,000 ft.

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 (Averitt, 1972, Fig. 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 includes the Williams Fork Mountains and forms the south edge of the basin. 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, which, in places, have upgraded some of the coals to anthracite.

Virtually all of the coals mined to date in the Green

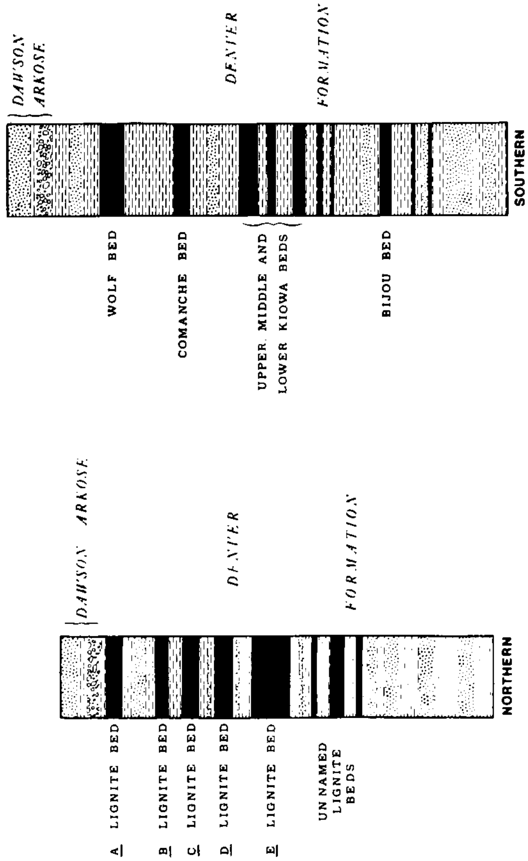


Figure 11. Generalized stratigraphic columns of Denver Formation lignites in the northern and southern lignite areas, Denver sub-basin, Denver region (no vertical scale) (Kirkham and Ladwig, 1979, Fig. 17).

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; *see* Fig. 2) are preserved toward the interior of the basin, away from outcrops of the Mesaverde, on or near which most of the coal mining to date has taken place. A major part of the region contains multiple coal beds in several formations below a depth of 3,000 ft (in the central part of the Sand Wash basin, coals are present to depths in excess of 10,000 ft), as shown on the map by Jones and others (1978).

The Mesaverde coals in the Green River region, for the most part, are high-volatile C bituminous in rank and vary in thickness from approximately 3-20 ft. The younger Lance Formation coals, which have been mined only locally in the past (but are not mined at present), appear to be subbituminous B or C and range up to 10 ft. in thickness. The overlying Fort Union coals have been observed to be as thick as 40 ft or more on geophysical logs of oil 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

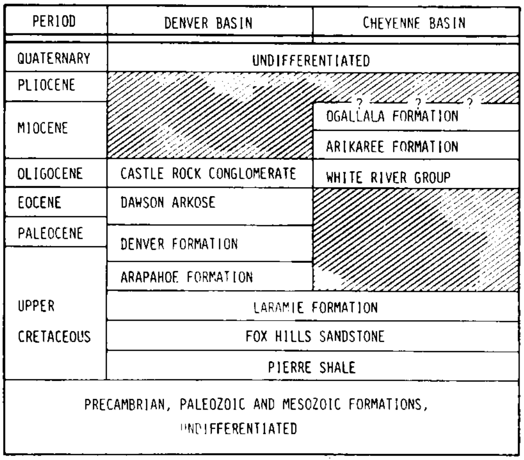


Figure 12. Generalized stratigraphic correlation chart, Denver and Cheyenne sub-basins, Denver coal region (Kirkham and Ladwig, 1979, Fig. 10).

Union and Lance coals, those in the Wasatch Formation probably are subbituminous B or C in rank, range from a few feet to 20 ft. or more in thickness, and may be surface-minable in parts of the Green River region.

This region to date has produced more than 105 million short tons of coal (or approximately 16% of the State's coal) from nearly 200 mines. During 1978, more than 9.38 million tons of coal were produced in the Green River region, Colorado, which is about two-thirds of all of the coal produced in the State (*see* Tables 10, 11, and 12). Production from this region in 1980 amounted to nearly 12.6 million short tons (more than 67% of the State's total) from 10 surface and 4 underground mines; 95% of this coal came from surface mines.

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 ft, although very little work has been done so far in evaluating the coals below "minable" depths. Speltz (1976) estimates that nearly one 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 the Denver area; or exported to States such as Illinois, Iowa, Nebraska, and Texas.

North Park Region (or field)

The North Park coal region, located in Grand and Jackson Counties (Fig 1), lies in a high (8,000-9,000-ft), 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 composed of both flows and intrusive bodies. As defined (*see* Averitt, 1972), North Park coal field lies 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, which may aggregate as much as 12,000 ft in thickness (Figs. 2, 15, and 16). The Coalmont consists 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 were formed in flood basins and swamps between meandering streams. The Coalmont Formation unconformably overlies the marine Pierre Shale (Upper Cretaceous).

North Park Coal Field is the only part of the region in which coal has been mined, from 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 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 (*see* Table 14).

The North Park region has produced nearly 4.5 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 UPRR main line at Laramie, Wyoming (*see* map by Jones and others, 1978).

During 1978, the North Park region produced 642,066 short tons of steam coal from two surface, or open-pit mines, the Canadian and the Kerr, located on the east flank of McCallum anticline (which produces oil and gas from Lower Cretaceous sandstones). This production represents a 29 percent increase over 1977 (Tables 9, 10, 11) and is about 4.5 percent of the total output for the State. These two mines produce subbituminous A coal from a 50-60 ft-thick bed (the "Sudduth") near the base of the Coalmont

GREEN RIVER REGION - ILES FORMATION

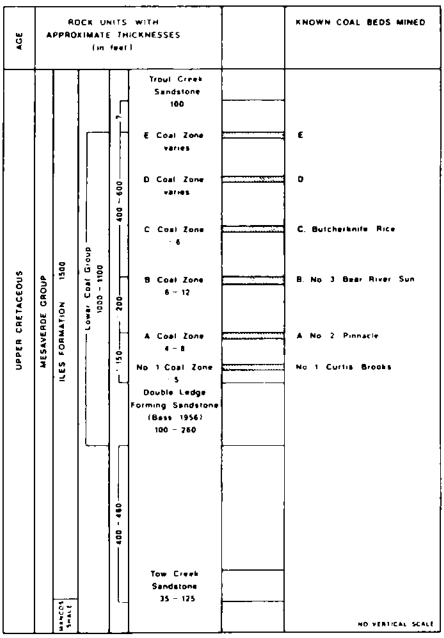


Figure 13. Stratigraphic column, coal-bearing Iles Formation, lower Mesaverde Group, Green River region (no vertical scale).

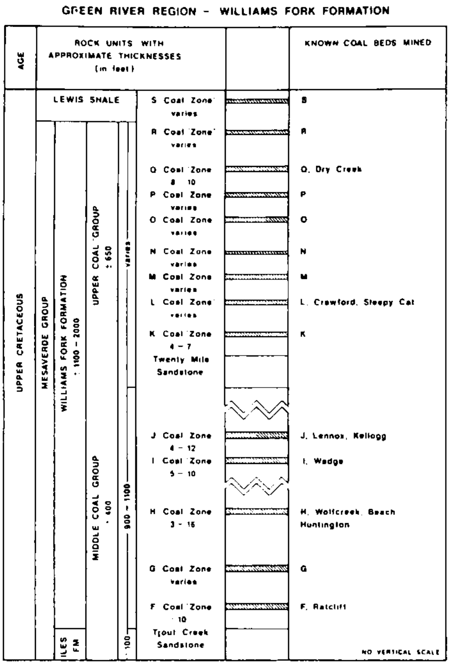


Figure 14. Stratigraphic column, coal-bearing Williams Fork Formation, upper Mesaverde Group, Green River region (no vertical scale).

Formation (Fig. 16), which, in the vicinity of the mines, dips from 45°-60° to the east, creating unique mining problems. This coal ranges up to 11,000-plus Btu/lb, with 0.2-0.7% sulfur, 2.1-10.8% ash, and 11.0-14.4% moisture, as-received (Dawson and Murray, 1978, p. 164, 165).

Three surface mines produced nearly 807,000 tons of coal during 1980 (4.3% of the State's total), and are estimated to have produced only about 533,000 tons in 1981.

Middle Park 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 exists within this 250-300-sq-mi southern extension of North Park basin.

Raton Mesa 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 the south-plunging axis of which, in Colorado, is located 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 (Huajatolla), Tertiary-age igneous intrusions that rise to elevations above 12,000 ft; 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 Vermejo Formation (Upper Cretaceous), which is the oldest coal-bearing sequence in the basin (Fig. 17). Immediately above the Vermejo is the coal-bearing Raton Formation, of Upper Cretaceous-Paleocene ages (Fig. 18). The multiple, lenticular coal beds in both of these sequences generally are less than 10 ft in thickness.

As described earlier, the coals of both formations in the southern part of the Colorado portion of the region—essentially, 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 ft).

Trinidad Coal Field (Fig. 1) has produced considerable coal since the late 1800's, much of it of coking quality—nearly 175 million tons through 1979, or 27 percent of the total for the entire State, from more than 150 mines, most of them underground. Historically, this is the most important coal field—and Las Animas is the most important coal-producing county—in Colorado (Table 8). Table 14 summarizes the coal analyses from this field. Most of the Trinidad field's 1980 production—762,686 tons out of a total of 842,185 tons—came from CF&I Steel's two captive metallurgical coal mines, the Allen and the Maxwell. One small surface mine and one small underground mine, produced the balance of the field's 1980 production. Coal from the CF&I Steel Co. mines is shipped by rail to the company's steel mill in Pueblo, located approximately 150 miles to the north, where it is coked.

Walsenburg Coal Field (Fig. 1), in Huerfano County, so far has produced more than 75.5 million tons of coal, mostly non-coking, which is about 12 percent of the cumulative production to date in Colorado (Table 8). Most of this coal has been mined from the lower part of the Vermejo Formation (Fig. 17). No

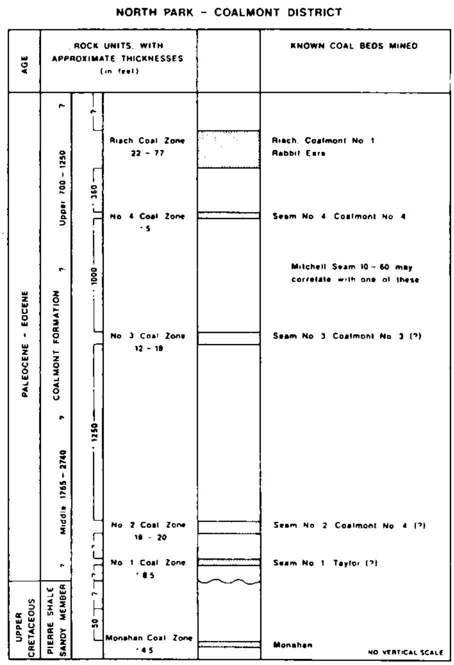


Figure 15. Stratigraphic column, coal-bearing part of Coalmont Formation, Coalmont district, North Park region (no vertical scale).

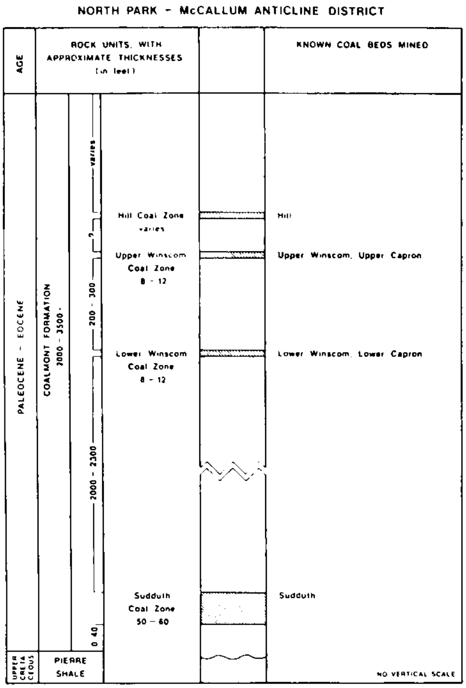


Figure 16. Stratigraphic column, coal-bearing part of Coalmont Formation, McCallum Anticline district, North Park region (no vertical scale).

coal was mined in this field for a number of years until late in 1978, when a small surface mine was opened. During 1980, some 23,500 tons of coal was produced from a small surface mine located in Huerfano County.

The Raton Mesa region (Colorado portion) has produced more than 247 million tons of coal to date from approximately 370 mines; this represents nearly 40 percent of all of the coal produced in Colorado. This region has produced more coal, by far, than any other region in the State—at least 115 million tons more than the second place Denver region (Tables 10, 11; Figs. 6, 7). Despite the large volume of coal that has been removed from the Raton Mesa region, more than 94 percent of the estimated in-place resource of 13.2 billion tons still remains in the ground (Table 11).

Essentially all of the mining to date 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.

San Juan River Region

The San Juan River coal region is located in southwest Colorado and in part of west-central Colorado as far north as the Grand Valley-Grand Junction area and the southern part of Delta County (Fig. 1; *also see maps* by Jones and others, 1978; and 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 (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 the town 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 ft 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 on Table 14 .

To date, La Plata and Montezuma Counties have produced more than 6.76 million tons of coal, which is more than 75 percent of the total for the entire San Juan River region. Production during 1980 from two small underground mines in LaPlata County totalled 93,619 short tons. Most of this coal is used locally for domestic and industrial purposes.

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. The only currently producing mine in this field, Peabody Coal's Nucla multiple-bench surface mine, furnishes approximately 92,000 tons of coal per

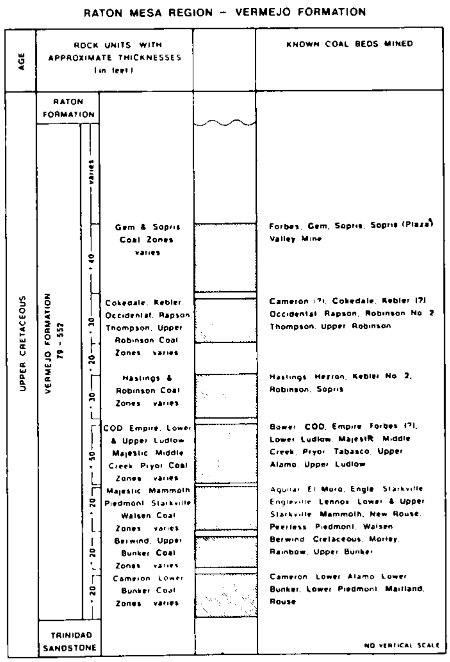


Figure 17. Stratigraphic column, coal-bearing Vermejo Formation, Raton Mesa region (no vertical scale).

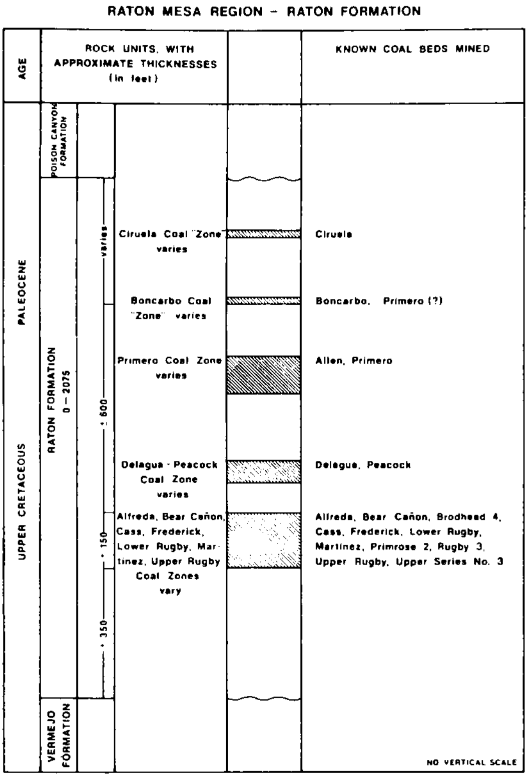


Figure 18. Stratigraphic column, coal-bearing Raton Formation, Raton Mesa region (no vertical scale).

year to the nearby Nucla power plant (capacity, about 37 MW). Three minable coal beds, 3-5 ft in thickness, occur in the Dakota sequence in this area (*see* Table 14 and Fig. 22). The Nucla-Naturita coal field to date has produced over 2.2 million tons of coal, or about 24 percent of the total for the San Juan River region.

Pagosa Springs Coal Field, located in Archuleta County (Fig. 1), has produced more than 450,000 tons of bituminous coal over the years. The lone operating mine in the field, the Martinez, strip mined, mined only 8,424 tons of coal in 1980; however, this mine produced more than 227,000 short tons of coal during the first eleven months of 1981.

Tongue Mesa Coal Field, which had been placed within the Uinta region in previous articles (Hornbaker and others, 1976), herein is included within the San Juan River region (Fig. 1). Although not shown as such on recent maps (Fig. 1; Jones and others, 1978), the Tongue Mesa 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 Late Cretaceous and early Tertiary ages. The field is located on Cimarron Ridge, about 20 mi southeast of the town of Montrose and 8 mi east of U.S. Highway 550, and it straddles the Montrose County-Ouray County line. The coal-bearing "Mesaverde" sequence has been eroded west of Tongue Mesa field.

The coals in this field occur within a 900-ft-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 ft in thickness, occur on Tongue Mesa in the lower 200 ft of the Fruitland Formation. The most persistent and the thickest coal bed here, the Cimarron (or Lou Creek), together with several thinner coals, have been underground-mined intermittently from the 1890's until the 1940's. No mines presently are active in the field.

Tongue Mesa coals generally are subbituminous B in rank and often are considerably oxidized and "bony" (*see* Table 14).

Since the late 1800's, the San Juan River region has produced slightly more than 9 million tons of coal (from nearly 200 mines), which represents about 1.4 percent of the total for Colorado (*see* Tables 10, 11, and 12). In 1979, the region produced 298,574 short tons of bituminous coal from four underground and three surface mines. This volume represents less than 2 percent of the State's total production.

South Park Region (Field)

South Park coal region, in Park County, lies entirely within a small, high (9,000-10,000 ft in elevation), intermontane structural and topographic basin with the same name (Fig. 1).

The coal-bearing Laramie Formation (Upper Cretaceous) (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 (*see* Table 14); however, no modern analyses are available.

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 ft (Hornbaker and others, 1976).

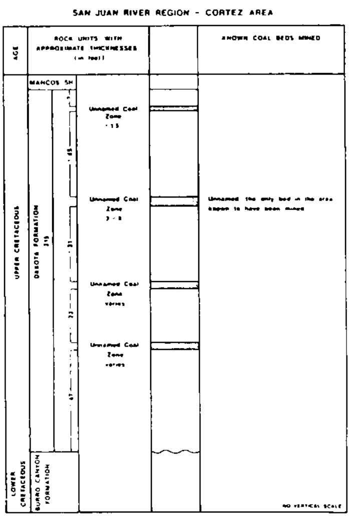


Figure 19. Stratigraphic column, coal-bearing member of Dakota Sandstone, Cortez area, Durango field, San Juan River region (no vertical scale).

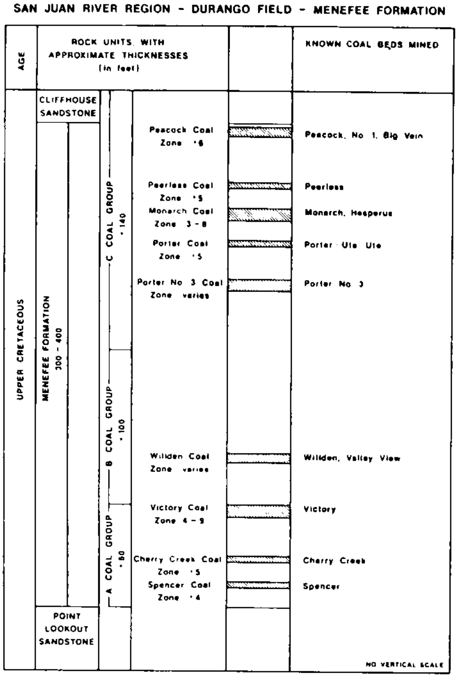


Figure 20. Stratigraphic column, coal-bearing Menefee Formation, Durango field, San Juan River region (no vertical scale).

Uinta 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 that part of the region located in Colorado 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 sq mi, 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 25,000+ ft of sediments filling its deepest part, which is located 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 that occurs here. As a result, the southeast part of the Uinta region contains large resources of coking coal, much of it of premium grade and high in methane content; and commonly under more than 1,000 ft of overburden (Murray, Fender, and Jones, 1977).

The eight coal fields in the Uinta region that exist around its periphery are briefly discussed below in alpha-

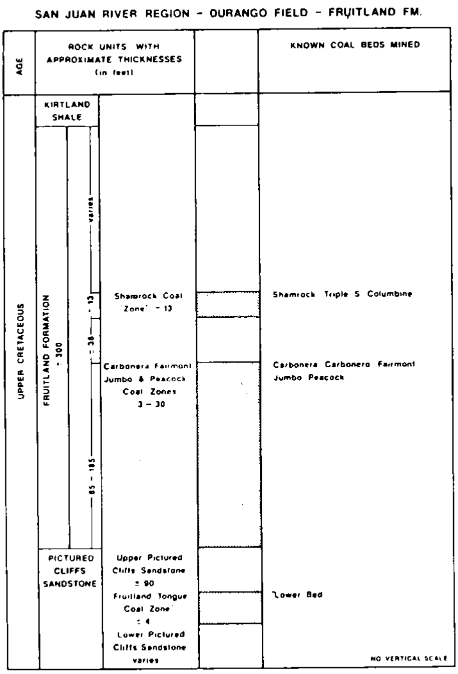


Figure 21. Stratigraphic column, coal-bearing Fruitland Formation, Durango field, San Juan River region (no vertical scale).

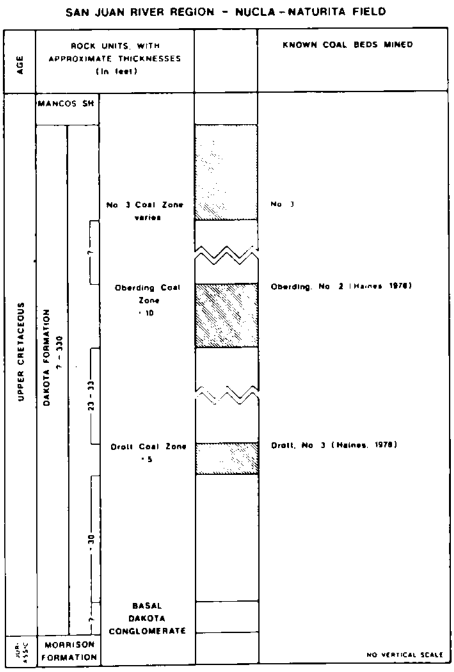


Figure 22. Stratigraphic column, coal-bearing part of Dakota Formation, Nucla-Naturita field, San Juan River region (no vertical scale).

betical order (Fig. 1). All of these fields are, or have been, productive from the Mesaverde Group (Fig. 2). The Lower White River field is the only one not presently producing; however, several companies have been conducting exploration in the area that may result in the opening of one or more coal mines within the next few years. Representative ranges of analyses for each field are given on Table 14. Production figures by county and for the region are shown on Tables 7 through 13.

Book Cliffs Field contains a number of high-quality coal beds in the Mount Garfield Formation of the Mesaverde Group (Fig. 24); these 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-sq-mi-area considered) at approximately 7.2 billion tons to a depth of 6,000 ft. During 1980, more than 781,000 tons of coal were produced from the Book Cliffs field, all from underground mines—two in Garfield County (which produced only 15,500 tons) and four in Mesa County.

Carbondale Field, located at the eastern edge of the region, in Garfield and Pitkin Counties, produces high-quality coking coal from the Mesaverde Group (Fig. 27). In the Coal Basin area, 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 ft in the 165-sq-mi-area considered have been estimated at more than 5.2 billion tons. During 1980, this field produced 736,532 tons of coal, all of it sold for metallurgical purposes.

Crested Butte Field is 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 ft. 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 ft in thickness. Original in-place coal resources, to a depth of 6,000 ft, in the 240-sq-mi-area surveyed, are estimated at some 1.56 billion tons (Hornbaker and others, 1976). A small amount of steam coal was produced from one underground mine in the field during 1980.

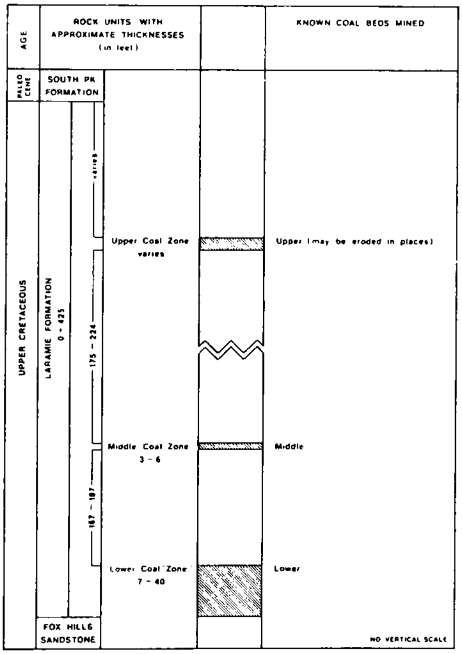


Figure 23. Stratigraphic column, coal-bearing Laramie Formation, Como area, South Park region (no vertical scale).

Danforth Hills Field, which extends from Axial south to Meeker, is situated at the northeast limit of the Uinta region, in Rio Blanco and southern Moffat Counties. This field is separated from the Yampa field, Green River region, to the north by Axial Basin, a topographic low in which the coal-bearing Mesaverde Group, which crops out in hills both to the north and south, has been stripped away. Both subdivisions of the Mesaverde Group here, the Iles (Fig. 25) and Williams Fork (Fig. 26) 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 ft, in the approximately 400 sq mi for which the estimate was made, total more than 10.5 billion tons (Hornbaker and others, 1976). More than 2.89 million tons of coal were produced from this field in 1980; nearly 2.7 million tons came from the multi-bench Colowyo surface mine (this mine is estimated to have produced some 3.1 million tons during 1981). The balance of this field's production (nearly 208,000 tons) came from two underground mines operated by Northern Coal Company; these two mines are estimated to have produced less than 133,000 tons of coal in 1981.

Grand Hogback Field is located along the east rim of the Piceance Creek basin, the edge of which is sharply upturned to form the prominent Grand Hogback monocline. This feature extends south of Meeker for some 40 mi to Rifle, then makes an abrupt bend to the southeast, through the old mining town of New Castle, where the hogback is cut through by the Colorado River, then to Glenwood Springs, where the structure again trends south, marking the eastern edge of the Uinta region (Fig. 1). Coal-bearing Mesaverde sediments crop out along the length of the Grand Hogback, with its 40-degree to near-vertical dips, where coal has 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, in Garfield County, 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. 27). The numerous coal beds in this sequence range from approximately 3 ft to more than 18 ft in thickness. Original inplace resources to a depth of 6,000 ft in the 160-sq-mi-area considered is estimated at more than 3 billion tons (Hornbaker and others, 1976).

Grand Mesa Field, situated on the south flank of the prominent Grand Mesa, a very large flat-topped feature over 10,000 ft in elevation that is capped by Tertiary volcanic flows, lies primarily in Delta County. 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 are coals in the Book Cliffs field (Fig. 24). The coal beds in Grand Mesa field range from high-volatile C bituminous to subbituminous A and are typically 4-14 ft in thickness. Original in-place resources, to a depth of 6,000 ft, in the 530-sq-mi-area for which the estimate was made, probably exceed 8.6 billion tons (Hornbaker and others, 1976). Two small mines, one surface and one underground, located in Delta County, produced more than 117,000 tons of bituminous steam coal in 1980.

Lower White River 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 (the largest field in Colorado), is located in southern Moffat County. Coals in

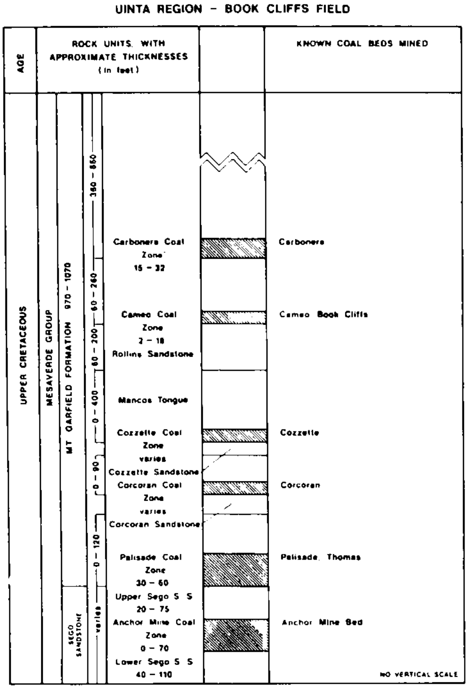


Figure 24. Stratigraphic column, coal-bearing Mesaverde Group, Book Cliffs field, Uinta region (no vertical scale).

Lower White River field are in both the Williams Fork and Iles Formations (*see* Figs. 25, 26). 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. Coal beds here vary from about 8-12 ft or more in thickness and are high-volatile C bituminous in rank. In the 930-sq-mi-area surveyed, 11.76 billion tons of in-place coal resources have been estimated to a depth of 6,000 ft. No coal mining has taken place in Lower White River field for a number of years. However, in 1981 Western Fuels Utah, Inc. began construction of the Deserado mine (on the site of the old Staley Gordon mine), which will undergroundmine large amounts of coal to fuel on electric power plant to be built in eastern Utah.

Somerset Field is 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. 28), are high-volatile B and C bituminous, and range up to 25-30 ft in thickness. In the eastern part of the field, near the settlement of Somerset, coking coal of relatively good quality is produced at mines that include U.S. Steel's Somerset mine, the largest underground mine in Colorado (present capacity, approximately one million tons per year). Nearly 2.3 million tons of coal were produced from six underground mines in this field during 1980; of this amount, nearly 1.44 million tons (or 63%) were used for metallurgical purposes. In-place coal resources to a depth of 6,000 ft in the 320-sq-mi-area investigated are conservatively estimated at more than 8 billion tons (Hornbaker and others, 1976).

The Uinta coal region produced nearly 3 million tons of coal in 1977, one-fourth of the State's total output (Table 11); 1980 production in the region was more than 6.6 million tons, most of it (59%) from underground mines. Since the late 1880's, this important region has produced more than 110 million tons of

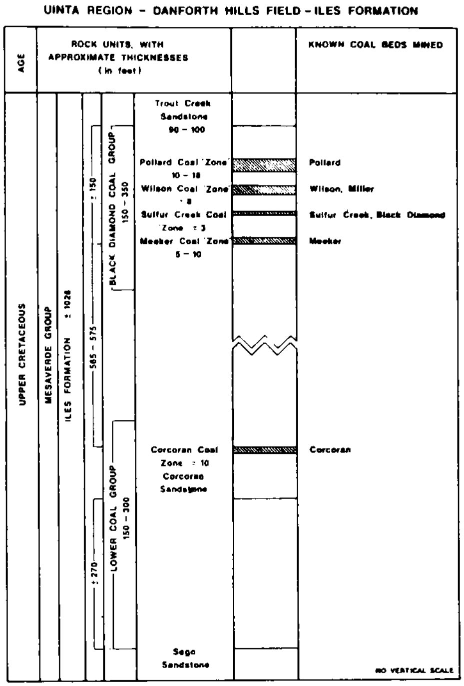


Figure 25. Stratigraphic column, coal-bearing Iles Formation, lower Mesaverde Group, Danforth Hills field, Uinta region (no vertical scale).

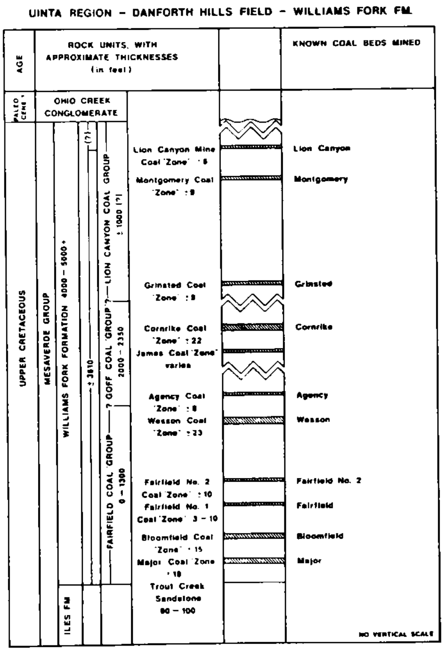


Figure 26. Stratigraphic column, coal-bearing Williams Fork Formation, upper Mesaverde Group, Danforth Hills field, Uinta region (no vertical scale).

coal, which constitutes nearly 15 percent of the total for all of Colorado (Table 10), from nearly 300 mines. Currently, the Uinta region is second only to the Green River region in annual production, and first in the State in the production of both underground-mined coal and coking coal.

The only coal fields in the Uinta region not presently served by railroads are Crested Butte and Lower White River. A spur line more than 20 mi in length recently was completed, extending from near the western terminus of the D&RGW line at Craig, southward through the Williams Fork Mountains and across Axial Basin to Colowyo Coal's large new multi-bench surface mine in the northeast part of the Danforth Hills. This mine is scheduled to produce approximately 3 million tons of coal per year by about 1981 from 10 beds in the William Fork Formation that total about 60 ft in thickness (Dawson and Murray, 1978, p. 178).

Coal Resources of Colorado

According to the U.S. Bureau of Mines (1977a), Colorado ranks 7th in the total U.S. demonstrated reserve base of coal (16.3 billion short tons) and 4th in the reserve base of bituminous coal. 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 ft, only 128.95 billion short tons (29.7% of the total) are classed as remaining *identified* resources (to a depth of 3,000 ft) (Averitt, 1975, p. 14). However, these data are considered to be very preliminary, inasmuch as detailed or specific information on the occurrence and thickness of coal exists in only about 25 percent of the coal-bearing areas of Colorado (Averitt, 1975, p. 43).

The U.S. Bureau of Mines (1977a) estimates the demonstrated *reserve* base of Colorado coals (as of January 1, 1976) to be about 16.3 billion short tons, of which only 3.8 billion short tons (23% of the total) are surface-minable. The demonstrated reserve base includes all coals, except lignite, that occur at depths above 1,000 ft; only bituminous coal and anthracite 28 in. or more in thickness, and subbituminous coal and lignite 60 in. or more in thickness, are included in the demonstrated reserve base. The Colorado Geological Survey estimates that over 80 percent of the total coal *resources* of the State (0-6,000 ft of overburden) will be minable only by underground methods. Overall recovery of the total 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 by even the most advanced mining methods now conceivable. 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 this 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% 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 (Kirkham and Ladwig, 1979) indicates that approximately 10-15 billion short tons of lignite, in beds at least 4 ft thick occurring above a depth of 1,000 ft, may exist in-place in the central part of the Denver region.

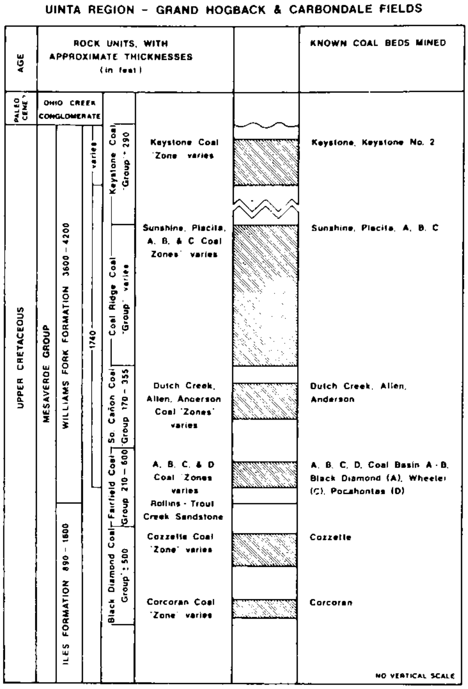


Figure 27. Stratigraphic column, coal-bearing part of Mesaverde Group, Grand Hogback and Carbondale fields, Uinta region (no vertical scale).

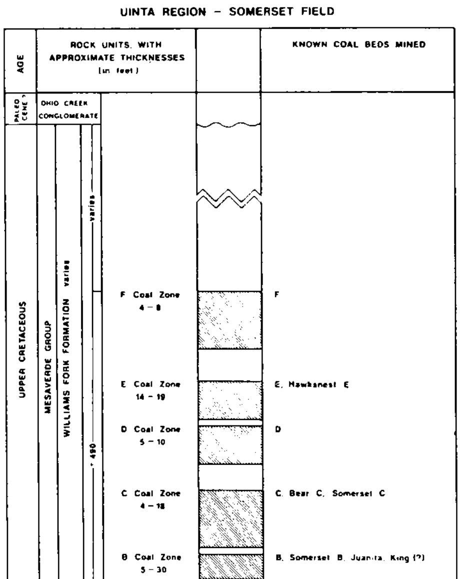


Figure 28. Stratigraphic column, coal-bearing Williams Fork Formation, Upper Mesaverde Group, Somerset field, Uinta region (no vertical scale).

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